MODEL 546 SERVICE MANUAL



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REV 12/09/21

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MODEL
546

SERVICE MANUAL

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ZAMBONI®

BACK

1 SAFETY BULLETIN

Safety Bulletin

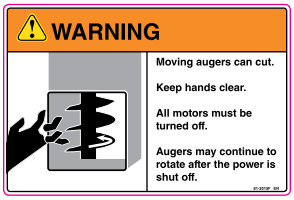
IMPORTANT REMINDERS!

DO NOT OPERATE OR SERVICE THE ZAMBONI ICE RESURFACING MACHINE WITHOUT READING THE OPERATING INSTRUCTIONS, VIEWING THE VIDEO PRESENTATIONS "ICE RESURFACER OPERATION" AND "CONDITIONER MAINTENANCE" AND BEING PROPERLY TRAINED FOR ITS SAFE OPERATION. OBSERVE ALL LABELS AND INSTRUCTIONS.

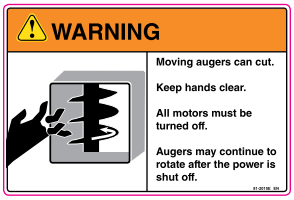
The Zamboni ice resurfacer is to be **operated by one person.** The machine is not designed nor built to accommodate riders. See the Zamboni Company's position on second seats and "riders" here: https://zamboni.com/no-riders/ Keep everyone off of the ice surface and out of the path of the ice resurfacing machine while moving and/or in operation.

Anyone operating, servicing or interacting with the Zamboni ice resurfacer should be trained annually in the safe operation and use of the machine. Trained operators and service personnel should review the materials annually to re-familiarize themselves with the safe and proper operation of the ice resurfacer. Each machine is delivered to its new owner with digital safety materials on a USB drive located on the key ring. Operating instructions, maintenance schedules, parts lists, operations video, maintenance video and its service manual are included in the digital files.

Familiarize yourself and your staff with these and other areas of potential hazard or danger:



Conveyor intake
(view safety guard list DM-2021G)



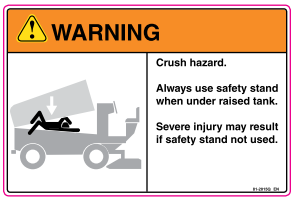
Conveyor discharge opening
(view safety guard list DM-2021G)



Horizontal conveyor screw
(view safety guard list DM-2021G)



Sharp blade
(view Conti Blade Changing Assistant page)



Crush hazards



Missing safety guards
(view safety guard list DM-2021G)



Missing safety labels and/or safety wall poster
(request replacements)



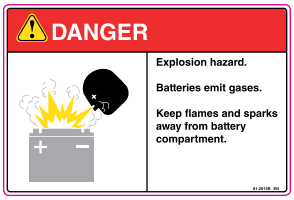
Improper maintenance / lack of maintenance
(see maintenance schedule in your machine service manual)



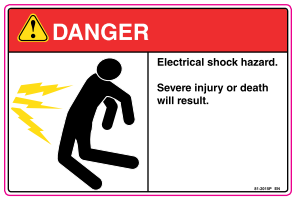
Lack of use of proper Personal Protective Equipment or "PPE"



Fuel handling



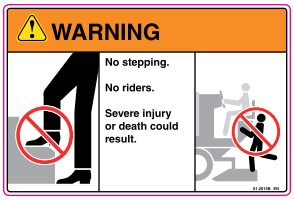
Battery maintenance



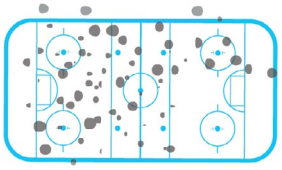
Risk of electric shock



Unsafe operation of equipment by staff not properly trained
(request replacement Service Manual on USB)



Unsafe operation of equipment



Air quality issues
(resources for air quality)

All of these topics and more are referenced in this packet of information. Detailed information relating to each is located in your machine's service manual and operating instructions.

CONVEYORS, BELTS, CHAINS, CRUSH, PINCH AND CUT HAZARDS

Always use proper personal protective equipment and familiarize yourself and your staff with local and regional rules and regulations governing PPE. Keep hands and feet away from conveyors, belts, chains and other moving parts.

Check for obstructions if conveyor stops ONLY after turning off the engine and removing the key. If any part of the conveyor system becomes plugged or clogged, or appears to be plugged or clogged, the conveyor should be flushed out with water. This procedure must be done only after the machine has been removed from the ice and the engine or power has been shut off. Under no circumstances should the operator attempt to clean or clear the conveyor system or parts around it while the machine is on the ice or the engine is running. Never use fingers or hands to clear a conveyor clog. Do not insert fingers or hands into the conveyors.

Important safety guards have been developed for existing and older equipment in the field. Kits to retrofit these machines are available with a detailed listing by machine model and serial number here: (view safety guard list DM-2021G). Removal of any safety guard or modification of your equipment should not be performed nor permitted.

Inspect your machine to make sure that it is properly equipped with these guards and that all safety labels are in place. If safety labels are missing or painted over, replacements are available at no cost. Contact your Zamboni Authorized Distributor or Zamboni Customer Service. (https://zamboni.com/register-as-a-zamboni-product-owner/).

Keep hands, feet and body out from under the snow dump tank, conditioner and other raised parts until they are securely blocked and supported using proper maintenance stands and methods discussed in your machine's operating instructions. Remove the key from the ignition.

Use extreme caution when making contact with the shaving blade/knife as it can cause injury whether it is sharp or dull. Always use properly rated PPE. Reduce the risk associated with blade changes by using a blade changing assistant tool (view Conti Blade Changing Assistant page). Familiarize yourself and your staff with the facility's policies regarding blade change procedures and proper PPE.

IMPROPER MAINTENANCE OR LACK OF MAINTENANCE

Follow the manufacturers' recommended maintenance schedules. These are located in your machine's service manual which originally accompanied your machine at delivery. For a replacement service manual, contact your Zamboni Authorized Distributor or Zamboni Customer Service (https://zamboni.com/distributor-locator/).

It is the owners' and operators' responsibility to perform inspections and preventative maintenance programs to ensure that all component parts are kept in good working order. It is critical that anyone working on or servicing the ice resurfacer exercise caution at all times. Never perform any maintenance or service on the machine without first turning the machine off and removing the key. Everyone interacting with the machine must properly trained and qualified for the task before them. They should familiarize themselves with the part of the resurfacer which they intend to service prior to doing the work by reading the operating instructions and service manual and reviewing operations and maintenance videos before performing any service or maintenance or operating the resurfacer.

Conduct a "circle check" before putting the ice resurfacer into use at least on a daily basis. A basic circle check diagram is included in the machine's service manual within the operating instructions and is available separately via this link: https://zamboni.com/circle-check/

Everyone interacting with the ice resurfacer should be made aware of and held accountable for the use of PPE. Staff should have access to equipment and must be instructed on the importance of the proper use of PPE. Make sure that your facility follows local and regional standards and regulations regarding PPE.

Only qualified and trained staff should attempt to perform maintenance and service the machine. Additional caution should be taken when performing specialized service such as:

- Battery maintenance
- Battery charger service
- Brake component replacement (including awareness of asbestos material if applicable)
- Highly technical service of the engine and optional equipment
- Drilling, welding, painting or other intensive maintenance and repair tasks

Additional caution should also be taken to familiarize yourself and your staff with:

- Flammability of oils, fuels and lubricants
- Toxicity of oils, fuels and lubricants
- Risk of electric shock
- Crush, pinch and cut hazards

Additional information and details relating to these and other considerations are included in this packet beginning in the "General Safety Practices" section. Please review this information and make sure it is available to your staff and all service personnel. This information can be downloaded by anyone at anytime at: https://zamboni.com/register-as-a-zamboni-product-owner/

AIR QUALITY AND BUILDING VENTILATION

Ensuring a healthy indoor environment should be a daily priority of every person who works in or manages ice arenas. It may be especially important when higher outdoor temperatures are present at the beginning and end of the typical ice arena season. With higher temperatures, some operations have issues relating to increased humidity inside their buildings as well as difficulty in retaining a sheet of ice.

While these may be concerns for the operator, they should never be addressed at the expense of air quality in your building. The following are safety reminders and resources relating to this subject:

BUILDING VENTILATION

Important references and information regarding regulations are available online. Many trade publications and industry groups provide helpful information relating to air quality. Locate the local regulations and information relating to your location.

The United States Ice Rink Association has a web page with important information regarding indoor air quality for ice arena owners and operators: https://www.usicerinks.com/resources/ indoor-air-quality

U.S. EPA Information on air quality: https://www.epa.gov/indoor-air-quality-iaq/indoor-air-quality-and-ice-arenas

The Ontario Recreational Facilities Association shares their air quality reference materials here: https://zamboni.com/air-quality-and-emissions/

Never operate ice resurfacing equipment in an enclosed rink without adequate ventilation.

Make sure your ventilation system is working properly and turned on when operating the resurfacer.

Make sure you are in compliance with local/regional/provincial/federal or other regulations as well as any local building codes and health and safety laws. Air quality requirements can vary from one locality to another and since few buildings are identical, the actual amount of ventilation needed should be assessed and implemented at each ice arena accordingly.

Readings of carbon monoxide (CO) and nitrogen oxide (NO_x) and other required readings should be taken at least on a daily basis.

Sources of air contamination can include but are not limited to:

- ice resurfacing machine or ice edger
- heaters, furnaces, boilers
- polluted air intake
- cigarette smoke
- refrigerant leaks
- CO_2 tanks
- fireworks
- fuel with impurities
- restaurant and/or vendor equipment
- idling vehicles outside of the building and/or other outside emissions

It is the rink operator's responsibility to ensure clean air at all times. If you are unsure if your ventilation is adequate, consult with a qualified Heating Ventilation Air Conditioning (HVAC) professional and/or local air quality officials.

PROPERLY MAINTAIN YOUR ICE RESURFACING EQUIPMENT

For fuel-powered equipment, tune the engine and make all adjustments recommended in your machine's digital service manual which has been provided by the manufacturer of the engine. Familiarize yourself and your staff with the fuel source used in your facility and the potential issues related to that fuel.

Only warm up the engine prior to resurfacing in a properly ventilated area, with an exhaust line to the outside or the machine being outdoors.

It is imperative that proper maintenance is performed by a qualified mechanic on a regularly scheduled basis.

However, even if an internal combustion engine is equipped with a LPG/CNG, catalytic converter and/or high-rise exhaust kit, it still produces emissions and a buildup of these emission fumes is hazardous.

The Zamboni Company continues to build the Zamboni ice resurfacer with safety as a primary consideration. We have an ongoing effort to instruct arena owners and operators in the safe and proper operation of our machines. Additional training tips and materials are continually being developed and provided online. If your resurfacer is kept in good repair, operated properly and safety instructions and warnings are followed, accidents and injuries can be avoided. We would like to take this opportunity to re-emphasize some areas of the machine's operation which must be strictly adhered to by the operators of each resurfacer and enforced by the owner.

Share all of this information with your staff. Also, review with your staff all safety and operation information sent previously by Zamboni including manuals, video presentations, safety labels and the machine room's safety wall poster.

An arena owner/operator/manager has no greater responsibility than ensuring a safe environment for the patrons and staff at their facility. The Zamboni Company and your Zamboni Authorized Distributor are committed to assisting you in your performance of this all-important task.

IF YOU HAVE QUESTIONS, PLEASE CONTACT US:

Locate your Zamboni Authorized Distributor
https://zamboni.com/distributor-locator/)

Zamboni Company USA, Inc. (United States) 562.633.0751
Zamboni Company Ltd. (Canada) 519.758.5000
Zamboni Europe AB (Sweden/Europe) +46 291 206 80

Safety Bulletin

This bulletin should be printed or saved digitally and shared with all staff working on or around the Zamboni ice resurfacer. If you retain digital files on your machine's digital service manual (USB key ring) add this information and advise your staff of the update. If you keep a printed copy of these materials, it should be placed in a prominent position in the Operating Instructions Manual.

General Safety Practices

Safety



This symbol warns of possible personal injury.

The safety rules and regulations in this section are representative of some, but not all, rules and regulations. The guidelines of Occupational Safety and Health Administration ("OSHA") as well as the Canadian Centre for Occupational Health and Safety ("CCOHS") are paraphrased without representation that the rules and regulations have been reproduced verbatim. Please refer to Section 1910 of the Federal Register and subsequent revisions for a complete list of OSHA rules and regulations. Please refer to your provincial Health and Safety regulatory body for a complete list of CCOHS rules and regulations. Regulations vary from state to state; province to province as well as country to country. Operate your Zamboni ice resurfacer in accordance with local regulations.

Important Safety Notice

Periodic and proper operation, lubrication and maintenance is important for the safety and reliability of your Zamboni machine. The ice resurfacer operation manual outlines recommended procedures, some of which require the use of special tools or work methods. Improper operation and lack of maintenance of your machine is dangerous and could result in injury or death.

READ AND UNDERSTAND ALL SAFETY PRECAUTIONS AND WARNINGS BEFORE OPERATING, OR PERFORMING LUBRICATION AND MAINTENANCE ON THIS MACHINE.

Basic safety precautions are outlined in the SAFETY bulletin and in the description of operations where hazards exist. Warning labels have been affixed to the machine to provide instructions and to identify specific hazards which could cause bodily injury or death to you or other persons.

It is the responsibility of the owner to perform a job safety analysis of all hazards associated with the total environment in which the Zamboni machine will operate and to train all personnel annually.

The warnings in the manual and on the machine are identified by the symbols:

DANGER!



Operations that may cause product damage are identified on the product and this publication. Zamboni cannot anticipate every possible circumstance that might involve potential hazard.

The warnings in this manual and on the machine are therefore not all inclusive. If a procedure, tool or work method not specifically recommended by Zamboni is used, a competent person must be consulted to assure the safety of you and others and that the machine will not be damaged or made unsafe by the procedures you choose. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedure you choose. When in doubt, contact your Zamboni Authorized Distributor or Zamboni Customer Service for consultation and advice.

DANGER !



Do not operate or perform maintenance on this machine unless you have read and understand the instructions in THIS BULLETIN AND THE OPERATION MANUAL. Improper machine operation and maintenance is dangerous and could result in injury or death. Contact Zamboni or your Zamboni Authorized Distributor for a replacement manual. Proper operation and maintenance is your responsibility.

Accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. A person must be alerted to potential hazards. This person should also have the necessary training, skills and tools to perform safely, including properly rated personal protective equipment.

Equipment specifications are subject to change at any time. These changes may affect the service given to the product. Please obtain the most current information from Zamboni or your Zamboni Authorized Distributor before attempting to perform any job or service.

Warning Signs and Labels

There are several specific safety signs on your Zamboni machine.

Make sure that you can read and understand all of the safety signs. Clean or replace them if you cannot read the words or see the pictures. When cleaning the labels use a cloth, water and soap. Do not use solvent, gasoline, etc.

You must replace a label if it is damaged, missing or cannot be read. If a label is on a part that is replaced, make sure a new label is installed on the replaced part. Contact Zamboni or your Zamboni Authorized Distributor for new labels at no cost.

DANGER !



Only trained and authorized personnel may operate this machine. For safe operation, read and follow the manual furnished with this machine and observe the following warnings:

- Keep all guards in place. Do not operate the Zamboni machine if any guard is damaged or missing.
- Check all controls and warning devices for proper operation.
- Put directional control or shift lever in neutral before "ON-OFF" switch is turned on.
- Start, turn and brake smoothly. Slow down for turns, slippery or uneven surfaces. Use extreme caution when turning or on inclines.
- Watch out for pedestrians and obstructions, check overhead clearances.
- Do not permit riders on the Zamboni machine at any time.
- Do not allow anyone to stand or pass under the elevated portion of any machine.
- Be sure operating surface can safely support machine.
- Observe safety rules when handling fuel on engine powered machines and when changing or charging batteries for electric machines.
- Never cover, hide or remove any safety label.

Crushing or Cutting Prevention

- Support equipment and attachments properly when working beneath them.
- Do not depend on hydraulic cylinders to hold up. Any attachment can fail if a control is moved or if a hydraulic line leaks or breaks.
- Never attempt adjustments while the machine is moving or is running unless otherwise specified.
- Where there are mechanical linkages, the clearance in the linkage area will increase or decrease with movement of the assembly.
- Stay clear of all rotating and moving parts.
- Keep objects away from moving fan blades. They will throw or cut any object or tool that falls or is pushed into them.
- Retainer pins, when struck with force, can fly out and injure nearby persons. Make sure the area is clear of people when driving retainer pins.
- Wear protective glasses when striking a retainer pin to avoid injury to your eyes.
- Chips or other debris can fly off objects when struck. Make sure no one can be injured by flying debris before striking any object.
- Keep all guards in place and in good repair.

Fire or Explosion Prevention

Fuels (Gasoline, Propane - LPG, Compressed Natural Gas - CNG)



Gasoline, LPG, CNG and their vapors are extremely flammable. LPG and CNG vapors reduce oxygen available for breathing and may cause suffocation. Gasoline vapors are extremely flammable and cause flash fires.

- Never smoke when filling, installing or changing the fuel tanks on the machine.
- Keep all sources of open flame, spark or other ignition such as stoves, furnaces, water heaters or any appliance using a pilot light away from fuel storage, fuel use and refueling areas. Under well ventilated conditions, a minimum distance of 20 feet from all ignition sources is recommended.
- Do not operate the machine if an odor of gasoline or LPG or CNG is present or if other explosive conditions exist.
- Refuel outdoors or in a well ventilated area.
- DO NOT refuel when the engine is running or hot. Allow engine and engine exhaust system and catalytic convertor (if equipped) to cool for a minimum of five minutes before refueling.
- Never fill the gasoline tank completely full or to a point where the gasoline is overflowing. Always leave a small portion of the gas tank and the entire fill tube empty. This will allow for the expansion and movement of the gasoline and will minimize sloshing and potentially spilling the gasoline when the machine moves.
- If gasoline is spilled, avoid creating any source of ignition until the gasoline has been completely removed.
- LPG is heavier than air and spreads rapidly. Stop all leaks quickly. Shut off the source of gas.
- If a fire starts, evacuate the area and notify the fire department.
- For a fire in the engine compartment, shut off engine. Shut off the gas flow at the tank valves for LPG and CNG powered vehicles before trying to extinguish. Make sure your staff knows how to properly use it.
- Always have a properly maintained fire extinguisher located in the Zamboni machine room. Make sure your staff knows how to properly use it.
- Fire extinguishing media must be dry chemical, foam, or CO_2 for use on large fires.

Propane Tank Storage and Handling

- Avoid skin contact with liquid because of possibility of freeze burn. Use propane resistant gloves when working with the propane tank connections. Always use a full face mask and wear a long sleeve shirt or jacket, in addition to all required personal protective equipment.
- The storage and handling of LP gas and tanks and refueling of the machine should be in accordance with the locally applicable codes and standards.

- US machine owners can reference the National Fire Prevention Association (NFPA) https://www.nfpa.org/codes-and-standards/allcodes- and-standards/list-of-codes-and-standards/detail?code=58 Canadian machine owners can reference Standards Council of Canada https://www.scc.ca/en/ standardsdb/standards/7318
- Only properly trained and designated persons should charge or exchange the LP gas tanks.
- The engine should be stopped and no persons should be on the Zamboni machine during refueling.
- Always install tanks and make tank connections outdoors or in a well ventilated area away from heat, ignition sources and open flames. NO SMOKING ALLOWED during these operations.
- Store tanks in an authorized location (outside, detached storage is required) with adequate ventilation.
- Store tanks in upright position, away from heat/ignition sources.
- Reasonable care should be exercised in handling the LP gas containers to avoid damage. Do not drop, throw, roll or drag LP gas containers or any associated parts of the containers or fuel system.
- The careless handling of LP gas containers can result in a serious accident. Extreme care should be exercised when transporting containers so that they are not accidently dropped or physically damaged. When it is necessary to move more than one container at one time, a proper carrying device should be provided and used.
- Physical damage such as dents, scrapes or gouges may materially weaken the structure of the tank and render it unsafe for use.
- All LP gas containers should be regularly inspected before recharging and examined again before reuse, for the following defects or damage: Leaks, dents, scrapes, gouges, or corrosion of the pressure vessel, with emphasis on the bottom of the cylinders.
    - Damage to the various valves and liquid level gauge.
    - Debris in the relief valve.
    - Indication of leakage at valves and or threaded connection.
    - Deterioration, damage or loss of flexible seals in the fill or servicing connection;
  - Do not overfill LP gas containers.
  - Keep container valve closed and plugged when not in use.
  - Never use a match or open flame to check for leaks, use a soap solution.
  - Always close the LPG tank service valve when the Zamboni machine is parked for the night or for any extended length of time.
  - Observe the tank manufacturers' guidelines regarding expiration dates and retirement of older tanks.

CNG Fuel System

The installation of distribution, storage and dispensing (charging) systems and CNG cylinder charging must be done in accordance with locally applicable codes and standards.

U.S. machine owners can reference the National Fire Prevention Association (NFPA) NFPA 52 Compressed Natural Gas (CNG) Vehicular Fuel Systems and any other applicable regulations. Canadian machine owners can reference: ANSI/IAS NGV4.1-1999 / CSA 12.5-M99 (R04). Your local gas utility company must be advised of your installation.

Only properly trained and designated persons should charge the CNG fuel cylinders on the machine.

- Never smoke when changing the CNG fuel cylinders on the machine.
- Keep all sources of open flame, spark or other ignition such as stoves, furnaces, water heaters or any appliance using a pilot light away from fuel storage, fuel use and refueling areas. Under well ventilated conditions, a minimum distance of 20 feet from all possible ignition sources is recommended.
- Never charge the cylinders in excess of their maximum allowable service pressure at normal temperature. DOT and TC containers shall be charged in accordance with DOT and TC regulations.

Oils

- Hydraulic oil and its vapors are flammable and will ignite if they contact a hot surface such as an exhaust pipe or manifold. A flash fire can occur.
- Hot oil and components can cause personal injury. Do not allow hot oil or components to contact the skin.
- At operating temperature, the hydraulic tank is hot and can be under pressure.
- Remove the hydraulic tank filler cap only after the machine has been stopped and the filler cap is cool enough to remove with your bare hand.
- Remove the hydraulic tank filler cap slowly to relieve pressure.

Batteries

- Battery fumes may cause fire or explosion. Battery acid can cause burns.
- Only trained and designated personnel should recharge or exchange batteries.
- Service, exchange and handle batteries only in authorized areas where proper safety and ventilation facilities are provided (i.e. eye wash stand, showers, etc.).
- Do not smoke, or expose battery to sparks or flame when checking, charging or servicing battery. Keep chains and metallic tools away from the top of the battery.
- Highly explosive gases are present and are especially hazardous toward the end of the charging period as the battery approaches a full charge condition.
  DO NOT OVERCHARGE THE BATTERIES.
- Cover the top of the battery with plywood or other insulating material before removing it from the machine.

- Do not add acid to a "wet" battery, add distilled water only.
- When preparing a dry charged battery for service, follow the battery manufacturer's instructions. Clean and tighten all electrical connections.
- Check daily for loose or frayed electrical wires. Have all loose or frayed electrical wires tightened, repaired or replaced before operating the Zamboni ice resurfacer.

Lubricants

Most lubricants are flammable

- Keep all lubricants stored in properly marked containers and away from unauthorized persons.
- Store all oily rags or other flammable material in an approved container, in a safe place.
- Do not weld or flame cut on pipes or tubes that contain flammable fluids. Clean them thoroughly with non-flammable solvent before welding or flame cutting on them.
- Remove all flammable materials such as oil and other debris before they accumulate on the Zamboni machine.
- Do not expose the ice resurfacer to flames, burning, etc.

Lines, Tubes and Hoses

- Do not bend or strike high pressure lines. Do not install bent or damaged lines, tubes or hoses.
- Repair any loose or damaged oil lines, tubes and hoses. Leaks can cause fires. Contact Zamboni or your Zamboni Authorized Distributor for repair or replacement.
- Check lines, tubes and hoses carefully. Do not use your bare hand to check for leaks. Use a board or cardboard to check for leaks. Tighten all connections to the recommended torque. Replace if any of the following conditions are found:
    - End fittings damaged or leaking;
    - Outer covering chafed or cut and wire reinforcing exposed;
    - Outer covering ballooning locally;
    - Evidence of kinking or crushing of the flexible part of hose;
    - End fittings displaced;
- Make sure that all clamps, guards and heat shields are installed correctly to prevent vibration, rubbing against other parts and excessive heat during operation.

Safe Operation

Mounting and Dismounting

- Mount and dismount the ice resurfacer only where steps and/or handholds are provided.
- Use both hands and face the Zamboni machine when mounting and dismounting. Use extra care when wet or slippery conditions exist.
- Never get on or off a moving Zamboni machine. Never jump off the machine.
- Do not try to climb on or off the ice resurfacer when carrying tools or supplies.

Before Operating the Zamboni Machine

- Operate the machine only from the operator's station.
- Adjust the seat so that full pedal travel can be obtained with the operator's back against the seat back.
- The Zamboni machine is equipped with a lighting system, make sure all lights are working properly.
- Make sure no one is working on, underneath or close to the ice resurfacer before turning on the key or beginning to move the machine. Make sure the area is free of personnel.
- Do not move the machine or move any of the controls if there is a "DO NOT OPERATE" or similar warning tag attached to the start switch or controls.
- Move the transmission control lever to NEUTRAL.
- Clear all personnel from the machine and the area.
- Clear all obstacles from the path of the ice resurfacer. Beware of hazards such as curbs, blocks, posts, wire, cans, etc.
- Make sure the horn and all other warning devices are working properly.
- Check for proper operation of all controls.

Operation

- Obey all traffic rules and warning signs.
- Always observe floor load limits and overhead clearances.
- When turning the ice resurfacer, slow down to safe speed.

Parking

- Park the Zamboni machine in authorized areas only.
- Move the hydrostatic transmission control lever or directional switch to NEUTRAL.
- Turn the key switch OFF and remove the key.
- If possible, park the machine on a flat and level surface. If the machine is parked on any kind of grade, the wheels must be blocked with wheel chocks to prevent the vehicle from rolling away after it has been parked.
- Set parking brake if the machine is equipped with a parking brake.
- Store in well ventilated area.

Engine Emission Systems - Inspection and Maintenance

DANGER!



Internal combustion engines produce exhaust emissions that contain dangerous gases, including carbon monoxide (CO) and nitrogen oxides (NO_x). These gases can cause serious injury or death.

The rink MUST be adequately ventilated during every operation of the ice resurfacer. Also the resurfacer must be kept properly maintained and serviced at all times and the engine timing should always be properly set. Each person who operates and maintains the resurfacer should be so instructed.

Please keep in mind that adequate ventilation, monitoring the facility's indoor air quality (for CO and NO_2 levels) and the condition of the machine is, at all times, the complete responsibility of the rink owner and operators.

The safe and correct operation and maintenance of the resurfacer, the engine and the engine exhaust system includes:

- Measuring the facility's indoor air quality (for CO and NO_2 levels), daily;
- Measuring engine emission levels;
- Adjusting engine components (when applicable) to ensure correct operation and optimum engine emission levels;
- Inspecting, adjusting (when applicable), maintaining and replacing engine and exhaust system components when required.

If you do not have the tools, education or expertise to inspect, maintain, repair or replace these items, contact Zamboni or your Zamboni Authorized Distributor for assistance.

Optional Emission System Components

Machines may be equipped with the following emission systems components: catalytic converter (two way and three way), engine controller and oxygen sensor(s). Some are optional and some are standard with all current model machines featuring them as standard equipment.

Catalytic Converter

The purpose of the catalytic converter is reduce the tail pipe emissions of the vehicle. However, correct operation of the catalytic converter must be verified by measuring the engine emission levels before and after the catalytic converter by using an exhaust gas analyzer (4 or 5 gas). The performance of the catalytic convertor must be measured every 300 hours and replaced at recommended intervals or when no longer operational.

Engine Controller/ Engine Control Module (ECM)

The purpose of the engine controller/ engine control module is to try to control the engine's air-fuel ratio to a predetermined level thus producing optimum engine performance. The correct operation of the engine controller can be verified using a "mixture monitor" tool (ZPN 7K-40410) for some machines.

Oxygen Sensor

Oxygen sensors are critical components used by the engine controller or engine control module. Correct oxygen sensor operation should be verified at each engine service or tune-up (every 300 hours) and replaced at recommended intervals or when no longer operational. Machines with engine control modules will indicate diagnostic trouble codes (DTCs) to indicate needed service.

Engine Emission Inspection

The engine emission checks must take place:

- Upon catalytic converter installation;
- Every tune-up or 300 hours of operation (or sooner if required by state or local regulations or indicated by machine duty cycle or performance);

Record the engine emission levels.

As a guideline reference, the post-cat emissions should show a reduction of no less than 75% in the carbon monoxide (CO) level. Typically the reduction in CO is much greater, around 90%. If the reduction in CO is less than 75% then the engine or the exhaust system components (which includes the catalytic converter) must be inspected, adjusted, repaired or replaced.

WARNING!



These engine emission checks are NOT substitutes for the daily emission monitoring of facility indoor air quality. In addition, the guideline reference for emission reductions should NOT be a substitute for any applicable government guidelines, standards or regulations.

IMPORTANT SAFETY GUARDS AND MATERIALS AVAILABLE FOR YOUR ZAMBONI MACHINE

The following items are available for owners and operators of our machines. Should you require replacement safety materials (warning and safety labels; or a safety poster), they are available at no cost to replace those originally provided with the delivery of the machines.

Auger and conditioner guard kits KZ-77500, KZ-77510, KZ-72100, KZ-40500, and KZ-40505 are available to update the applicable machine models listed below to current machine production guarding standards. KZ-40500 and KZ-40505 employ a snow tank switch to unlock a solenoid allowing for hydraulic vertical auger motor flow that is disabled when the snow tank is up. All other kits contain physical guard panels to restrict operator access to moving components like augers and belts. Please note that for the installation of the KZ-77500 conditioner guard kit, drilling and assembly is required.

To order, please contact your Zamboni Authorized Distributor and have your machine model number and serial number available.

Find your Local Zamboni Authorized Distributor at zamboni.com/distributor-locator

Part #	Description	Machine Model (S/N if applicable)
CONICAL SNOW SHIELD		
00-07956	CONICAL SNOW SHIELD KIT	- HD - HDA - HDB - KB
00-05699	CONICAL SNOW SHIELD KIT	- JRD
49-18380	CONICAL SNOW SHIELD KIT	- 500 (S/N 2804-5620) - 552 (S/N 4493-5656)
49-18390	CONICAL SNOW SHIELD KIT	- 520 - 525 - 526
VIDEOS		
DU-00100	ICE RESURFACER OPERATION + CONDITIONER MAINTENANCE VIDEO	- ALL MODELS
SAFETY LABELS		
DM-2015P EN	ELECTRIC MACHINE SAFETY LABEL KIT -INQUIRE ABOUT OTHER LANGUAGES AVAILABLE	- PLEASE NOTE MACHINE SERIAL NUMBERS HERE:
DM-2015R EN	FUEL MACHINE SAFETY LABEL KIT -INQUIRE ABOUT OTHER LANGUAGES AVAILABLE	- PLEASE NOTE MACHINE SERIAL NUMBERS HERE:
SAFETY POSTER		
DM-2020B	SAFETY POSTER (DUPLICATE / SAME AS INCLUDED IN THIS MAILING)	- ALL MODELS

IMPORTANT SAFETY GUARDS AND MATERIALS AVAILABLE FOR YOUR ZAMBONI MACHINE

Part #	Description	Machine Model (S/N if applicable)
CONDITIONER AND HORIZONTAL AUGER GUARDS		
KZ-77500	CONDITIONER GUARD KIT	- 500 - 540 - 545 - 546 - 552 - 520 - 525 - 526 - 400 - 440 - 445 - 446 - HDA - HDB
VERTICAL AUGER GUARDS		
KZ-72100	VERTICAL AUGER CHUTE EXTENSION KIT	- 500 (THROUGH S/N 5620) - 520 - 525 - 526 - 552 (THROUGH S/N - 5656) - HDA - HDB
KZ-77510	VERTICAL AUGER GUARD KIT (Tall Wash Water Tank)	- 500 (S/N 5621+) - 540 - 545 - 546 - 552 (S/N 5657+)
KZ-40505	VERTICAL AUGER INTERLOCK KIT	- 500 (THROUGH S/N -5620) - 520 - 525 - 526 - 552 (THROUGH S/N -5656) - HDA - HDB
KZ-40500	VERTICAL AUGER INTERLOCK KIT	- 400 - 440 - 445 - 446

To order, please contact your Zamboni Authorized Distributor and have your machine model number and serial number available. Find your Local Zamboni Authorized Distributor at zamboni.com/distributor-locator

2 MANUFACTURER'S WARRANTY

ZAMBONI COMPANY USA, INC.
15714 Colorado Ave. Paramount, CA 90723 USA +1 562 633 0751 +1 562 633 9365 zamboni.com

MANUFACTURER'S WARRANTY

Zamboni Company USA, Inc., hereinafter referred to as ZAMBONI, warrants all parts and materials installed on the Zamboni® ice resurfacing machine to be free from defects in material and workmanship under normal use for a period of two (2) years or 2,000 hours, whichever comes first, following shipment from our factory to the original user.

The obligation of ZAMBONI under this warranty is limited to replacing at our factory any part or parts supplied by us, which shall, within the warranty period be returned to us with transportation charges prepaid, and which our examination shall disclose to our satisfaction to have been defective.

This warranty being expressly in lieu of all other warranties expressed or implied, and of all other obligations or liabilities on our part. ZAMBONI neither assumes nor authorizes any other person to assume for us any other liability in connection with the sale. ZAMBONI reserves the right to inspect service records for evidence of regular maintenance and proper care of the machine. The warranty will not apply to damages or failures resulting from misuse, negligence, accident, alteration or improper service.

ZAMBONI reserves the right, at any time or times to revise or modify, discontinue or change any models of the ice resurfacer or any part or parts thereof, without notice and without incurring any liability or obligation to the purchaser.

ZAMBONI COMPANY USA, INC.

ZAMBONI®

BACK

3 OPERATING INSTRUCTIONS

PLEASE REFER TO THE OWNER'S AREA FOR LATEST VERSION OF THE OPERATING INSTRUCTIONS

CLICK HERE

BACK

4 TROUBLESHOOTING GUIDE

ZAMBONI®

TROUBLESHOOTING GUIDE
Zamboni® Ice Resurfacer
DM-22000

Many of the problems and corrective actions noted in this Guide are visually demonstrated and discussed in our Video Presentation on "Conditioner Maintenance" (ZP-06004). To achieve optimum results from your machine, we recommend obtaining this video tape so your personnel can better maintain your resurfacer. Subjects on the tape are marked with an asterisk (*).

Malfunction	Probable Cause	Corrective Action
Unsatisfactory shaving blade leaving wavy ice conditions.	Dull blade	*BLADE MUST BE SHARP. Most often the cause of shaving problems. A sharp blade will shave easier and will not tend to push the conditioner off the ice.
Blade chatters	Blade @ incorrect angle	* Refer to Operating Instructions. The angle of the blade should be about 10˚ in relation to the conditioner runner.
	Tire pressure low	Can affect shaving. Inflate tires to correct and uniform pressure.
	Lift bar and down pressure mechanism	* See Parts List for illustration of cylinder and related components. It is extremely important that these parts are in proper working order. When operating properly, weight from the rear of the machine will be transferred to the conditioner. See that all bushings are not worn excessively. Keep tension on down pressure leaf spring with set screw.
	Bushings worn	
	Cylinder working improperly	Check for leaks. It may be necessary to repack the cylinder or replace it. Check pins at both ends of cylinder for excessive wear and slop.
	Springs in conditioner	* Leaf springs and coil springs must be in good condition and tight if the blade holding bar is to be held firm.
Grooving the ice	Dull blade	* When the blade is dull, operator often lowers blade to cut more. The blade may then be far below the runner and may actually lift the conditioner runners off of the ice when traveling straight ahead. If making a turn with blade set this way, grooving of ice will likely occur. Install a sharp blade and recheck.
Conditioner leaving scratch on ice	Nick in blade	*Sharpen blade.
	Foreign matter on runners or other parts on conditioner.	*Check and remove foreign matter. File.

FRANK J. ZAMBONI & CO., INC. 15714 Colorado Ave., Paramount CA 90723-4211 • PH (562) 633-0751 • FAX (562) 633-9365

Malfunction	Probable Cause	Corrective Action
Difficult to adjust blade	Worn parts	*Check blade adjusting screw and related parts.
	Dirt, debris in mechanism	*Clean blade adjusting mechanism completely.
Conditioner runners riding high off ice	Dull blade	*When dull, blade tends to lift the runners off the ice. Try a freshly sharpened knife.
	Runners not straight	*Check with straight edge. Straighten if needed.
	Twist in conditioner	*Set on level surface. Disconnect from lift bar. If runners do not lay flat, conditioner must be straightened.
Leakage from side of conditioner	Dull blade lifting conditioner	*Change blade; set at proper angle; test.
	Improper fit at ends of squeegee	*Adjust or replace squeegee. Ends of squeegee should be tight to conditioner side plates.
Water freezing unevenly on surface	Cool water used on extremely cold ice surface	*Use hot water as ice making water.
Ice thickness building up too fast	Dull blade	*Install sharp blade.
	Blade at wrong angle	*Set blade at approximately 10˚ as explained in Operating Instructions.
	Too much water	*Keep closer control on water. After light skating session, you may only want to cut, wash and squeegee ice and not apply ice making water.
Ice building up on edge	Not edging often enough	Use edger more frequently.
Unable to make good ice in single pass	Not using wash water when resurfacing	*Use wash water operation in conjuction with other resurfacing operations.
Machine skidding, inadequate traction	Tire pressure low	Inflate tires to correct and uniform pressure.
	Oil getting on tires	Check and eliminate oil leaks on machine. Clean floor of storage room to eliminate oil.
	Dull blade	*Put on sharp blade.
	Tires worn	Tungsten tip - see that studs are in good condition. Ice grip tread - if tire tread is smooth, buff or roughen them up slightly at a local tire shop.
USE OF CHAINS OR STANDARD RUBBER TIRES IS **NOT** RECOMMENDED		

Malfunction	Probable Cause	Corrective Action
Difficult to steer	Insufficient lubrication	Lubricate steering linkage.
	Tire pressure low	Inflate tires to correct and uniform pressure.
	Worn or loose steering linkage	Refer to Parts List. Check steering system completely including hydraulic steering control, cylinder, joints, knuckles and front wheel bearings.
Inadequate hydraulic pressure	Lack of oil	Check and add as required.
	Oil filter dirty	Change oil filter.
	Faulty hydraulic pump	Parts may be worn. Replace or rebuild pump.
	Sticky relief valve	Replace relief valve.
Inadequate power for conveyor	Engine RPM too low	Check by selecting lower hydrostatic transmission selector setting and higher engine RPM.
	Faulty seal on conveyor	Disconnect small drain hose from motor and check amount of oil coming out of seal drain while motor is operating. Should only be slight amount; if too much, replace or rebuild motor.
	Faulty pump; lack of hydraulic pressure	Check by moving valve handles so that cylinder bottoms out. You should hear oil going "over relief" and engine RPM drop slightly. If faulty, rebuild or replace motor.
Hydraulic cylinder leaks	Worn or cracked packing	Overhaul cylinder and replace cylinder packing.
Conditioner won't lift high enough	Tire pressure low	Inflate tires to correct pressure.
Water pump will not work	Water lines plugged	*Flush water lines.
	Broken or loose belt	*Check. Replace if needed.
	Burned out impeller	*Replace impeller. Clean pump completely before replacing. Try pump while impeller is removed.
Water coming around front of conditioner	Water pump not working	*See item above.
	Too much wash water	*If more wash water is being dropped than the pump is picking up, squeegee will push it forward of the blade. Correct by cutting down slightly on amount of wash water being used.

Malfunction	Probable Cause	Corrective Action
Slush being left by machine	Improper fit on squeegee Wash water system not working properly	*Check. Replace if needed. *Check complete system. Inlet may be plugged, thereby causing water and snow to be forced under squeegee.
Water valve difficult	Damaged valves	*If valve is frozen while in closed position, pressure of ice may have deformed stem of valve. Check. Replace if needed.
Will not spread water evenly	Water distribution pipe clogged	*Flush out water tanks well. Remove ends of distribution pipe and clean completely.

BACK

5 PARTS LIST

PLEASE REFER TO THE OWNER'S AREA FOR LATEST VERSION OF THE PARTS LIST

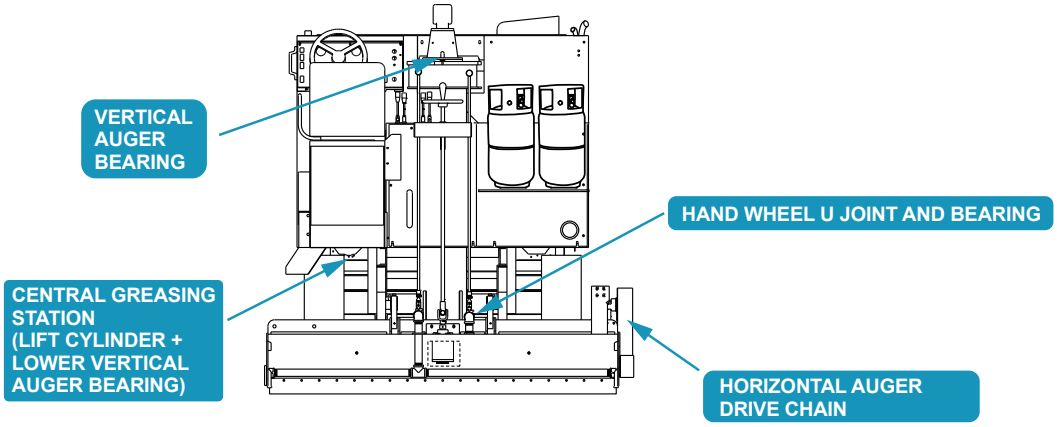
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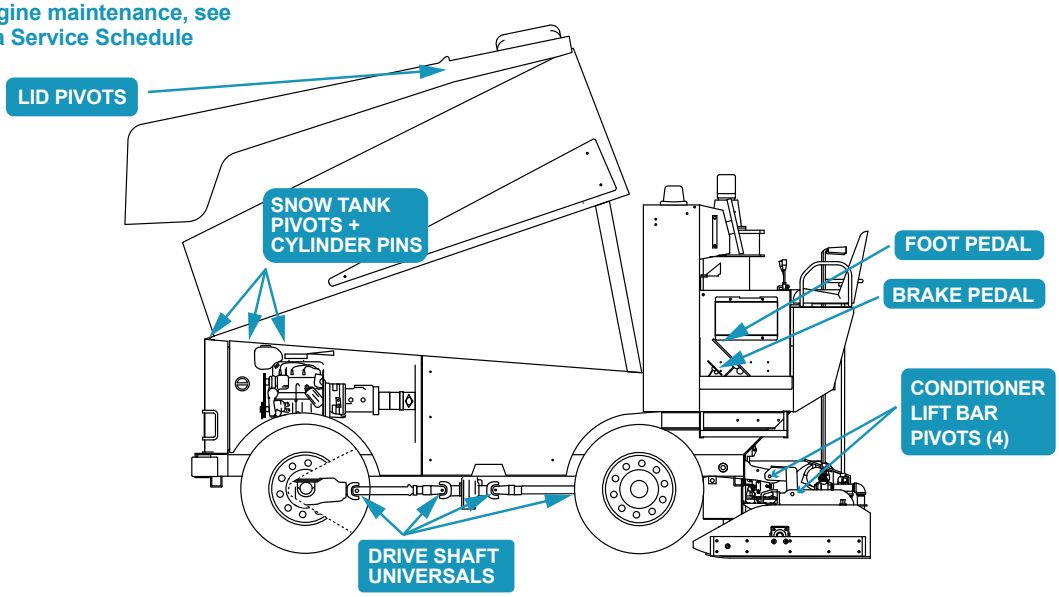
6 MAINTENANCE SCHEDULE / LOGS

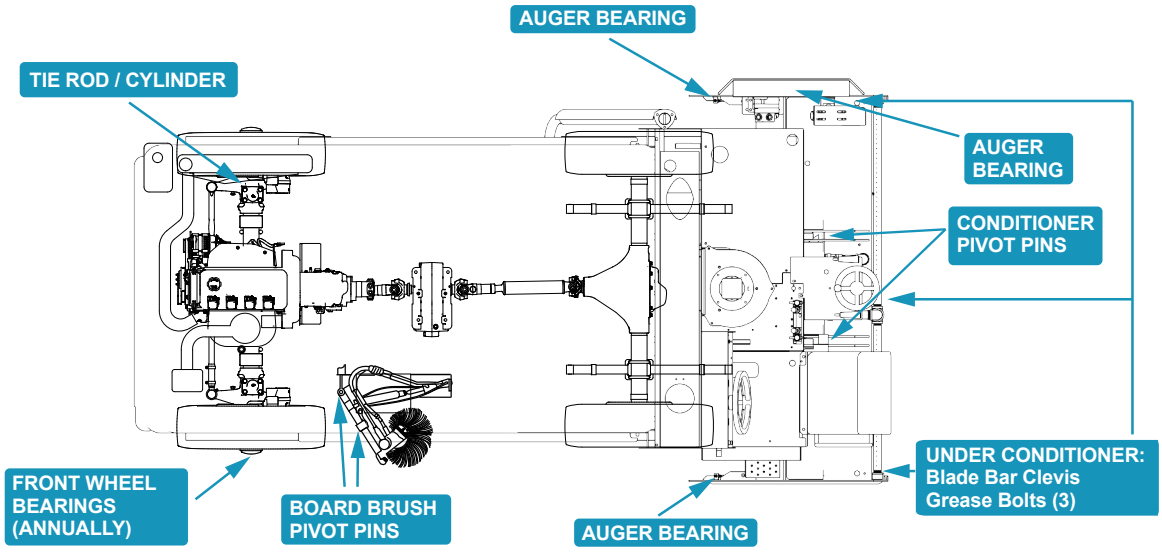
PREVENTATIVE MAINTENANCE: GREASING SITES

MODEL 546



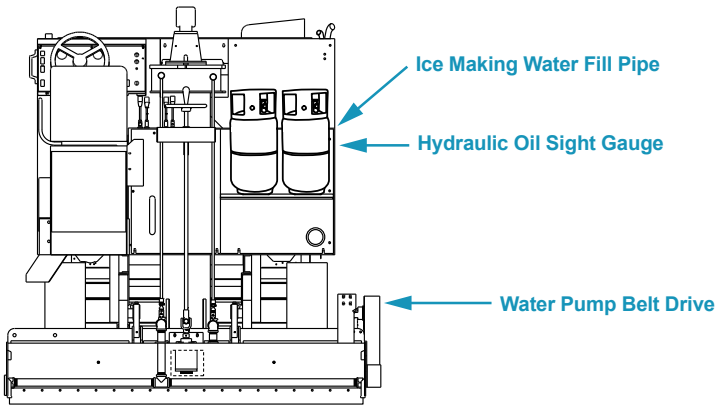
For engine maintenance, see Kubota Service Schedule



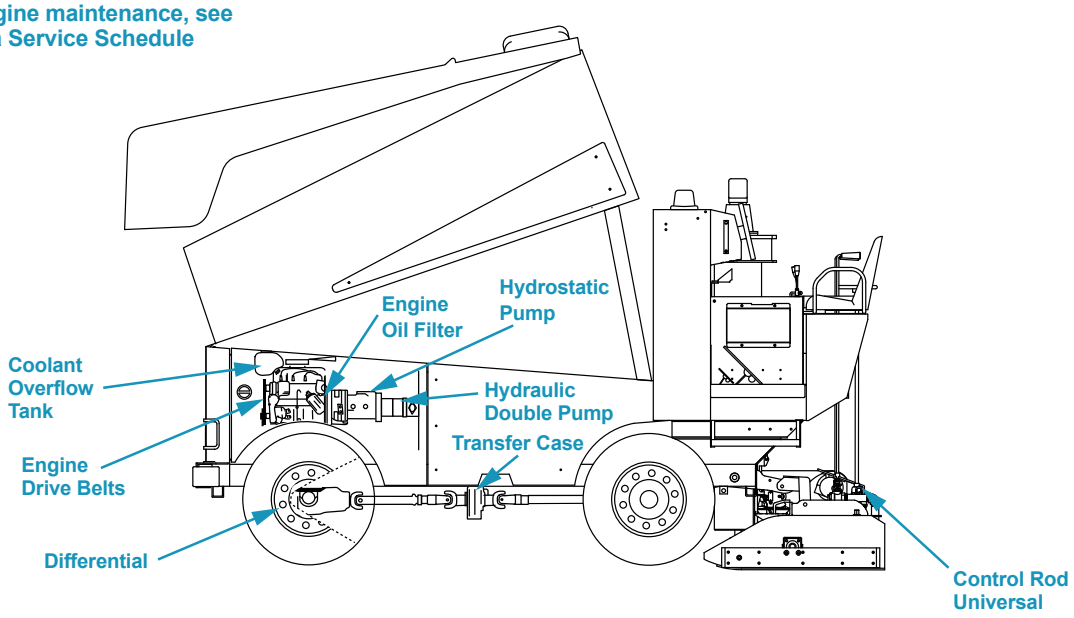


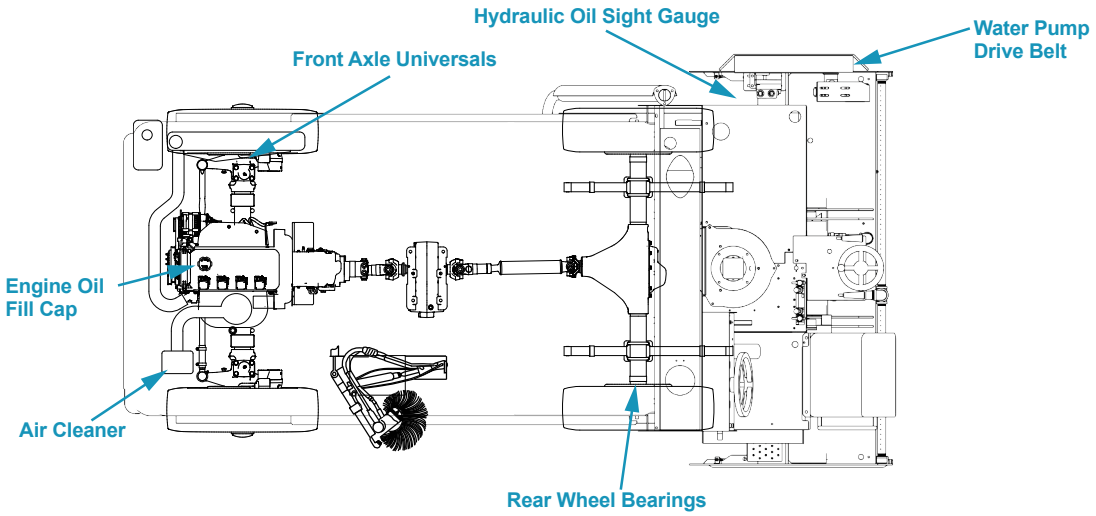
PREVENTATIVE MAINTENANCE: INSPECTION SITES

MODEL 546



For engine maintenance, see Kubota Service Schedule





PREVENTATIVE MAINTENANCE SCHEDULE

MODEL 546

Intervals	Description	Lubricant
Daily	Check hydraulic oil level Check blade for sharpness/angle Grease bottom vertical auger bearing Brief "walk around" visual inspection	• Grease (#2) NLGI or equiv.) • ISO 32 AW Hydraulic Oil
Weekly	Lubricate and check adjustment of horizontal conveyor chain (5/16" deflection) Grease horizontal conveyor bearings Grease vertical conveyor bearings Grease lift bar pins and bolts Grease foot pedal Grease brake pedal (under operator's platform) Grease blade adjusting universal Grease board brush pivot pins Check tire pressure (75 PSI) Clean wash water basket	• Grease (#2 NLGI or equiv.)
Monthly	Change engine oil and oil filter* (every 200 hrs of operation) Grease steering linkage Grease drive shaft universal bearings Grease dump tank cylinder pins Grease dump tank lid pivot bolts Grease drive shaft slip joints Check oil level in differentials Check oil level in transfer case Check adjustment on wash water pump drive belt (7/32" deflection) Check adjustment and condition of down pressure springs	• Grease (#2 NLGI or equiv.) • SAE10W-30 • EP-90 (B)
Semi-Annually	Check hydraulic hoses for wear Check water hoses for wear Check electrical wiring for wear	• Grease (#2 NLGI or equiv.)
Annually	Change hydraulic oil filter - after first hydraulic filter change (50 hrs), should be replaced after each additional 500 hours Repack wheel bearings Inspect axle shaft universals Check hydraulic oil for contamination and change if necessary Clean rust spots and repaint Change oil in differentials	• Grease (#2 NLGI or equiv.) • ISO 32 AW Hydraulic Oil • EP-90 (A)

(A) Although desirable to use the same type of oil, in an emergency, type A or any good quality automatic transmission oil and 10W-30 MS are compatible with ISO 32 AW Hydraulic Oil.
(B) Use SAE 80 for extremely low temperature

***Note:** For engine maintenance, see Kubota Service Schedule.

PREVENTATIVE MAINTENANCE SCHEDULE

MODEL 546

THIS SCHEDULE HAS BEEN SET UP AS A GUIDE ONLY. MORE FREQUENT INTERVALS MAY BE REQUIRED DEPENDING ON OPERATING CONDITIONS. (EXAMPLE: DRIVING THE MACHINE OUTSIDE OF THE BUILDING ON UNPAVED OR HEAVILY SANDED PARKING LOTS.)

ALL OF THE GREASE FITTINGS ON THE MACHINE COME EQUIPPED WITH RED PLASTIC DUST CAPS. REINSTALLING THESE AFTER GREASING WILL KEEP THE CONTAMINANTS OUT AND WILL HELP YOU LOCATE THEM THE NEXT TIME.

NOTE: WHEN WE RECOMMEND "DAILY", WE SUGGEST THAT THE GREASING IS DONE AFTER THE LAST FLOOD OF THE DAY. THIS WILL FLUSH THE WATER OUT OF THE BEARINGS BEFORE THE OVERNIGHT SHUTDOWN.

AS A GENERAL GUIDE: 1 HOUR ON THE HOURMETER IS THE EQUIVALENT TO 40 MILES ON AN ODOMETER. EXAMPLE: 100 HOURS RUN IS EQUAL TO 4,000 MILES TRAVELED.

MODEL 546
PREVENTATIVE MAINTENANCE LOG

DATE	BY	HOURS	DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	REPLACED COMPONENT(S)

Zamboni Model 546
ENGINE EMISSION SYSTEMS
INSPECTION AND MAINTENANCE

DANGER!



Internal combustion engines produce exhaust emissions that contain dangerous gases, including carbon monoxide (CO) and nitrogen dioxide (NO_2). These gases can cause serious injury or death.

The rink MUST be adequately ventilated during every operation of the Ice Resurfacer. Also the resurfacer must be kept properly maintained and serviced at all times and the engine timing should always be properly set. Each person who operates and maintains the resurfacer should be so instructed.

Please keep in mind that adequate ventilation, monitoring the facility's indoor air quality (for CO and NO_2 levels) and the condition of the machine is, at all times, the complete responsibility of the rink.

Operation and Maintenance

The safe and correct operation and maintenance of the resurfacer, the engine and the engine exhaust system includes:

- Measuring the facility's indoor air quality (for CO and NO_2 levels) **daily**;
- Measuring and recording the engine emission levels every 300 hours. The emission levels must not have increased more than 20% from the previous readings;
- Adjusting engine components (when applicable) to ensure correct operation and optimum engine emission levels;
- Inspecting, adjusting (when applicable), maintaining and replacing engine and exhaust system components when required;
- Starting and warming up the engine properly so that the machine is in "closed loop" mode when on the ice;
- Never operating the machine with the check engine light on continously.

If you do not have the tools, education or expertise to inspect, maintain, repair or replace these items, contact a reputable, licensed mechanic for assistance.

ZAMBONI®

Engine Emission System Components

This machine is equipped with an engine system that complies with CARB/EPA standards. In order to comply with these standards, the machine is equipped with the following items:

- Electronic Control Unit (ECU)
- Electronic Fuel Injection (EFI)
- electronic governor
- three-way catalytic converter
- Oxygen sensor
- MAP sensor
- engine coolant temperature sensor
- ambient air temperature sensor
- on-board diagnostic system
- check engine light

All of these items are used to ensure that the engine operates properly and meets the emission level standards. However, exhaust emissions are still being produced by the engine and while the level of the harmful pollutants are reduced, the air quality in the rink must still be monitored to make sure that the air is healthy. Refer to Chapter 4 in the Operating Instruction Manual for more information.

Engine Emission Inspection

The engine emission checks must take place:

- Every tune-up or 300 hours of operation (or sooner if required by state or local regulations or indicated by machine duty cycle or performance;
- Upon catalytic convertor installation.

Record the engine emision levels in the Engine Emission System - Inspection and Maintenance Chart.

Compare the emission readings with the emission levels from the previous inspection. ***If the emission levels have increased by 20% or more*** for any of the gases measured from the previous inspection, ***the emission system requires closer inspection and testing***. The catalytic convertor may also need to be replaced.

DANGER!



These engine emission checks are NOT substitutes for the daily emission monitoring of facility indoor air quality. In addition, the guideline reference for emission reductions should NOT be a substitute for any applicable government guidelines, standards or regulations.

Zamboni Model 546
ENGINE EMISSION SYSTEM
INSPECTION AND MAINTENANCE CHART

Machine serial no. _____ Fuel type _____

Date	Hours	By	Engine Condition	After catalytic convertor						Levels OK compared to previous testing?
				HC ppm	CO %	CO2 %	O2 %	NOx ppm	AFR	Must be less than 20% increase for any gas measured
			Idle							
			Load							
			Idle							
			Load							
			Idle							
			Load							
			Idle							
			Load							
			Idle							
			Load							

Note: To load the engine, move the conditioner to the fully lifted position and hold for 15 seconds

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7 KUBOTA® ENGINE

Zamboni Model 546
ENGINE INSPECTION AND SERVICE INTERVALS

The inspection and service intervals for the Kubota WG1605-G-E3 (gasoline) and WG1605-L-E3 (LP) engines are listed below:

	Item	Service Interval							
		Every 8 hrs (Daily)	Every 50 hrs (Weekly)	Every 100 hrs	Every 200 hrs	Every 1000 hrs	Every 2000 hrs	Every 1 year	Every 2 years
	Checking engine oil level	☆							
	Checking and fill coolant	☆							
	Checking air cleaner element	if necessary							
	Cleaning air cleaner element	if necessary		☆					
	Checking LPG tank setting condition	if necessary							
	Checking LPG fuel connector	☆							
	Changing engine oil		★		☆				
	Replacing oil filter cartridge		★		☆				
	Checking gasoline fuel hose and clamp bands		☆						
	Checking LPG fuel hose and clamp bands		☆						
	Cleaning spark plug			☆					
	Checking fuel filter			☆					
	Check fan belt tension and damage			☆					
	Checking battery electrolyte level			☆					
	Replacing fuel filter			if necessary					
	Checking LPG tank setting condition				☆				
	Checking radiator hoses and clamp bands				☆				
	Draining vaporizer & EPR				☆				
	Checking PCV valve					☆			
	Checking coolant hose of LPG vaporizer					☆			
	Checking LPG Lock off valve					☆			
	Checking valve clearance					☆			
	Replacing spark plug						☆		
*	Replacing air cleaner element							☆	
	Replacing gasoline fuel hose, clamp bands and fuel filter							☆	
	Cleaning fuel tank inside (for gasoline fuel)							☆	
	Cleaning water jacket and radiator interior							☆	
	Replacing intake air line								☆
	Replacing breather hose								☆
	Replacing LPG fuel hose and clamp bands								☆
	Replacing coolant hose of LPG vaporizer								☆
**	Checking LPG vaporizer								☆
	Replacing radiator hoses and clamp bands								☆
	Changing radiator coolant								☆
	Replacing battery								☆

★ Change engine oil and replace oil filter cartridge after the first 50 hours of operation.
*: Change more often when operating under dusty conditions.
**: If you do not have the proper tools and / or are not mechanically proficient, contact your local KUBOTA dealer.

In addition to the above engine inspection and service intervals, the following must be checked, measured and recorded every 300 hours, per the Zamboni 546 Operating Instructions and Zamboni 546 Engine Emission Systems Inspection and Maintenance documents:

- Check exhaust system for leaks; inspect, adjust (when applicable), maintain and replace engine and exhaust system components as required
- Measure and record engine emission levels. The emission levels must not have increased more than 20% from previous readings

Record date of service, description of service performed, and person performing service in the engine service log. Refer to the following documents for more additional service information.

REFERENCE DOCUMENTS:

- **KUBOTA WORKSHOP MANUAL (Doc# 9Y111-06611) - MAINTENANCE CHECKLIST, pg. G-6**
- **KUBOTA OPERATOR'S MANUAL (Doc# EG523-8916-3) - SERVICE INTERVALS, pg. G-6**
- **ZAMBONI 546 OPERATING INSTRUCTIONS (Doc# DM-20546) - ENGINE**
- **ZAMBONI 546 ENGINE EMISSION SYSTEMS INSPECTION AND MAINTENANCE (Doc# DM-54624)**

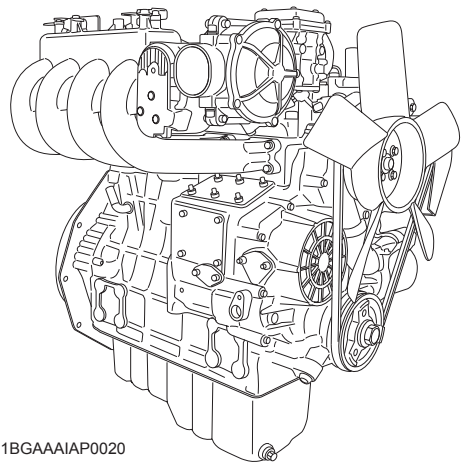
ENGLISH

OPERATOR'S MANUAL

KUBOTA

LIQUID COOLED GASOLINE/LPG ENGINE

MODELS WG1605-G-E3
WG1605-L-E3
WG1605-GL-E3



1BGAAAIAP0020

EG523-8916-3

READ AND SAVE THIS BOOK

Kubota

ENGLISH

FOREWORD

You are now the proud owner of a KUBOTA Engine. This engine is a product of KUBOTA quality engineering and manufacturing. It is made of fine materials and under a rigid quality control system. It will give you long, satisfactory service. To obtain the best use of your engine, please read this manual carefully. It will help you become familiar with the operation of the engine and contains many helpful hints about engine maintenance. It is KUBOTA's policy to utilize as quickly as possible every advance in our research. The immediate use of new techniques in the manufacture of products may cause some small parts of this manual to be outdated. KUBOTA distributors and dealers will have the most up-to-date information. Please do not hesitate to consult with them.

SAFETY FIRST

This symbol, the industry's "Safety Alert Symbol", is used throughout this manual and on labels on the machine itself to warn of the possibility of personal injury. Read these instructions carefully. It is essential that you read the instructions and safety regulations before you attempt to assemble or use this unit.

DANGER :	Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.
WARNING :	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION :	Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.
IMPORTANT :	Indicates that equipment or property damage could result if instructions are not followed.
NOTE :	Gives helpful information.

ENGLISH

CONTENTS

⚠SAFE OPERATION 1

SERVICING OF THE ENGINE 1

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SAFE OPERATION

Careful operation is your best assurance against an accident. Read and understand this section carefully before operating the engine. All operators, no matter how much experience they may have, should read this and other related manuals before operating the engine or any equipment attached to it. It is the owner's obligation to provide all operators with this information and instruct them on safe operation.

Be sure to observe the following for safe operation.

1. OBSERVE SAFETY INSTRUCTIONS

- Read and understand carefully this "OPERATOR'S MANUAL" and "LABELS ON THE ENGINE" before attempting to start and operate the engine.
- Learn how to operate and work safely. Know your equipment and its limitations. Always keep the engine in good condition.
- Before allowing other people to use your engine, explain how to operate and have them read this manual before operation.
- DO NOT modify the engine. UNAUTHORIZED MODIFICATIONS to the engine may impair the function and/or safety and affect engine life. If the engine does not perform properly, consult your local Kubota Engine Distributor first.



1AAACAAAP008B

2. WEAR SAFE CLOTHING AND PERSONAL PROTECTIVE EQUIPMENT (PPE)

- DO NOT wear loose, torn or bulky clothing around the machine that may catch on working controls and projections or into fans, pulleys and other moving parts causing personal injury.
- Use additional safety items-PPE, e.g. hard hat, safety protection, safety goggles, gloves, etc., as appropriate or required.
- DO NOT operate the machine or any equipment attached to it while under the influence of alcohol, medication, or other drugs, or while fatigued.
- DO NOT wear radio or music headphones while operating the engine.


1AEAAAAP0130

3. CHECK BEFORE STARTING & OPERATING THE ENGINE

- Be sure to inspect the engine before operation. Do not operate the engine if there is something wrong with it. Repair it immediately.
- Ensure all guards and shields are in place before operating the engine. Replace any that are damaged or missing.
- Check to see that you and others are a safe distance from the engine before starting.
- Always keep the engine at least 3 feet (1 meter) away from buildings and other facilities.
- DO NOT allow children or livestock to approach the machine while the engine is running.
- DO NOT start the engine by shorting across starter terminals.



1BAABADAP0010

4. KEEP THE ENGINE AND SURROUNDINGS CLEAN

- Be sure to stop the engine before cleaning.
- Keep the engine clean and free of accumulated dirt, grease and trash to avoid a fire. Store flammable fluids in proper containers and cabinets away from sparks and heat.
- Check for and repair leaks immediately.
- DO NOT stop the engine without idling; Allow the engine to cool down, first. Keep the engine idling for about 5 minutes before stopping unless there is a safety problem that requires immediate shut down.



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5. SAFE HANDLING OF FUEL AND LUBRICANTS -KEEP AWAY FROM FIRE

- Always stop the engine before refueling and/or lubricating.
- DO NOT smoke or allow flames or sparks in your work area. Fuel is extremely flammable and explosive under certain conditions.
- Refuel at a well ventilated and open place. When fuel and/or lubricants are spilled, refuel after letting the engine cool down.
- Do not use unapproved containers e.g. buckets, bottles, jars. Use approved fuel storage containers and dispensers.



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- If running the engine on LPG, use the standard LPG fuel recommended by KUBOTA. The use of other fuel may cause a hazardous or dangerous condition.
- LPG fuel in the gaseous state is heavier than air and will settle in low areas, this may be hazardous.
  Please follow all operator's manual instructions when changing the fuel tank and servicing the fuel system.

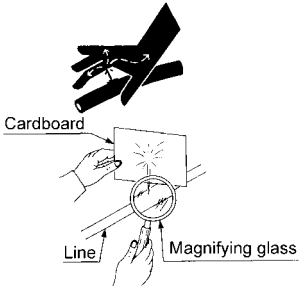
6. EXHAUST GASES & FIRE PREVENTION

- Engine exhaust fumes can be very harmful if allowed to accumulate. Be sure to run the engine in a well ventilated location and where there are no people or livestock near the engine.
- The exhaust gas from the muffler is very hot. To prevent a fire, do not expose dry grass, mowed grass, oil or any other combustible materials to exhaust gas. Keep the engine and muffler clean at all times.
- To avoid a fire, be alert for leaks of flammable substances from hoses and lines. Be sure to check for leaks from hoses or pipes, such as fuel and hydraulic fluid by following the maintenance check list.
- To avoid a fire, do not short across power cables and wires. Check to see that all power cables and wirings are in good condition. Keep all electrical connections clean. Bare wire or frayed insulation can cause a dangerous electrical shock and personal injury.



7. ESCAPING FLUID

- Relieve all pressure in the air, the oil and the cooling systems before disconnecting any lines, fittings or related items.
- Be cautious of possible pressure relief when disconnecting any device from a pressurized system that utilizes pressure. DO NOT check for pressure leaks with your hand. High pressure oil or fuel can cause personal injury.
- Escaping fluid under pressure has sufficient force to penetrate skin causing serious personal injury.
- Fluid escaping from pinholes may be invisible. Use a piece of cardboard or wood to search for suspected leaks: do not use hands and body. Use safety goggles or other eye protection when checking for leaks.
- If injured by escaping fluid, see a medical doctor immediately. This fluid can produce gangrene or severe allergic reaction.



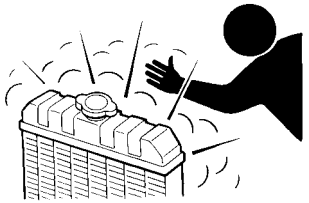
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8. CAUTIONS AGAINST BURNS & BATTERY EXPLOSION

- To avoid burns, be cautious of hot components, e.g. muffler, muffler cover, radiator, hoses, engine body, coolants, engine oil, etc. during operation and after the engine has been shut off.
- DO NOT remove the radiator cap while the engine is running or immediately after stopping. Otherwise hot water will spout out from the radiator. Wait until the radiator is completely cool to the touch before removing the cap. Wear safety goggles.
- Be sure to close the coolant drain valve, secure the pressure cap, and fasten the pipe band before operating. If these parts are taken off, or loosened, it will result in serious personal injury.
- The battery presents an explosive hazard. When the battery is being charged, hydrogen and oxygen gases are extremely explosive.
- DO NOT use or charge the battery if its fluid level is below the LOWER mark.
  Otherwise, the component parts may deteriorate earlier than expected, which may shorten the service life or cause an explosion. Immediately, add distilled water until the fluid level is between the UPPER and LOWER marks.
- Keep sparks and open flames away from the battery, especially during charging. DO NOT strike a match near the battery.
- DO NOT check the battery charge by placing a metal object across the terminals. Use a voltmeter or hydrometer.
- DO NOT charge a frozen battery. There is a risk of explosion. When frozen, warm the battery up to at least 16°C (61°F).



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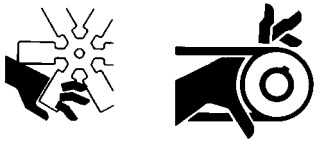
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9. KEEP HANDS AND BODY AWAY FROM ROTATING PARTS

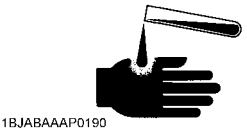
- Be sure to stop the engine before checking or adjusting the belt tension and cooling fan.
- Keep your hands and body away from rotating parts, such as the cooling fan, V-belt, fan drive pulley or flywheel. Contact with rotating parts can cause severe personal injury.
- DO NOT run the engine without safety guards. Install safety guards securely before operation.



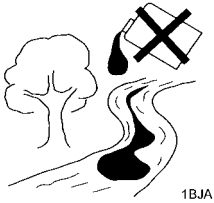
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10. ANTI-FREEZE & DISPOSAL OF FLUIDS

- Anti-freeze is poisonous. If it is swallowed, seek immediate medical help. Do NOT make a person throw up unless told to do so by poison control or a health care professional. Use standard first aid and CPR for signs of shock or cardiac arrest. Call your local Poison Control Center or your local emergency number for further assistance.
- Wear rubber gloves to avoid personal injury, when you treat anti-freeze. In case of contact with skin, wash it off immediately.
- DO NOT mix different types of Anti-freeze. The mixture can produce a chemical reaction causing harmful substances. Use approved or genuine KUBOTA Anti-freeze.
- Be mindful of the environment and the ecology. Before draining any fluids, determine the correct way to dispose of them. Observe the relevant environmental protection regulations when disposing of oil, fuel, coolant, brake fluid, filters and batteries.
- When draining fluids from the engine, place a suitable container underneath the engine body.
- DO NOT pour waste onto the ground, down a drain, or into any water source. Dispose of waste fluids according to environmental regulations.



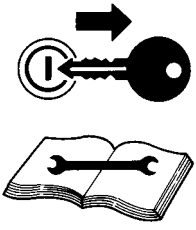
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11. CONDUCTING SAFETY CHECKS & MAINTENANCE

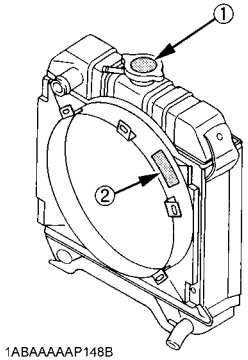
- When inspecting the engine or servicing, place the engine on a large flat surface. DO NOT work on anything that is supported ONLY by lift jacks or a hoist. Always use blocks or the correct stands to support the engine before servicing.
- Disconnect the battery from the engine before conducting service. Put a "DO NOT OPERATE!" tag on the key switch to avoid accidental starting.
- To avoid sparks from an accidental short circuit always disconnect the battery's ground cable (-) first and reconnect it last.
- Be sure to stop the engine and remove the key when conducting daily and periodic maintenance, service and cleaning.
- Check or conduct maintenance after the engine, coolant, muffler, or muffler cover have cooled off completely.
- Always use the appropriate tools and fixtures. Verify that they are in good condition before performing any service work. Make sure you understand how to use them before service.
- Use ONLY correct engine barring techniques for manually rotating the engine. DO NOT attempt to rotate the engine by pulling or prying on the cooling fan and V-belt. This practice can cause serious personal injury or premature damage to the cooling fan and belt.



1BJABAAAP0200

- Replace fuel pipes and lubricant pipes with their hose clamps every 2 years or earlier whether they are damaged or not. They are made of rubber and age gradually.
- When servicing is performed together by two or more persons, take care to perform all work safely.
- Keep a first aid kit and fire extinguisher handy at all times.

12. WARNING AND CAUTION LABELS



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① Part No. 19077-8724-1 or 16667-8724-1
(55mm in diameter) (37mm in deameter)



1ABACAAAP036K

② Part No. TA040-4957-1
Do not get your hands close to engine fan and fan belt.



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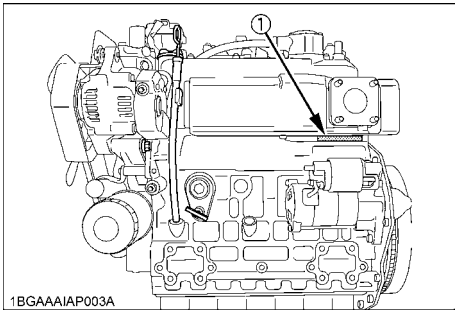
13. CARE OF WARNING AND CAUTION LABELS

1. Keep warning and caution labels clean and free from obstructing material.
2. Clean warning and caution labels with soap and water, dry with a soft cloth.
3. Replace damaged or missing warning and caution labels with new labels from your local KUBOTA dealer.
4. If a component with warning and caution label(s) affixed is replaced with a new part, make sure the new label(s) is (are) attached in the same location(s) as the replaced component.
5. Mount new warning and caution labels by applying to a clean dry surface and pressing any bubbles to the outside edge.

SERVICING OF THE ENGINE

Your dealer is interested in your new engine and has the desire to help you get the most value from it. After reading this manual thoroughly, you will find that you can do some of the regular maintenance yourself.
However, when in need of parts or major service, be sure to see your KUBOTA dealer.
For service, contact the KUBOTA Dealership from which you purchased your engine or your local KUBOTA dealer.
When in need of parts, be prepared to give your dealer the engine serial number.
Locate the serial number now and record them in the space provided.

	Type	Serial No.
Engine		
Date of Purchase		
Name of Dealer		
(To be filled in by purchaser)		



(1) Engine serial number

IMPORTANT INFORMATION OF EMISSION REGULATION

To conform to U.S. EPA Phase 3 and CARB LSI (Large SI) emission regulations, the following standards must be followed before using the WG1605-E3 engine.

1. EXHAUST SYSTEM (COMMON)

THE WG1605-E3 ENGINE MUST USE THE BELOW CATALYTIC PARTS.

GENUINE PART	PART NO.
CATALYTIC CONVERTER	EG523-1212△
CATALYTIC MUFFLER	EG526-1211△

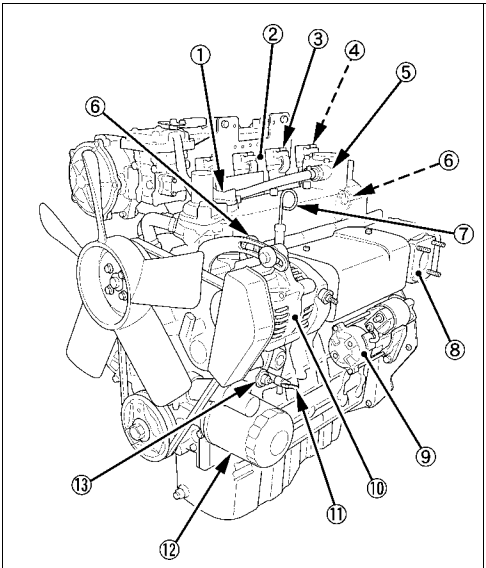
Any modifications to the fuel system or any adjustments made on this engine will cause this engine to be in non-compliance with emission regulations.

2. LPG REGULATOR WITH VAPORIZER (WG1605-L-E3 / WG1605-GL-E3)

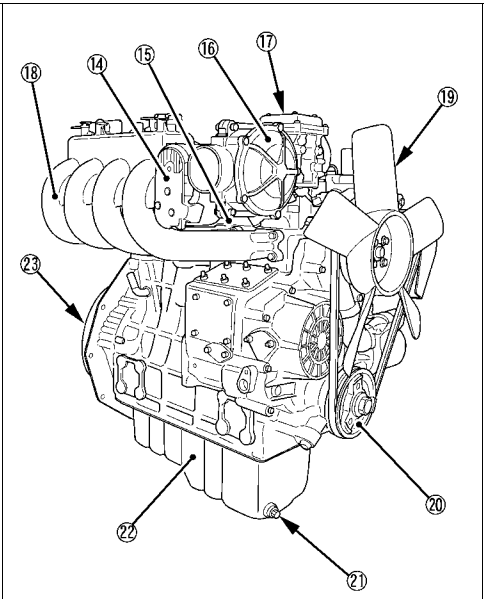
When operating WG1605-L-E3 / WG1605-GL-E3 on LPG, only a KUBOTA genuine regulator assy (D-STAGE) and lock off valve with LPG filter can be used.

Only this regulator assy (D-STAGE) and lock off valve with LPG filter can be installed by an authorized KUBOTA DISTRIBUTOR or the manufacturer of the equipment in which this engine is used.

NAMES OF PARTS



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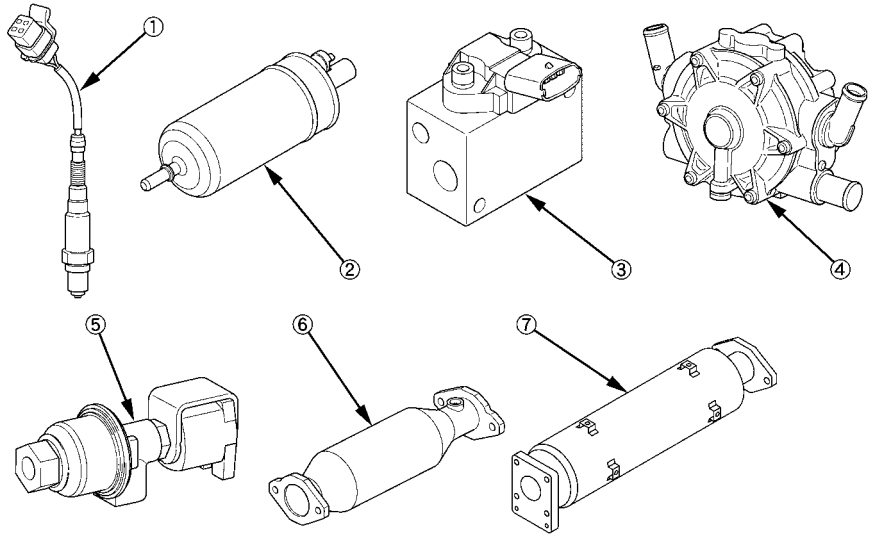


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Ref. No.	Part Name	Type			Ref. No.	Part Name	Type		
		G	L	GL			G	L	GL
(1)	Oil filler plug	○	○	○	(13)	Oil pressure switch	○	○	○
(2)	Delivery pipe (gasoline)	○	-	○	(14)	Electronic control throttle	○	○	○
(3)	Plug ignition coil	○	○	○	(15)	Injector	○	-	○
(4)	Spark plug	○	○	○	(16)	Gas mixer	-	○	○
(5)	PCV valve	○	○	○	(17)	Pressure regulator	-	○	○
(6)	Engine hook	○	○	○	(18)	Intake manifold	○	○	○
(7)	Oil level gauge	○	○	○	(19)	Cooling fan	○	○	○
(8)	Exhaust manifold	○	○	○	(20)	Fan drive pulley	○	○	○
(9)	Starter	○	○	○	(21)	Oil drain plug	○	○	○
(10)	Alternator	○	○	○	(22)	Oil pan	○	○	○
(11)	Coolant drain cock	○	○	○	(23)	Flywheel	○	○	○
(12)	Oil filter cartridge	○	○	○	(24)	ECU (Engine Control Unit)	○	○	○

G Type : WG1605-G-E3, L Type : WG1605-L-E3, GL Type : WG1605-GL-E3

NOTE :
- (24) ECU (Engine Control Unit) is not connected to the engine in the figure above.



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Ref. No.	Part Name	Type		
		G	L	GL
(1)	Sensor (O2)	○	○	○
(2)	Fuel pump	○	-	○
(3)	Manifold (FPM)	○	-	○
(4)	Regulator assy (D-STAGE)	-	○	○
(5)	Lock off valve	-	○	○
(6)	Catalytic converter	○	○	○
(7)	Catalytic muffler	○	○	○

G Type : WG1605-G-E3, L Type : WG1605-L-E3, GL Type : WG1605-GL-E3

PRE-OPERATION CHECK

BREAK-IN

During the engine break-in period, observe the following by all means:

1. Change engine oil and oil filter cartridge after the first 50 hours of operation. (See "ENGINE OIL" in "PERIODIC SERVICE" section.)
2. When ambient temperature is low, operate the machine after the engine has been completely warmed up.

DAILY CHECK

To prevent trouble from occurring, it is important to know the conditions of the engine well. Check it before starting.

⚠ CAUTION

To avoid personal injury:

- **Be sure to install shields and safeguards attached to the engine when operating.**
- **Stop the engine at a flat and wide space when checking.**
- **Keep dust or fuel away from the battery, wiring, muffler and engine to prevent a fire. Check and clear them before operating everyday. Pay attention to the heat of the exhaust pipe or exhaust gas so that it can not ignite trash.**

Item		Ref. page
1. Parts which had trouble in previous operation		-
2. By walking around the machine	(1) Oil or water leaks	16 to 20
	(2) Engine oil level and contamination	16, 17
	(3) Amount of fuel	15
	(4) Amount of coolant	18 to 20
	(5) Dust in air cleaner dust cup	21
	(6) Damaged parts and loosened bolts and nuts	-
3. By inserting the key into the starter switch	(1) Proper functions of meters and pilot lamps; no stains on these parts	-
4. By starting the engine	(1) Unusual engine noise	9
	(2) Engine start-up condition	6
	(3) Slow-down and acceleration behavior	9

OPERATING THE ENGINE

STARTING THE ENGINE (NORMAL)

CAUTION

To avoid personal injury:

- **Do not allow children to approach the machine while the engine is running.**
- **Be sure to install the machine on which the engine is installed, on a flat place.**
- **Do not run the engine on gradients.**
- **Do not run the engine in an enclosed area. Exhaust gas can cause air pollution and exhaust gas poisoning.**
- **Keep your hands away from rotating parts (such as fan, pulley, belt, flywheel etc.) during operation.**
- **Do not operate the machine while under the influence of alcohol or drugs.**
- **Do not wear loose, torn or bulky clothing around the machine. It may catch on moving parts or controls, leading to the risk of accident. Use additional safety items, e.g. hard hat, safety boots or shoes, eye and hearing protection, gloves, etc., as appropriate or required.**
- **Do not wear radio or music headphones while operating engine.**
- **Check to see if it is safe around the engine before starting.**
- **Reinstall safeguards and shields securely and clear all maintenance tools when starting the engine after maintenance.**

IMPORTANT :

- When starting the engine after a long storage (of more than 3 months), activate the starter for about 10 seconds to allow oil to reach every engine part.

Gasoline

1*. Turn the fuel selector switch* to the "GASOLINE" position.

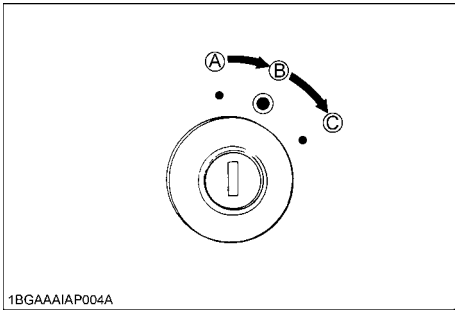
NOTE:
*The step 1 above is for GL type only.
*The fuel selector switch is not provided by KUBOTA.

LPG

1. Open the liquid withdrawal valve of the LPG fuel tank.
2*. Turn the fuel selector switch* to the "LPG" position.

NOTE:
*The step 2 above is for GL type only.
*The fuel selector switch is not provided by KUBOTA.

3. Insert the key into the starter switch and turn it to the "ON" (◉) position.



(A) “OFF“
(B) “ON”
(C) “START”

4. Check to see that MIL (Malfunction Indicator Light) is ON.

5. Turn the key to the "START" position and the starter will begin turning. Release the key immediately, when the engine starts.

6. Check to see that MIL (Malfunction Indicator Light) is OFF.
If not, immediately stop the engine and check the cause.

7. Warm up the engine at medium speed running for 3 to 5 minutes.

IMPORTANT :
- Be sure to warm up the engine not only in winter but also in other warmer seasons.
- In case of converting the fuel (gasoline ⟷ LPG) while running the engine, the engine should be operated with the engine speed high and no-loaded. If you convert the fuel with the engine speed low, the engine will stop.

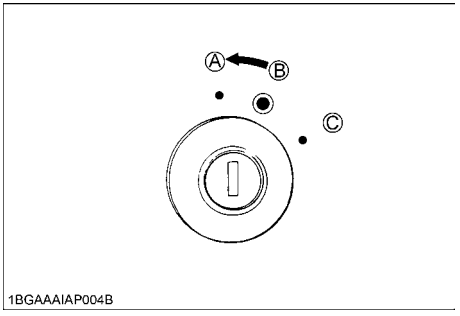
STOPPING THE ENGINE

Gasoline

1. **Cool down the engine for 2 to 3 minutes.**
2. **Turn the starter switch to the "OFF" (●) position.**
3. **Remove the key at the "OFF" position.**

LPG

1. **Cool down the engine for 2 to 3 minutes.**
2. **Turn the starter switch to the "OFF" (●) position.**
3. **Close the liquid withdrawal valve of the LPG fuel tank.**
4. **Remove the key at the "OFF" position.**



(A) “OFF“
(B) “ON”
(C) “START”

CHECKS DURING OPERATION

While running, make the following checks to see that all parts are working correctly.

■Radiator cooling water (Coolant)

WARNING

To avoid personal injury:

- **Do not remove radiator cap until coolant temperature is well below its boiling point. Then loosen cap slightly to the stop position, to relieve any pressure, before removing cap completely.**

If the coolant temperature warning lamp lights up or if steam or coolant does not stop squirting from the radiator overflow pipe, turn off the load and **keep the engine idling (COOLING-DOWN) for at least 5 minutes** to let it cool down gradually. Then stop the engine and take the following inspection and servicing.

1. Check to see if the coolant runs short or if there is any coolant leak;
2. Check to see if there is any obstacle around the cooling air inlet or outlet;
3. Check to see if there is any dirt or dust between radiator fins and tube;
4. Check to see if the fan belt is too loose; and
5. Check to see if radiator water pipe is clogged.

■Oil pressure lamp

The lamp lights up to warn the operator that the engine oil pressure has dropped below the prescribed level. If this should happen during operation or should not go off even after the engine is accelerated more than 1000rpm, immediately stop the engine and check the following:

1. Engine oil level (See "ENGINE OIL" in "PERIODIC SERVICE" section.)

■Immediately stop the engine if;

- The engine suddenly slows down or accelerates.
- Unusual noises are suddenly heard.

■If MIL (Malfunction Indicator Light) lights up:

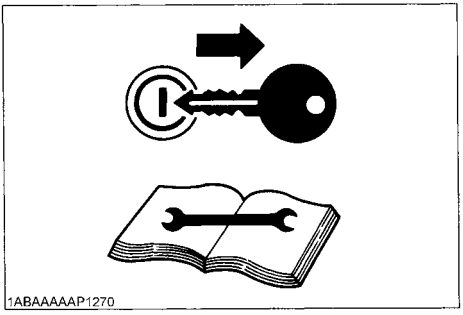
Consult your KUBOTA dealer.

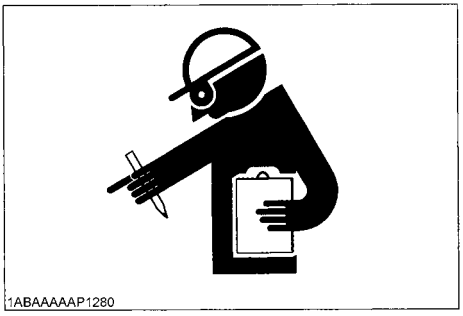
MAINTENANCE

CAUTION

To avoid personal injury:

- **Be sure to conduct daily checks, periodic maintenance, refueling or cleaning on a level surface with the engine shut off and remove the key.**
- **Before allowing other people to use your engine, explain how to operate, and have them read this manual before operation.**
- **Always use proper tools, that are in good condition. Make sure you understand how to use them, before performing any service work.**
- **When installing, be sure to tighten all bolts lest they should be loose. Tighten the bolts by the specified torque.**
- **Do not put any tools on the battery, or battery terminals may short out. Severe burns or fire could result. Detach the battery from the engine before maintenance.**
- **Do not touch muffler or exhaust pipes while they are hot; Severe burns could result.**





SERVICE INTERVALS

Non-warranty maintenance, repair, or replacement of the emission control devices and systems should be performed by a qualified repair establishment or individual which has the experience and equipment to perform such work.
See the Emission Warranty Statement.

In order to keep your engine in good working conditions, be sure to follow the maintenance / checking schedule given in the table below. (The schedule applies to an engine in use under normal conditions.)

Items		Interval				Remarks	Ref. Page
		Every 8 hours (daily)	Every 50 hours (weekly)	Every 100 hours	Every 200 hours		
Each part	Check / Clean	●					-
Engine oil	Check / Replenish	●					16
	Change		(Initial change)		●		17
Oil filter cartridge	Change		(Initial change)		●		17
Spark plug	Clean			▲			18
	Adjust			▲			18
	Change						-
Air cleaner element	Check	▲					21
	Clean	▲		●			21
	Change						21
Intake pipe / clamp bands	Change						-
Fuel filter	Check			●			-
	Change			▲			-
Fuel tank	Clean					Gasoline line	-
	Check setting	▲			●	LPG line	15
Fuel pipe / clamps (Gasoline line)	Check		●				15
	Change						15
Fuel pipe / clamps (LPG line: LPG tank to regulator assy (D-EPR))	Check the connector	●					-
	Check fuel leakage		●				15
	Change						-

▲: If necessary

IMPORTANT:

*1 Change more often when operating under dusty conditions.

*2 If you do not have the proper tools and/or are not mechanically proficient, contact your local KUBOTA dealer.

To ensure the best quality and reliability, use new KUBOTA Genuine parts or their equivalents for repair and replacement, whenever you have maintenance done.

Items		Interval				Remarks	Ref. Page
		Every 1000 hours	Every 2000 hours	Yearly	Each 2 years		
Each part	Check / Clean						-
Engine oil	Check / Replenish						16
	Change						17
Oil filter cartridge	Change						17
Spark plug	Clean						18
	Adjust						18
	Change		●				-
Air cleaner element	Check						21
	Clean						21
	Change			●*1			21
Intake pipe / clamp bands	Change				●		-
Fuel filter	Check						-
	Change			●			-
Fuel tank	Clean			●		Gasoline line	-
	Check setting					LPG line	15
Fuel pipe / clamps (Gasoline line)	Check						15
	Change			●			15
Fuel pipe / clamps (LPG line: LPG tank to regulator assy (D-EPR))	Check the connector						-
	Check fuel leakage						15
	Change				●		-

▲: If necessary

IMPORTANT:

*1 Change more often when operating under dusty conditions.

*2 If you do not have the proper tools and/or are not mechanically proficient, contact your local KUBOTA dealer.

To ensure the best quality and reliability, use new KUBOTA Genuine parts or their equivalents for repair and replacement, whenever you have maintenance done.

Items		Interval				Remarks	Ref. Page
		Every 8 hours (daily)	Every 50 hours (weekly)	Every 100 hours	Every 200 hours		
Breather tube	Change						-
PCV valve	Check						-
LPG vaporizer regulator	Check					Hot water line	15
	Change					Hot water line	-
	Check inner parts*2						-
LPG Lock off valve	Check						-
Battery	Check			●			-
	Change						-
Radiator coolant	Check	●					18
	Change						19
Radiator hoses and clamp bands	Check				●		20
	Change						20
Radiator and water jacket	Clean						20
Fan belt tension	Check			●			25
	Adjust			▲			25
Valve clearance	Adjust						-

▲: If necessary

IMPORTANT:

*1 Change more often when operating under dusty conditions.

*2 If you do not have the proper tools and/or are not mechanically proficient, contact your local KUBOTA dealer.

To ensure the best quality and reliability, use new KUBOTA Genuine parts or their equivalents for repair and replacement, whenever you have maintenance done.

Items		Interval				Remarks	Ref. Page
		Every 1000 hours	Every 2000 hours	Yearly	Each 2 years		
Breather tube	Change				●		-
PCV valve	Check	●					-
LPG vaporizer regulator	Check	●				Hot water line	15
	Change				●	Hot water line	-
	Check inner parts*2				●		-
LPG Lock off valve	Check	●					-
Battery	Check						-
	Change				●		-
Radiator coolant	Check						18
	Change				●		19
Radiator hoses and clamp bands	Check						20
	Change				●		20
Radiator and water jacket	Clean			●			20
Fan belt tension	Check						25
	Adjust						25
Valve clearance	Adjust	●*2					-

▲: If necessary

IMPORTANT:

*1 Change more often when operating under dusty conditions.

*2 If you do not have the proper tools and/or are not mechanically proficient, contact your local KUBOTA dealer.

To ensure the best quality and reliability, use new KUBOTA Genuine parts or their equivalents for repair and replacement, whenever you have maintenance done.

PERIODIC SERVICE

FUEL

Fuel is flammable and can be dangerous. You should handle fuel with care.

■Gasoline

[WG1605-G-E3 / WG1605-GL-E3]

1. Use unleaded gasoline and E10 only.

IMPORTANT :

- DO NOT use gasoline blended with methyl alcohol.

■Fuel level check and refueling

1. Check to see that the fuel level is above the lower limit of the fuel level gauge.
2. If the fuel is too low, add fuel to the upper limit. Do not overfill.

■Checking the fuel pipes

⚠ CAUTION

To avoid personal injury;

- **Stop the engine before checking or replacing the fuel pipes. Broken fuel pipes can cause fires.**

Check the fuel pipes every 50 hours of operation. When if;

1. If the clamp band is loose, apply oil to the screw of the band, and tighten the band securely.
2. If the fuel pipes, made of rubber, become worn out, replace them and clamp bands every year.
3. If the fuel pipes and clamp bands are found worn or damaged before one year passes, replace or repair them at once.

IMPORTANT :

- When the fuel pipes are not installed, plug them at both ends with clean cloth or paper to prevent dirt from entering. Dirt in the pipes can cause fuel injector malfunction.

NOTE :

- For the locations of fuel pipes, see “Fuel system diagrams” in “FUEL SYSTEM AND DIAGRAMS” section.

■LPG

[WG1605-L-E3 / WG1605-GL-E3]

1. Use Commercial LPG only.
2. Fuel tank is liquid withdrawal type.

IMPORTANT :

- Be sure that the fill up valve and the liquid withdrawal valve are closed.
- Be sure that LPG hose is connected with the liquid withdrawal valve.
- Be sure that LPG tank is placed firmly not to move by machine vibration.
  (See "FUEL SYSTEM AND DIAGRAMS" section.)

■LPG leakage check

[WG1605-L-E3 / WG1605-GL-E3]

⚠ WARNING

To avoid personal injury:

- **Never test for gas leaks with a flame.**

Turn on the gas at low idling rpm and use a soap solution or equivalent to check all connections for leaks between the fuel tank and dual fuel injector.
Bubbles will indicate a loose connection.

■LPG fuel tank check

[WG1605-L-E3 / WG1605-GL-E3]

Check that LPG fuel tank is installed firmly.
Be sure that the fill up valve and liquid withdrawal valve of the LPG fuel tank can be opened and closed easily.

■LPG regulator check

[WG1605-L-E3 / WG1605-GL-E3]

Check that the hot water lines are not leaking.

ENGINE OIL

⚠ CAUTION

To avoid personal injury:

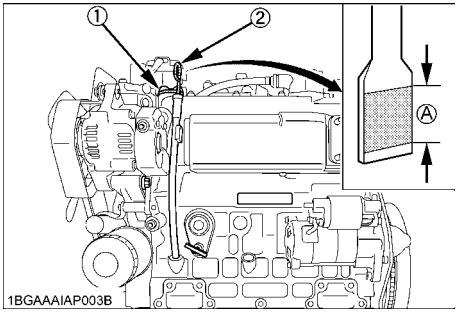
- **Be sure to stop the engine before checking and changing the engine oil and the oil filter cartridge.**
- **Contact with engine oil can damage your skin. Put on gloves when using engine oil. If you come in contact with engine oil, wash it off immediately.**

NOTE :

- Be sure to inspect the engine, locating it on a level place. If placed on gradients accurately, oil quantity may not be measured.

■Checking oil level and adding engine oil

1. Check the engine oil level before starting or more than 5 minutes after stopping the engine.
2. Remove the oil level gauge, wipe it clean and reinstall it.
3. Take the oil level gauge out again, and check the oil level.



(1) Oil filler plug
(2) Oil level gauge

[Lower end of oil level gauge]
(A) Engine oil level within this range is proper.

4. If the oil level is too low, remove the oil filler plug, and add new oil to the prescribed level.
5. After adding oil, wait more than 5 minutes and check the oil level again. It takes some time for the oil to drain down to the oil pan.

Models	Engine oil quantity
WG1605-G-E3 WG1605-L-E3 WG1605-GL-E3	6.0 L (1.59 U.S.gals.)

IMPORTANT :

- Engine oil should have properties of API classification SL or higher.
- Change the type of engine oil according to the ambient temperature.

Above 25°C (77°F)	SAE30 or SAE10W-30 SAE15W-40
0°C to 25°C (32°F to 77°F)	SAE20 or SAE10W-30
0°C to -20°C (32°F to -4°F)	SAE10W or SAE10W-30

- When using oil of different brands from the previous one, be sure to drain all the previous oil before adding the new engine oil.

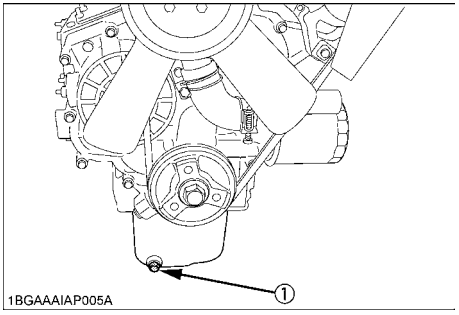
■Changing engine oil

CAUTION

To avoid personal injury:

- **Be sure to stop the engine before draining engine oil.**
- **When draining engine oil, place some container underneath the engine and dispose it according to local regulations.**
- **Do not drain oil after running the engine. Allow engine to cool down sufficiently.**

1. Change oil after the initial 50 hours of operation and every 200 hours thereafter.
2. Remove the drain plug at the bottom of the engine, and drain all the old oil. Drain oil will drain easier when the oil is warm.



(1) Oil drain plug

3. Replace the drain plug gasket.
4. Add new engine oil up to the upper limit of the oil level gauge.

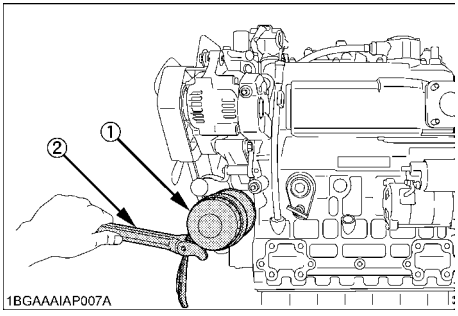
■Replacing the oil filter cartridge

CAUTION

To avoid personal injury:

- **Be sure to stop the engine before changing the oil filter cartridge.**
- **Allow engine to cool down sufficiently, oil can be hot and cause burns.**

1. Replace the oil filter cartridge after the initial 50 hours of operation and every 200 hours thereafter.
2. Remove the old oil filter cartridge with a filter wrench.
3. Apply a film of oil to the gasket for the new cartridge.
4. Screw in the cartridge by hand. When the gasket contacts the seal surface, tighten the cartridge enough by hand. Because, if you tighten the cartridge with a wrench, it will be tightened too much.



(1) Oil filter cartridge
(2) Remove with a filter wrench
(Tighten with your hand)

5. After the new cartridge has been replaced, the engine oil level normally decreases a little. Thus, run the engine for a while and check for oil leaks through the seal before checking the engine oil level. Add oil if necessary.

NOTE :

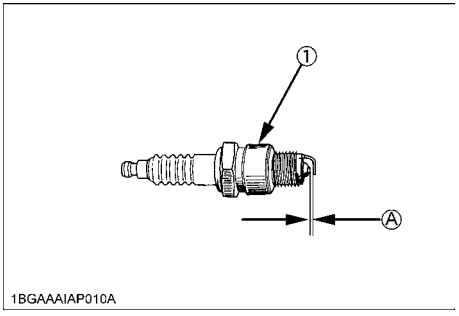
- Wipe off any oil sticking to the machine completely.

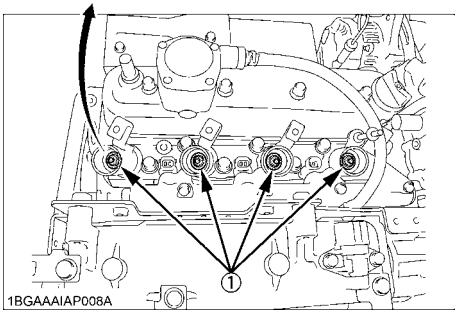
SPARK PLUG

■Cleaning and adjustment clearance

If the spark plug electrode or its insulator is soiled or is covered with deposited carbon, it may cause engine trouble. The soil, carbon deposits etc. can be brushed off using a wire brush.
After cleaning, be sure to adjust for proper clearance.

◆ Tightening Torque
25 to 30 N-m (2.5 to 3.0 kgf-m, 18.0 to 21.6 ft-lbs)





(1) Spark plug (A) Clearance : 0.7 to 0.8 mm (0.028 to 0.032 in.)

RADIATOR

Coolant will last for one day's work if filled all the way up before operation start. Make it a rule to check the coolant level before every operation.

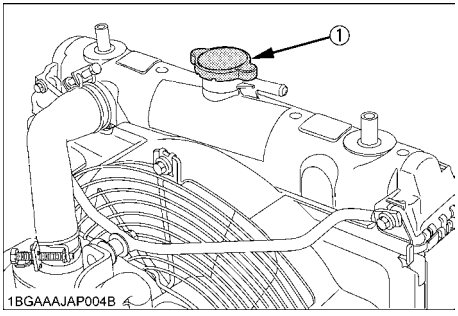
⚠ WARNING

To avoid personal injury:

- **Do not stop the engine suddenly, stop it after about 5 minutes of unloaded idling.**
- **Work only after letting the engine and radiator cool off completely (more than 30 minutes after it has been stopped).**
- **Do not remove the radiator cap while coolant is hot. When cool to the touch, rotate cap to the first stop to allow excess pressure to escape. Then remove cap completely.**
  If overheats should occur, steam may gush out from the radiator or recovery tank; Severe burns could result.

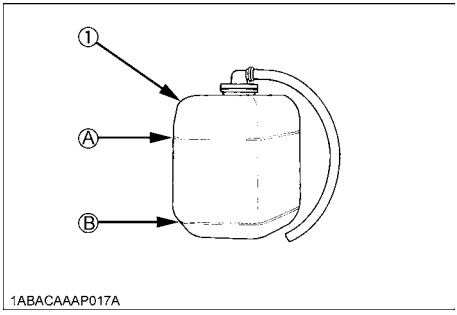
■Checking coolant level, adding coolant

1. Remove the radiator cap, after the engine has completely cooled, and check to see that coolant reaches the supply port.



(1) Radiator pressure cap

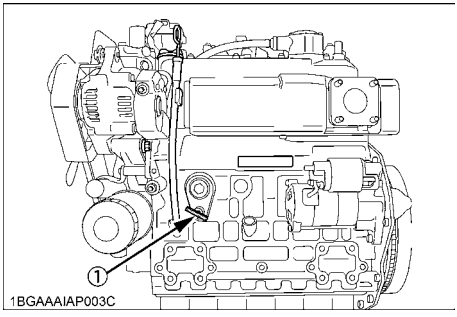
2. If the radiator is provided with a recovery tank, check the coolant level of the recovery tank. When it is between the "FULL" and "LOW" marks, the coolant will last for one day's work.



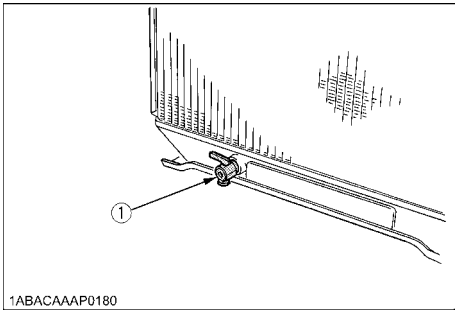
1ABACAAAP017A

(1) Recovery tank (A) "FULL" (B) "LOW"

3. When the coolant level drops due to evaporation, add water only up to the full level.
4. Check to see that two drain cocks; one is at the crankcase side and the other is at the lower part of the radiator as figures below.



1BGAAAIAP003C



1ABACAAAP0180

(1) Coolant drain cock

IMPORTANT :
- If the radiator cap has to be removed, follow the caution and securely retighten the cap.
- If coolant should be leak, consult your local KUBOTA dealer.
- Make sure that muddy or sea water does not enter the radiator.
- Use clean, fresh water and 50% anti-freeze to fill the recovery tank.
- Do not refill recovery tank with coolant over the "FULL" level mark.
- Be sure to close the radiator cap securely. If the cap is loose or improperly closed, coolant may leak out and decrease quickly.

■Changing coolant

1. To drain coolant, always open both drain cocks and simultaneously open the radiator cap as well. With the radiator cap kept closed, a complete drain of water is impossible.
2. Remove the overflow pipe of the radiator pressure cap to drain the recovery tank.
3. Prescribed coolant volume (U.S.gallons)

Models	Quantity
WG1605-G-E3 WG1605-L-E3 WG1605-GL-E3	4.0 L (1.06 U.S.gals.)

NOTE :
- Coolant quantities shown are for standard radiators.

4. An improperly tightened radiator cap or a gap between the cap and the seat quickens loss of coolant.
5. Coolant (Radiator cleaner and anti-freeze)

Season	Coolant
All seasons	Pure water and anti-freeze (See "Anti-freeze" in “RADIATOR” section.)

■Remedies for quick decrease of coolant

1. Check any dust and dirt between the radiator fins and tube. If any, remove them from the fins and the tube.
2. Check the tightness of the fan belt. If loose, tighten it securely.
3. Check the internal blockage in the radiator hose. If scale forms in the hose, clean with the scale inhibitor or its equivalent.

■Checking radiator hoses and clamp bands

CAUTION

To avoid personal injury:

- **Be sure to check radiator hoses and clamp bands periodically. If radiator hose is damaged or coolant leaks, overheats or severe burns could occur.**

Check to see if radiator hoses are properly fixed every 200 hours of operation or 6 months, whichever comes first.

1. If hose clamps are loose or water leaks, tighten hose clamp securely.
2. Replace hoses and tighten hose clamps securely, if radiator hoses are swollen, hardened or cracked.

Replace hoses and hose clamps every 2 years or earlier, if checked and found that hoses are swollen, hardened or cracked.

■Precaution at overheating

The event that the coolant temperature is nearly or more than the boiling point is called **"OVERHEATING"**.

While running, make the following checks to see that all parts are working correctly. **If anything is unusual, inspect it, referring to the relevant description in "MAINTENANCE" and "PERIODIC SERVICE" section**.

◆ Coolant

If the coolant temperature warning lamp lights up or if steam or coolant does not stop squirting from the radiator overflow pipe, turn off the load and **keep the engine idling (COOLING-DOWN) for at least 5 minutes** to let it cool down gradually. Then stop the engine and take the following inspection and servicing.

1. Check to see if the coolant runs short or if there is any coolant leak;
2. Check to see if there is any obstacle around the cooling air inlet or outlet;
3. Check to see if there is any dirt or dust between radiator fins and tube;
4. Check to see if the fan belt is too loose; and
5. Check to see if radiator water pipe is clogged.

■Cleaning radiator core (outside)

If dust is between the fin and tube, wash it away with running water.

IMPORTANT :

- Do not clean radiator with firm tools such as spatulas or screwdrivers. They may damage specified fin or tube. It can cause coolant leaks or decrease cooling performance.

■Anti-freeze

CAUTION

To avoid personal injury:

- **When using anti-freeze, put on some protection such as rubber gloves. (Anti-freeze is poisonous.)**
- **If it is swallowed, seek immediate medical help. Do NOT make a person throw up unless told to do so by poison control or a health care professional. Use standard first aid and CPR for signs of shock or cardiac arrest. Call your local Poison Control Center or your local emergency number for further assistance.**
- **When anti-freeze comes in contact with the skin or clothing, wash it off immediately.**
- **Do not mix different types of anti-freeze. The mixture can produce chemical reaction causing harmful substances.**
- **Anti-freeze is extremely flammable and explosive under certain conditions. Keep fire and children away from anti-freeze.**
- **When draining fluids from the engine, place some container underneath the engine body.**
- **Do not pour waste onto the grounds, down a drain, or into any water source.**
- **Also, observe the relevant environmental protection regulations when disposing of anti-freeze.**

Always use a 50/50 mix of long-life coolant and clean soft water in KUBOTA engines.

Contact KUBOTA concerning coolant for extreme conditions.

1. Long-life coolant (hereafter LLC) comes in several types. Use ethylene glycol (EG) type for this engine.
2. Before employing LLC-mixed cooling water, flush the radiator with fresh water. Repeat this procedure 2 or 3 times to clean up the radiator and engine block from inside.
3. Mixing the LLC
   Premix 50% LLC with 50% clean soft water. When mixing, stir it up well, and then fill into the radiator.

4. The procedure for the mixing of water and anti-freeze differs according to the make of the anti-freeze. Refer to SAE J1034 standard, more specifically also to SAE J814c.

Vol % Anti-freeze	Freezing Point		Boiling Point *	
	℃	℉	℃	℉
50	-37	-34	108	226

*At 1.013 x 10^5Pa (760 mmHg) pressure (atmospheric). A higher boiling point is obtained by using a radiator pressure cap which permits the development of pressure within the cooling system.

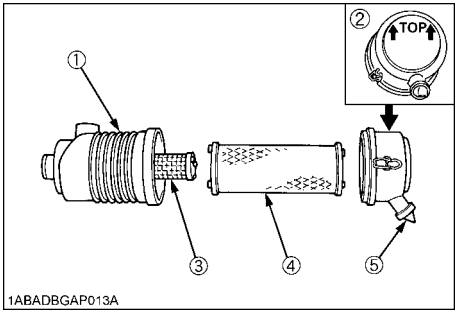
5. Adding the LLC
   (1) Add only water if the coolant level reduces in the cooling system by evaporation.
   (2) If there is a coolant leak, add the LLC of the same manufacturer and type in the same coolant percentage.
   *Never add any long-life coolant of different manufacturer. (Different brands may have different additive components, and the engine may fail to perform as specified.)
6. When the LLC is mixed, do not employ any radiator cleaning agent. The LLC contains anti-corrosive agent. If mixed with the cleaning agent, sludge may build up, adversely affecting the engine parts.
7. Kubota's genuine long-life coolant has a service life of 2 years. Be sure to change the coolant every 2 years.

NOTE :
- The above data represents industry standards that necessitate minimum glycol content in the concentrated anti-freeze.

AIR CLEANER

Since the air cleaner employed on this engine is a dry type, never apply oil to it.

1. Open the evacuator valve once a week under ordinary conditions - or daily when used in a dusty place. This will get rid of large particles of dust and dirt.
2. Wipe the inside air cleaner clean with cloth if it is dirty or wet.
3. Avoid touching the element except when cleaning.
4. When dry dust adheres to the element, blow compressed air from the inside turning the element. Pressure of compressed air must be under 205 kPa (2.1 kgf/cm², 30 psi).
5. Replace the primary element every year or every 6 cleanings.
   If the primary element is stained heavily, replace it soon. At this time, replace the secondary element too.
6. The secondary element should be removed only if it is to be replaced.
7. To protect the engine, do not remove the secondary element in servicing the primary element.



(1) Air cleaner body
(2) Cover
(3) Secondary element
(4) Primary element
(5) Evacuator valve

IMPORTANT :
- Make sure the hooking clip for cover for the element is tight enough. If it is loose, dust and dirt may be sucked in, wearing down the cylinder liner and piston ring earlier and thereby resulting in poor power output.
- Do not overservice the air cleaner element. Overservicing may cause dirt to enter the engine causing premature wear. Use the dust indicator as a guide on when to service.

■Cleaning primary air cleaner element

1. To clean the element, use clean dry compressed air on the inside of the element.
   Air pressure at the nozzle must not exceed 205 kPa (2.1kgf/cm², 30psi).
   Maintain reasonable distance between the nozzle and the filter.

■Evacuator valve

Open the evacuator valve once a week under ordinary conditions - or daily when used in a dusty place - to get rid of large particles of dust and dirt.

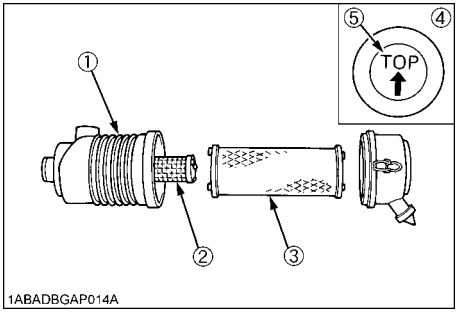
■For the air cleaner with a dust cup (optional)

Remove and clean out the dust cup before it becomes half full with dust; usually once a week, or even every day if the working surroundings are dusty.

Install the air cleaner dust cup with "TOP" indicated on the rear of the cup in the up position. (However, it may be installed in either direction when the cover is placed at the lower part.)

IMPORTANT :

- If the dust cup is mounted incorrectly, dust or dirt does not collect in the cup, and direct attachments of the dust to the element will cause its lifetime to shorten to a great extent.

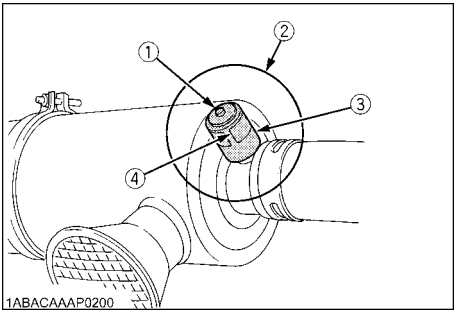


(1) Air cleaner body
(2) Secondary element
(3) Primary element
(4) Dust cup
(5) "TOP" mark

■Dust indicator (optional)

If the red signal on the dust indicator attached to the air cleaner is visible, the air cleaner has reached the service level.

Clean the element immediately, and reset the signal with the "RESET" button.



(1) "RESET" button
(2) Dust indicator
(3) Service level
(4) Signal

FUEL SYSTEM AND DIAGRAMS

■LPG fuel system

Never use LPG fuel on the WG1605-G-E3 engine. Otherwise severe damage will occur.

- All fuel connections added to this engine must be installed by qualified personnel and utilizing recognized procedures and standards.
- These non-KUBOTA installed parts, such as hoses, fittings, and piping should be approved for LPG use and conform to UL, CSA, NFPA, MSHA and all other applicable standards.
- For the location of the lock off valve with LPG filter and regulator assy (D-STAGE), see “Fuel system diagrams” section.

■Tightening torques and leak check for LPG regulator with vaporizer

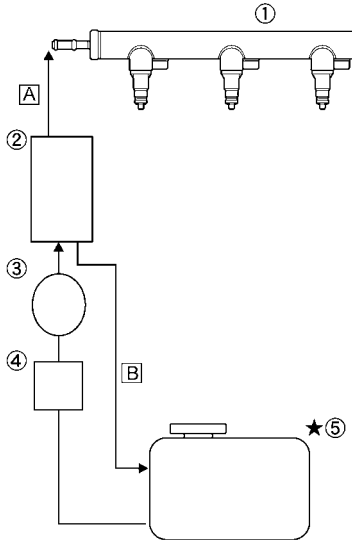
1. Each fitting must be sealed with approved joint sealant compound, and be tightened to the specified torque using a wrench and leak check must be performed as shown in the below table.

			Tightening torque			Leak check pressure		
FITTING	Q'ty	SIZE	N-m	kgf-m	ft-lbs	kPa	Kgf/cm²	psi
LPG OUT (VAPOR)	1	ϕ19 mm (3/4”) Hose Fitting	---	---	---	1745±15	17.8±0.15	253±2.1
LPG IN (LIQUID)*	1	1/4-18 NPTF	19.6 to 39.2	2.0 to 4.0	14.5 to 28.9			
WATER IN/OUT	2	ϕ16 mm (5/8”) Hose Fitting	---	---	---	210±10	2.1±0.1	29.9±1.4

*NOT KUBOTA supplied

■Fuel system diagrams

[WG1605-G-E3]



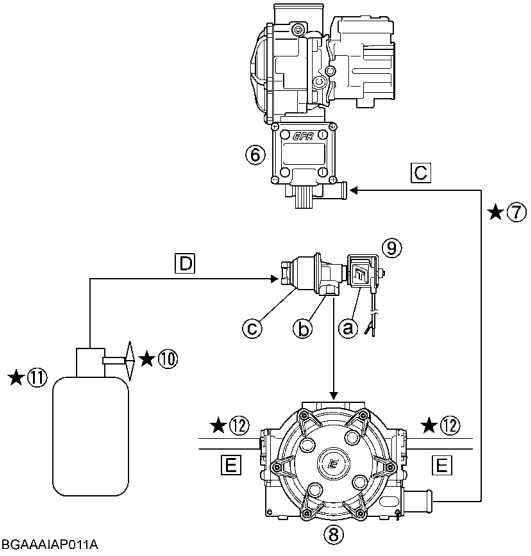
1BGAAAIAP009A

(1) Delivery pipe assy
(2) Manifold (FPM)
(3) Fuel pump assy
(4) Fuel filter
★ (5) Gasoline tank
(6) Regulator assy (D-EPR)
★ (7) Vapor hose
(8) Regulator assy (D-STAGE)
(9) Lock off valve with LPG filter
(a) Solenoid
(b) Outlet
(c) Filter bowl
★ (10) LPG manual valve
★ (11) LPG tank
★ (12) Coolant hose

NOTE :
- The ★-marked component parts are Not Provided by KUBOTA.

(A) Gasoline line
(B) Bleed / Return circuit
(C) Gaseous propane line
(D) Liquid propane line
(E) Hot coolant inlet or outlet line

[WG1605-L-E3]



1BGAAAIAP011A

[WG1605-GL-E3]
Both of G and L types

ELECTRIC WIRING

CAUTION

To avoid personal injury:

- **Shorting of electric cable or wiring may cause a fire.**
  - **Check to see if electric cables and wiring are swollen, hardened or cracked.**
  - **Keep dust and water away from all power connections.**
    Loose wiring terminal parts, make bad connections. Be sure to repair them before starting the engine.

Damaged wiring reduces the capacity of electrical parts. Change or repair damaged wiring immediately.

FAN BELT

■Adjusting fan belt tension

CAUTION

To avoid personal injury:

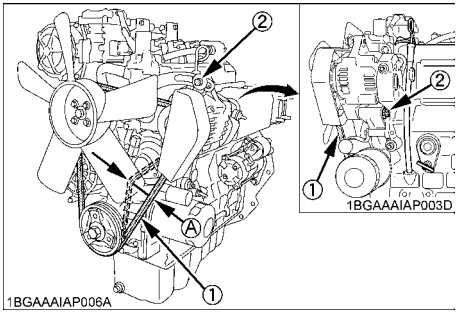
- **Be sure to stop the engine and remove the key before checking the belt tension.**
- **Be sure to reinstall the detached safety shield after maintenance or checking.**

Proper fan belt tension	A deflection of between 7 to 9 mm (0.28 to 0.35 in.) when the belt is pressed in the middle of the span.

1. Stop the engine and remove the key.
2. Apply moderate thumb pressure to belt between the pulleys.
3. If tension is incorrect, loosen the alternator mounting bolts and, using a lever placed between the alternator and the engine block, pull the alternator out until the deflection of the belt falls within acceptable limits.
4. Replace fan belt if it is damaged.

IMPORTANT :

- If belt is loosen or damaged and the fan is damaged, it could result in overheats or insufficient charging. Correct or replace belt.



(1) Fan belt
(2) Bolt and nut
(A) 7 to 9 mm (0.28 to 0.35 in.) (under load of 10 kgf (22.1 lbs))

CARRIAGE AND STORAGE

CARRIAGE

CAUTION

To avoid personal injury:

- **Fix the engine securely not to fall during operation.**
- **Do not stand near or under the engine while carrying it.**
- **The engine is heavy. In handling it, be very alert not to get your hands and body caught in.**

1. Use carrier such as a crane when moving the engine to avoid bodily injury. Support the engine securely to avoid injury or damage.
2. When lifting the engine, put the hook securely to metal fittings attached to the engine. Use strong hook and fittings enough to hang the engine.

STORAGE

CAUTION

To avoid personal injury:

- **Do not clean the machine with engine running.**
- **To avoid the danger of exhaust fume poisoning, do not operate the engine in a closed building without proper ventilation.**
- **When storing the engine just after running, let the engine cool off.**

Before storing the engine for more than a few months, remove any dirt on the machine, and:

1. Drain the coolant in the radiator. Open the cock at the bottom of the radiator, and remove the pressure cap to drain water completely. Leave the cock open. Hang a note written "No water" on the pressure cap. Since water may freeze when the temperature drops below 0°C (32°F), it is very important that no water is left in the machine.

NOTE :

- When using anti-freeze, it is not necessary to take step (1) above.

2. Remove dirty engine oil, fill with new oil and run the engine for about 5 minutes to let the oil penetrate to all the parts.
3. Check all the bolts and nuts, and tighten if necessary.
4. Remove the battery from the engine, adjust the electrolyte level, and recharge it. Store the battery in a dry and dark place.
5. When the engine is not used for a long period of time, run it for about 5 minutes under no load every 2 to 3 months to keep it free from rust. If the engine is stored without any running, moisture in the air may condense into dew over the sliding parts of the engine, resulting in rust there.
6. If you forget to run the engine for longer than 5 to 6 months, apply enough engine oil to the valve guide and valve stem seal and make sure the valve works smoothly before starting the engine.
7. Store the engine in a flat place and remove the key from engine.
8. Do not store the engine in a place where has flammable materials such as dry grass or straw.
9. When covering the engine for storage, let engine and muffler cool off completely.
10. Operate the engine after checking and repairing damaged wirings or pipes, and clearing flammable materials carried by mouse.

TROUBLESHOOTING

The engine malfunctions can result from a large number of causes. The following describes symptoms that are encountered relatively more often than others, their major causes and remedies.

■ When it is difficult to start the engine

Cause	Countermeasures
Fuel doesn't flow.	* Check the fuel tank, fuel filter, fuel hoses and fuel pump. * As fuel will be filtered by the filter, if there should be water or other foreign matters on the filter, clean the filter.
Valve clearance is not as specified.	* Adjust valve clearance when the engine is cold.
Engine oil becomes thick in cold weather and engine cranks slow.	* Change grade of oil according to the weather (temperature).
Low compression	* Bad valve or excessive wear of rings, pistons and liners cause insufficient compression. Replace with new parts.
Battery is discharged and the engine will not crank.	* Charge battery. * In winter, always remove battery from machine, charge fully and keep indoors. Install in machine at time of use.
Clogged air cleaner	* Clean or replace.
Spark plug electrodes are wet with gasoline	* Dry electrode and restart.
Defective starter	* Repair or replace.
Defective main switch	* Repair or replace.
Defective vaporizer	* Replace.
Defective lock off valve	* Replace.
Disconnection	* Check the wire harness.

■ When output is insufficient

Cause	Countermeasures
Compression is insufficient.	* Bad valve or excessive wear of rings, pistons and liners cause insufficient compression. Replace with new parts.
Fuel is insufficient.	* Check fuel system.
Overheating of moving parts	* Check lubricating oil system. * Check to see if lubricating oil filter is working properly. * Filter element deposited with impurities would cause poor lubrication. Change element. * Check to see if the clearance of bearing is within factory specs.
Valve clearance is not as specified.	* Adjust valve clearance when the engine is cold.
Air cleaner is dirty.	* Clean or replace.
Defective spark plug	* Clean or replace.
Defective ignition coil	* Replace.
Disconnection	* Check the wire harness.

■ **When engine speed is insufficient**

Cause	Countermeasures
Improper or defective spark plug	* Clean or replace.
Defective ignition coil	* Replace.
Defective throttle body	* Replace.
Breather tube has separated.	* Attach correctly.
Improper input signal to ECU	* Check the wire harness.
Disconnection	* Check the wire harness.

■ **When engine suddenly stops**

Cause	Countermeasures
Lack of fuel	* Check the fuel tank and refill the fuel, if necessary. * Also check the fuel system for air or leaks.
Moving parts are overheated due to shortage of lubrication oil or improper lubrication.	* Check amount of engine oil with oil level gauge. * Check lubricating oil system. * Replace oil filter cartridge.
Clogged air cleaner	* Clean or replace.
Disconnection	* Check the wire harness.

■ **When excessive black exhaust gas is observed**

Cause	Countermeasures
Fuel system is bad.	* Check the fuel system.
Fuel is extremely poor quality.	* Replace fuel.

■ **When white exhaust gas is observed**

Cause	Countermeasures
Excessive engine oil	* Reduce to specified level.
Piston ring and liner worn or stuck	* Replace.
Defective valve stem seal	* Replace.

■ **When lubricant oil consumption is excessive**

Cause	Countermeasures
Oil leaking from oil seal, gasket, etc.	* Replace.
Defective valve stem seal	* Replace.
Piston ring and liner worn or stuck	* Replace.

■ **When engine overheats**

Cause	Countermeasures
Engine oil insufficient	* Check oil level. Replenish oil as required.
Fan belt broken or elongated	* Change belt or adjust belt tension.
Coolant insufficient	* Replenish coolant.
Excessive concentration of antifreeze	* Add water only or change to coolant with the specified mixing ratio.
Radiator net or radiator fin clogged with dust	* Clean net or fin carefully.
Inside of radiator or coolant flow route corroded	* Clean or replace radiator and parts.
Defective fan or radiator or radiator cap	* Replace defective parts.
Defective thermostat	* Check thermostat and replace if necessary.
Defective temperature sensor	* Check temperature with thermometer and replace if necessary.
Overload running	* Reduce load.
Head gasket defective or water leakage	* Replace parts.

NOTE :
- If the cause of trouble can not be found, consult your KUBOTA dealer.
- If MIL (Malfunction Indicator Light) lights up, consult your KUBOTA dealer.

SPECIFICATIONS

Model			WG1605-G-E3	WG1605-L-E3
			Gasoline	LPG
Type			Vertical, Water-cooled 4 cycle	
No. of cylinders - bore x stroke		mm (in.)	4-ϕ79 x 78.4 (3.11 x 3.09)	
Total displacement		L (cu-in.)	1.537 (93.79)	
Brake horse power	SAE Gross intermittent	kW(HP) / min^{-1}(rpm)	42.5 (57.0) / 3600 37.0 (49.6) / 3000	41.0 (55.0) / 3600 36.0 (48.3) / 3000
	SAE net intermittent	kW(HP) / min^{-1}(rpm)	33.5 (44.9) / 3000	32.5 (43.6) / 3000
	SAE net continuous	kW(HP) / min^{-1}(rpm)	25.0 (33.5) / 3000	
Max. torque	SAE Gross intermittent	N-m(lbf-ft) / min^{-1}(rpm)	120 (88.5) / 2400	117 (86.3) / 2400
Governor type			Electronic Governor	
Ignition system			Full transistor battery ignition type	
Fuel used			Unleaded gasoline	Commercial LPG
Lubricating oil capacity		L (US gals.)	6.0 (1.59)	
Starter			12 V x 1.0 kW	
Total dimensions (L x W x H)		mm (in.)	592 (23.3) x 479 (18.9) x 652 (25.7)	
Weight (Dry)		kg (lbs)	119 (262.3)	120 (264.6)
Common tune up specification				
Minimum bare idling speed		min^{-1} (rpm)	800 ± 25	
Maximum bare speed		min^{-1} (rpm)	3000 ± 25	
Ignition timing		deg. BTDC / rpm	26° / 3000, 10° / 800	20° / 3000, 10° / 800
Spark plug type / Spark plug gap		mm (in.)	NGK IFR6F8DN 0.7 to 0.8 (0.028 to 0.031)	
Intake / Exhaust valve clearance Check when engine is cold.		mm (in.)	0.165 ± 0.02 (0.0065 ± 0.00079)	

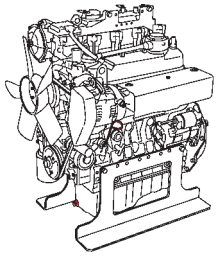
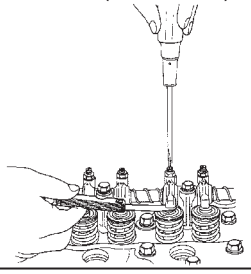
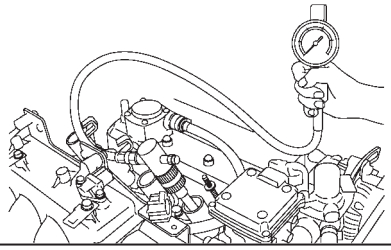
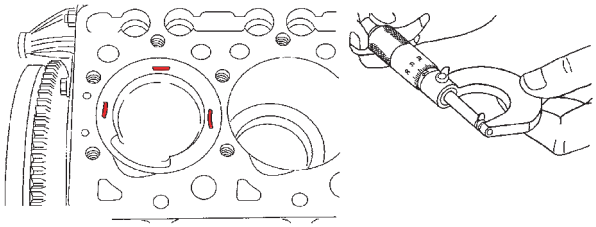
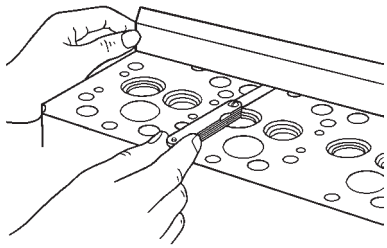
NOTE :
- Specifications are subject to change without notice.
- LPG regulator with vaporizer operates on a liquid withdrawal type system.

Model			WG1605-GL-E3	
			Gasoline	LPG
Type			Vertical, Water-cooled 4 cycle	
No. of cylinders - bore x stroke		mm (in.)	4-ø79 x 78.4 (3.11 x 3.09)	
Total displacement		L (cu-in.)	1.537 (93.79)	
Brake horse power	SAE Gross intermittent	kW(HP) / min^{-1}(rpm)	42.5 (57.0) / 3600 37.0 (49.6) / 3000	41.0 (55.0) / 3600 36.0 (48.3) / 3000
	SAE net intermittent	kW(HP) / min^{-1}(rpm)	33.5 (44.9) / 3000	32.5 (43.6) / 3000
	SAE net continuous	kW(HP) / min^{-1}(rpm)	25.0 (33.5) / 3000	
Max. torque	SAE Gross intermittent	N-m(lbf-ft) / min^{-1}(rpm)	120 (88.5) / 2400	117 (86.3) / 2400
Governor type			Electronic Governor	
Ignition system			Full transistor battery ignition type	
Fuel used			Unleaded gasoline	Commercial LPG
Lubricating oil capacity		L (US gals.)	6.0 (1.59)	
Starter			12 V x 1.0 kW	
Total dimensions (L x W x H)		mm (in.)	592 (23.3) x 479 (18.9) x 652 (25.7)	
Weight (Dry)		kg (lbs)	121 (267.0)	
Common tune up specification				
Minimum bare idling speed		min^{-1} (rpm)	800 ± 25	
Maximum bare speed		min^{-1} (rpm)	3000 ± 25	
Ignition timing		deg. BTDC / rpm	26° / 3000, 10° / 800	20° / 3000, 10° / 800
Spark plug type / Spark plug gap		mm (in.)	NGK IFR6F8DN 0.7 to 0.8 (0.028 to 0.031)	
Intake / Exhaust valve clearance Check when engine is cold.		mm (in.)	0.165 ± 0.02 (0.0065 ± 0.00079)	

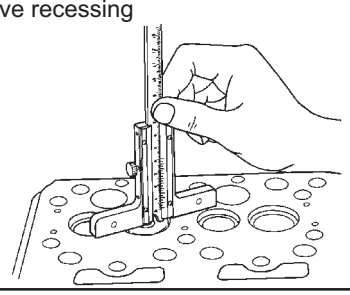
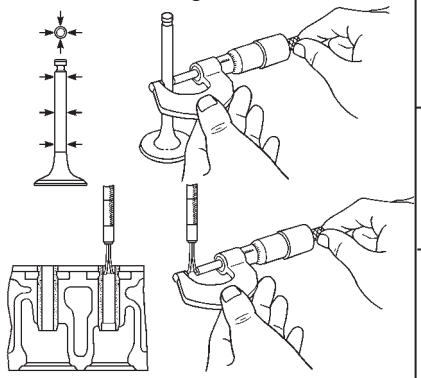
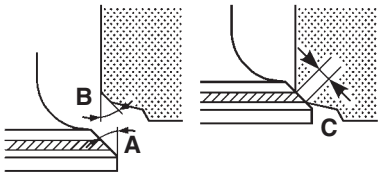
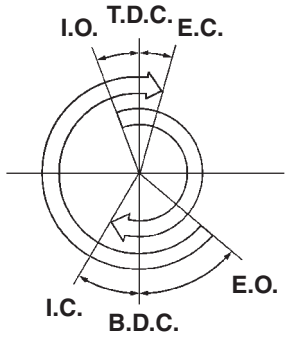
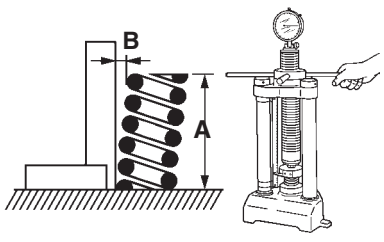
NOTE :
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- LPG regulator with vaporizer operates on a liquid withdrawal type system.

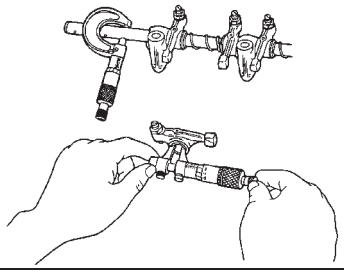
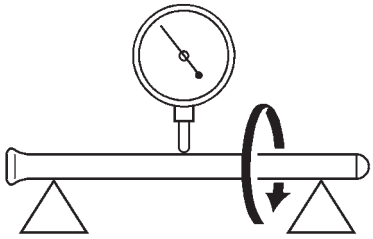
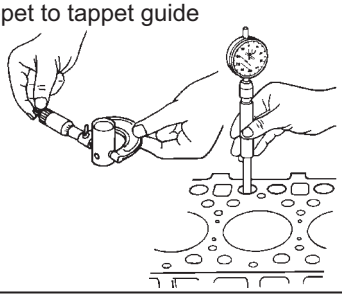
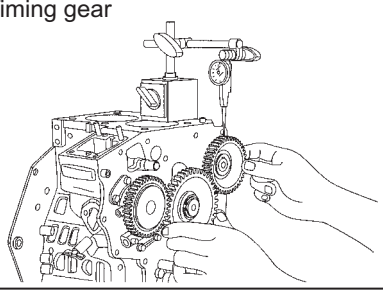
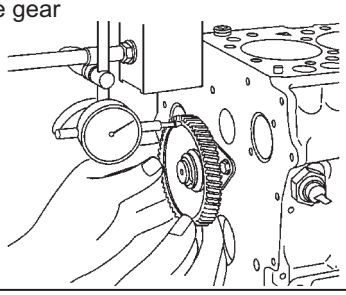
SERVICING SPECIFICATIONS

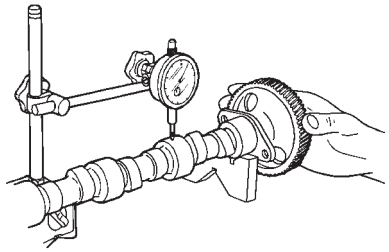
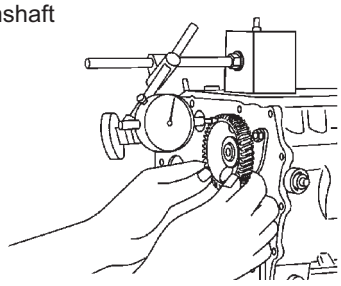
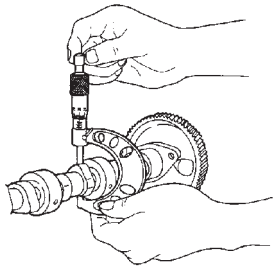
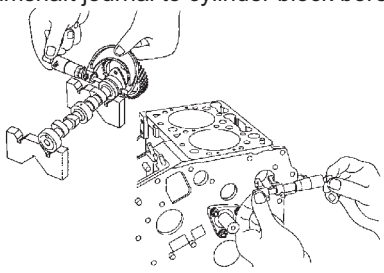
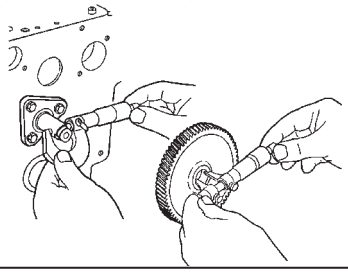
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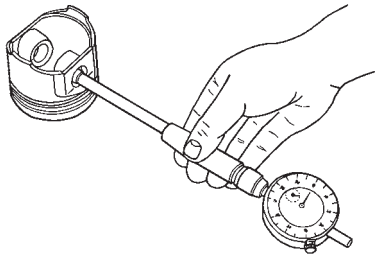
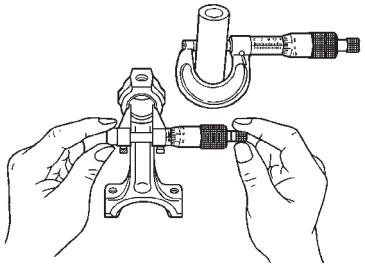
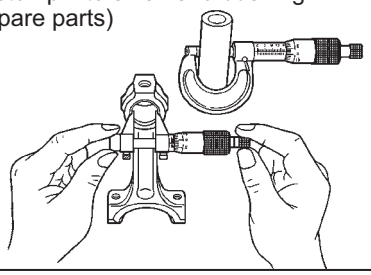
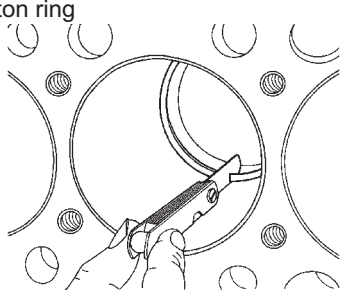
Item		Factory Specification	Allowable Limit
Lubricating oil capacity 	All models	6.0 L 1.6 U.S. gals	—
Valve clearance (When cold) 	All models	0.145 to 0.185 mm 0.00571 to 0.00728 in.	—
Compression pressure 	All models	1.27 MPa 13.0 kgf/cm^2 185 psi	0.88 MPa 9.0 kgf/cm^2 130 psi
Top clearance 	All models	1.2 to 1.5 mm 0.048 to 0.059 in.	—
Cylinder head surface 	Flatness	All models	—	0.05 mm 0.002 in.

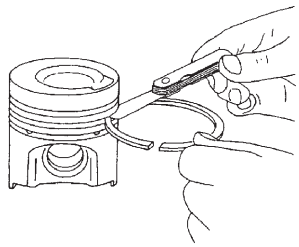
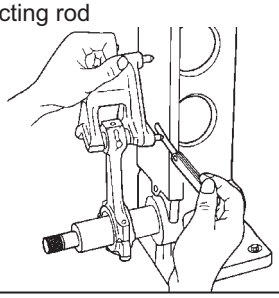
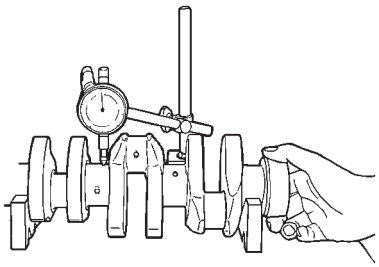
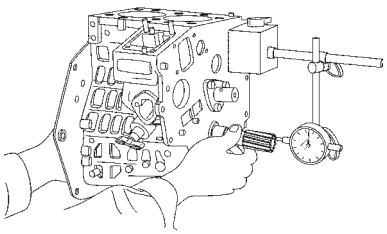
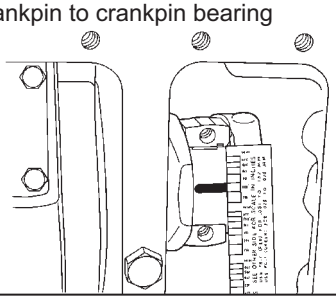
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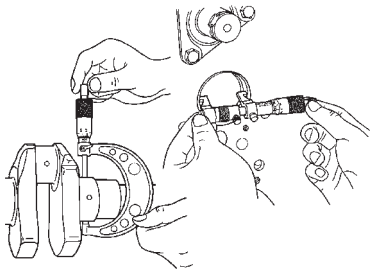
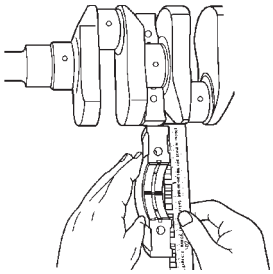
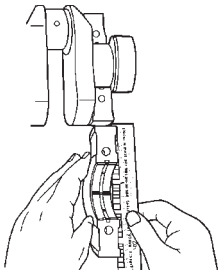
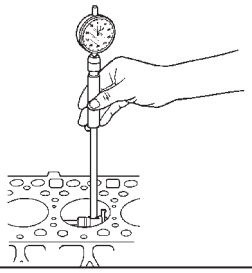
Item			Factory Specification	Allowable Limit
Valve recessing 		All models	0.050 mm (Protrusion) to 0.25 mm (Recessing) 0.0020 in. (Protrusion) to 0.0098 in. (Recessing)	0.40 mm (Recessing) 0.016 in. (Recessing)
Valve stem to valve guide 	Clearance	All models	0.035 to 0.065 mm 0.0014 to 0.0025 in.	0.10 mm 0.0039 in.
	Valve stem O.D.	All models	6.960 to 6.975 mm 0.2741 to 0.2746 in.	—
	Valve guide I.D.	All models	7.010 to 7.025 mm 0.2760 to 0.2765 in.	—
Valve & valve seat 	Face angle **(A)** (Intake)	All models	1.0 rad 60°	—
	Face angle **(A)** (Exhaust)	All models	1.0 rad 60°	—
	Seat angle **(B)** (Intake)	All models	1.0 rad 60°	—
	Seat angle **(B)** (Exhaust)	All models	1.0 rad 60°	—
	Seat width **(C)** (Intake)	All models	2.12 mm 0.0835 in.	—
	Seat width **(C)** (Exhaust)	All models	2.12 mm 0.0835 in.	—
Valve timing 	Open (Intake valve)	All models	0.38 rad before T.D.C. 22° before T.D.C.	—
	Close (Intake valve)	All models	0.82 rad after B.D.C. 47° after B.D.C.	—
	Open (Exhaust valve)	All models	0.91 rad before B.D.C. 52° before B.D.C.	—
	Close (Exhaust valve)	All models	0.30 rad after T.D.C. 17° after T.D.C.	—
Valve spring 	Free length **(A)**	All models	35.1 to 35.6 mm 1.39 to 1.40 in.	34.8 mm 1.37 in.
	Tilt **(B)**	All models	—	1.0 mm 0.039 in.
	Setting load / Setting length	All models	74 N / 31.0 mm 7.5 kgf / 31.0 mm 17 lbf / 1.22 in.	63 N / 31.0 mm 6.4 kgf / 31.0 mm 14 lbf / 1.22 in.

Item			Factory Specification	Allowable Limit
Rocker arm shaft to rocker arm 	Oil clearance	All models	0.016 to 0.045 mm 0.00063 to 0.0017 in.	0.10 mm 0.0039 in.
	Rocker arm shaft O.D.	All models	11.973 to 11.984 mm 0.47138 to 0.47181 in.	—
	Rocker arm I.D.	All models	12.000 to 12.018 mm 0.47244 to 0.47314 in.	—
Push rod 	Alignment	All models	—	0.25 mm 0.0098 in.
Tappet to tappet guide 	Oil clearance	All models	0.020 to 0.062 mm 0.00079 to 0.0024 in.	0.07 mm 0.003 in.
	Tappet O.D.	All models	19.959 to 19.980 mm 0.78579 to 0.78661 in.	—
	Tappet guide I.D.	All models	20.000 to 20.021 mm 0.78741 to 0.78822 in.	—
Timing gear 	Backlash (Crank gear to idle gear)	All models	0.0320 to 0.115 mm 0.00126 to 0.00452 in.	0.15 mm 0.0059 in.
	Backlash (Idle gear to cam gear)	All models	0.0360 to 0.114 mm 0.00142 to 0.00448 in.	0.15 mm 0.0059 in.
	Backlash (Idle gear to injection pump gear)	All models	0.0340 to 0.116 mm 0.00134 to 0.00456 in.	0.15 mm 0.0059 in.
	Backlash (Crank gear to oil pump drive gear)	All models	0.0320 to 0.118 mm 0.00126 to 0.00464 in.	0.15 mm 0.0059 in.
Idle gear 	Side clearance	All models	0.20 to 0.51 mm 0.0079 to 0.020 in.	0.80 mm 0.031 in.

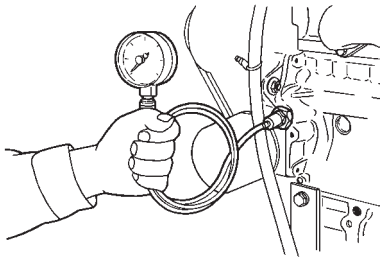
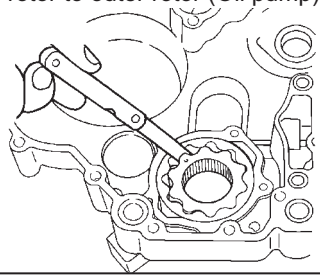
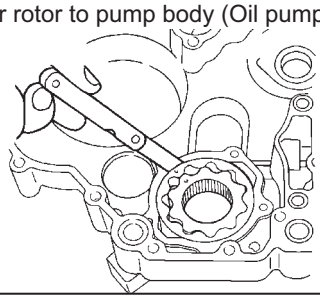
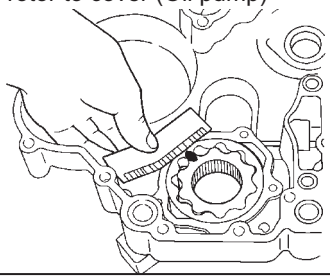
Item			Factory Specification	Allowable Limit
Camshaft 	Alignment	All models	—	0.01 mm 0.0004 in.
Camshaft 	Side clearance	All models	0.0700 to 0.220 mm 0.00276 to 0.00866 in.	0.30 mm 0.012 in.
Cam 	Intake	All models	28.80 mm 1.134 in.	28.75 mm 1.132 in.
	Exhaust	All models	29.00 mm 1.142 in.	28.95 mm 1.140 in.
Camshaft journal to cylinder block bore 	Oil clearance	All models	0.050 to 0.091 mm 0.0020 to 0.0035 in.	0.15 mm 0.0059 in.
	Camshaft journal O.D.	All models	35.934 to 35.950 mm 1.4148 to 1.4153 in.	—
	Cylinder block bore I.D.	All models	36.000 to 36.025 mm 1.4174 to 1.4183 in.	—
Idle gear shaft to idle gear bushing 	Oil clearance	All models	0.020 to 0.054 mm 0.00079 to 0.0021 in.	0.10 mm 0.0039 in.
	Idle gear shaft O.D.	All models	25.967 to 25.980 mm 1.0224 to 1.0228 in.	—
	Idle gear bushing I.D.	All models	26.000 to 26.021 mm 1.0237 to 1.0244 in.	

Item			Factory Specification	Allowable Limit
Piston pin bore 	Piston pin bore I.D.	All models	22.000 to 22.013 mm 0.86615 to 0.86665 in.	22.03 mm 0.8673 in.
Piston pin to small end bushing 	Oil clearance	All models	0.014 to 0.038 mm 0.00056 to 0.0014 in.	0.15 mm 0.0059 in.
	Piston pin O.D.	All models	22.002 to 22.011 mm 0.86622 to 0.86657 in.	—
	Small end bushing I.D.	All models	22.025 to 22.040 mm 0.86713 to 0.86771 in.	—
Piston pin to small end bushing (Spare parts) 	Oil clearance	All models	0.0650 to 0.144 mm 0.00256 to 0.00566 in.	0.15 mm 0.0059 in.
	Small end bushing I.D.	All models	22.076 to 22.146 mm 0.86914 to 0.87188 in.	—
Piston ring 	Ring gap (Top ring)	All models	0.30 to 0.45 mm 0.012 to 0.017 in.	1.25 mm 0.0492 in.
	Ring gap (Second ring)	All models	0.30 to 0.45 mm 0.012 to 0.017 in.	1.25 mm 0.0492 in.
	Ring gap (Oil ring)	All models	0.20 to 0.70 mm 0.0079 to 0.027 in.	1.25 mm 0.0492 in.

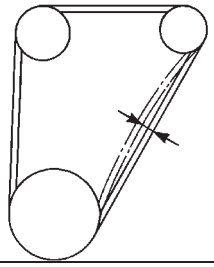
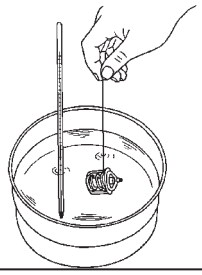
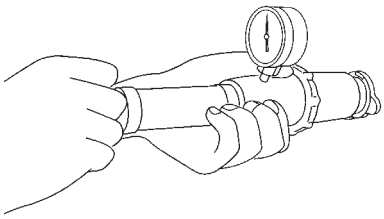
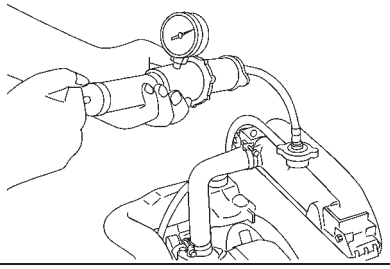
Item			Factory Specification	Allowable Limit
Piston ring groove to piston ring 	Clearance (Top ring)	All models	0.040 to 0.080 mm 0.0016 to 0.0031 in.	0.2 mm 0.008 in.
	Clearance (Second ring)	All models	0.030 to 0.070 mm 0.0012 to 0.0027 in.	0.2 mm 0.008 in.
	Clearance (Oil ring)	All models	0.020 to 0.055 mm 0.00079 to 0.0021 in.	0.15 mm 0.0059 in.
Connecting rod 	Alignment	All models	—	0.15 mm 0.0059 in.
Crankshaft 	Alignment	All models	—	0.02 mm 0.0008 in.
Crankshaft 	Side clearance	All models	0.15 to 0.31 mm 0.0059 to 0.012 in.	0.50 mm 0.020 in.
Crankpin to crankpin bearing 	Oil clearance	All models	0.065 to 0.091 mm 0.0026 to 0.0035 in.	0.20 mm 0.0079 in.
	Crankpin O.D.	All models	39.959 to 39.975 mm 1.5732 to 1.5738 in.	—
	Crankshaft bearing I.D.	All models	40.040 to 40.050 mm 1.5764 to 1.5767 in.	—

Item			Factory Specification	Allowable Limit
Crankshaft journal to crankshaft bearing 1 	Oil clearance	All models	0.0340 to 0.114 mm 0.00134 to 0.00448 in.	0.20 mm 0.0079 in.
	Crankshaft journal O.D.	All models	47.934 to 47.950 mm 1.8872 to 1.8877 in.	—
	Crankshaft bearing 1 I.D.	All models	47.984 to 48.048 mm 1.8892 to 1.8916 in.	—
Crankshaft journal to crankshaft bearing 2 (Flywheel side) 	Oil clearance	All models	0.034 to 0.095 mm 0.0014 to 0.0037 in.	0.20 mm 0.0079 in.
	Crankshaft journal O.D.	All models	47.934 to 47.950 mm 1.8872 to 1.8877 in.	—
	Crankshaft bearing 2 I.D.	All models	47.984 to 48.029 mm 1.8892 to 1.8909 in.	—
Crankshaft journal to crankshaft bearing 3 (Intermediate) 	Oil clearance	All models	0.0340 to 0.103 mm 0.00134 to 0.00405 in.	0.20 mm 0.0079 in.
	Crankshaft journal O.D.	All models	51.921 to 51.940 mm 2.0442 to 2.0448 in.	—
	Crankshaft bearing 3 I.D.	All models	51.974 to 52.024 mm 2.0463 to 2.0481 in.	—
Cylinder 	Bore I.D. (Standard size)	All models	79.000 to 79.019 mm 3.1103 to 3.1109 in.	79.15 mm 3.116 in.
	Bore I.D. (Oversize)	All models	79.500 to 79.519 mm 3.1300 to 3.1306 in.	79.65 mm 3.136 in.

(2) LUBRICATING SYSTEM

Item			Factory Specification	Allowable Limit
Engine oil pressure 	Engine oil pressure (At idle speed)	All models	49 kPa 0.50 kgf/cm^2 7.1 psi	—
	Engine oil pressure (At rated speed)	All models	196 to 441 kPa 2.00 to 4.49 kgf/cm^2 28.5 to 63.9 psi	147 kPa 1.50 kgf/cm^2 21.3 psi
Inner rotor to outer rotor (Oil pump) 	Clearance	All models	0.060 to 0.18 mm 0.0024 to 0.0071 in.	—
Outer rotor to pump body (Oil pump) 	Clearance	All models	0.100 to 0.180 mm 0.00394 to 0.00708 in.	—
Inner rotor to cover (Oil pump) 	Clearance	All models	0.025 to 0.075 mm 0.00099 to 0.0029 in.	—

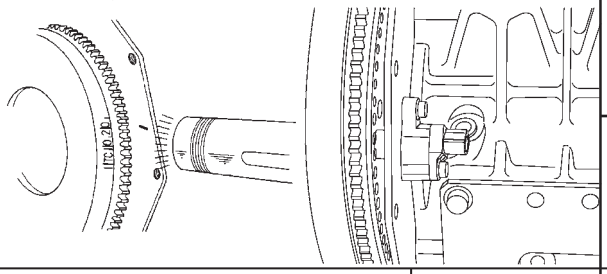
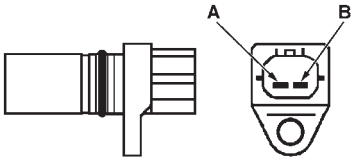
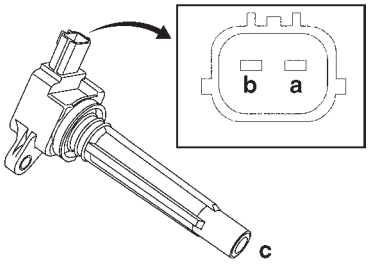
(3) COOLING SYSTEM

Item			Factory Specification	Allowable Limit
Fan belt 	Tension	All models	7.0 to 9.0 mm (0.28 to 0.35 in.) deflection at 98 N (10 kgf, 22 lbf) of force	—
Thermostat 	Valve opening temperature (At beginning)	All models	69.5 to 72.5 °C 157.1 to 162.5 °F	—
	Valve opening temperature (Opened completely)	All models	85 °C 185 °F	—
Radiator cap 	Pressure falling time	All models	10 seconds or more 88 → 59 kPa 0.89 → 0.61 kgf/cm^2, 12 → 8.6 psi	—
Radiator 	Water tightness	All models	No leaks at specified pressure	—

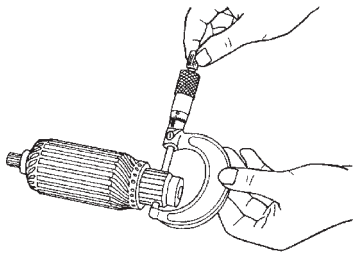
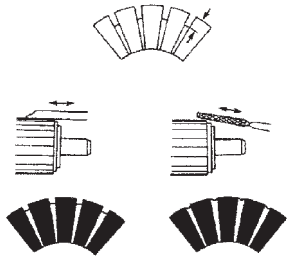
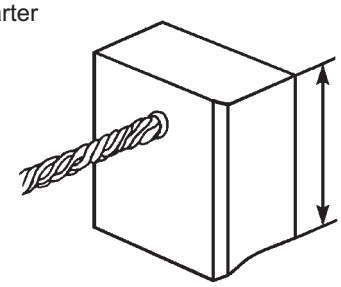
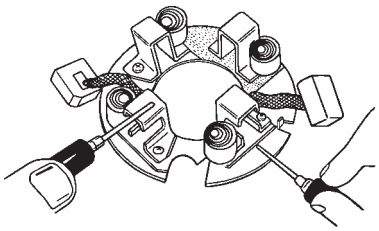
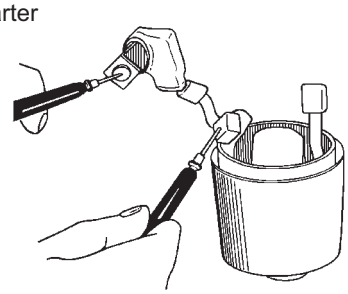
(4) FUEL SYSTEM

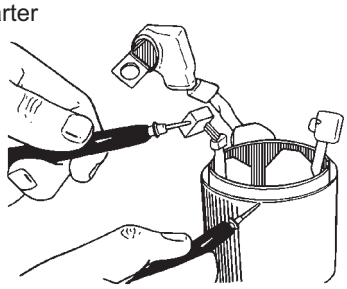
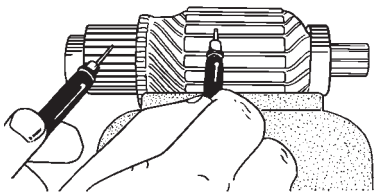
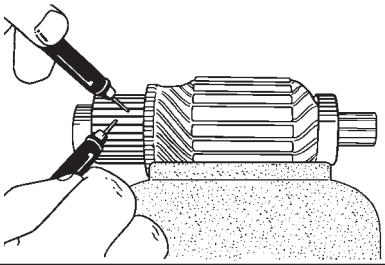
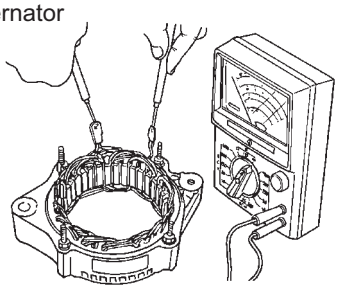
Item			Factory Specification	Allowable Limit
Engine speed	Lo-idling speed	All models	800 min^{-1} (rpm) (775 to 825 min^{-1} (rpm))	—
Engine speed	Hi-idling speed	All models	3000 min^{-1} (rpm) (2975 to 3025 min^{-1} (rpm))	—

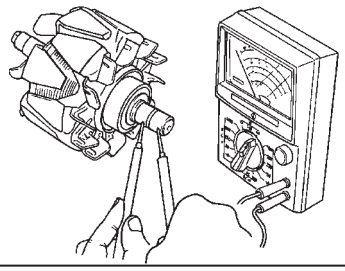
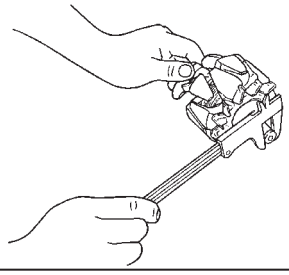
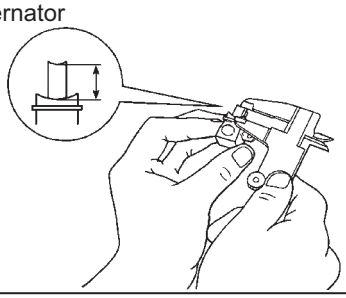
(5) IGNITION SYSTEM

Item			Factory Specification	Allowable Limit
Ignition timing 		Gasoline fuel	0.45 rad (26 °) before T.D.C. / 3000 min^{-1} (rpm) 0.17 rad (10 °) before T.D.C. / 800 min^{-1} (rpm)	—
		LPG fuel	0.35 rad (20 °) before T.D.C. / 3000 min^{-1} (rpm) 0.17 rad (10 °) before T.D.C. / 800 min^{-1} (rpm)	—
Crank Sensor Cam Sensor 	Resistance **A - B**	All models	Crank Sensor 470 to 530 kΩ at 20 °C (68 °F)	—
			Cam Sensor 1.85 to 2.45 kΩ at 20 °C (68 °F)	—
Spark plug gap 		All models	0.70 to 0.80 mm 0.028 to 0.031 in.	—
Ignition coil 	a - b	All models	0.63 to 0.77Ω at 25 °C (77 °F)	—
	a - c	All models	7.29 to 8.91 kΩ at 25 °C (77 °F)	—

(6) ELECTRICAL SYSTEM

Item			Factory Specification	Allowable Limit
Starter 	Commutator O.D.	All models	28.0 mm 1.10 in.	27.0 mm 1.06 in.
	Difference of commutator O.D's	All models	Less than 0.05 mm 0.002 in.	0.4 mm 0.02 in.
Starter 	Mica under cut	All models	0.50 to 0.80 mm 0.020 to 0.031 in.	0.20 mm 0.0079 in.
Starter 	Brush length	All models	16.0 mm 0.630 in.	10.5 mm 0.413 in.
Starter 	Brush holder resistance (Brush holder - Holder support)	All models	Infinity	—
Starter 	Field coil resistance (Lead - Brush)	All models	Continuity	—

Item			Factory Specification	Allowable Limit
Starter 	Field coil resistance (Brush - Yoke)	All models	Infinity	—
Starter 	Armature coil resistance (Commutator - Armature coil core)	All models	Infinity	—
Starter 	Armature coil resistance (Segment - Segment)	All models	Continuity	—
Alternator 	Stator resistance	All models	Less than 1.0 Ω	—

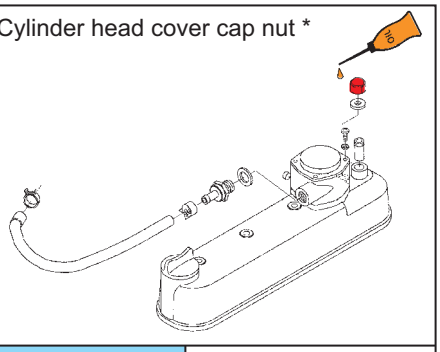
Item			Factory Specification	Allowable Limit
Alternator 	Rotor resistance	All models	2.9 Ω	—
Alternator 	Slip ring O.D.	All models	14.4 mm 0.567 in.	14.0 mm 0.551 in.
Alternator 	Brush length	All models	10.0 mm 0.394 in.	8.4 mm 0.33 in.

TIGHTENING TORQUES

(1) Special Tightening Torques

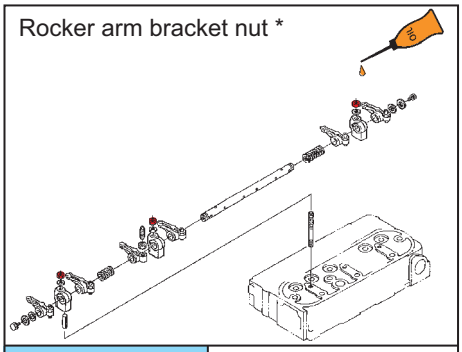
For " * " marked screws, bolts and nuts on under table, apply engine oil to their threads and seats before tightening.

Cylinder head cover cap nut *



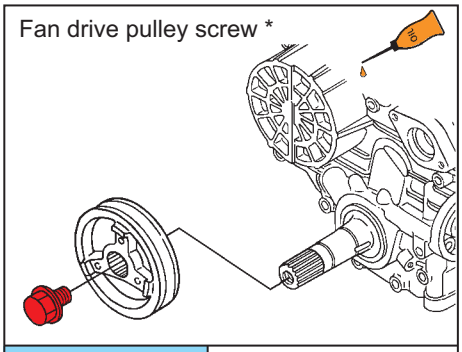
All models	6.9 to 8.8 N·m 0.71 to 0.89 kgf·m 5.1 to 6.4 lbf·ft

Rocker arm bracket nut *



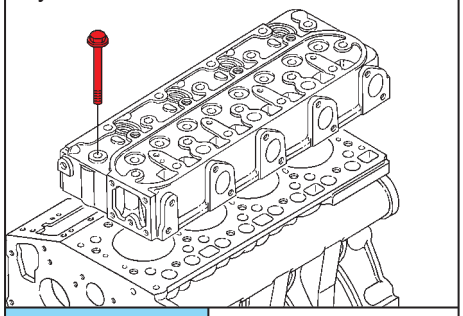
All models	21.6 to 26.5 N·m 2.21 to 2.70 kgf·m 16.0 to 19.5 lbf·ft

Fan drive pulley screw *



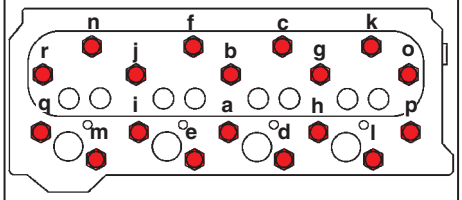
All models	235 to 245 N·m 24.0 to 24.9 kgf·m 174 to 180 lbf·ft

Cylinder head screw



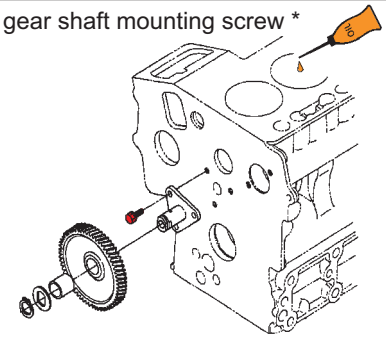
All models	63.7 to 68.6 N·m 6.50 to 6.99 kgf·m 47.0 to 50.5 lbf·ft

Cylinder head tightening order



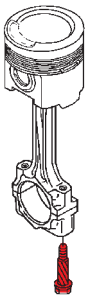
All models	a → r

Idle gear shaft mounting screw *



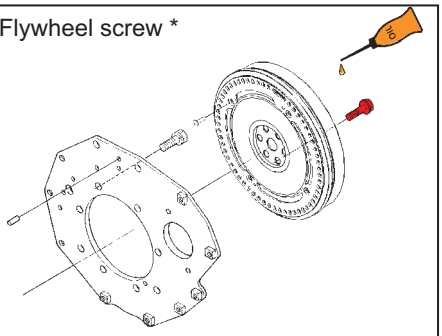
All models	9.81 to 11.2 N·m 1.00 to 1.15 kgf·m 7.24 to 8.31 lbf·ft

Connecting rod screw *



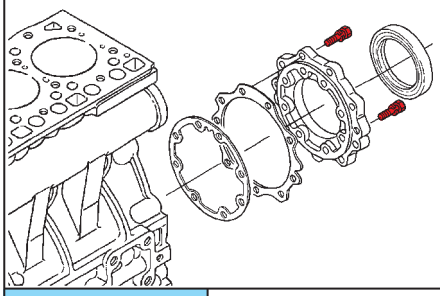
All models	41.2 to 46.1 N·m 4.21 to 4.70 kgf·m 30.4 to 34.0 lbf·ft

Flywheel screw *



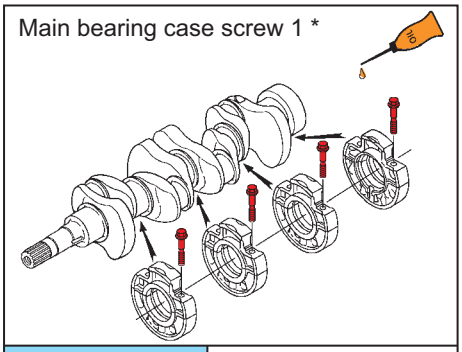
All models	53.9 to 58.8 N·m 5.50 to 5.99 kgf·m 39.8 to 43.3 lbf·ft

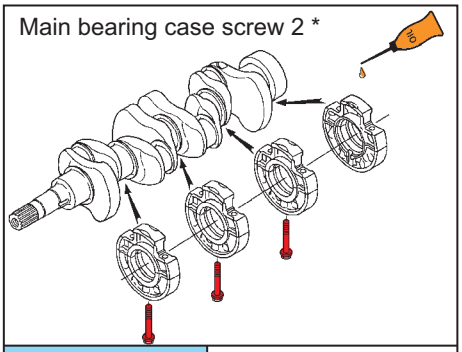
Bearing case cover mounting screw

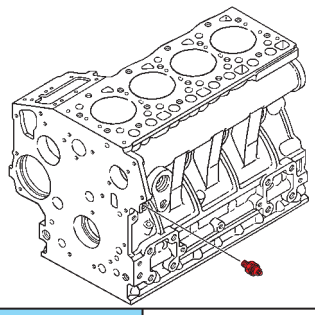


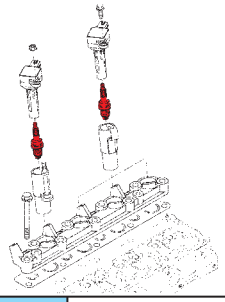
All models	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

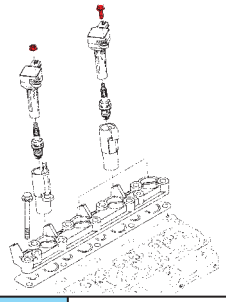
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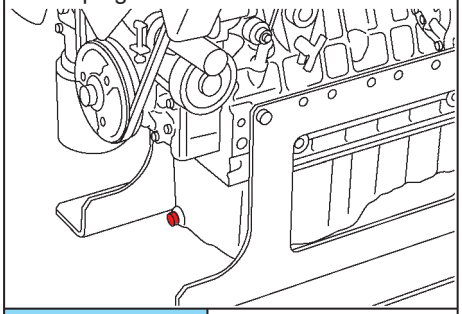
Main bearing case screw 1 *	
	
All models	29.4 to 34.3 N·m 3.00 to 3.49 kgf·m 21.7 to 25.2 lbf·ft

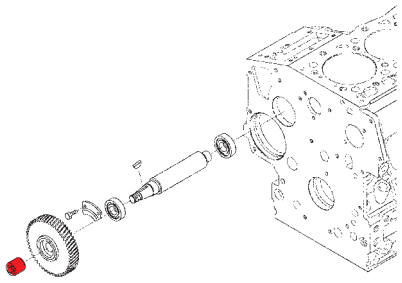
Main bearing case screw 2 *	
	
All models	49.0 to 53.9 N·m 5.00 to 5.49 kgf·m 36.2 to 39.7 lbf·ft

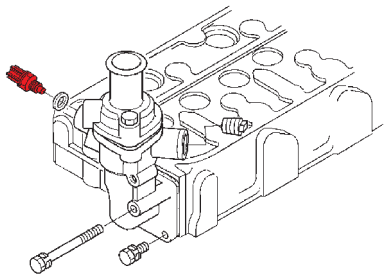
Oil pressure switch	
	
All models	14.7 to 19.6 N·m 1.50 to 1.99 kgf·m 10.9 to 14.4 lbf·ft

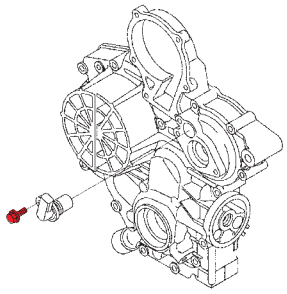
Spark plug	
	
All models	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.6 lbf·ft

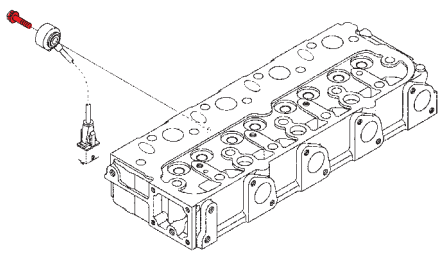
Ignition coil mounting screw/nut	
	
All models	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

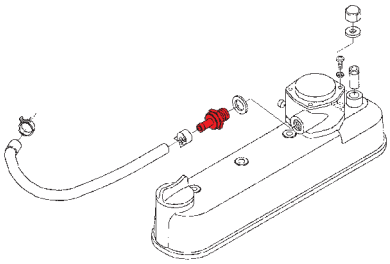
Drain plug	
	
All models	32.4 to 37.3 N·m 3.31 to 3.80 kgf·m 23.9 to 27.5 lbf·ft

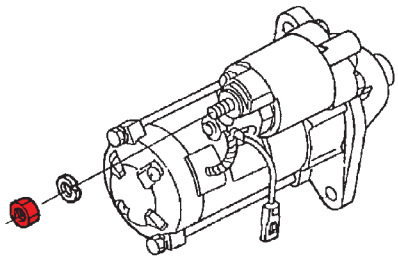
Injection pump gear cap nut	
	
All models	58.8 to 68.6 N·m 6.00 to 6.99 kgf·m 43.4 to 50.5 lbf·ft

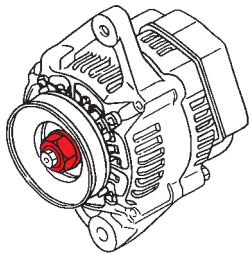
Water temperature sensor	
	
All models	16.7 to 19.6 N·m 1.71 to 1.99 kgf·m 12.4 to 14.4 lbf·ft

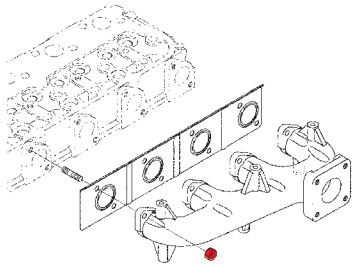
Rotation sensor mounting screw	
	
All models	3.0 to 6.0 N·m 0.31 to 0.61 kgf·m 2.3 to 4.4 lbf·ft

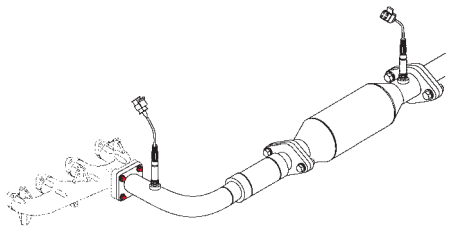
Knock sensor mounting screw	
	
All models	15.0 to 25.0 N·m 1.53 to 2.54 kgf·m 11.1 to 18.4 lbf·ft

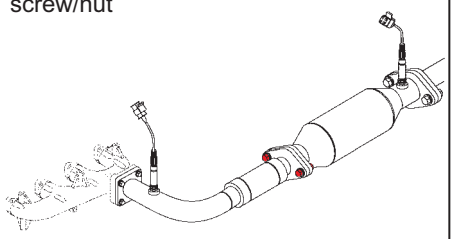
PCV Valve	
	
All models	16.0 to 24.0 N·m 1.64 to 2.44 kgf·m 11.8 to 17.7 lbf·ft

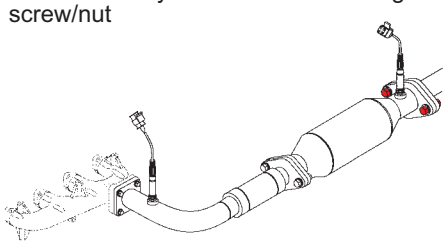
Starter (B terminal nut)	
	
All models	5.88 to 11.8 N·m 0.600 to 1.20 kgf·m 4.34 to 8.70 lbf·ft

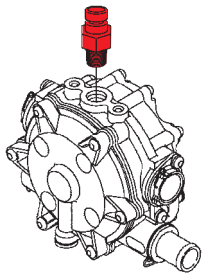
Alternator's pulley nut	
	
All models	58.4 to 78.9 N·m 5.95 to 8.05 kgf·m 43.1 to 58.2 lbf·ft

Exhaust manifold mounting nut	
	
All models	15.7 to 18.6 N·m 1.60 to 1.89 kgf·m 11.6 to 13.7 lbf·ft

Outlet of Exhaust manifold nut	
	
All models	29.4 to 34.3 N·m 3.00 to 9.16 kgf·m 21.7 to 25.2 lbf·ft

Inlet of Catalytic converter mounting screw/nut	
	
All models	48.1 to 55.9 N·m 4.91 to 5.70 kgf·m 35.5 to 41.2 lbf·ft

Outlet of catalytic converter mounting screw/nut	
	
All models	77.5 to 90.2 N·m 7.91 to 9.19 kgf·m 57.2 to 66.5 lbf·ft

LPG in	
	
All models	19.6 to 39.2 N·m 2.00 to 3.99 kgf·m 14.5 to 28.9 lbf·ft

(2) General Tightening Torques

Screw and bolt material grades are shown by numbers punched on the screw and bolt heads.

Prior to tightening, be sure to check out the numbers as shown below.

None or 4 : Standard grade

7 : Special grade

Nominal Diameter	Standard Grade	Special Grade
M6	7.9 to 9.3 N·m 0.80 to 0.95 kgf·m 5.8 to 6.8 lbf·ft	9.81 to 11.2 N·m 1.00 to 1.15 kgf·m 7.24 to 8.31 lbf·ft
M8	18 to 20 N·m 1.8 to 2.1 kgf·m 13 to 15 lbf·ft	24 to 27 N·m 2.4 to 2.8 kgf·m 18 to 20 lbf·ft
M10	40 to 45 N·m 4.0 to 4.6 kgf·m 29 to 33 lbf·ft	49 to 55 N·m 4.9 to 5.7 kgf·m 37 to 41 lbf·ft
M12	62 to 72 N·m 6.4 to 7.4 kgf·m 47 to 53 lbf·ft	78 to 90 N·m 7.9 to 9.2 kgf·m 58 to 66 lbf·ft

WSM

WORKSHOP MANUAL
GASOLINE,LPG ENGINE

WG1605-G-E3,WG1605-L-E3, WG1605-GL-E3

Kubota

KiSC issued 10, 2012 A

TO THE READER

This Workshop Manual tells the servicing personnel about the mechanism, servicing and maintenance of the WG1605-G-E3, WG1605-L-E3 and WG1605-GL-E3. It contains 4 parts: **"Information"**, **"General"**, **"Mechanism"** and **"Servicing"**.

■ **Information**

This section contains information below.

- Safety First
- Specification
- Important Items of Exhaust Emission Regulation
- Performance Curve
- Dimension
- Wiring Diagram

■ **General**

This section contains information below.

- Engine Identification
- General Precautions
- Maintenance Check List
- Check and Maintenance
- Special Tools

■ **Mechanism**

This section contains information on the structure and the function of the unit. Before you continue with the subsequent sections, make sure that you read this section.

■ **Servicing**

This section contains information below.

- Troubleshooting
- Servicing Specifications
- Tightening Torques
- Checking, Disassembling and Servicing

All illustrations, photographs and specifications contained in this manual are of the newest information available at the time of publication.

KUBOTA reserves the right to change all information at any time without notice.

Since this manual includes many models, information or illustrations and photographs can show more than one model.

January, 2012

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I INFORMATION

INFORMATION

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1. SAFETY FIRST

⚠ SAFETY FIRST

- **This symbol, the industry's "Safety Alert Symbol", is used throughout this manual and on labels on the machine itself to warn of the possibility of personal injury. Read these instructions carefully.**
- **It is essential that you read the instructions and safety regulations before you try to repair or use this unit.**

⚠ DANGER
- **Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.**

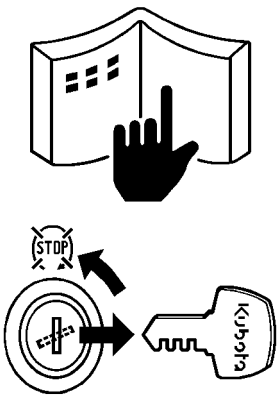
⚠ WARNING
- **Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.**

⚠ CAUTION
- **Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.**

■ IMPORTANT
- **Indicates that equipment or property damage could result if instructions are not followed.**

■ NOTE
- **Gives helpful information.**

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BEFORE YOU START SERVICE

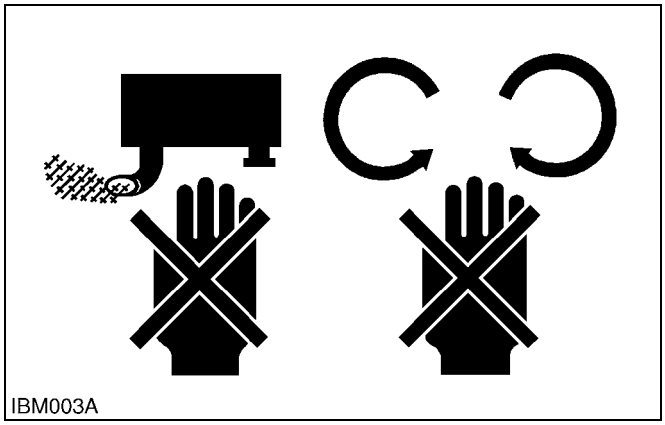
- Read all instructions and safety instructions in this manual and on your engine safety decals.
- Clean the work area and engine.
- Park the machine on a stable and level ground.
- Let the temperature of the engine decrease before you start a job.
- Stop the engine, then remove the key.
- Disconnect the battery negative cable.
- Hang a **"DO NOT OPERATE"** tag in the operator station.

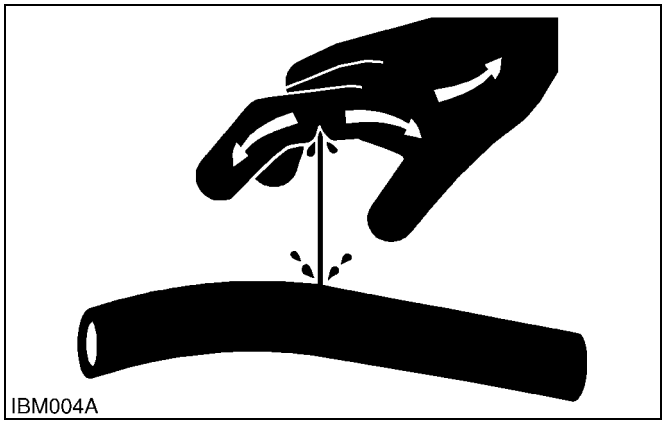
WSM000001INI0002US0

START SAFELY

- Do not do the procedures below when you start the engine.
  - short across starter terminals
  - bypass the safety start switch
- Do not make unauthorized modifications to the engine. This can cause damage and decrease the engine life.

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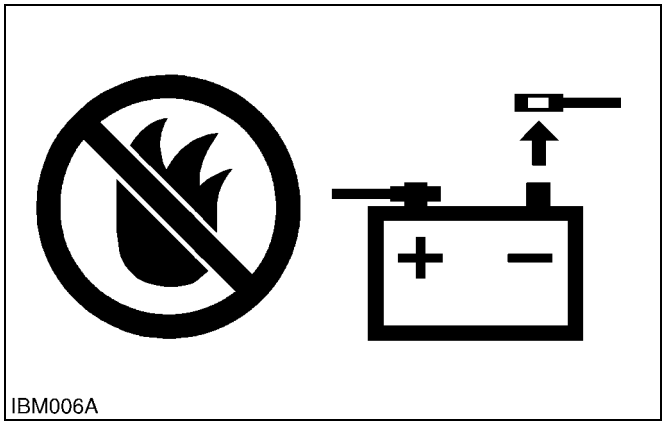

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IBM004A

OPERATE SAFELY

- Do not use the machine after you consume alcohol or medication or when you are tired.
- Put on applicable clothing and safety equipment.
- Use applicable tools only. Do not use alternative tools or parts.
- When 2 or more persons do servicing, make sure that you do it safely.
- Do not touch the hot parts or parts that turn when the engine operates.
- Do not remove the radiator cap when the engine operates, or immediately after it stops. If not, hot water can spout out from the radiator. Only remove the radiator cap when it is at a sufficiently low temperature to touch with bare hands. Slowly loosen the cap to release the pressure before you remove it fully.
- Released fluid (fuel or hydraulic oil) under pressure can cause damage to the skin and cause serious injury. Release the pressure before you disconnect hydraulic or fuel lines. Tighten all connections before you apply the pressure.
- Do not open a fuel system under high pressure. The fluid under high pressure that stays in fuel lines can cause serious injury. Do not disconnect or repair the fuel lines, sensors, or any other components between the fuel pump and injectors on engines with a common rail fuel system under high pressure.
- Put on an applicable ear protective device (earmuffs or earplugs) to prevent injury against loud noises.

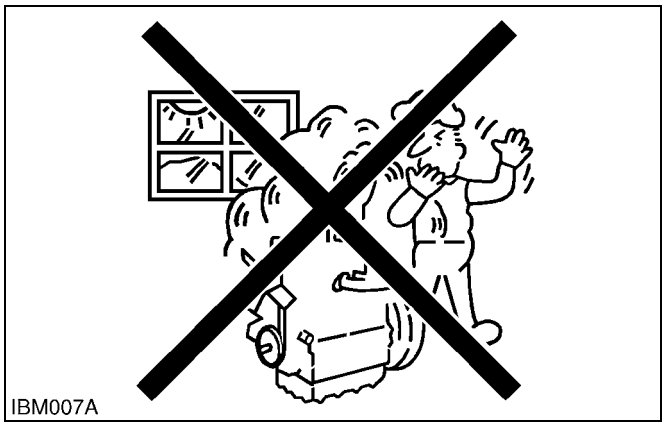
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PREVENT A FIRE

- Fuel is very flammable and explosive under some conditions. Do not smoke or let flames or sparks in your work area.
- To prevent sparks from an accidental short circuit, always disconnect the battery negative cable first and connect it last.
- The battery gas can cause an explosion. Keep the sparks and open flame away from the top of battery, especially when you charge the battery.
- Make sure that you do not spill fuel on the engine.

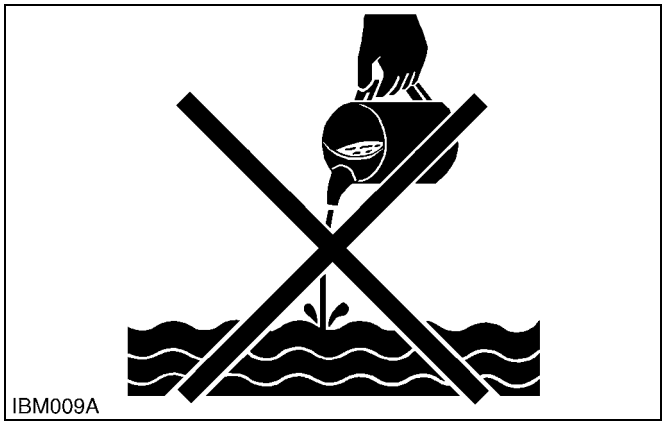
WSM000001INI0005US1


IBM007A

KEEP A GOOD AIRFLOW IN THE WORK AREA

- If the engine is in operation, make sure that the area has good airflow. Do not operate the engine in a closed area. The exhaust gas contains poisonous carbon monoxide.

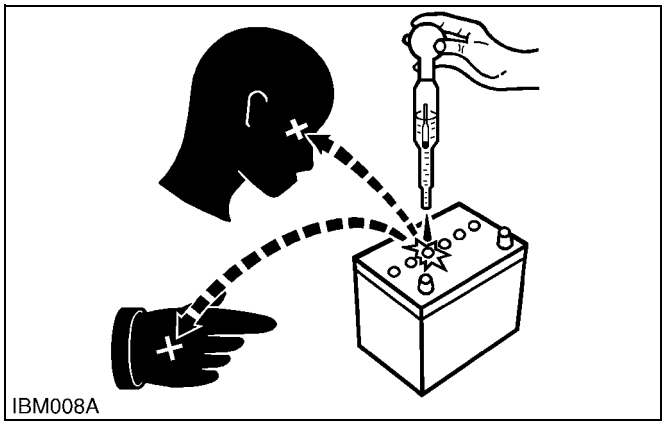
WSM000001INI0006US1


IBM009A

DISCARD FLUIDS CORRECTLY

- Do not discard fluids on the ground, down the drain, into a stream, pond, or lake. Obey related environmental protection regulations when you discard oil, fuel, coolant, electrolyte and other dangerous waste.

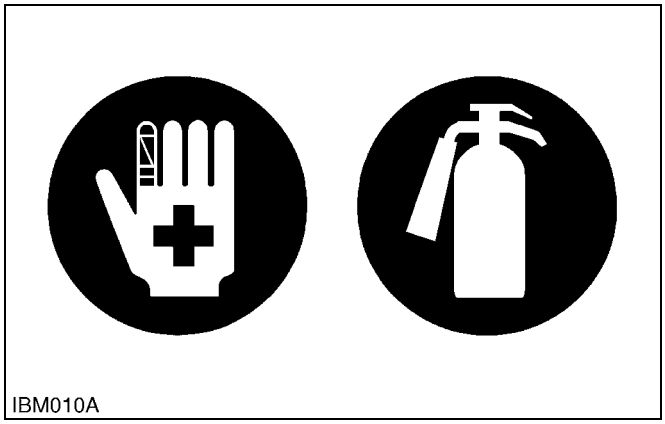
WSM000001INI0007US1


IBM008A

PREVENT ACID BURNS

- Keep electrolyte away from your eyes, hands and clothing. Sulfuric acid in battery electrolyte is poisonous and it can burn your skin and clothing and cause blindness. If you spill electrolyte on yourself, clean yourself with water, and get medical aid immediately.

WSM000001INI0008US1


IBM010A

PREPARE FOR EMERGENCIES

- Keep a first aid kit and fire extinguisher ready at all times.
- Keep the emergency contact telephone numbers near your telephone at all times.

WSM000001INI0009US1

2. SPECIFICATIONS

Model	WG1605-G-E3	WG1605-L-E3
	Gasoline fuel	LPG fuel
Number of Cylinder	4	
Type	Vertical, water cooled, 4-cycle Gasoline engine	Vertical, water cooled, 4-cycle LPG engine
Bore × Stroke	79.0 × 78.4 mm (3.11 × 3.09 in.)	
Total Displacement	1.537 L (93.79 cu.in.)	
SAE Gross Intermittent	42.5 kW (57.0 HP) / 3600 min^{-1} (rpm) 37.0 kW (49.6 HP) / 3000 min^{-1} (rpm)	41.0 kW (55.0 HP) / 3600 min^{-1} (rpm) 36.0 kW (48.3 HP) / 3000 min^{-1} (rpm)
ISO / SAE Net Intermittent	38.5 kW (51.6 HP) / 3600 min^{-1} (rpm) 33.5 kW (44.9 HP) / 3000 min^{-1} (rpm)	37.1 kW (49.8 HP) / 3600 min^{-1} (rpm) 32.5 kW (43.6 HP) / 3000 min^{-1} (rpm)
ISO Net Continuous	30.8 kW (41.3 HP) / 3600 min^{-1} (rpm) 26.8 kW (35.9 HP) / 3000 min^{-1} (rpm)	29.7 kW (39.8 HP) / 3600 min^{-1} (rpm) 26.1 kW (35.0 HP) / 3000 min^{-1} (rpm)
Maximum Bare Speed	3575 to 3625 min^{-1} (rpm) 2975 to 3025 min^{-1} (rpm)	
Minimum Bare Idling Speed	725 to 775 min^{-1} (rpm)	
Cylinder Head	Overhead-Valve	
Ignition System	Full Transistor Battery Ignition Type	
Governor	Electronic Governor	
Direction of Rotation	Counter-Clockwise (Viewed from Flywheel Side)	
Spark Plug Type / Spark Plug Gap	NGK IFR6F8DN 0.70 to 0.80 mm (0.028 to 0.031 in.)	
Ignition Timing	0.45 rad (26 °) before T.D.C. / 3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10 °) before T.D.C. / 750 min^{-1} (rpm), 800 min^{-1} (rpm)	0.35 rad (20 °) before T.D.C. / 3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10 °) before T.D.C. / 750 min^{-1} (rpm), 800 min^{-1} (rpm)
Firing Order	1-3-4-2	
Compression Ratio	9.1: 1	
Lubricating System	Forced Lubrication by Trochoid Pump	
Oil Pressure Indication	Electrical Type Switch	
Lubricating Filter	Full Flow Paper Filter (Cartridge Type)	
Cooling System	Pressurized Radiator, Forced Circulation with Water Pump	
Starting System	Electric Starting with Starter	
Starting Motor	12 V, 1.0 kW	
Battery	12 V, 52 AH or Equivalent	
Charging Alternator	12 V, 480 W, 720 W	
Fuel	*Unleaded Automobile Gasoline	Commercial LPG
Lubricating Oil	Better than SL Class (API) SAE 10W-30	
Lubricating Oil Capacity	6.0 L (1.6 U.S.gals)	
Catalytic Muffler / Converter	Three Way Catalyst	
Weight (Dry)	119 kg (262 lbs)	120 kg (265 lbs)
Application	General Power Source	

*The specification described above is of the standard engine of each model.
*Conversion Formula: HP = 0.746 kW, PS = 0.7355 kW

***KUBOTA RECOMMENDED LPG FUEL SPECIFICATIONS**

- Commercial Propane gas only.
- Equivalent to Propanes H-D-5 of GPA* standards.

(vol %)

C_3H_8	C_3H_6	C_4H_{10}	Others
≥ 90 %	≤ 5 %	≤ 2.5 %	–

*GPA means Gas Processors Association (U.S.A.)

Model	WG1605-GL-E3	
	Gasoline fuel	LPG fuel
Number of Cylinder	4	
Type	Vertical, water cooled, 4-cycle Dual Fuel (Gasoline / LPG) engine	
Bore × Stroke	79.0 × 78.4 mm (3.11 × 3.09 in.)	
Total Displacement	1.537 L (93.79 cu.in.)	
SAE Gross Intermittent	42.5 kW (57.0 HP) / 3600 min^{-1} (rpm) 37.0 kW (49.6 HP) / 3000 min^{-1} (rpm)	41.0 kW (55.0 HP) / 3600 min^{-1} (rpm) 36.0 kW (48.3 HP) / 3000 min^{-1} (rpm)
ISO / SAE Net Intermittent	38.5 kW (51.6 HP) / 3600 min^{-1} (rpm) 33.5 kW (44.9 HP) / 3000 min^{-1} (rpm)	37.1 kW (49.8 HP) / 3600 min^{-1} (rpm) 32.5 kW (43.6 HP) / 3000 min^{-1} (rpm)
ISO Net Continuous	30.8 kW (41.3 HP) / 3600 min^{-1} (rpm) 26.8 kW (35.9 HP) / 3000 min^{-1} (rpm)	29.7 kW (39.8 HP) / 3600 min^{-1} (rpm) 26.1 kW (35.0 HP) / 3000 min^{-1} (rpm)
Maximum Bare Speed	3575 to 3625 min^{-1} (rpm) 2975 to 3025 min^{-1} (rpm)	
Minimum Bare Idling Speed	725 to 775 min^{-1} (rpm)	
Cylinder Head	Overhead-Valve	
Ignition System	Full Transistor Battery Ignition Type	
Governor	Electronic Governor	
Direction of Rotation	Counter-Clockwise (Viewed from Flywheel Side)	
Spark Plug Type / Spark Plug Gap	NGK IFR6F8DN 0.70 to 0.80 mm (0.028 to 0.031 in.)	
Ignition Timing	0.45 rad (26 °) before T.D.C. / 3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10 °) before T.D.C. / 750 min^{-1} (rpm), 800 min^{-1} (rpm)	0.35 rad (20 °) before T.D.C. / 3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10 °) before T.D.C. / 750 min^{-1} (rpm), 800 min^{-1} (rpm)
Firing Order	1-3-4-2	
Compression Ratio	9.1: 1	
Lubricating System	Forced Lubrication by Trochoid Pump	
Oil Pressure Indication	Electrical Type Switch	
Lubricating Filter	Full Flow Paper Filter (Cartridge Type)	
Cooling System	Pressurized Radiator, Forced Circulation with Water Pump	
Starting System	Electric Starting with Starter	
Starting Motor	12 V, 1.0 kW	
Battery	12 V, 52 AH or Equivalent	
Charging Alternator	12 V, 480 W, 720 W	
Fuel	*Unleaded Automobile Gasoline	Commercial LPG
Lubricating Oil	Better than SL Class (API) SAE 10W-30	
Lubricating Oil Capacity	6.0 L (1.6 U.S.gals)	
Catalytic Muffler / Converter	Three Way Catalyst	
Weight (Dry)	121 kg (267 lbs)	
Application	General Power Source	

*The specification described above is of the standard engine of each model.
*Conversion Formula: HP = 0.746 kW, PS = 0.7355 kW

*KUBOTA RECOMMENDED LPG FUEL SPECIFICATIONS

- Commercial Propane gas only.
- Equivalent to Propanes H-D-5 of GPA* standards.

(vol %)

C_3H_8	C_3H_6	C_4H_{10}	Others
≥ 90 %	≤ 5 %	≤ 2.5 %	–

*GPA means Gas Processors Association (U.S.A.)

9Y1210661INI0001US0

3. IMPORTANT ITEMS OF EXHAUST EMISSION REGULATION

WG1605 is available and unavailable in those countries.

kW, Disp.	Model	Type	North America	Europe	Japan
19 < P, 1.0 < L	WG1605-G-E3, WG1605-L-E3, WG1605-GL-E3	E3	Available	Available	Non-available

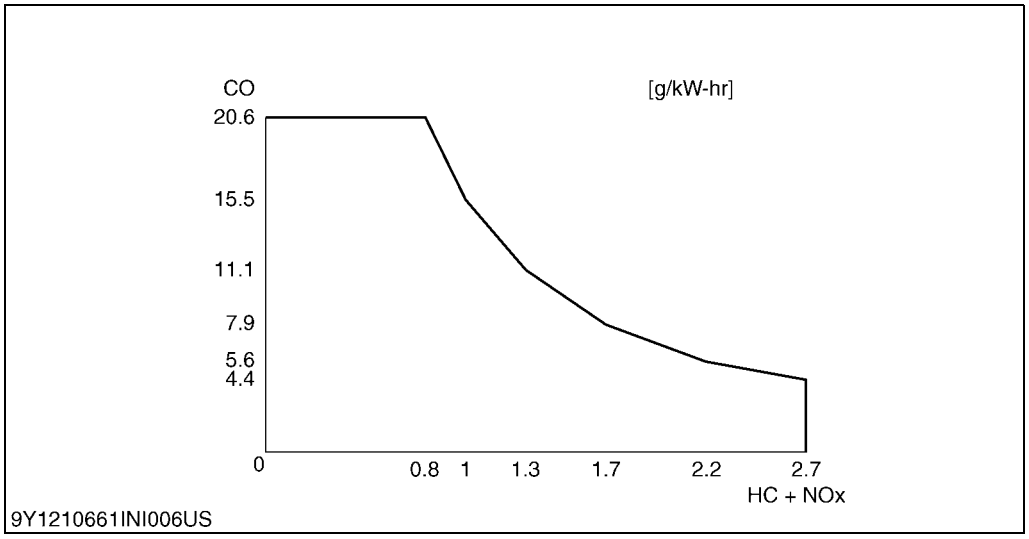
Current and future emission regulations.

$HC+NO_x/CO$ (g/kWh)

Countries		kW, disp.	2009	2010	2011	2012	2013	2014	2015	2016
USA	CARB	19 < P < 560 1.0 < L	2.7/4.4* **	0.8/20.6*						
	EPA	19 < P ≤ 560 1.0 < L	2.7/4.4* **							
Canada		19 < P	None							
Japan		19 ≤ P < 560	HC/0.6 g/kWh, NO_x/0.6 g/kWh, CO/20 g/kWh							
EU		19 < P	None							

- *: with evaporative emission regulation
- **: See figure below

9Y1210661INI0002US0



9Y1210661INI0017US0

[1] THREE-WAY CATALYST

A three-way catalyst is a catalyst that oxidizes HC to CO_2 and H_2O and also CO to CO_2 respectively and at the same time reduces NOx to N_2 near the stoichiometric ratio.

The main basic component of an exhaust gas purification system that uses a three-way catalyst is feedback control of air-fuel ratio by means of an O_2 sensor for the purpose of maximizing the emission purification efficiency characteristic with reference to the intake air-fuel ratio of the three-way catalyst.

KUBOTA engines have two kinds of catalytic devices, catalytic muffler and catalytic converter.

9Y1210661INI0004US0

[2] VAPORIZER AND LOCK OFF VALVE (WG1605-L-E3, WG1605-GL-E3)

Vaporizer requires a normally-closed electrically controlled fuel lock off valve that is close coupled to the vaporizer and off when ignition switch is off or when the engine is not running normally (supplied from KUBOTA). In operation without a lock off upstream the vaporizer will flow fuel with the engine off. The vaporizer is not a fuel shut-off safety device.

9Y1210661INI0016US0

[3] LENGTH OF THE VAPOR HOSE (WG1605-L-E3, WG1605-GL-E3)

Vapor hose length must not exceed 700 mm (27.6 in), shorter is generally considered better. Care should be taken with hose routing and length to minimize the affect on vaporizer vibration isolation. The metal reinforced hose should not be used.

9Y1210661INI0007US0

[4] IMPORTANT NOTICE

These instructions are provided to the Final Engine Assemblers (FEA) who must ensure the engine, exhaust system (catalyst), fuel system etc, are installed correctly in the engine's certified configuration.

Please make sure whether emission-related items are certain on application review.

(for EPA only)

Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.

The contractual agreement contract is necessary before mass-production.

9Y1210661INI0018US0

[5] EMISSION-RELATED INSTALLATION INSTRUCTIONS

(1) Exhaust System

KUBOTA supplies a certified catalyst. FEA must use a KUBOTA certified catalyst and assemble the exhaust system parts according to the instructions.

No other catalyst is certified for use with WG1605 Engine. No Other Catalyst can be used.

FEA may only install the exhaust system parts confirmed at application review.

9Y1210661INI0019US0

(2) Intake System

To prevent decreases of engine output performance, intake resistance must be kept below a certain point.

9Y1210661INI0020US0

(3) Crankcase Ventilation Connections

Crankcase emissions may not be discharged directly into the ambient atmosphere throughout its useful life. (40 CFR 1048.115 (a))

9Y1210661INI0021US0

(4) Gasoline Fuel System

If your equipment uses a volatile liquid fuel (such as gasoline), they must meet the evaporative emission standards of 40 CFR 1048.

9Y1210661INI0022US0

(5) Gaseous Fuel System

FEA must use only the vaporizer and the lock off valve KUBOTA offers and assemble the LPG fuel system parts according to the instructions.

9Y1210661INI0023US0

(6) Engine Control Unit (ECU)

Installation must use all 4 of the vibration mounts.
ECU header pins must be horizontal or point downward.

9Y1210661INI0024US0

(7) Vehicle Interface Connectors

Vehicle interface connectors shall be connected with your wire harness.

9Y1210661INI0025US0

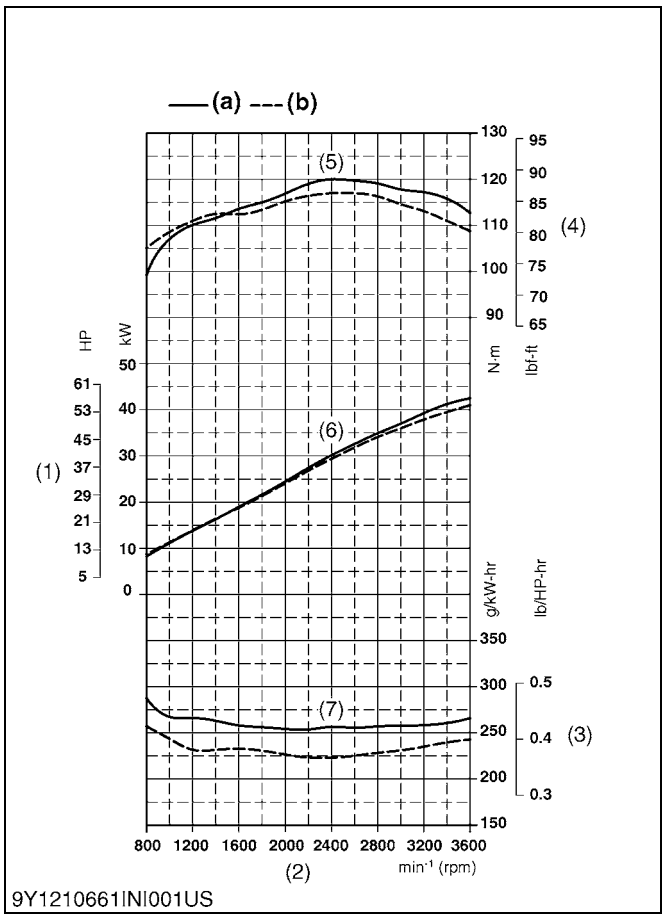
(8) Malfunction Indicator Light (MIL)

When the MIL goes on, it must display "Check Engine", "Service Engine Soon", or a similar message that EPA approve. (40 CFR 1048.110 (b))

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4. PERFORMANCE CURVES

WG1605-G/L/GL-E3



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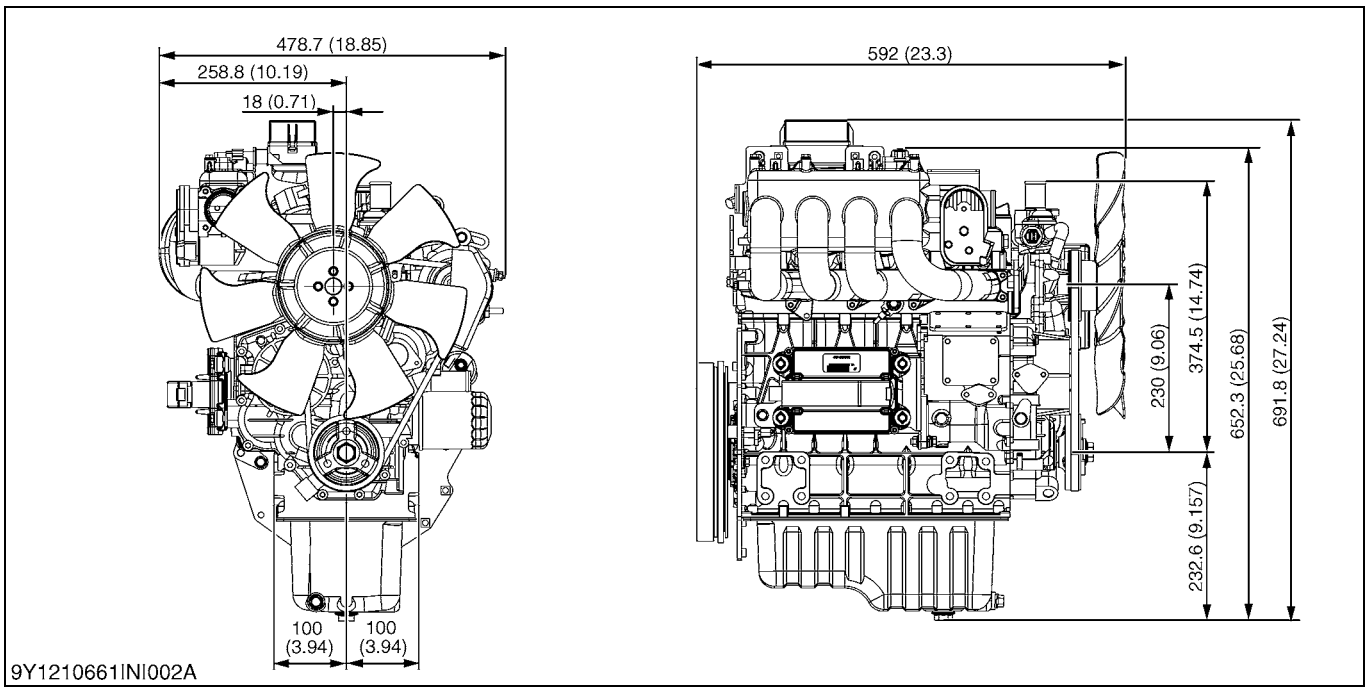
(1) Brake Horsepower
(2) Engine Speed
(3) Specific Fuel Consumption
(4) Torque
(5) Gross Intermittent Torque
(6) Gross Intermittent Brake Horsepower
(7) Gross Intermittent Specific Fuel Consumption

a: Gasoline Use
b: LP Gas Use

9Y1210661INI0005US0

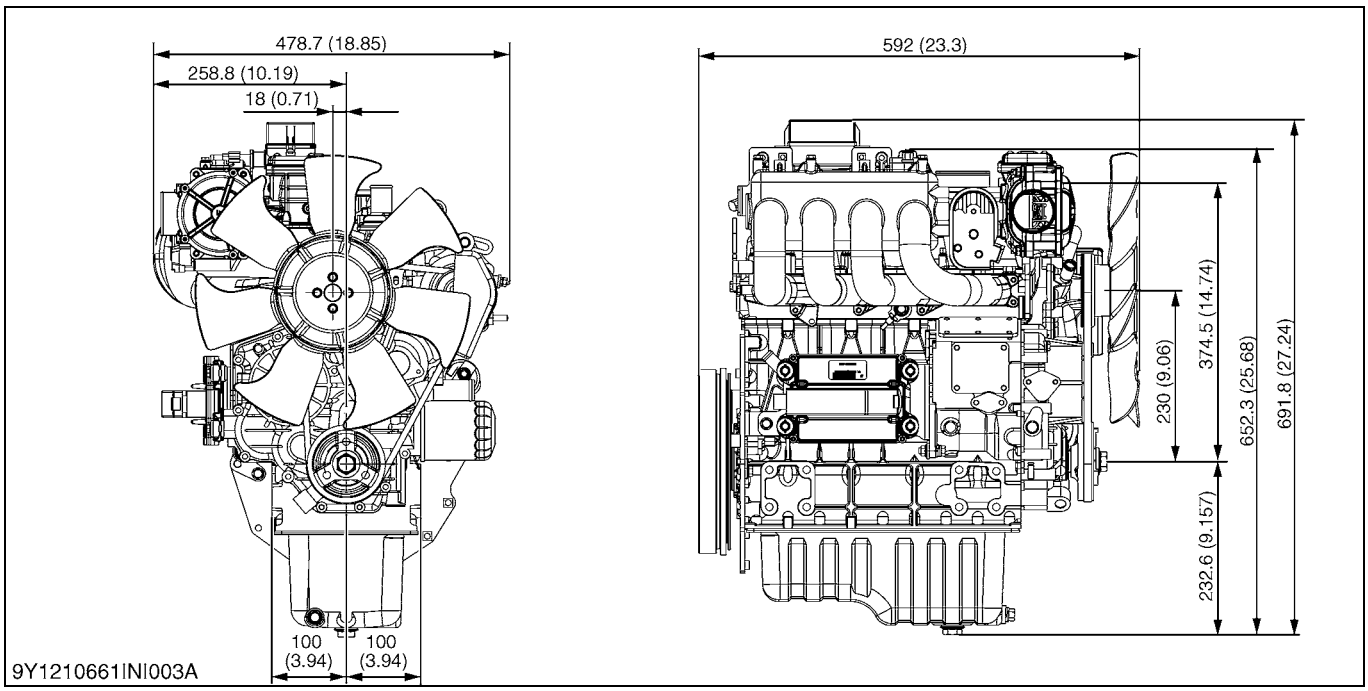
5. DIMENSIONS

WG1605-G-E3



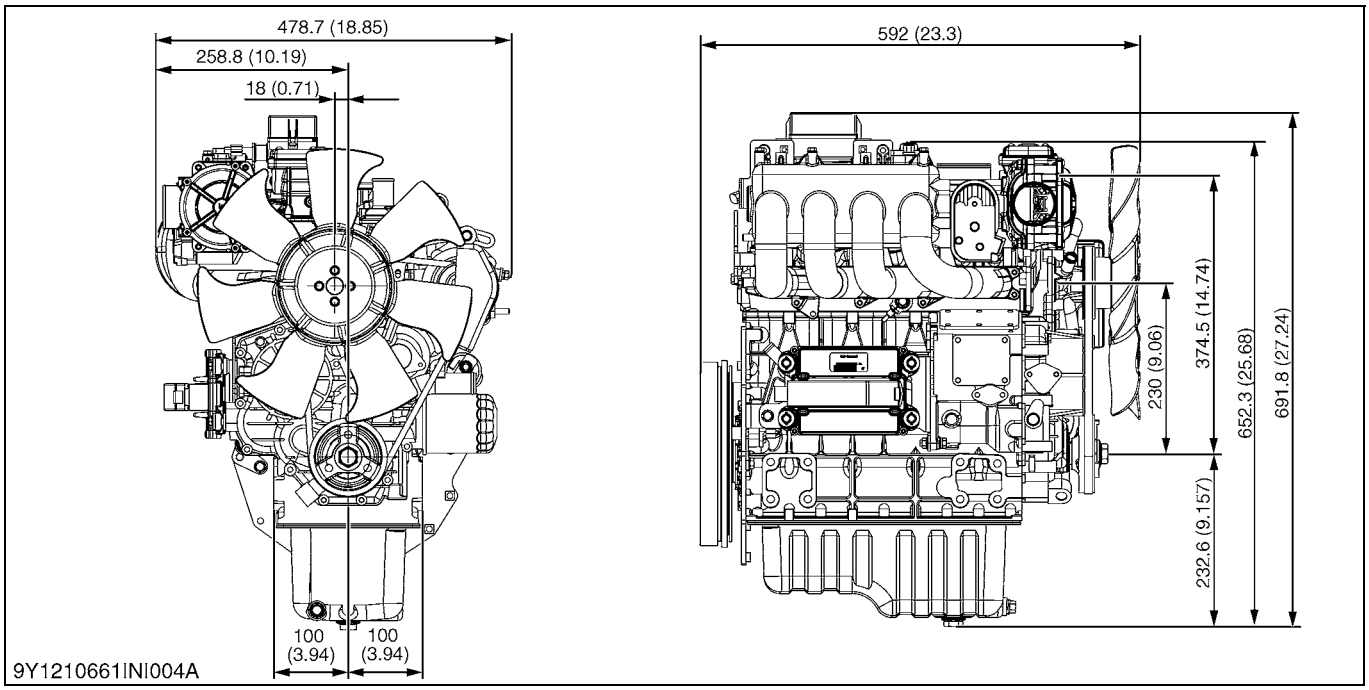
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WG1605-L-E3



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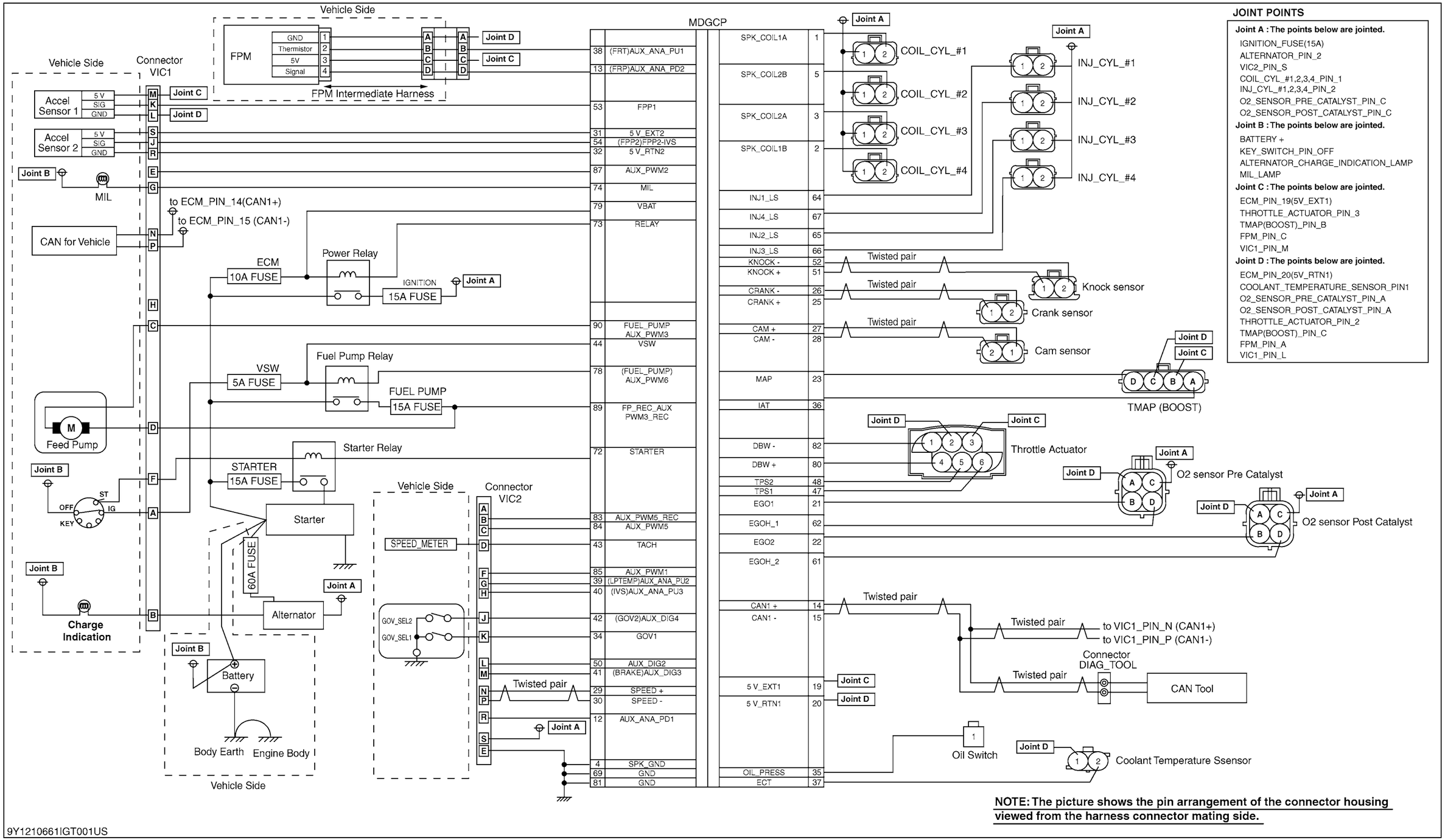
WG1605-GL-E3



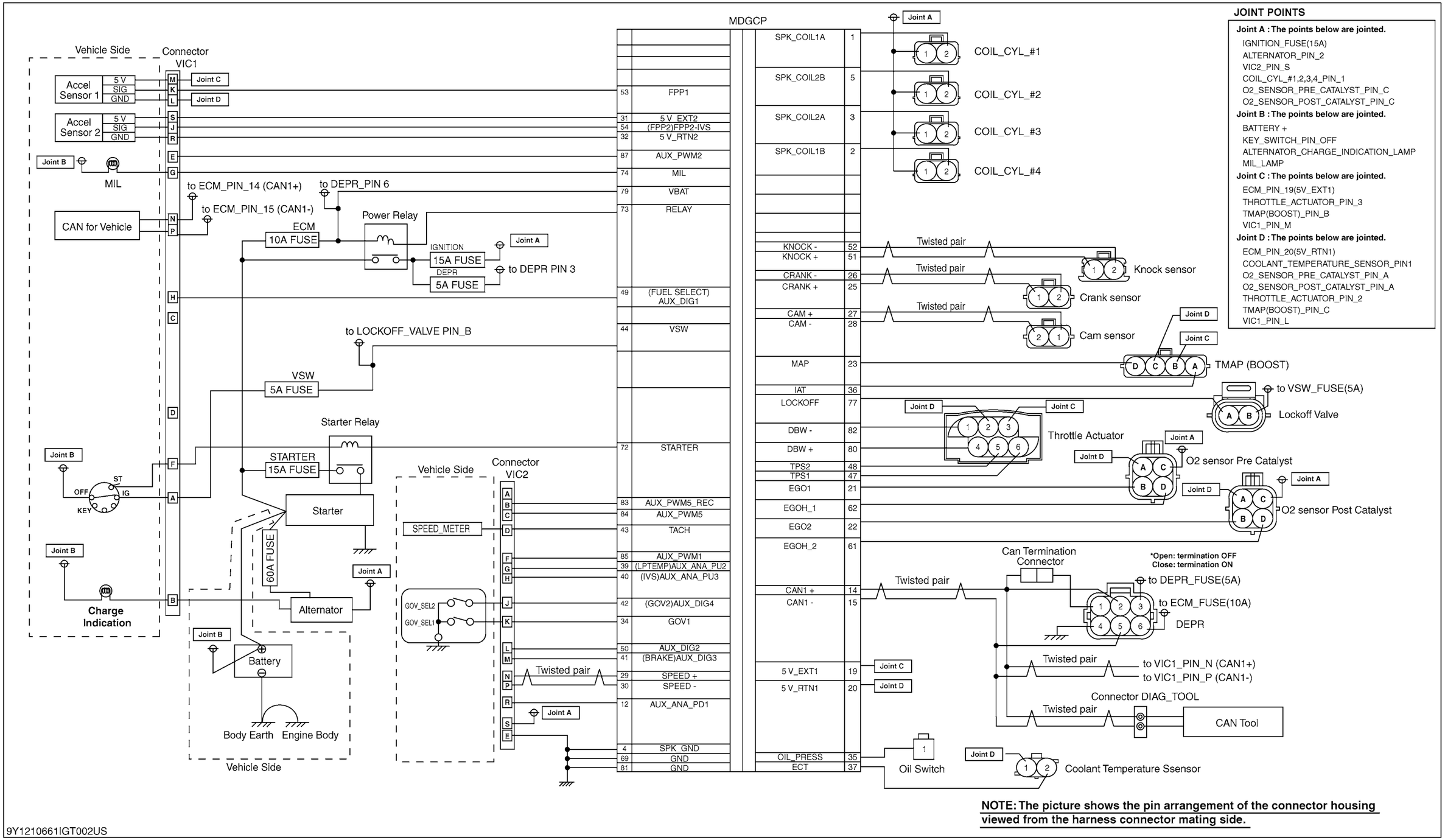
9Y1210661INI0011US0

6. WIRING DIAGRAM

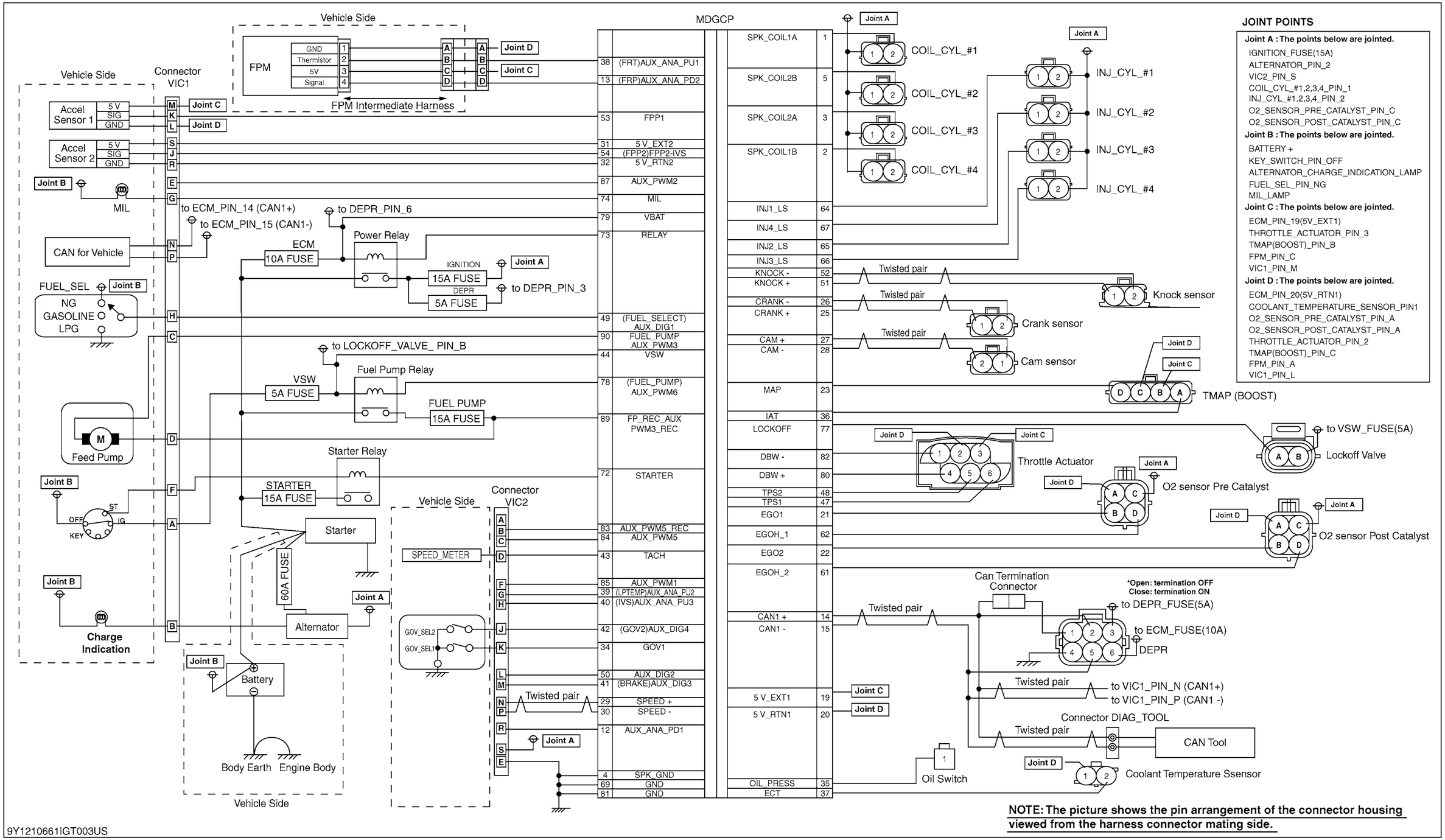
WG1605-G-E3



WG1605-L-E3


Vehicle Side
Connector VIC1
Accel Sensor 1
5 V
SIG
GND
Accel Sensor 2
Joint B
MIL
CAN for Vehicle
to ECM_PIN_14 (CAN1+)
to ECM_PIN_15 (CAN1-)
to DEPR_PIN 6
Power Relay
ECM
10A FUSE
IGNITION
15A FUSE
DEPR
5A FUSE
Joint A
to DEPR PIN 3
to LOCKOFF_VALVE PIN_B
VSW
5A FUSE
Starter Relay
STARTER
15A FUSE
Starter
ST
IG
OFF
KEY
60A FUSE
Alternator
Charge Indication
Battery
Body Earth
Engine Body
Vehicle Side
Connector VIC2
SPEED_METER
GOV_SEL2
GOV_SEL1
Twisted pair
MDGCP
53 FPP1
31 5 V_EXT2
54 (FPP2)FPP2-IVS
32 5 V_RTN2
87 AUX_PWM2
74 MIL
79 VBAT
73 RELAY
49 (FUEL SELECT) AUX_DIG1
44 VSW
72 STARTER
83 AUX_PWM5_REC
84 AUX_PWM5
43 TACH
85 AUX_PWM1
39 (LPTEMP)AUX_ANA_PU2
40 (IVS)AUX_ANA_PU3
42 (GOV2)AUX_DIG4
34 GOV1
50 AUX_DIG2
41 (BRAKE)AUX_DIG3
29 SPEED +
30 SPEED -
12 AUX_ANA_PD1
4 SPK_GND
69 GND
81 GND
SPK_COIL1A 1
SPK_COIL2B 5
SPK_COIL2A 3
SPK_COIL1B 2
KNOCK - 52
KNOCK + 51
CRANK - 26
CRANK + 25
CAM + 27
CAM - 28
MAP 23
IAT 36
LOCKOFF 77
DBW - 82
DBW + 80
TPS2 48
TPS1 47
EGO1 21
EGOH_1 62
EGO2 22
EGOH_2 61
CAN1 + 14
CAN1 - 15
5 V_EXT1 19
5 V_RTN1 20
OIL_PRESS 35
ECT 37
COIL_CYL_#1
COIL_CYL_#2
COIL_CYL_#3
COIL_CYL_#4
Twisted pair
Knock sensor
Crank sensor
Cam sensor
TMAP (BOOST)
to VSW_FUSE(5A)
Lockoff Valve
Throttle Actuator
O2 sensor Pre Catalyst
O2 sensor Post Catalyst
Can Termination Connector
*Open: termination OFF
Close: termination ON
to DEPR_FUSE(5A)
to ECM_FUSE(10A)
DEPR
to VIC1_PIN_N (CAN1+)
to VIC1_PIN_P (CAN1-)
Connector DIAG_TOOL
CAN Tool
Oil Switch
Coolant Temperature Ssensor
JOINT POINTS
Joint A : The points below are jointed.
IGNITION_FUSE(15A)
ALTERNATOR_PIN_2
VIC2_PIN_S
COIL_CYL_#1,2,3,4_PIN_1
O2_SENSOR_PRE_CATALYST_PIN_C
O2_SENSOR_POST_CATALYST_PIN_C
Joint B : The points below are jointed.
BATTERY +
KEY_SWITCH_PIN_OFF
ALTERNATOR_CHARGE_INDICATION_LAMP
MIL_LAMP
Joint C : The points below are jointed.
ECM_PIN_19(5V_EXT1)
THROTTLE_ACTUATOR_PIN_3
TMAP(BOOST)_PIN_B
VIC1_PIN_M
Joint D : The points below are jointed.
ECM_PIN_20(5V_RTN1)
COOLANT_TEMPERATURE_SENSOR_PIN1
O2_SENSOR_PRE_CATALYST_PIN_A
O2_SENSOR_POST_CATALYST_PIN_A
THROTTLE_ACTUATOR_PIN_2
TMAP(BOOST)_PIN_C
VIC1_PIN_L
NOTE: The picture shows the pin arrangement of the connector housing viewed from the harness connector mating side.
9Y1210661IGT002US

WG1605-GL-E3


Vehicle Side
FPM
GND
Thermistor
5V
Signal
Joint D
Joint C
FPM Intermediate Harness
Vehicle Side
Connector VIC1
Accel Sensor 1
Accel Sensor 2
5 V
SIG
GND
Joint C
Joint D
Joint B
MIL
to ECM_PIN_14 (CAN1+)
to ECM_PIN_15 (CAN1-)
to DEPR_PIN_6
CAN for Vehicle
Power Relay
ECM
10A FUSE
IGNITION
15A FUSE
DEPR
5A FUSE
Joint A
to DEPR_PIN_3
FUEL_SEL
NG
GASOLINE
LPG
to LOCKOFF_VALVE_ PIN_B
Fuel Pump Relay
VSW
5A FUSE
FUEL PUMP
15A FUSE
Feed Pump
Starter Relay
STARTER
15A FUSE
Starter
60A FUSE
Alternator
Charge Indication
ST
IG
OFF
KEY
Battery
Body Earth
Engine Body
Vehicle Side
Connector VIC2
SPEED_METER
GOV_SEL2
GOV_SEL1
Twisted pair
MDGCP
38 (FRT)AUX_ANA_PU1
13 (FRP)AUX_ANA_PD2
53 FPP1
31 5 V_EXT2
54 (FPP2)FPP2-IVS
32 5 V_RTN2
87 AUX_PWM2
74 MIL
79 VBAT
73 RELAY
49 (FUEL_SELECT) AUX_DIG1
90 FUEL_PUMP AUX_PWM3
44 VSW
78 (FUEL_PUMP) AUX_PWM6
89 FP_REC_AUX PWM3_REC
72 STARTER
83 AUX_PWM5_REC
84 AUX_PWM5
43 TACH
85 AUX_PWM1
39 (LPTEMP)AUX_ANA_PU2
40 (IVS)AUX_ANA_PU3
42 (GOV2)AUX_DIG4
34 GOV1
50 AUX_DIG2
41 (BRAKE)AUX_DIG3
29 SPEED +
30 SPEED -
12 AUX_ANA_PD1
4 SPK_GND
69 GND
81 GND
SPK_COIL1A 1
SPK_COIL2B 5
SPK_COIL2A 3
SPK_COIL1B 2
INJ1_LS 64
INJ4_LS 67
INJ2_LS 65
INJ3_LS 66
KNOCK - 52
KNOCK + 51
CRANK - 26
CRANK + 25
CAM + 27
CAM - 28
MAP 23
IAT 36
LOCKOFF 77
DBW - 82
DBW + 80
TPS2 48
TPS1 47
EGO1 21
EGOH_1 62
EGO2 22
EGOH_2 61
CAN1 + 14
CAN1 - 15
5 V_EXT1 19
5 V_RTN1 20
OIL_PRESS 35
ECT 37
Joint A
COIL_CYL_#1
COIL_CYL_#2
COIL_CYL_#3
COIL_CYL_#4
INJ_CYL_#1
INJ_CYL_#2
INJ_CYL_#3
INJ_CYL_#4
Twisted pair
Knock sensor
Crank sensor
Cam sensor
Joint D
Joint C
TMAP (BOOST)
Throttle Actuator
to VSW_FUSE(5A)
Lockoff Valve
O2 sensor Pre Catalyst
O2 sensor Post Catalyst
Can Termination Connector
*Open: termination OFF
Close: termination ON
to DEPR_FUSE(5A)
to ECM_FUSE(10A)
DEPR
to VIC1_PIN_N (CAN1+)
to VIC1_PIN_P (CAN1 -)
Connector DIAG_TOOL
CAN Tool
Oil Switch
Coolant Temperature Ssensor
JOINT POINTS
Joint A : The points below are jointed.
IGNITION_FUSE(15A)
ALTERNATOR_PIN_2
VIC2_PIN_S
COIL_CYL_#1,2,3,4_PIN_1
INJ_CYL_#1,2,3,4_PIN_2
O2_SENSOR_PRE_CATALYST_PIN_C
O2_SENSOR_POST_CATALYST_PIN_C
Joint B : The points below are jointed.
BATTERY +
KEY_SWITCH_PIN_OFF
ALTERNATOR_CHARGE_INDICATION_LAMP
FUEL_SEL_PIN_NG
MIL_LAMP
Joint C : The points below are jointed.
ECM_PIN_19(5V_EXT1)
THROTTLE_ACTUATOR_PIN_3
TMAP(BOOST)_PIN_B
FPM_PIN_C
VIC1_PIN_M
Joint D : The points below are jointed.
ECM_PIN_20(5V_RTN1)
COOLANT_TEMPERATURE_SENSOR_PIN1
O2_SENSOR_PRE_CATALYST_PIN_A
O2_SENSOR_POST_CATALYST_PIN_A
THROTTLE_ACTUATOR_PIN_2
TMAP(BOOST)_PIN_C
FPM_PIN_A
VIC1_PIN_L
NOTE: The picture shows the pin arrangement of the connector housing viewed from the harness connector mating side.
9Y1210661IGT003US

G GENERAL

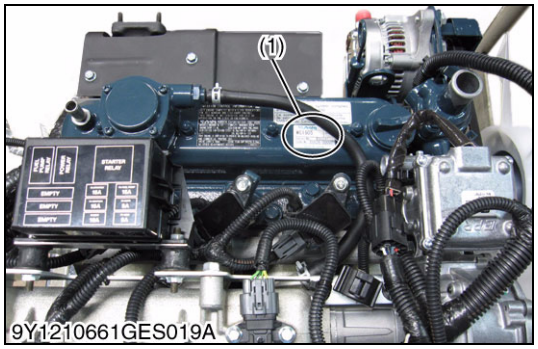
GENERAL

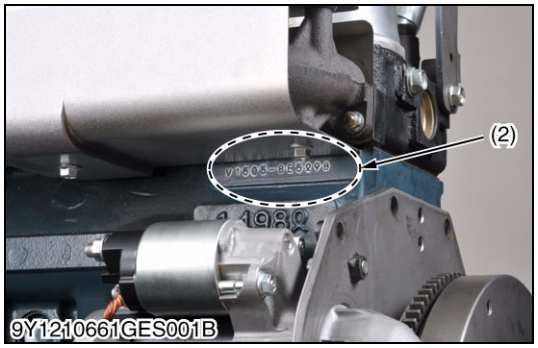
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1. ENGINE IDENTIFICATION

[1] ENGINE MODEL NAME, CODE NUMBER AND ENGINE SERIAL NUMBER





When contacting the manufacture, always specify your engine model name, code number and serial number.

The engine model, code number and its serial number need to be identified before the engine can be serviced or parts replaced.

■ **Engine Model Name and Number Label**

The engine model name, the engine serial number and engine code number are written in this label.

■ **Engine Serial Number**

The engine serial number is an identification number for the engine.

It is marked after the engine model name.

It indicates the engine series, the production year and month, and the lot number.

Engine Series

Number or Alphabet	Series	Number or Alphabet	Series
1	05 (include: WG)	6	GZ, OC, AC, EA, E
2	V3	7	03 (include: WG)
3	08	8	07
4	SM (include: WG)	A	EA, RK
5	Air Cooled Gasoline	B	03 (KET Production)

Production Year

Alphabet or Number	Year	Alphabet or Number	Year
1	2001	F	2015
2	2002	G	2016
3	2003	H	2017
4	2004	J	2018
5	2005	K	2019
6	2006	L	2020
7	2007	M	2021
8	2008	N	2022
9	2009	P	2023
A	2010	R	2024
B	2011	S	2025
C	2012	T	2026
D	2013	V	2027
E	2014		

(1) Engine Model Name and Number Label (2) Engine Serial Number

(To be continued)

(Continued)

Production Month and Lot Number

Month	Engine Lot Number	
January	A0001 ~ A9999	B0001 ~
February	C0001 ~ C9999	D0001 ~
March	E0001 ~ E9999	F0001 ~
April	G0001 ~ G9999	H0001 ~
May	J0001 ~ J9999	K0001 ~
June	L0001 ~ L9999	M0001 ~
July	N0001 ~ N9999	P0001 ~
August	Q0001 ~ Q9999	R0001 ~
September	S0001 ~ S9999	T0001 ~
October	U0001 ~ U9999	V0001 ~
November	W0001 ~ W9999	X0001 ~
December	Y0001 ~ Y9999	Z0001 ~

* Alphabetical letters **"I"** and **"O"** are not used.

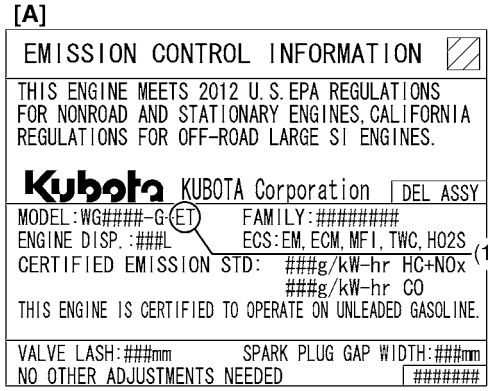
(a) (b)(c)(d) (e)
e.g. WG1605 - 1 C U 0001

(a) **WG1605**: Engine Model Name
(b) **1**: Engine Series (WG1605 series)
(c) **C**: Production Year (2012)
(d) **U**: Production Month (October)
(e) **0001**: Lot Number: (**0001 ~ 9999** or **A001 ~ Z999**)

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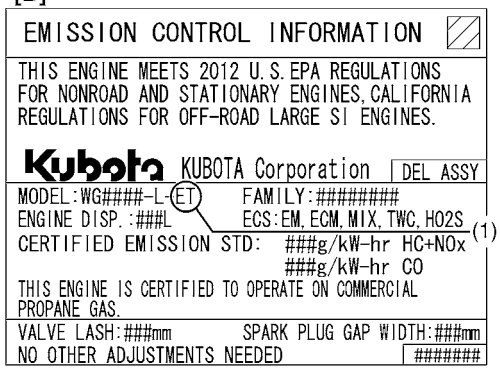
[2] E3 ENGINE

[A]



9Y1210661GES012B

[B]



9Y1210661GES013B

[C]



9Y1210661GES014B

[Example: Engine Model Name WG1605-G/L/GL-E3-XXXX]

The emission controls previously implemented in various countries to prevent air pollution will be stepped up as Non-Road Emission Standards continue to change. The timing or applicable date of the specific Non-Road Emission regulations depends on the engine displacement and output classification.

Over the past several years, KUBOTA has been supplying SI engines that comply with regulations in the respective countries affected by Non-Road Emission regulations. For KUBOTA Engines, E3 will be the designation that identifies engine models affected by the next emission phase (See the table below).

When servicing or repairing ###-E3 series engines, use only replacement parts for that specific E3 engine, designated by the appropriate E3 KUBOTA Parts List and perform all maintenance services listed in the appropriate KUBOTA Operator's Manual or in the appropriate E3 KUBOTA Workshop Manual. Use of incorrect replacement parts or replacement parts from other emission level engines (for example: E2 engines), may result in emission levels out of compliance with the original E3 design and EPA or other applicable regulations. Please refer to the emission label located on the engine head cover to identify Engine Displacement and Output classification and Emission Control Information. E3 engines are identified with "ET" at the end of the Model designation, on the US EPA label. Please note: E3 is not marked on the engine.

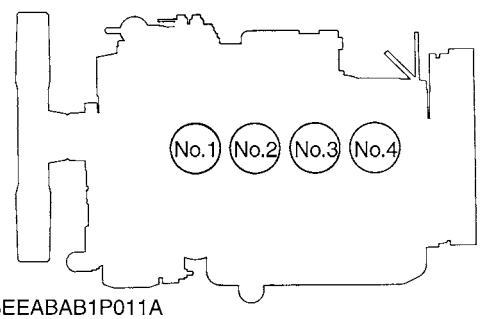
Category (1)	Displacement and Output classification	EPA Regulation
ET	Label / **Family Name: #KBXB#######**	Phase 3

(1) "E3" engines are identified with "ET" at the end of the Model designation, on the US EPA label.
"E3" designates Phase 3 / Tier 3 models, depending on engine displacement and output classification.

[A] WG1605-G-E3
[B] WG1605-L-E3
[C] WG1605-GL-E3

9Y1210661GEG0037US0

[3] CYLINDER NUMBER



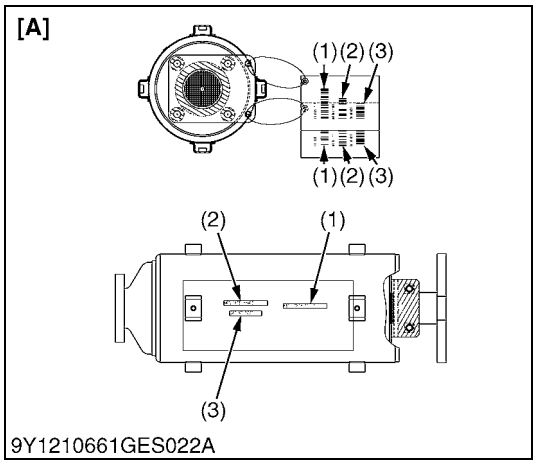
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The cylinder numbers of KUBOTA gasoline, gasoline / LPG and natural gas engine are designated as shown in the figure.

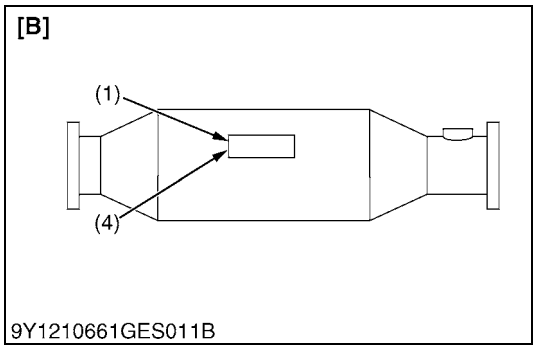
The sequence of cylinder numbers is given as No.1, No.2, No.3 and No.4 starting from the gear case side.

9Y1210661GEG0006US0

[4] CATALYTIC MUFFLER / CONVERTER



9Y1210661GES022A



9Y1210661GES011B

KUBOTA provides the catalytic muffler and converter as the catalyst parts.

The parts number, the manufacturing date and the catalyst lot number are marked on surfaces of the catalyst parts as the catalyst identification.

■ **NOTE**

- **New service catalytic muffler has the bar code tag of the catalyst identification as the figure.**

■ **IMPORTANT**

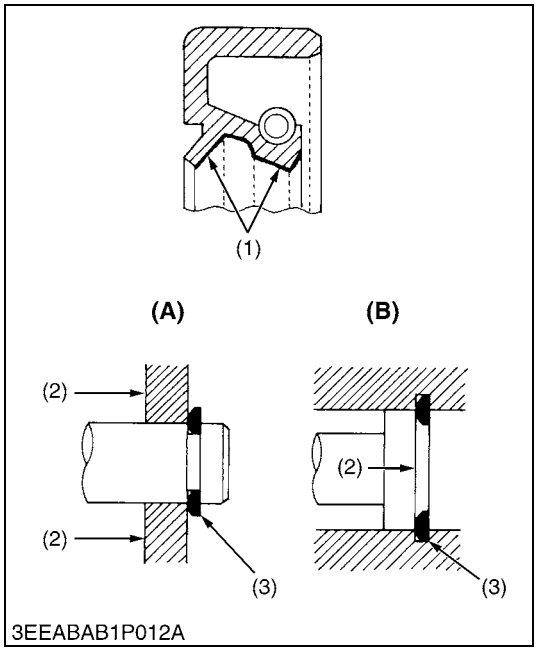
- **To trace of the catalytic muffler / converter, put down the catalyst identification and engine identification when new service catalytic muffler / converter is installed.**

(1) Part Number
(2) Manufacturing Date 5 digits
(3) Catalyst Lot Number 4 digits
(4) Date / Serial Number

[A] CATALYTIC MUFFLER
[B] CATALYTIC CONVERTER

9Y1210661GEG0038US0

2. GENERAL PRECAUTIONS



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- During disassembly, carefully arrange removed parts in a clean area to prevent confusion later. Screws, bolts and nuts should be replaced in their original position to prevent reassembly errors.
- When special tools are required, use KUBOTA genuine special tools. Special tools which are not frequently used should be made according to the drawings provided.
- Before disassembling or servicing live wires, make sure to always disconnect the grounding cable from the battery first.
- Remove oil and dirt from parts before measuring.
- Use only KUBOTA genuine parts for parts replacement to keep engine performance and to ensure safety.
- Gaskets and O-rings must be replaced during reassembly. Apply grease to new O-rings or oil seals before assembling.
- When reassembling external or internal snap rings, position them so that sharp edge faces against the direction from which a force is applied.
- Be sure to perform run-in the serviced or reassemble engine. Do not try to give heavy load at once, or serious damage may result to the engine.

(1) Grease
(2) Force
(3) Place the Sharp Edge the Direction of Force
(A) External Snap Ring
(B) Internal Snap Ring

9Y1210318GEG0007US0

3. MAINTENANCE CHECK LIST

To keep long-lasting and safe engine performance, make it a rule to do regular inspections by following the table below. (The schedule applies to an engine in use under normal conditions.)

[WG1605-G-E3,WG1605-L-E3,WG1605-GL-E3]

	Item	Service Interval							
		Every 8 hrs (Daily)	Every 50 hrs (Weekly)	Every 100 hrs	Every 200 hrs	Every 1000 hrs	Every 2000 hrs	Every 1 year	Every 2 years
	Checking engine oil level	☆							
	Checking and fill coolant	☆							
	Checking air cleaner element	if necessary							
	Cleaning air cleaner element	if necessary		☆					
	Checking LPG tank setting condition	if necessary							
	Checking LPG fuel connector	☆							
	Changing engine oil		★		☆				
	Replacing oil filter cartridge		★		☆				
	Checking gasoline fuel hose and clamp bands		☆						
	Checking LPG fuel hose and clamp bands		☆						
	Cleaning spark plug			☆					
	Checking fuel filter			☆					
	Check fan belt tension and damage			☆					
	Checking battery electrolyte level			☆					
	Replacing fuel filter			if necessary					
	Checking LPG tank setting condition				☆				
	Checking radiator hoses and clamp bands				☆				
	Checking PCV valve					☆			
	Checking coolant hose of LPG vaporizer					☆			
	Checking LPG Lock off valve					☆			
	Checking valve clearance					☆			
	Replacing spark plug						☆		
*	Replacing air cleaner element							☆	
	Replacing gasoline fuel hose, clamp bands and fuel filter							☆	
	Cleaning fuel tank inside (for gasoline fuel)							☆	
	Cleaning water jacket and radiator interior							☆	
	Replacing intake air line								☆
	Replacing breather hose								☆
	Replacing LPG fuel hose and clamp bands								☆
	Replacing coolant hose of LPG vaporizer								☆
**	Checking LPG vaporizer								☆
	Replacing radiator hoses and clamp bands								☆
	Changing radiator coolant								☆
	Replacing battery								☆

★ Change engine oil and replace oil filter cartridge after the first 50 hours of operation.

*: Change more often when operating under dusty conditions.

**: If you do not have the proper tools and / or are not mechanically proficient, contact your local KUBOTA dealer.

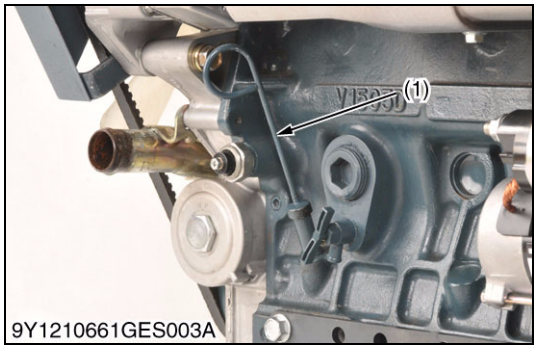
CAUTION

- **When changing or inspecting, be sure to level and stop the engine.**

9Y1210661GEG0008US0

4. CHECK AND MAINTENANCE

[1] DAILY CHECK POINTS



Checking Engine Oil Level

1. Level the engine.
2. To check the oil level, draw out the dipstick (1), wipe it clean, reinsert it, and draw it out again.
   Check to see that the oil level lies between the two notches.
3. If the level is too low, add new oil to the specified level.

■ **IMPORTANT**

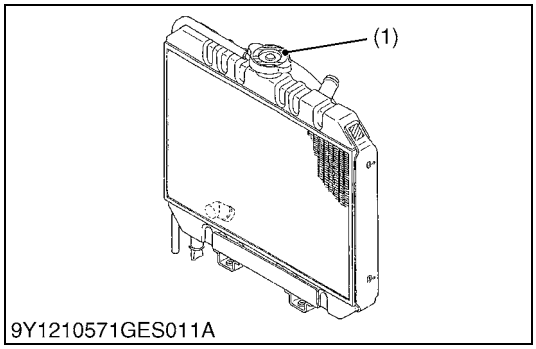
- **When using an oil of different maker or viscosity from the previous one, drain old oil. Never mix two different types of oil.**
- **Use the proper SAE Engine oil according to ambient temperatures.**

■ **NOTE**

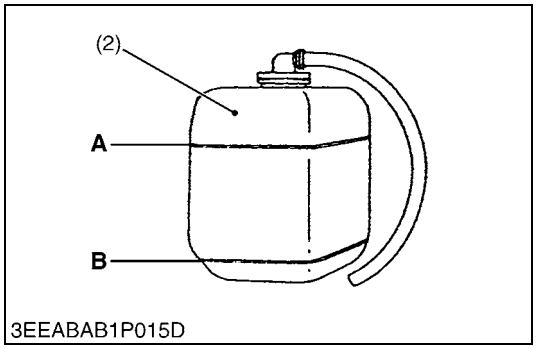
- **Be sure to inspect the engine, locating it on a horizontal place. If placed on gradients, accurately, oil quantity may not be measured.**
- **Be sure to keep the oil level between upper and lower limits of the dipstick. Too much oil may cause a drop in output or excessive blow-by gas. On the closed breather type engine in which mist is sucked through port, too much oil may caused oil hammer. While too little oil, may seize the engine's rotating and sliding parts.**

(1) Dipstick

9Y1210661GEG0009US0



9Y1210571GES011A



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Checking and Fill Coolant

1. Without recovery tank:
   Remove the radiator cap (1) and check to see that the coolant level is just below the port.
   With recovery tank (2):
   Check to see that the coolant level lies between **FULL"A"** and **LOW "B"**.
2. If coolant level is too low, check the reason for decreasing coolant.
   (Case 1)
   If coolant is decreasing by evaporation, fill only fresh, soft water.
   (Case 2)
   If coolant is decreasing by leak, fill coolant of the same manufacture and type in the specified mixture ratio (fresh, soft water and L.L.C.). If the coolant brand cannot be identified, drain out all of the remaining coolant and refill with a totally new brand of coolant mix.

CAUTION

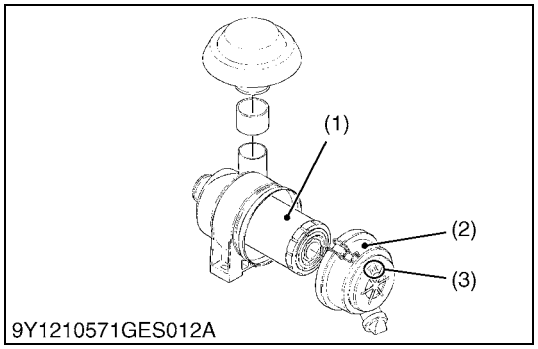
- **Do not remove the radiator cap until coolant temperature is below its boiling point. Then loosen the cap slightly to relieve any excess pressure before removing the cap completely.**

IMPORTANT

- **During filling the coolant, air must be vented from the engine coolant passages. The air vents by jiggling the radiator upper and lower hoses.**
- **Be sure to close the radiator cap securely. If the cap is loose or improperly closed, coolant may leak out and the engine could overheat.**
- **Do not use an antifreeze and scale inhibitor at the same time.**
- **Never mix the different type or brand of L.L.C..**

(1) Radiator Cap
(2) Recovery Tank
A: FULL
B: LOW

9Y1210571GEG0037US0



9Y1210571GES012A


3EEAEAB1P006A

Checking Air Cleaner Element (If necessary)

1. Remove the dust cup in the air cleaner.
2. Check the dust in the dust cup and the element.

(When reassembling)

- Install the air cleaner dust cup with **"TOP"** indicated on the rear of the cup.

(1) Element
(2) Dust Cap
(3) **"TOP"** Mark

9Y1210571GEG0038US0

Cleaning Air Cleaner Element (If necessary)

1. Remove the air cleaner element.
2. Use clean dry compressed air on the inside of the element.
   Pressure of compressed air must be under 205 kPa (2.1 kgf/cm^2, 30 psi).
   Keep reasonable distance between the nozzle and the filter

■ **NOTE**

- **The air cleaner uses a dry element. Never apply oil to it.**
- **Do not run the engine with filter element removed.**
- **Change the element once a year or every 6th cleaning**

9Y1210661GEG0050US0

Checking LPG Tank Setting Condition (If necessary) (WG1605-L-E3, WG1605-GL-E3)

1. Check the setting condition of LPG fuel tank.

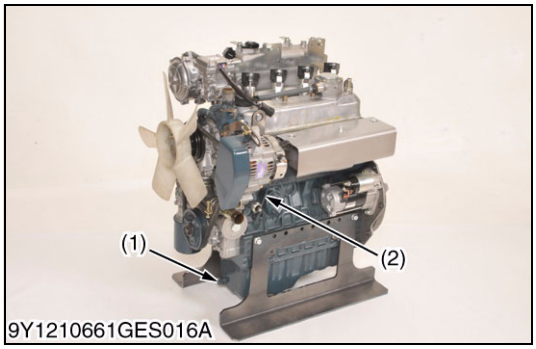
9Y1210661GEG0010US0

Checking LPG Fuel Connector (WG1605-L-E3, WG1605-GL-E3)

1. Check the connector of LPG line (hoses and clamps).

9Y1210661GEG0011US0

[2] CHECK POINTS OF INTIAL 50 HOURS



Changing Engine Oil

CAUTION

- **Be sure to stop engine before changing engine oil.**

1. Start and warm up the engine for approx. 5 minutes.
2. Place an oil pan underneath the engine.
3. To drain the used oil, remove the drain plug (1) at the bottom of the engine and drain the oil completely.
4. Screw the drain plug (1).
5. Fill new oil up to upper line on the dipstick (2).

IMPORTANT

- **When using an oil of different maker or viscosity from the previous one, remove all of the old oil.**
- **Never mix two different types of oil.**
- **Engine oil should have properties of API classification better than SH.**
- **Use the proper SAE Engine Oil according to ambient temperature.**

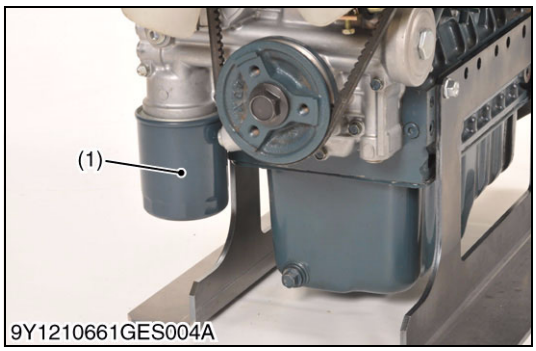
Above 25 °C (77 °F)	SAE30 or SAE10W-30 or SAE15W-40
0 °C to 25 °C (32 °F to 77 °F)	SAE20 or SAE10W-30
0 °C to −20 °C (32 °F to −4 °F)	SAE10W or SAE10W-30

Engine oil capacity	6.0 L 1.6 U.S.gals

Tightening torque	Drain plug	32.4 to 37.3 N·m 3.31 to 3.80 kgf·m 23.9 to 27.5 lbf·ft

(1) Drain Plug (2) Dipstick

9Y1210661GEG0012US0



Replacing Oil Filter Cartridge

CAUTION

- **Be sure to stop the engine before changing filter cartridge.**

1. Remove the oil filter cartridge (1) with the filter wrench.
2. Apply a slight coat of oil onto the new cartridge gasket.
3. To install the new cartridge, screw it in by hand. Over tightening may cause deformation of rubber gasket.
4. After the new cartridge has been replaced, the engine oil normally decrease a little. Thus see that the engine oil does not leak through the seal and be sure to read the oil level on the dipstick. Then, fill the engine oil up to the specified level.

IMPORTANT

- **To prevent serious damage to the engine, replacement element must be highly efficient. Use only a KUBOTA genuine filter or its equivalent.**

(1) Engine Oil Filter Cartridge

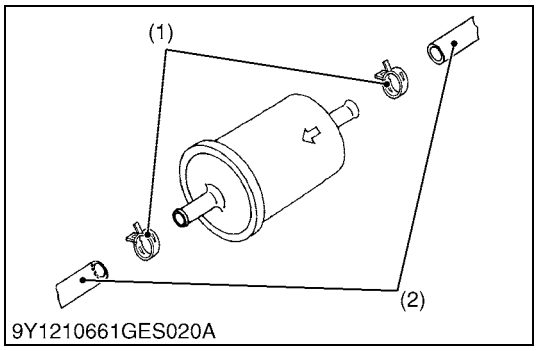
9Y1210661GEG0013US0

[3] CHECK POINTS OF EVERY 50 HOURS

CAUTION

- **Stop the engine when trying the check and replace prescribed below.**
- **Make sure to check the fuel line periodically. The fuel line is subject to wear and aging, fuel may leak out onto the running engine, causing a fire.**

9Y1210318GEG0020US0



9Y1210661GES020A

Checking Gasoline Fuel Hose and Clamp Bands

Check the fuel hoses every 50 hours of operation.

1. Use good engineering judgment to ensure that all fuel-line fittings will remain securely connected to prevent fuel leakage throughout the useful life of the equipment.
   Replace the fuel hose together with the clamp every year.
2. If the fuel hose and clamp are found to be damaged or deteriorate earlier than year, then replace or remedy.
3. After the fuel hose and the clamp have been replaced, make sure that there is no fuel leakage.

(1) Clamp (2) Fuel Hose

9Y1210661GEG0043US0

Checking LPG Fuel Hose and Clamp Bands (WG1605-G-E3, WG1605-L-E3, WG1605-GL-E3)

■ **IMPORTANT**

- **Never test for gas leaks with a FLAME.**

■ **NOTE**

- **Check for fuel leakage with soapy water or gas-detector, if leakage is found, correct leakage or replace the hose.**

9Y1210661GEG0014US0

[4] CHECK POINTS OF EVERY 100 HOURS

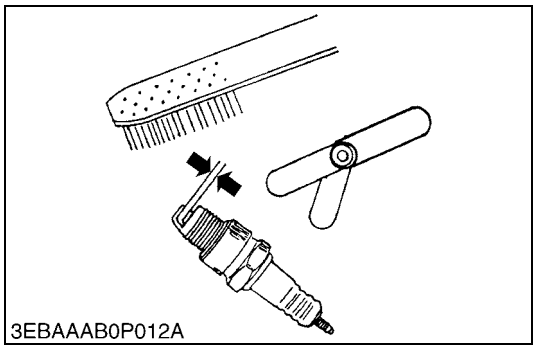

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Cleaning Air Cleaner Element

1. Remove the air cleaner element.
2. Use clean dry compressed air on the inside of the element. Pressure of compressed air must be under 205 kPa (2.1 kgf/cm^2, 30 psi).
   Keep reasonable distance between the nozzle and the filter.

■ **NOTE**
- **The air cleaner uses a dry element. Never apply oil to it.**
- **Do not run the engine with filter element removed.**
- **Change the element once a year or every 6th cleaning.**

9Y1210661GEG0042US0


3EBAAAB0P012A

Cleaning Spark Plug

1. Remove the spark plug, and remove carbon from the electrode with a wire brush or other tools.
2. Measure the spark plug gap with a feeler gauge, and adjust or replace the spark plug if the measured gap differs from the factory specification.
3. Replace the spark plug if the electrode or the insulator is deformed or cracked.
4. Tighten the spark plug with a plug wrench.

■ **IMPORTANT**

(When reassembling)
- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Fix the ignition coil by screw / nut.**

Spark plug gap	Factory specification	0.70 to 0.80 mm 0.028 to 0.031 in.

Spark plug	NGK IFR6F8DN

Tightening torque	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.6 lbf·ft
	Ignition coil mounting screw / nut	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

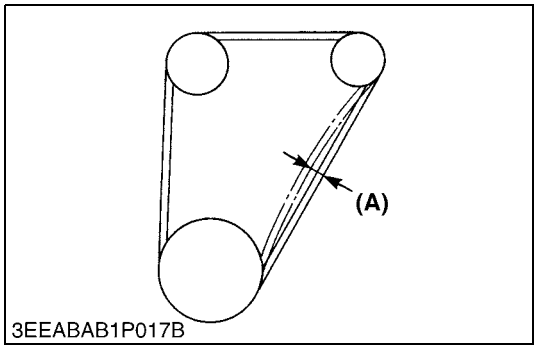
9Y1210661GEG0044US0

Checking Fuel Filter

1. Check the fuel filter.
2. If the fuel filter is dirty, clean it or replace it.

⚠ **CAUTION**
- **Stop the engine when trying to check and clean the fuel filter.**
- **Gasoline fuel is extremely flammable, so avoid fires.**

9Y1210318GEG0028US0



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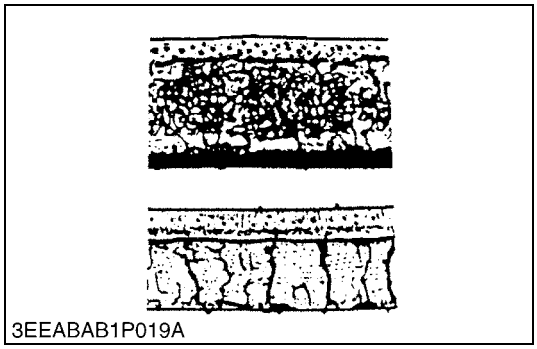
Fan Belt Tension

1. Measure the deflection **(A)**, depressing the belt halfway between the fan drive pulley and alternator pulley at specified force 98 N (10 kgf, 22 lbf).
2. If the measurement is not within the factory specifications, loosen the alternator mounting screws and relocate the alternator to adjust.

Deflection **(A)**	Factory specification	7.0 to 9.0 mm 0.28 to 0.35 in.

(A) Deflection

9Y1210318GEG0001US0

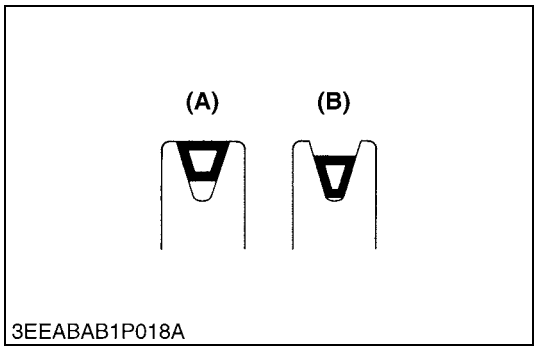

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Fan Belt Damage and Wear

1. Check the fan belt for damage.
2. If the fan belt is damaged, replace it.
3. Check if the fan belt is worn and sunk in the pulley groove.
4. If the fan belt is nearly worn out and deeply sunk in the pulley groove, replace it.

(A) Good **(B) Bad**

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Checking Battery Electrolyte Level

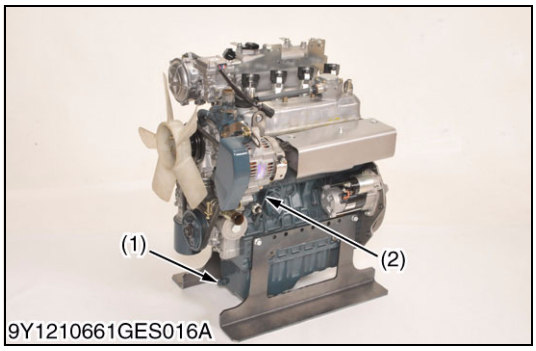
1. Check the battery electrolyte level.
2. If the level is below than lower level line, add the distilled water to pour level of each cell.

CAUTION

- **Never remove the vent plugs while the engine is running.**
- **Keep electrolyte away from eyes, hands and clothes. If you are spattered with it, wash it away completely with water immediately and get medical attention.**
- **Wear eye protection and rubber gloves when working around battery.**

9Y1210318GEG0026US0

[5] CHECK POINTS OF EVERY 200 HOURS



Changing Engine Oil

CAUTION

- **Be sure to stop engine before changing engine oil.**

1. Start and warm up the engine for approx. 5 minutes.
2. Place an oil pan underneath the engine.
3. To drain the used oil, remove the drain plug (1) at the bottom of the engine and drain the oil completely.
4. Screw the drain plug (1).
5. Fill new oil up to upper line on the dipstick (2).

IMPORTANT

- **When using an oil of different maker or viscosity from the previous one, remove all of the old oil.**
- **Never mix two different types of oil.**
- **Engine oil should have properties of API classification better than SH.**
- **Use the proper SAE Engine Oil according to ambient temperature.**

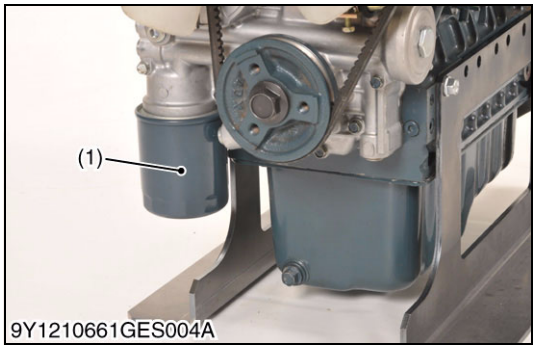
Above 25 °C (77 °F)	SAE30 or SAE10W-30 or SAE15W-40
0 °C to 25 °C (32 °F to 77 °F)	SAE20 or SAE10W-30
0 °C to −20 °C (32 °F to −4 °F)	SAE10W or SAE10W-30

Engine oil capacity	6.0 L 1.6 U.S.gals

Tightening torque	Drain plug	32.4 to 37.3 N·m 3.31 to 3.80 kgf·m 23.9 to 27.5 lbf·ft

(1) Drain Plug (2) Dipstick

9Y1210661GEG0012US0



Replacing Oil Filter Cartridge

CAUTION

- **Be sure to stop the engine before changing filter cartridge.**

1. Remove the oil filter cartridge (1) with the filter wrench.
2. Apply a slight coat of oil onto the new cartridge gasket.
3. To install the new cartridge, screw it in by hand. Over tightening may cause deformation of rubber gasket.
4. After the new cartridge has been replaced, the engine oil normally decrease a little. Thus see that the engine oil does not leak through the seal and be sure to read the oil level on the dipstick. Then, fill the engine oil up to the specified level.

IMPORTANT

- **To prevent serious damage to the engine, replacement element must be highly efficient. Use only a KUBOTA genuine filter or its equivalent.**

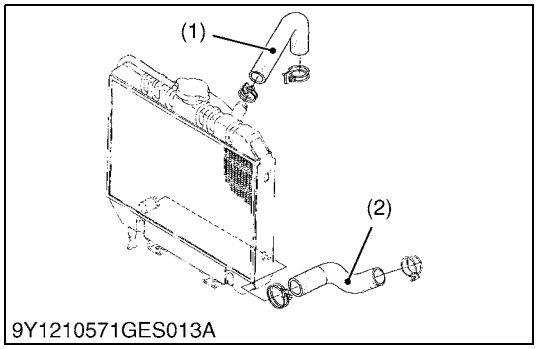
(1) Engine Oil Filter Cartridge

9Y1210661GEG0013US0

Checking LPG Tank Setting Condition (WG1605-L-E3,WG1605-GL-E3)

1. Check the setting condition of LPG fuel tank.

9Y1210661GEG0016US0



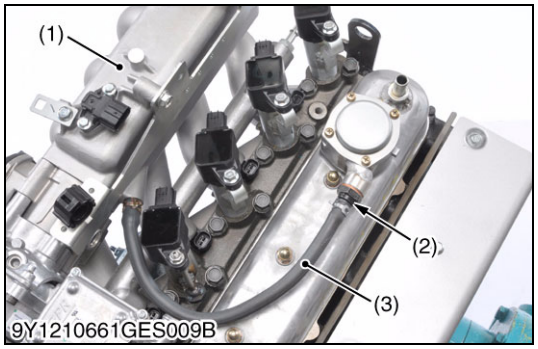
Checking Radiator Hoses and Clamp Bands

1. Check to see if the radiator hoses are properly fixed every 200 hours of operation or every six months, whichever comes first.
2. If the clamp is loose, apply oil to the threads and retighten it securely.
3. The coolant hose is made of rubber and tends to age. It must be replaced every two years. Also replace the clamp and tighten it securely.

(1) Upper Hose (2) Lower Hose

9Y1210571GEG0039US0

[6] CHECK POINTS OF EVERY 1000 HOURS

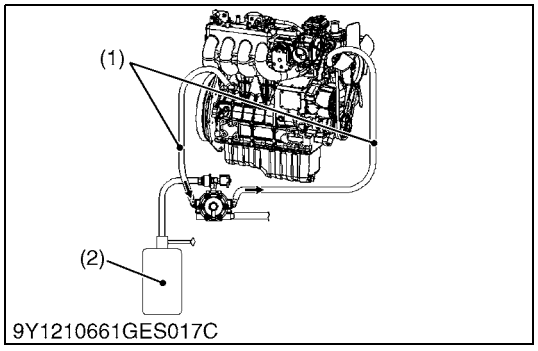


Checking PCV Valve

1. Disconnect the breather hose (3) from the intake manifold (1).
2. Blow into the breather hose (3).
3. Stop to blow.
4. Make sure that a slight operation sound is heard from the PCV valve.
5. If there is no operation sound, replace the PCV valve (2).
6. Connect the breather hose (3) to the intake manifold (1)

(1) Intake Manifold (3) Breather Hose
(2) PCV Valve

9Y1210661GEG0039US0

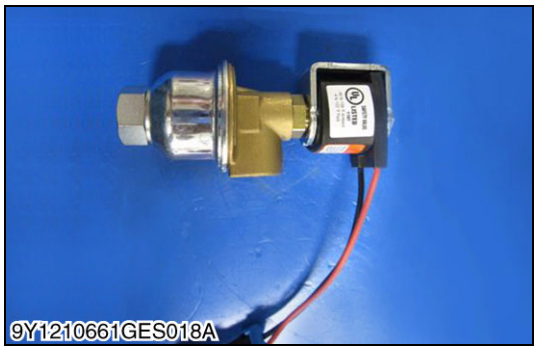


Checking Coolant Hose of LPG Vaporizer

1. Check the coolant hoses (1) for damage.
2. If the coolant hose is damaged, replace it.

(1) Coolant Hose (2) LPG Tank

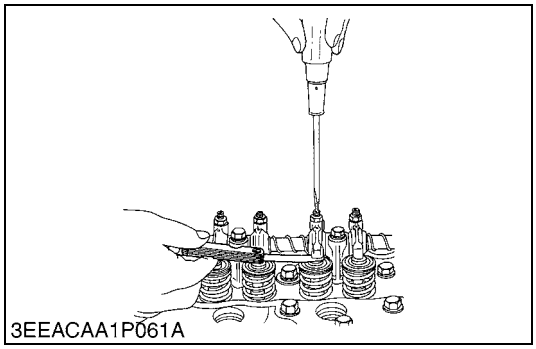
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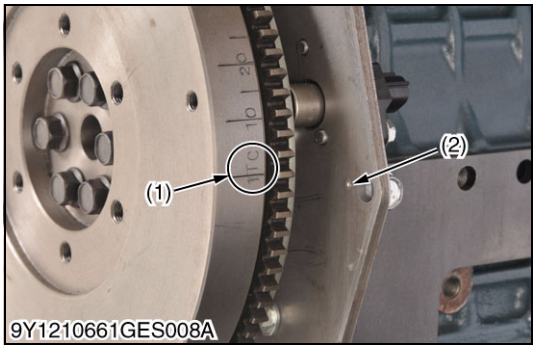


Checking LPG Lock Off Valve

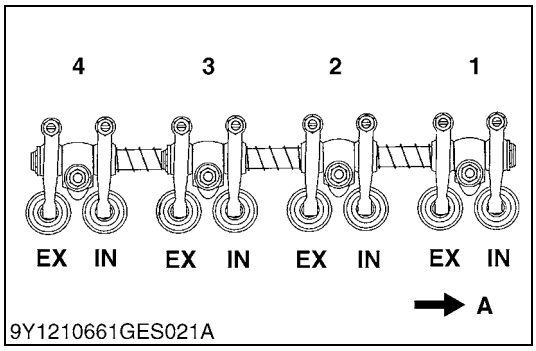
1. Start the engine.
2. Make sure that an operation sound of solenoid is heard from the LPG lock off valve.
3. Make sure that there is no fuel leakage from the LPG lock off valve.
4. If there is no operation sound or fuel leakage, replace the LPG lock off valve.

9Y1210661GEG0040US0


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9Y1210661GES008A



9Y1210661GES021A

Checking Valve Clearance

■ **IMPORTANT**

- **The valve clearance must be checked and adjusted when engine is cold.**

1. Remove the cylinder head cover.
2. Align the **"1TC"** mark (1) on the flywheel and alignment mark (2) on the rear end plate so that the No. 1 piston comes to the compression top dead center.
3. Check the following valve clearance marked with "☆" using a feeler gauge.
4. If the clearance is not within the factory specifications, adjust with the adjusting screw.
5. Then turn the flywheel 6.28 rad (360 °), and align the **"1TC"** mark (1) on the flywheel and alignment mark (2) on the rear end plate so that the No. 1 piston comes to the overlap position.
6. Check the following valve clearance marked with "☆" using a feeler gauge.
7. If the clearance is not within the factory specifications, adjust with the adjusting screw.

Adjustable Cylinder Location of Piston		Intake valve	Exhaust valve
When No. 1 piston is at compression top dead center	1st	☆	☆
	2nd	☆	
	3rd		☆
	4th		
When No. 1 piston is at overlap position	1st		
	2nd		☆
	3rd	☆	
	4th	☆	☆

Intake and exhaust valve clearance (cold)	Factory specification	0.145 to 0.185 mm 0.00571 to 0.00728 in.

■ **NOTE**

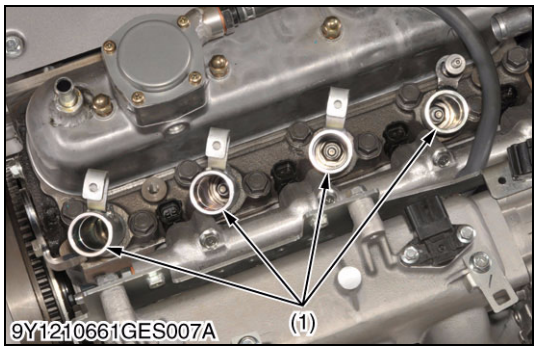
- **The sequence of cylinder numbers is given as No. 1, No. 2, No. 3 and No. 4 starting from the gear case side.**
- **After adjusting the valve clearance, secure the adjusting screw with the lock nut.**

(1) **"1TC"** Mark
(2) Alignment Mark

A: Gear Case Side

9Y1210661GEG0045US0

[7] CHECK POINTS OF EVERY 2000 HOURS



Replacing Spark Plug

1. Disconnect the ignition coil.
2. Remove the spark plug.
3. Replace the new spark plug.
4. Tighten the spark plug with a plug wrench.

■ IMPORTANT

(When reassembling)

- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Fix the ignition coil by screw / nut.**

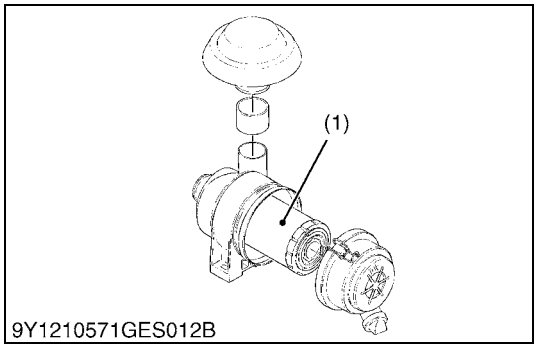
Spark plug	NGK IFR6F8DN

Tightening torque	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.6 lbf·ft
	Ignition coil mounting screw / nut	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

(1) Spark Plug

9Y1210661GEG0046US0

[8] CHECK POINTS OF EVERY 1 YEAR

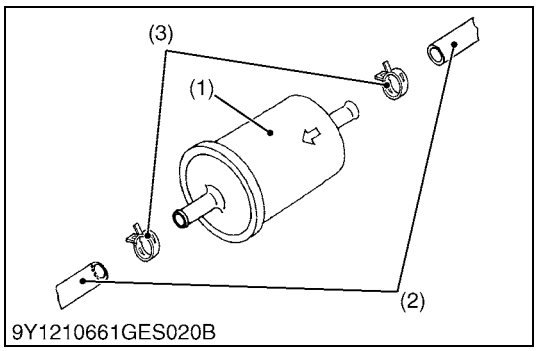


Replacing Air Cleaner Element

1. Remove the dust cup from the air cleaner.
2. After cleaning the dust cup, remove the air cleaner element.
3. Replace the new air cleaner element.

(1) Air Cleaner Element

9Y1210571GEG0040US0



Replacing Gasoline Fuel Hose, Clamp Bands and Fuel Filter

1. Replace the fuel filter (1) with a new one.
2. Replace the hose (2) and clamp (3).

⚠ CAUTION

- **In order to reduce the fuel pressure, do not remove the fuel hose at least 3 minutes after stopping the engine.**
- **Remove the hose after covering the hose with a waste to prevent scatter of fuel.**

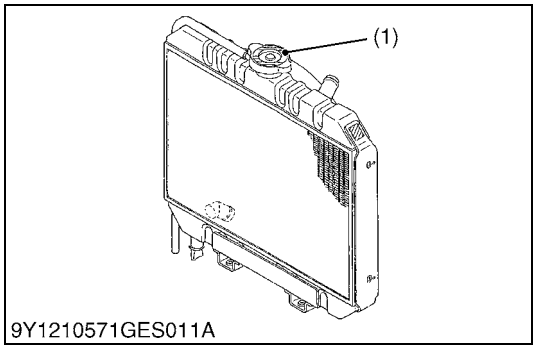
(1) Fuel Filter
(2) Fuel Hose
(3) Clamp

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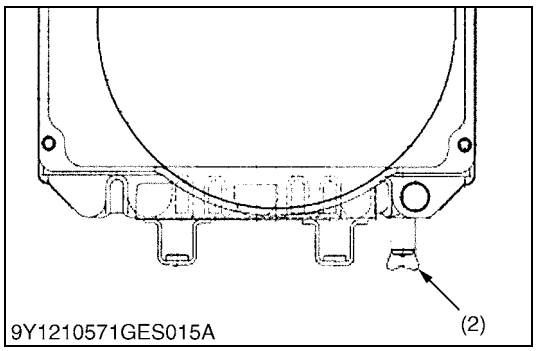
Cleaning Fuel Tank Inside (for Gasoline Fuel)

1. Following the unit / machine's operators manual, drain the gasoline fuel in the fuel tank.
2. Clean the fuel tank inside.

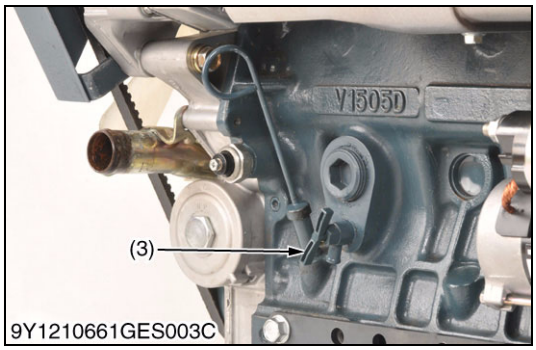
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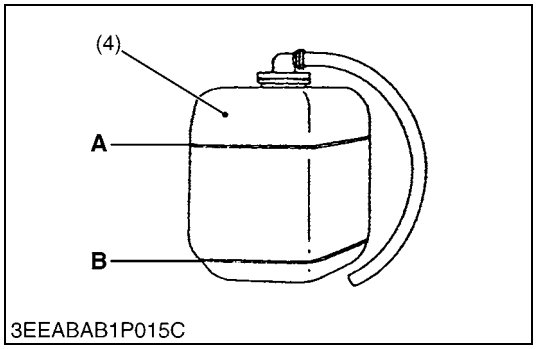
9Y1210571GES011A



9Y1210571GES015A



9Y1210661GES003C



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Cleaning Water Jacket and Radiator Interior

CAUTION

- **Do not remove the radiator cap when the engine is hot. Then loosen cap slightly to the stop to relieve any excess pressure before removing cap completely.**

1. Stop the engine and let cool down.
2. To drain the coolant, open the radiator drain plug (2) and remove the radiator cap (1). Then radiator cap (1) must be removed to completely drain the coolant. And open the drain valve (3) of engine body.
3. After all coolant is drained, close the drain plug.
4. Fill with clean water and cooling system cleaner.
5. Follow directions of the cleaner instruction.
6. After flushing, fill with clean water and anti-freeze until the coolant level is just below the port. Install the radiator cap (1) securely.
7. Fill with coolant up to **FULL "A"** mark on the recovery tank (4).
8. Start and operate the engine for few minutes.
9. Stop the engine and let cool. Check coolant level of recovery tank (4) and add coolant if necessary.

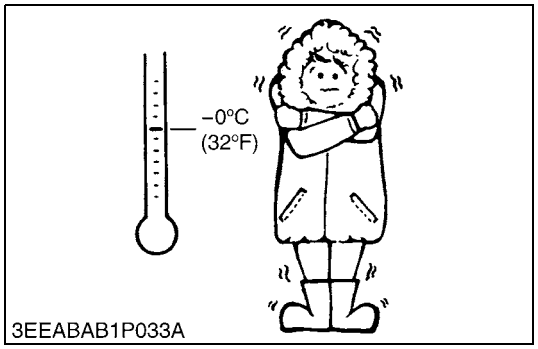
IMPORTANT

- **Do not start engine without coolant.**
- **Use clean, fresh, soft water and anti-freeze to fill the radiator and recovery tank.**
- **When the anti-freeze is mixed with fresh, soft water, the anti-freeze mixing ratio must be less than 50 %.**
- **Securely tighten radiator cap. If the cap is loose or improperly fitted, water may leak out and the engine could overheat.**

(1) Radiator Cap
(2) Drain Plug
(3) Drain Valve
(4) Recovery Tank

A: FULL
B: LOW

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Anti-Freeze

- There are two types of anti-freeze available: use the permanent type (PT) for this engine.
- Before adding anti-freeze for the first time, clean the radiator interior by pouring fresh, soft water and draining it a few times.
- The procedure for mixing water and anti-freeze differs according to the make of the anti-freeze and the ambient temperature. Basically, it should be referred to SAE J1034 standard, more specifically also to SAE J814c.
- Mix the anti-freeze with fresh, soft water, and then fill into the radiator.

■ **IMPORTANT**

- **When the anti-freeze is mixed with fresh, soft water, the anti-freeze mixing ratio must be less than 50 %.**

Vol % anti-freeze	Freezing point		Boiling point*	
	°C	°F	°C	°F
40	−24	−11	106	223
50	−37	−35	108	226

* At 1.01 × 100000 Pa (760 mmHg) pressure (atmospheric). A higher boiling point is obtained by using a radiator pressure cap which permits the development of pressure within the cooling system.

■ **NOTE**

- **The above data represents industrial standards that necessitate a minimum glycol content in the concentrated anti-freeze.**
- **When the coolant level drops due to evaporation, add fresh, soft water only to keep the anti-freeze mixing ratio less than 50 %. In case of leakage, add anti-freeze and fresh, soft water in the specified mixing ratio.**
- **Anti-freeze absorbs moisture. Keep unused anti-freeze in a tightly sealed container.**
- **Do not use radiator cleaning agents when anti-freeze has been added to the coolant.**
  (Anti-freeze contains an anti-corrosive agent, which will react with the radiator cleaning agent forming sludge which will affect the engine parts.)

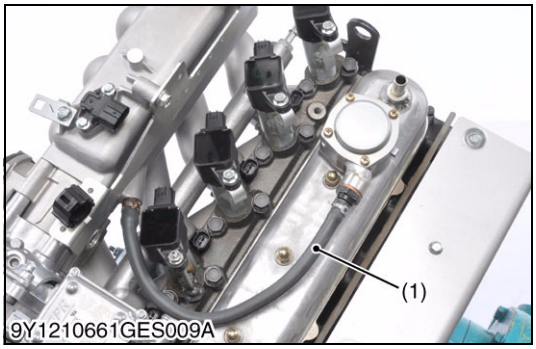
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[9] CHECK POINTS OF EVERY 2 YEARS

Replacing Intake Air Line

1. Replace the intake hose and the clamps between the air cleaner and the electronic throttle body or gas mixer.

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Replacing Breather Hose

1. Replace the breather hose and the clamps between the head cover and the intake manifold.

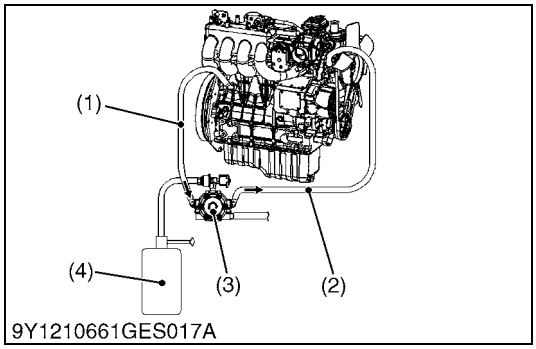
(1) Breather Hose

9Y1210661GEG0048US0

Replacing LPG Fuel Hose and Clamp Bands (WG1605-L-E3, WG1605-GL-E3)

1. Replace the fuel hose and the clamps.

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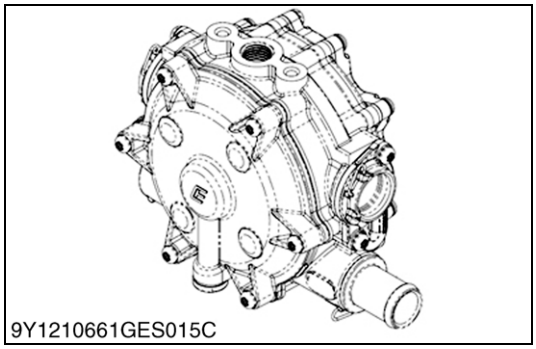


Replacing Coolant Hose of LPG Vaporizer (WG1605-L-E3, WG1605-GL-E3)

1. Connect the new coolant hose (1) and (2) to the vaporizer (3).
2. Fill the coolant to radiator, and bleed the air from the vaporizer (3).

(1) Coolant Hose
(2) Coolant Hose
(3) Vaporizer
(4) LPG Tank

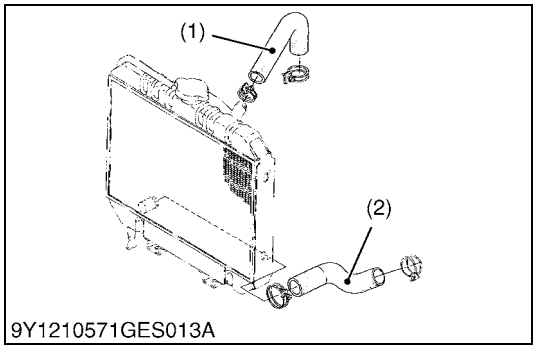
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Checking LPG Vaporizer (WG1605-L-E3, WG1605-GL-E3)

1. Make sure that any fuel leaks at the inlet and outlet fittings.
2. Make sure that the mounting bracket to ensure the vaporizer is securely mounted.

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Replacing Radiator Hoses and Clamp Bands

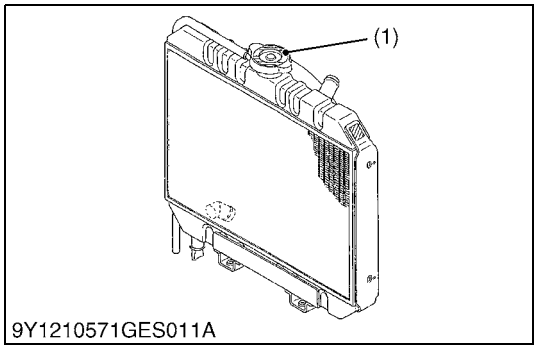
CAUTION

- **Do not remove the radiator cap when the engine is hot. Then loosen cap slightly to the stop to relieve any excess pressure before removing cap completely.**

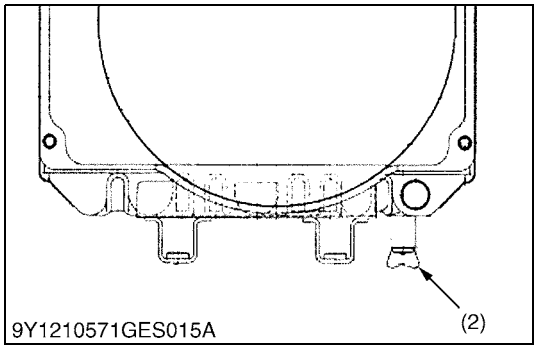
1. Drain the coolant.
2. Loosen the clamp bands.
3. Remove the upper hose (1) and lower hose (2).
4. Replace new upper / lower hose (1), (2) and clamp bands.
5. Tighten the clamp bands.
6. Fill with clean water and anti-freeze until the coolant level is just below the port. Install the radiator cap securely.

(1) Upper Hose
(2) Lower Hose

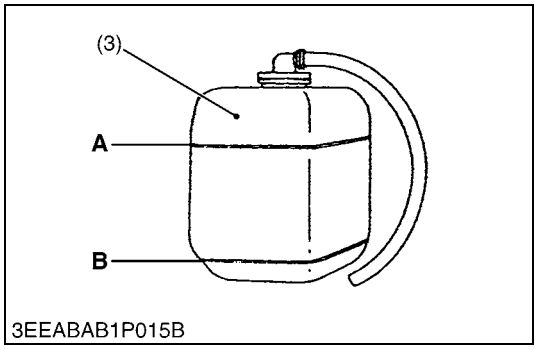
9Y1210571GEG0042US0



9Y1210571GES011A



9Y1210571GES015A



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Changing Radiator Coolant (L.L.C.)

CAUTION

- **Do not remove the radiator cap when the engine is hot. Then loosen cap slightly to the stop to relieve any excess pressure before removing cap completely.**

1. Stop the engine and let cool down.
2. To drain the coolant, open the radiator drain plug (2) and remove the radiator cap (1). Then radiator (1) must be removed to completely drain the coolant. And open the drain valve of engine body.
3. After all coolant is drained, close the drain plug (2).
4. Fill with clean water and cooling system cleaner.
5. Follow directions of the cleaner instruction.
6. After flushing, fill with clean water and anti-freeze until the coolant level is just below the port. Install the radiator cap (1) securely.
7. Fill with coolant up to **FULL"A"** mark on the recovery tank (3).
8. Start and operate the engine for few minutes.
9. Stop the engine and let cool. Check coolant level of radiator and recovery tank (3) and add coolant if necessary.

IMPORTANT

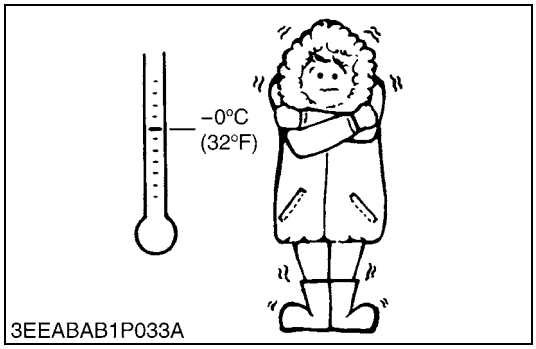
- **Do not start engine without coolant.**
- **Use clean, fresh, soft water and anti-freeze to fill the radiator and recovery tank.**
- **When the anti-freeze is mixed with fresh, soft water, the anti-freeze mixing ratio must be less than 50 %.**
- **Securely tighten radiator cap. If the cap is loose or improperly fitted, water may leak out and the engine could overheat.**

(1) Radiator Cap
(2) Drain Plug
(3) Recovery Tank

A: Full
B: Low

(To be continued)

(Continued)



(Anti-freeze)

- There are two types of anti-freeze available; use the permanent type (PT) for this engine.
- Before adding anti-freeze for the first time, clean the radiator interior by pouring fresh, soft water and drain it a few times.
- The procedure for mixing water and anti-freeze differs according to the make of the anti-freeze and the ambient temperature. Basically, it should be referred to SAE J1034 standard, more specifically also to SAE J814c.
- Mix the anti-freeze with fresh, soft water, and then fill into the radiator.

■ **IMPORTANT**

- **When the anti-freeze is mixed with fresh, soft water, and anti-freeze mixing ratio must be less than 50 %.**

Vol % anti-freeze	Freezing point		Boiling point*	
	°C	°F	°C	°F
40	−24	−11	106	223
50	−37	−35	108	226

* At 1.01 x 100000 Pa (760 mmHg) pressure (atmospheric). A higher boiling point is obtained by using a radiator pressure cap which permits the development of pressure within the cooling system.

■ **NOTE**

- **The above data represents industrial standards that necessitate a minimum glycol content in the concentrated anti-freeze.**
- **When the coolant level drops due to evaporation, add fresh, soft water only to keep the anti-freeze mixing ratio less than 50 %. In case of leakage, add anti-freeze and fresh, soft water in the specified mixing ratio.**
- **Anti-freeze absorbs moisture. Keep unused anti-freeze in a tightly sealed container.**
- **Do not use radiator cleaning agents when anti-freeze has been added to the coolant.**
  (Anti-freeze contains an anti-corrosive agent, which will react with the radiator cleaning agent forming sludge which will affect the engine parts.)

9Y1210571GEG0043US0

Replacing Battery

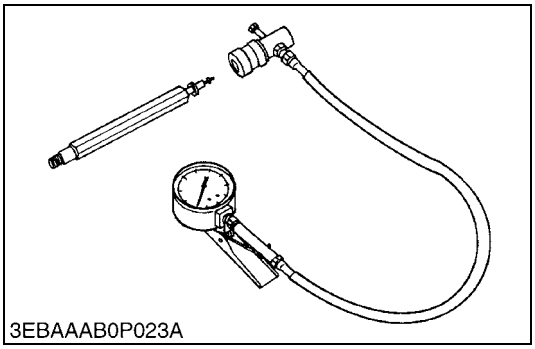
CAUTION

- **When the battery is being activated, hydrogen and oxygen gases in the battery are extremely explosive. Keep open sparks and flames away from the battery at all times, especially when charging the battery.**
- **When charging battery, remove battery vent plugs.**
- **When disconnecting the cable from the battery, start with the negative terminal first. When connecting the cable to the battery, start with the positive terminal first.**
- **Never check battery charge by placing a metal object across the posts.**

1. Disconnect the negative terminal and positive terminal.
2. Remove the battery holder.
3. Remove the used battery.
4. Replace the new battery.
5. Tighten the battery holder.
6. Connect the positive terminal.
7. Connect the negative terminal.

9Y1210318GEG0058US0

5. SPECIAL TOOLS

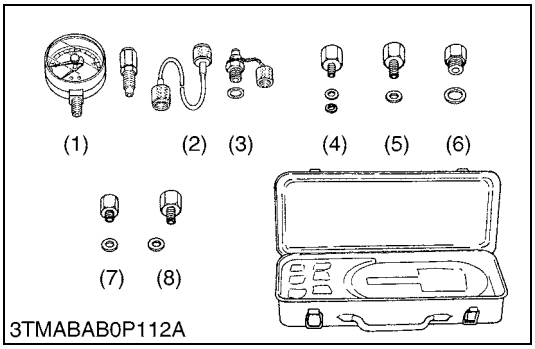

3EBAAAB0P023A

Compression Tester

Code No.
- 07909-30251

Application
- Use to measure gasoline engine compression and diagnose the engine for a major overhaul.

WSM000001GEG0088US0



3TMABAB0P112A

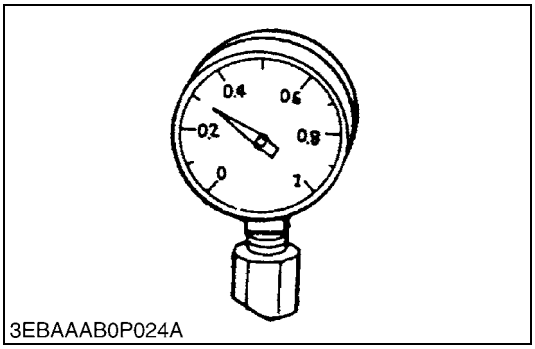
Oil Pressure Tester

Code No.
- 07916-32032

Application
- Use to measure lubricating oil pressure.

(1) Gauge
(2) Cable
(3) Threaded Joint
(4) Adaptor **1**
(5) Adaptor **2**
(6) Adaptor **3**
(7) Adaptor **4**
(8) Adaptor **5**

WSM000001GEG0015US0



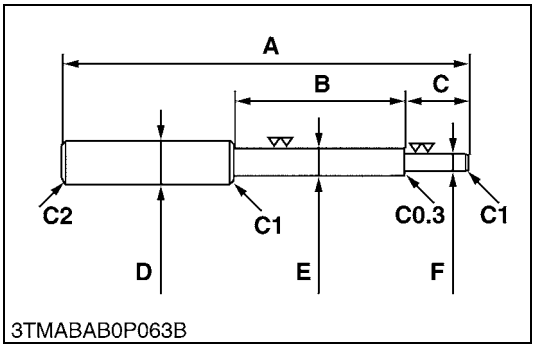
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Pressure Gauge

Specification
- 1745 kPa (17.79 kgf/cm^2, 253.1 psi)

Application
- Check the pressure of vaporizer.

9Y1210661GEG0049US0



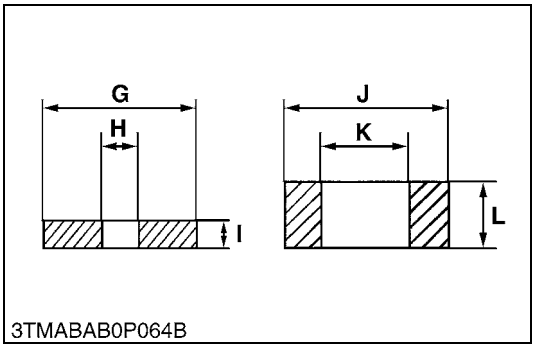
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Valve Guide Replacing Tool

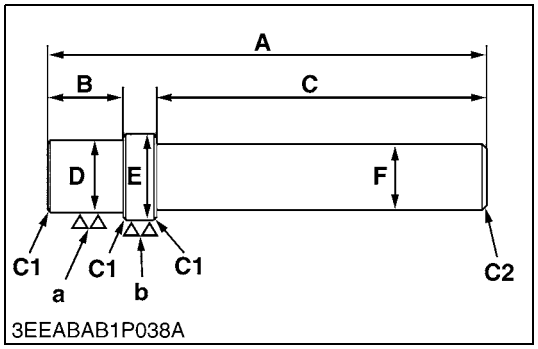
Application
- Use to press out and press fit the valve guide.

A	225 mm (8.86 in.)
B	70 mm (2.8 in.)
C	45 mm (1.8 in.)
D	20 mm dia. (0.79 in. dia.)
E	11.7 to 11.9 mm dia. (0.461 to 0.468 in. dia.)
F	6.50 to 6.60 mm dia. (0.256 to 0.259 in. dia.)
G	25 mm dia. (0.98 in. dia.)
H	6.70 to 7.00 mm dia. (0.264 to 0.275 in. dia.)
I	5.0 mm (0.20 in.)
J	20 mm dia. (0.79 in. dia.)
K	12.5 to 12.8 mm dia. (0.493 to 0.503 in. dia.)
L	8.90 to 9.10 mm (0.351 to 0.358 in.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)
C0.3	Chamfer 0.3 mm (0.01 in.)

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3EEABAB1P038A

Bushing Replacing Tool

Application

- Use to press out and press fit the bushing.

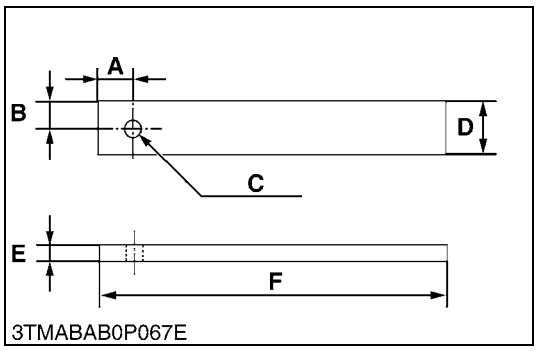
[For small end bushing]

A	157 mm (6.18 in.)
B	24 mm (0.94 in.)
C	120 mm (4.72 in.)
D	21.8 to 21.9 mm dia. (0.859 to 0.862 in. dia.)
E	24.8 to 24.9 mm dia. (0.977 to 0.980 in. dia.)
F	20 mm dia. (0.79 in. dia.)
a	6.3 µm (250 µin.)
b	6.3 µm (250 µin.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)

[For idle gear bushing]

A	196 mm (7.72 in.)
B	26 mm (1.0 in.)
C	150 mm (5.91 in.)
D	25.80 to 25.90 mm dia. (1.016 to 1.019 in. dia.)
E	28.80 to 28.90 mm dia. (1.134 to 1.137 in. dia.)
F	20 mm dia. (0.79 in. dia.)
a	6.3 µm (250 µin.)
b	6.3 µm (250 µin.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)

9Y1210661GEG0032US0



3TMABAB0P067E

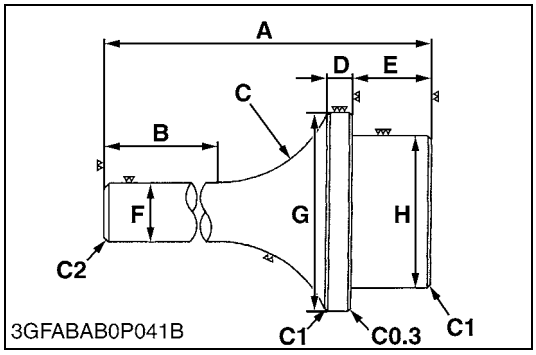
Flywheel Stopper

Application

- Use to loosen and tighten the flywheel screw.

A	20 mm (0.79 in.)
B	15 mm (0.59 in.)
C	10 mm dia. (0.39 in. dia.)
D	30 mm (1.2 in.)
E	8.0 mm (0.31 in.)
F	200 mm (7.87 in.)

9Y1210661GEG0036US0



3GFABAB0P041B

Crankshaft Bearing 1 Replacing Tool

Application

- Use to press out and press fit the crankshaft bearing 1.

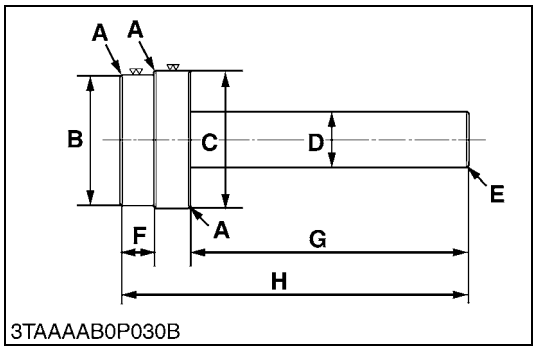
[Press out]

A	135 mm (5.31 in.)
B	72 mm (2.8 in.)
C	40 mm radius (1.6 in. radius)
D	10 mm (0.39 in.)
E	24 mm (0.94 in.)
F	20 mm dia. (0.79 in. dia.)
G	51.20 to 51.40 mm dia. (2.016 to 2.023 in. dia.)
H	47.30 to 47.50 mm dia. (1.863 to 1.870 in. dia.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)
C0.3	Chamfer 0.30 mm (0.012 in.)

[Press fit]

A	135 mm (5.31 in.)
B	72 mm (2.8 in.)
C	40 mm radius (1.6 in. radius)
D	10 mm (0.39 in.)
E	24 mm (0.94 in.)
F	20 mm dia. (0.79 in. dia.)
G	68 mm dia. (2.7 in. dia.)
H	47.30 to 47.50 mm dia. (1.863 to 1.870 in. dia.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)
C0.3	Chamfer 0.30 mm (0.012 in.)

9Y1210661GEG0034US0



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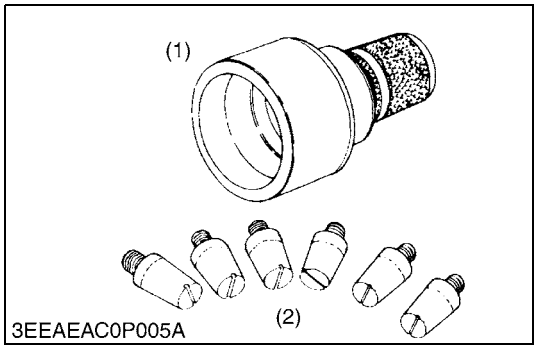
Governor Gear Holder Bushing Replacing Tool

Application

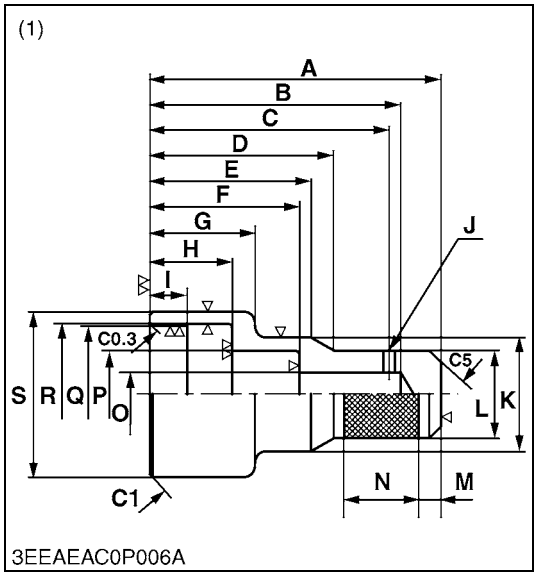
- Use to press out and to press fit the governor gear holder bushing.

A	C1: Chamfer 1.0 mm (0.039 in.)
B	73.90 to 74.00 mm dia. (2.910 to 2.913 in. dia.)
C	69.80 to 69.90 mm dia. (2.748 to 2.751 in. dia.)
D	30 mm dia. (1.2 in. dia.)
E	C2: Chamfer 2.0 mm (0.079 in.)
F	18 mm (0.71 in.)
G	150 mm (5.91 in.)
H	188 mm (7.40 in.)

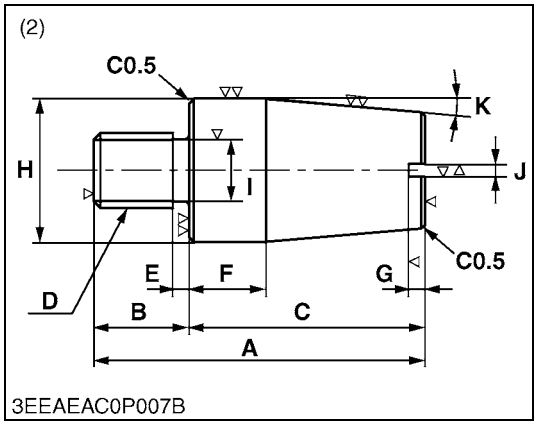
9Y1210661GEG0033US0



3EEAEAC0P005A



3EEAEAC0P006A



3EEAEAC0P007B

Crank Sleeve Setter

Application

- Use to fix the crankshaft sleeve.

(1) Auxiliary socket for pushing

A	130 mm (5.12 in.)
B	112 mm (4.41 in.)
C	107 mm (4.21 in.)
D	82 mm (3.2 in.)
E	72 mm (2.8 in.)
F	67 mm (2.6 in.)
G	47 mm (1.8 in.)
H	36.00 to 36.20 mm (1.418 to 1.425 in.)
I	17 mm (0.67 in.)
J	5.0 mm dia. (0.20 in. dia.)
K	52 mm dia. (2.0 in. dia.)
L	40 mm dia. (1.6 in. dia.)
M	10 mm (0.39 in.)
N	33 mm (1.3 in.)
O	20 mm dia. (0.79 in. dia.)
P	40 mm dia. (1.6 in. dia.)
Q	72.10 to 72.15 mm dia. (2.839 to 2.840 in. dia.)
R	73 mm dia. (2.9 in. dia.)
S	83 mm dia. (3.3 in. dia.)
C0.3	Chamfer 0.30 mm (0.012 in.)
C1	Chamfer 1.0 mm (0.039 in.)
C5	Chamfer 5.0 mm (0.20 in.)

(2) Sleeve guide

A	42 mm (1.7 in.)
B	12 mm (0.47 in.)
C	30 mm (1.2 in.)
D	M10 × Pitch 1.25
E	2.0 mm (0.079 in.)
F	10 mm (0.39 in.)
G	2.0 mm (0.079 in.)
H	17.90 to 17.95 mm dia. (0.7048 to 0.7066 in. dia.)
I	8.0 mm dia. (0.31 in. dia.)
J	1.8 mm (0.071 in.)
K	0.09 rad (5 °)
C0.5	Chamfer 0.5 mm (0.02 in.)

9Y1210661GEG0035US0

1 ENGINE

MECHANISM

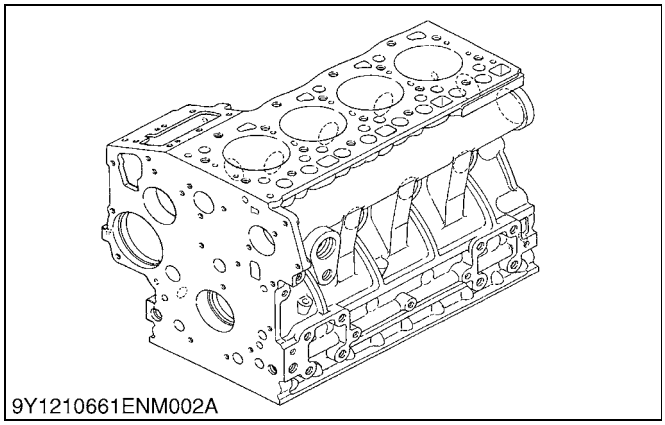
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1. ENGINE BODY

[1] CYLINDER BLOCK

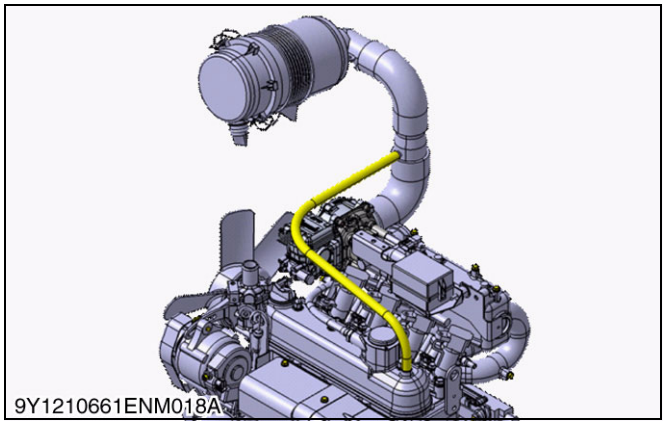

9Y1210661ENM002A

The engine has a high durability tunnel-type cylinder block in which the crank bearing component is a constructed body. Furthermore, liner less type, allow effective cooling, less distortion, and greater wear resistance. The noise level is reduced to a minimum because each cylinder has its own chamber.

To increase the rigidity of the cylinder block, parts of engine block which support main bearing case has thicker rib for additional rigidness to improve noise and vibration.

9Y1210661ENM0001US0

[2] POSITIVE CRANKCASE VENTILATION (PCV) SYSTEM

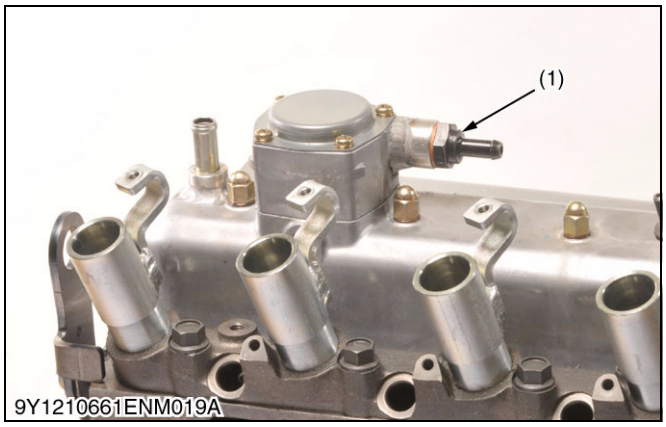

9Y1210661ENM018A

During normal compression stroke, a small amount of gases in the combustion chamber escapes past the piston. Approximately 70 % of these blowby gases are unburned fuel (HC) that can dilute and contaminate the engine oil, cause corrosion to critical parts, and contribute to sludge build up.

The purpose of the Positive Crankcase Ventilation (PCV) system is to remove these harmful gases from the crankcase before damage occurs and combine them with the engine's normal incoming air / fuel charge.

9Y1210661ENM0014US0

[3] PCV VALVE



9Y1210661ENM019A

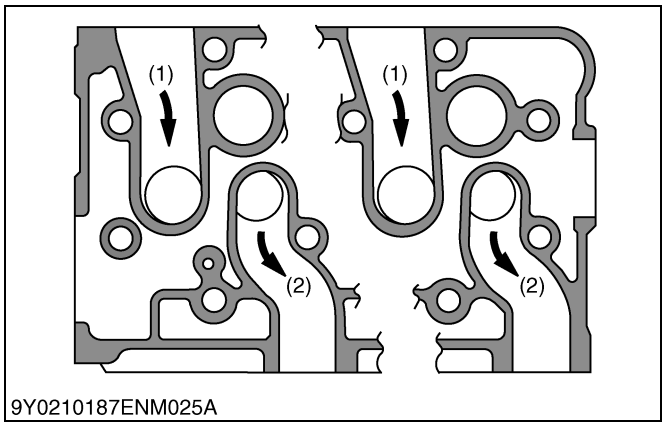
The PCV valve consists of a spring and a valve, and it is installed between an engine body and an intake manifold.

The PCV valve controls the inhalation volume of blow-by gas and the volume of fresh air according to the engine operation status.

(1) PCV Valve

9Y1210661ENM0015US0

[4] CYLINDER HEAD



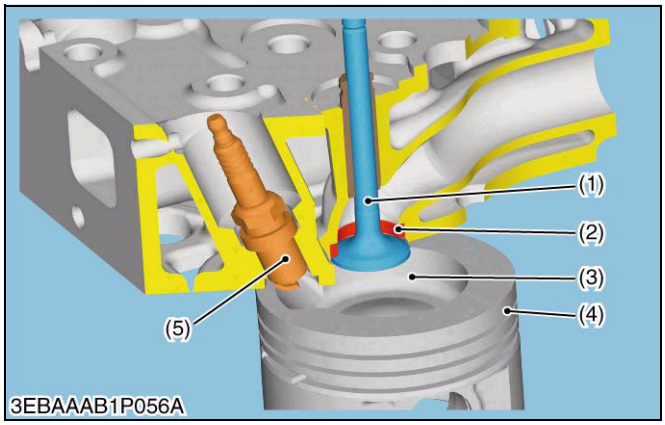
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Intake and Exhaust Port

The cross-flow type intake / exhaust ports, which lower the heat conduction from the exhaust port to the intake port. The low heat conduction keeps the intake air from being heated and expanded by the exhaust gas.

(1) Intake Port
(2) Exhaust Port

9Y1210661ENM0027US0



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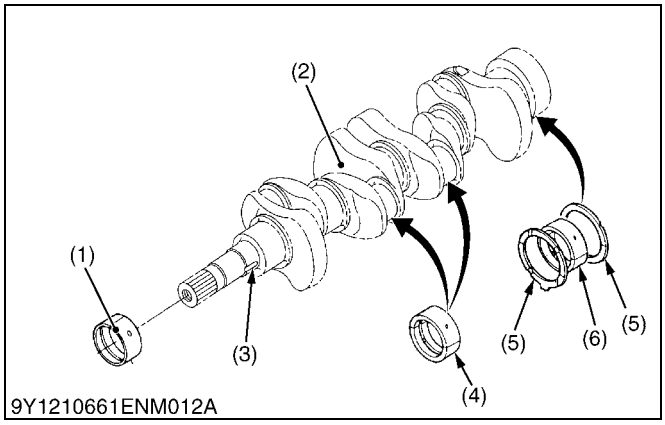
Combustion System

The Spark Ignition type combustion chamber, compactly placed on top of the piston head, successfully reduces emissions. To ensure even more reliable emission life, the intake / exhaust valve seats are fitted with special heat resistant stellite alloys.

(1) Valve
(2) Valve Seat
(3) Main Combustion Chamber
(4) Piston
(5) Spark Plug

9Y1210318ENM0004US0

[5] CRANKSHAFT



9Y1210661ENM012A

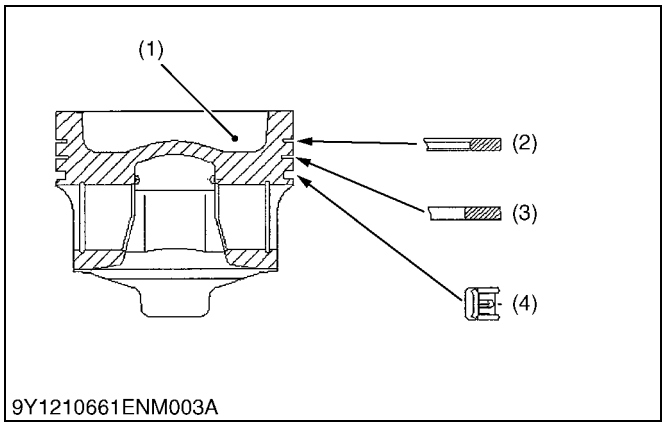
The crankshaft with the connecting rod converts the reciprocating motion of the piston into rotating motion. The crankshaft (2) has oil passages drilled so that oil can flow from the main bearings to the crank pin bearings.

The front journal is supported by a sleeve type bearing (crankshaft bearing 1) (1), the intermediate journal by a split type (crankshaft bearing 3) (4), and the rear by a split type (crankshaft bearing 2) (6) with thrust bearings (5).

(1) Crankshaft Bearing 1
(2) Crankshaft
(3) Feather Key
(4) Crankshaft Bearing 3
(5) Thrust Bearing
(6) Crankshaft Bearing 2

9Y1210661ENM0011US0

[6] PISTON AND PISTON RING



9Y1210661ENM003A

Piston and Piston Ring

The piston has a slightly oval shape when cold (in consideration of thermal expansion) and a concave head.

Top Ring:

The top ring is of plain barrel face type. The barrel face type has an arc sliding surface easy to run in and prevents abnormal wears by providing a maintained oil film against the lined wall.

Second Ring:

For the second ring, the tapered outer surface area that comes in contact with the lined wall is reduced to obtain a high surface pressure for the prevention of gas leakage, compression leakage and oil spillage.

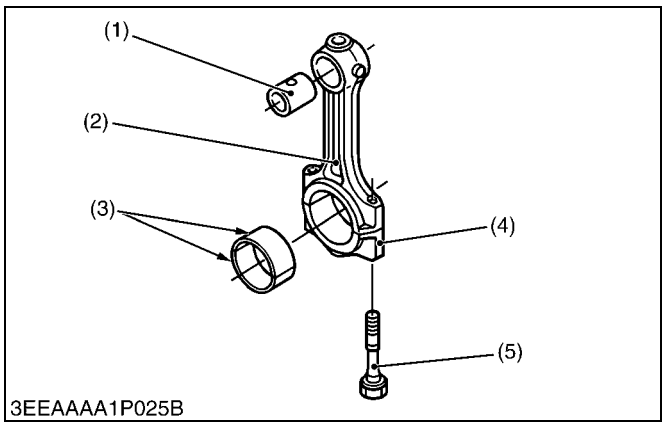
Oil Ring:

Oil ring consists of three steel components, that is upper and lower rails and one spacer being held between two rails. This function is particularly effective in preventing oil-up because of high boost at the time of engine coasting.

(1) Combustion Chamber
(2) Top Ring
(3) Second Ring
(4) Oil Ring

9Y1210661ENM0002US0

[7] CONNECTING ROD



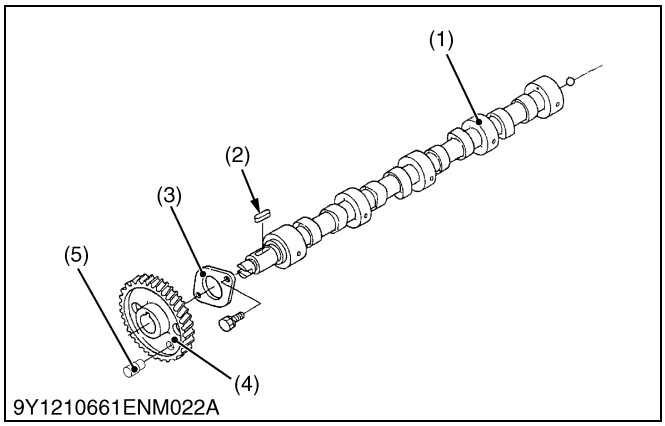
3EEAAAA1P025B

The connecting rod (2) is used to connect the piston with the crankshaft. The big end of the connecting rod has a crankpin bearing (3) (split type) and the small end has a small end bushing (1) (solid type).

(1) Small End Bushing
(2) Connecting Rod
(3) Crankpin Bearing
(4) Connecting Rod Cap
(5) Connecting Rod Screw

9Y1210318ENM0009US0

[8] CAMSHAFT



9Y1210661ENM022A

The camshaft (1) is made of special cast iron, and the journal and cam sections are chilled to resist wear.

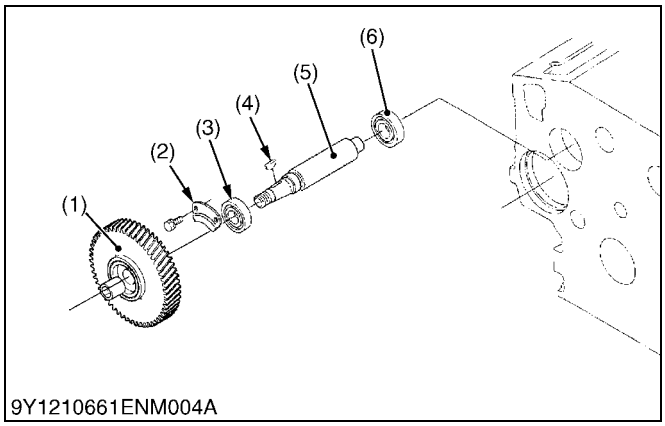
The cams on the camshaft cause the intake and exhaust valves to open as the camshaft rotates. The bearing and journals are force-lubricated.

A rotation detective pin is attached to the cam gear.

(1) Camshaft
(2) Feather Key
(3) Camshaft Stopper
(4) Cam Gear
(5) Pin

9Y1210661ENM0029US0

[9] GEAR SHAFT



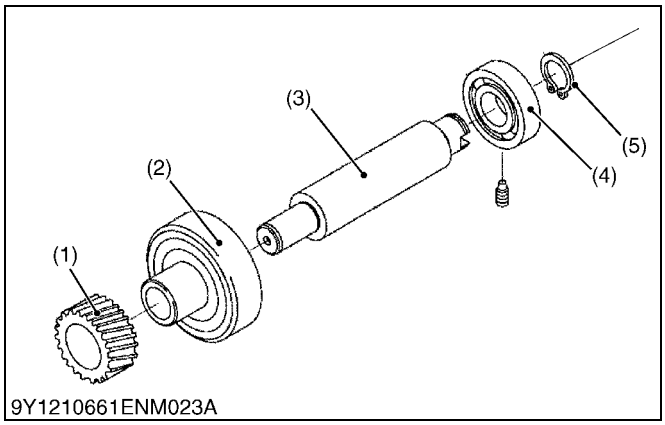
9Y1210661ENM004A

The gear shaft is a shaft that was changed from the fuel camshaft for 05-E3B engine to the shaft with no cam.

(1) Injection Pump Gear
(2) Stopper
(3) Ball Bearing
(4) Feather key
(5) Gear shaft
(6) Ball Bearing

9Y1210661ENM0009US0

[10] PTO SHAFT



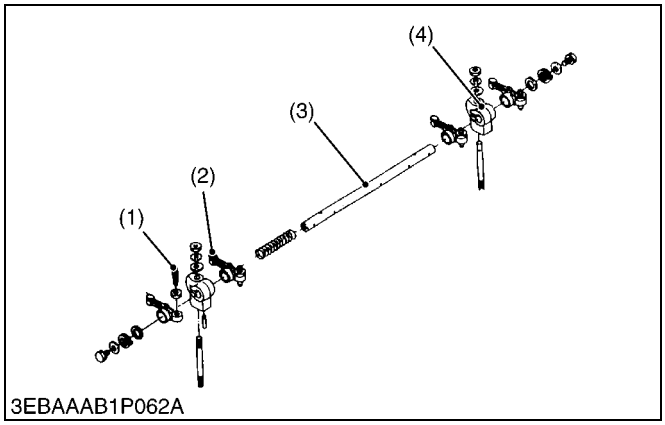
9Y1210661ENM023A

It is possible to takeoff the power of hydraulic pump drive from the PTO shaft.

(1) Governor Gear
(2) Governor Gear Holder
(3) PTO Shaft
(4) Bearing
(5) Snap Ring

9Y1210661ENM0031US0

[11] ROCKER ARM ASSEMBLY



3EBAAAB1P062A

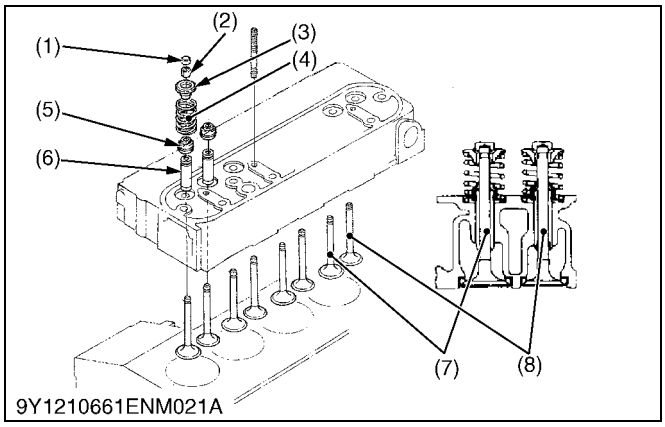
The rocker arm assembly includes the rocker arms (2) and adjusting screws (1), the end of which rests on the push rods, rocker arm brackets (4) and rocker arm shaft (3).

The rocker arms swing and transmits the reciprocating motion of the push rods to the inlet and exhaust valves to open and close them.

(1) Adjusting Screw
(2) Rocker Arm
(3) Rocker Arm Shaft
(4) Rocker Arm Bracket

9Y1210318ENM0012US0

[12] INLET AND EXHAUST VALVES



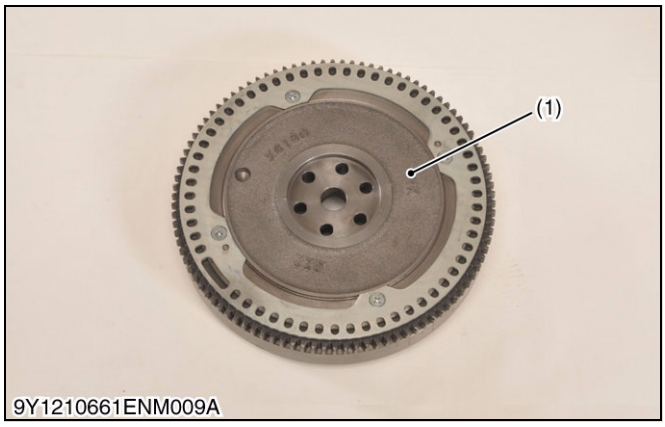
The valve and its guide for the inlet are different from those for the exhaust.

Other parts, such as the spring (4), spring retainer (3), collet (2), stem seal (5), and cap (1) are the same for both the inlet and exhaust.

(1) Valve Cap
(2) Collet
(3) Spring Retainer
(4) Spring
(5) Stem Seal
(6) Valve Guide
(7) Inlet Valve
(8) Exhaust Valve

9Y1210661ENM0028US0

[13] FLYWHEEL



The flywheel (1) is connected with the crankshaft, it stores the rotating force in the combustion stroke as inertial energy to rotate the crankshaft smoothly.

The flywheel periphery is provided with marks showing fuel injection timing and top dead center.

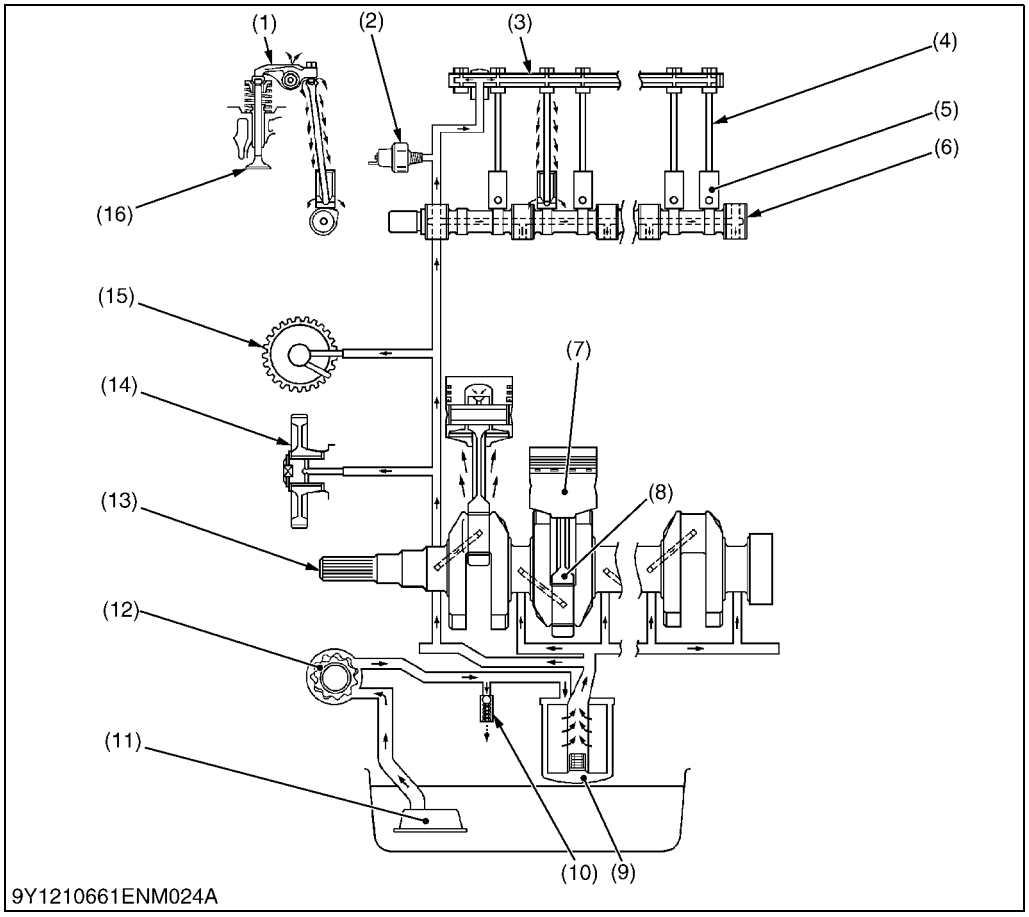
The flywheel has gear teeth around its outer rim, which mesh with the drive pinion of the starter. Also, a rotor for determining the ignition timing is attached to the flywheel.

(1) Flywheel

9Y1210661ENM0032US0

2. LUBRICATING SYSTEM

[1] GENERAL



(1) Rocker Arm
(2) Oil Pressure Switch
(3) Rocker Arm Shaft
(4) Push Rod
(5) Tappet
(6) Camshaft
(7) Piston
(8) Connecting Rod
(9) Oil Filter Cartridge
(10) Relief Valve
(11) Oil Strainer
(12) Oil Pump
(13) Crankshaft
(14) Idle Gear
(15) PTO Shaft
(16) Valve

Engine lubricating system may be classified as:

- Full pressure feed type
- Pressure feed and splash type

KUBOTA engines have lubricating system of full pressure feed type.

This system consists of an oil strainer (11), oil pump (12), relief valve (10), oil filter cartridge (9) and oil pressure switch (2).

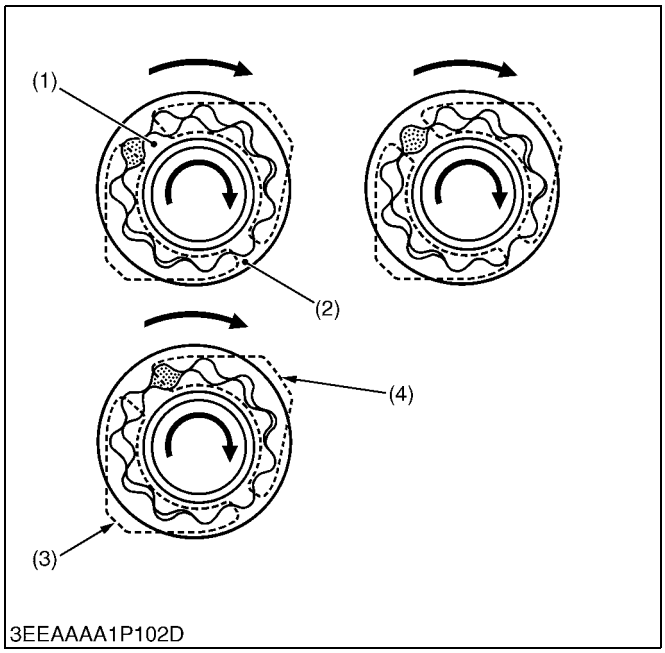
The oil pump sucks lubricating oil from the oil pan through the oil strainer and the oil flows down to the oil filter, cartridge where it is further filtered. Then the oil is forced to crankshaft (13), connecting rods (8), idle gear (14), PTO shaft (15), camshaft (6) and rocker arm shaft (3) to lubricate each part through the oil gallery.

Some part of oil, splashed by the crankshaft or leaking and dropping from gaps of each part, lubricates following parts.

- Pistons (7)
- Cylinder walls
- Small ends of connecting rods
- Tappets (5)
- Push rods (4)
- Intake and exhaust valves (16)
- Timing gears

9Y1210661ENM0030US0

[2] OIL PUMP



3EEAAAA1P102D

This oil pump has an inner rotor (1) and an outer rotor (2).

The inner rotor (1), which is driven by crankshaft, rotates the outer rotor (2) in the same direction.

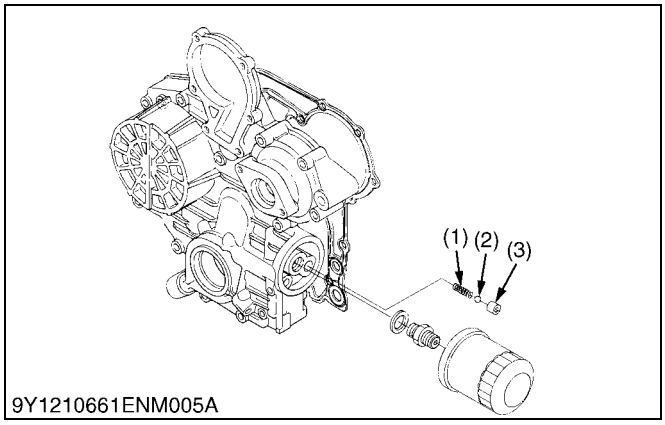
The inner rotor (1) has one less lobe than the outer rotor (2), and they are eccentrically engaged with each other.

This allows the other lobes to slide over the outer lobes, making a seal to prevent back-up of oil. As the lobes slide up and over the lobes on the outer rotor (2), oil is drawn in. As the lobes fall into the outer rotor's cavities, oil is squeezed out.

(1) Inner Rotor
(2) Outer Rotor
(3) Inlet Port
(4) Outlet Port

9Y1210661ENM0033US0

[3] RELIEF VALVE



9Y1210661ENM005A

The relief valve prevents the damage to the lubricating system due to the high pressure of the oil.

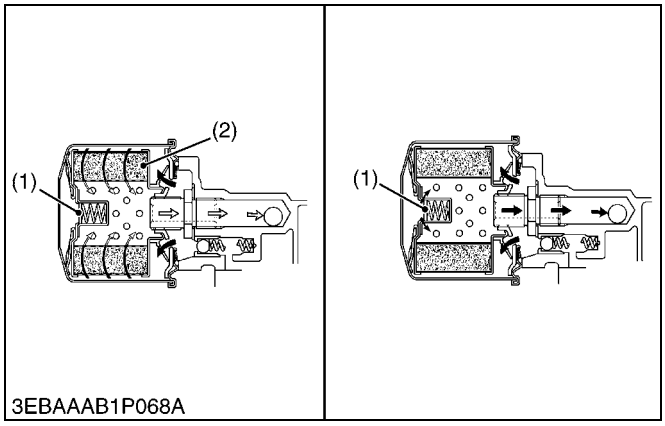
This relief valve is a ball direct acting type, and is best suited for low pressures.

When the pressure of the oil, forced by the pump, exceeds the specified value, the oil pushes back the ball (2) and escapes to the oil pan.

(1) Spring
(2) Ball
(3) Valve Seat

9Y1210661ENM0005US0

[4] OIL FILTER CARTRIDGE



3EBAAAB1P068A

After lubricating, the lubricating oil brings back various particles of grit and dirt to the oil pan. Those particles and the impurities in the lubricating oil can cause wear or seizure of the engine parts. It may also impair the physical and chemical properties of the oil itself.

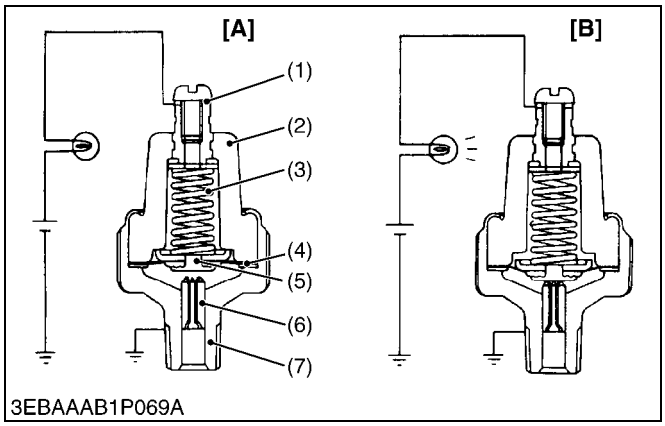
The lubricating oil which is force-fed by the pump, is filtered by the filter cartridge with the filter element (2).

When the filter element accumulates on excessive amount of dirt and the oil pressure in the inlet line builds up by 98 kPa (1.0 kgf/cm^2, 14 psi) more than the outlet line, the bypass valve (1) opens to allow the oil to flow from the inlet into the outlet line, bypassing the filter element.

(1) Bypass Valve
(2) Filter Element

9Y1210318ENM0019US0

[5] OIL PRESSURE SWITCH



3EBAAAB1P069A

The oil pressure switch is mounted on the cylinder block and is led to the lubricating oil passage.

When the oil pressure falls below the specified value, the oil pressure warning lamp lights.

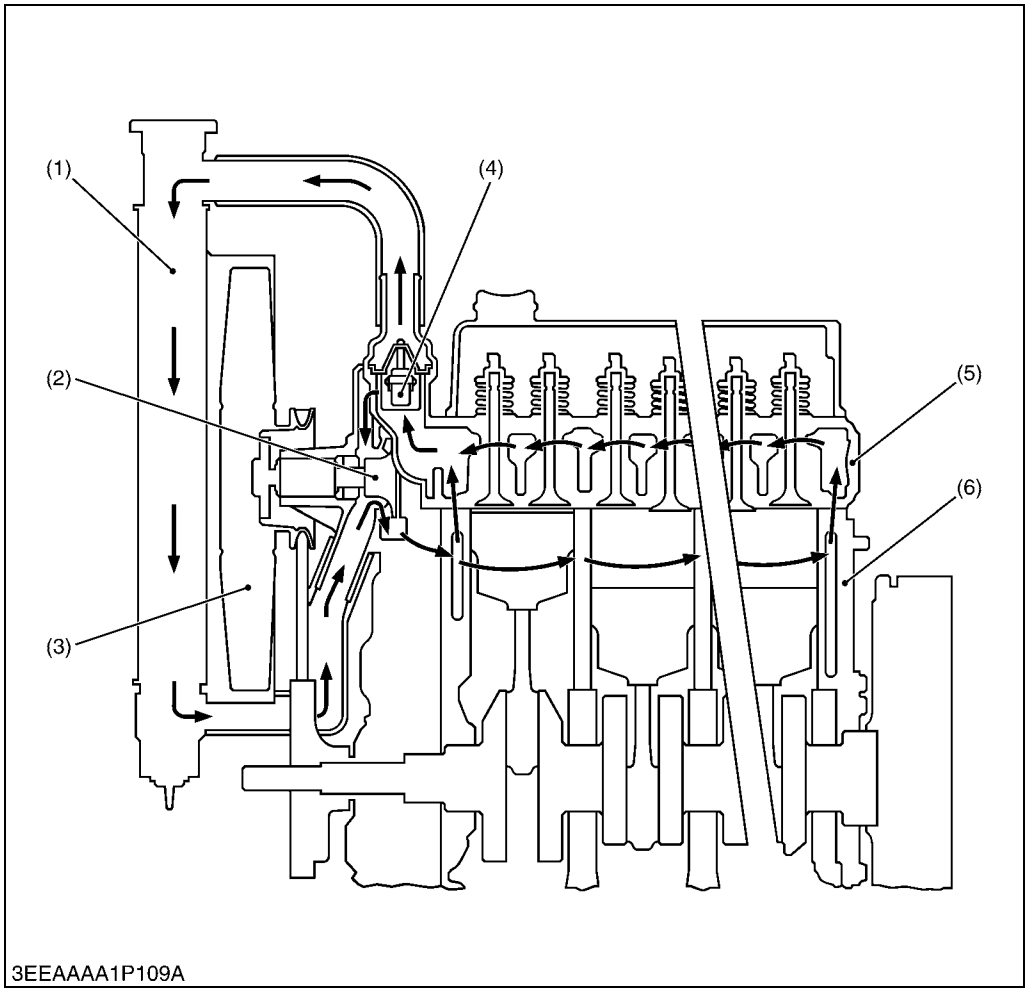
(1) Terminal
(2) Insulator
(3) Spring
(4) Rubber Gasket
(5) Contact Rivet
(6) Contact
(7) Oil Switch Body

[A] At the proper oil pressure
[B] At lower oil pressure, 50 kPa (0.5 kgf/cm^2, 7 psi) or less

9Y1210318ENM0020US0

3. COOLING SYSTEM

[1] GENERAL



3EEAAAA1P109A

(1) Radiator
(2) Water Pump
(3) Cooling Fan
(4) Thermostat
(5) Cylinder Head
(6) Cylinder Block

The cooling system consists of a radiator (1), a centrifugal water pump (2), a cooling fan (3) and a thermostat (4).

The coolant is cooled through the radiator core, and the fan behind the radiator pulls the cooling air through the core to improve cooling.

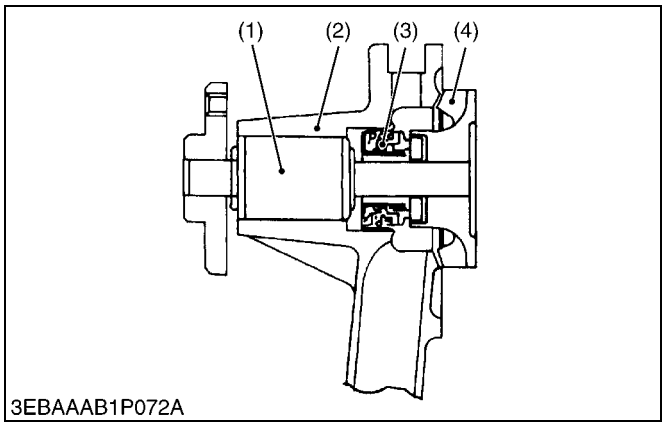
The water pump sucks the coolant from the radiator or from the cylinder head and forces it into the cylinder block.

The thermostat opens or closes according to the coolant temperature, to allow the coolant to flow from the cylinder block to the radiator while open, or only to the water pump while closed.

Thermostat's valve opening temperature	Factory specification	69.5 to 72.5 °C 157.1 to 162.5 °F

9Y1210661ENM0012US0

[2] WATER PUMP



3EBAAAB1P072A

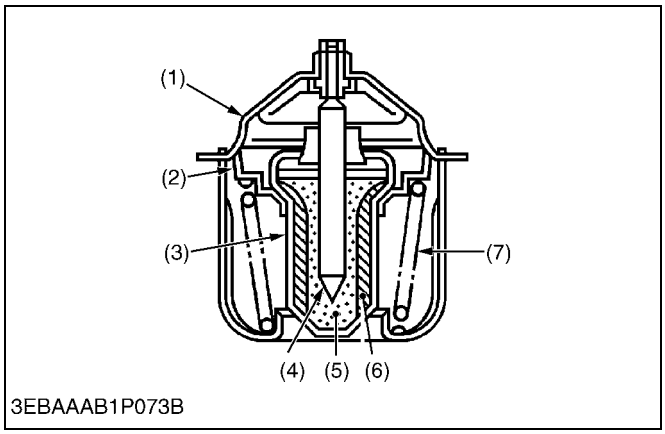
The water pump is driven by the crankshaft and a V belt. The rotating impeller (4) in the water pump sucks the coolant from the radiator and sends it into the water jacket in the cylinder block.

The mechanical seal (3) prevents the water from entering the bearing unit (1).

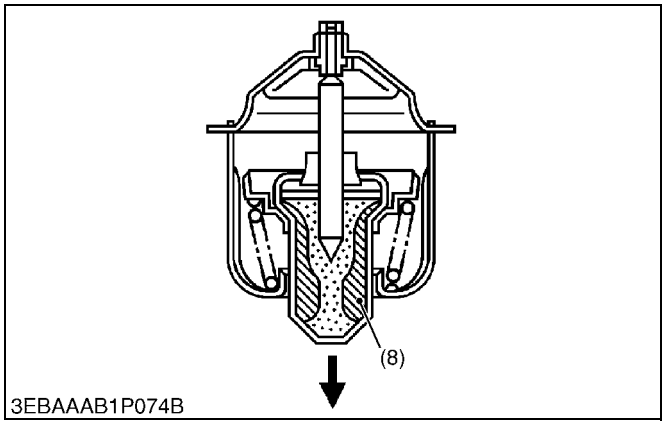
(1) Bearing Unit
(2) Water Pump Body
(3) Mechanical Seal
(4) Impeller

9Y1210318ENM0023US0

[3] THERMOSTAT



3EBAAAB1P073B



3EBAAAB1P074B

The thermostat is of the wax pellet type.

The thermostat controls the flow of the coolant to the radiator to keep the proper temperature.

The case, which serves as a valve seat, has a spindle inserted in the pellet (3) which is installed to the valve (2). The spindle is covered with the synthetic rubber (5) in the pellet.

The wax is charged between the pellet and the rubber.

■ **At low temperature (lower than valve opening temperature (at beginning))**

The valve (2) is seated by the spring (7) and the coolant circulates in the engine through the water return hose without running into the radiator. Only the air in the water jacket escapes to the radiator through the leak hole of the thermostat.

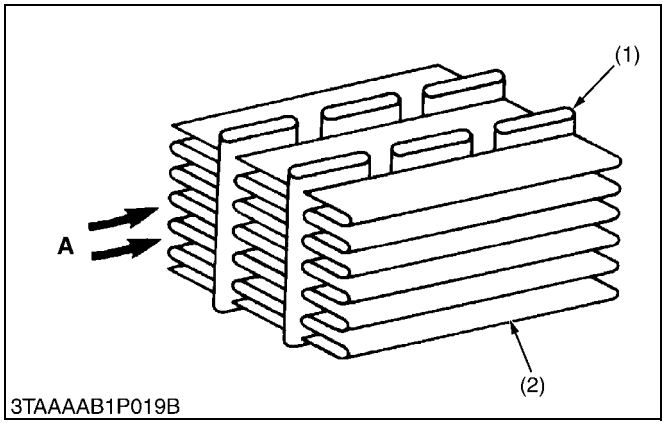
■ **At high temperature (higher than valve opening temperature (opened completely))**

As the coolant temperature rises, the wax in the pellet (3) turns liquid and expands, repelling the spindle, which causes the pellet to lower. The valve (2) opens to send the coolant to the radiator.

(1) Seat
(2) Valve
(3) Pellet
(4) Spindle
(5) Synthetic Rubber
(6) Wax (Solid)
(7) Spring
(8) Wax (liquid)

9Y1210571ENM0022US0

[4] RADIATOR



3TAAAAB1P019B

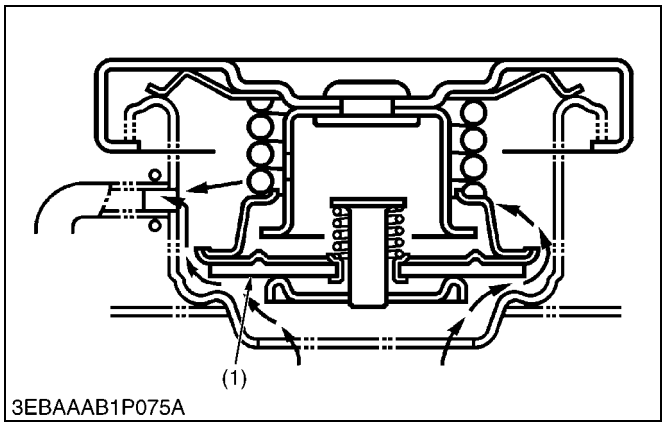
The radiator core consists of coolant carrying tubes (1) and fins (2) meeting at a right angle with the tubes. The fin is a louverless, corrugated type which is light in weight, high in heat exchange ratio and less apt to clog.

The coolant in the tubes is cooled by the air flowing through the tube walls and fins.

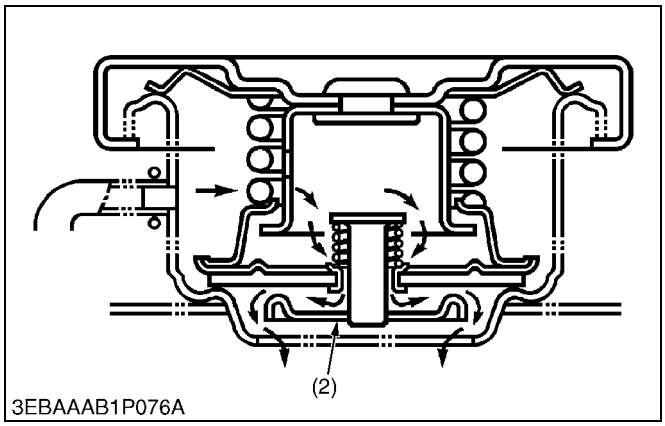
(1) Tube
(2) Fin
A: Cooling Air

9Y1210318ENM0025US0

[5] RADIATOR CAP



3EBAAAB1P075A



3EBAAAB1P076A

The pressure type radiator cap prevents differences in pressure between the inside and the outside of the radiator from deforming the radiator.

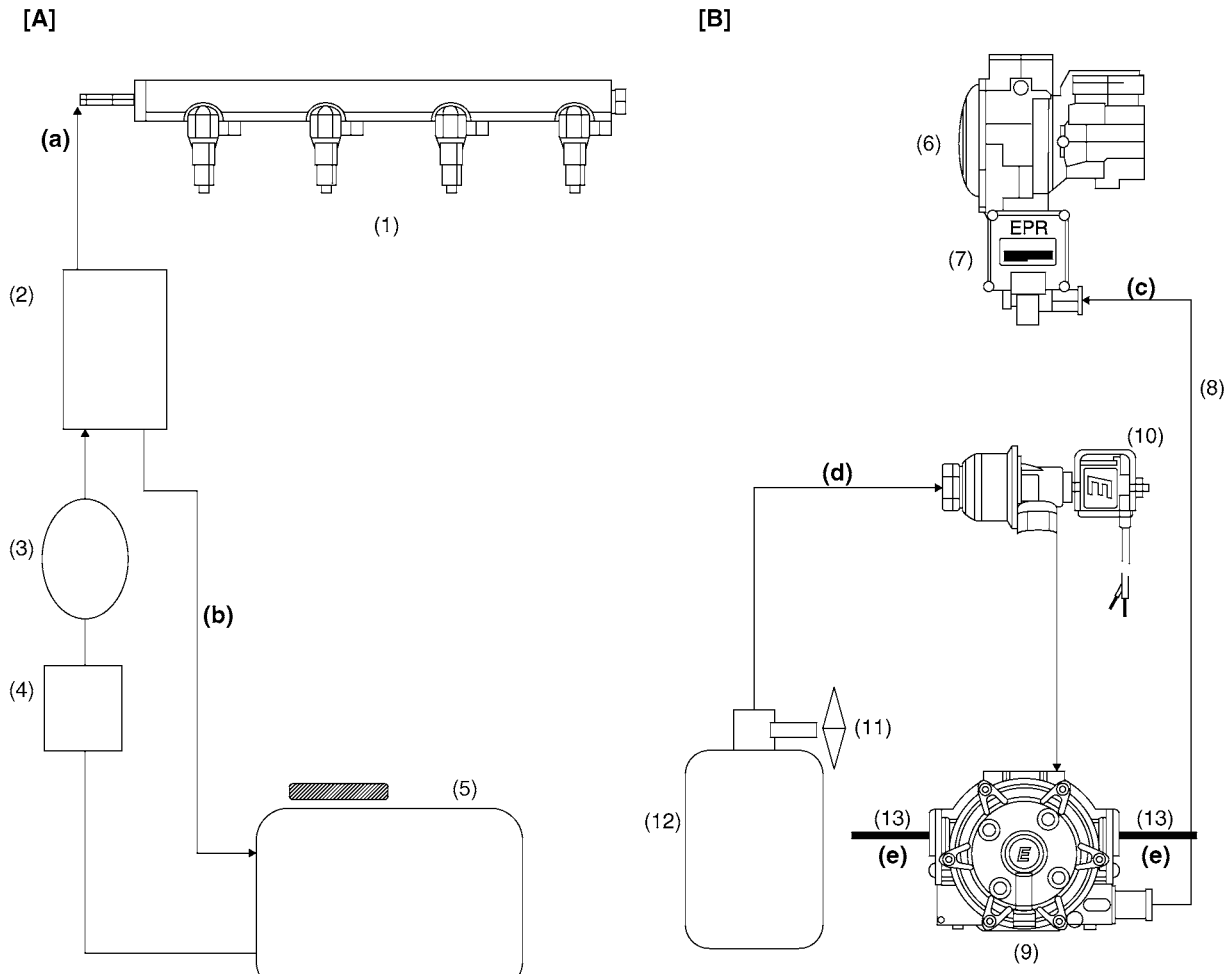
When the coolant temperature rises and the pressure in the radiator increases above the specified pressure, the pressure valve (1) opens to reduce the internal pressure.

When the coolant temperature falls and a vacuum forms in the radiator, the vacuum valve (2) opens to introduce the air into the radiator.

(1) Pressure Valve (Opening pressure 88 kPa (0.90 kgf/cm^2, 13 psi))
(2) Vacuum Valve

9Y1210318ENM0026US0

4. FUEL SYSTEM
[1] GENERAL



(1) Delivery Pipe
(2) Fuel Pressure Manifold (FPM)
(3) Fuel Pump
(4) Fuel Filter
(5) Gasoline Tank*
(6) Mixer
(7) Regulator (D-EPR)
(8) Vapor Hose*
(9) Vaporizer (DSR)
(10) Lock Off Valve
(11) LPG Manual Valve*
(12) LPG Tank*
(13) Coolant Hose*

[A] Gasoline Fuel
[B] LPG Fuel

(a) Gasoline Line*
(b) Bleed / Return Circuit*
(c) Gaseous Propane Line*
(d) Liquid Propane Line*
(e) Hot Coolant Inlet or Outlet Line*

Component Marked * is Not Provided by KUBOTA

WG1605-G-E3:

The fuel is fed from the gasoline tank (5) through the fuel filter (4) to the delivery pipe (1) by the fuel pump (3).

WG1605-L-E3:

The LPG fuel stored in the LPG tank (12) is sent to vaporizer (9) by pressure in the gaseous phase in the tank through the lock off valve (10).

The LPG fuel is evaporated in vaporizer (9) and is sent to the regulator (7) as a gaseous fuel of gas pressure near the atmospheric pressure.

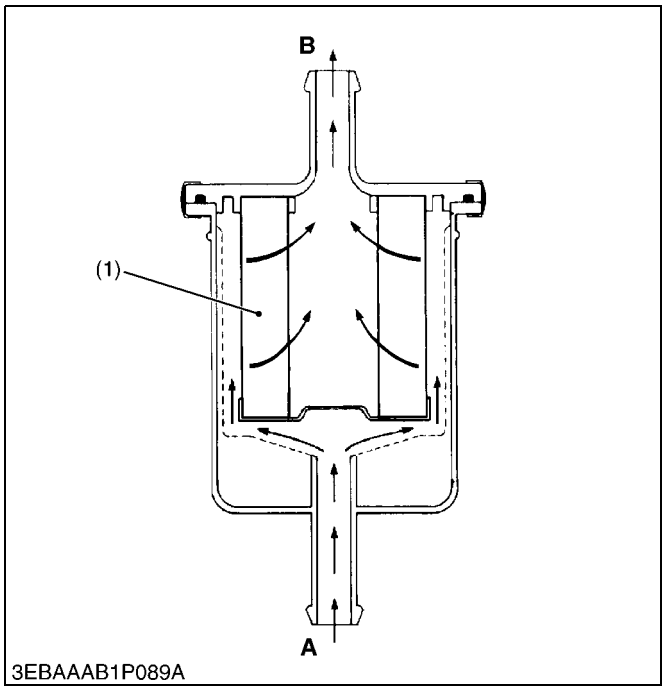
The regulator (7) mixes the gas and air is supplied in the cylinder.

WG1605-GL-E3:

This fuel system has 2 ways (gasoline fuel and LPG fuel).

9Y1210661ENM0016US0

[2] FUEL FILTER (WG1605-G-E3, WG1605-GL-E3)



3EBAAAB1P089A

The fuel filter is installed in the fuel line between the fuel tank and the feed pump.

As the fuel flows from the inlet **"A"** through the filter element (1), the dirt and impurities in the fuel are filtered, allowing only clean fuel to penetrate the inside of the filter element. The cleaned fuel flows out from the outlet **"B"**.

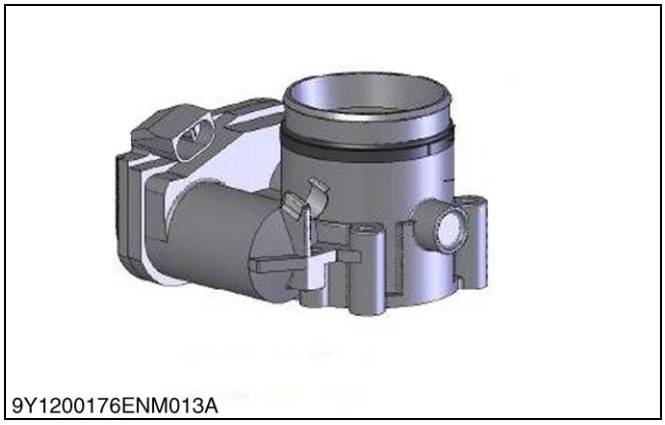
Type of filter element	Accordion-pleated paper type
Material of filter element	Cotton fiber
Filter mesh	15 μm (0.00059 in.)

(1) Filter Element

A: Inlet
B: Outlet

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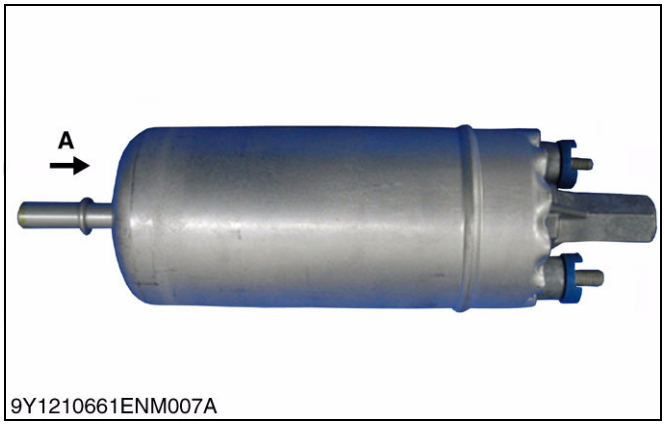
[3] ELECTRONIC THROTTLE BODY (ETB)


9Y1200176ENM013A

The ETB is connected to the intake manifold of the engine. The ETB uses an electric motor connected to the throttle shaft. In addition, an accelerator position sensor (a foot pedal position sensor) is located in the operator's compartment. When the engine is running, electrical signals are sent from the accelerator position sensor (the foot pedal position sensor) to the Engine Control Unit (ECU) when the operator depresses or releases the accelerator. The ECU then sends an electrical signal to the motor on the ETB to increase or decrease the angle of the throttle blade, thus increasing or decreasing the air flow to the engine.

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[4] FUEL PUMP (WG1605-G-E3, WG1605-GL-E3)



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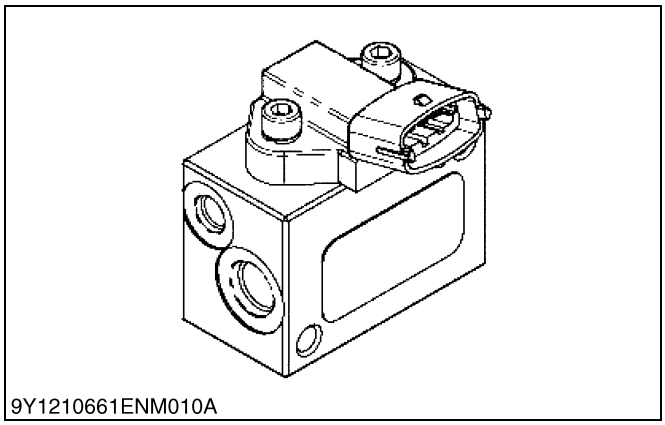
The gasoline system will use an external electric gasoline fuel pump. The pump will be mounted in the chassis of the vehicle, or equipment near the fuel tank. Gasoline rated fuel hose and securing devices supplied by the OEM, will be used to transfer the pumped fuel to the Gasoline Fuel Pressure Manifold assembly. The OEM may have installed a fuel filtration device ahead of the electric pump, which may be located in the tank or an external filter. Most industrial equipment will be exposed to dusty and dirty environments, therefore use caution when opening the gasoline tank, to prevent dirt and debris from falling in the tank. For filter maintenance, refer to "3. MAINTENANCE CHECK LIST".

The electric gasoline fuel pump, used on USA emission certified engines are a critical part of the certified emissions system, and do not require any periodic adjustment.

The pump will be mounted in the chassis of the vehicle, or equipment near the fuel tank. Gasoline rated fuel hose and securing devices supplied by the OEM, will be used to transfer the pumped fuel to the Gasoline Fuel Pressure Manifold.

A: From Fuel Tank

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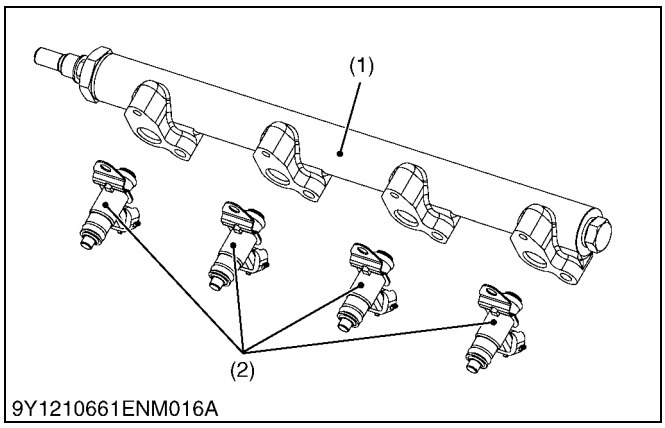

9Y1210661ENM010A

Fuel Pressure Manifold (FPM) (WG1605-G-E3, WG1605-GL-E3)

The gasoline fuel system, uses a Fuel Pressure Manifold assembly, to control the delivery pressure to the delivery pipe. The manifold is mounted to the chassis, between the electric fuel pump and the delivery pipe. The manifold is equipped with a sensor, which provides the ECU with the gasoline fuel temperature, and pressure being regulated to the delivery pipe. The ECU uses the fuel temperature and pressure, to calculate the precise amount of gasoline, to be injected to the engine during operation. The manifold is designed into the system, to control pressure, as well as the amount of gasoline, to be returned to the fuel tank. In normal gasoline delivery systems, the electric fuel pump, delivers a constant pressure to the delivery pipe, and allows a significant amount of fuel to be recycled to the tank, thus causing the gas to heat and vaporize, and requiring the use of a vapor recovery system to control the excess vapor. The system manages the fuel pressure at the manifold and minimizes the amount of returned fuel, thus reducing the vapor fuel in the tank.

9Y1210661ENM0018US0

[5] INJECTORS AND DELIVERY PIPE (WG1605-G-E3, WG1605-GL-E3)



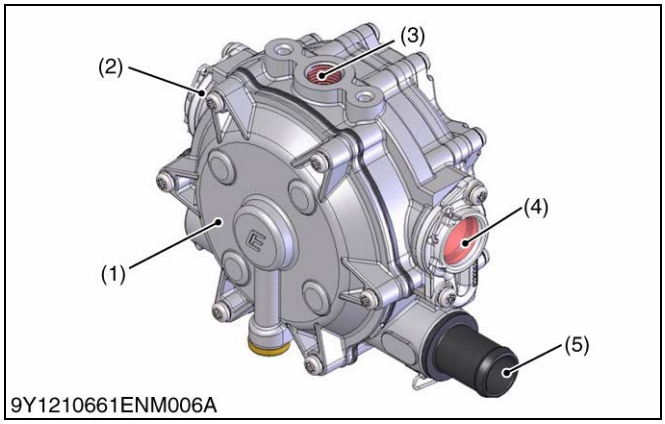
9Y1210661ENM016A

The gasoline fuel delivery system, uses a delivery pipe (1) mounted with injectors (2), for each cylinder. The Engine Control Unit (ECU) will use the gasoline fuel delivery calibrations, to pulse width modulate each injector (2), to deliver the correct amount of gasoline, for optimized performance and emission control. The injector pulsing or "firing" is accomplished by supplying a 12 volt supply, to the positive side of the injector coil, and switching the ground circuit side, using the injector drivers, internal to the ECU. Injectors (2) are an emissions control device, and do not require periodic adjustment.

(1) Delivery Pipe (2) Injector

9Y1210661ENM0019US0

[6] VAPORIZER (DUAL STAGE REGULATOR (DSR)) (WG1605-L-E3, WG1605-GL-E3)



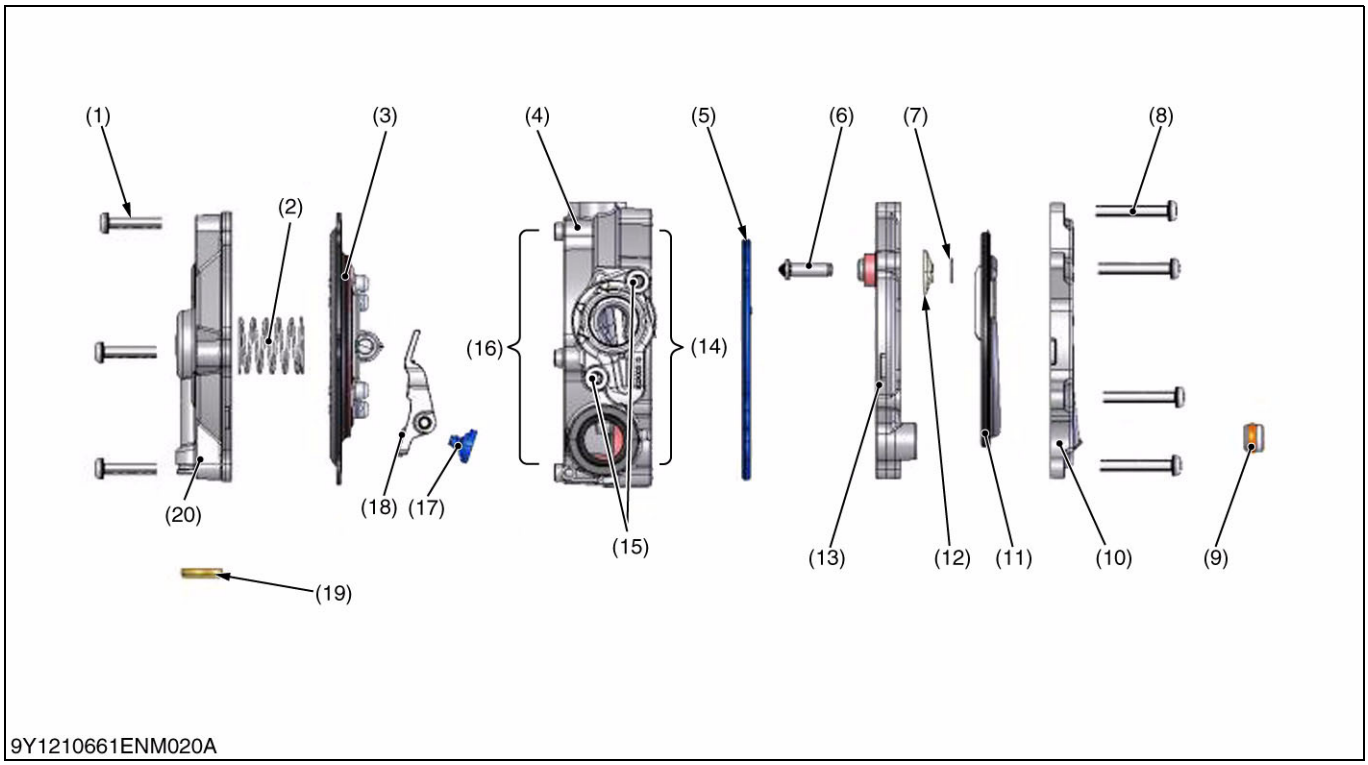
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When evaporating by primary chamber of vaporizer liquid LPG needs the evaporation heat.

This vaporizer installs the water jacket, throws the coolant of engine, heats primary chamber, promotes evaporation.

(1) Vaporizer
(2) Hot Coolant In / Out
(3) Fuel In
(4) Hot Coolant Out / In
(5) Fuel Out

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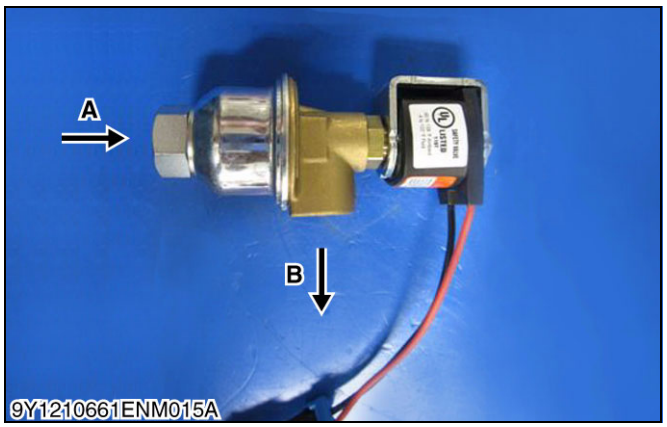
(1) Secondary Cover Screw
(2) Secondary Spring
(3) Secondary Diaphragm
(4) Heat Exchanger
(5) Coolant Gasket
(6) Primary Pin
(7) Primary Spring Retaining Clip
(8) Primary Cover Screw
(9) Primary Test Port Plug
(10) Primary Cover
(11) Primary Diaphragm
(12) Primary Spring
(13) Primary Plate
(14) Primary Chamber
(15) Coolant Fitting Housing Retaining Screw
(16) Secondary Chamber
(17) Secondary Seat
(18) Secondary Lever
(19) Secondary Cover Vent
(20) Secondary Cover

The DSR is a combination vaporizer, pressure regulating device. The DSR is a two stage regulator that is normally closed, when the engine is not running. When the engine is cranking or running, a partial vacuum is created in the fuel line, which connects the regulator to the Direct Electronic Pressure Regulators (DEPR), and mixer. This partial vacuum opens the second stage regulator, permitting fuel to flow to the DEPR, and mixer.

As the propane passes through the heat exchanger (4), the fuel expands, and creates pressure inside the primary chamber (14). The pressure rises as the fuel expands, when the pressure rises above 10.34 kPa (1.500 psi); sufficient pressure is exerted on the primary diaphragm (11), and press against the primary pin (6), thus closing off the flow of fuel. This action causes the flow of fuel, into the regulator to be regulated. When the engine is cranking, sufficient vacuum will be introduce into the secondary chamber (16), from the EPR / mixer, drawing the secondary diaphragm (3) down onto the secondary lever (18), allowing vaporized fuel, to pass to the mixer. Increased vacuum, in the secondary chamber (16), increases the downward action on the secondary lever (18), allowing more fuel to flow to the mixer.

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[7] LOCK OFF VALVE (WG1605-L-E3, WG1605-GL-E3)

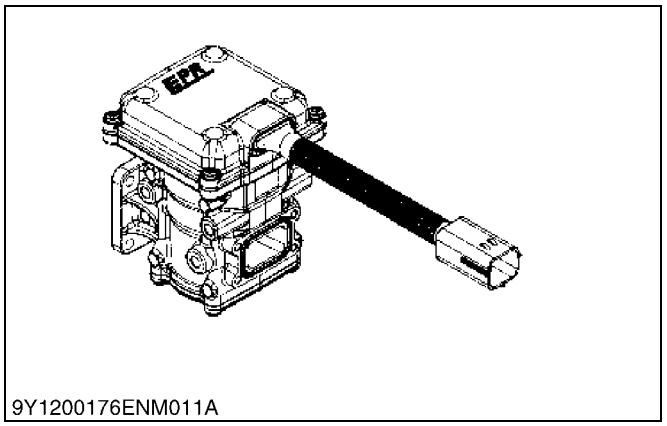


Vaporizer requires a normally-closed electrically controlled fuel lock off valve that is close coupled to the vaporizer and off when ignition switch is off or when the engine is not running normally. In operation without a lock off upstream the vaporizer will flow fuel with the engine off. The vaporizer is not a fuel shut-off safety device

A: From LPG Tank **B: To Vaporizer**

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[8] DIRECT ELECTRONIC PRESSURE REGULATOR (DEPR) (WG1605-L-E3, WG1605-GL-E3)

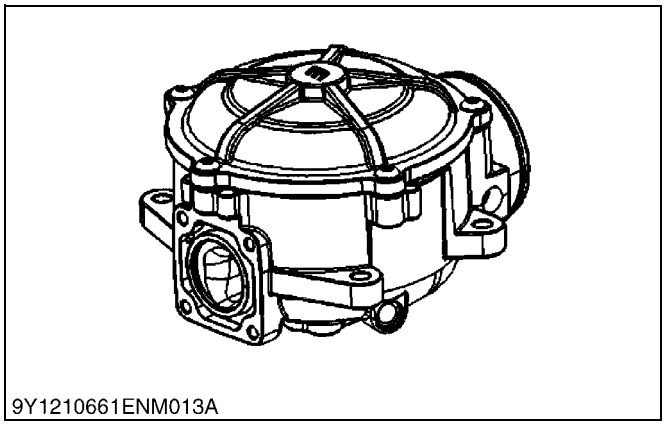


The Direct Electronic Pressure Regulator (DEPR) is the primary fuel control device, used to keep both performance and emissions control. The DEPR contains an internal computer, which communicates to the Engine Control Unit (ECU), via a Communications Area Network (CAN), high speed connection.

The DEPR precisely controls the fuel flow required to ensure Stoichiometric (correct air / fuel mixture for complete burn) fuel delivery to the engine combustion chambers. The DEPR also contains internally mounted fuel pressure and temperature sensors, which provide input across the CAN link, to the ECU, for fuel calculation. The ECU will process this information and command changes back across the CAN link, to the DEPR, to adjust fueling.

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[9] MIXER (WG1605-L-E3, WG1605-GL-E3)

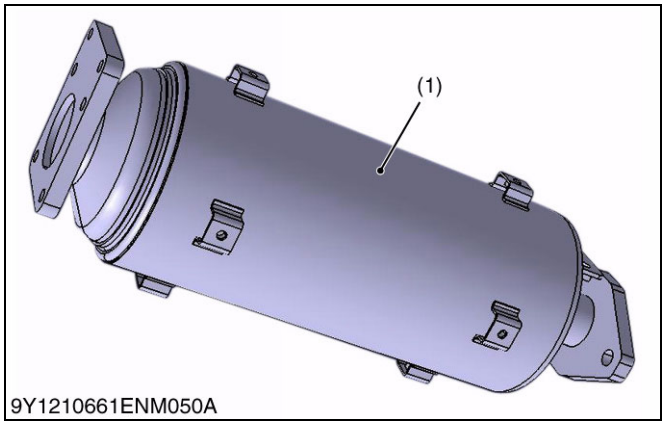


The air valve mixer is an air-fuel metering device, and is completely self-contained. The mixer is an air valve design, utilizing a relatively constant pressure drop, to draw fuel into the mixer from cranking, to full load. The mixer is mounted in the air stream, ahead of the throttle control device.

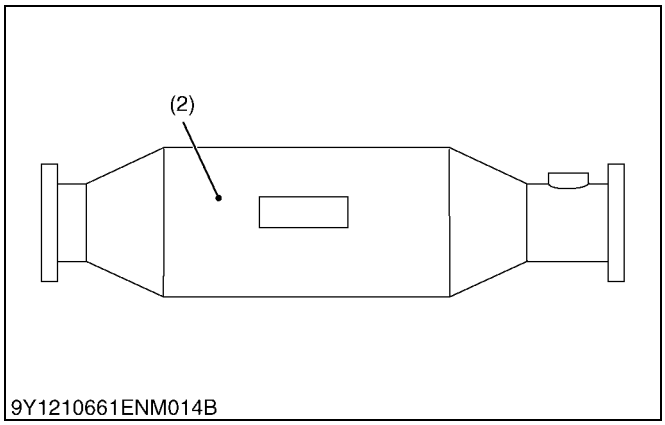
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5. EXHAUST SYSTEM

[1] THREE-WAY CATALYST



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A three-way catalyst is a catalyst that oxidizes HC to CO_2 and H_2O and also CO to CO_2 respectively and at the same time reduces NOx to N_2 near the stoichiometric ratio.

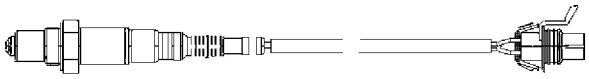
The main basic component of an exhaust gas purification system that uses a three-way catalyst is feedback control of air-fuel ratio by means of an oxygen sensor for the purpose of maximizing the emission purification efficiency characteristic with reference to the intake air-fuel ratio of the three-way catalyst.

KUBOTA engines have two kinds of catalytic devices, catalytic muffler and catalytic converter.

(1) Catalytic Muffler (2) Catalytic Converter

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[2] OXYGEN SENSOR



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An Oxygen sensor is an essential element of a feedback control of air-fuel ratio. The sensor has a mechanism in which a zirconia tube, which is a solid electrolyte, is exposed into the exhaust gas and the outside of a zirconia tube to an exhaust gas, the inside to an atmosphere with a known oxygen concentration respectively. Any difference produced between the two sides of the zirconia tube causes electromotive force to be generated. Oxygen sensor should be installed at the catalyst inlet and outlet each.

[Pre-Catalyst Oxygen Sensor]

When the air-fuel ratio is rich, HC, CO, H_2, etc. react with the oxygen (O_2) that remains in the exhaust gas. This causes a significant reduction of the concentration of the remaining oxygen, which considerably increases the ratio of it to the concentration of oxygen contained in the atmosphere inside, increasing the electromotive force. When the air-fuel ratio is lean, the process is the other way around, resulting in a significant drop in the electromotive force near the stoichiometric ratio. That is, the feedback control functions as electronic control that reduces the air-fuel ratio when it is judged to be on the rich side based on the electromotive force and increases the ratio when it is on the lean side.

[Post-Catalyst Oxygen Sensor]

A post-catalyst oxygen sensor provides information that can be used 1) to diagnose how efficiently a catalyst is using the available oxygen to react and 2) to adjust or trim pre-catalyst equivalence ratio (air-fuel ratio) to a desired level to optimize catalyst conversion efficiency.

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6. ELECTRICAL SYSTEM

[1] STARTING SYSTEM

(1) General

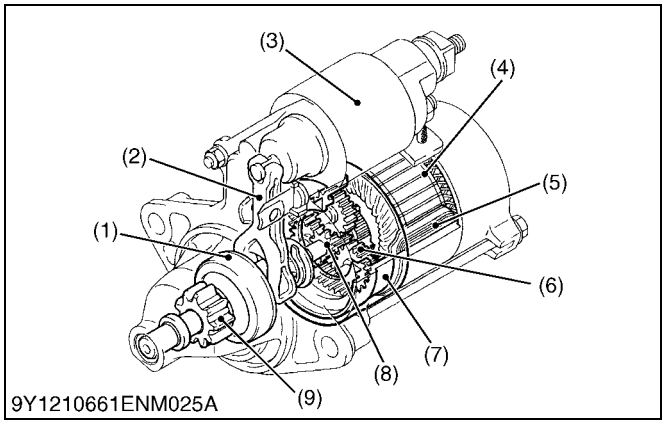
The starting device consists of the starter, starter switch, fuse, battery etc., and the outline of the basic operation is as the followings;

1. Voltage from battery is added to the **B** terminal of starter switch through the fuse.
2. If the starter switch is turned on, **B** terminal will be connected to **AC**, and the electrical current will flow to each load.
3. If the starter switch is turned to the starting position, **B** terminal will be connected to **AC**, **19**, and **50** will be connected to the **ST** terminal of starter (in case of the type with safety relay, it shall be connected via relay) to start the engine.
4. After the engine is started, if you have let your hand off the starter switch, it automatically returns to **ON** position.

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(2) Starter

[A] P Type Starters

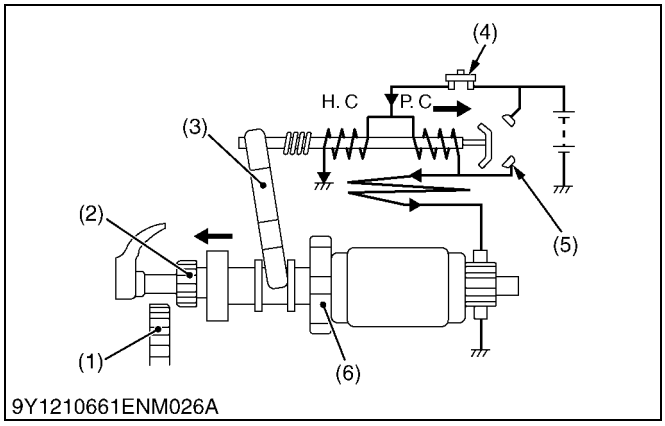


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- The P type starters are reduction type starters that uses a planetary gears. The P types use the same type of compact, high-speed motor as the reduction type, and have planetary gears between the clutch and armature.
  As a result, a more compact and lightweight starter design has been achieved.
- To engage with the engine, the magnetic switch moves the clutch forward via the drive lever.
  The clutch slides along a shaft (planetary carrier shaft) connected to the planetary gears.
- The P type starters are equipped with shock absorbers that reduce the shock generated during starter actuation.

(1) Clutch	(6) Planetary Gear
(2) Drive Lever	(7) Internal Gear
(3) Magnetic Switch	(8) Sun Gear
(4) Armature	(9) Pinion Gear
(5) Field Coil	

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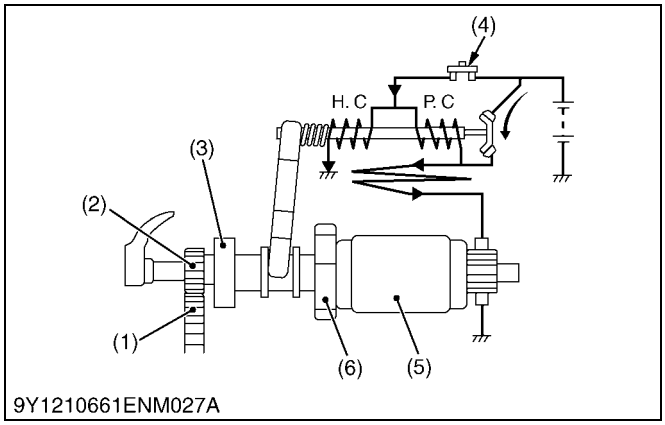
Starter Switch ON

When the starter switch is on, current flows to both the pull-in coil PC and holding coil HC, and the plunger is pulled in by the electromagnetic force generated in both coils.

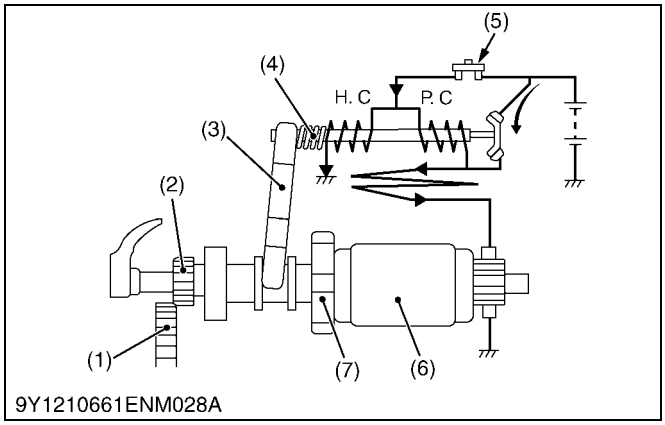
The pinion gear is thus pushed out to the left, and engages with the ring gear.

(1) Ring Gear	(4) Starter Switch
(2) Pinion Gear	(5) Plunger
(3) Drive Lever	(6) Planetary Gear

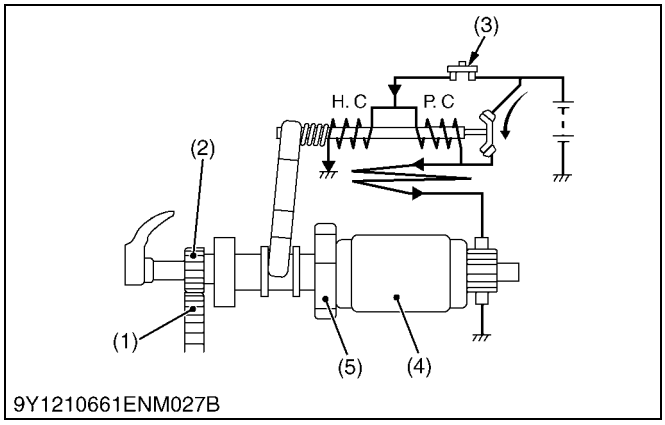
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9Y1210661ENM027A



9Y1210661ENM028A



9Y1210661ENM027B

When the Pinion Gear Engages with the Ring Gear without Collision

When the pinion gear engages with the ring gear at a certain position, the magnetic switch main contact closes, and a large current flows through the main contact to the armature.

The force of the armature spiral spline pushes the pinion gear forward, engaging the pinion gear with the ring gear to start the engine.

(1) Ring Gear
(2) Pinion Gear
(3) Clutch
(4) Starter Switch
(5) Armature

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When the Pinion Gear and Ring Gear Collide

If the pinion gear and ring gear teeth contact, the pinion gear cannot move any further. If this happens, the magnetic switch drive spring compresses, and the magnetic switch contact closes. As a result, the armature rotates at high torque, and the teeth alignment position slides. The compression force of the drive spring and the force of the armature spiral spline move the pinion gear forward, engaging the pinion gear with the ring gear to start the engine.

(1) Ring Gear
(2) Pinion Gear
(3) Drive Gear
(4) Drive Spring
(5) Starter Switch
(6) Armature
(7) Planetary Gear

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When the Engine is Started

When the engine starts, the clutch idles to prevent the ring gear from driving the armature in reverse.

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Starter Switch OFF

When the starter switch is turned **OFF**, the magnetic switch attraction is cancelled and the pinion gear is returned by the magnetic switch return spring.

The main contact then opens, interrupting the flow of current to the armature.

(1) Ring Gear
(2) Pinion Gear
(3) Starter Switch
(4) Armature
(5) Planetary Gear

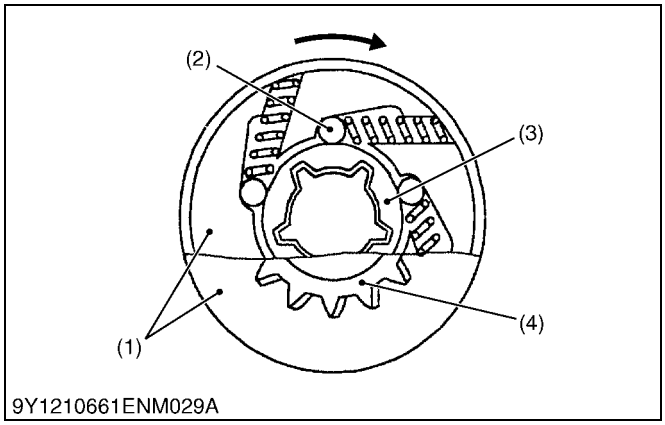
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[B] Overrunning Clutch

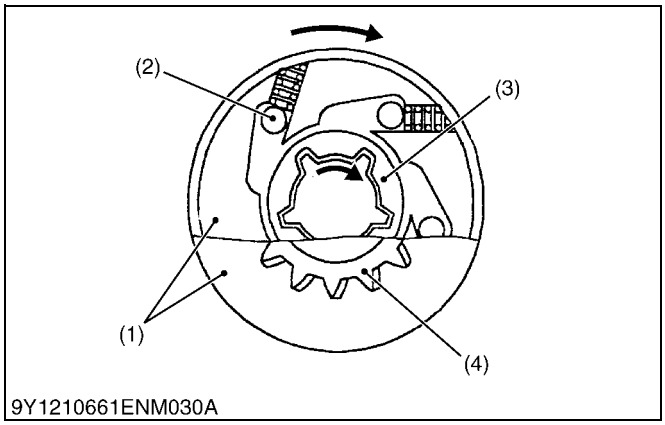
Function

In case that the pinion gear and ring gear are still inter meshed even when the engine is started, the motor will be forced to run in abnormal rotation, and the armature, brush, etc. will be damaged.In order to prevent such an error, the overrunning clutch will function as the device to let the pinion race against the armature shaft when the engine is started, and to shut off transmission of rotation of the engine to the motor.

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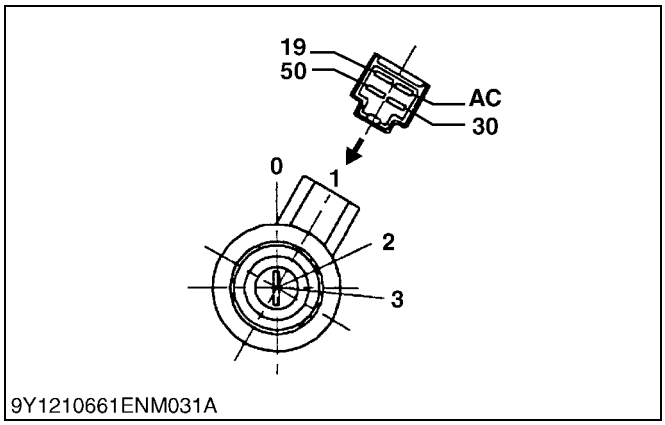
Action

1. When starting:
   If the outer is rotated in the arrow mark direction receiving rotation of the armature, the clutch roller will be pushed toward the narrower side of clearance between the outer concave side and the inner so that the outer and inner will be locked. The roller will function as a wedge between the inner and outer, and will transmit the rotation of the outer to the inner, and both will rotate in the same speed.
2. After the engine is started:
   When the pinion is forced to rotate by the ring gear, rotation of the inner (rotation of engine x gear ratio) will become faster than that of the outer (a number of rotation of armature), and the clutch roller will move toward the direction that compresses the spring.
   Consequently, clearance between the outer concave side and the inner becomes wide to prevent overrunning of the armature.
   (It is required to decrease the contact pressure of the pinion gear and ring gear to realize smooth separation of the pinion gear, and for the sake of this, the pinion gear must be in the state of racing.)

(1)	Outer (Integral Structure with Spline Tube)	(3)	Inner (Integral Structure with Pinion Tube)
(2)	Clutch Roller	(4)	Pinion Gear

9Y1210661ENM0045US0

(3) Starter Switch



9Y1210661ENM031A

Starter Switch

Starter switch is an important part comprising of the starting device of engine. Particularly, as seizing of the starter may be incurred due to failure of the starter switch, careful consideration is required for the installation position, place, and direction, so that rain or cleaning water should not directly splash on the starter switch.

As the standard part of KUBOTA engine, the starter switch in below figure is recommended.

[Connection Diagram]

Position	19	30	50	AC
0				
1		●		●
2	●	●		●
3	●	●	●	●

9Y1210661ENM032US

9Y1210661ENM0046US0

(4) Starter Safety System

The ECU can be configured for either auto cranking (crank until starting) or crank limiting (maximum crank time and disabling of starter if frequency and number of tries is too high).

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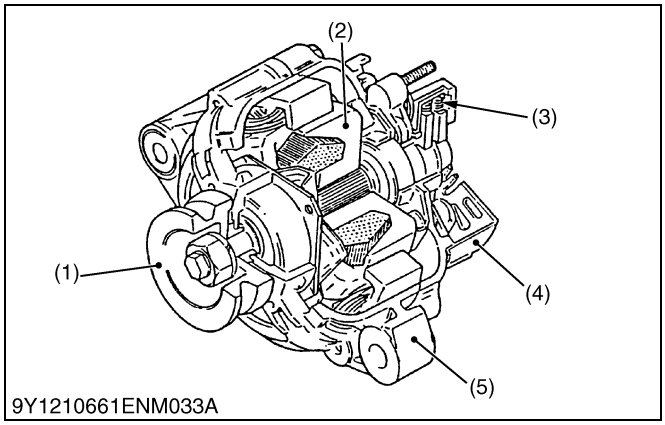
[2] CHARGING SYSTEM

(1) General

The function of the charging device is to charge batteries.

9Y1210661ENM0048US0

(2) IC Regulator Built-in Type Alternator



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The alternator is the incorporated with an IC regulator, this has been made small size and light weight by the semiconductor technique of the IC regulator.

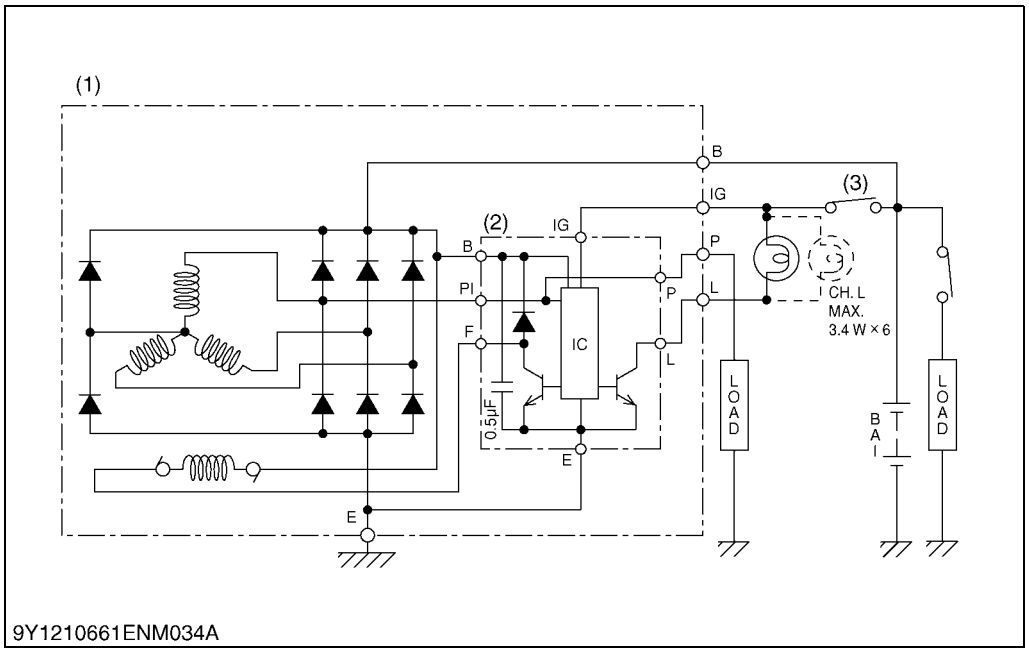
The cooling property and safety is improved by incorporating the cooling fan and roller that is an integral structure.

Further, the serviceability is also improved by facilitating mounting and removal of the rectifier and IC regulator.

(1) Pulley
(2) Rotor
(3) Brush
(4) Cover
(5) Drive and Frame

9Y1210661ENM0049US0

D2 Type Regulator



9Y1210661ENM034A

(1) Alternator Assembly
(2) IC Regulator
(3) Key Switch

IC regulator has a special feature that makes it possible to interrupt field current by using the transistor or IC instead of the contact-point-type regulator.

IC regulator has the special features as follows:

1. Readjustment for this regulator is unnecessary because the control voltage does not change over time. Further, vibration-proof property and durability is excellent because IC regulator has no moving parts.
2. Since IC regulator has over-temperature compensation property, which makes the control voltage low if the temperature is increased, it makes it possible to properly charge the batteries.
   The circuit inside IC regulator is as shown in the following figure.
   It consists of the monolithic IC-incorporated hybrid IC. (Since the inside circuit of the monolithic IC is extremely complex, it is described as **M.IC** circuit.)
   Tr1 has the function as the contact point to control field electrical current, and as the charging lamp relay to light the charging lamp.
   M.IC controls **Tr1** and **Tr2** by detecting decrease of the output voltage of alternator, decrease of the **L** terminal voltage, disconnection of the rotor coil, etc.

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Charge Light Control

Turns the charge light **ON** and **OFF** in accordance with alternator power generation.

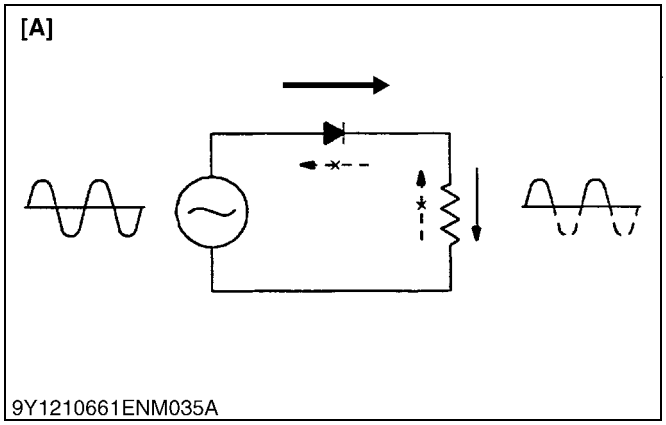
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Specification of Alternator with IC (Incorporated with) Regulator

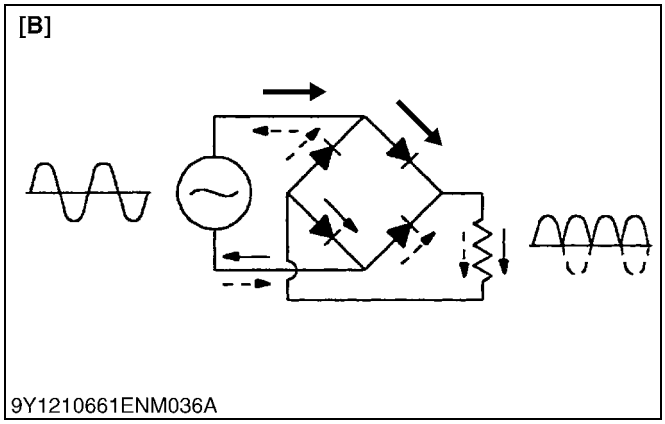
Nominal voltage	12 V
Maximum output	40 A, 60 A
Rotational direction	Right as seen from pulley side
Armature wiring	3 phase, Y wiring
Rectifying system	Total wave rectification
min^{-1} (rpm) at no load (when cold)	14 V at 0 A 1050 to 1350 min^{-1} (rpm)
min^{-1} (rpm) at max. output (when cold)	14 V at maximum output below 4000 min^{-1} (rpm)

Generating capacity will be determined by rpm of engine and pulley ratio.

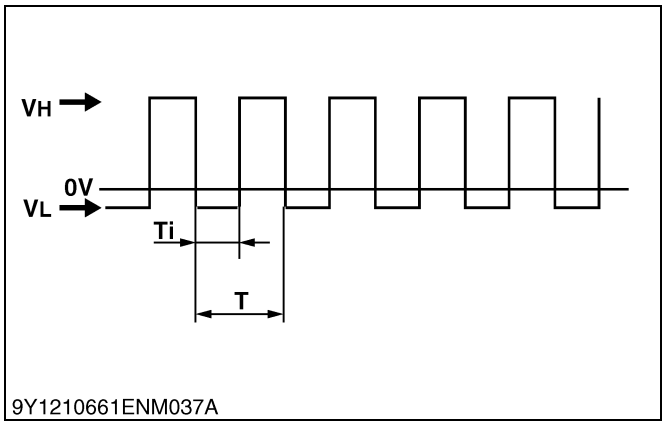
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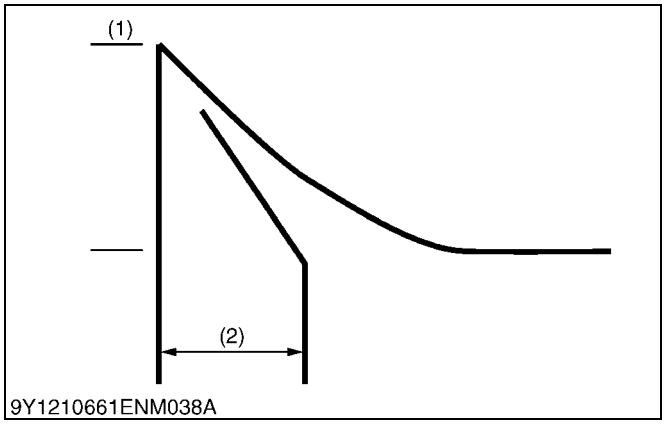
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Total Wave Rectification

In case of the generator for mobile equipment of which purpose is to charge the batteries, alternating current cannot be used as it is. Because of this, it is required to conduct the action called rectification so that the alternating current can be changed to direct current. Alternator conducts rectification by means of diode.

If the voltage is applied to diode in the normal direction, enough electrical current can flow even by small voltage, however if applied in the reverse direction, it inhibits the reserve flow of electrical current.

Using this property, alternate current generated in the stator coil is changed to the direct current.

As for the rectification using diode, there are two methods, i.e., "half-wave rectification" that takes out only positive portion of alternate current, and 'total-wave rectification' that rectifies both positive and negative current and change to the direct current.

[A] Half-wave Rectification **[B] Total-wave Rectification**

9Y1210661ENM0053US0

Alternator P Terminal

P terminal waveform: The alternator **P** terminal outputs rotation signals required by a tachometer, etc.

The **P** terminal corresponds with one phase of the alternator stator and the output waveform during power generation is a waveform equivalent to the rectangular wave with a frequency in proportion to the number of revolutions of the alternator.

Frequency (1/T):	**Number of Revolutions of Alternator [rpm] / 10 [Hz]**
Duty (Ti/T):	**Approx. 50 %**
VH (average):	**About +0 to 2 V with Reference to the Alternator B Terminal Voltage (Average)**
VL:	**About −2 to 0 V**

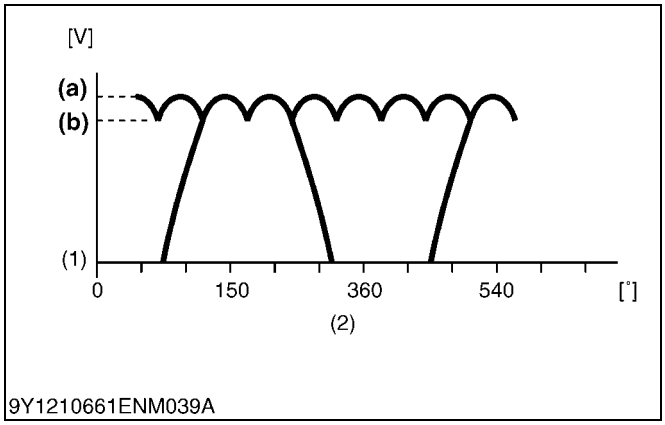
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■ **NOTE**

- **As with the B terminal waveform, the P terminal waveform includes noise, which varies depending on the number of revolutions, output and wiring (see the waveform in a separate material).**
- **Surge voltage may be generated by any charging cable disconnection (especially with high number of revolutions / high output), etc.**

(1) Approx. 150 V (2) Approx. 180 ms

9Y1210661ENM0055US0



9Y1210661ENM039A

Surge voltage waveform with any charging cable disconnection.

- May be VHmin = 6.5 V in high electric load shedding or unloaded condition with the battery fully charged.

(1) Voltage
(2) Angle of Rotation (°)
(a) VH max
(b) VH min

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Load Connected To the P Terminal

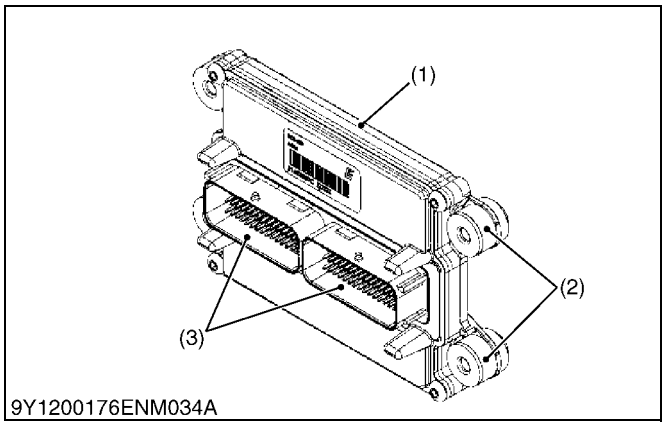
P terminal output current: 0.5 A max (average current).

■ **NOTE**

- **Ensure that there is no load short circuit or wrong wiring.**
- **Do not connect inductive or capacitive load (connection of such load subject to discussion of the specification).**
- **When detecting a waveform, take the noise and VHmin into consideration.**
- **Take the surge voltage into consideration for the input of the load.**
- **Use the actual equipment for sufficient check of the operation of the load.**

9Y1210661ENM0057US0

[3] ENGINE CONTROL UNIT (ECU)

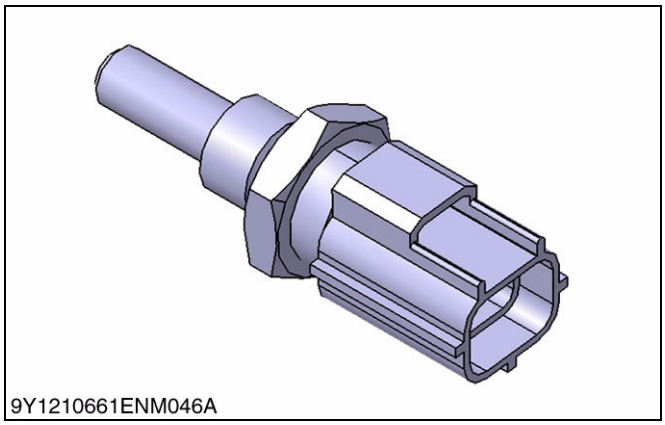


9Y1200176ENM034A

The ECU will use signal inputs, from the engine sensors, to control the fuel metering and speed control, while the engine is running. As well, the ECU will provide diagnostic control, over the fuel system.

9Y1210661ENM0025US0

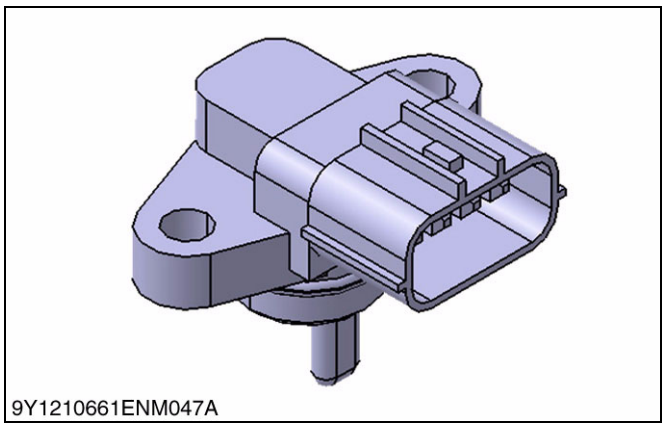
[4] WATER TEMPERATURE SENSOR


9Y1210661ENM046A

Ignition timing, fuel rate, and boost levels can be configured to vary with engine coolant temperature. This is typically done at very cold or very hot conditions. Coolant temperature is also used in the airflow models in the ECU.

9Y1210661ENM0058US0

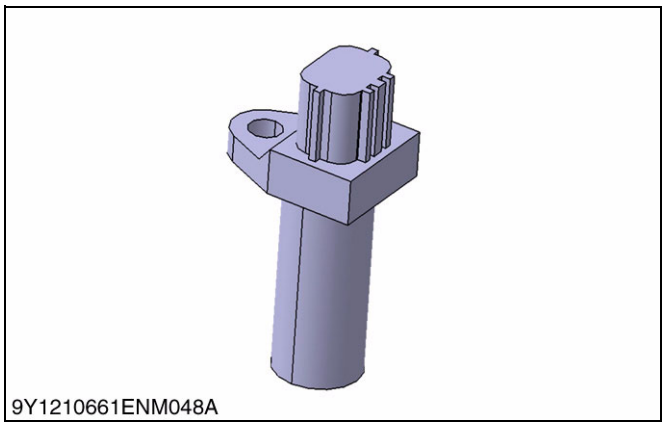
[5] TEMPERATURE AND MANIFOLD ABSOLUTE PRESSURE SENSOR (TMAP SENSOR)


9Y1210661ENM047A

TMAP sensor is mounted in the intake manifold and measures the absolute pressure as well as the temperature of the air / fuel stream. MAP data is used by the ECU for calculating airflow pressure. The temperature information from the TMAP is used for a density correction in the mass air flow calculation.

9Y1210661ENM0059US0

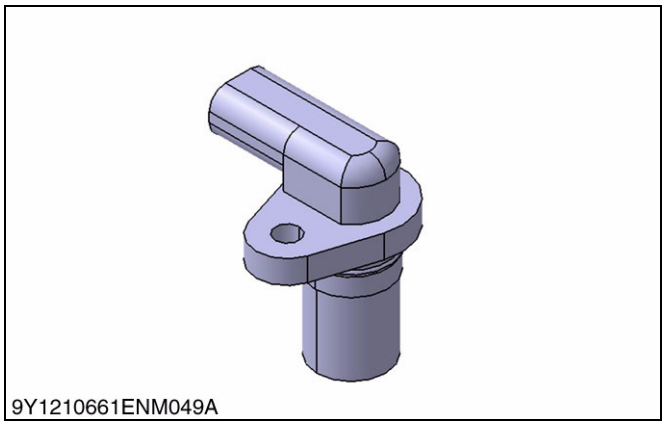
[6] CRANKSHAFT POSITION SENSOR


9Y1210661ENM048A

The Crankshaft Position Sensor provides engine speed information.

9Y1210661ENM0060US0

[7] CAMSHAFT POSITION SENSOR


9Y1210661ENM049A

The Camshaft Position sensor informs the ECU which cylinders are in compression to signal spark timing.

9Y1210661ENM0061US0

[8] KNOCK SENSOR


9Y1210661ENM017A

The knock sensor is used to detect detonation through mechanical vibration in the engine block and / or cylinder heads and provide feedback for the ignition system to retard spark to reduce knock intensity. In most applications the knock sensor is used to protect the engine from damage that can be caused from detonation or knock based on fixed spark advance.

The Knock Sensor is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the Engine Control Unit (ECU) to use. The knock sensor sends a base or "no knock" signal to the ECU, when knocking does occur the sensor detects the increased vibration, and increases the voltage output to the ECU. When the ECU receives the voltage change, the ECU will slightly retard the timing, until such time, the knocking no longer exists.

9Y1210661ENM0026US0

[9] IGNITION COIL


9Y1210661ENM044A

Ignition coil is a transformer to generate high electric voltage necessary for the ignition. Around the iron core of multi-layer thin crude steel plates, secondary coil is wound, on whose outside, in the same direction, primary coil is wound. The empty space in the case is filled with resin for electric insulation and good heat radiation.

The ignition timing is controlled by ECU and the high voltage is applied to the spark plugs by the ECU signals.

9Y1210661ENM0062US0

SERVICING

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1. TROUBLESHOOTING

[1] FOR GENERAL

Symptom	Probable Cause	Solution	Reference Page
Engine Will Not Turn Over	Engine jammed	Check engine to find the problem and repair it	–
	Battery discharged	Charge	–
	Starter malfunctioning	Repair or replace	1-S23
	Wires disconnected	Reconnect	–
Engine Turns Over Slowly but Does Not Start	Increased resistance of moving parts	Repair or replace	–
	Excessively high viscosity engine oil at low temperature	Use specified engine oil	G-7
Engine Turns Over at Normal Speed but Does Not Start	Compression leak	Check the compression pressure and repair	1-S12
	Improper valve clearance	Adjust	1-S23
	Damaged ignition coil	Replace	1-S20
	Damaged spark plug	Adjust spark plug gap or replace	G-12
	Clogged air cleaner	Clean or replace	G-12
Rough Low-Speed Running and Idling	Damaged ignition coil	Replace	1-S20
	Damaged spark plug	Adjust spark plug gap or replace	G-12
	Improper valve clearance	Adjust	1-S23
Rough High-Speed Running	Damaged spark plug	Adjust spark plug gap or replace	G-12
	Damaged ignition coil	Replace	1-S20
Engine Speed Does Not Increase	Clogged air cleaner	Clean or replace	–
	Damaged ignition coil	Replace	1-S20
	Damaged throttle body	Replace	–
	Breather tube has separated	Attach correctly	–
	Improper input signal to ECU	Check the wire harness	–
Deficient Output	Improper intake or exhaust valve sealing	Replace	1-S42
	Improper valve clearance	Adjust	1-S13
	Piston ring and cylinder worn	Replace	1-S50, 1-S56
	Clogged air cleaner	Clean or replace	G-12
Engine Noise	Improper valve clearance	Adjust	1-S13
	Spark knock due to low-octane fuel or carbon	Use higher-octane fuel and remove carbon	–
	Rattles from loosely mounted external components	Retighten	–

Symptom	Probable Cause	Solution	Reference Page
Exhaust Flames	Damaged ignition coil	Replace	1-S20
	Damaged spark plug	Adjust spark plug or replace	G-12
	Wires disconnected or damaged wire	Reconnect / replace	–
	Bad connection of ignition coil and spark plug	Reconnect	–

9Y1210661ENS0001US0

[2] FOR GASOLINE FUEL

Symptom	Probable Cause	Solution	Reference Page
Engine Turns Over at Normal Speed but Does Not Start	No fuel	Fill fuel	–
	Damaged fuel system	Check fuel line and electronic throttle body and repair	–

9Y1210661ENS0002US0

[3] FOR LPG FUEL

Symptom	Probable Cause	Solution	Reference Page
Engine Will Not Turn Over	Damaged vaporizer	Replace	–
	Damaged lock off valve	Replace	–
Engine Turns Over at Normal Speed but Does Not Start	No LPG fuel	Fill LPG fuel Check LPG tank valve Check lock off valve	–
Rough Low-Speed Running and Idling	Shortage of gas supply	Fill LPG fuel Check lock off valve	–
Defection Output	LPG density is rich or lean	Repair or replace of fuel system Replace vaporizer	–

9Y1210661ENS0003US0

2. SERVICING SPECIFICATIONS

ENGINE BODY

Item		Factory Specification	Allowable Limit
Valve Clearance (Cold)		0.145 to 0.185 mm 0.00571 to 0.00728 in.	–
Compression Pressure	–	1.27 MPa 13.0 kgf/cm^2 185 psi	0.88 MPa 9.0 kgf/cm^2 130 psi
	Variance Among Cylinder	–	10% or less
Top Clearance		1.2 to 1.5 mm 0.048 to 0.059 in.	–
Cylinder Head Surface	Flatness	–	0.05 mm 0.002 in.
Valve Recessing (Intake and Exhaust)		−0.050 to 0.25 mm −0.0020 to 0.0098 in.	0.40 mm 0.016 in.
Valve Stem to Valve Guide	Clearance	0.035 to 0.065 mm 0.0014 to 0.0025 in.	0.10 mm 0.0039 in.
• Valve Stem	O.D.	6.960 to 6.975 mm 0.2741 to 0.2746 in.	–
• Valve Guide	I.D.	7.010 to 7.025 mm 0.2760 to 0.2765 in.	–
Valve Face	Angle (Intake)	1.0 rad 60 °	–
	Angle (Exhaust)	1.0 rad 60 °	–
Valve Seat	Angle (Intake)	1.0 rad 60 °	–
	Angle (Exhaust)	1.0 rad 60 °	–
	Width	2.12 mm 0.0835 in.	–
Valve Timing (Intake Valve)	Open	0.38 rad 22 ° before T.D.C.	–
	Close	0.82 rad 47 ° after B.D.C.	–
Valve Timing (Exhaust Valve)	Open	0.91 rad 52 ° before B.D.C.	–
	Close	0.30 rad 17 ° after T.D.C.	–

Item		Factory Specification	Allowable Limit
Valve Spring	Free Length	35.1 to 35.6 mm 1.39 to 1.40 in.	34.8 mm 1.37 in.
	Tilt	–	1.0 mm 0.039 in.
	Setting Load / Setting Length	74 N / 31.0 mm 7.5 kgf / 31.0 mm 17 lbf / 1.22 in.	63 N / 31.0 mm 6.4 kgf / 31.0 mm 14 lbf / 1.22 in.
Rocker Arm Shaft to Rocker Arm	Oil Clearance	0.016 to 0.045 mm 0.00063 to 0.0017 in.	0.10 mm 0.0039 in.
• Rocker Arm Shaft	O.D.	11.973 to 11.984 mm 0.47138 to 0.47181 in.	–
• Rocker Arm	I.D.	12.000 to 12.018 mm 0.47244 to 0.47314 in.	–
Push Rod	Alignment	–	0.25 mm 0.0098 in.
Tappet to Tappet Guide Bore	Oil Clearance	0.020 to 0.062 mm 0.00079 to 0.0024 in.	0.07 mm 0.003 in.
• Tappet	O.D.	19.959 to 19.980 mm 0.78579 to 0.78661 in.	–
• Tappet Guide Bore	I.D.	20.000 to 20.021 mm 0.78741 to 0.78822 in.	–
Timing Gear			
• Crank Gear to Idle Gear 1	Backlash	0.0320 to 0.115 mm 0.00126 to 0.00452 in.	0.15 mm 0.0059 in.
• Idle Gear 1 to Cam Gear	Backlash	0.0360 to 0.114 mm 0.00142 to 0.00448 in.	0.15 mm 0.0059 in.
• Idle Gear 1 to Injection Pump Gear	Backlash	0.0340 to 0.116 mm 0.00134 to 0.00456 in.	0.15 mm 0.0059 in.
• Idle Gear 1 to Idle Gear 2	Backlash	0.0330 to 0.117 mm 0.00130 to 0.00460 in.	0.15 mm 0.0059 in.
• Idle Gear 2 to Governor Gear	Backlash	0.0300 to 0.117 mm 0.00119 to 0.00460 in.	0.15 mm 0.0059 in.
Idle Gear			
• Idle Gear 1	Side Clearance	0.20 to 0.51 mm 0.0079 to 0.020 in.	0.80 mm 0.031 in.
• Idle Gear 2	Side Clearance	0.20 to 0.51 mm 0.0079 to 0.020 in.	0.80 mm 0.031 in.
Camshaft	Side Clearance	0.0700 to 0.220 mm 0.00276 to 0.00866 in.	0.30 mm 0.012 in.
	Alignment	–	0.01 mm 0.0004 in.

Item		Factory Specification	Allowable Limit
Cam Height	Intake	28.80 mm 1.134 in.	28.75 mm 1.132 in.
	Exhaust	29.00 mm 1.142 in.	28.95 mm 1.140 in.
Camshaft Journal to Cylinder Block Bore	Oil Clearance	0.050 to 0.091 mm 0.0020 to 0.0035 in.	0.15 mm 0.0059 in.
• Camshaft Journal	O.D.	35.934 to 35.950 mm 1.4148 to 1.4153 in.	–
• Cylinder Block Bore	I.D.	36.000 to 36.025 mm 1.4174 to 1.4183 in.	–
Idle Gear Shaft to Gear Bushing • Idle Gear 1	Oil Clearance	0.020 to 0.054 mm 0.00079 to 0.0021 in.	0.10 mm 0.0039 in.
• Idle Gear Bushing	I.D.	26.000 to 26.021 mm 1.0237 to 1.0244 in.	–
• Idle Gear Shaft 1	O.D.	25.967 to 25.980 mm 1.0224 to 1.0228 in.	–
• Idle Gear 2	Oil Clearance	0.020 to 0.054 mm 0.00079 to 0.0021 in.	0.10 mm 0.0039 in.
• Idle Gear Bushing	I.D.	26.000 to 26.021 mm 1.0237 to 1.0244 in.	–
• Idle Gear Shaft 2	O.D.	25.967 to 25.980 mm 1.0224 to 1.0228 in.	–
Piston Pin Bore	I.D.	22.000 to 22.013 mm 0.86615 to 0.86665 in.	22.03 mm 0.8673 in.
Piston Pin to Small End Bushing	Oil Clearance	0.014 to 0.038 mm 0.00056 to 0.0014 in.	0.15 mm 0.0059 in.
• Piston Pin	O.D.	22.002 to 22.011 mm 0.86622 to 0.86657 in.	–
• Small End Bushing	I.D.	22.025 to 22.040 mm 0.86713 to 0.86771 in.	–
Piston Pin to Small End Bushing (Spare Parts)	Oil Clearance	0.0650 to 0.144 mm 0.00256 to 0.00566 in.	0.15 mm 0.0059 in.
• Small End Bushing	I.D.	22.076 to 22.146 mm 0.86914 to 0.87188 in.	–
Piston Ring Gap	Top Ring	0.30 to 0.45 mm 0.012 to 0.017 in.	1.25 mm 0.0492 in.
	Second Ring	0.30 to 0.45 mm 0.012 to 0.017 in.	1.25 mm 0.0492 in.
	Oil Ring	0.20 to 0.70 mm 0.0079 to 0.027 in.	1.25 mm 0.0492 in.

Item		Factory Specification	Allowable Limit
Piston Ring to Piston Ring Groove	Top Ring (Clearance)	0.040 to 0.080 mm 0.0016 to 0.0031 in.	0.2 mm 0.008 in.
	Second Ring (Clearance)	0.030 to 0.070 mm 0.0012 to 0.0027 in.	0.2 mm 0.008 in.
	Oil Ring (Clearance)	0.020 to 0.19 mm 0.00079 to 0.0074 in	0.2 mm 0.008 in
Connecting Rod	Alignment	–	0.05 mm 0.002 in.
Crankshaft	Side Clearance	0.15 to 0.31 mm 0.0059 to 0.012 in.	0.50 mm 0.020 in.
	Alignment	–	0.02 mm 0.0008 in.
Crankpin to Crankpin Bearing	Oil Clearance	0.065 to 0.091 mm 0.0026 to 0.0035 in.	0.20 mm 0.0079 in.
• Crankpin	O.D.	39.959 to 39.975 mm 1.5732 to 1.5738 in.	–
• Crankpin Bearing	I.D.	40.040 to 40.050 mm 1.5764 to 1.5767 in.	–
Crankshaft Journal to Crankshaft Bearing 1	Oil Clearance	0.0340 to 0.114 mm 0.00134 to 0.00448 in	0.20 mm 0.0079 in.
• Crankshaft Journal	O.D.	47.934 to 47.950 mm 1.8872 to 1.8877 in	–
• Crankshaft Bearing 1	I.D.	47.984 to 48.048 mm 1.8892 to 1.8916 in.	–
Crankshaft Journal to Crankshaft Bearing 2	Oil Clearance	0.034 to 0.095 mm 0.0014 to 0.0037 in.	0.20 mm 0.0079 in.
• Crankshaft Journal	O.D.	47.934 to 47.950 mm 1.8872 to 1.8877 in.	–
• Crankshaft Bearing 2	I.D.	47.984 to 48.029 mm 1.8892 to 1.8909 in.	–
Crankshaft Journal to Crankshaft Bearing 3	Oil Clearance	0.0340 to 0.103 mm 0.00134 to 0.00405 in.	0.20 mm 0.0079 in.
• Crankshaft Journal	O.D.	51.921 to 51.940 mm 2.0442 to 2.0448 in.	–
• Crankshaft Bearing 3	I.D.	51.974 to 52.024 mm 2.0463 to 2.0481 in.	–
Cylinder Liner [Standard]	I.D.	79.000 to 79.019 mm 3.1103 to 3.1109 in.	79.15 mm 3.116 in.
Cylinder Liner [Oversize: 0.5 mm (0.02 in.)]	I.D.	79.500 to 79.519 mm 3.1300 to 3.1306 in.	79.65 mm 3.136 in.

LUBRICATING SYSTEM

Item		Factory Specification	Allowable Limit
Engine Oil Pressure	At Idle Speed	49 kPa 0.50 kgf/cm^2 7.1 psi	–
	At Rated Speed	196 to 441 kPa 2.00 to 4.49 kgf/cm^2 28.5 to 63.9 psi	147 kPa 1.50 kgf/cm^2 21.3 psi
Inner Rotor to Outer Rotor	Clearance	0.060 to 0.18 mm 0.0024 to 0.0071 in.	–
Outer Rotor to Pump Body	Clearance	0.100 to 0.180 mm 0.00394 to 0.00708 in.	–
Inner Rotor to Cover	Clearance	0.025 to 0.075 mm 0.00099 to 0.0029 in	–

COOLING SYSTEM

Item		Factory Specification	Allowable Limit
Fan Belt	Tension	7.0 to 9.0 mm / 98 N 0.28 to 0.35 in. / 98 N (10 kgf, 22 lbf)	–
Thermostat	Valve Opening Temperature (At Beginning)	69.5 to 72.5 °C 157.1 to 162.5 °F	–
	Valve Opening Temperature (Opened Completely)	85 °C 185 °F	–
Radiator Cap	Pressure Falling Time	10 seconds or more 88 → 59 kPa 0.89 → 0.61 kgf/cm^2 12 → 8.6 psi	–
Radiator	Weak Leakage Test Pressure (210 kPa, 2.14 kgf/cm^2, 30.5 psi)	No leak at specified pressure	–

IGNITION SYSTEM

Item		Factory Specification	Allowable Limit
Ignition Timing	Gasoline fuel	0.45 rad (26 °) before T.D.C. / 3000 min^{-1} (rpm)	–
		0.17 rad (10 °) before T.D.C. / 800 min^{-1} (rpm)	–
	LPG fuel	0.35 rad (20 °) before T.D.C. / 3000 min^{-1} (rpm)	–
		0.17 rad (10 °) before T.D.C. / 800 min^{-1} (rpm)	–
Crank Sensor	Resistance	1.85 to 2.45 kΩ at 20 °C (68 °F)	–
Cam Sensor	Resistance	470 to 530 Ω at 20 °C (68 °F)	–
Spark Plug (NGK: IFR6F8DN)	Plug Gap	0.70 to 0.80 mm 0.028 to 0.031 in.	–
Resistance of Ignition Coil	Primary (+) - (−)	0.63 to 0.77 Ω at 25 °C (77 °F)	–
	Secondary Side (Primary (+) - Plug Cap)	7.29 to 8.91 kΩ at 25 °C (77 °F)	–

ELECTRICAL SYSTEM

Item		Factory Specification	Allowable Limit
Starter	Commutator (O.D.)	28.0 mm 1.10 in.	27.0 mm 1.06 in.
	Difference (O.D.)	Less than 0.05 mm 0.002 in.	0.4 mm 0.02 in.
	Mica (Undercut)	0.50 to 0.80 mm 0.020 to 0.031 in.	0.20 mm 0.0079 in.
	Brush (Length)	16.0 mm 0.630 in.	10.5 mm 0.413 in.
Alternator	No-load Voltage	14.2 V to 14.8 V at 5000 min^{-1} (rpm), 25 °C (77 °F)	–
	Stator (Resistance)	Less than 1.0 Ω	–
	Rotor (Resistance)	2.9 Ω	–
	Slip Ring (O.D.)	14.4 mm 0.567 in.	14.0 mm 0.551 in.
	Brush (Length)	10.0 mm 0.394 in.	8.4 mm 0.33 in.

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3. TIGHTENING TORQUES

Screws, bolts and nuts must be tightened to the specified torque using a torque wrench, several screws, bolts and nuts such as those used on the cylinder head must be tightened in proper sequence and the proper torque.

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[1] TIGHTENING TORQUES FOR GENERAL USE SCREWS, BOLTS AND NUTS

■ **NOTE**

- **For "*" marked screws, bolts and nuts on the table, apply engine oil to their threads and seats before tightening.**
- **The letter "M" in Size × Pitch means that the screw, bolt or nut dimension stands for metric. The size is the nominal outside diameter in mm of the threads. The pitch is the nominal distance in mm between two threads.**

Item	Dimension × Pitch	N·m	kgf·m	lbf·ft
Cylinder head screw	M10 × 1.25	63.7 to 68.6	6.50 to 6.99	47.0 to 50.5
*Connecting rod screw	M8 × 1.0	41.2 to 46.1	4.21 to 4.70	30.4 to 34.0
*Flywheel screw	M10 × 1.25	53.9 to 58.8	5.50 to 5.99	39.8 to 43.3
*Fan drive pulley screw	M14 × 1.5	235 to 245	24.0 to 24.9	174 to 180
*Main bearing case screw 1	M8 × 1.25	29.4 to 34.3	3.00 to 3.49	21.7 to 25.2
*Main bearing case screw 2	M9 × 1.25	49.0 to 53.9	5.00 to 5.49	36.2 to 39.7
*Cylinder head cover cap nut	M7 × 1.0	6.9 to 8.8	0.71 to 0.89	5.1 to 6.4
Oil pressure switch	PT 1/8	14.7 to 19.6	1.50 to 1.99	10.9 to 14.4
Bearing case cover mounting screw	M6 × 1.0	9.81 to 11.3	1.00 to 1.15	7.24 to 8.33
*Rocker arm bracket nut	M7 × 1.0	21.6 to 26.5	2.21 to 2.70	16.0 to 19.5
*Idle gear shaft mounting screw	M6 × 1.0	9.81 to 11.3	1.00 to 1.15	7.24 to 8.33
Injection pump gear cap nut	M12 × 1.5	58.8 to 68.6	6.00 to 6.99	43.4 to 50.5
Drain plug	M12 × 1.25	32.4 to 37.3	3.31 to 3.80	23.9 to 27.5
Rotation sensor mounting screw	M6 × 1.0	3.0 to 6.0	0.31 to 0.61	2.3 to 4.4
Spark plug	M14 × 1.25	24.5 to 29.4	2.50 to 2.99	18.1 to 21.6
Ignition coil mounting screw / nut	M6 × 1.0	9.81 to 11.3	1.00 to 1.15	7.24 to 8.33
Knock sensor mounting screw	M6 × 1.0	15.0 to 25.0	1.53 to 2.54	11.1 to 18.4
Water temperature sensor	M12 × 1.5	16.7 to 19.6	1.71 to 1.99	12.4 to 14.4
PCV Valve	M16 × 1.5	16.0 to 24.0	1.64 to 2.44	11.8 to 17.7
Exhaust manifold mounting nut	M7 × 1.0	15.7 to 18.6	1.60 to 1.89	11.6 to 13.7
Outlet of exhaust manifold nut	M8 × 1.25	29.4 to 34.3	3.00 to 3.49	21.7 to 25.2
Starter **B** terminal nut	M8 × 1.25	5.88 to 11.8	0.600 to 1.20	4.34 to 8.70
Alternator's pulley nut	–	58.4 to 78.9	5.95 to 8.05	43.1 to 58.2
Inlet of catalytic muffler / converter mounting screw / nut	M10 × 1.25	48.1 to 55.9	4.91 to 5.70	35.5 to 41.2
Outlet of catalytic muffler / converter mounting screw / nut	M12 × 1.25	77.5 to 90.2	7.91 to 9.19	57.2 to 66.5
LPG in	–	19.6 to 39.2	2.00 to 3.99	14.5 to 28.9

9Y1210661ENS0005US0

[2] TIGHTENING TORQUES FOR GENERAL USE SCREWS, BOLTS

If the tightening torque is not specified, refer to the table below for the none specified torques values.

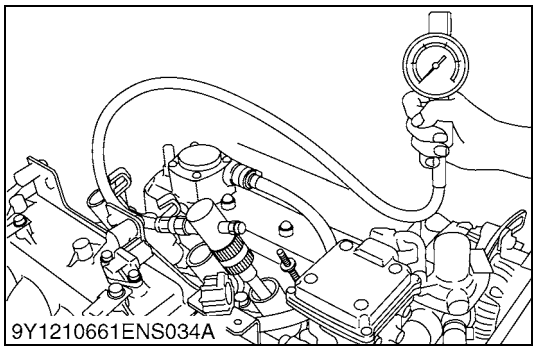
Indication on top of bolt	4 No-grade or 4T			7 7T		
Unit	**N·m**	**kgf·m**	**lbf·ft**	**N·m**	**kgf·m**	**lbf·ft**
M6	7.9 to 9.3	0.80 to 0.95	5.8 to 6.8	9.81 to 11.2	1.00 to 1.15	7.24 to 8.31
M8	18 to 20	1.8 to 2.1	13 to 15	24 to 27	2.4 to 2.8	18 to 20
M10	40 to 45	4.0 to 4.6	29 to 33	49 to 55	5.0 to 5.7	37 to 41
M12	63 to 72	6.4 to 7.4	47 to 53	78 to 90	7.9 to 9.2	58 to 66

9Y1210661ENS0090US0

4. CHECKING, DISASSEMBLING AND SERVICING

[1] CHECKING AND ADJUSTING

(1) Engine Body



Compression Pressure

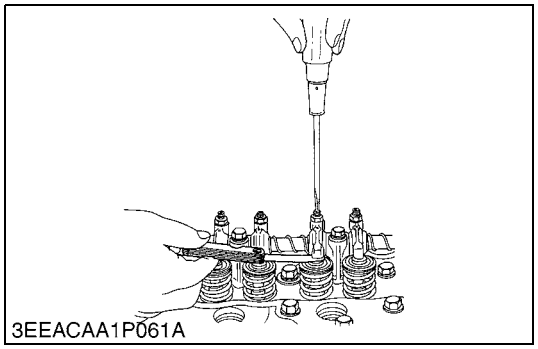
1. Run the engine until it is warmed up.
2. Stop the engine.
3. Remove the air cleaner, the catalytic muffler / converter and all spark plugs.
4. Set a compression tester with the adaptor to the spark plug hole.
5. Run the engine with the starter for 5 to 10 seconds keeping throttle valve fully open and read the maximum compression pressure.
6. Repeat steps 4 and 5 for each cylinder.
7. If the measurement is below the allowable limit, apply a small amount of oil to the cylinder wall through the spark plug hole and measure the compression pressure again.
8. If the compression pressure is still less than the allowable limit, check the top clearance, valve clearance and cylinder head.
9. If the compression pressure increases after applying oil, check the cylinder wall and piston rings.

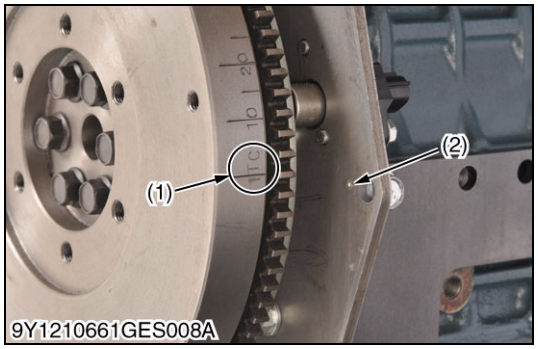
■ **NOTE**

- **Check the compression pressure with the specified valve clearance.**
- **Always use a fully charged battery for performing this test.**
- **Variances in cylinder compression values should be under 10 %.**
- **Replace the catalytic muffler / converter gasket with a new one**

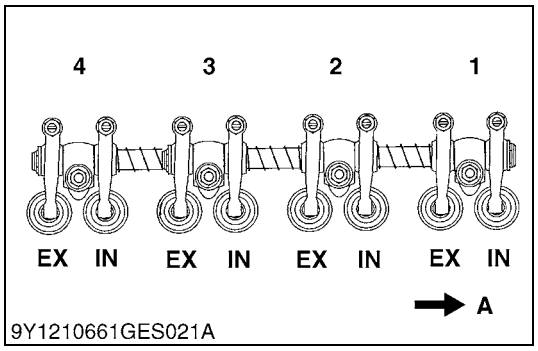
Compression pressure	Factory specification	1.27 MPa 13.0 kgf/cm^2 185 psi
	Allowable limit	0.88 MPa 9.0 kgf/cm^2 130 psi

9Y1210661ENS0006US0


3EEACAA1P061A



9Y1210661GES008A



9Y1210661GES021A

Adjusting Valve Clearance

■ **IMPORTANT**

- **The clearance must be checked and adjusted when engine is cold.**

1. Remove the cylinder head cover and the spark plugs.
2. Align the **"1TC"** mark (1) on the flywheel and alignment mark (2) on the rear end plate so that the No. 1 piston comes to the compression top dead center.
3. Check the following valve clearance marked with "☆" using a feeler gauge.
4. If the clearance is not within the factory specifications, adjust with the adjusting screw.
5. Then turn the flywheel 6.28 rad (360 °), and align the **"1TC"** mark (1) on the flywheel and alignment mark (2) on the rear end plate so that the No. 1 piston comes to the overlap position.
6. Check the following valve clearance marked with "☆" using a feeler gauge.
7. If the clearance is not within the factory specifications, adjust with the adjusting screw.

Adjustable Cylinder Location of Piston		Intake valve	Exhaust valve
When No. 1 piston is at compression top dead center	1st	☆	☆
	2nd	☆	
	3rd		☆
	4th		
When No. 1 piston is at overlap position	1st		
	2nd		☆
	3rd	☆	
	4th	☆	☆

Intake and exhaust valve clearance (cold)	Factory specification	0.145 to 0.185 mm 0.00571 to 0.00728 in.

■ **NOTE**

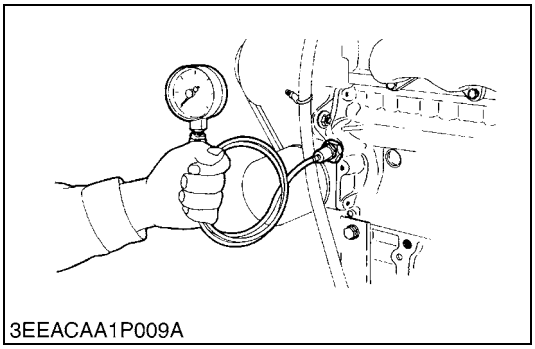
- **The sequence of cylinder numbers is given as No. 1, No. 2, No. 3 and No. 4 starting from the gear case side.**
- **After adjusting the valve clearance, secure the adjusting screw with the lock nut.**

(1) **"1TC"** Mark
(2) Alignment Mark

A: Gear Case Side

9Y1210661ENS0087US0

(2) Lubricating System


3EEACAA1P009A

Engine Oil Pressure

1. Remove the engine oil pressure switch, and set an oil pressure tester.
2. Start the engine. After warming up, measure the oil pressure of both idling and rated speeds.
3. If the oil pressure is less than the allowable limit, check the following.
   - Engine oil insufficient
   - Oil pump damaged
   - Oil strainer clogged
   - Oil filter cartridge clogged
   - Oil gallery clogged
   - Excessive oil clearance
   - Foreign matter in the relief valve

(When reassembling)

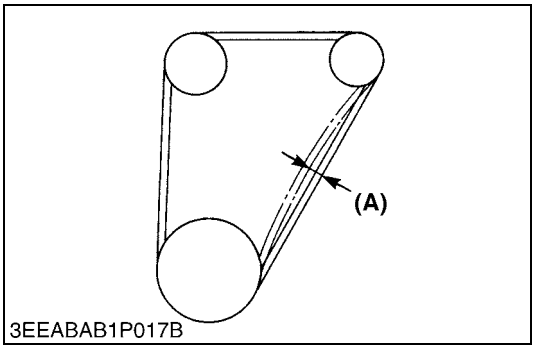
- After checking the engine oil pressure, tighten the engine oil pressure switch to the specified torque.

Engine oil pressure	At idle speed	Factory specification	49 kPa 0.50 kgf/cm^2 7.1 psi
	At rated speed	Factory specification	196 to 441 kPa 2.00 to 4.49 kgf/cm^2 28.5 to 63.9 psi
		Allowable limit	147 kPa 1.50 kgf/cm^2 21.3 psi

Tightening torque	Oil pressure switch	14.7 to 19.6 N·m 1.50 to 1.99 kgf·m 10.9 to 14.4 lbf·ft

9Y1210661ENS0008US0

(3) Cooling System



3EEABAB1P017B

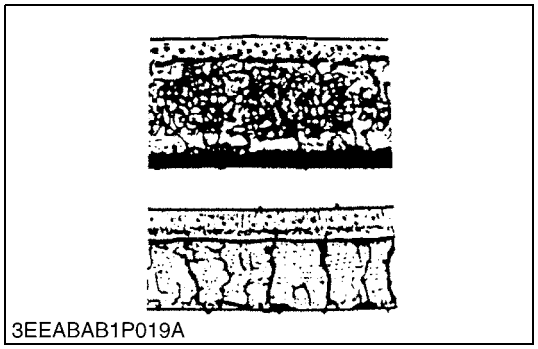
Fan Belt Tension

1. Measure the deflection **(A)**, depressing the belt halfway between the fan drive pulley and alternator pulley at specified force 98 N (10 kgf, 22 lbf).
2. If the measurement is not within the factory specifications, loosen the alternator mounting screws and relocate the alternator to adjust.

Deflection **(A)**	Factory specification	7.0 to 9.0 mm 0.28 to 0.35 in.

(A) Deflection

9Y1210318GEG0001US0

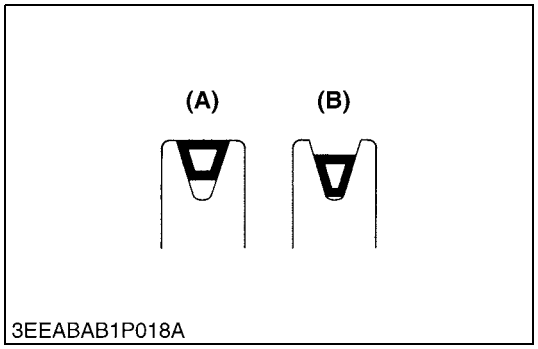

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Fan Belt Damage and Wear

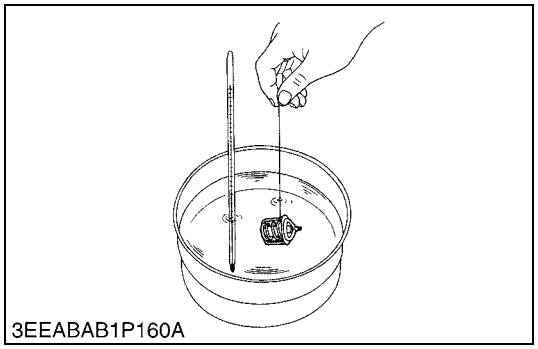
1. Check the fan belt for damage.
2. If the fan belt is damaged, replace it.
3. Check if the fan belt is worn and sunk in the pulley groove.
4. If the fan belt is nearly worn out and deeply sunk in the pulley groove, replace it.

(A) Good **(B) Bad**

9Y1210318GEG0002US0



3EEABAB1P018A


3EEABAB1P160A

Thermostat Valve Opening Temperature

1. Suspend the thermostat in the water by a string with its end inserted between the valve and seat.
2. Heating the water gradually, read the temperature when the valve opens and leaves the string.
3. Continue heating and read the temperature when the valve opens approx. 8 mm (0.3 in.).
4. If the measurement is not within the factory specifications, replace the thermostat.

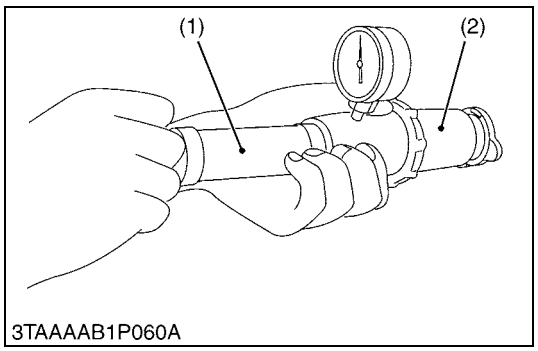
Thermostat's valve opening temperature	Factory specification	69.5 to 72.5 °C 157.1 to 162.5 °F
Temperature at which thermostat completely opens	Factory specification	85 °C 185 °F

9Y1210661ENS0009US0

CAUTION

- **When removing the radiator cap, wait at least ten minutes after the engine has stopped and cooled down. Otherwise, hot water may gush out, scalding nearby people.**

9Y1210318ENS0018US0



3TAAAAB1P060A

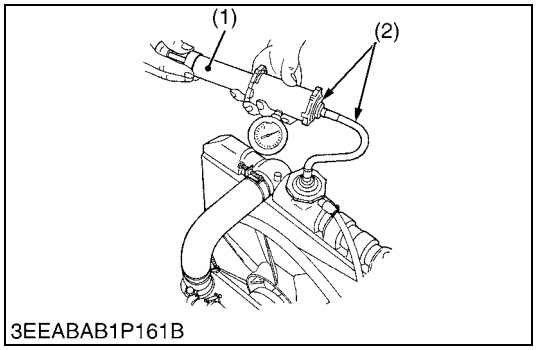
Radiator Cap Air Leakage

1. Set a radiator tester (1) and an adaptor (2) on the radiator cap.
2. Apply the specified pressure (90 kPa, 0.9 kgf/cm^2, 10 psi), and measure the time for the pressure to fall to 60 kPa (0.6 kgf/cm^2, 9 psi).
3. If the measurement is less than the factory specification, replace the radiator cap.

Pressure falling time	Factory specification	10 seconds or more 88 → 59 kPa 0.89 → 0.61 kgf/cm^2 12 → 8.6 psi

(1) Radiator Tester (2) Adaptor

9Y1210661ENS0010US0



3EEABAB1P161B

Radiator Water Leakage

1. Pour a specified amount of water into the radiator.
2. Set a radiator tester (1) and an adaptor (2) and raise the water pressure to the specified pressure (210 kPa, 2.14 kgf/cm^2, 30.5 psi).
3. Check the radiator for water leaks.
4. For water leak from the pinhole, repair with the radiator cement. When water leak is excessive, replace the radiator.

Radiator water leakage test pressure	Factory specification	No leak at specified pressure

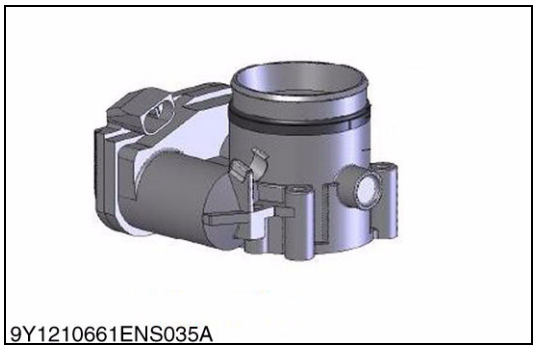
■ **NOTE**

- **The pressure of the leak test is different from each radiator specification.**
  Thus, do the leak test, refer to the test pressure of each radiator specification.

(1) Radiator Tester (2) Adaptor

9Y1210661ENS0067US0

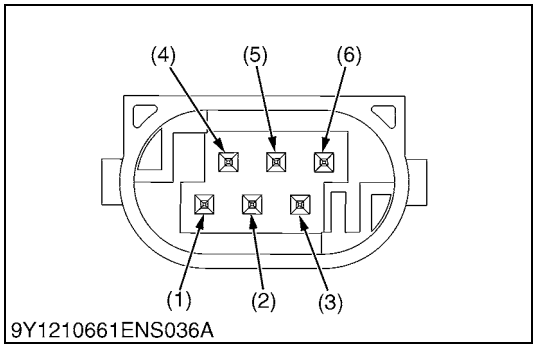
(4) Fuel System


9Y1210661ENS035A

Resistance of Throttle Body

1. Disconnect the connector.
2. Measure the resistance between terminal **1** and terminal **4** with an ohmmeter.
3. If the resistance is 0 ohm or infinity, replace it.
4. Measure the resistance between terminal **2** and terminal **3** with an ohmmeter.
5. If the resistance is not with in the factory specifications, replace it.

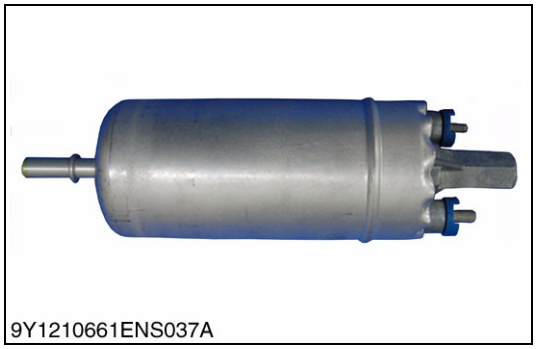
Resistance	Factory specification	Terminal **1** – Terminal **4**	Continuity
		Terminal **2** – Terminal **3**	0.875 to 1.625 kΩ at 20 °C (68 °F)



9Y1210661ENS036A

(1) Terminal **1**
(2) Terminal **2**
(3) Terminal **3**
(4) Terminal **4**
(5) Terminal **5**
(6) Terminal **6**

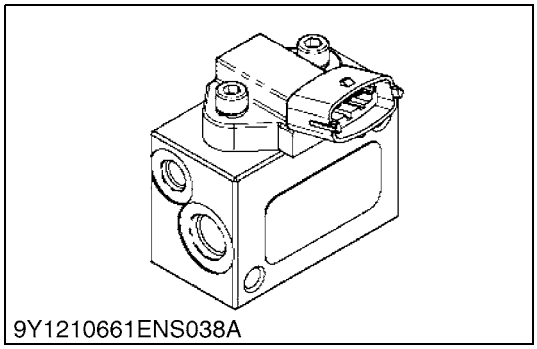
9Y1210661ENS0091US0

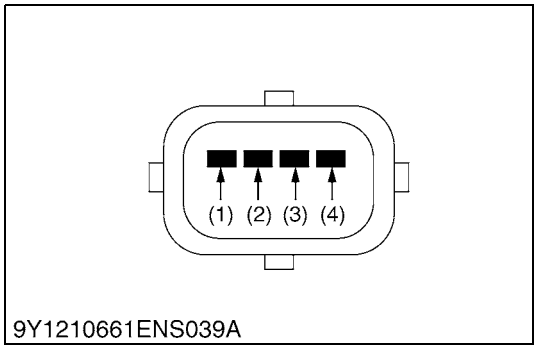

9Y1210661ENS037A

Fuel Pump

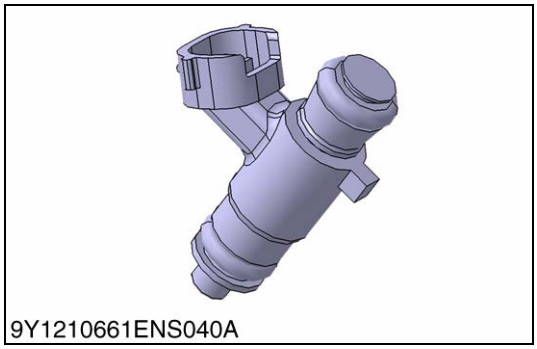
1. Disconnect the wiring.
2. Measure the resistance between terminals with an ohmmeter.
3. If the resistance is 0 ohm or infinity, replace it.

9Y1210661ENS0092US0


9Y1210661ENS038A



9Y1210661ENS039A


9Y1210661ENS040A

Resistance of Fuel Pressure Manifold (FPM)

1. Disconnect the connector.
2. Measure the resistance between terminal **1** and terminal **2** with an ohmmeter.
3. If the resistance is not with in the factory specifications, replace it.

Resistance	Factory specification	Terminal **1** – Terminal **2**	2.35 to 2.65 kΩ at 20 °C (68 °F)

(1) Terminal **1**
(2) Terminal **2**
(3) Terminal **3**
(4) Terminal **4**

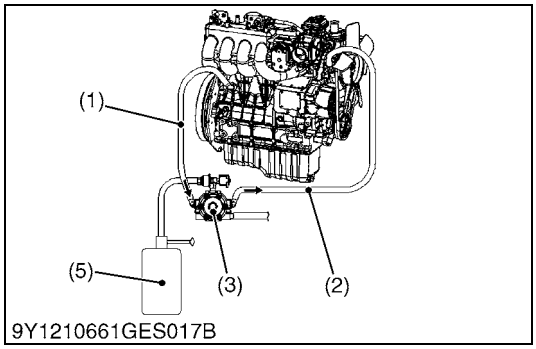
9Y1210661ENS0093US0

Injector

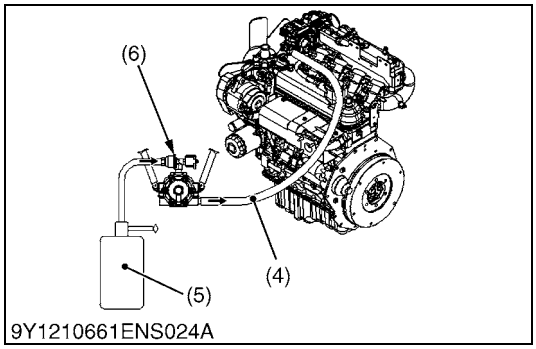
1. Disconnect the connector.
2. Measure the resistance between terminals with an ohmmeter.
3. If the resistance is not with in the factory specifications, replace it.

Resistance	Factory specification	11.7 to 12.3 Ω at 20 °C (68 °F)

9Y1210661ENS0094US0



9Y1210661GES017B



9Y1210661ENS024A

Vaporizer Hose

1. Connect the coolant hose (1) and (2) through the vaporizer.
2. Connect the vapor hose (4).

CAUTION

- **All fuel connections added to this engine must be installed by qualified personnel and utilizing recognized procedures and standards.**
- **These non-KUBOTA installed parts, such as hoses, fittings, piping, should be approved for LPG use and conform to UL, CSA, NFPA, and all other recognized standards.**
- **An approved, lock off valve must be directly connected to the KUBOTA vaporizer.**

NOTE

- **The LPG liquid in joint (fitting) to the vaporizer / regulator is not provided in the KIT by KUBOTA, due to the many different connection requirements by the OEM.**
- **Vapor hose length must not exceed 700 mm (27.6 in), shorter is generally considered better.**
- **Each hose must be tightened with a hose clamp.**

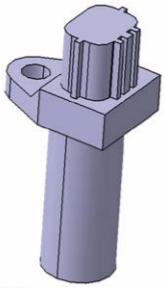
Tightening torque	LPG in	19.6 to 39.2 N·m 2.00 to 3.99 kgf·m 14.5 to 28.9 lbf·ft

(1) Coolant Hose (ϕ16 mm (5/8 in.) Hose Fitting)
(2) Coolant Hose (ϕ16 mm (5/8 in.) Hose Fitting)
(3) Vaporizer
(4) Vapor Hose
(5) LPG Tank
(6) Lock Off Valve

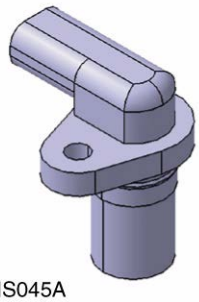
9Y1210661ENS0078US0

(5) Ignition System

[A]


9Y1210661ENS046A

[B]


9Y1210661ENS045A

Resistance of Crank Sensor / Cam Sensor

1. Disconnect the connector.
2. Measure the resistance with an ohmmeter.
3. If the resistance is not with in the factory specifications, replace it.

Resistance **[A]**	Factory specification	1.85 to 2.45 kΩ at 20 °C (68 °F)
Resistance **[B]**	Factory specification	470 to 530 Ω at 20 °C (68 °F)

NOTE

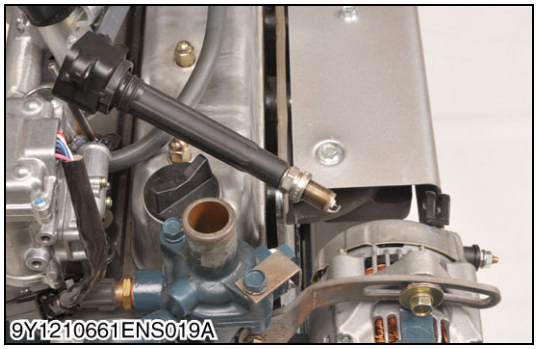
- **This table shows the results of the test conducted by using the "Sanwa-made testers SP-10/SP-150" (analog meter).**
- **Use of other testers than those above may show different measured results.**

(When reassembling)

- **Make sure to be connected firmly.**

[A] Crank Sensor **[B] Cam Sensor**

9Y1210661ENS0095US0



Spark Test

(For gasoline)

1. Disconnect all injector connector.
2. Remove the spark plug, put it inside the ignition coil firmly, and then ground the threaded section to the engine body (not to painted or resin parts).
3. Rotate the starter with the key switch and check that the plug sparks.
4. If test is **OK**, tighten the spark plug with a plug wrench.

(For LPG)

1. Close the LPG tank valve.
2. Disconnect the lock off valve connector.
3. Remove the spark plug, put it inside the ignition coil firmly, and then ground the threaded section to the engine body (not to painted or resin parts).
4. Disconnect other ignition coil connector.
5. Rotate the starter with the key switch and check that the plug sparks.
6. If test is **OK**, tighten the spark plug with a plug wrench.

■ **IMPORTANT**

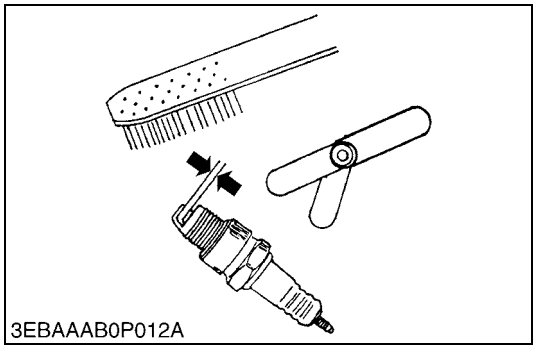
(When reassembling)

- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Make sure that the removed connectors are correctly connected.**
  Open the LPG tank valve (for LPG).

CAUTION

- **This test is hazardous of electric shocks. Never use hand or screwdriver to press the plug to ground it to the engine body.**
- **Keep inflammable away from the engine.**

9Y1210661ENS0088US0


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Spark Plug Gap

1. Remove the spark plug, and remove carbon from the electrode with a wire brush or other tools.
2. Measure the spark plug gap with a feeler gauge, and repair or replace the plug if the measured gap differs from the factory specification.
3. Replace the plug if the electrode or the insulator is deformed or cracked.
4. Tighten the plug with a plug wrench.

■ **IMPORTANT**

(When reassembling)

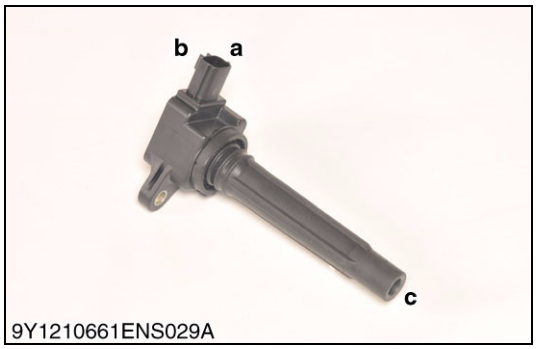
- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Fix the ignition coil by screw / nut.**

Spark plug gap	Factory specification	0.70 to 0.80 mm 0.028 to 0.031 in

Spark plug	NGK: IFR6F8DN

Tightening torque	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.6 lbf·ft
	Ignition coil mounting screw / nut	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

9Y1210661ENS0089US0



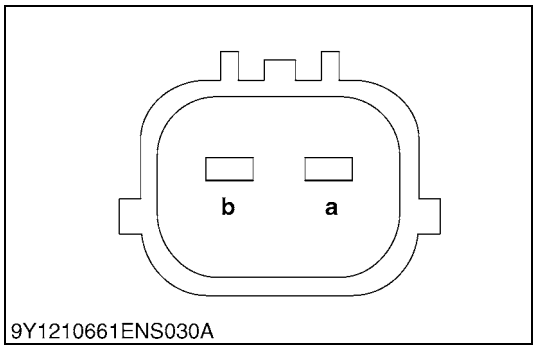
9Y1210661ENS029A

Resistance of Ignition Coil

1. Disconnect the ignition coil.
2. Measure the resistance with an ohmmeter.
3. If the resistance is not with in the factory specifications, replace it.

Resistance	Factory specification	**a – b**	0.63 to 0.77 Ω at 25 °C (77 °F)
		a – c	7.29 to 8.91 kΩ at 25 °C (77 °F)

9Y1210661ENS0079US0



9Y1210661ENS030A

(6) Electrical System

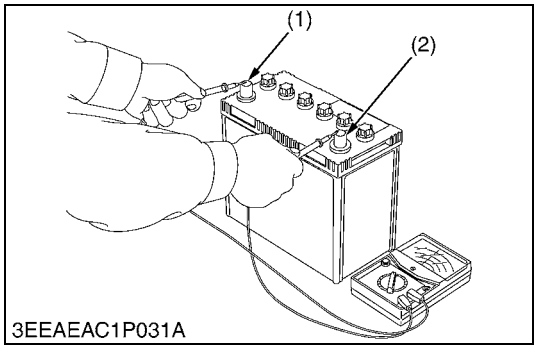
CAUTION

- **To avoid accidental short circuit, be sure to attach the positive cable to the positive terminal before the negative cable is attached to the negative terminal.**
- **Never remove the battery cap while the engine is running.**
- **Keep electrolyte away from eyes, hands and clothes. If you are spattered with it, wash it away completely with water immediately.**
- **Keep open sparks and flames away from the battery at all times. Hydrogen gas mixed with oxygen becomes very explosive.**

IMPORTANT

- **If the machine is to be operated for a short time without battery (using a slave battery for starting), use additional current (lights) while engine is running and insulate terminal of battery. If this advice is disregarded, damage to alternator and regulator may result.**

9Y1210661ENS0096US0



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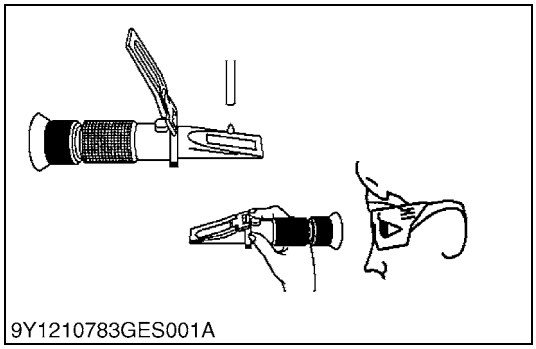
Battery Voltage

1. Stop the engine.
2. Measure the voltage with a circuit tester between the battery terminals.
3. If the battery voltage is less than the factory specification, check the battery specific gravity and recharge the battery.

Battery voltage	Factory specification	More than 12 V

(1) Positive Terminal (2) Negative Terminal

9Y1210661ENS0097US0


9Y1210783GES001A

Battery Specific Gravity

CAUTION

- **If battery acid (dilute sulfuric acid) gets on you it could cause blindness or burns, or could cause corrosion of machinery and tools so please be careful when handling.**
- **Wear safety glasses and rubber gloves when performing battery maintenance and inspection (measuring specific gravity, replenishing water, or charging).**
- **If the gas that is generated is ignited by an ignition source, it may explode so be very careful with sparks and fire.**
- **Keep your body and face as far away from the battery as you can when performing maintenance and inspection.**
- **Do not allow people who do not know how to handle a battery or who do not sufficiently understand the danger perform inspection or maintenance.**

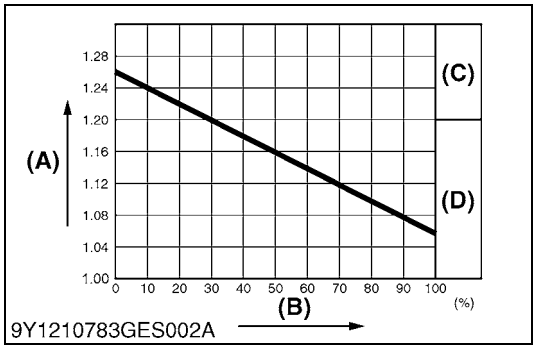
(Measurement items)

■ **Zero adjustment**

1. Open the cover and drip water on the prism surface using the included rod.
2. Close the cover.
3. Aim in a direction that is bright, look into the lens, and adjust the focus until the gradations can be seen clearly.
4. If the boundary line is not on the gradation baseline (0 position), turn the adjustment screw until it matches.
5. When zero adjustment is complete, wipe the prism and cover surface with a soft cloth or tissue paper.

■ **Measurement of test fluid**

1. Open the cover and drip test fluid on the prism surface using the included rod.
2. Close the cover.
3. Aim in a direction that is bright, look into the lens and read the gradation of the blue boundary line.
4. When the measurement is complete, wipe the prism and cover surface with a soft cloth or tissue paper.



9Y1210783GES002A

(Reference)

Electrolyte specific gravity and amount of discharge.
Use the following table as a reference.

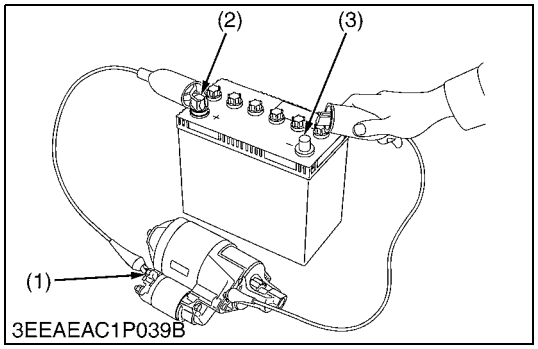
(A) Electrolyte Specific Gravity	**(C) Good**
(B) Discharge	**(D) Charging is necessary.**

■ **NOTE**

Temperature conversion of electrolyte specific gravity

- **Battery electrolyte specific gravity changes based on temperature.**
- **Insert the value identified on a specific gravity meter into the following conversion equation for temperature correction to learn an accurate specific gravity value. (Standard temperature assumed to be 20 °C (68 °F))**
  D_{20} = Dt + 0.0007 (t - 20)
  D_{20} = specific gravity value converted to standard temperature of 20 °C (68 °F)
  D_t = measured specific gravity value at the electrolyte temperature t °C

9Y1210661ENS0107US0



Motor Test

CAUTION

- **Secure the starter to prevent it from jumping up and down while testing the motor.**

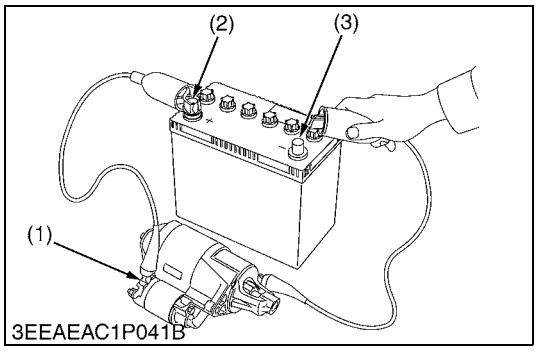
1. Disconnect the battery negative cable from the battery.
2. Disconnect the battery positive cable from the battery.
3. Disconnect the leads from the starter **B** terminal.
4. Remove the starter from the engine.
5. Connect a jumper lead from the starter **C** terminal (1) to the battery positive terminal (2).
6. Connect a jumper lead momentarily between the starter's body and the battery negative terminal (3).
7. If the motor does not run, starter is failure.
   Repair or replace the starter.

NOTE

- **B terminal: It is the terminal which connects the cable from the battery to the starter.**
- **C terminal: It is the terminal which connects the cable from the motor to the magnet switch.**

(1) **C** Terminal
(2) Positive Terminal
(3) Negative Terminal

9Y1210318ENS0038US0



Magnetic Switch Test

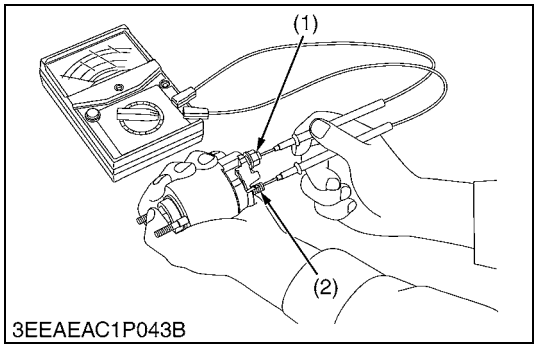
1. Disconnect the battery negative cable from the battery.
2. Disconnect the battery positive cable from the battery.
3. Disconnect the leads from the starter **B** terminal.
4. Remove the starter from the engine.
5. Connect a jumper lead from the starter **S** terminal (1) to the battery positive terminal (2).
6. Connect a jumper lead momentarily between the starter's body and the battery negative terminal (3).
7. If the pinion gear does not pop out, the magnetic switch is failure. Repair or replace the starter.

NOTE

- **B terminal: It is the terminal which connects the cable from the battery to the starter.**
- **S terminal: It is the terminal which connects the cable from the starter switch to the magnet switch.**

(1) **S** Terminal
(2) Positive Terminal
(3) Negative Terminal

9Y1210318ENS0039US0

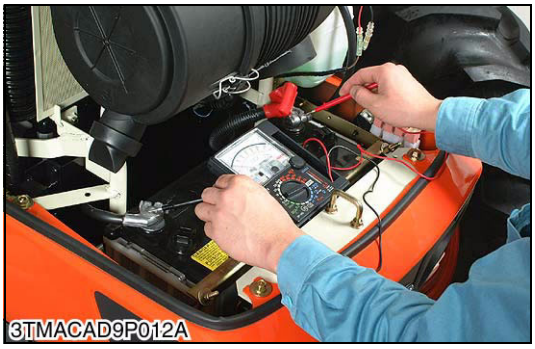


Magnet Switch Continuity Test

1. Check the continuity across the **C** terminal (1) and the **B** terminal (2) with a circuit tester, pushing in the plunger.
2. If not continuous or if a certain value is indicated, replace the magnet switch.

(1) **C** Terminal
(2) **B** Terminal

9Y1210318ENS0040US0



Alternator on Unit Test

(Before testing)

- Before alternator on unit test, check the battery terminal connections, circuit connection, fan belt tension, charging indicator lamp, fuses on the circuit, and abnormal noise from the alternator.
- Prepare full charged battery for the test.

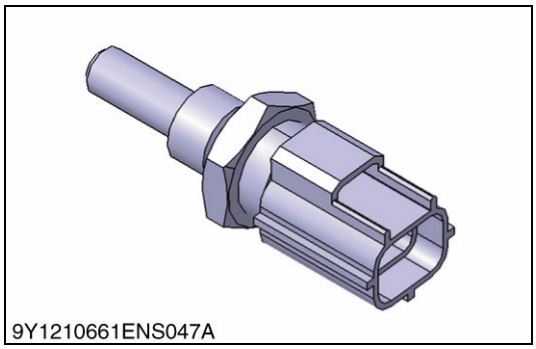
■ **NOTE**

- **Be careful not to touch the rotating engine parts while engine is running.**
  Keep safety distance from the engine rotating parts.

1. Start the engine.
2. When the engine is operating measure the voltage between two battery terminals. If the voltage is between 14.2 V and 14.8 V, the alternator is operating normally.
3. If the results of alternator on unit test are not within the specifications, disassemble the alternator and check the each component part for finding out the failure. See the "DISASSEMBLING AND ASSEMBLING" and "SERVICING" for alternator.

Regulating voltage at no load	Factory specification	14.2 to 14.8 V at 5000 min^{-1} (rpm), 25 °C (77 °F)

9Y1210318ENS0043US0

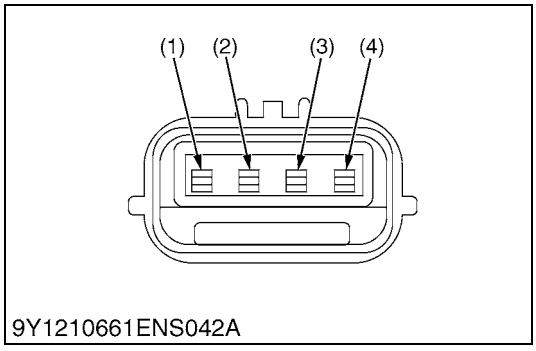


Resistance of Water Temperature Sensor

1. Disconnect the connector.
2. Measure the resistance with an ohmmeter.
3. If the resistance is not with in the factory specifications, replace it.

Resistance	Factory specification	2.32 to 2.59 kΩ at 20 °C (68 °F)

9Y1210661ENS0099US0



Resistance of Temperature and Manifold Absolute Pressure (TMAP) Sensor

1. Measure the resistance between the terminal **1** and terminal **3** of the sensor.
2. If the measurement is not in the factory specification, the sensor is damaged. Then replace it with a new one.
3. If the measurement is in the factory specification, the sensor is correct electrically.

Resistance of pressure sensor	Factory specifica-tion	Terminal **1** – Terminal **3**	5.4 to 6.6 kΩ at 0 °C (32 °F)

(1) Terminal **1**
(2) Terminal **2**
(3) Terminal **3**
(4) Terminal **4**

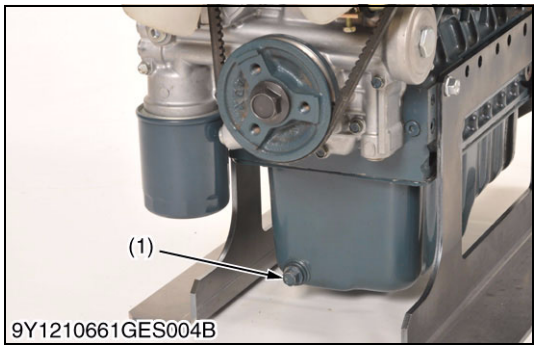
9Y1210661ENS0100US0

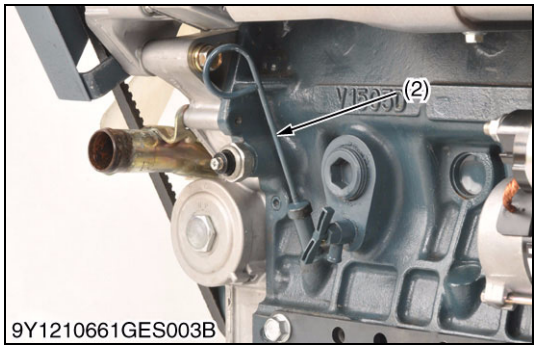
[2] DISASSEMBLING AND ASSEMBLING

■ **IMPORTANT**
- **When reassembling, replace all of the O-rings and gaskets by new ones.**
- **When disassembling the LPG engine after completely consuming the fuel in piping.**
- **In order to reduce the fuel pressure, do not remove the fuel hose at least 3 minutes after stopping the engine.**

9Y1210661ENS0101US0

(1) Draining Coolant and Engine Oil





Draining Engine Oil

1. Start and warm up the engine for approx. 5 minutes.
2. Place an oil pan underneath the engine.
3. Remove the drain plug (1) to drain oil.
4. After draining, screw in the drain plug (1).

(When refilling)
- Fill the engine oil up to the upper line on the dipstick (2).

■ **IMPORTANT**
- **When using an oil of different maker or viscosity from the previous one, remove all of the old oil.**
- **Never mix two different types of oil.**
- **Engine oil should have properties of API classification SH.**
- **Use the proper SAE Engine Oil according to ambient temperature.**

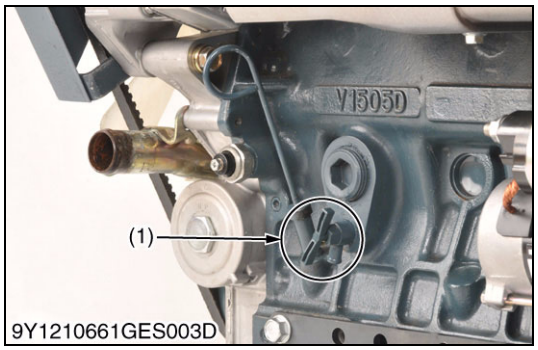
Above 25 °C (77 °F)	SAE30 or SAE10W-30 or SAE15W-40
0 °C to 25 °C (32 °F to 77 °F)	SAE20 or SAE10W-30
0 °C to −20 °C (32 °F to −4 °F)	SAE10W or SAE10W-30

Engine oil capacity	6.0 L 1.6 U.S. gals

Tightening torque	Drain plug	32.4 to 37.3 N·m 3.31 to 3.80 kgf·m 23.9 to 27.5 lbf·ft

(1) Drain Plug (2) Dipstick

9Y1210661ENS0014US0



Draining Coolant

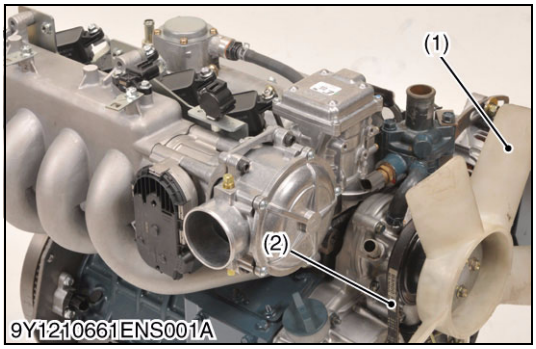
CAUTION
- **Never remove radiator cap while operating or immediately after stopping. Otherwise, hot water will spout out from the radiator. Wait for more than ten minutes to cool the radiator, before opening the cap.**

1. Prepare a bucket. Open the coolant drain valve.

(1) Coolant Drain Valve

9Y1210661ENS0015US0

(2) External Components



Alternator, Starter and Others

1. Remove the air cleaner, catalytic muffler / converter and exhaust manifold.
2. Remove the cooling fan (1), fan pulley and fan belt (2).
3. Remove the alternator.
4. Remove the starter.

(When reassembling)

- Check to see that there are no cracks on the belt surface.
- Replace the exhaust system gasket with a new one.

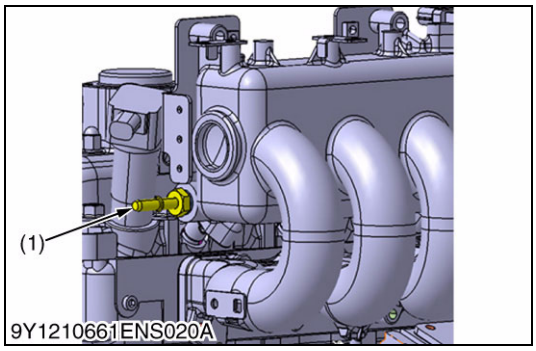
■ **IMPORTANT**

- **After reassembling the fan belt (2), be sure to adjust the fan belt tension.**
- **Do not confuse the direction of the cooling fan (1).**
- **To trace of the catalytic muffler / converter, put down the catalyst identification and engine identification when new service catalytic muffler / converter is installed.**

Tightening torque	Exhaust manifold mounting nut	15.7 to 18.6 N·m 1.60 to 1.89 kgf·m 11.6 to 13.7 lbf·ft
	Outlet of exhaust manifold nut	29.4 to 34.3 N·m 3.00 to 3.49 kgf·m 21.7 to 25.2 lbf·ft
	Inlet of catalytic muffler / converter mounting screw / nut	48.1 to 55.9 N·m 4.91 to 5.70 kgf·m 35.5 to 41.2 lbf·ft
	Outlet of catalytic muffler / converter mounting screw / nut	77.5 to 90.2 N·m 7.91 to 9.19 kgf·m 57.2 to 66.5 lbf·ft

(1) Cooling Fan (2) Fan Belt

9Y1210661ENS0102US0



Fuel Line (WG1605-G-E3, WG1605-GL-E3)

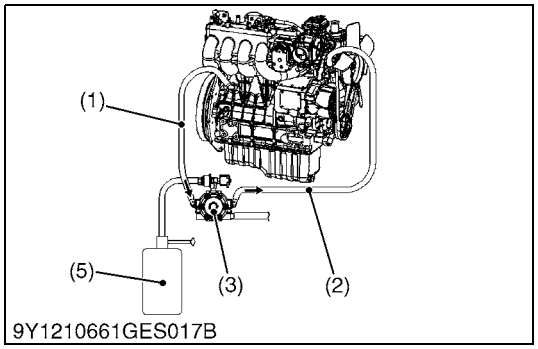
1. Disconnect the gasoline hose from the connector (1).

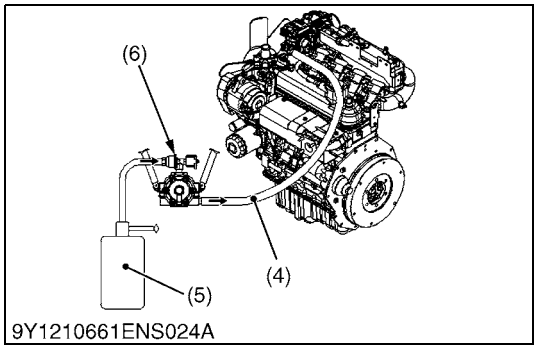
CAUTION

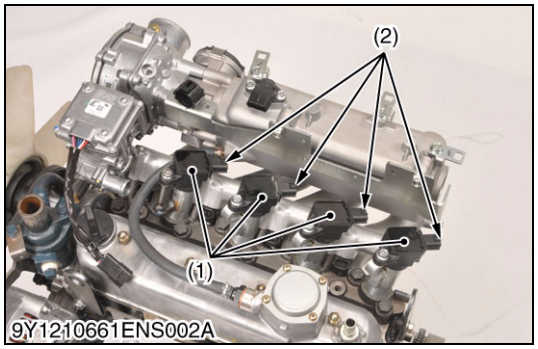
- **In order to reduce the fuel pressure, do not remove the fuel hose at least 3 minutes after stopping the engine.**
- **Remove the hose after covering the hose with a waste to prevent scatter of fuel.**

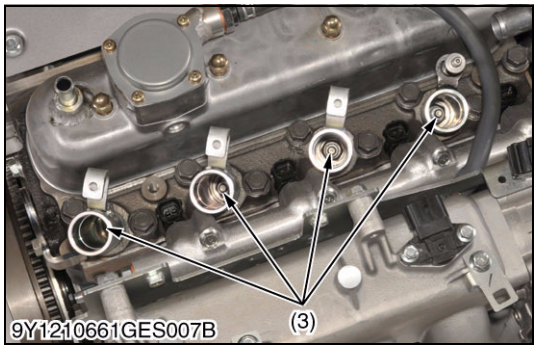
(1) Gasoline Hose Connector

9Y1210661ENS0103US0









Vapor Hose and Coolant Hose (WG1605-L-E3, WG1605-GL-E3)

CAUTION

- **Close the LPG tank valve.**
- **In order to reduce the fuel pressure, do not remove the fuel hose at least 3 minutes after stopping the engine.**
- **Vent the air of the water passage of vaporizer (3) after removing the coolant hose (1), (2).**

1. Disconnect the vapor hose (4).
2. After drain the coolant, disconnect the coolant hose (1), (2).
3. Remove the vaporizer (3) (if necessary).

IMPORTANT

- **When disassembling the fuel system, make sure that the LPG tank valve is closed.**

(When reassembling)

- Bleed the vaporizer after supplying coolant.

(1) Coolant Hose
(2) Coolant Hose
(3) Vaporizer
(4) Vapor Hose
(5) LPG Tank
(6) Lock Off Valve

9Y1210661ENS0017US0

Ignition Coil and Spark Plug

1. Disconnect the ignition coil connector (2).
2. Remove the ignition coil (1).
3. Remove the spark plug (3).

(When reassembling)

- Tighten the spark plug with a plug wrench.

NOTE

(When reassembling)

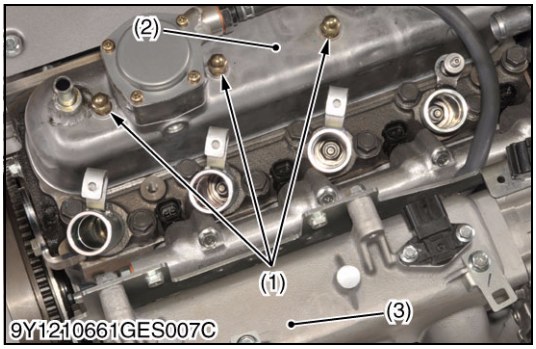
- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Make sure that the removed connectors are correctly connected.**
- **Fix the ignition coil by screw / nut.**

Tightening torque	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.5 lbf·ft
	Ignition coil mounting screw / nut	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

(1) Ignition Coil
(2) Ignition Coil Connector
(3) Spark Plug

9Y1210661ENS0080US0

(3) Cylinder Head, Valves and Oil Pan



Cylinder Head Cover

1. Remove the cylinder head cover cap nut (1).
2. Remove the cylinder head cover (2).
3. Remove the intake manifold (3).

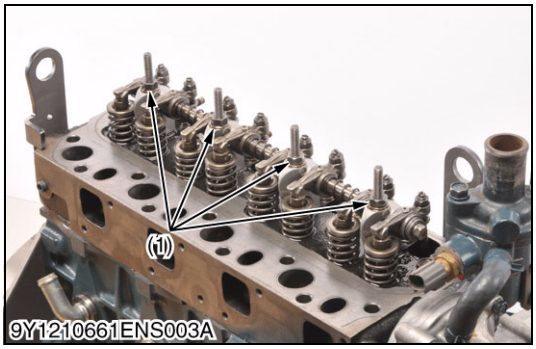
(When reassembling)

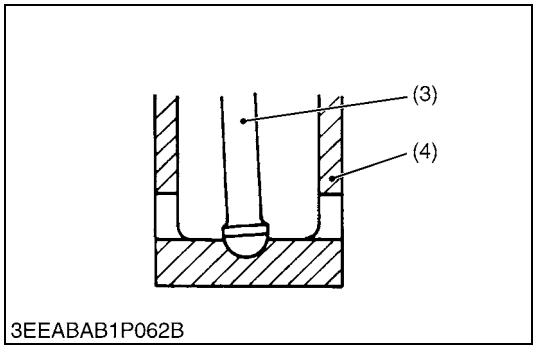
- Check to see if the cylinder head cover gasket is not damaged.

Tightening torque	Cylinder head cover cap nut	6.9 to 8.8 N·m 0.71 to 0.89 kgf·m 5.1 to 6.4 lbf·ft

(1) Cylinder Head Cover Cap Nut
(2) Cylinder Head Cover
(3) Intake Manifold

9Y1210661ENS0081US0





Rocker Arm and Push Rod

1. Remove the rocker arm bracket nuts (1).
2. Remove the rocker arm assembly (2).
3. Remove the push rods (3).

(When reassembling)

- When putting the push rods (3) onto the tappets (4), check to see if their ends are properly engaged with the dimples.

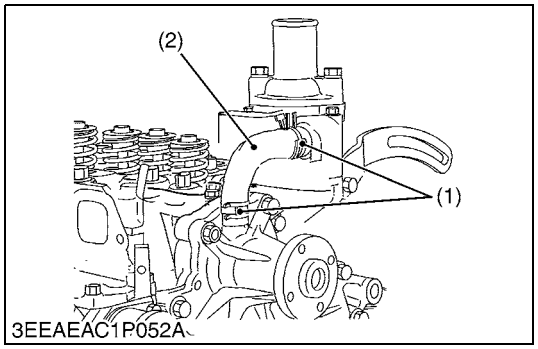
■ **IMPORTANT**

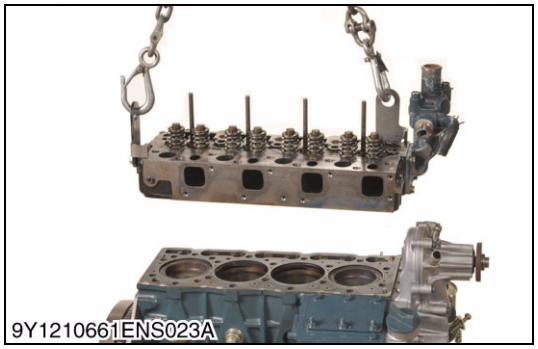
- **After installing the rocker arm, be sure to adjust the valve clearance.**

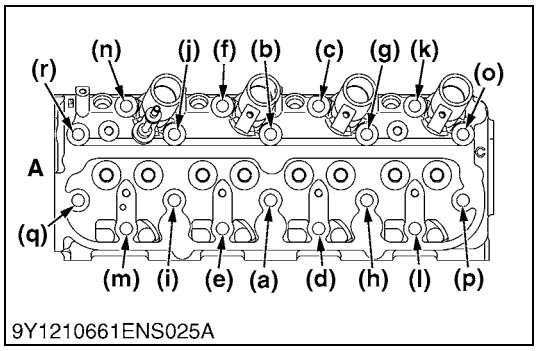
Tightening torque	Rocket arm bracket nut	21.6 to 26.5 N·m 2.21 to 2.70 kgf·m 16.0 to 19.5 lbf·ft

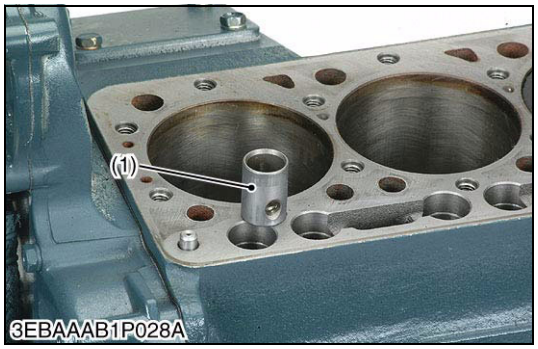
(1) Rocker Arm Bracket Nut
(2) Rocker Arm Assembly
(3) Push Rod
(4) Tappet

9Y1210661ENS0082US0









Cylinder Head

1. Loosen the pipe clamps (2), and remove the water return hose (1).
2. Remove the cylinder head screw in the order of **(r)** to **(a)**.
3. Remove the spark plug.
4. Remove the injector flange (WG1605-G-E3, WG1605-GL-E3) / ignition coil flange (WG1605-L-E3).
5. Lift up the cylinder head to remove.
6. Remove the cylinder head gasket.

(When reassembling)

- Replace the cylinder head gasket with a new one.
- Tighten the cylinder head screws after applying sufficient oil.
- Tighten the cylinder head screws in order of **(a)** to **(r)**.
- Tighten them uniformly, or the head may deform in the long run.

■ **NOTE**

- **injector flange (WG1605-G-E3, WG1605-GL-E3), ignition coil flange (WG1605-L-E3) mounting screw: length = 105 mm (4.13 in.)**
- **others: 80.5 mm (3.17 in.)**

Tightening torque	Cylinder head screw	63.7 to 68.6 N·m 6.50 to 6.99 kgf·m 47.0 to 50.5 lbf·ft
	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.5 lbf·ft

(1) Water Return Hose
(2) Hose Clamp

A: Gear Case Side
(r) to (a): To Loosen
(a) to (r): To Tighten

9Y1210661ENS0083US0

Tappets

1. Remove the tappets (1) from the crankcase.

(When reassembling)

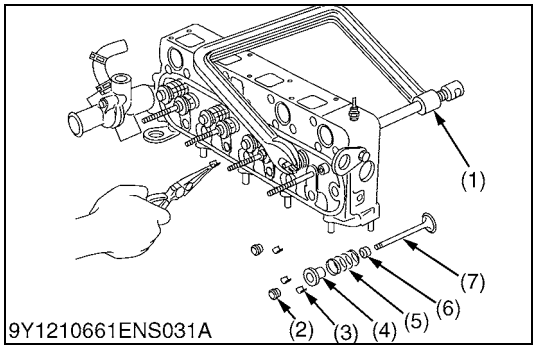
- Visually check the contact between tappets and cams for proper rotation. If defect is found, replace tappets.
- Before installing the tappets, apply engine oil thinly around them.

■ **IMPORTANT**

- **Do not change the combination of tappet and tappet guide.**

(1) Tappet

9Y1210318ENS0065US0



Valves

1. Remove the valve caps (2).
2. Remove the valve spring collet (3), pushing the valve spring retainer (4) with valve spring replacer (1).
3. Remove the valve spring retainer (4), valve spring (5) and valve stem seal (6).
4. Remove the valve (7).

(When reassembling)

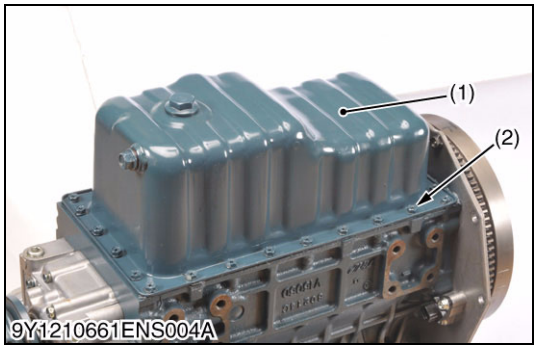
- Wash the valve stem and valve guide hole, and apply engine oil sufficiently.
- After installing the valve spring collets, lightly tap the stem to assure proper fit with a plastic hammer.

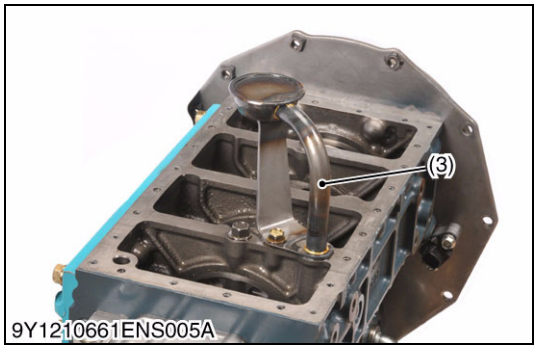
■ **IMPORTANT**

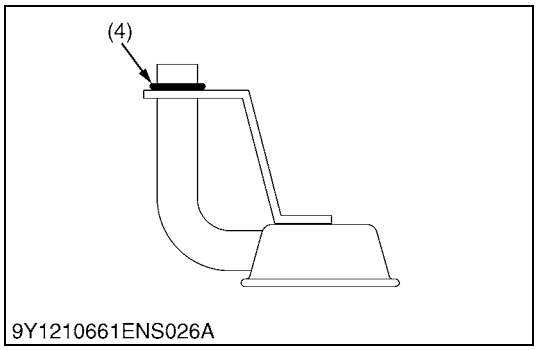
- **Do not change the combination of valve and valve guide.**

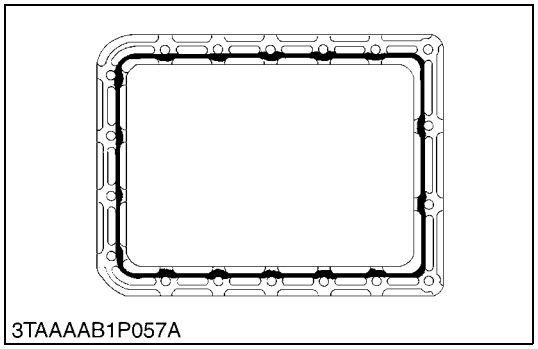
(1) Valve Spring Replacer
(2) Valve Cap
(3) Valve Spring Collet
(4) Valve Spring Retainer
(5) Valve Spring
(6) Valve Stem Seal
(7) Valve

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Oil Pan and Oil Strainer

1. Remove the oil pan mounting screws (2).
2. Remove the oil pan (1) by lightly tapping the rim of the pan with a wooden hammer.
3. Remove the oil strainer (3).

(When reassembling)

- After cleaning the oil strainer, check to see that the filter mesh in clean, and install it.
- Visually check the O-ring (4), apply engine oil, and install it.
- Securely fit the O-ring to the oil strainer.
- To avoid uneven tightening, tighten oil pan mounting screws in diagonal order form the center.

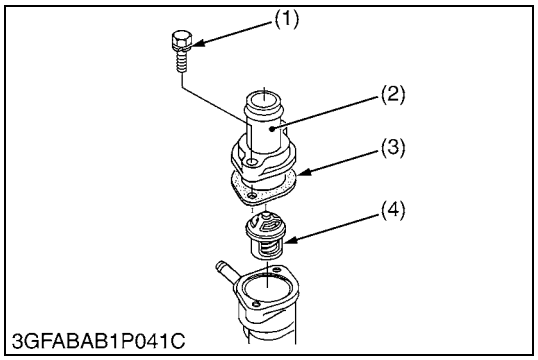
■ **IMPORTANT**

- **Scrape off the old adhesive completely. Wipe the sealing surface clean. Now apply new adhesive 3.0 to 5.0 mm (0.12 to 0.19 in.) thick all over the contact surface. Apply the adhesive also on the center of the flange as well as on the inner wall of each bolt hole.**
- **Cut the nozzle of the "liquid gasket" (Three Bond 1207D or equivalent) container at its second notch. Apply "liquid gasket" about 5.0 mm (0.19 in.) thick.**
  Within 20 minutes after the application of fluid sealant, reassemble the components. Wait then for about 30 minutes, and pour oil in the crankcase.

(1) Oil Pan
(2) Oil Pan Mounting Screw
(3) Oil Strainer
(4) O-ring

9Y1210661ENS0023US0

(4) Thermostat



Thermostat Assembly

1. Remove the thermostat cover mounting screws (1), and remove the thermostat cover (2).
2. Remove the thermostat assembly (4).

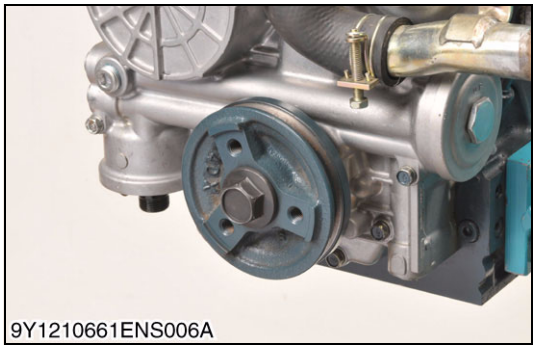
(When reassembling)

- Apply a liquid gasket (Three Bond 1215 or equivalent) only at the thermostat cover side of the gasket (3).

(1) Thermostat Cover Mounting Screw
(2) Thermostat Cover
(3) Thermostat Cover Gasket
(4) Thermostat Assembly

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(5) Timing Gear, Camshaft, Gear Shaft and PTO Shaft


9Y1210661ENS006A

Fan Drive Pulley

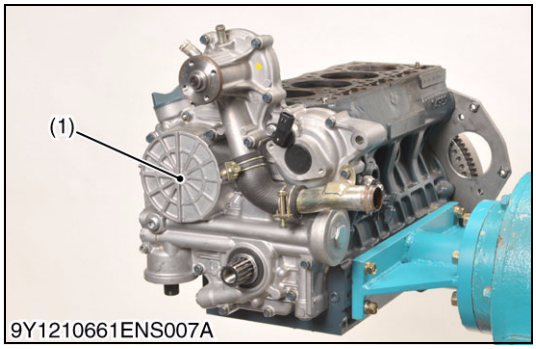
1. Secure the flywheel to keep it from turning.
2. Remove the fan drive pulley screw.
3. Draw out the fan drive pulley with a puller.

(When reassembling)

- Apply engine oil to the fan drive pulley retaining screws. And tighten it.

Tightening torque	Fan drive pulley screw	235 to 245 N·m 24.0 to 24.9 kgf·m 174 to 180 lbf·ft

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9Y1210661ENS007A

Gear Case

1. Remove the gear case (1).

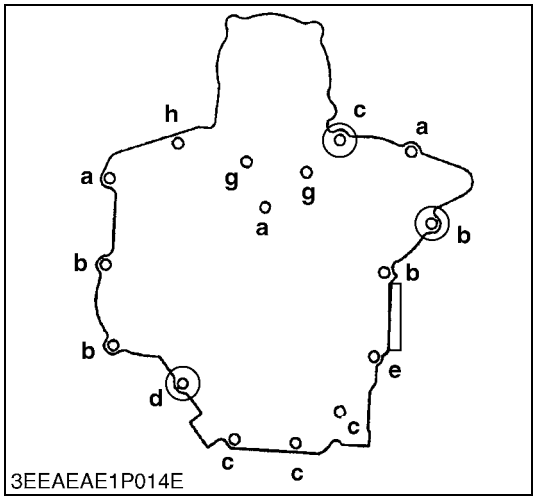
(When reassembling)

- Apply a liquid gasket (Three Bond 1215 or equivalent) to both sides of the gear case gasket.

(1) Gear Case

a: Bolt Length = 45 mm (1.8 in.)
b: Bolt Length = 50 mm (2.0 in.)
c: Bolt Length = 55 mm (2.2 in.)
d: Bolt Length = 65 mm (2.6 in.)
e: Bolt Length = 68 mm (2.7 in.)
g: Bolt Length = 85 mm (3.3 in.)
h: Nut

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Water Pump Assembly

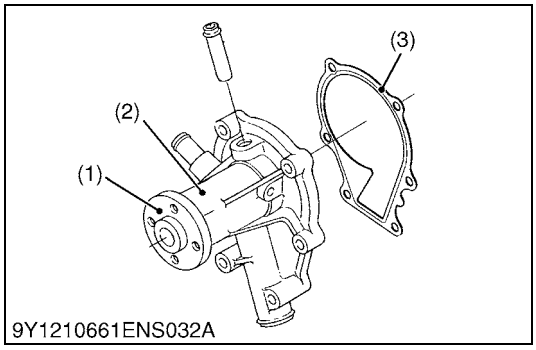
1. Remove the water pump assembly (2) from the gear case cover.

(When reassembling)

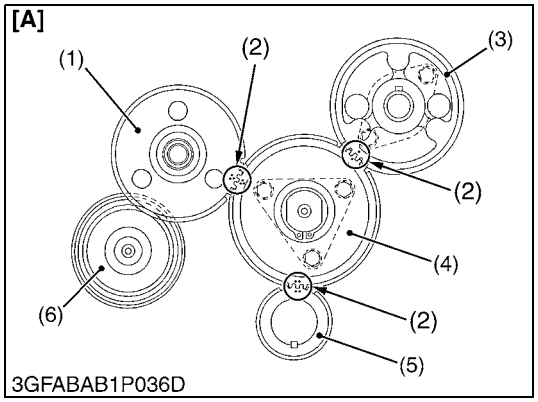
- Apply a liquid gasket (Three Bond 1215 or equivalent) to both sides of water pump gasket (3).

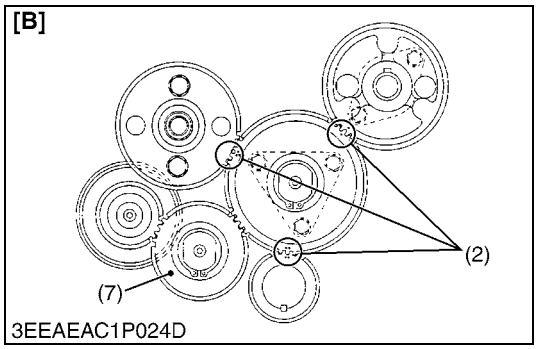
(1) Water Pump Flange
(2) Water Pump Assembly
(3) Water Pump Gasket

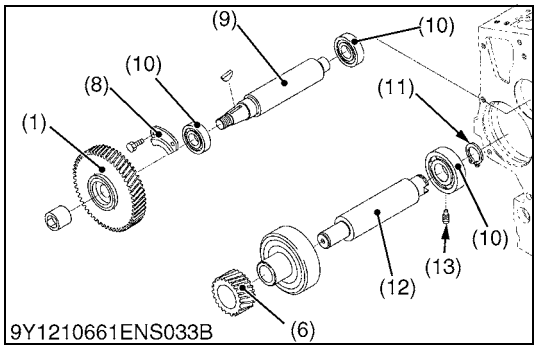
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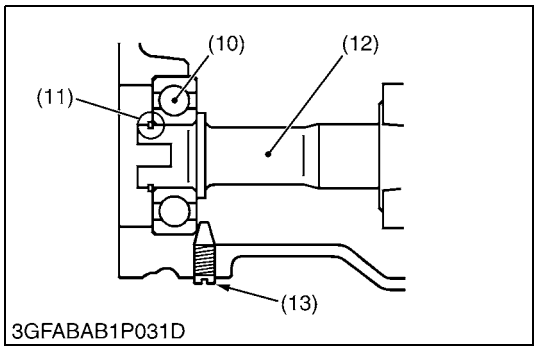


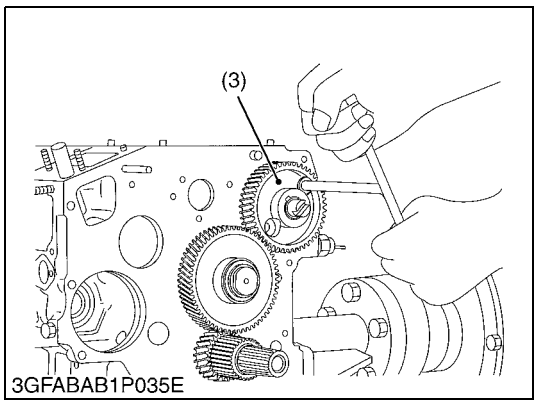
9Y1210661ENS032A











Cam Gear, Idle Gear 1, 2 and Governor Gear

1. Remove the idle gear 2 (7) / idle gear 1 (4).
2. Remove the fuel camshaft stopper (8).
3. Draw out the injection pump gear (1) with fuel gear shaft (9).
4. Remove the camshaft stopper bolt.
5. Remove the cam gear (3) with camshaft.
6. Remove the external snap ring (11) from the PTO shaft (12).
7. Remove the governor gear (6) with PTO shaft (12).

■ **NOTE**

- **Three-lever type fork lever**
  To remove the governor shaft, follow the procedures in 5, 6 above and never remove fork lever and the max torque limiter.

(When reassembling)

- Apply engine oil thinly to the fuel camshaft before installation.
- Make sure to assemble the external snap ring of the governor shaft.
- Check the governor shaft for smooth rotation.

■ **IMPORTANT**

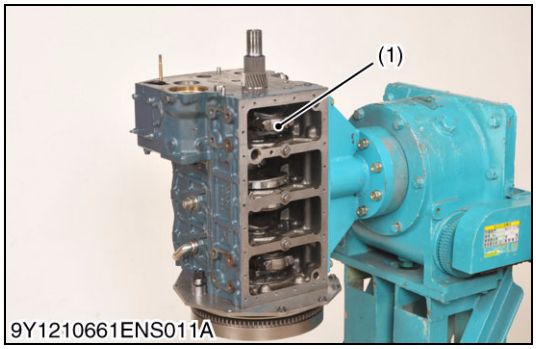
- **There is a model of idle gear 1 (4) and idle gear 2 (7) by the difference of the method of transmission the power to the governor gear (6).**
- **When replacing the ball bearing of governor shaft, securely fit the ball bearing (10) to the crankcase, apply an adhesive (Three Bond 1324B or equivalent) to the set screw (13), and fasten the screw until its tapered part contacts the circumferential end of the ball bearing.**
- **When installing the idle gear, be sure to align the alignment marks on each gears.**

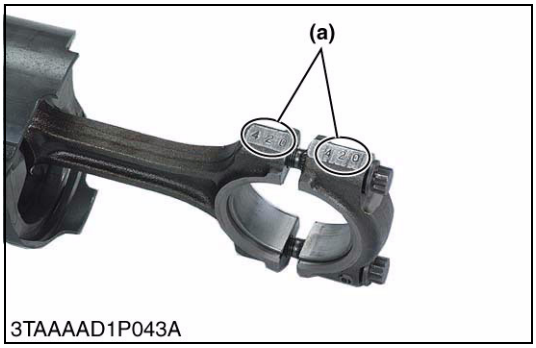
(1) Injection Pump Gear
(2) Alignment Mark
(3) Cam Gear
(4) Idle Gear 1
(5) Crank Gear
(6) Governor Gear
(7) Idle Gear 2
(8) Fuel Camshaft Stopper
(9) Gear Shaft
(10) Ball Bearing
(11) External Snap Ring
(12) PTO Shaft
(13) Set Screw

[A] One Idle Gear Type
[B] Two Idle Gear Type

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(6) Piston and Connecting Rod





Connecting Rod Cap

1. Remove the connecting rod caps (1) using a hexagonal 8 mm socket.

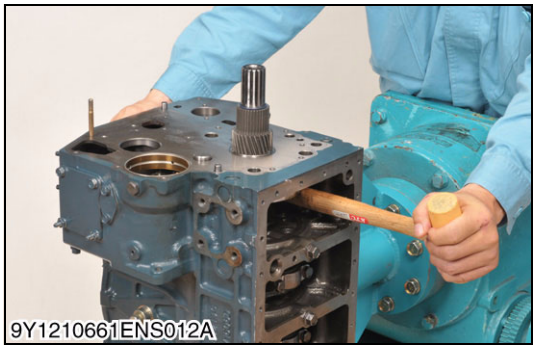
(When reassembling)

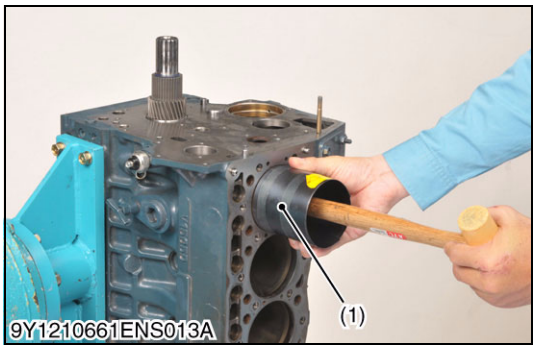
- Align the marks **(a)** with each other. (Face the marks toward the intake manifold.)
- Apply engine oil to the connecting rod screws and lightly screw it in by hand, then tighten it to the specified torque.
  If the connecting rod screw won't be screwed in smoothly, clean the threads.
  If the connecting rod screw is still hard to screw in, replace it.

Tightening torque	Connecting rod screw	41.2 to 46.1 N·m 4.21 to 4.70 kgf·m 30.4 to 34.0 lbf·ft

(1) Connecting Rod Cap **(a) Mark**

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Piston

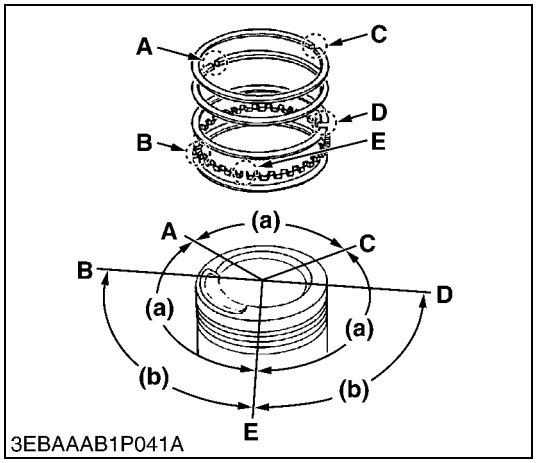
1. Turn the flywheel and bring the piston to top dead center.
2. Draw out the piston upward by lightly tapping it from the bottom of the crankcase with the grip of a hammer.
3. Draw out the other pistons after the same method as above.

(When reassembling)

- Before inserting the piston into the cylinder, apply enough engine oil to the piston.
- When inserting the piston into the cylinder, face the mark on the connecting rod to the fuel camshaft.
- When inserting the piston into the cylinder, place the gap **"C"** of the top compression ring on the opposite side of the slant portion, and stagger the gaps **"A"**, **"E"** of the second compression ring and spacer making 2.09 rad (120 °) from the gap of the top compression ring. Further, stagger the gaps **"D"**, **"B"** of the upper and lower side rail making 1.6 rad (90 °) from the gap of the spacer.

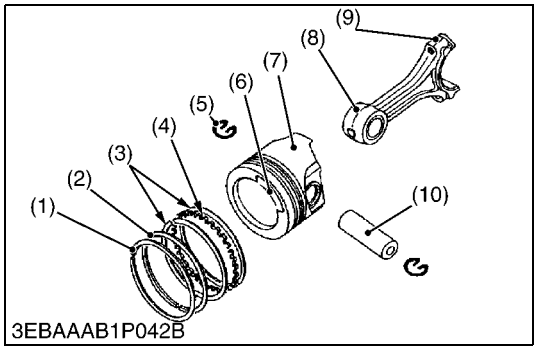
■ **IMPORTANT**

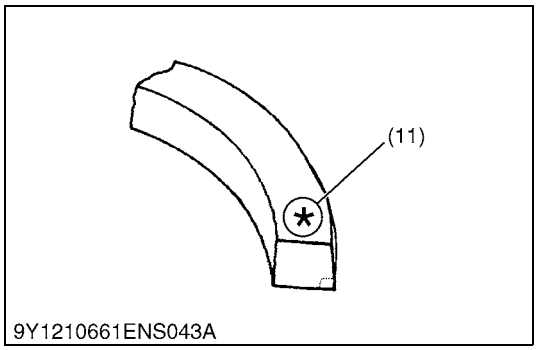
- **Do not change the combination of cylinder and piston. Make sure of the position of each piston by marking. For example, mark "1" on the No. 1 piston.**
- **When installing the piston into the cylinder, place the gaps of all of the piston rings as shown in the figure.**
- **Carefully insert the piston using a piston ring compressor (1). Otherwise, their chrome-plated section may be scratched, causing trouble inside the cylinder.**



(1) Piston Ring Compressor
A: Second Compression Ring Gap
B: Side Rail Gap
C: Top Compression Ring Gap
D: Side Rail Gap
E: Spacer Gap
(a) 2.09 rad (120 °)
(b) 1.6 rad (90 °)

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Piston Ring and Connecting Rod

1. Remove the piston rings using a piston ring tool.
2. Remove the piston pin (10), and separate the connecting rod (8) from the piston (7).

(When reassembling)

- When installing the second ring (2), assemble the rings so that the manufacturer's mark (11) near the gap faces the top of the piston.
- Apply engine oil to the piston pin.
- When installing the connecting rod to the piston, immerse the piston in 80 °C (176 °F) oil for 10 to 15 minutes and insert the piston pin to the piston.
- When installing the connecting rod to the piston, align the mark (9) on the connecting rod to the plug recess (6).

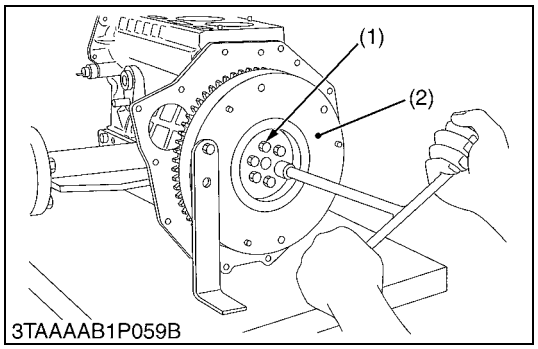
■ **IMPORTANT**

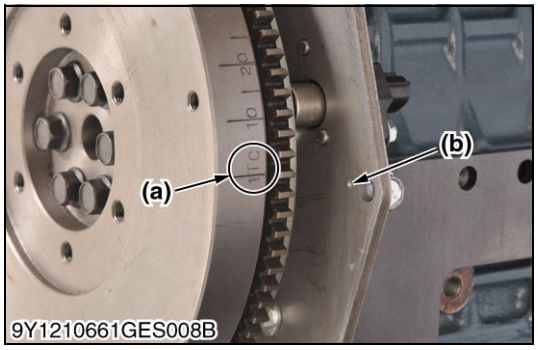
- **Mark the same number on the connecting rod and the piston so as not to change the combination.**

(1) Top Ring
(2) Second Ring
(3) Side Rail
(4) Spacer
(5) Piston Pin Snap Ring
(6) Plug Recess
(7) Piston
(8) Connecting Rod
(9) Mark
(10) Piston Pin
(11) Manufacturer's Mark
Top Ring: 1N
Second Ring: 2N
Oil Ring: None

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(7) Crankshaft





Flywheel

1. Secure the flywheel to keep it from turning using a flywheel stopper.
2. Remove all flywheel screws (1) and then remove the flywheel (2).

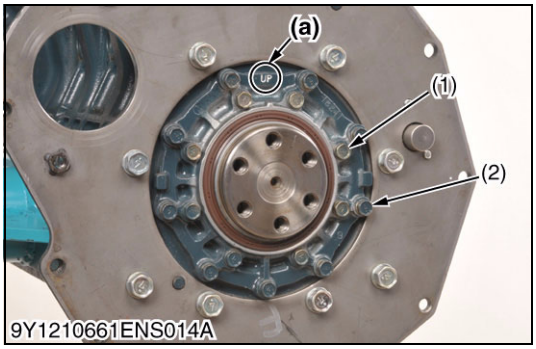
(When reassembling)

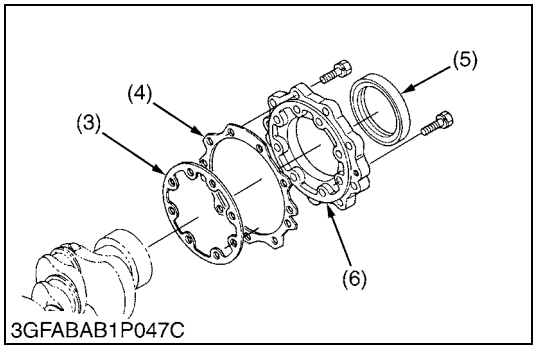
- Align the **"1TC"** mark **(a)** on the outer surface of the flywheel horizontally with the alignment mark **(b)** on the rear end plate. Now fit the flywheel in position.
- Apply engine oil to the threads and the undercut surface of the flywheel screw and fit the screw.

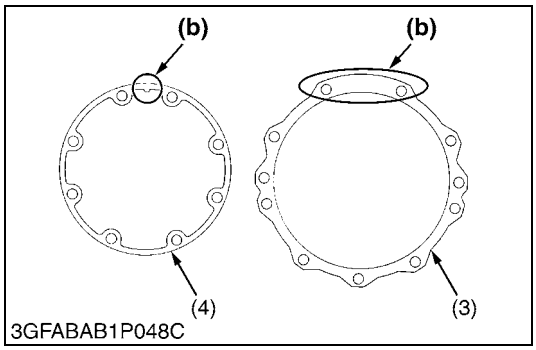
Tightening torque	Flywheel screw	53.9 to 58.8 N·m 5.50 to 5.99 kgf·m 39.8 to 43.3 lbf·ft

(1) Flywheel Screw
(2) Flywheel
(a) 1TC Mark
(b) Alignment Mark

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Bearing Case Cover

1. Remove the bearing case cover mounting screws. First, remove inside screws (1) and then outside screws (2).
2. Remove the bearing case cover (6).

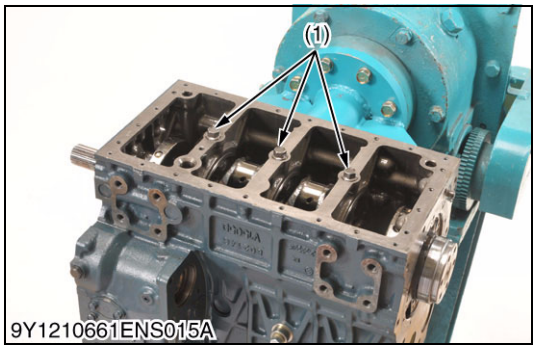
(When reassembling)

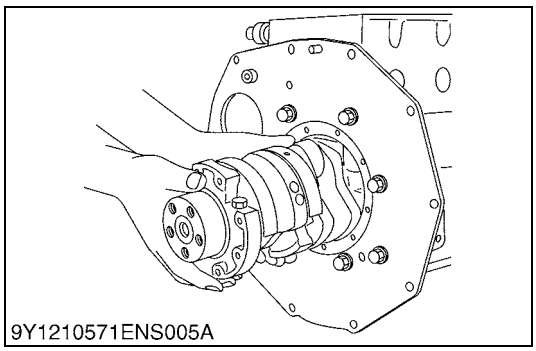
- Fit the bearing case gasket (3) and the bearing case cover gasket (4) with correct directions.
- Install the bearing case cover (6) to position the casting mark "UP" **(a)** on it upward.
- Apply engine oil to the oil seal (5) lip and be careful that it is not rolled when installing.
- Tighten the bearing case cover mounting screws with even force on the diagonal line.

Tightening torque	Bearing case cover mounting screw	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

(1) Bearing Case Cover Mounting Screw (Inside)
(2) Bearing Case Cover Mounting Screw (Outside)
(3) Bearing Case Gasket
(4) Bearing Case Cover Gasket
(5) Oil Seal
(6) Bearing Case Cover
(a) Top Mark "UP"
(b) Upside

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Crankshaft Assembly

1. Remove the main bearing case screw 2 (1).
2. Pull out the crankshaft assembly

■ **IMPORTANT**

- **Be careful to protect crankshaft bearing 1 from scratches, caused by the crank shaft, etc.**

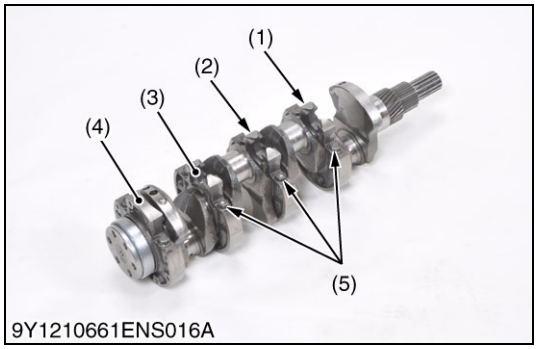
(When reassembling)

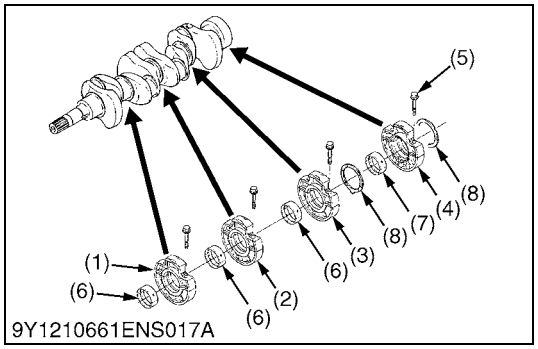
- Clean the oil passage of the crankshaft with compressed air.
- Apply oil to the main bearing case screw 2 (1).
- Install the crankshaft assembly, aligning the screw hole of main bearing case with the screw hole of crankcase.
- Clean the oil passage of the crankshaft with compressed air.

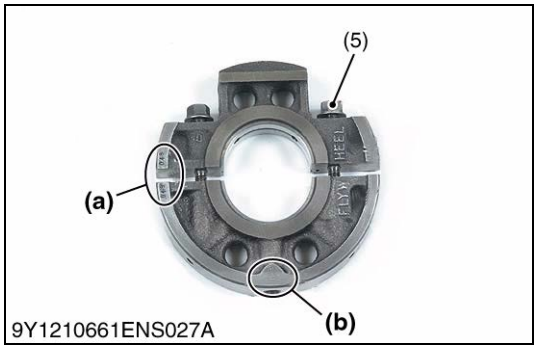
Tightening torque	Main bearing case screw 2	49.0 to 53.9 N·m 5.00 to 5.49 kgf·m 36.2 to 39.7 lbf·ft

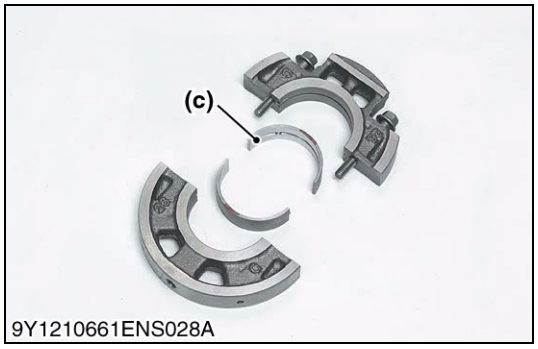
(1) Main Bearing Case Screw 2

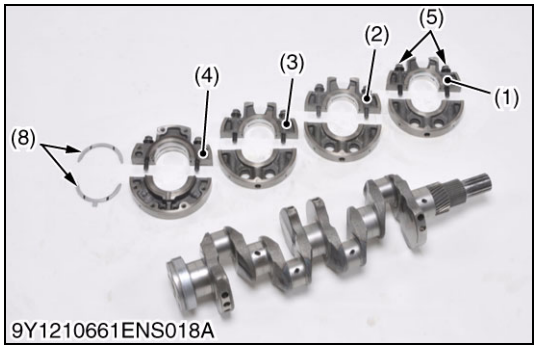
9Y1210661ENS0033US0











Main Bearing Case Assembly

1. Remove the two main bearing case screws 1 (5), and remove the main bearing case assembly 1 (1), being careful with crankshaft bearing 3 (7).
2. Remove the main bearing case assembly 2 (2), the main bearing case assembly 3 (3) and the main bearing case assembly (4) as above. Keep in mind, however, that the thrust bearing (8) is installed in the main bearing case assembly (4).

(When reassembling)

- Clean the oil passage in the main bearing cases.
- Apply clean engine oil to the bearings.
- Install the main bearing case assemblies in original positions. Since diameters of main bearing cases vary, install them in order of marking **(b)** from the gear case side. (Refer to the figure.)
- Be careful not to confuse the top and bottom of the crankshaft bearing 3 (7). (Install the bearing with the oil groove **(c)** up.).
- Match the alignment numbers **(a)** on the main bearing case assembly 1.
- Do the same for the main bearing case assembly 2 (2), the main bearing case assembly 3 (3) and the main bearing case assembly (4) too.
- When installing the main bearing case 1, 2 and 3, face the mark **"FLYWHEEL"** to the flywheel.
- Install the thrust bearing (8) with its oil groove facing outward.
- Make sure that the main bearing case moves smoothly after tightening the main bearing case screw 1 (5) to the specified torque.

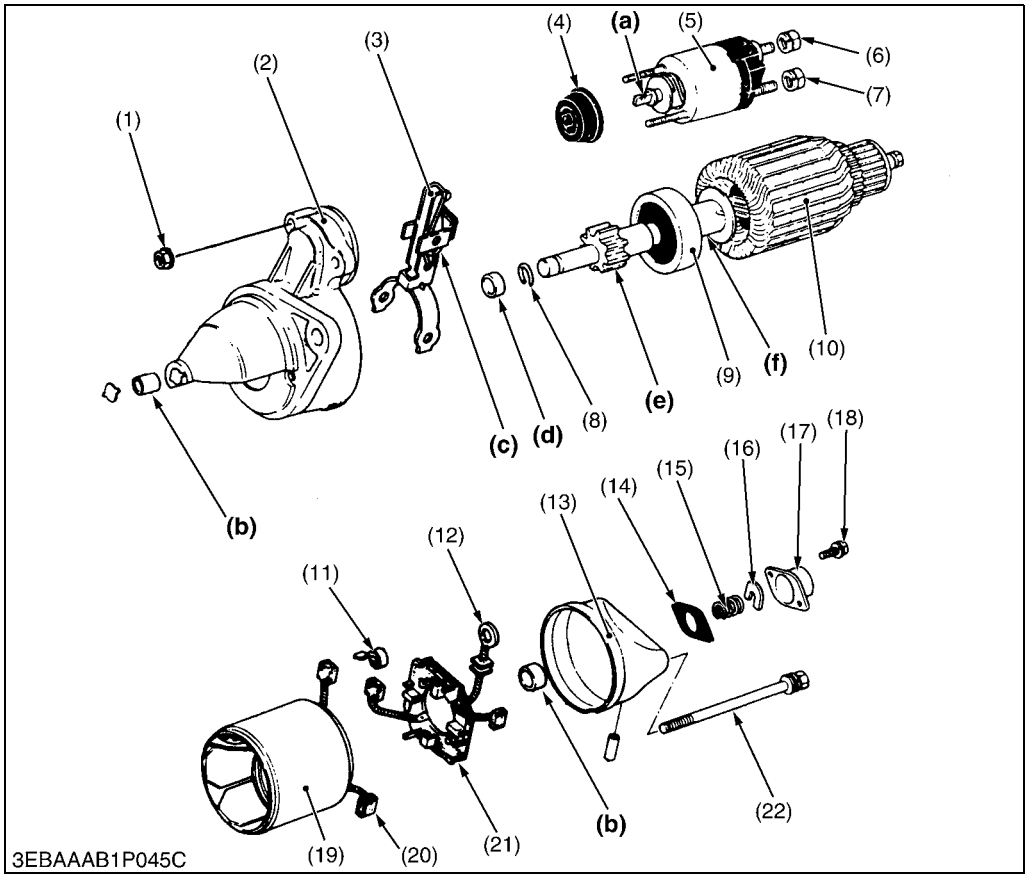
Tightening torque	Main bearing case screw 1	29.4 to 34.3 N·m 3.00 to 3.49 kgf·m 21.7 to 25.2 lbf·ft

(1) Main Bearing Case Assembly 1
(2) Main Bearing Case Assembly 2
(3) Main Bearing Case Assembly 3
(4) Main Bearing Case Assembly
(5) Main Bearing Case Screw 1
(6) Crankshaft Bearing 2
(7) Crankshaft Bearing 3
(8) Thrust Bearing

(a) Alignment Number
(b) Marking (A, B, C)
(c) Oil Groove

9Y1210661ENS0034US0

(8) Starter



(1) Solenoid Switch Mounting Nut
(2) Starter Drive Housing
(3) Drive Lever
(4) Gasket
(5) Solenoid Switch
(6) **B** Terminal Nut
(7) **C** Terminal Nut
(8) Snap Ring
(9) Overrunning Clutch
(10) Armature
(11) Brush Spring
(12) Connecting Lead
(13) Rear End Frame
(14) Gasket
(15) Brake Spring
(16) Brake Shoe
(17) End Frame Cap
(18) Screw
(19) Yoke
(20) Brush
(21) Brush Holder
(22) Through Bolt

1. Remove the **C** terminal nut (7), and disconnect the connecting lead (12).
2. Remove the solenoid switch mounting nuts (1), then the solenoid switch (5).
3. Remove the end frame cap (17).
4. Remove the brake shoe (16), brake spring (15) and gasket (14).
5. Remove the through bolts (22), then the rear end frame (13).
6. Remove the brush from the brush holder while holding the spring up.
7. Remove the brush holder (21).
8. Draw out the yoke (19) from the starter drive housing (2).
9. Draw out the armature (10) with the drive lever (3).

■ **NOTE**

- **Do not damage to the brush and commutator.**

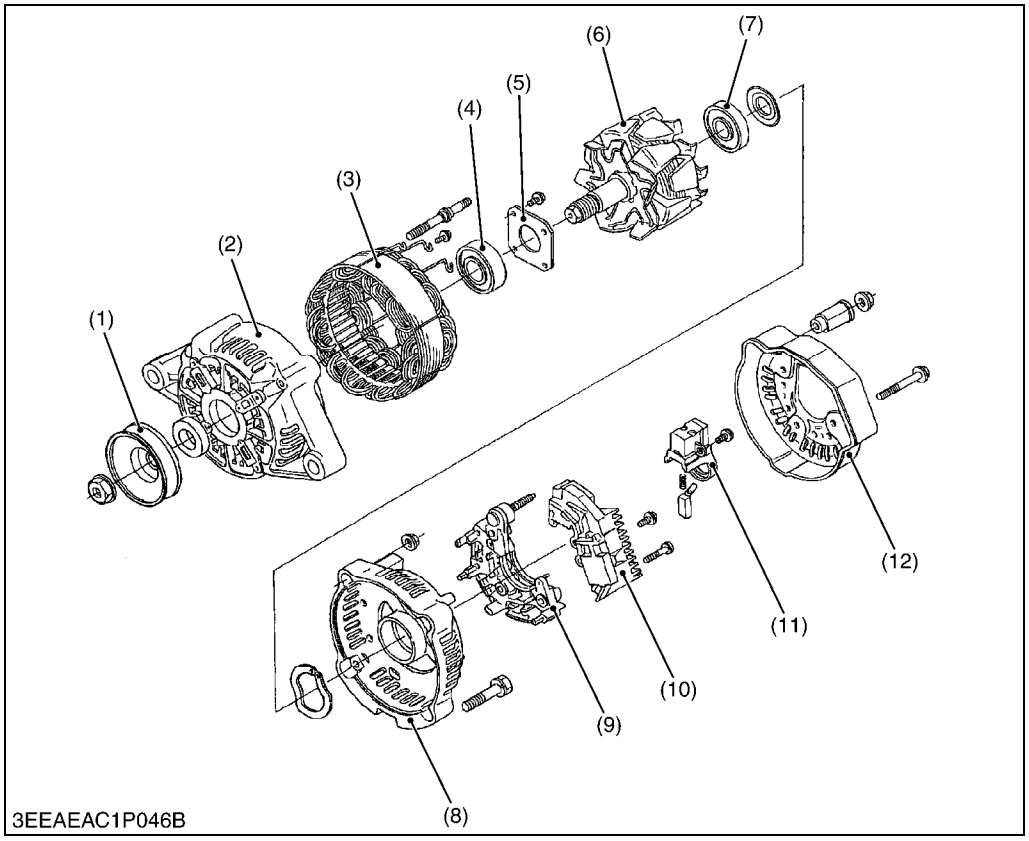
(When reassembling)

- Apply grease (DENSO.CO.LTD. No. 50 or equivalent) to the parts indicated in the figure.
  - Joint of solenoid switch **(a)**
  - Bushing **(b)**
  - Drive lever **(c)**
  - Collar **(d)**
  - Teeth of pinion gear **(e)**
  - Armature shaft **(f)**

Tightening torque	Starter's terminal **B** mounting nut	5.88 to 11.8 N·m 0.600 to 1.20 kgf·m 4.34 to 8.70 lbf·ft

9Y1210661ENS0035US0

(9) Alternator



(1) Pulley
(2) Drive End Frame
(3) Stator
(4) Bearing
(5) Retainer Plate
(6) Rotor
(7) Bearing
(8) Rear End Frame
(9) Rectifier
(10) IC Regulator
(11) Brush Holder
(12) Rear End Cover

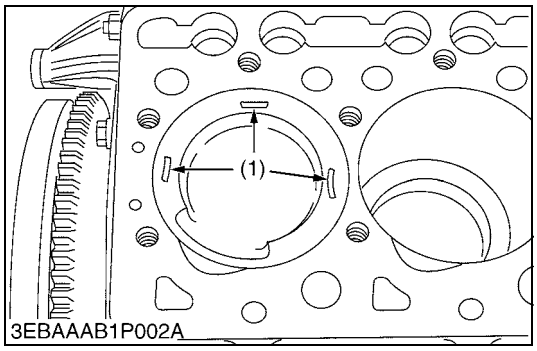
1. Remove the pulley (1).
2. Remove the rear end cover (12).
3. Remove the brush holder (11).
4. Remove the IC regulator (10).
5. Remove the four screws holding the stator lead wires.
6. Remove the rectifier (9).
7. Remove the rear end frame (8).
8. Press out the rotor (6) from drive end frame (2).
9. Remove the retainer plate (5).
10. Press out the bearing (4) from drive end frame (2) with a press and jig.
11. Lightly secure the rotor with a vise to prevent damage, and remove the bearing (7) with a puller.

(When reassembling)

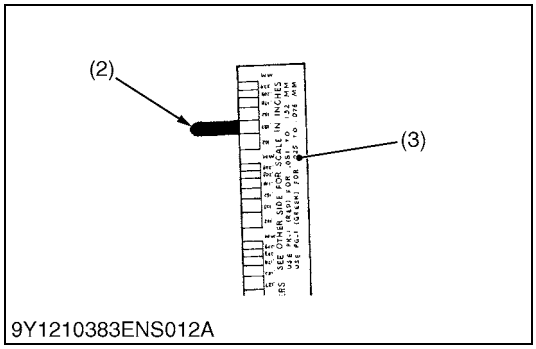
Tightening torque	Alternator's pulley nut	58.4 to 78.9 N·m 5.95 to 8.05 kgf·m 43.1 to 58.2 lbf·ft

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[3] SERVICING
(1) Cylinder Head and Valves



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9Y1210383ENS012A

Top Clearance

1. Remove the cylinder head.
2. With the piston at TDC, use grease to affix three or four plastigauges (1) of a diameter 1.5 mm (0.059 in.) × 5.0 to 7.0 mm (0.20 to 0.27 in.) long to the crown of the piston; keep the gauges away from the intake valve and combustion chamber fittings.
3. Take the piston to an intermediate position, install the cylinder head and tighten the head bolts to the specified torque.
4. Turn the crankshaft so the piston goes through TDC.
5. Remove the cylinder head and compare the width of the crushed plastigauges (2) with the scale (3).
6. If they are out of spec, check the oil clearance of the crank pin, journal and piston pins.

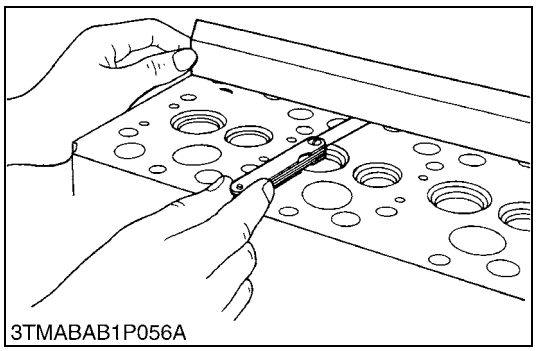
■ **NOTE**
- **Top clearance = Width of the crushed plastigauge (2).**

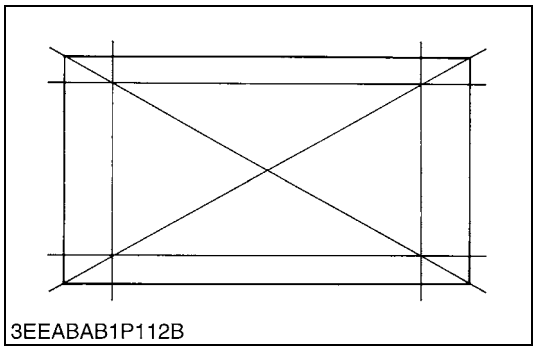
Top clearance	Factory specification	1.2 to 1.5 mm 0.048 to 0.059 in

Tightening torque	Cylinder head screws	63.7 to 68.6 N·m 6.50 to 6.99 kgf·m 47.0 to 50.5 lbf·ft

(1) Plastigauge
(2) Crushed Plastigauge
(3) Scale

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3EEABAB1P112B

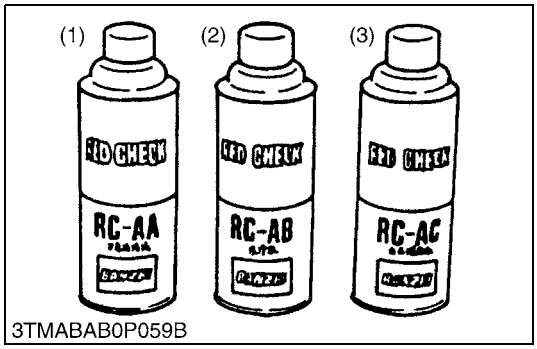
Cylinder Head Surface Flatness

1. Clean the cylinder head surface.
2. Place a straightedge on the cylinder head's four sides and two diagonal as shown in the figure.
   Measure the clearance with a feeler gauge.
3. If the measurement exceeds the allowable limit, correct it with a surface grinder.

■ **IMPORTANT**
- **Be sure to check the valve recessing after correcting.**

Cylinder head surface flatness	Allowable limit	0.05 mm 0.002 in.

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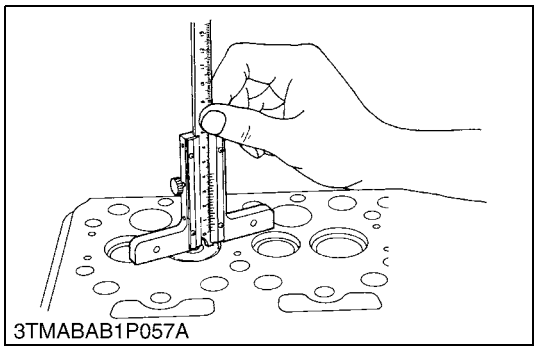
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Cylinder Head Flaw

1. Prepare an air spray red check.
2. Clean the surface of the cylinder head with the detergent (2).
3. Spray the cylinder head surface with the red permeative liquid (1). Leave it five to ten minutes after spraying.
4. Wash away the red permeative liquid on the cylinder head surface with the detergent (2).
5. Spray the cylinder head surface with the white developer (3).
6. If flawed, it can be identified as red marks.

(1) Red Permeative Liquid
(2) Detergent
(3) White Developer

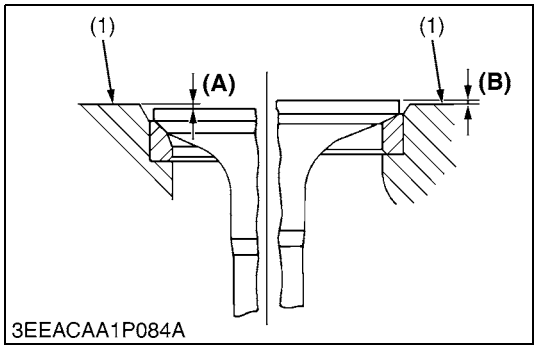
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Valve Recessing

1. Clean the cylinder head, the valve face and seat.
2. Insert the valve into the valve guide.
3. Measure the valve recessing with a depth gauge.
4. If the measurement exceeds the allowable limit, replace the valve.
5. If it still exceeds the allowable limit after replacing the valve, replace the cylinder head.

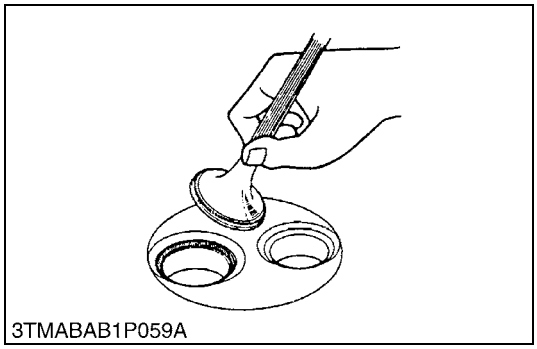
Valve recessing (Intake and Exhaust)	Factory specification	0.050 (protrusion) to 0.25 (recessing) mm 0.0020 (protrusion) to 0.0098 (recessing) in.
	Allowable limit	0.40 (recessing) mm 0.016 (recessing) in.



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(1) Cylinder Head Surface
(A) Recessing
(B) Protrusion

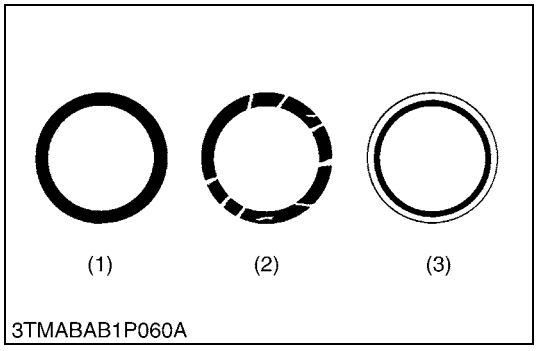
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3TMABAB1P059A

Valve Seating

1. Coat the valve face lightly with prussian blue and put the valve on its seat to check the contact.
2. If the valve does not seat all the way around the valve seat or the valve contact is less than 70 %, correct the valve seating as follows.
3. If the valve contact does not comply with the reference value, replace the valve or correct the contact of valve seating.

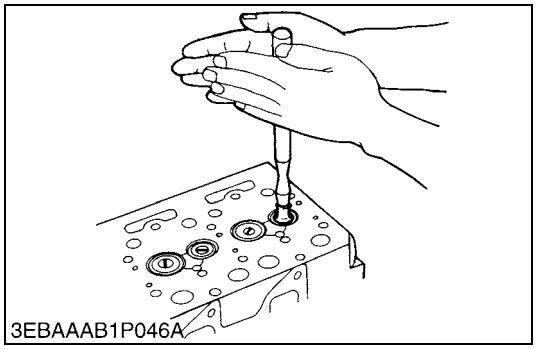
Valve seat width	Factory specification	2.12 mm 0.0835 in.



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(1) Correct
(2) Incorrect
(3) Incorrect

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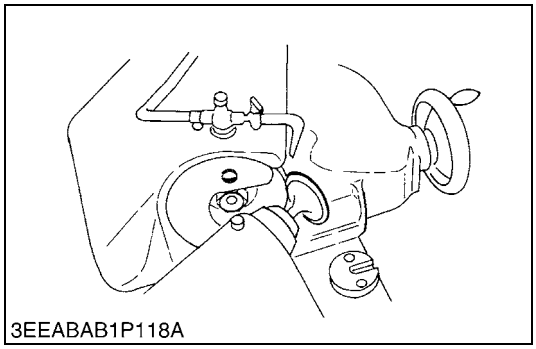
Valve Lapping

1. Apply compound evenly to the valve lapping surface.
2. Insert the valve into the valve guide. Lap the valve onto its seat with a valve flapper or screwdriver.
3. After lapping the valve, wash the compound away and apply oil, then repeat valve lapping with oil.
4. Apply prussian blue to the contact surface to check the seated rate. If it is less than 70 %, repeat valve lapping again.

■ **IMPORTANT**

- **When valve lapping is performed, be sure to check the valve recessing and adjust the valve clearance after assembling the valve.**

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Correcting Valve and Valve Seat

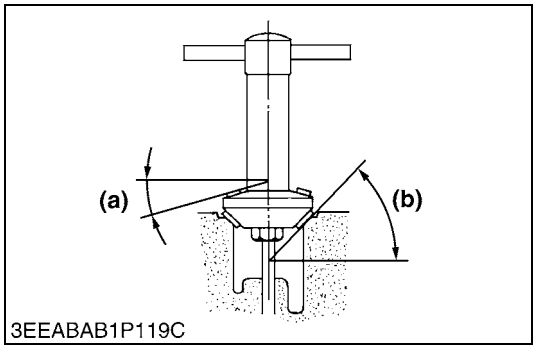
■ **NOTE**

- **Before correcting the valve and seat, check the valve stem and the I.D. of valve guide section, and repair them if necessary.**
- **After correcting the valve seat, be sure to check the valve recessing.**

1) Correcting Valve

1. Correct the valve with a valve refacer.

Valve face angle	Factory specification	IN.	1.0 rad 60 °
		EX.	1.0 rad 60 °

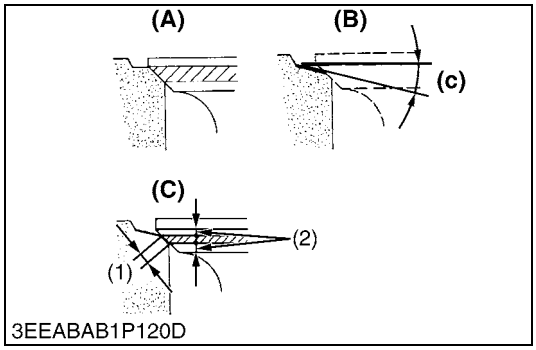


3EEABAB1P119C

2) Correcting Valve Seat

1. Slightly correct the seat surface with a 1.0 rad (60 °) valve seat cutter.
2. Resurface the seat surface with a 0.52 rad (30 °) valve seat cutter so that the width is close to specified valve seat width (2.12 mm, 0.0835 in.).
3. After resurfacing the seat, inspect for even valve seating, apply a thin film of compound between the valve face and valve seat, and fit them with valve lapping tool.
4. Check the valve seating with prussian blue. The valve seating surface should show good contact all the way around.

Valve seat angle	Factory specification	IN.	1.0 rad 60 °
		EX.	1.0 rad 60 °

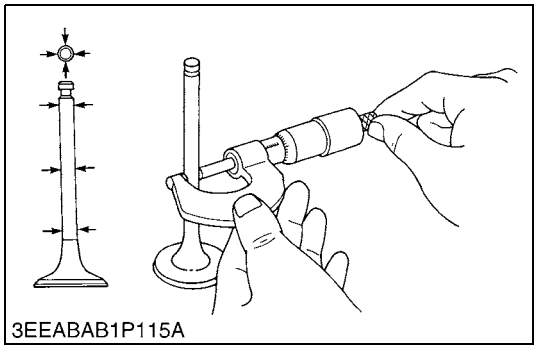


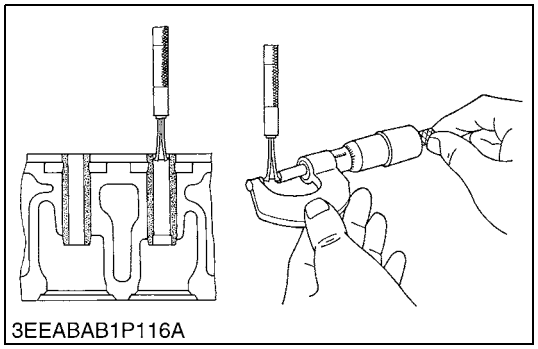
3EEABAB1P120D

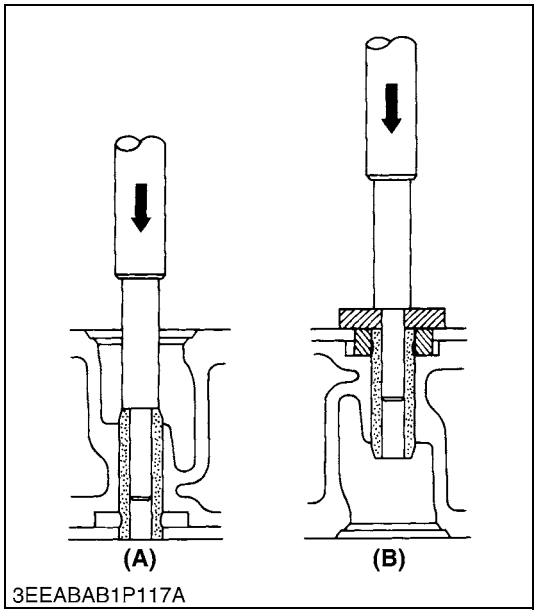
(1) Valve Seat Width
(2) Identical Dimensions

(A) Check Contact
(B) Correct Seat Width
(C) Check Contact
(a) 0.52 rad (30 °)
(b) 1.0 rad (60 °)
(c) 0.52 rad (30 °)

9Y1210661ENS0064US0


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3EEABAB1P116A



3EEABAB1P117A

Clearance between Valve Stem and Valve Guide

1. Remove carbon from the valve guide section.
2. Measure the valve stem O.D. with an outside micrometer.
3. Measure the valve guide I.D. with a small hole gauge, and calculate the clearance.
4. If the clearance exceeds the allowable limit, replace the valves. If it still exceeds the allowable limit, replace the valve guide.

Clearance between valve stem and valve guide	Factory specification	0.035 to 0.065 mm 0.0014 to 0.0025 in
	Allowable limit	0.10 mm 0.0039 in.

Valve stem O.D.	Factory specification	6.960 to 6.975 mm 0.2741 to 0.2746 in
Valve guide I.D.	Factory specification	7.010 to 7.025 mm 0.2760 to 0.2765 in

9Y1210661ENS0039US0

Replacing Valve Guide

(When removing)

1. Press out the used valve guide using a valve guide replacing tool.

(When installing)

1. Clean a new valve guide and valve guide bore, and apply engine oil to them.
2. Press in a new valve guide using a valve guide replacing tool.
3. Ream precisely the I.D. of the valve guide to the specified dimension.

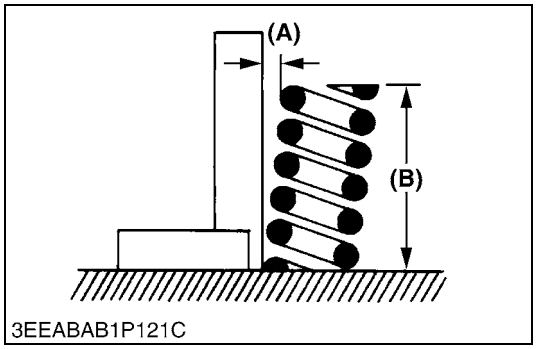
Valve guide I.D. (Intake and exhaust)	Factory specification	7.010 to 7.025 mm 0.2760 to 0.2765 in

■ **IMPORTANT**

- **Do not hit the valve guide with a hammer during replacement.**

(A) When Removing **(B) When Installing**

9Y1210661ENS0040US0



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Free Length and Tilt of Valve Spring

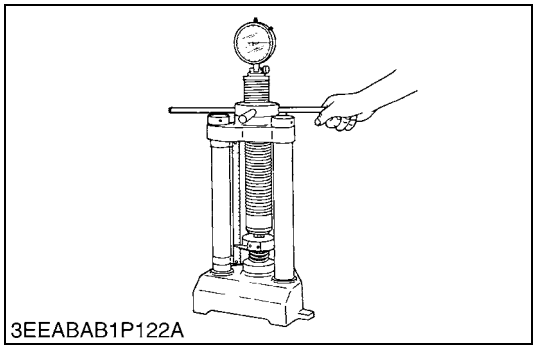
1. Measure the free length **(B)** of valve spring with vernier calipers. If the measurement is less than the allowable limit, replace it.
2. Put the spring on a surface plate, place a square on the side of the spring.
3. Check to see if the entire side is in contact with the square. Rotate the valve spring and measure the maximum tilt **(A)**. If the measurement exceeds the allowable limit, replace it.
4. Check the entire surface of the valve spring for scratches. If there is any defect, replace it.

Tilt **(A)**	Allowable limit	1.0 mm 0.039 in.

Free length **(B)**	Factory specification	35.1 to 35.6 mm 1.39 to 1.40 in
	Allowable limit	34.8 mm 1.37 in

(A) Tilt **(B) Free length**

9Y1210661ENS0041US0


3EEABAB1P122A

Valve Spring Setting Load

1. Place the valve spring on a tester and compress it to the same length it is actually compressed in the engine.
2. Read the compression load on the gauge.
3. If the measurement is less than the allowable limit, replace it.

Setting load / setting length	Factory specification	74 N / 31.0 mm 7.5 kgf / 31.0 mm 17 lbf / 1.22 in
	Allowable limit	63 N / 31.0 mm 6.4 kgf / 31.0 mm 14 lbf / 1.22 in

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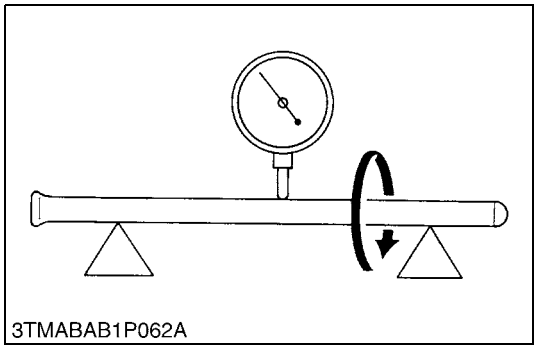
Oil Clearance between Rocker Arm and Rocker Arm Shaft

1. Measure the rocker arm shaft O.D. with an outside micrometer.
2. Measure the rocker arm I.D. with an inside micrometer, and then calculate the oil clearance.
3. If the oil clearance exceeds the allowable limit, replace the rocker arm and measure the oil clearance again. If it still exceeds the allowable limit, replace also the rocker arm shaft.

Oil clearance between rocker arm and rocker arm shaft	Factory specification	0.016 to 0.045 mm 0.00063 to 0.0017 in.
	Allowable limit	0.15 mm 0.0059 in.

Rocker arm shaft O.D.	Factory specification	11.973 to 11.984 mm 0.47138 to 0.47181 in
Rocker arm I.D.	Factory specification	12.000 to 12.018 mm 0.47244 to 0.47314 in.

9Y1210661ENS0071US0

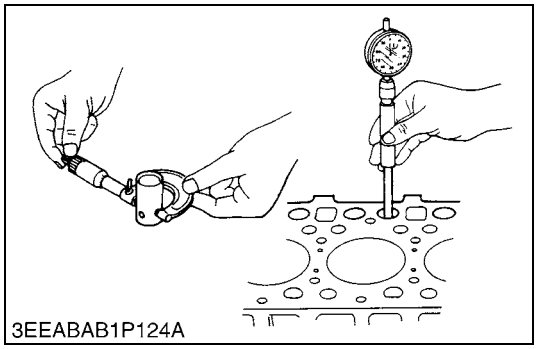

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Push Rod Alignment

1. Place the push rod on V blocks.
2. Measure the push rod alignment.
3. If the measurement exceeds the allowable limit, replace the push rod.

Push rod alignment	Allowable limit	0.25 mm 0.0098 in.

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Oil Clearance between Tappet and Tappet Guide Bore

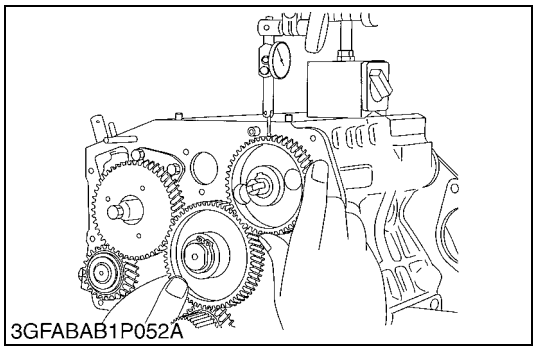
1. Measure the tappet O.D. with an outside micrometer.
2. Measure the I.D. of the tappet guide bore with a cylinder gauge, and calculate the oil clearance.
3. If the oil clearance exceeds the allowable limit or the tappet is damaged, replace the tappet.

Oil clearance between tappet and tappet guide bore	Factory specification	0.020 to 0.062 mm 0.00079 to 0.0024 in
	Allowable limit	0.07 mm 0.003 in.

Tappet O.D.	Factory specification	19.959 to 19.980 mm 0.78579 to 0.78661 in
Tappet guide bore I.D.	Factory specification	20.000 to 20.021 mm 0.78741 to 0.78822 in

9Y1210661ENS0070US0

(2) Timing Gear and Camshaft


3GFABAB1P052A

Timing Gear Backlash

1. Set a dial indicator (lever type) with its tip on the gear tooth.
2. Move the gear to measure the backlash, holding its mating gear.
3. If the backlash exceeds the allowable limit, check the oil clearance of the shafts and the gear.
4. If the oil clearance is proper, replace the gear.

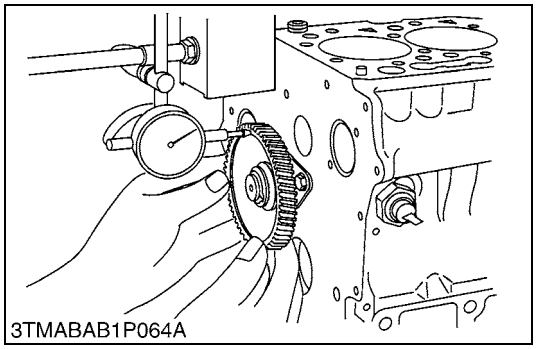
Backlash between idle gear 1 and crank gear	Factory specification	0.0320 to 0.115 mm 0.00126 to 0.00452 in
	Allowable limit	0.15 mm 0.0059 in.
Backlash between idle gear 1 and cam gear	Factory specification	0.0360 to 0.114 mm 0.00142 to 0.00448 in
	Allowable limit	0.15 mm 0.0059 in.
Backlash between idle gear 1 and injection pump gear	Factory specification	0.0340 to 0.116 mm 0.00134 to 0.00456 in
	Allowable limit	0.15 mm 0.0059 in.
(equipped with idle gear 2) Backlash between idle gear 1 and idle gear 2	Factory specification	0.0330 to 0.117 mm 0.00130 to 0.00460 in.
	Allowable limit	0.15 mm 0.0059 in.

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Governor Gear Backlash

Backlash between injection pump gear and governor gear	Factory specification	0.0300 to 0.117 mm 0.00119 to 0.00460 in.
	Allowable limit	0.15 mm 0.0059 in.
(equipped with idle gear 2) idle gear 2 and governor gear	Factory specification	0.0300 to 0.117 mm 0.00119 to 0.00460 in.
	Allowable limit	0.15 mm 0.0059 in.

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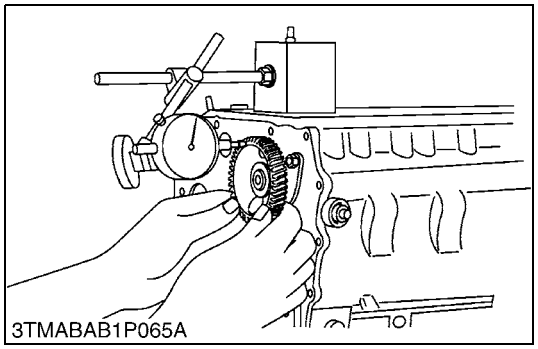

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Idle Gear 1 and 2 Side Clearance

1. Set a dial indicator with its tip on the idle gear.
2. Measure the side clearance by moving the idle gear to the front and rear.
3. If the measurement exceeds the allowable limit, replace the idle gear collar.

Idle gear 1 and 2 side clearance	Factory specification	0.20 to 0.51 mm 0.0079 to 0.020 in.
	Allowable limit	0.80 mm 0.031 in.

9Y1210661ENS0046US0

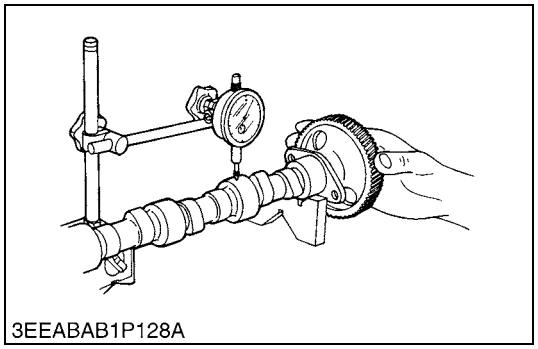

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Camshaft Side Clearance

1. Set a dial indicator with its tip on the camshaft.
2. Measure the side clearance by moving the cam gear to the front and rear.
3. If the measurement exceeds the allowable limit, replace the camshaft stopper.

Camshaft side clearance	Factory specification	0.0700 to 0.220 mm 0.00276 to 0.00866 in
	Allowable limit	0.30 mm 0.012 in.

9Y1210661ENS0072US0

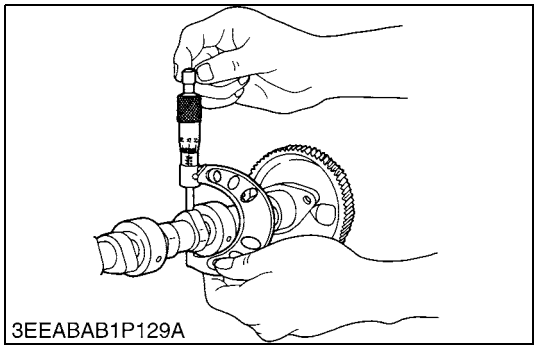

3EEABAB1P128A

Camshaft Alignment

1. Support the camshaft with V blocks on the surface plate at both end journals.
2. Set a dial indicator with its tip on the intermediate journal.
3. Measure the camshaft alignment.
4. If the measurement exceeds the allowable limit, replace the camshaft.

Camshaft alignment	Allowable limit	0.01 mm 0.0004 in.

9Y1210318ENS0103US0

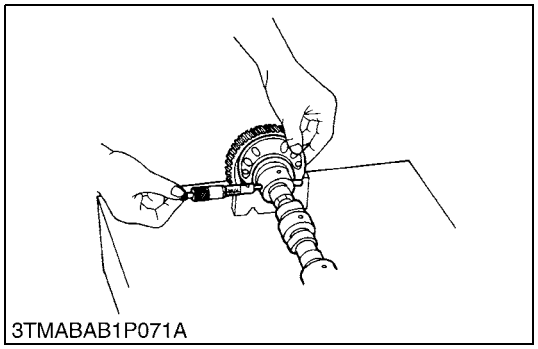

3EEABAB1P129A

Cam Height

1. Measure the height of the cam at its highest point with an outside micrometer.
2. If the measurement is less than the allowable limit, replace the camshaft.

Cam height	Factory specification	IN.	28.80 mm 1.134 in.
		EX.	29.00 mm 1.142 in
	Allowable limit	IN.	28.75 mm 1.132 in.
		EX.	28.95 mm 1.140 in.

9Y1210661ENS0073US0


3TMABAB1P071A

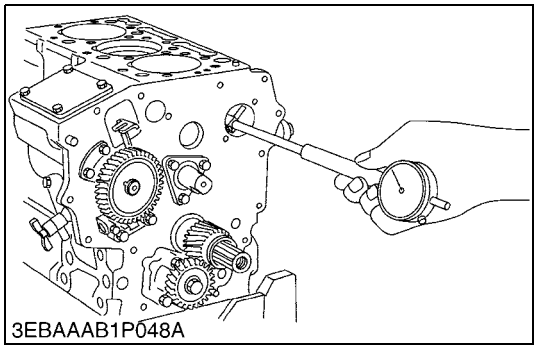
Oil Clearance of Camshaft Journal

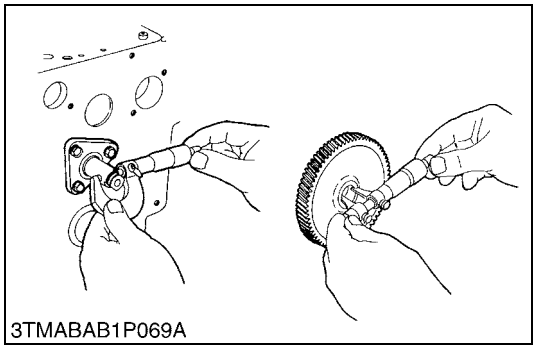
1. Measure the camshaft journal O.D. with an outside micrometer.
2. Measure the cylinder block bore I.D. for camshaft with a inside micrometer, and calculate the oil clearance.
3. If the clearance exceeds the allowable limit, replace the camshaft.

Oil clearance of camshaft journal	Factory specification	0.050 to 0.091 mm 0.0020 to 0.0035 in.
	Allowable limit	0.15 mm 0.0059 in.

Camshaft journal O.D.	Factory specification	35.934 to 35.950 mm 1.4148 to 1.4153 in
Camshaft bearing I.D. (Cylinder block bore I.D.)	Factory specification	36.000 to 36.025 mm 1.4174 to 1.4183 in

9Y1210661ENS0048US0


3EBAAAB1P048A


3TMABAB1P069A

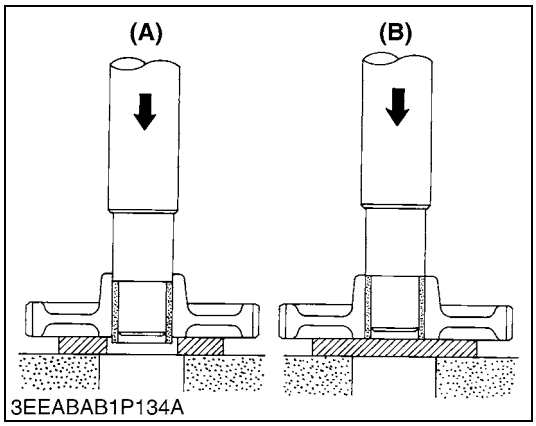
Oil Clearance between Idle Gear Shaft 1 and 2 and Idle Gear Bushing

1. Measure the idle gear shaft O.D. with an outside micrometer.
2. Measure the idle gear bushings I.D. with an inside micrometer, and calculate the oil clearance.
3. If the oil clearance exceeds the allowable limit, replace the bushing.
4. If it still exceeds the allowable limit, replace the idle gear shaft.

Oil clearance between idle gear shaft (1 and 2) and idle gear bushing	Factory specification	0.020 to 0.054 mm 0.00079 to 0.0021 in
	Allowable limit	0.10 mm 0.0039 in.

Idle gear shaft 1 and 2 O.D.	Factory specification	25.967 to 25.980 mm 1.0224 to 1.0228 in
Idle gear bushing 1 and 2 I.D.	Factory specification	26.000 to 26.021 mm 1.0237 to 1.0244 in

9Y1210661ENS0049US0



3EEABAB1P134A

Replacing Idle Gear Bushing

(When removing)

1. Press out the used idle gear bushing using an idle gear bushing replacing tool.

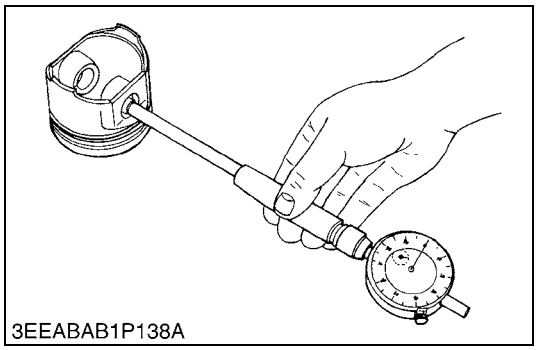
(When installing)

1. Clean a new idle gear bushing and idle gear bore, and apply engine oil to them.
2. Press in a new bushing using an idle gear bushing replacing tool, until it is flush with the end of the idle gear.

(A) When Removing **(B) When Installing**

9Y1210318ENS0107US0

(3) Piston and Connecting Rod

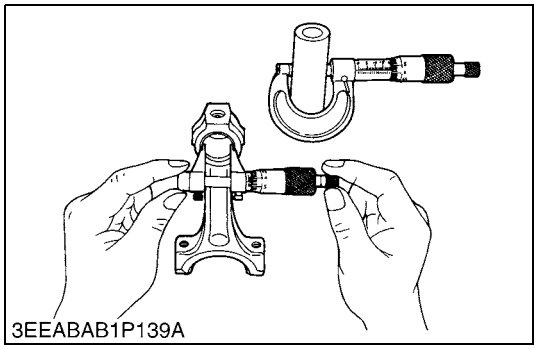

3EEABAB1P138A

Piston Pin Bore I.D.

1. Measure the piston pin bore I.D. in both the horizontal and vertical directions with a cylinder gauge.
2. If the measurement exceeds the allowable limit, replace the piston.

Piston pin bore I.D.	Factory specification	22.000 to 22.013 mm 0.86615 to 0.86665 in
	Allowable limit	22.03 mm0.8673 in.

9Y1210661ENS0050US0


3EEABAB1P139A

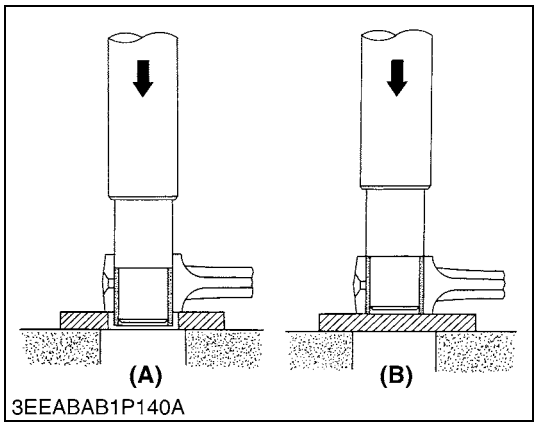
Oil Clearance between Piston Pin and Small End Bushing

1. Measure the O.D. of the piston pin where it contacts the bushing with an outside micrometer.
2. Measure the small end bushing I.D. with an inside micrometer, and calculate the oil clearance.
3. If the oil clearance exceeds the allowable limit, replace the bushing. If it still exceeds the allowable limit, replace the piston pin.

Oil clearance between piston pin and small end bushing	Factory specification	0.014 to 0.038 mm 0.00056 to 0.0014 in.
	Allowable limit	0.10 mm 0.0039 in.

Piston pin O.D.	Factory specification	22.002 to 22.011 mm 0.86622 to 0.86657 in
Small end bushing I.D.	Factory specification	22.025 to 22.040 mm 0.86713 to 0.86771 in

9Y1210661ENS0074US0



3EEABAB1P140A

Replacing Small End Bushing

(When removing)

1. Press out the used bushing using a small end bushing replacing tool. (Refer to "5. SPECIAL TOOLS" on page G-24.)

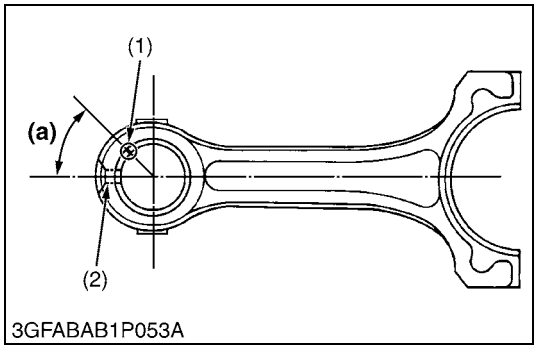
(When installing)

1. Clean a new small end bushing and bore, and apply engine oil to them.
2. Using a small end bushing replacing tool, press in a new bushing (service parts) taking due care to see that the connecting rod hole matches the bushing hole.

[Servicing parts dimension]

Oil clearance between piston pin and small end bushing (Spare parts)	Factory specification	0.014 to 0.038 mm 0.00056 to 0.0014 in
	Allowable limit	0.15 mm 0.0059 in.

Small end bushing I.D. (Spare parts)	Factory specification	22.076 to 22.146 mm 0.86914 to 0.87188 in.

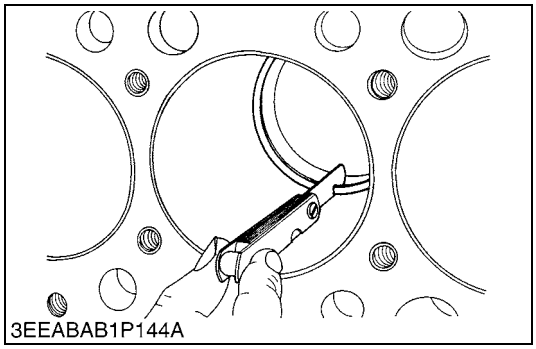


3GFABAB1P053A

(1) Seam
(2) Oil Hole

(A) When Removing
(B) When Installing
(a) 0.79 rad (45 °)

9Y1210661ENS0075US0

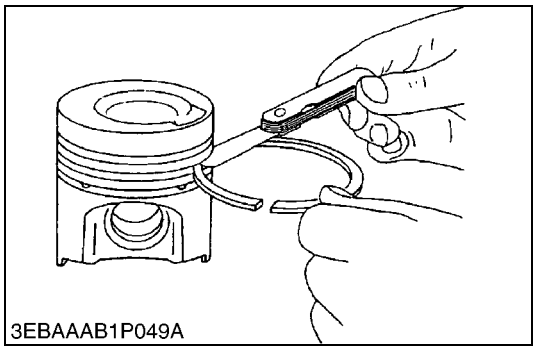

3EEABAB1P144A

Piston Ring Gap

1. Insert the piston ring into the lower part of the cylinder (the least worn out part) with a piston ring compressor and piston.
2. Measure the ring gap with a feeler gauge.
3. If the measurement exceeds the allowable limit, replace the piston ring.

Piston ring gap	Top ring	Factory specification	0.30 to 0.45 mm 0.012 to 0.017 in
		Allowable limit	1.25 mm 0.0492 in.
	Second ring	Factory specification	0.30 to 0.45 mm 0.012 to 0.017 in.
		Allowable limit	1.25 mm 0.0492 in.
	Oil ring	Factory specification	0.20 to 0.70 mm 0.0079 to 0.027 in.
		Allowable limit	1.25 mm 0.0492 in.

9Y1210661ENS0053US0

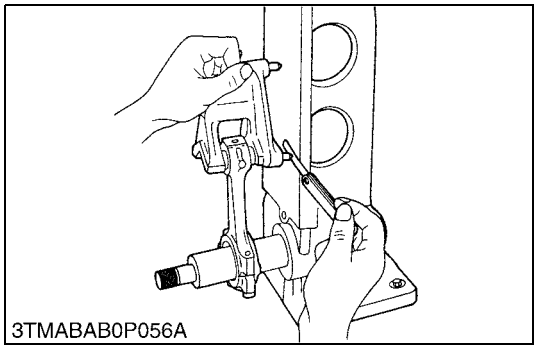

3EBAAAB1P049A

Clearance between Piston Ring and Piston Ring Groove

1. Clean the rings and the ring grooves, and install each ring in its groove.
2. Measure the clearance between the ring and the groove with a thickness gauge.
3. If the clearance exceeds the allowable limit, replace the piston ring.
4. If the clearance still exceeds the allowable limit with new ring, replace the piston.

Clearance between piston ring and piston ring groove	Top ring	Factory specification	0.040 to 0.080 mm 0.0016 to 0.0031 in
		Allowable limit	0.2 mm 0.008 in.
	Second ring	Factory specification	0.030 to 0.070 mm 0.0012 to 0.0027 in
		Allowable limit	0.2 mm 0.008 in.
	Oil ring	Factory specification	0.020 to 0.19 mm 0.00079 to 0.0074 in.
		Allowable limit	0.2 mm 0.008 in.

9Y1210661ENS0054US0


3TMABAB0P056A

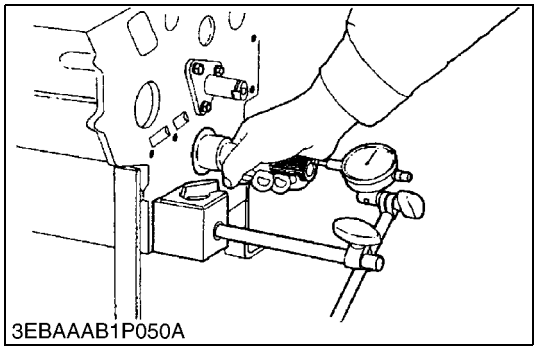
Connecting Rod Alignment

1. Remove the crankpin bearing, and install the connecting rod cap.
2. Install the piston pin in the connecting rod.
3. Install the connecting rod on the connecting rod alignment tool.
4. Put a gauge over the piston pin, and move it against the face plate.
5. If the gauge does not fit squarely against the face plate, measure the space between the pin of the gauge and the face plate.
6. If the measurement exceeds the allowable limit, replace the connecting rod.

Space between gauge pin face plate	Allowable limit	0.05 mm 0.002 in.

9Y1210318ENS0113US0

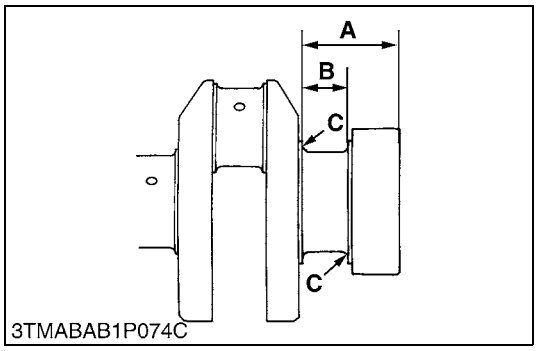
(4) Crankshaft


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Crankshaft Side Clearance

1. Set a dial indicator with its tip on the end of the crankshaft.
2. Measure the side clearance by moving the crankshaft to the front and rear.
3. If the measurement exceeds the allowable limit, replace the thrust bearings.
4. If the same size bearing is useless because of the crankshaft journal wear, replace it with an oversize one referring to the table and figure.

Crankshaft side clearance	Factory specification	0.15 to 0.31 mm 0.0059 to 0.012 in.
	Allowable limit	0.50 mm 0.020 in.



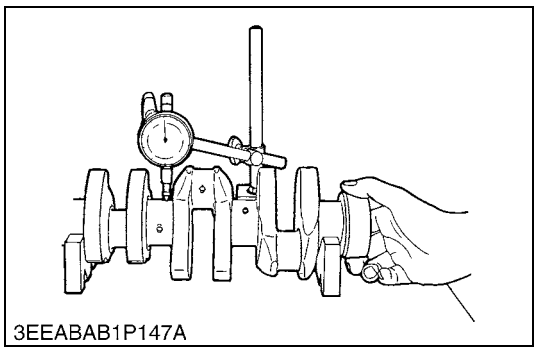
3TMABAB1P074C

(Reference)

- Oversize dimensions of crankshaft journal

Oversize	0.2 mm 0.008 in.	0.4 mm 0.02 in.
Dimension **A**	51.50 to 51.70 mm 2.028 to 2.035 in.	51.60 to 51.80 mm 2.032 to 2.039 in.
Dimension **B**	28.20 to 28.25 mm 1.111 to 1.112 in.	28.40 to 28.45 mm 1.119 to 1.120 in.
Dimension **C**	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius
The crankshaft journal must be fine-finished to higher than Rmax = 0.8S		

9Y1210661ENS0055US0

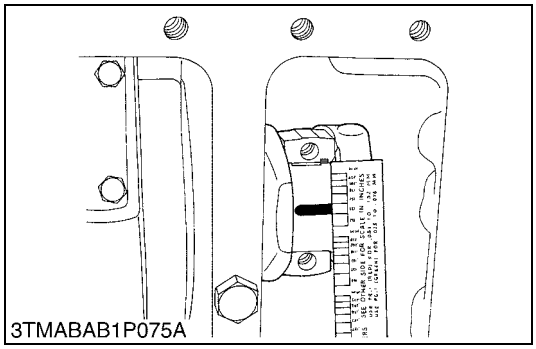

3EEABAB1P147A

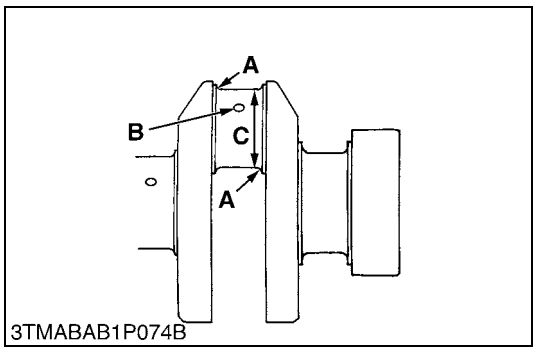
Crankshaft Alignment

1. Support the crankshaft with V blocks on the surface plate at both end journals.
2. Set a dial indicator with its tip on the intermediate journal.
3. Measure the crankshaft alignment.
4. If the measurement exceeds the allowable limit, replace the crankshaft.

Crankshaft alignment	Allowable limit	0.02 mm 0.0008 in.

9Y1210318ENS0115US0


3TMABAB1P075A



3TMABAB1P074B

Oil Clearance between Crankpin and Crankpin Bearing

1. Clean the crankpin and crankpin bearing.
2. Put a strip of plastigauge on the center of the crankpin.
3. Install the connecting rod cap and tighten the connecting rod screws to the specified torque, and remove the cap again.
4. Measure the amount of the flattening with the scale, and get the oil clearance.
5. If the oil clearance exceeds the allowable limit, replace the crankpin bearing.
6. If the same size bearing is useless because of the crankpin wear, replace it with an undersize one referring to the table and figure.

■ **NOTE**
- **Never insert the plastigauge into the crankpin oil hole.**
- **Be sure not to move the crankshaft while the connecting rod screws are tightened.**

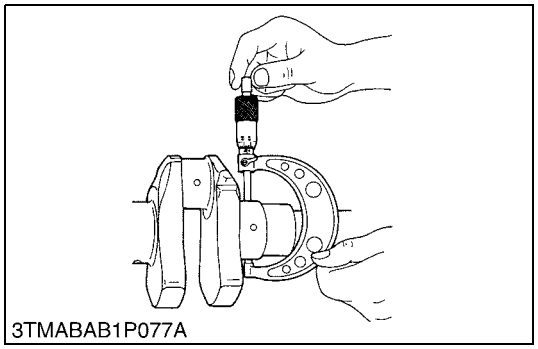
Oil clearance between crankpin and crankpin bearing	Factory specification	0.065 to 0.091 mm 0.0026 to 0.0035 in
	Allowable limit	0.15 mm 0.0059 in.

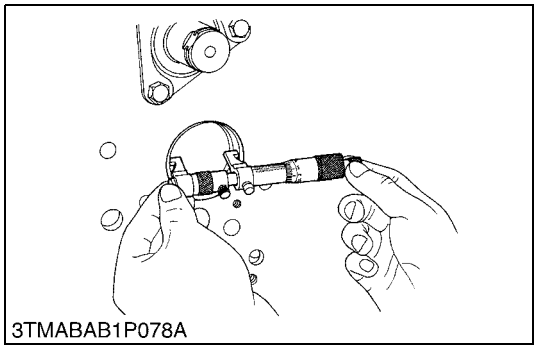
Crankpin O.D.	Factory specification	39.959 to 39.975 mm 1.5732 to 1.5738 in
Crankpin bearing I.D.	Factory specification	40.040 to 40.050 mm 1.5764 to 1.5767 in

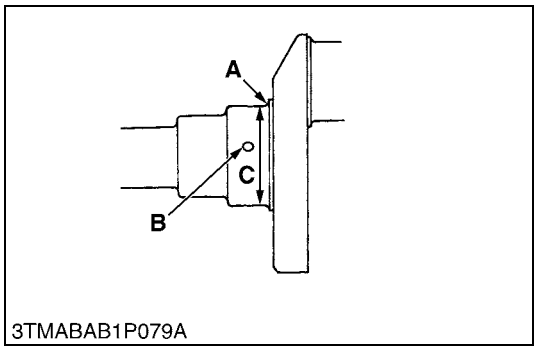
(Reference)
- Undersize dimensions of crankpin

Undersize	**0.2 mm 0.008 in.**	**0.4 mm 0.02 in.**
Dimension **A**	2.8 to 3.2 mm radius 0.11 to 0.12 in. radius	2.8 to 3.2 mm radius 0.11 to 0.12 in. radius
*Dimension **B**	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief
Dimension **C**	39.759 to 39.775 mm dia. 1.5654 to 1.5659 in. dia.	39.559 to 39.575 mm dia. 1.5575 to 1.5580 in. dia.
The crankpin journal must be fine-finished to higher than Rmax = 0.8S *Holes to be de-burred and edges rounded with 1.0 to 1.5 mm (0.040 to 0.059 in.) relief.		

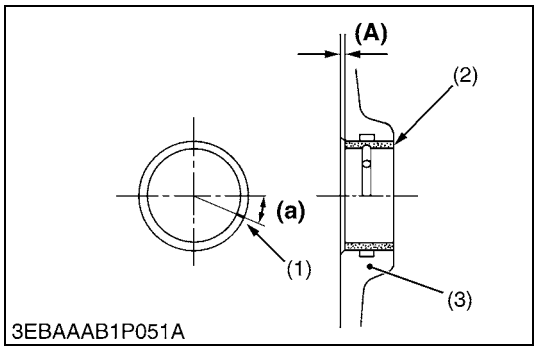
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3TMABAB1P078A



3TMABAB1P079A



3EBAAAB1P051A

Oil Clearance between Crankshaft Journal and Crankshaft Bearing 1

1. Measure the O.D. of the crankshaft front journal with an outside micrometer.
2. Measure the I.D. of the crankshaft bearing 1 with an inside micrometer, and calculate the oil clearance.
3. If the oil clearance exceeds the allowable limit, replace the crankshaft bearing 1.
4. If the same size bearing is useless because of the crankshaft journal wear, replace it with an undersize one referring to the table and the figure.

Oil Clearance between crankshaft journal and crankshaft bearing 1	Factory specification	0.0340 to 0.114 mm 0.00134 to 0.00448 in
	Allowable limit	0.20 mm 0.0079 in.

Crankshaft journal O.D.	Factory specification	47.934 to 47.950 mm 1.8872 to 1.8877 in
Crankshaft bearing 1 I.D.	Factory specification	47.984 to 48.048 mm 1.8892 to 1.8916 in

(Reference)

- Undersize dimensions of crankshaft journal

Undersize	**0.2 mm 0.008 in.**	**0.4 mm 0.02 in.**
Dimension **A**	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius
*Dimension **B**	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief
Dimension **C**	47.734 to 47.750 mm dia. 1.8793 to 1.8799 in. dia.	47.534 to 47.550 mm dia. 1.8715 to 1.8720 in. dia.
The crankshaft journal must be fine-finished to higher than Rmax = 0.8S *Holes to be de-burred and edges rounded with 1.0 to 1.5 mm (0.040 to 0.059 in.) relief.		

9Y1210661ENS0057US0

Replacing Crankshaft Bearing 1

(When removing)

1. Press out the used crankshaft bearing 1 using a crankshaft bearing 1 replacing tool.

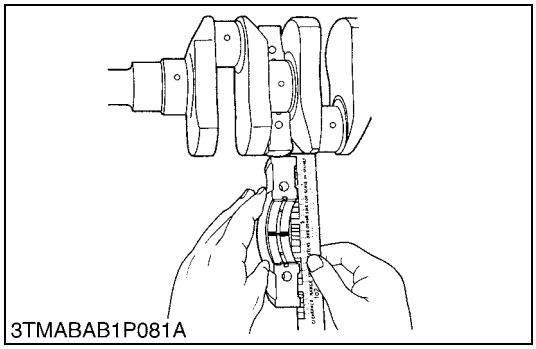
(When installing)

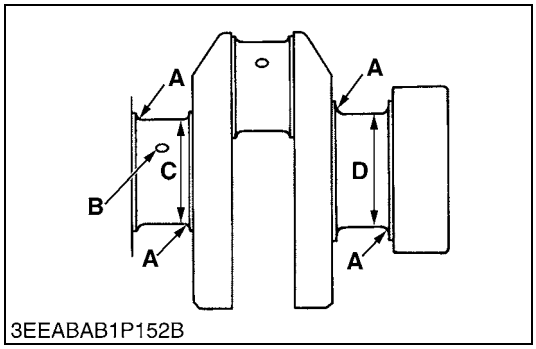
1. Clean a new crankshaft bearing 1 and crankshaft journal bore, and apply engine oil to them.
2. Using a crankshaft bearing 1 replacing tool, press in a new bearing 1 (2) so that its seam (1) directs toward the exhaust manifold side. (See figure.)

Dimension **(A)**	Factory specification	0 to 0.3 mm 0 to 0.01 in.

(1) Seam
(2) Crankshaft Bearing 1
(3) Cylinder Block
(A) Dimension
(a) 0.37 rad (21 °)

9Y1210318ENS0118US0


3TMABAB1P081A



3EEABAB1P152B

Oil Clearance between Crankshaft Journal and Crankshaft Bearing 2 (Crankshaft Bearing 3)

1. Put a strip of plastigauge on the center of the journal.
2. Install the bearing case and tighten the bearing case screws 1 to the specified torque, and remove the bearing case again.
3. Measure the amount of the flattening with the scale, and get the oil clearance.
4. If the oil clearance exceeds the allowable limit, replace the crankshaft bearing 2 (crankshaft bearing 3).
5. If the same size bearing is useless because of the crankshaft journal wear, replace it with an undersize one referring to the table and figure.

■ **NOTE**

- **Be sure not to move the crankshaft while the bearing case screws are tightened.**

Oil clearance between crankshaft journal and crankshaft bearing 2	Factory specification	0.034 to 0.095 mm 0.0014 to 0.0037 in
	Allowable limit	0.20 mm 0.0079 in.

Crankshaft journal O.D. (Flywheel side)	Factory specification	47.934 to 47.950 mm 1.8872 to 1.8877 in
Crankshaft bearing 2 I.D.	Factory specification	47.984 to 48.029 mm 1.8892 to 1.8909 in

Oil clearance between crankshaft journal and crankshaft bearing 3	Factory specification	0.0340 to 0.103 mm 0.00134 to 0.00405 in
	Allowable limit	0.20 mm 0.0079 in.

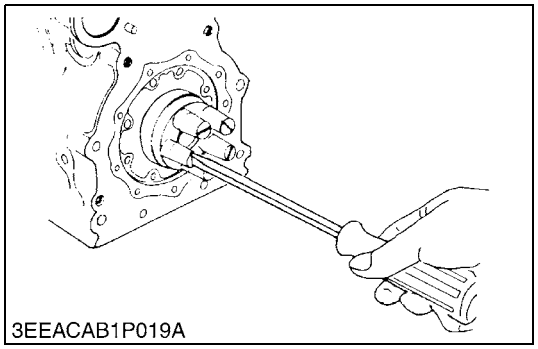
Crankshaft journal O.D. (Intermediate)	Factory specification	51.921 to 51.940 mm 2.0442 to 2.0448 in
Crankshaft bearing 3 I.D.	Factory specification	51.974 to 52.024 mm 2.0463 to 2.0481 in

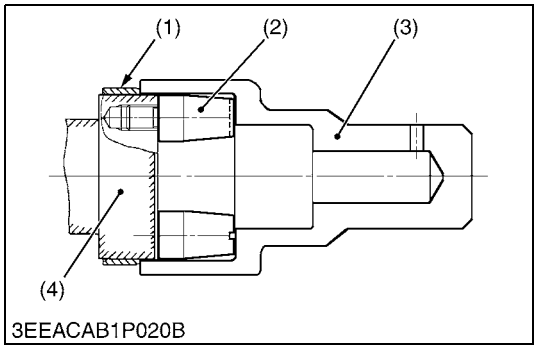
(Reference)

- Undersize dimensions of crankshaft journal

Undersize	**0.2 mm 0.008 in.**	**0.4 mm 0.02 in.**
Dimension **A**	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius
*Dimension **B**	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief
Dimension **C**	47.734 to 47.750 mm dia. 1.8793 to 1.8799 in. dia.	47.534 to 47.550 mm dia. 1.8715 to 1.8720 in. dia.
Dimension **D**	51.721 to 51.740 mm dia. 2.0362 to 2.0370 in. dia.	51.521 to 51.540 mm dia. 2.0284 to 2.0291 in. dia.
The crankshaft journal must be fine-finished to higher than Rmax = 0.8S *Holes to be de-burred and edges rounded with 1.0 to 1.5 mm (0.040 to 0.059 in.) relief.		

9Y1210661ENS0058US0


3EEACAB1P019A



3EEACAB1P020B

Replacing Crankshaft Sleeve

1. Remove the used crankshaft sleeve.
2. Set the sleeve guide (2) to the crankshaft.
3. Heat a new sleeve to a temperature between 150 and 200 °C (302 and 392 °F), and fix the sleeve to the crankshaft as shown in figure.
4. Press fit the sleeve using the auxiliary socket for pushing (3).

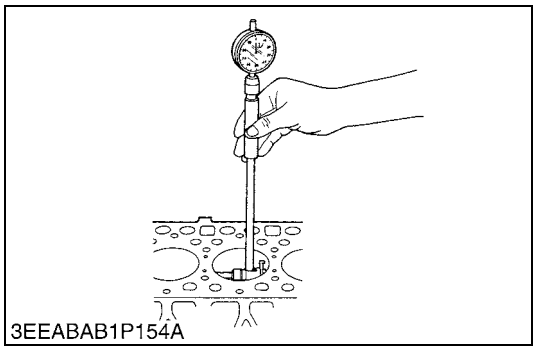
■ **NOTE**

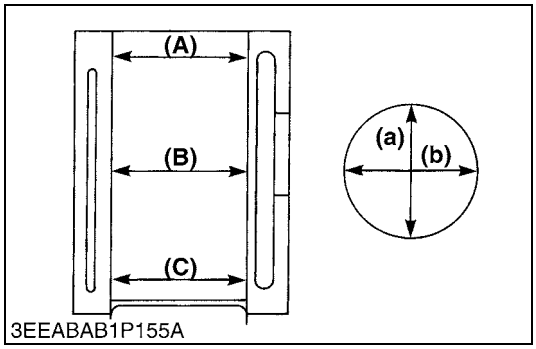
- **Mount the sleeve with its largely chamfered surface facing outward.**
- **Should heating is not enough, a sleeve might stop halfway, so careful.**

(1) Crankshaft Sleeve
(2) Sleeve Guide
(3) Auxiliary Socket for Pushing
(4) Crankshaft

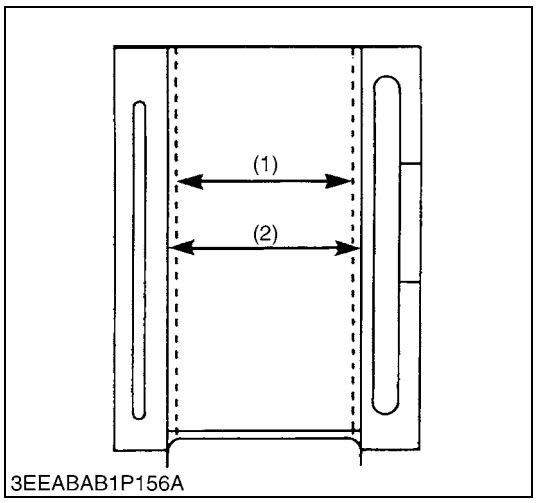
9Y1210661ENS0106US0

(5) Cylinder


3EEABAB1P154A



3EEABAB1P155A



3EEABAB1P156A

Cylinder Wear

1. Measure the I.D. of the cylinder at the six positions (see figure) with a cylinder gauge to find the maximum and minimum I.D.'s.
2. Get the difference (Maximum wear) between the maximum and the minimum I.D.'s.

Cylinder I.D.	Factory specification	79.000 to 79.019 mm 3.1103 to 3.1109 in
	Allowable limit	79.15 mm 3.116 in.

(A) Top
(B) Middle
(C) Bottom (Skirt)
(a) Right-Angled to Piston Pin
(b) Piston Pin Direction

9Y1210661ENS0076US0

Correcting Cylinder (Oversize)

1. When the cylinder is worn beyond the allowable limit, bore and hone it to the specified dimension.

Cylinder liner I.D.	Factory specification	79.500 to 79.519 mm 3.1300 to 3.1306 in
	Allowable limit	79.65 mm 3.136 in.
Finishing	Hone to 2.2 to 3.0 µmRz (87 to 110 µin.Rz)	

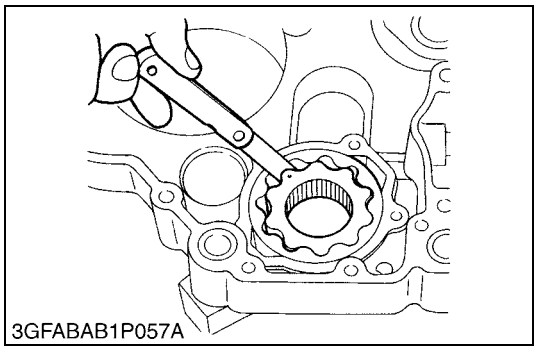
2. Replace the piston and piston rings with oversize ones.
   Oversize: 0.5 mm (0.02 in.)
   Marking: 05

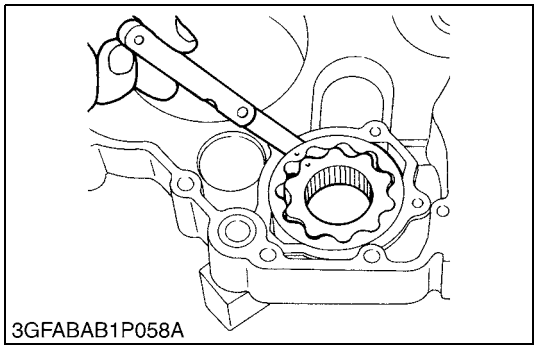
■ **NOTE**
- **When the oversize cylinder is worn beyond the allowable limit, replace the cylinder block with a new one.**

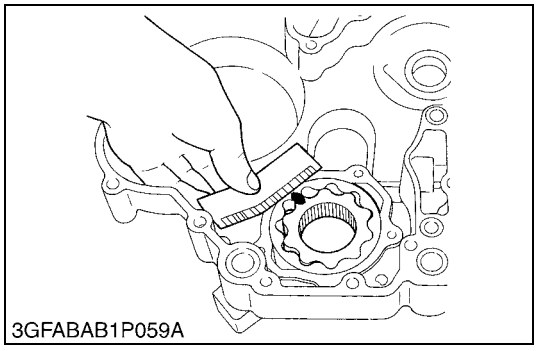
(1) Cylinder I.D. (Before Correction) (2) Cylinder I.D. (Oversize)

9Y1210661ENS0077US0

(6) Oil Pump


3GFABAB1P057A


3GFABAB1P058A


3GFABAB1P059A

Rotor Lobe Clearance

1. Measure the clearance between lobes of the inner rotor and the outer rotor with a feeler gauge.
2. If the clearance exceeds the factory specifications, replace the oil pump rotor assembly.

Rotor lobe clearance	Factory specification	0.060 to 0.18 mm 0.0024 to 0.0071 in.

9Y1210661ENS0084US0

Clearance between Outer Rotor and Pump Body

1. Measure the clearance between the outer rotor and the pump body with a feeler gauge.
2. If the clearance exceeds the factory specifications, replace the oil pump rotor assembly.

Clearance between outer rotor and pump body	Factory specification	0.100 to 0.180 mm 0.00394 to 0.00708 in.

9Y1210661ENS0085US0

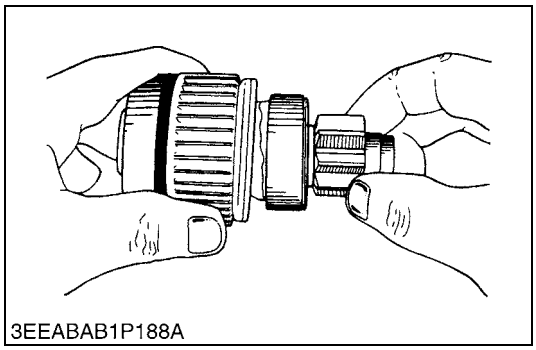
Clearance between Rotor and Cover

1. Put a strip of plastically onto the rotor face with grease.
2. Install the cover and tighten the screws.
3. Remove the cover carefully, and measure the amount of the flattening with the scale and get the clearance.
4. If the clearance exceeds the factory specifications, replace the oil pump rotor assembly.

Clearance between rotor and cover	Factory specification	0.025 to 0.075 mm 0.00099 to 0.0029 in.

9Y1210661ENS0086US0

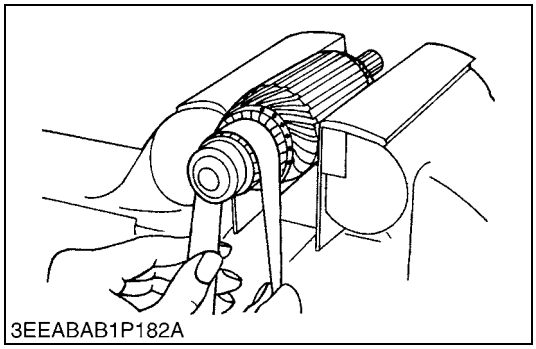
(7) Starter


3EEABAB1P188A

Overrunning Clutch

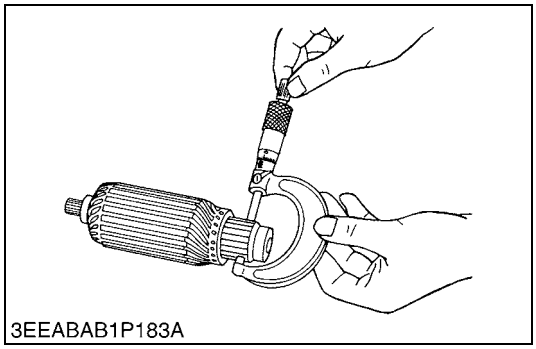
1. Inspect the pinion for wear or damage.
2. If there is any defect, replace the overrunning clutch assembly.
3. Check that the pinion turns freely and smoothly in the overrunning direction and does not slip in the cranking direction.
4. If the pinion slips or does not rotate in the both directions, replace the overrunning clutch assembly.

9Y1210318ENS0125US0


3EEABAB1P182A

Commutator and Mica

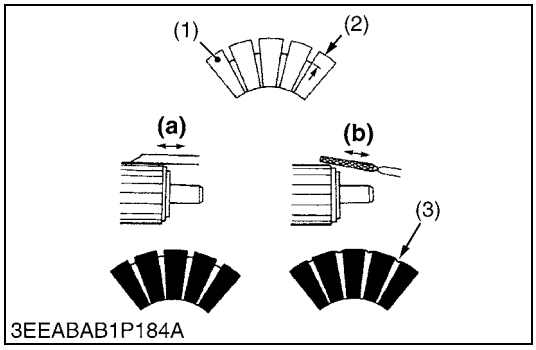
1. Check the contact face of the commutator for wear, and grind the commutator with emery paper if it is slightly worn.
2. Measure the commutator O.D. with an outside micrometer at several points.
3. If the minimum O.D. is less than the allowable limit, replace the armature.
4. If the difference of the O.D.'s exceeds the allowable limit, correct the commutator on a lathe to the factory specification.
5. Measure the mica undercut.
6. If the undercut is less than the allowable limit, correct if with a saw blade and chamfer the segment edges.


3EEABAB1P183A

Commutator O.D.	Factory specification	28.0 mm 1.10 in.
	Allowable limit	27.0 mm 1.06 in.

Difference of O.D.'s	Factory specification	Less than 0.05 mm 0.002 in.
	Allowable limit	0.4 mm 0.02 in.

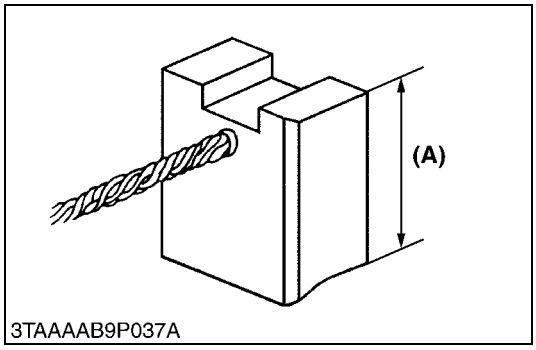
Mica under cut	Factory specification	0.50 to 0.80 mm 0.020 to 0.031 in.
	Allowable limit	0.20 mm 0.0079 in.



3EEABAB1P184A

(1) Segment
(2) Undercut
(3) Mica
(a) Good
(b) Bad

9Y1210661ENS0061US0



3TAAAAB9P037A

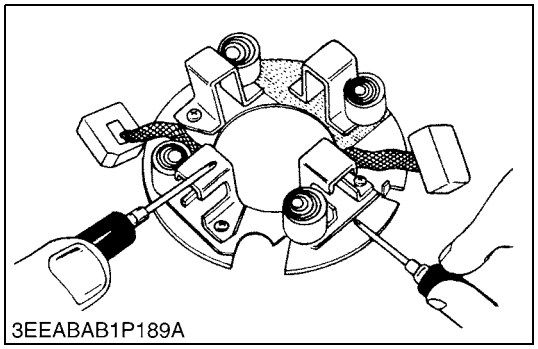
Brush Wear

1. If the contact face of the brush is dirty or dusty, clean it with emery paper.
2. Measure the brush length **(A)** with vernier calipers.
3. If the length is less than the allowable limit, replace the yoke assembly and brush holder.

Brush length **(A)**	Factory specification	16.0 mm 0.630 in.
	Allowable limit	10.5 mm 0.413 in.

(A) Brush Length

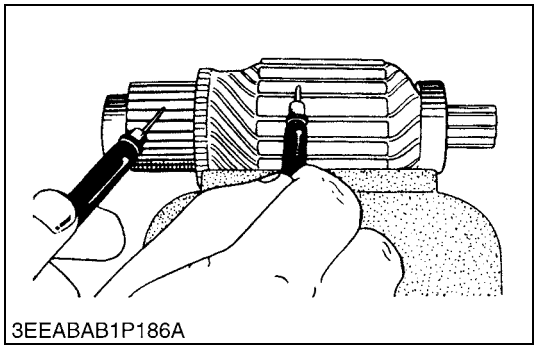
9Y1210661ENS0062US0


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Brush Holder

1. Check the continuity across the brush holder and the holder support with an ohmmeter.
2. If it conducts, replace the brush holder.

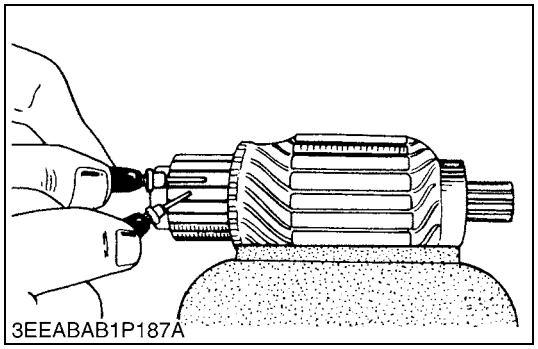
9Y1210318ENS0128US0

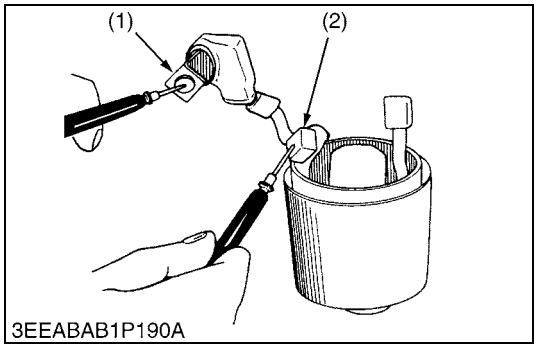

3EEABAB1P186A

Armature Coil

1. Check the continuity across the commutator and armature coil core with an ohmmeter.
2. If it conducts, replace the armature.
3. Check the continuity across the segments of the commutator with an ohmmeter.
4. If it does not conduct, replace the armature.

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3EEABAB1P187A



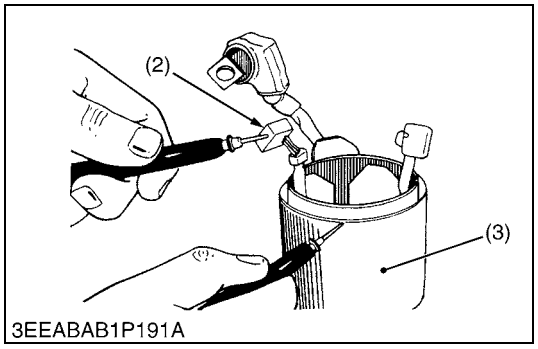
3EEABAB1P190A

Field Coil

1. Check the continuity across the lead (1) and brush (2) with an ohmmeter.
2. If it does not conduct, replace the yoke assembly.
3. Check the continuity across the brush (2) and yoke (3) with an ohmmeter.
4. If it conducts, replace the yoke assembly.

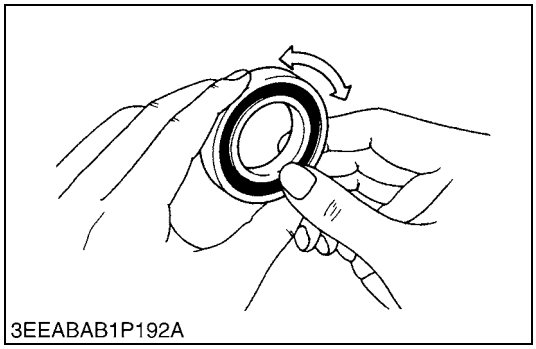
(1) Lead
(2) Brush
(3) Yoke

9Y1210318ENS0130US0



3EEABAB1P191A

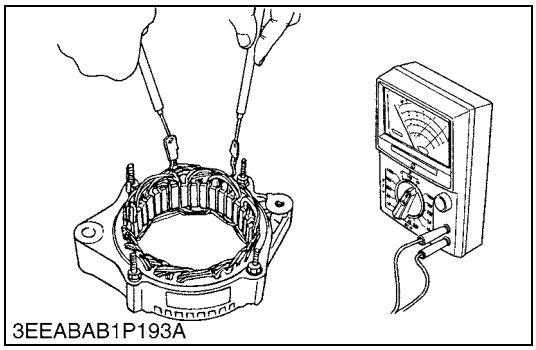
(8) Alternator


3EEABAB1P192A

Bearing

1. Check the bearing for smooth rotation.
2. If it does not rotate smoothly, replace it.

9Y1210318ENS0131US0

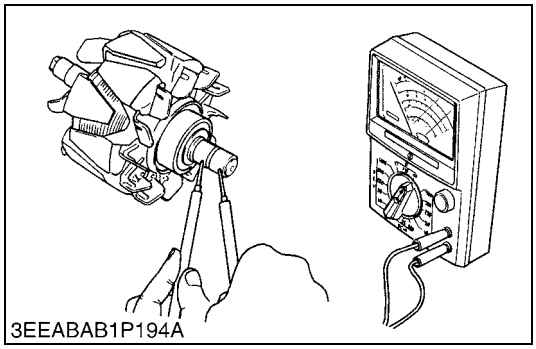

3EEABAB1P193A

Stator

1. Measure the resistance across each lead of the stator coil with resistance range of circuit tester.
2. If the measurement is not within factory specification, replace it.
3. Check the continuity across each stator coil lead and core with resistance range of circuit tester.
4. If infinity is not indicated, replace it.

Resistance	Factory specification	Less than 1.0 Ω

9Y1210318ENS0132US0

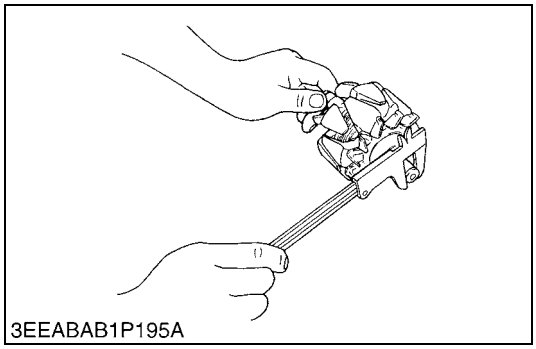

3EEABAB1P194A

Rotor

1. Measure the resistance across the slip rings.
2. If the resistance is not the factory specification, replace it.
3. Check the continuity across the slip ring and core with resistance range of circuit tester.
4. If infinity is not indicated, replace it.

Resistance	Factory specification	2.9 Ω

9Y1210318ENS0133US0

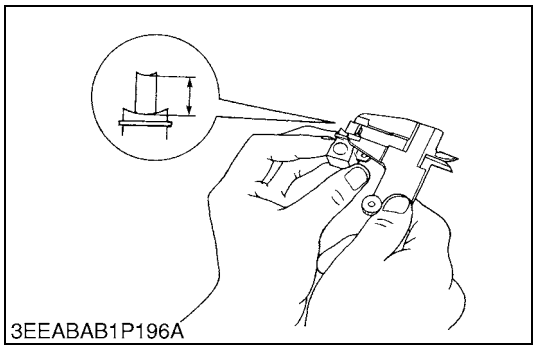

3EEABAB1P195A

Slip Ring

1. Check the slip ring for score.
2. If scored, correct with an emery paper or on a lathe.
3. Measure the O.D. of slip ring with vernier calipers.
4. If the measurement is less than the allowable limit, replace it.

Slip ring O.D.	Factory specification	14.4 mm 0.567 in.
	Allowable limit	14.0 mm 0.551 in.

9Y1210318ENS0134US0

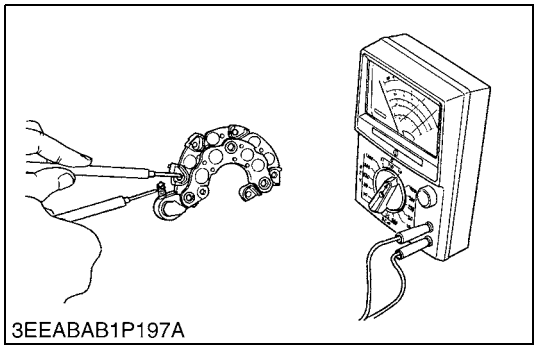

3EEABAB1P196A

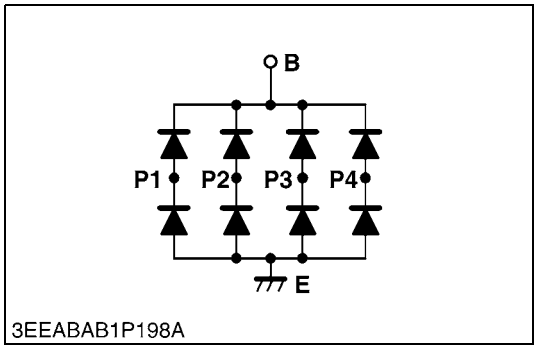
Brush Wear

1. Measure the brush length with vernier calipers.
2. If the measurement is less than allowable limit, replace it.
3. Make sure that the brush moves smoothly.
4. If the brush is damaged, replace it.

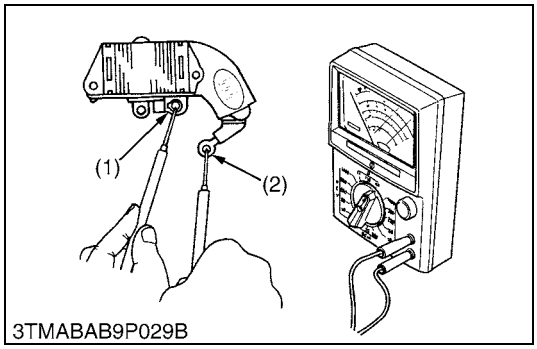
Brush length	Factory specification	10.0 mm 0.394 in.
	Allowable limit	8.4 mm 0.33 in.

9Y1210661ENS0063US0


3EEABAB1P197A



3EEABAB1P198A



3TMABAB9P029B

Rectifier

1. Check the continuity across each diode of rectifier with resistance range of circuit tester.
2. The rectifier is normal if the diode in the rectifier conducts in one direction and does not conduct in the reverse direction.

9Y1210318ENS0136US0

IC Regulator

1. Check the continuity across the **B** terminal (2) and the **F** terminal (1) of IC regulator with resistance range of circuit tester.
2. The IC regulator is normal if the conducts in one direction and does not conduct in the reverse direction.

(1) **F** Terminal (2) **B** Terminal

9Y1210318ENS0137US0

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Printed in Japan 2012. 10, S, EI, EI, engusa Code No.9Y111-06611
2012. 01, S, EI, EI, engusa

KUBOTA Corporation

DM-54625 – FAULT CODE MIL FLASH PROCEDURE, 546

PURPOSE

This document covers the procedure for obtaining the MIL (Malfunction Indicator Lamp) FLASH CODE for fault code diagnostics on Zamboni model 546 ice resurfacers equipped with a Kubota engine. Alternatively, DIAGNOSTIC TROUBLE CODE(S) (DTC) can be determined using a laptop with the proper software installed and the appropriate diagnostic connector. This procedure is for use when a laptop is not available.

Once the MIL FLASH CODE is determined using the procedure below, the corresponding Kubota DIAGNOSTIC TROUBLE CODE (DTC) can be cross-referenced using this chart:

MIL FLASH CODES and corresponding DTCs

MIL FLASH CODE	DTC		MIL FLASH CODE	DTC		MIL FLASH CODE	DTC
111*	N/A		212	1112		342	342
112	112		216	16		359	359
113	113		217	217		371	1171
116	116		219	219		372	1172
117	117		221	221		421	420
118	118		222	222		521	1521
121	121		223	223		524	524
122	122		261	261		562	562
123	123		262	262		563	563
127	107		264	264		621	601
128	108		265	265		624	604
134	134		267	267		626	606
137	107		268	268		627	627
151	1151		269	270		628	628
152	1152		271	271		629	629
154	154		287	87		642	642
155	1155		288	88		643	643
156	1156		291	91		652	652
161	1161		292	92		653	653
162	1162		311	2111		686	686
165	1165		312	2112		687	687
171	171		326	326		712	1612
172	172		327	327		713	1613
173	1173		335	2135		714	1614
182	182		336	336		715	1615
183	183		337	337		716	1616
211	1111		341	341			

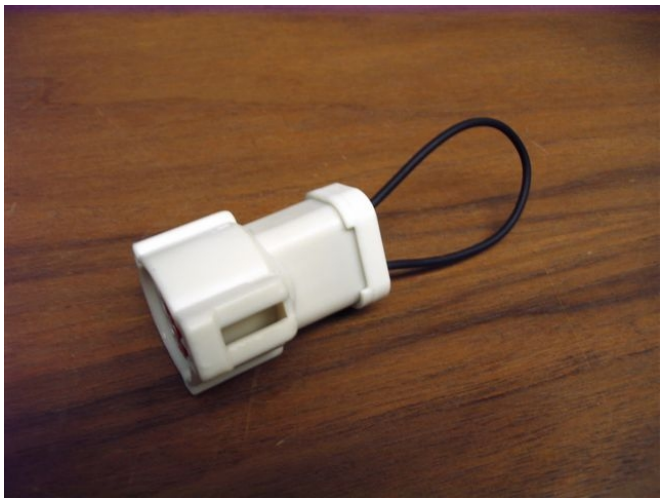
* MIL 111 is Leader/Trailer Code – see page 3

After the corresponding DTC is determined, use this code to troubleshoot the engine according to Kubota diagnostics literature.

DM-54625 – FAULT CODE MIL FLASH PROCEDURE, 546

REQUIRED PARTS

75-18541 – ECU GROUND JUMPER PLUG
This part is included in the tool box for each machine shipped. Spares can also be ordered if necessary.



ENGINE LOOM COM CONNECTOR – located on top right of engine, part of existing wiring loom

S/Ns 546-10133 through 546-10155 2 wires in COM connector UNABLE TO PRODUCE MIL FLASH CODE	S/Ns 546-10156+ 4 wires in COM connector ABLE TO PRODUCE MIL FLASH CODE
	

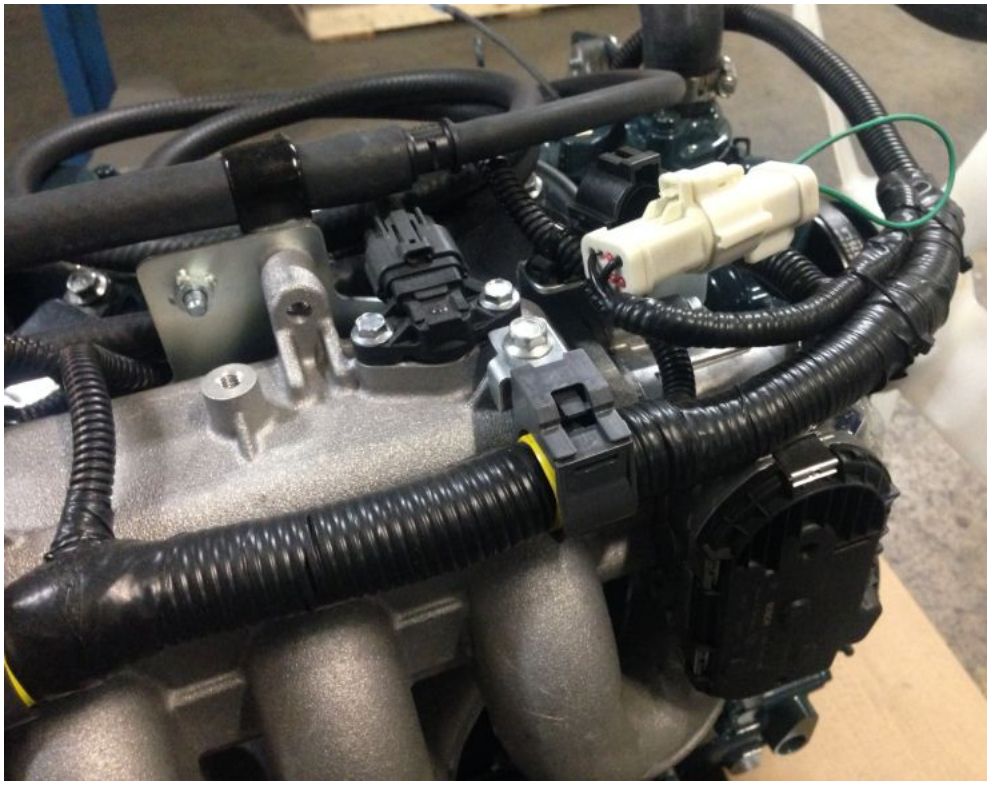
Only machine S/N 546-10157 and later (4-wires @ COM connector) are able to blink MIL FLASH CODES per this procedure. Machines produced prior to this S/N require either a laptop connection or CAN diagnostic kit KZ-54627.

DM-54625 - FAULT CODE MIL FLASH PROCEDURE, 546

MIL FLASH CODE PROCEDURE

1. Locate the white COM connector on engine wiring loom shown above

2. Connect 75-18541 ECU GROUND JUMPER PLUG to the mating white COM connector on the engine wiring loom, as shown below



3. Turn the key to the on position and watch the amber LED Malfunction Indicator Light (MIL) on the dash
4. When reading the MIL FLASH CODE(S), the MIL will have short pauses between flashes for the representation of a digit and longer pauses between digits
5. The MIL will first blink the leader/trailer code (111) in the following manner:
    a. **ON**, OFF, OFF, **ON**, OFF, OFF, **ON**, OFF, OFF
    b. This is blinking 1--1--1--, or 111
    c. The light will do this for a total of 3 times (111 - 111 - 111) before it produces the stored MIL FLASH CODE(S)

6. The MIL will next blink stored MIL FLASH CODE(S), with the same short pauses between the blinks for the representation of a digit and longer pauses between digits. There are 3 digits for each MIL FLASH CODE and the code will be flashed a total of 3 times.
    a. Example:
        i. **ON**, OFF, OFF = 1
        ii. **ON**, OFF, **ON**, OFF, **ON**, OFF, **ON**, OFF, **ON**, OFF, OFF = 5
        iii. **ON**, OFF, **ON**, OFF, **ON**, OFF, **ON**, OFF, **ON**, OFF, **ON**, OFF, OFF = 6
        iv. The above flash sequence would represent MIL FLASH CODE 156, which corresponds to DTC 1156 in the above chart. This would be the DTC for "Closed-loop gasoline bank 1 A/F is too rich," per the Kubota DTC list. This DTC list can be found in the machine manual.
        v. The first stored fault will blink 3 times (in this ex. 156 – 156 – 156) before flashing the next stored fault
    b. All MIL FLASH CODES will blink 3 times, and when complete, 111 – 111 – 111 will repeat, indicating all MIL FLASH CODES have been relayed.
7. Once all stored codes have been flashed, the overall sequence will repeat. The engine needs to start and run a total of 4 times, after the code has been resolved, before the ECU turns off the MIL.

MIL FLASH CODE/DTC LIST		KUBOTA WG1605		
DTC/ Pcode	Fault	CAN SPN	CAN FMI	MIL Flash Code
	Leader/Trailer Code			111
(P0) 016	CRANK or CAM could not synchronize during start	636	8	216
(P0) 107	MAP Signal open or shorted to ground	106	4	127
(P0) 108	MAP signal shorted high	106	16	128
(P0) 112	IAT Sensor Low/Shorted Input	105	4	112
(P0) 113	IAT Sensor High/Open Input	105	3	113
(P0) 116	ECT higher than warning threshold	110	15	116
(P0) 117	ECT Sensor Low/Shorted Input	110	4	117
(P0) 118	ECT Sensor High/Open Input	110	3	118
(P0) 121	TPS 1-2 voltage difference lower than expected	51	1	121
(P0) 122	Throttle Position Signal 1 low voltage	51	4	122
(P0) 123	Throttle Position Signal 1 high voltage	51	3	123
(P0) 131	O2 Bank 1 Sensor 1 Low Input	NA		
(P0) 132	O2 Bank 1 Sensor 1 High Input	NA		
(P0) 133	O2 Bank 1 Sensor 1 Slow Response	NA		
(P0) 134	O2 Bank 1 Sensor 1 No Activity	724	10	134
(P0) 135	Front O2 sensor heater control fault	NA		
(P0) 137	Rear oxygen sensor low voltage	NA		
(P0) 138	Rear oxygen sensor high voltage	NA		
(P0) 141	Rear oxygen sensor heater control fault	NA		
(P0) 1151	Closed-loop LPG A/F is too lean	520206	0	151
(P0) 1152	Closed-loop LPG A/F is too rich	520206	1	152
(P0) 154	Post-Cat O2 Signal No Activity	520208	10	154
(P0) 1155	Closed-loop gasoline bank 1 A/F is too lean	520204	0	155
(P0) 1156	Closed-loop gasoline bank 1 A/F is too rich	520204	1	156
(P0) 1165	Catalyst inactive on LPG	520213	10	165
(P0) 1166	Catalyst inactive on NG	NA		
(P0) 171	Pre-cat A/F is lean	520200	0	171
(P0) 172	Pre-cat A/F is rich	520200	1	172
(P0) 182	Gasoline Fuel Temp Sensor A Low Input	174	4	182
(P0) 183	Gasoline Fuel Temp Sensor A High Input	174	3	183
(P0) 187	LPG Fuel Temp Low Voltage	NA		
(P0) 188	LPG Fuel Temp High Voltage	NA		
(P0) 215	LP or NG fuel purge time exceeded following key-off	NA		
(P0) 217	Engine Overheat Condition	110	0	217
(P0) 219	Engine Overspeed Condition	515	15	219
(P0) 221	TPS 1-2 voltage difference higher than expected	51	0	221
(P0) 222	Throttle Position Signal 2 low voltage	520251	4	222
(P0) 223	Throttle Position Signal 2 high voltage	520251	3	223
(P0) 231	Fuel Pump Circuit Low	NA		
(P0) 232	Fuel Pump Circuit High	NA		
(P0) 261	Injector 1 Low/Open	651	5	261
(P0) 262	Injector 1 High/Short	651	6	262
(P0) 264	Injector 2 Low/Open	652	5	264
(P0) 265	Injector 2 High/Short	652	6	265
(P0) 267	Injector 3 Low/Open	653	5	267
(P0) 268	Injector 3 High/Short	653	6	268
(P0) 270	Injector 4 Low/Open	654	5	269
(P0) 271	Injector 4 High/Short	654	6	271
(P0) 273	Injector 5 Low/Open	NA		
(P0) 274	Injector 5 High/Short	NA		
(P0) 276	Injector 6 Low/Open	NA		
(P0) 277	Injector 6 High/Short	NA		
(P0) 87	Gasoline Fuel Pressure too low	94	1	287
(P0) 88	Gasoline Fuel Pressure too high	94	0	288
(P0) 91	Gasoline Fuel Pressure low voltage	94	4	291
(P0) 92	Gasoline Fuel Pressure high voltage	94	3	292
(P0) 326	Knock signal excessive or erratic	731	2	326
(P0) 327	Knock signal open or not present	731	4	327
(P0) 336	CRANK signal noise	636	2	336
(P0) 337	No CRANK signal	636	4	337
(P0) 340	Camshaft Position Sensor A (no signal)	NA		
(P0) 341	CAM signal noise	723	2	341

MIL FLASH CODE/DTC LIST		KUBOTA WG1605		
DTC/ Pcode	Fault	CAN SPN	CAN FMI	MIL Flash Code
(P0) 342	Camshaft Position Sensor A (no signal)	723	4	342
(P0) 359	Fuel (LPG or NG) run-out longer than expected	1239	7	359
(P0) 420	Catalyst inactive on gasoline	520211	10	421
(P0) 523	Oil pressure signal open or shorted high	NA		
(P0) 524	Engine Oil Pressure Too Low	100	1	524
(P0) 562	Battery Voltage Low	168	17	562
(P0) 563	Battery Voltage High	168	15	563
(P0) 601	Microprocessor failure - FLASH	628	13	621
(P0) 603	Keep Alive Memory Error	NA		
(P0) 604	Microprocessor failure - RAM	630	12	624
(P0) 606	Microprocessor failure - COP	1347	6	626
(P0) 615	Starter relay fault	NA		
(P0) 616	Starter relay control short to GND	NA		
(P0) 617	Starter relay coil short to 12V	NA		
(P0) 627	Gasoline fuel pump relay control wire open	1348	5	627
(P0) 628	Gasoline fuel pump relay control wire short to ground	1348	4	628
(P0) 629	Gasoline fuel pump relay control wire short to 12 V	1348	3	629
(P0) 637	Pin 85 (AUX_PWM4) open/short to GND	NA		
(P0) 638	Electronic throttle control performance	NA		
(P0) 642	5V Reference #1 (pin 9) voltage low	1079	4	642
(P0) 643	5V reference #1 voltage high	1079	3	643
(P0) 650	Malfunction Indicator Lamp Control open	NA		
(P0) 652	5V Reference #2 voltage low	1080	4	652
(P0) 653	5V Reference #2 voltage high	1080	3	653
(P0) 655	Engine Protection Lamp fault	NA		
(P0) 681	Customer Auxiliary Shutdown #1	NA		
(P0) 685	Power relay coil open	NA		
(P0) 686	Power relay short to GND	1485	4	686
(P0) 687	Power relay short to 12V	1485	3	687
(P0) 1122	Throttle Actuator TPS A Low Input	NA		
(P0) 1123	Throttle Actuator TPS A High Input	NA		
(P0) 1153	Closed-loop NG A/F is too lean	NA		
(P0) 1154	Closed-loop NG A/F is too rich	NA		
(P0) 1161	LPG Adaptive-learn A/F is too lean	520202	0	161
(P0) 1162	LPG Adaptive-learn A/F is too rich	520202	1	162
(P0) 1163	NG Adaptive-learn A/F is too lean	NA		
(P0) 1164	NG Adaptive-learn A/F is too rich	NA		
(P0) 1171	EPR delivery pressure higher than expected	520260	0	371
(P0) 1172	EPR delivery pressure lower than expected	520260	1	372
(P0) 1173	EPR-ECU communications lost	520260	31	173
(P0) 1174	EPR voltage supply high	NA		
(P0) 1175	EPR voltage supply low	NA		
(P0) 1176	EPR internal actuator fault detected	NA		
(P0) 1177	EPR internal circuitry fault detected	NA		
(P0) 1178	EPR internal communications fault detected	NA		
(P0) 1219	Customer specified engine overspeed limit exceeded	NA		
(P0) 1222	Throttle Actuator TPS B Low Input	NA		
(P0) 1223	Throttle Actuator TPS B High Input	NA		
(P0) 1272	Accelerator pedal signal low voltage	NA		
(P0) 1273	Accelerator pedal signal high voltage	NA		
(P0) 1515	AUX 5V ANALOG INPUT 4 open or high	NA		
(P0) 1516	AUX 5V ANALOG INPUT 4 low	NA		
(P0) 1517	AUX 5V ANALOG INPUT 3 open or high	NA		
(P0) 1518	AUX 5V ANALOG INPUT 3 low	NA		
(P0) 1541	AUX 5V ANALOG INPUT 1 high	NA		
(P0) 1542	AUX 5V ANALOG INPUT 1 low or open	NA		
(P0) 1543	AUX 5V ANALOG INPUT 2 high or open	NA		
(P0) 1544	AUX 5V ANALOG INPUT 2 low	NA		
(P0) 1551	AUX DIGITAL INPUT 1 high	NA		
(P0) 1552	AUX DIGITAL INPUT 1 low	NA		
(P0) 1553	AUX DIGITAL INPUT 2 high	NA		
(P0) 1554	AUX DIGITAL INPUT 2 low	NA		
(P0) 1555	AUX DIGITAL INPUT 3 high	NA		

MIL FLASH CODE/DTC LIST		KUBOTA WG1605		
DTC/ Pcode	Fault	CAN SPN	CAN FMI	MIL Flash Code
(P0) 1556	AUX DIGITAL INPUT 3 low	NA		
(P0) 1562	Extreme overvoltage - ECM damage possible	NA		
(P0) 1563	AUX 5V ANALOG INPUT 5 open or high	NA		
(P0) 1564	AUX 5V ANALOG INPUT 5 low	NA		
(P0) 1602	EEPROM version incorrect	NA		
(P0) 1605	EEPROM calibration information lost	NA		
(P0) 1609	Calibration mismatch with firmware	NA		
(P0) 1612	Watchdog processor blocked outputs (RTI 1)	629	31	712
(P0) 1613	Microprocessor failure - RTI 2	629	31	713
(P0) 1614	Microprocessor failure - RTI 3	629	31	714
(P0) 1615	Microprocessor failure - A/D	629	31	715
(P0) 1616	Microprocessor failure - Interrupt	629	31	716
(P0) 1619	Unauthorized calibration upload or update	NA		
(P0) 1644	MIL control short to GND	NA		
(P0) 1645	MIL control short to 12V	NA		
(P0) 1681	Customer Auxiliary Shutdown #1	NA		
(P0) 1682	Customer Auxiliary Shutdown #2	NA		
(P0) 1683	Customer Auxiliary Shutdown #3	NA		
(P0) 2115	APP1 indicates off-idle while IVS indicates idle	NA		
(P0) 2121	APP1/FPP1 lower than APP2/FPP2	NA		
(P0) 2122	APP1/FPP1 signal low voltage	NA		
(P0) 2123	APP1/FPP! signal high voltage	NA		
(P0) 2126	APP1/FPP1 higher than APP2/FPP2	NA		
(P0) 2127	APP2/FPP2 signal low voltage	NA		
(P0) 2128	APP2/FPP2 signal high voltage	NA		
(P0) 2130	IVS stuck at idle, APP 1/2 mismatch	NA		
(P0) 2131	IVS stuck at off-idle, APP 1/2 mismatch	NA		
(P0) 2139	APP1 indicates idle while IVS indicates off-idle	NA		
(P0) 2300	Ignition coil A low current	NA		
(P0) 2301	Ignition coil A high current	NA		
(P0) 2302	Ignition coil A secondary open	NA		
(P0) 2303	Ignition coil B low current	NA		
(P0) 2304	Ignition coil B high current	NA		
(P0) 2305	Ignition coil B secondary open	NA		
(P0) 2306	Ignition coil C low current	NA		
(P0) 2307	Ignition coil C high current	NA		
(P0) 2308	Ignition coil C secondary open	NA		
(P0) 2309	Ignition coil D low current	NA		
(P0) 2310	Ignition coil D high current	NA		
(P0) 2311	Ignition coil D secondary open	NA		
(P0) 2112	Unable to reach higher TPS	51	7	312
(P0) 2111	Unable to reach lower TPS	51	7	311
(P0) 2135	TPS1/2 simultaneous voltages out of range	51	31	335
(P0) 1111	Fuel rev limit	515	16	211
(P0) 1112	Spark rev limit	515	0	212
(P0) 1521	CHT higher than expected 1	110	16	521

DM

DIAGNOSIS MANUAL
ECM SYSTEM

WG1605-G-E3,WG1605-L-E3, WG1605-GL-E3

Kubota

KiSC issued 06, 2012 A

I INFORMATION

INFORMATION

CONTENTS

1. SAFETY FIRST I-1

1. SAFETY FIRST

⚠ SAFETY FIRST

- **This symbol, the industry's "Safety Alert Symbol", is used throughout this manual and on labels on the machine itself to warn of the possibility of personal injury. Read these instructions carefully.**
- **It is essential that you read the instructions and safety regulations before you attempt to repair or use this unit.**

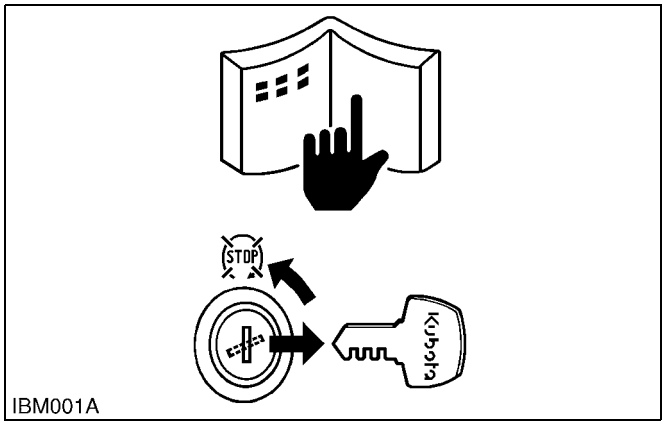
⚠ DANGER
- **Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.**

⚠ WARNING
- **Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.**

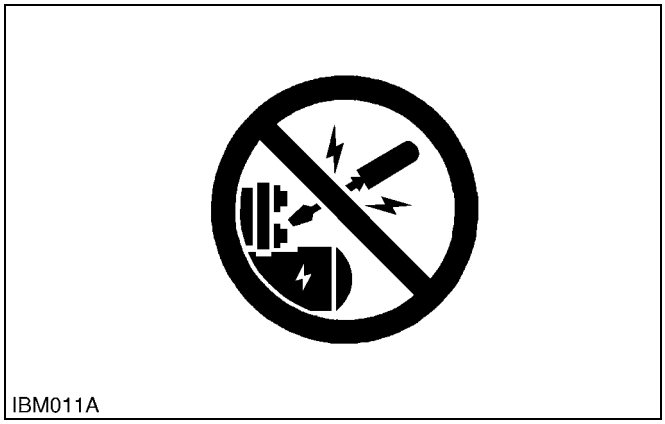
⚠ CAUTION
- **Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.**

■ IMPORTANT
- **Indicates that equipment or property damage could result if instructions are not followed.**

■ NOTE
- **Gives helpful information.**



IBM001A

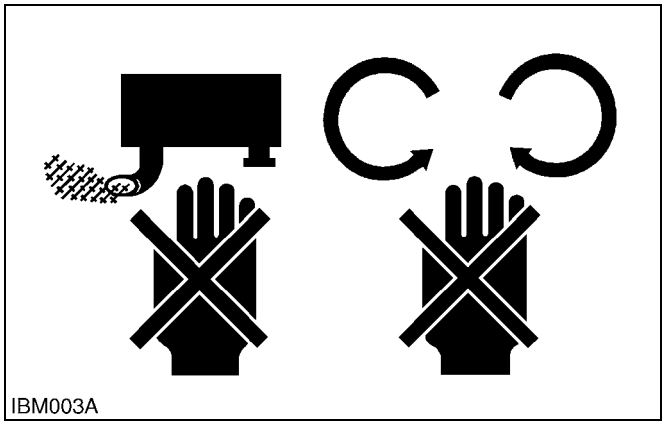

IBM011A

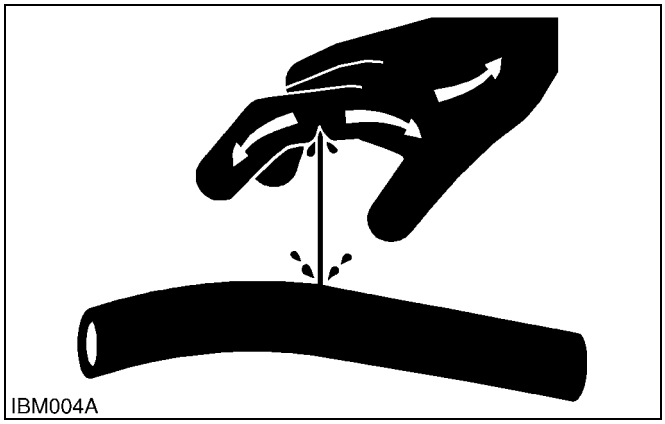
BEFORE SERVICING AND REPAIRING

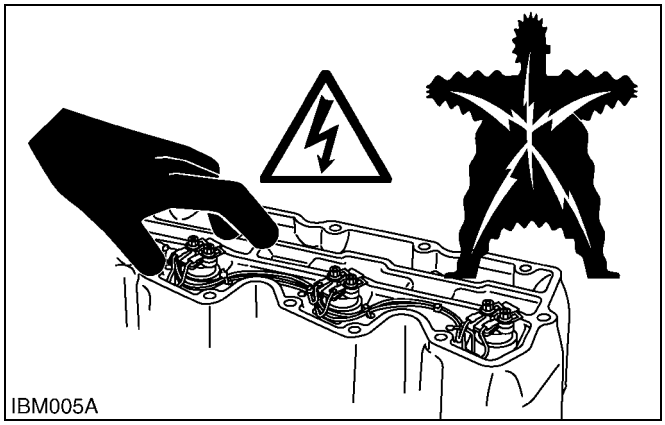
- Read all instructions and safety instructions in this manual and on your machine safety decals.
- Clean the work area and machine.
- Park the machine on a firm and level ground.
- Allow the engine to cool before proceeding.
- Stop the engine, and remove the key.
- Disconnect the battery negative cable.
- Hang a **"DO NOT OPERATE"**tag in operator station.

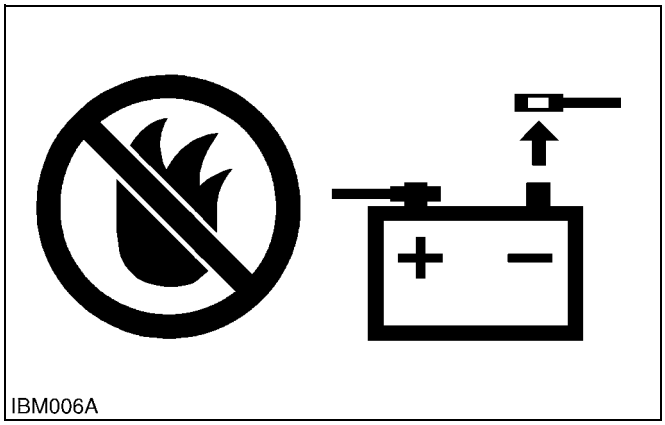
SAFETY STARTING

- Do not start the engine by shorting across starter terminals or bypassing the safety start switch.
- Unauthorized modifications to the engine may impair the function and / or safety and affect engine life.


IBM003A


IBM004A


IBM005A

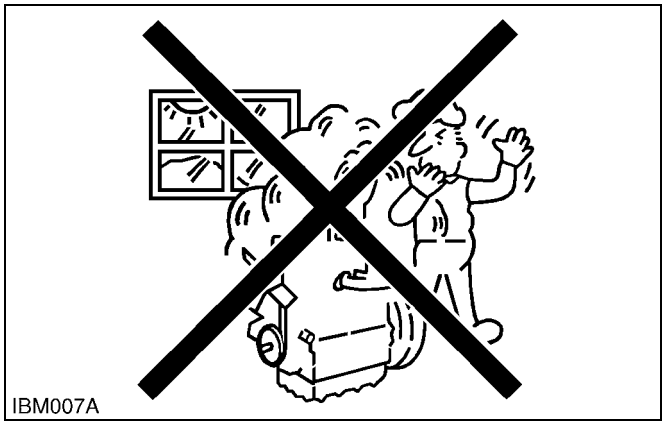

IBM006A

SAFETY WORKING

- Do not work on the machine while under the influence of alcohol, medication, or other substances or while fatigued.
- Wear close fitting clothing and safety equipment appropriate to the job.
- Use tools appropriate to the work. Makeshift tools, parts, and procedures are not recommended.
- When servicing is performed together by two or more persons, take care to perform all work safely.
- Do not touch the rotating or hot parts while the engine is running.
- Never remove the radiator cap while the engine is running, or immediately after stopping. Otherwise, hot water will spout out from radiator. Only remove radiator cap when cool enough to touch with bare hands. Slowly loosen the cap to first stop to relieve pressure before removing completely.
- Escaping fluid (fuel or hydraulic oil) under pressure can penetrate the skin causing serious injury. Relieve pressure before disconnecting hydraulic or fuel lines. Tighten all connections before applying pressure.
- Wear a suitable hearing protective device such as earmuffs or earplugs to protect against objectionable or uncomfortable loud noises.
- Do not open high-pressure fuel system.
  High-pressure fluid remaining in fuel lines can cause serious injury. Do not disconnect or attempt to repair fuel lines, sensors, or any other components between the high-pressure fuel pump and injectors on engines with high pressure common rail fuel system.
- High voltage exceeding 100 V is generated in the ECM and injector.
  Pay sufficient caution to electric shock when performing work activities.

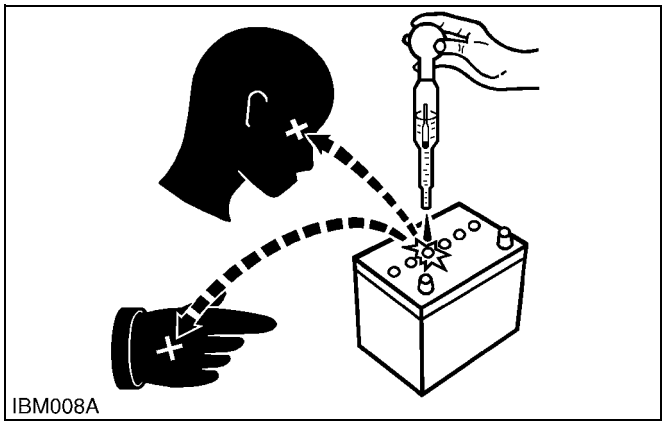
AVOID FIRES

- Fuel is extremely flammable and explosive under certain conditions. Do not smoke or allow flames or sparks in your working area.
- To avoid sparks from an accidental short circuit, always disconnect the battery negative cable first and connect it last.
- Battery gas can explode. Keep sparks and open flame away from the top of battery, especially when charging the battery.
- Make sure that no fuel has been spilled on the engine.


IBM007A

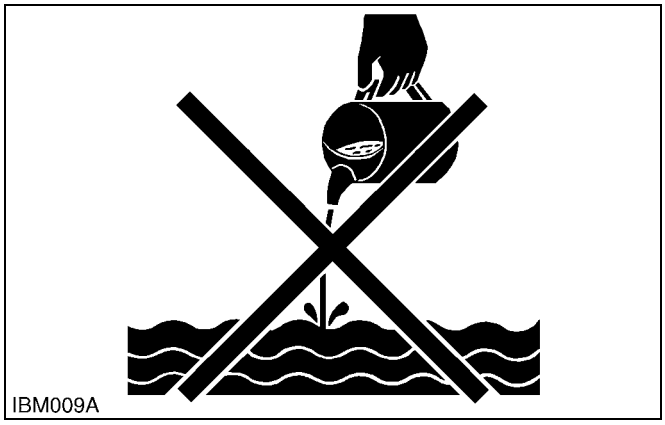
VENTILATE WORK AREA

- If the engine must be running to do some work, make sure the area is well ventilated. Never run the engine in a closed area. The exhaust gas contains poisonous carbon monoxide.


IBM008A

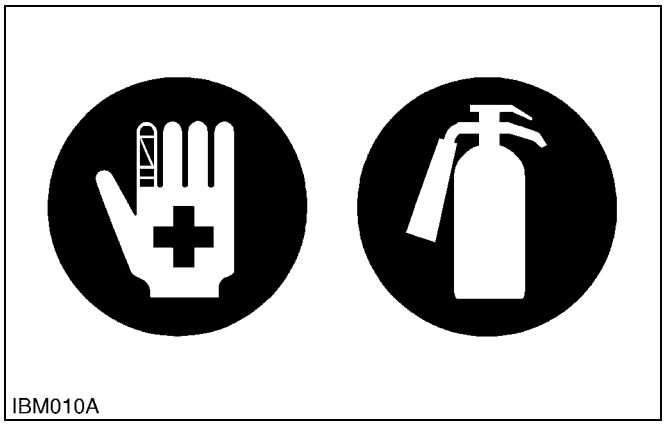
PREVENT ACID BURNS

- Sulfuric acid in battery electrolyte is poisonous. It is strong enough to burn skin, clothing and cause blindness if splashed into eyes. Keep electrolyte away from eyes, hands and clothing. If you spill electrolyte on yourself, flush with water, and get medical attention immediately.


IBM009A

DISPOSE OF FLUIDS PROPERLY

- Do not pour fluids into the ground, down a drain, or into a stream, pond, or lake. Observe relevant environmental protection regulations when disposing of oil, fuel, coolant, electrolyte and other harmful waste.


IBM010A

PREPARE FOR EMERGENCIES

- Keep a first aid kit and fire extinguisher handy at all times.
- Keep emergency numbers for doctors, ambulance service, hospital and fire department near your telephone.

1 ECM SYSTEM

SERVICING

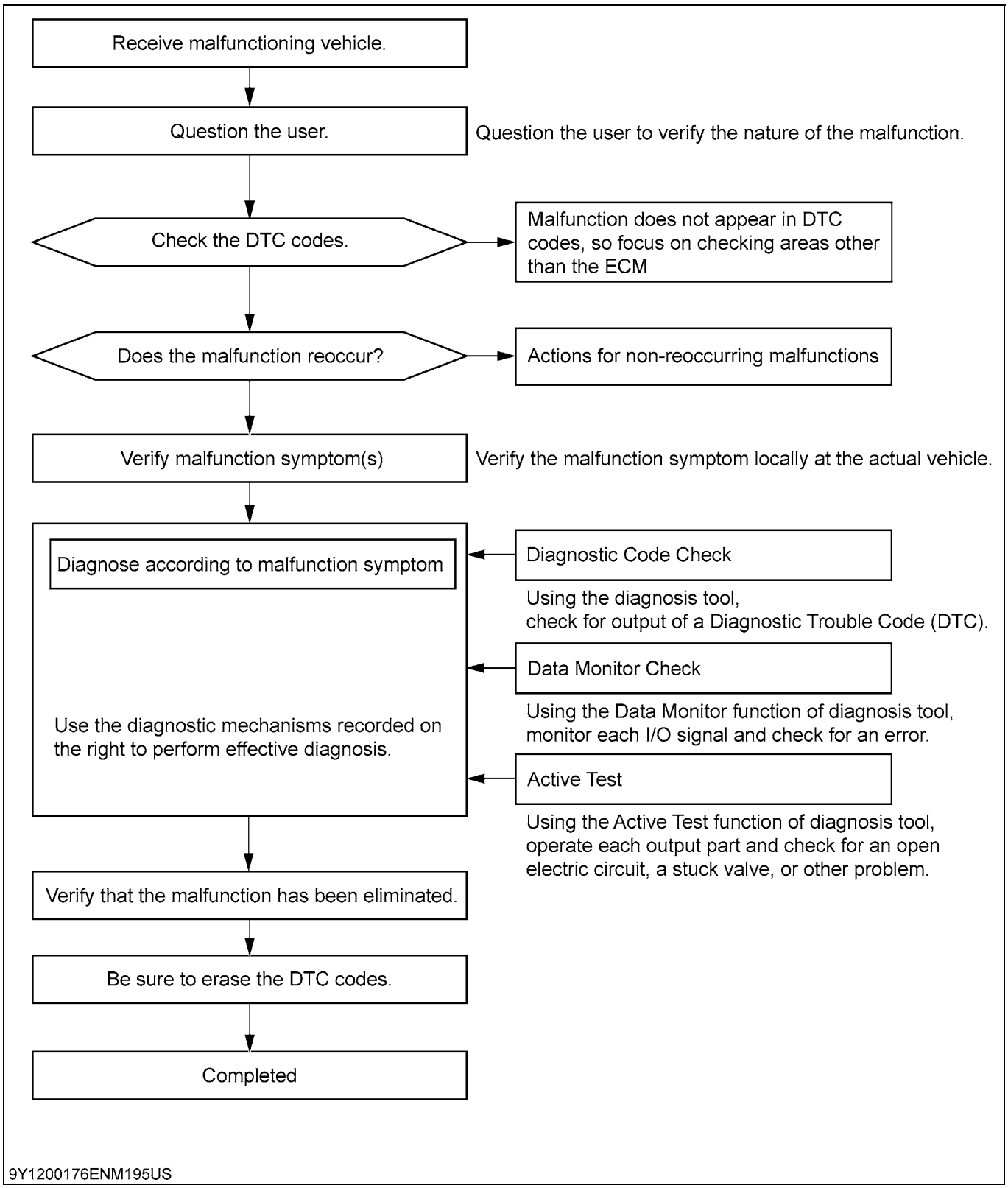
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1. OUTLINE

[1] OVERALL DIAGONOSTIC PROCEDURE



9Y1200176ENM195US

[2] QUESTIONING

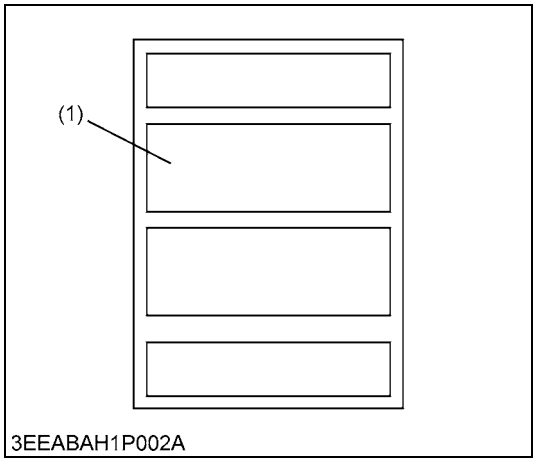
- Use the trouble check sheet to ensure that the customer's explanation is fully understood.
- Accurately judge information concerning the malfunction.
  Grasp the situation firmly, using five 5W1H (Who, What, When, Where, Why, How) as a basis.
  Ex: Low ambient temperature, starting, normal conditions, proximity to engine, metallic noise, etc.

(Reference)

Do not ask random questions. Ask questions that will aid in narrowing down the possible malfunctioning system while making educated guesses based on the malfunction symptoms.

Questioning Points

What?	Malfunction symptom
When?	Date, time, frequency of occurrence.
Where?	Field conditions
What were conditions like at the time of malfunction?	Driving conditions, operating conditions, weather.
What happened?	Type of malfunction.



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Trouble Check Sheet for WG Engines

When the machine is received from the customer, it is necessary to verify the "malfunction symptoms" and the "generated malfunction data" with the customer. This is performed based on the trouble check sheet.

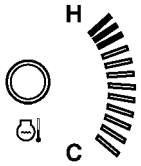
(1) Trouble Check Sheet

Because:

- The malfunction symptom may not be reproduced at the workshop.
- The customer's complaint does not always match the malfunction.
- If the person performing repairs is not working from the correct malfunction symptoms, man-hours will be wasted.

The question chart can aid the service person in diagnosing, repairing and verifying repair work.

Trouble Check Sheet for WG Engines				
Machine details				
Customer name				
Customer address				
Machine model		Machine serial number		
Engine serial number		Purchase date		
Repair date		Hourmeter indicator	hours	
Warranty				
Warranty Judgment	☐ Yes		☐ No	
Defective parts	☐ Injector		☐ Ignition Coil	
	☐ Fuel Filter			
	☐ Others ( )			
Replace parts details				
Injector	Quantity	Units	Part number	
	Serial number	Cylinder 1 ( )	Cylinder 2 ( )	
		Cylinder 3 ( )	Cylinder 4 ( )	
	Defective injector	☐ Injector 1	☐ Injector 2	
		☐ Injector 3	☐ Injector 4	
Actual part replacement	☐ Injector		☐ Ignition Coil	
	☐ Fuel Filter			
	☐ ECM		☐ Others ( )	
Customer complaint				
☐ 1. Engine no start	☐ a. No initial combustion		☐ b. No complete combustion	
	☐ c. No cranking			
☐ 2. Difficult to start	☐ a. Engine crank slowly			
	☐ b. Others ( )			
☐ 3. Poor idling	☐ a. Incorrect first idle		☐ b. Noise	
	☐ c. Hunting idle from ( ) to ( ) min^{-1} (rpm)			
	☐ d. High idling ( ) min^{-1} (rpm)			
	☐ e. Low idling ( ) min^{-1} (rpm)			
	☐ f. Rough			
	☐ g. Others ( )			
☐ 4. Poor driveability	☐ a. Hesitation		☐ b. Surging	
	☐ c. Knocking		☐ d. Lack of power	
	☐ e. Others ( )			
☐ 5. Abnormal smoke	☐ a. Black		☐ b. White	
	☐ c. Others ( )			
☐ 6. Fuel leakage	☐ a. Large quantity		☐ b. Blurred	
	Leaking from:	☐ Injector	☐ Ignition Coil	
		☐ Others ( )		
☐ 7. Engine not stop				
☐ 8. Engine stall				
☐ 9. Others				

<table>
<tr><th colspan="3">Condition when problem occurs (Duplicated answers can be possible)</th></tr>
<tr><td rowspan="4">1. Weather</td><td>☐ a. Fine</td><td>☐ b. Cloudy</td></tr>
<tr><td>☐ c. Rainy</td><td>☐ d. Snow</td></tr>
<tr><td>☐ e. Flood</td><td></td></tr>
<tr><td colspan="2">☐ f. Others ( )</td></tr>
<tr><td>2. Outdoor temperature</td><td colspan="2">Approx. °C (°F)</td></tr>
<tr><td>3. Altitude</td><td colspan="2">Approx. m</td></tr>
<tr><td rowspan="5">4. Engine coolant</td><td>☐ a. Cold</td><td rowspan="5">Write the position of the indicator on coolant temperature gauge.
 

9Y1200058ENI031A</td></tr>
<tr><td>☐ b. Warming up</td></tr>
<tr><td>☐ c. After warming up</td></tr>
<tr><td>☐ d. Any temperature</td></tr>
<tr><td>☐ e. Others ( )</td></tr>
<tr><td rowspan="5">5. Engine operation</td><td>☐ a. Starting</td><td>☐ b. Just after starting</td></tr>
<tr><td>☐ c. Idling</td><td>☐ d. Racing</td></tr>
<tr><td>☐ e. Acceleration</td><td>☐ f. Deceleration</td></tr>
<tr><td>☐ g. While at work</td><td></td></tr>
<tr><td colspan="2">☐ h. Others ( )</td></tr>
<tr><td rowspan="2">6. Problem frequency</td><td>☐ a. Constant</td><td>☐ b. Once only</td></tr>
<tr><td>☐ c. Sometime (Time per day/month)</td><td></td></tr>
<tr><td>7. Engine warning light</td><td>☐ Turn on a light</td><td>☐ Turn off a light</td></tr>
<tr><td>8. Optional parts</td><td colspan="2">Fill the parts in if you use optional parts or non-genuine parts for electrical, intake/exhaust and fuel system.
( )</td></tr>
<tr><th colspan="3">Dealer check</th></tr>
<tr><td>1. Duplicate the problem</td><td>☐ a. Yes (Duplicate)</td><td>☐ b. No (Not occur)</td></tr>
<tr><td rowspan="2">2. Diagnosis trouble code</td><td colspan="2">☐ a. Abnormal (What is code)</td></tr>
<tr><td colspan="2">☐ b. Normal (No code)</td></tr>
<tr><td rowspan="3">3. Appearance</td><td>☐ a. Normal</td><td>☐ b. Cracked</td></tr>
<tr><td>☐ c. Discolored</td><td></td></tr>
<tr><td colspan="2">☐ d. Others ( )</td></tr>
<tr><td rowspan="2">4. Fuel condition</td><td colspan="2">☐ a. Normal</td></tr>
<tr><td colspan="2">☐ b. Abnormal ( )</td></tr>
</table>

[3] ABBREVIATIONS

ACRONYM	DEFINITION
AC	Alternating Current
AF	Air Fuel Ratio
AL	Adaptive Learn
ATC	After Top Center
ATDC	After Top Dead Center
AVV	Air Valve Vacuum
BARO	Barometric Pressure
BAT	Battery
BHP	Brake Horse Power
BL	Block Learn
BP	Barometric Pressure
BTU	British Thermal Unit
°C	Celsius
CC	Cubic Centimeter
CAC	Charged Air Cooler
CAN	Controller Area Network
CARB	California Air Resources Board
CAT	Catalyst
CCP	CAN Calibration Protocol
CFM	Cubic Feet Per Minute
CHT	Cylinder Head Temperature
CID	Cubic Inch Displacement
CKP	Crankshaft Position Sensor
CL	Closed Loop
CMP	Camshaft Position Sensor
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPP	Clutch Pedal Position Sensor
CTP	Closed Throttle Position
DBW	Drive-By-Wire
DC	Direct Current
DFCO	Decel Fuel Cut Off
DFI	Direct Fuel Injection
DLC	Data Link Connector
DM	Diagnostic Message
DMM	Digital Multi-Meter (high impedance)
DST	Diagnostic Scan Tool
DTC	Diagnostic Trouble Code
DVOM	Digital Voltage and Ohm Meter (high imp.)
ECIPP	EControls Proprietary Protocol
ECM	Engine Control Module
ECT	Engine Coolant Temperature
EDIS	EControls Display and Interface Software
EGO	Exhaust Gas Oxygen Sensor
EGR	Exhaust Gas Recirculation
EI	Electronic Ignition

ACRONYM	DEFINITION
EMI	Electromagnetic Interference
EMWT	Exhaust Manifold Water Temperature
EOBD	Euro Onboard Diagnostic
EPR	Electronic Pressure Regulator
ERWT	Exhaust Manifold Riser Temperature
ETB	Electronic Throttle Body
ETC	Electronic Throttle Control
EVAP	Evaporative Emissions
°F	Fahrenheit
FC	Fan Control
FDR	Flight Data Recorder
FF	Flex Fuel
FMI	Failure Mode Indicator
FO	Firing Order
FP	Fuel Pressure
FPM	Fuel Pressure Module
FPP	Foot Pedal Position
FRP	Fuel Rail Pressure
FRT	Fuel Rail Temperature
FSS	Fault Snapshot
FT	Fuel Temperature
FT	Fuel Trim
ft. lb.	Foot Pounds
FTP	Federal Test Procedure
GCP	Global Control Platform
GEN	Generator
GND	Ground
GPM	Grams Per Mile
HC	Hydrocarbon
HVS	High Voltage Switch
HDGCP	Heavy-Duty Global Control Platform (On-Road Heavy-Duty)
HEGO	Heated Exhaust Gas Oxygen Sensor (same as HO_2S)
HO_2S	Heated Oxygen Sensor
HO_2S1	Upstream Heated Oxygen Sensor (Pre CAT)
HO_2S2	Downstream or Downstream Heated Oxygen Sensor (Pre CAT)
HP	Horsepower
IAC	Idle Air Control
IAT	Intake Air Temperature
IC	Ignition Control Circuit
ICM	Ignition Control Module
ICAV	Instant Crank Angle Velocity
ID	Inside Diameter
IFI	Indirect Fuel Injection
IGN	Ignition
IP	Instrument Panel
IPC	Instrument Panel Cluster
IVS	Idle Validation Switch
kHz	Kilohertz
Km	Kilometers

ACRONYM	DEFINITION
kPa	Kilopascals
KPH	Kilometers Per Hour
KOEC	Key On Engine Cranking
KOEO	Key On Engine Off
KOER	Key On Engine Running
KS	Knock Sensor
KV	Kilovolt
L.	Liter
lb.ft.	Pound Feet
LDGCP	Light-Duty Global Control Platform (Industrial, Smart/Logic Coil)
LED	Light Emitting Diode
LPG	Liquefied Propane Gas
LTFT	Long Term Fuel Trim
MAF	Mass Airflow Sensor
MAP	Manifold Absolute Pressure
MDGCP	Medium-Duty Global Control Platform (Industrial, Dumb Coil)
MDP	Manifold Differential Pressure
mP	Microprocessor
Mfg	Manufacture
MIL	Malfunction Indicator Lamp
mm	Millimeters
ms	Millisecond
mV	Millivolt
MPG	Miles Per Gallon
MPH	Miles Per Hour
NG	Natural Gas
Nm	Newton Meters
O_2	Oxygen Sensor
OBD	On-Board Diagnostics
OBD I	On-Board Diagnostics generation one
OBD II	On-Board Diagnostics generation two
OBD III	On-Board Diagnostics generation three
OBD IV	On-Board Diagnostics generation four
OC	Oxidation Catalyst
OD	Outside Diameter
OEM	Original Equipment Manufacture
OHC	Overhead Cam
OL	Open Loop
PC	Personal Computer
PCM	Powertrain Control Module
PCU	Powertrain Control Unit
PCV	Positive Crankcase Ventilation
PFI	Port Fuel Injection
PGN	Parameter Group Number
PPM	Parts Per Million
PSA	Pressure Switch Assembly
psi	Pounds Per Square Inch
PWM	Pulse Width Modulated
RAM	Random Access Memory

ACRONYM	DEFINITION
RFI	Radio Frequency Interference
RPM	Revolutions Per Minute
Rx	Receive
SA	Source Address
SFI	Sequential Fuel Injection
SOHC	Single Overhead Cam
SPFI	Sequential Port Fuel Injection
SPN	Suspect Parameter Number
SRI	Service Reminder Indicator
SRT	System Readiness Test
Tach	Tachometer
TBI	Throttle Body Injection
TDC	Top Dead Center
TIP	Throttle Inlet Pressure
TPS1	Throttle Position Sensor One
TPS2	Throttle Position Sensor Two
TSC	Torque/Speed Control
TWC	Threeway Catalyst
TWC+OC	Threeway Catalyst + Oxidation Catalytic Converter
Tx	Transmit
UEGO	Universal Exhaust Gas Oxygen Sensor (also called wide-range EGO)
VBAT	Battery Voltage
VDC	Voltage, Direct Current
VIN	Vehicle Identification Number
VR	Variable Reluctance
VSS	Vehicle Speed Sensor
Vsw	Switched, Ignition Voltage
WGP	Waste-Gate Pressure
WOT	Wide Open Throttle

2. SYMPTOM CHARTS BY COMPONENTS

[1] WG1605-G (GASOLINE) SYMPTOM CHARTS

	Important Preliminary Checks
Checks	**Action**
Before Using This Section	Before using this section you should have performed On Board Diagnostic Checks and determined that: • The Control Module and MIL (Malfunction Indicator Lamp) are operating correctly. • There are no Diagnostic Trouble Codes (DTCs) stored or a DTC exists but without a MIL. Several of the following symptom procedures call for a careful visual and physical check. The visual and physical checks are very important. The checks can lead to correcting a problem, without further checks, that may save valuable time. Most importantly talk to the operator about the failure this may provide important information about the fault.
Important Question to Ask the Operator	• When and how did the operator first notice the fault condition • What engine speed and load condition did the fault occur at • Did the fault occur just after or before refueling • Did the fault occur at start up or shut down • Did the fault occur at a particular time of day or during the shift • Did the fault occur in a particular location • Has there been any recent repair to the engine or vehicle • Has the fault ever occurred before • Has there been any new external customer installed devices added to the vehicle and or engine
Gasoline Fuel System Check	Verify the customer complaint. Locate the correct symptoms table. • Check the items indicated under that symptom. • Operate the vehicle under the conditions the symptom occurs. Verify HEGO switching between lean and rich. ■ **IMPORTANT** • **Normal HEGO switching indicates the Gasoline fuel system is in closed loop and operating correctly at that time.** • If a scan tool is available **take a snapshot** under the condition that the symptom occurs. Go to Engine Scan Tool Data. List to verify normal sensor values and parameters.
Visual and Physical Checks	• Check all ECM system fuses and circuit breakers. • Check the ECM ground for being clean, tight and in its proper location. • Check the vacuum hoses for splits, kinks and proper connections. • Check thoroughly for any type of fuel leak or restriction.
	• Check for air leaks at all the mounting areas of the intake manifold sealing surfaces. • Check for proper installation of the Throttle Body assembly.
	• Check for fuel leaks at the fuel rail and injectors. • Check the wiring for the following items: – Proper connections, pinches or cuts. • The following symptoms table contains groups of possible causes for each symptom. The order of these procedures is not important. If the scan tool readings do not indicate the problems, then proceed in a logical order easiest to check or most likely to cause first.

	Intermittent
Checks	**Action**
DEFINITION: The problem may or may not turn ON the Malfunction Indicator Lamp (MIL), or store a Diagnostic Trouble Code (DTC).	
Preliminary Checks	• Refer to Important Preliminary Checks. • Do not use the DTC tables. If a fault is an intermittent, the use of the DTC tables may result in the replacement of good parts.
Faulty Electrical Connections or Wiring	• Faulty electrical connections or wiring can cause most intermittent problems. • Check the suspected circuit for the following conditions: – Check for faulty fuses or circuit breakers. – Check for poorly mated electrical connectors. – Check for connector pin and terminals not fully seated. – Check for terminal pin damaged or deformation. – Check poor soldering in the joints and connectors. – Check for excessive wire strain on the harness. – Check for burned or damaged wiring. – Check for recently added customer installed electrical options which may be improperly spliced into the harness assembly. • Carefully remove all the connector terminals in the problem circuit in order to ensure the proper contact tension. If necessary, replace all the connector terminals in the problem circuit in order to ensure the proper contact tension. • Checking for poor terminal to wire connections requires removing the terminal from the connector body.
Operational Test	If a visual and physical check does not locate the cause of the problem, drive the vehicle with a scan tool. When the problem occurs, an abnormal voltage or scan reading indicates the problem may be in that circuit.
Intermittent Malfunction Indicator Lamp (MIL)	The following components can cause intermittent MIL and no DTC(s): • A defective relay Control Module driven solenoid, or a switch that can cause electrical system interference. Normally, the problem will occur when the faulty component is operating. • The improper installation of electrical devices, such as lights, 2-way radios, electric motors, etc. • The ignition secondary voltage, shorted to a ground. • The Malfunction Indicator Lamp (MIL) circuit or the Diagnostic Test Terminal intermittently shorted to ground. • The Control Module grounds.
Loss of DTC Memory	To check for the loss of the DTC Memory: 1. Disconnect the TMAP sensor. 2. Idle the engine until the Malfunction Indicator Lamp illuminates. The ECM should store a TMAP DTC. The TMAP DTC should remain in the memory, when the ignition is turned OFF. If the TMAP DTC does not store and remain, the ECM is faulty.

	No Start
Checks	**Action**
DEFINITION: The engine cranks OK but does not start.	
Preliminary Checks	• Refer to Important Preliminary Checks.
Control Module Checks	• Check the battery cranking voltage, voltage should not be less then 9.0 VDC. • Check the inline fuse in the ECM battery power circuit. Refer to Engine Controls Schematics. • Check battery power, ignition power and ground circuits to the ECM. Refer to Engine Control Schematics. Verify voltage and/or continuity for each circuit.
Sensor Checks	• Check the TMAP sensor. • Check the Camshaft position (CMP) and Crankshaft (CKP) position sensors. • Check the Gasoline pressure sensor.
Fuel System Checks	• Check for fuel pump electrical circuit. • Verify proper fuel pump pressure. • Verify proper Fuel rail pressure. • Refer to the Gasoline Fuel System Diagnosis. • Check Electrical connections at the injectors.
Ignition System Checks	• Check for the proper primary side ignition voltage output. • Verify that the spark plugs are correct. • Check the spark plugs for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Check for loose ignition coil connections at the coil.
Engine Mechanical Checks	• Check for the following: – Vacuum leaks – Improper valve timing – Low compression – Bent pushrods – Worn rocker arms – Broken or weak valve springs – Worn camshaft lobes
Exhaust System Checks	• Check the exhaust system for a possible restriction: – Inspect the exhaust system for damaged or collapsed pipes. – Inspect the muffler for signs of heat distress, or for possible internal failure. • Check for possible plugged catalytic converter. Refer to Restricted Exhaust System Diagnosis.

	Hard Start
Checks	**Action**
DEFINITION: The engine cranks OK, but does not start for a long time. The engine does eventually run, or may start but immediately dies.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Make sure the vehicle's operator is using the correct starting procedure.
Sensor Checks	• Check the Throttle position (TPS) sensor. • Check the Camshaft position (CMP) and Crankshaft (CKP) position sensors.
Fuel System Checks	• Check for fuel pump electrical circuit. • Verify proper fuel pump pressure. • Verify proper fuel rail pressure. • Refer to the Gasoline Fuel System Diagnosis. • Check Electrical connections at the injectors.
Ignition System Checks	• Check for the proper ignition voltage output. • Verify that the spark plugs are correct. • Check the spark plugs for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Check for loose ignition, coil connections. ■ **IMPORTANT** **1. If the engine starts but then immediately stalls. Check the Crankshaft Position (CKP) sensor.** **2. Check for improper gap, debris or faulty connections.**
Engine Mechanical Checks	• Check for the following: – Vacuum leaks – Improper valve timing – Low compression – Bent pushrods – Worn rocker arms – Broken or weak valve springs • Check the intake and exhaust manifolds, for casting flash.
Exhaust System Checks	• Check the exhaust system for a possible restriction: – Inspect the exhaust system for damaged or collapsed pipes. – Inspect the muffler for signs of heat distress, or for possible internal failure. • Check for possible plugged catalytic converter. Refer to Restricted Exhaust System Diagnosis.

Cuts Out, Misses	
Checks	**Action**
DEFINITION: A surging or jerking that follows engine speed, usually more pronounced as the engine load increases, which is not normally felt above 1500 RPM. The exhaust has a steady spitting sound at idle, low speed, or hard acceleration for the fuel starvation that can cause the engine to cut-out.	
Preliminary Checks	• Refer to Important Preliminary Checks.
Ignition System Checks	• Start the engine. • Wet down the secondary ignition system with water from a spray bottle and look/listen for arcing or misfiring as you apply water. • Check for proper ignition output voltage with spark tester. • Check for a cylinder misfire. • Verify that the spark plugs are correct. • Remove the spark plugs in these cylinders and check for the following conditions: – Insulation cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Visually/Physically inspect the secondary ignition for the following: – Ignition coil for cracks or carbon tracking.
Engine Mechanical Checks	• Perform a cylinder compression check. • Check the engine for the following: – Improper valve timing – Bent pushrods – Worn rocker arms – Worn camshaft lobes. – Broken or weak valve springs. • Check the intake and exhaust manifold passages, for casting flash.
Fuel System Checks	• Check the fuel system-plugged fuel filter, low fuel pressure, etc. Refer to Gasoline Fuel System Diagnosis. • Check the condition of the wiring to the fuel pump and injectors.
Additional Check	Check for Electromagnetic Interference (EMI). • EMI on the reference circuit can cause a missing condition. • Monitoring the engine RPM with a scan tool, can detect an EMI. • A sudden increase in the RPM with little change in the actual engine RPM, indicates EMI is present. • If the problem exists, check the routing of the secondary wires and the ground circuit.

Hesitation, Sag, Stumble	
Checks	**Action**
DEFINITION: The vehicle has a momentary lack of response, when depressing the accelerator. The condition can occur at any vehicle speed. The condition may cause the engine to stall, if it's severe enough.	
Preliminary Checks	Refer to Important Preliminary Checks.
Fuel System Checks	• Check the fuel pump electrical circuit. • Verify proper fuel pump pressure. • Verify proper fuel rail pressure. • Refer to the Gasoline Fuel System Diagnosis. • Check Electrical connections at the injectors.
Ignition System Checks	• Check for the proper ignition voltage output. • Verify that the spark plugs are correct. • Check for fouled spark plugs.
Additional Check	• Check for manifold vacuum or air induction system leaks. • Check the generator output voltage.

Backfire	
Checks	**Action**
DEFINITION: The fuel ignites in the intake manifold, or in the exhaust system, making a loud popping noise. A backfire which is heard in the intake manifold and air stream indicates that the fuel is being ignited in the intake manifold and is a result of a spark igniting the fuel air mixture. A backfire heard in the exhaust system indicates that there is an over fueling condition or a late spark event which ignites unburned fuel in the exhaust.	
Preliminary Check	• Refer to Important Preliminary Checks.
Ignition System Checks	• Check for the proper ignition coil output voltage using a spark tester. • Check the connection at each ignition coil. • Check the spark plugs. • Remove the plugs and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits
Engine Mechanical Check	• Check the engine for the following: – Improper valve timing – Engine compression – Manifold vacuum leaks – Intake manifold gaskets – Sticking or leaking valves – Exhaust system leakage • Check the intake and exhaust system for casting flash or other restrictions.
Fuel System Checks	• Perform a fuel system diagnosis. Refer to Gasoline Fuel System Diagnosis.

Lack of Power, Sluggishness, or Sponginess	
Checks	**Action**
DEFINITION: The engine delivers less than expected power. There is little or no increase in speed when partially applying the accelerator pedal.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Refer to the Gasoline Fuel system OBD System Check. • Compare the customer's vehicle with a similar unit. Make sure the customer has an actual problem. • Remove the air filter and check for dirt or restriction. • Check the vehicle transmission. Refer to the OEM transmission diagnostics.
Fuel System Checks	• Check for a restricted fuel filter, contaminated fuel, or improper fuel pressure. Refer to Gasoline Fuel System Diagnosis. • Check for the proper ignition output voltage, with the spark tester. • Check the fuel pump electrical circuit. • Verify proper fuel pump pressure. • Verify proper fuel rail pressure. • Refer to the Gasoline Fuel System Diagnosis. • Check electrical connections at the injectors.
Sensor Checks	• Check the Heated Exhaust Gas Oxygen Sensor (HEGO) for contamination and performance. Check for proper operation of the MAP sensor. • Check for proper operation of the TPS sensor.
Exhaust System Checks	• Check the exhaust system for a possible restriction: – Inspect the exhaust system for damaged or collapsed pipes. – Inspect the muffler for signs of heat distress or for possible internal failure. – Check for possible plugged catalytic converter.
Engine Mechanical Check	• Check the engine for the following: – Engine compression – Valve timing – Improper or worn camshaft. Refer to Engine Mechanical.
Additional Check	• Check the ECM grounds for being clean, tight, and in their proper locations. • Check the generator output voltage. • If all procedures have been completed, and no malfunction has been found, review and inspect the following items: – Visually and physically inspect all electrical connections within the suspected circuit and/or systems. – Check the brake system for sticking or dragging brakes.

Poor Fuel Economy	
Checks	**Action**
DEFINITION: Fuel economy, as measured by refueling records is noticeably lower than expected. Also, the economy is noticeably lower, than it was on this vehicle at one time as previously shown by refueling records.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Check the air cleaner element (filter) for dirt or being plugged. • Visually (Physically) check the vacuum hoses for splits, kinks and proper connections. • Check the operators driving habits for the following items: – Is there excessive idling or stop and go driving – Are the tires at the correct air pressure – Are excessively heavy loads being carried – Is there often rapid acceleration • Suggest to the owner to fill the fuel tank and to recheck the fuel economy. • Suggest that a different operator use the equipment and record the results.
Fuel System Checks	• Check the fuel Rail pressure. Refer to Gasoline Fuel System Diagnosis. • Check the fuel system for leakage.
Sensor Checks	• Check the Temperature Manifold Absolute Pressure (TMAP) sensor.
Ignition System Checks	• Verify that the spark plugs are correct. • Check the spark plugs. Remove the plugs and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits
Cooling System Checks	• Check the engine thermostat for always being open or for the wrong heat range.
Engine Mechanical Check	• Check the engine for the following: – Engine compression – Valve timing – Improper or worn camshaft. Refer to Engine Mechanical, in the Service Manual.
Additional Check	• Check the transmission shift pattern. Refer to the OEM Transmission Controls section in their Service Manual. • Check for dragging brakes.

Rough, Unstable or Incorrect Idle or Stalling	
Checks	**Action**
DEFINITION: The engine runs unevenly at idle. If severe enough, the engine or vehicle may shake. The engine idle speed may vary in RPMs. Either condition may be severe enough to stall the engine.	
Preliminary Check	• Refer to Important Preliminary Checks.
Sensor Checks	• Check for silicon contamination from fuel or improperly used sealant. The sensor will have a white powdery coating. The sensor will result in a high but false, signal voltage (rich exhaust indication). The ECM will reduce the amount of fuel delivered to the engine causing a severe drivability problem. • Check the Heated Exhaust Gas Oxygen Sensor (HEGO) performance. • Check the Temperature Manifold Absolute Pressure (TMAP) sensor response and accuracy.
Fuel System Checks	• Check for rich or lean symptoms that causes the condition. Drive the vehicle at the speed of the complaint. Monitoring the oxygen sensors will help identify the problem. • Verify proper operation of the injectors. • Perform a cylinder compression test. Refer to Engine Mechanical in the Service Manual. • Check the fuel Rail pressure. Refer to the Gasoline Fuel System Diagnosis. • Check injector electrical connections.
Ignition System Checks	• Check for the proper ignition output voltage using the spark tester. • Verify that the spark plugs are correct. • Check the spark plugs. Remove the plugs and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Blistered insulators – Heavy deposits
Additional Checks	• Check the ECM grounds for being clean, tight and in their proper locations. • Check the battery cables and ground straps. They should be clean and secure. Erratic voltage may cause all sensor readings to be skewed, resulting in poor idle quality.
Engine Mechanical Check	• Check the engine for the following: – Broken motor mounts – Improper valve timing – Low compression – Bent pushrods – Worn rocker arms – Broken or weak valve springs – Worn camshaft lobes

Surges/Chuggles	
Checks	**Action**
DEFINITION: The engine has a power variation under a steady throttle or cruise. The vehicle feels as if it speeds up and slows down with no change in the accelerator pedal.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Be sure the driver understands "the Torque Converter Clutch operation"
Sensor Checks	Check the Heated Exhaust Gas Oxygen Sensor (HEGO), performance.
Fuel System Checks	• Check for Rich or Lean symptom that causes the condition. Drive the vehicle at the speed of the complaint. Monitoring the oxygen sensors will help identify the problem. • Check the fuel rail pressure while the condition exists. Refer to Gasoline Fuel System Diagnosis. • Verify check injector electrical connections. • Check the in-line fuel filter for restrictions.
Ignition System Checks	• Check for the proper ignition output voltage using the spark tester. • Verify that the spark plugs are correct. • Check the spark plugs. Remove the plugs and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Check the Crankshaft Position (CKP) sensor.
Additional Check	• Check the ECM grounds for being clean, tight and in their proper locations. • Check the generator output voltage. • Check the vacuum hoses for kinks or leaks. • Check Transmission.

[2] WG1605-L (LPG) SYMPTOM CHARTS

	Important Preliminary Checks
Checks	**Action**
Before Using This Section	Before using this section, you should have performed On Board Diagnostic Check and determined that: • The Control Module and MIL (Malfunction Indicator Lamp) are operating correctly. • There are no Diagnostic Trouble Codes (DTCs) stored, or a DTC exists, but without a MIL. Several of the following symptom procedures call for a careful visual and physical check. The visual and physical checks are very important. The checks can lead to correcting a problem, without further checks, that may save valuable time. Most importantly talk to the operator about the failure this may provide important information about the fault.
Important Question to Ask the Operator	• When and how did the operator first notice the fault condition • What engine speed and load condition did the fault occur at • Did the fault occur just after or before refueling • Did the fault occur at start up or shut down • Did the fault occur at a particular time of day or during the shift • Did the fault occur in a particular location • Has there been any recent repair to the engine or vehicle • Has the fault ever occurred before • Has there been any new external customer installed devices added to the vehicle and or engine
LPG Fuel System Check	• Verify the customer complaint. • Locate the correct symptom table. • Check the items indicated, under that symptom. • Operate the vehicle, under the condition the symptoms occurs. Verify HEGO is switching between lean and rich. ■ **IMPORTANT** • **Normal HEGO switching, indicates the LPG fuel system is in closed loop, and operating correctly at that time.** • If a scan tool is available, **take a snapshot**, under the condition that the symptom occurs. Go to Engine Scan Tool Data List, to verify normal sensor values and parameters.
Visual and Physical Checks	• Check all ECM system fuses and/or circuit breakers. • Check the ECM ground for being clean, tight, and in its proper location. • Check the vacuum hoses for splits, kinks, and proper connections. • Check thoroughly for any type of leak or restriction. • Check for air leaks, at all the mounting areas, of the intake manifold sealing surfaces. • Check for proper installation of the mixer module assembly. • Check for air leaks, at the mixer assembly. • Check the wiring, for the following items: – Proper connections, pinches, or cuts. • Check the fuel level and fuel delivery system for leaks • Check the battery condition • The following symptom tables contain groups of possible causes, for each symptom. The order of these procedures is not important. If the scan tool readings do not indicate the problems, then proceed in a logical order, easiest to check, or most likely to occur first.

	Intermittent
Checks	**Action**
DEFINITION: The problem may or may not turn ON the Malfunction Indicator Lamp (MIL), or store a Diagnostic Trouble Code (DTC).	
Preliminary Checks	• Refer to Important Preliminary Checks. • Do not use the DTC tables, if a fault is an intermittent, the use of the DTC tables may result in the replacement of good parts.
Faulty Electrical Connections, or Wiring	• Faulty electrical connections, or wiring, can cause most intermittent problems. • Check the suspected circuit for the following conditions: – Faulty fuse, or circuit breaker – Connectors poorly mated – Corrosion or loose pins in the connectors – Terminals not fully seated, in the connector (backed out) – Terminals not properly formed, or damaged – Terminal to wire joints poorly connected – Terminal tension, insufficient – Wire strain from improper wire routing – Burned or damaged wires from contacting hot surfaces or rotating devices • Improper splicing method used when optional equipment is installed to the vehicle. • Carefully remove all the connector terminals in the problem circuit, in order to ensure the proper contact tension. If necessary, replace all the connector terminals in the problem circuit, in order to ensure the proper contact tension. • Checking for poor terminal, to wire connections, requires removing the terminal from the connector body.
Operational Test	If a visual and physical check does not locate the cause of the problem, drive the vehicle with a scan tool. When the problem occurs, an abnormal voltage or scan reading indicates the problem may be in that circuit.
Intermittent Malfunction Indicator Lamp (MIL)	The following components can cause intermittent MIL, and no DTC(s): • A defective relay Control Module driven solenoid, or a switch that can cause electrical system interference. Normally, the problem will occur when the faulty component is operating. • The improper installation of electrical devices, such as lights, 2-way radios, electric motors, etc. • The ignition, secondary voltage, is shorted to a ground. • The Malfunction Indicator Lamp (MIL) circuit, or the Diagnostic Test Terminal, is intermittently shorted to ground. • The Control Module grounds.
Loss of DTC Memory	To check for the loss of the DTC Memory: 1. Disconnect the TMAP sensor. 2. Idle the engine, until the Malfunction Indicator Lamp illuminates. The ECM should store a TMAP DTC. The TMAP DTC should remain in the memory, when the ignition is turned OFF. If the TMAP DTC does not store and remains, the ECM is faulty.
Additional Checks	

	No Start
Checks	**Action**
DEFINITION: The engine cranks OK, but does not start.	
Preliminary Checks	• Refer to Important Preliminary Checks.
Battery and Voltage Check	• Check the battery charge condition. • Check the battery cranking voltage, voltage less the 9.00 V are outside the parameters of operation. • Check Battery positive and negative cable ends for corrosion build up.
Control Module Checks	• Check the inline fuse in the ECM battery power circuit. Refer to Engine Controls Schematics. • Check battery power, ignition power, and ground circuits, to the ECM. Refer to Engine Control Schematics. Verify voltage and/or continuity, for each circuit.
Sensor Checks	• Crank sensor. • Cam sensor.
Fuel System Checks	■ **IMPORTANT** • **A closed LPG manual fuel shut off valve, will create a no start condition. Check the fuel supply line connection to ensure the Excess flow check valve has not set** • Check for air intake system leakage, between the mixer and the throttle body. • Verify proper operation, of the low pressure lock-off solenoids. • Fuel filter plugging. • Check the fuel system pressures. Refer to the LPG Fuel System Diagnosis. • Check the low pressure fuel supply hose for restrictions and or blockage. • Check for restrictions in the air intake system. • Check for large vacuum leaks in the intake system. • Check for proper mixer air valve operation. • Check for exhaust pipe or catalyst restrictions.
Ignition System Checks	■ **NOTE** • **LPG, being a gaseous fuel, requires higher secondary ignition system voltages, for the equivalent gasoline operating conditions.** • Check for the proper ignition voltage output. • Verify that the spark plugs are correct, for use with LPG. • Check the spark plugs, for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Check for loose ignition, coil connections, at the coil.
Engine Mechanical Checks	■ **IMPORTANT** • **The LPG Fuel system works on a fumigation principle, of fuel introduction, and is more sensitive, to intake manifold leakage, than the gasoline fuel supply system.** • Check for the following: – Vacuum leaks – Improper valve timing – Low compression – Bent pushrods – Worn rocker arms – Broken, or weak valve springs – Worn camshaft lobes
Exhaust System Checks	• Check the exhaust system, for a possible restriction: • Inspect the exhaust system, for damaged or collapsed pipes. • Inspect the muffler, for signs of heat distress, or for possible internal failure. • Check for, possible, plugged catalytic converter. Refer to Restricted Exhaust System Diagnosis.

	Hard Start
Checks	**Action**
DEFINITION: The engine cranks OK, but does not start for a long time. The engine does eventually run, or may start, but immediately dies.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Make sure the vehicle's operator is using the correct starting procedure. • Be sure that there is fuel in the fuel tank. • Check to make sure the manual tank valve is fully open.
Sensor Checks	• Check the Crankshaft Position (CKP) sensor. • Check the Camshaft sensor.
Fuel System Checks	■ **IMPORTANT** • **A closed LPG manual fuel shut off valve will create an extended crank, OR no start condition.** • Verify the excess flow valve, in the LPG manual shut-off valve, is not tripped. • Check mixer module assembly, for proper installation and leakage. • Verify proper operation, of the low pressure lock-off solenoids. • Check for air intake system leakage, between the mixer and the throttle body. • Check the fuel system pressures. Refer to the Fuel System Diagnosis.
Ignition System Checks	■ **NOTE** • **LPG, being a gaseous fuel, requires higher, secondary ignition system voltages, for the equivalent gasoline operating conditions.** • Check for the proper ignition voltage output • Verify that the spark plugs are correct, for use with LPG. • Check the spark plugs, for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Check for loose ignition coil connections. ■ **IMPORTANT** **1. If the engine starts, but then immediately stalls, check Crankshaft Position (CKP).** **2. Check for improper gap, debris, or faulty connections.**
Engine Mechanical Checks	■ **IMPORTANT** • **The LPG Fuel system, works on a fumigation principle of fuel introduction, and is more sensitive to intake manifold leakage, than the gasoline fuel supply system.** • Check for the following: – Vacuum leaks – Improper valve timing – Low compression – Bent pushrods – Worn rocker arms – Broken or weak valve springs – Worn camshaft lobes. Refer to Workshop Manual • Check the intake and exhaust manifolds, for casting flash.
Exhaust System Checks	• Check the exhaust system for a possible restriction: • Inspect the exhaust system, for damaged or collapsed pipes. • Inspect the muffler, for signs of heat distress, or for possible internal failure. • Check for possible, plugged, catalytic converter. Refer to Restricted Exhaust System Diagnosis.
Additional Checks	

	Cuts Out, Misses
Checks	**Action**
DEFINITION: A surging or jerking, that follows engine speed, usually more pronounced as the engine load increases, which is not normally felt, above 1500 RPM. The exhaust has a steady spitting sound at idle, low speed, or hard acceleration, for the fuel starvation, that can cause the engine to cut-out.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Check the battery condition. • Check the positive and negative cable connections. • Check the ECM and system grounds for corrosion at the connectors. • Check the coil electrical connections. • Check the air filter for restriction.
Ignition System Checks	• Start the engine. • Check for proper ignition output voltage, with spark tester. • Check for a cylinder misfire. • Verify that the spark plugs are correct for use, with LPG. • Remove the spark plugs and check for the following conditions: – Insulation cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Visually/Physically inspect the secondary ignition, for the following: – Ignition coils, for cracks or carbon tracking. • Wet down the secondary ignition system with water from a spray bottle and look / listen for arcing or misfiring as you apply water.
Engine Mechanical Checks	• Perform a cylinder compression check. • Check the engine for the following: – Improper valve timing – Bent pushrods – Worn rocker arms – Worn camshaft lobes. – Broken or weak valve springs. • Check the intake and exhaust manifold passages, for casting flash.
Fuel System Checks	• Check the fuel system-plugged fuel filter, low fuel pressure, etc. Refer to LPG Fuel System Diagnosis. • Check the condition of the wiring, to the low pressure lock-off solenoid. • Check the DEPR wire harness connection at the DEPR. • Check the VSW electrical connection to make sure it is fully seated and locked.
Additional Check	Check for Electromagnetic Interference (EMI). • EMI on the reference circuit can cause a missing condition. • Monitoring the engine RPM, with a scan tool, can detect an EMI. • A sudden increase, in the RPM, with little change in the actual engine RPM, indicates EMI is present. • If the problem exists, check the routing of the secondary wires, and the ground circuit. • Check for secondary electrical equipment improperly spliced into the engine electrical system.

	Hesitation, Sag, Stumble
Checks	**Action**
DEFINITION: The vehicle has a momentary lack of response when depressing the accelerator. The condition can occur at any vehicle speed. The condition may cause the engine to stall if it's severe enough.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Check the battery condition. • Check the positive and negative cable connections. • Check the ECM and system grounds for corrosion at the connectors. • Check the coil electrical connections. • Check the air filter for restriction.
Fuel System Checks	• Check the fuel pressure. Refer to LPG Fuel System Diagnosis. • Check for low fuel pressure, during a moderate, or full throttle acceleration. If the fuel pressure drops below specification, there is a possibility of a faulty low pressure regulator, or a restriction, in the fuel system. • Check the Manifold Absolute Pressure (MAP) sensor response and accuracy. • Check LPL electrical connection. • Check the mixer air valve for sticking or binding. • Check the mixer module assembly, for proper installation and leakage.
Ignition System Checks	■ **NOTE** • **LPG, being a gaseous fuel, requires higher secondary ignition system voltages, for the equivalent gasoline operating conditions. If a problem is reported on LPG, and not gasoline, do not discount the possibility of a LPG only, ignition system failure, and test the system accordingly.** • Check for proper ignition output voltage, with spark tester. • Verify that the spark plugs are correct, for use with LPG. • Check for fouled spark plugs.
Additional Check	• Check for manifold vacuum, or air induction, system leaks. • Check the generator, output voltage.

	Backfire
Checks	**Action**
DEFINITION: The fuel ignites in the intake manifold, or in the exhaust system, making a loud popping noise.	
Preliminary Check	• Refer to Important Preliminary Checks.
Ignition System Checks	■ **IMPORTANT** • **LPG, being a gaseous fuel, requires higher secondary ignition system voltages, for the equivalent gasoline operating conditions. The ignition system must be maintained in peak condition, to prevent backfire.** • Check for the proper ignition coil output voltage, using the spark tester. • Check the connection, at each ignition coil. • Check the spark plugs. • Remove the plugs, and inspect them, for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits
Engine Mechanical Check	■ **IMPORTANT** • **The LPG, Fuel system, works on a fumigation principle, of fuel introduction, and is more sensitive to intake manifold leakage, than a gasoline fuel supply system.** • Check the engine for the following: – Improper valve timing – Engine compression – Manifold vacuum leaks – Intake manifold gaskets – Sticking or leaking valves – Exhaust system leakage • Check the intake and exhaust system, for casting flash or other restrictions.
Fuel System Checks	• Perform a fuel system diagnosis. Refer to LPG Fuel System Diagnosis.

	Lack of Power, Sluggishness, or Sponginess
Checks	**Action**
DEFINITION: The engine delivers less than expected power. There is little or no increase in speed, when partially applying the accelerator pedal.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Refer to the LPG Fuel system, OBD System Check. • Compare the customer's vehicle, with a similar unit. Make sure the customer has an actual problem. Do not compare the power output, of the vehicle operating on LPG, to a vehicle operating on gasoline, as the fuels do have different drive feel characteristics. • Remove the air filter, and check for dirt or restriction. • Check the vehicle transmission. Refer to the OEM transmission diagnostics. • Verify the fuel tank has fuel.
Fuel System Checks	• Check for a restricted fuel filter, contaminated fuel, or improper fuel pressure. Refer to LPG Fuel System Diagnosis. • Check for the proper ignition output voltage, with the spark tester. • Check for proper installation, of the mixer module assembly. • Check all air inlet ducts, for condition and proper installation. • Check for fuel leaks, between the DSR, and the mixer. • Verify that the LPG tank manual shut-off valve is fully open. • Verify that liquid fuel (not vapor) is being delivered to the DSR.
Sensor Checks	• Check the Heated Exhaust Gas Oxygen Sensor (HEGO), for contamination and performance. • Check for proper operation of the MAP sensor. • Check for proper operation of the TPS sensor.
Exhaust System Checks	• Check the exhaust system, for a possible restriction: • Inspect the exhaust system, for damaged or collapsed pipes. • Inspect the muffler, for signs of heat distress, or for possible internal failure. • Check for possible plugged catalytic converter.
Engine Mechanical Check	• Check the engine for the following: – Engine compression – Valve timing • Improper or worn camshaft. Refer to Engine Mechanical, in the Service Manual.
Additional Check	• Check the ECM grounds, for being clean, tight, and in their proper locations. • Check the generator output voltage. • Visually and physically, inspect all electrical connections, within the suspected circuit and/or systems. • Check the scan tool data.

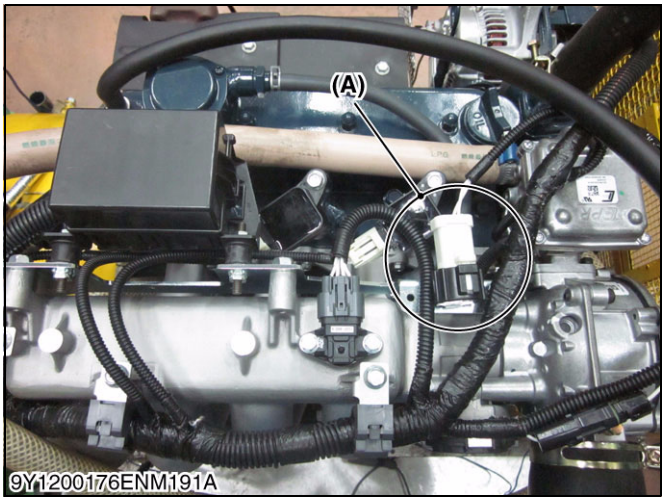
	Poor Fuel Economy
Checks	**Action**
DEFINITION: Fuel economy, as measured by refueling records, is noticeably lower than expected. Also, the economy is noticeably lower, than it was on this vehicle at one time, as previously shown by refueling records.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Check the air cleaner element (filter), for dirt or being plugged. • Visually (Physically) check the vacuum hoses, for splits, kinks, and proper connections. • Check the operators driving habits, for the following items: – Is there excessive idling, or stop and go driving? – Are the tires at the correct air pressure? – Are excessively heavy loads being carried? – Is their often rapid acceleration? • Suggest to the owner, to fill the fuel tank, and to recheck the fuel economy. • Suggest that a different operator, use the equipment and record the results.
Fuel System Checks	• Check the DSR fuel pressure. Refer to LPG Fuel System Diagnosis. • Check the fuel system for leakage.
Sensor Checks	• Check the Temperature Manifold Absolute Pressure (TMAP) sensor.
Ignition System Checks	• Verify that the spark plugs are correct, for use with LPG. Check the spark plugs. Remove the plugs, and inspect them, for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits
Cooling System Checks	• Check the engine thermostat, for always being open, or for the wrong heat range.
Engine Mechanical Check	• Check the engine for the following: – Engine compression – Valve timing • Improper or worn camshaft. Refer to Engine Mechanical, in the Service Manual.
Additional Check	• Check the transmission shift pattern. Refer to the OEM Transmission Controls section of the Service Manual. • Check for dragging brakes.

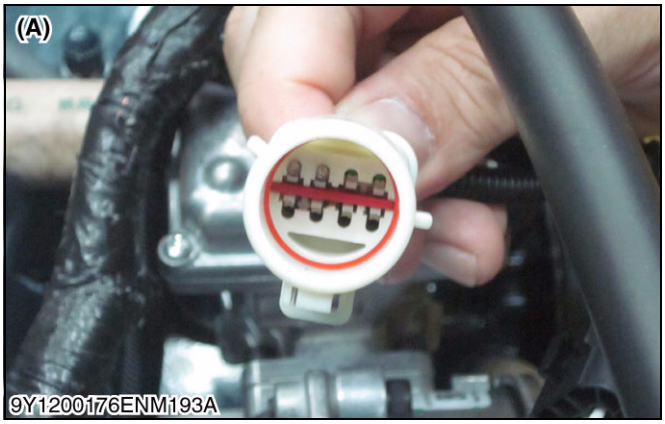
	Rough, Unstable, or Incorrect Idle, Stalling
Checks	**Action**
DEFINITION: The engine runs unevenly at idle. If severe enough, the engine or vehicle may shake. The engine idle speed may vary, in RPM. Either condition may be severe enough, to stall the engine.	
Preliminary Check	• Refer to Important Preliminary Checks.
Sensor Checks	• Check for silicon contamination, from fuel or improperly used sealant. The sensor will have a white powdery coating. The sensor will result in a high but false signal voltage (rich exhaust indication). The ECM will reduce the amount of fuel delivered to the engine, causing a severe driveability problem. • Check the Heated Exhaust Gas Oxygen Sensor (HEGO) performance: • Check the Temperature Manifold Absolute Pressure (TMAP) sensor, response and accuracy.
Fuel System Checks	• Check for rich or lean symptom, that causes the condition. Drive the vehicle, at the speed of the complaint. Monitoring the oxygen sensors, will help identify the problem. • Check for a sticking mixer air valve. • Perform a cylinder compression test. Refer to Engine Mechanical in the Service Manual. • Check the DSR fuel pressure. Refer to the LPG Fuel System Diagnosis. • Check mixer module assembly, for proper installation and connection.
Ignition System Checks	• Check for the proper ignition output voltage, using the spark tester. • Verify that the spark plugs are correct, for use with LPG. • Check the spark plugs. Remove the plugs and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Blistered insulators – Heavy deposits
Additional Checks	■ **IMPORTANT** • **The LPG Fuel system works on a fumigation principle, of fuel introduction, and is more sensitive to intake manifold leakage, than the gasoline fuel supply system.** • Check for vacuum leaks. Vacuum leaks can cause a higher than normal idle, and low throttle angle control command. • Check the ECM grounds, for being clean, tight, and in their proper locations. • Check the battery cables, and ground straps. They should be clean and secure. Erratic voltage may cause all sensor readings to be skewed, resulting in poor idle quality.
Engine Mechanical Check	• Check the engine for the following: – Broken motor mounts – Improper valve timing – Low compression – Bent pushrods – Worn rocker arms – Broken or weak valve springs – Worn camshaft lobes

	Surges/Chuggles
Checks	**Action**
DEFINITION: The engine has a power variation, under a steady throttle or cruise. The vehicle feels as if it speeds up and slows down, with no change in the accelerator pedal.	
Preliminary Checks	• Refer to Important Preliminary Checks. • Be sure the driver understands the Torque Converter Clutch operation.
Sensor Checks	Check the Heated Exhaust Gas Oxygen Sensor (HEGO) performance.
Fuel System Checks	• Check for Rich or Lean symptom that causes the condition. Drive the vehicle at the speed of the complaint. Monitoring the oxygen sensors will help identify the problem. • Check the fuel pressure, while the condition exists. Refer to LPG Fuel System Diagnosis. • Verify proper fuel control solenoid operation. • Verify that the LPG manual shut-off valve is fully open. • Check the in-line fuel filter for restrictions.
Ignition System Checks	• Check for the proper ignition output voltage, using a spark tester. • Verify that the spark plugs are correct, for use with LPG. • Check the spark plugs. Remove the plugs, and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Check the Crankshaft Position (CKP) sensor.
Additional Check	• Check the ECM grounds, for being clean, tight, and in their proper locations. • Check the generator output voltage. • Check the vacuum hoses, for kinks or leaks. • Check Transmission.

3. SET UP AND PROCEDURE DIAGNOSTIC TOOL

[1] DIAGNOSTIC CONNECTOR POSITION





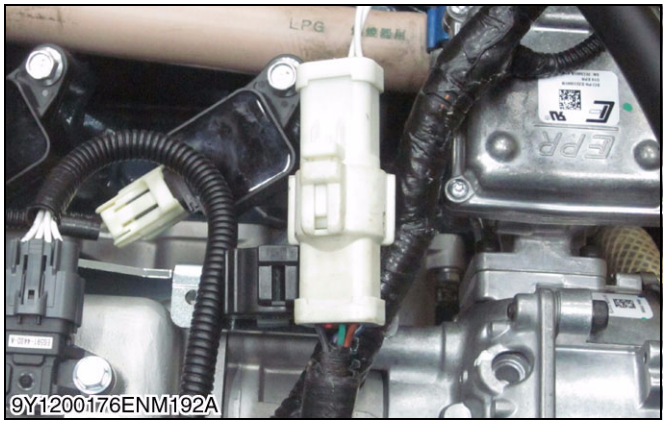
The connector for connecting the diagnostic tool is in the position shown in the figure.

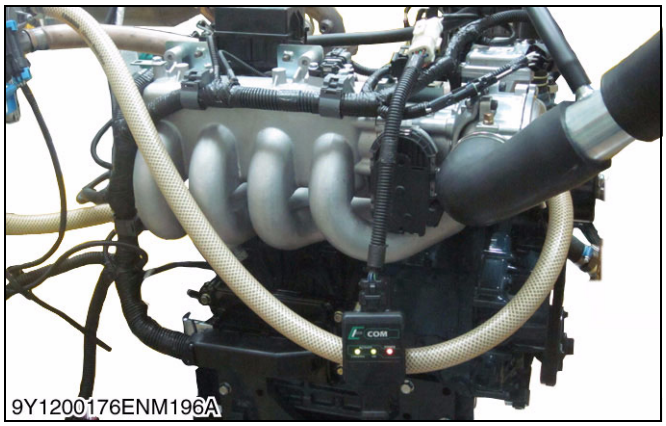
(A) Diagnostic Tool Connector

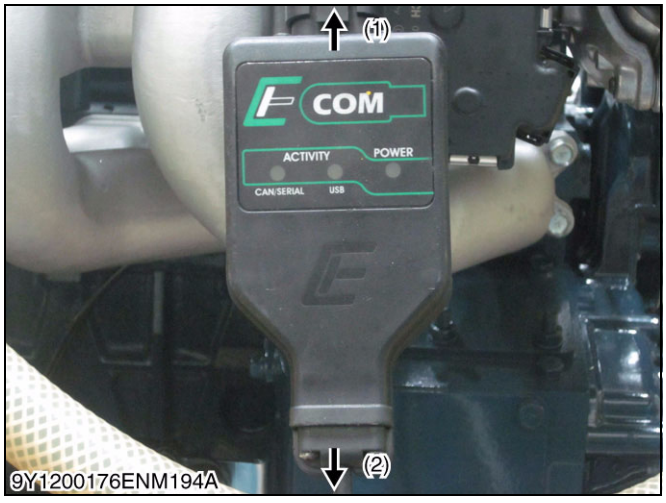
[2] DIAGNOSTIC TOOL CONNECTION PROCEDURE

■ **IMPORTANT**

- **At first time usage, it is necessary to install the software with administrator user account.**
- **Prepare a PC on which the diagnostic software has been installed.**
- **When connecting the diagnosis cable, don't have to switch off the key of the vehicle.**







1. Start up a PC on which diagnosis software has been installed with administrator user account.
2. Connect the vehicle-side connector to the interface (to vehicle) with administrator user account.
3. Connect the cable (USB) to the interface (to PC) and then connect the USB connector to the USB port on PC.
4. Start the diagnostic software.

■ **NOTE**

- **The power of diagnostic tool is supplied by the USB port.**
- **After installed the software, all USB ports can be used to connect the diagnosis cable.**
- **Connecting orders of diagnosis cables are not important.**

(1) Interface (To Vehicle) (2) Interface (To PC)

[3] SET UP AND PROCEDURE

(1) Overview

This manual is intended to be used as an aid for KUBOTA LSI engine customers. Certain portions of this manual are only intended for use by the KUBOTA LSI engine customers to understand the fault detection system. This section of the manual defines the diagnostics and recommended troubleshooting procedures associated with an EControls Global Control Platform (GCP) engine control module (ECM) for use on industrial and heavy-duty gas engines.
Kubota LSI engines use EControls diagnostic software to make the diagnosis of failure.

(2) Using the GCP Diagnostic Display Tool

Fault Code Broadcast

All diagnostic trouble codes are broadcast through EDIS for display on a PC. EDIS can acquire the data from the ECM through a protocol; CAN using the EControls Inc. Proprietary Protocol (ECIPP).

Faults may also be acquired over the CAN1 network through CAN J1939-based scan tools or multi-function display units.

Diagnostic Trouble Codes

The numeric diagnostic trouble codes assigned to the faults in this manual are cross-referenced to SAE's "Recommended Practice for Diagnostic Trouble Code Definitions" (SAE J2012). While these codes are recommended, customers may define their own codes by assigning a new number to the flash code in the diagnostic calibration. This will assign both the DTC as displayed in EDIS as well as the flash code output on the MIL output pin. EDIS may be used to connect to the GCP using either RS232 (serial) or Controller Area Network (CAN) communication protocols.

Serial Network

Fault code information can only be acquired through a PC tool compatible with ECIPP.

CAN

The GCP supports SAE J1939 CAN based diagnostic support. This includes:

- DM1: Active Diagnostic Trouble Codes
- DM2: Previously Active Diagnostic Trouble Codes
- DM3: Diagnostic Data Clear/Reset of Previously Active DTCs
- DM4: Freeze Frame Parameters
- DM5: Diagnostic Readiness (bytes 1, 2, and 3 are supported)
- DM11: Diagnostic Data Clear/Reset For Active DTCs
- DM12: Emissions-Related Active Diagnostic Trouble Codes
- DM19: Calibration Information

All diagnostic trouble codes broadcast over CAN1 will be according to SAE J1939 DM1 and DM2. MY08 MGCP ECUs are compliant with J1939 OBD-M, supporting the Diagnostic Messages above as well as user indicators and CAN data defined in the OBD-M protocol.

Faults available for broadcast and their respective SPN/FMI numbers are dependent on the application and engine calibration. There are 4 CAN SPN/FMI lists available in the GCP software set, contact EControls for a list of CAN SPN/FMIs.

The data capture at the occurrence of a fault, known in the ECM as fault snapshot (FSS), is available upon DM4 request. The following bytes are supported for DM4 if configured in the ECM software:

- Byte 1: Freeze Frame Length
- Byte 2-6: SPN, FMI, SPN Conversion Method, and Occurrence
- Byte 7: Manifold Absolute Pressure
- Byte 8-9: Engine Speed
- Byte 10: Engine Load (MAP based estimate)
- Byte 11: Engine Coolant Temperature
- Byte 14: # of starts since fault was last
- Byte 15: Index into FSS_storage table for Fault Snap Shot retrieval.

Resetting active and previously active DTCs is handled through DM11 and DM3, respectively. DM1 and DM2 lamp indicators are assigned to each fault based on the fault's diagnostic action as defined in the calibration. The lamps are assigned based on the configuration outlined in Table 1.

Table 1: J1939 Diagnostic Lamp Configuration

ECM Diagnostic Action	J1939 Lamp
MIL	MIL
Soft Warning	Amber
Hard Warning, Low Rev Limit, Shutdown	Red Stop
Power Derate 1 & 2	Protect
Forced Idle	None (use in combination with other action)

Diagnostic Calibration Configuration and Corrective Actions

Each fault within the GCP is capable of being uniquely configured in the engine's diagnostic calibration to cause one or more corrective actions while a given fault is active.

Table 2 identifies the configuration options and corrective actions available for configuration of each fault. The desired action is set by KUBOTA.

Table 2: Diagnostic Corrective Actions

Corrective Action	Description
Enable	Enables the fault for fault detection.
Shutdown	Cause an engine shutdown when fault becomes active.
Never Forget	Retain fault as historic/previously active until cleared by a technician and does not allow historic fault to be "auto-cleared".
Turn on MIL	Turn on MIL output when fault becomes active.
CL Disable	Disable closed-loop while the fault is active.
CL Disable Key-Cyc	Disable closed-loop while the fault is active and for the remainder of the key cycle.
AL Disable	Disable adaptive learn while the fault is active.
AL Disable Key-Cyc	Disable adaptive learn while the fault is active and for the remainder of the key cycle.
Power Derate 1	Limit TPS to the Power Derate 1 % set in the diagnostic calibration while the fault is active. The Power Derate 1 TPS % should be set higher than Power Derate 2 as Power Derate 2 adds a higher level of protection.
Power Derate 2	Limit TPS to the Power Derate 2 % set in the diagnostic calibration while the fault is active. If the calibration is set to "Latched for Key-Cycle" Power Derate 2 remains active until engine speed and FPP conditions are satisfied. The Power Derate 2 TPS % should be set lower than Power Derate 1 as Power Derate 2 adds a higher level of protection.
Low Rev Limit	Limit RPM to the Low Rev Limit speed set in the diagnostic calibration while the fault is active. If the calibration is set to "Latched for Key-Cycle" Low Rev Limit remains active until engine speed and FPP conditions are satisfied.
Forced Idle	Limit RPM to the Forced Idle speed set in the diagnostic calibration while the fault is active and for the remainder of the key cycle.
Soft Warning	Turn on the soft warning output when the fault becomes active.
Hard Warning	Turn on the hard warning output when the fault becomes active.
Stopped Check	Run fault detection/checking while the engine is in a key-on, engine-off condition. ■ **NOTE** • **It is recommended that this feature only be used for general sensor faults (high/low voltage) and some output drivers.**

Fault/Diagnostic Trouble Code Interaction

All fault and diagnostic information is managed through the Faults page. Interaction includes viewing fault messages, downloading fault data (fault snapshot and flight data recorder), erasing faults from memory, and defining variables for fault data logging.

Faults are separated into two categories, Active and Historic. Active faults are active in real-time and historic faults have been generated at some instance in time that may or may not be active in real-time. Once a fault has become active, it is immediately logged as historic and a snapshot and flight data log is saved.

Figure 1 shows an example of the fault page when an active fault has been generated. Notice that the fault is present in both the active and historic lists and the malfunction indicator lamp (MIL) has been illuminated.

Figure 2 shows an example of the fault page with a historic fault stored in memory.

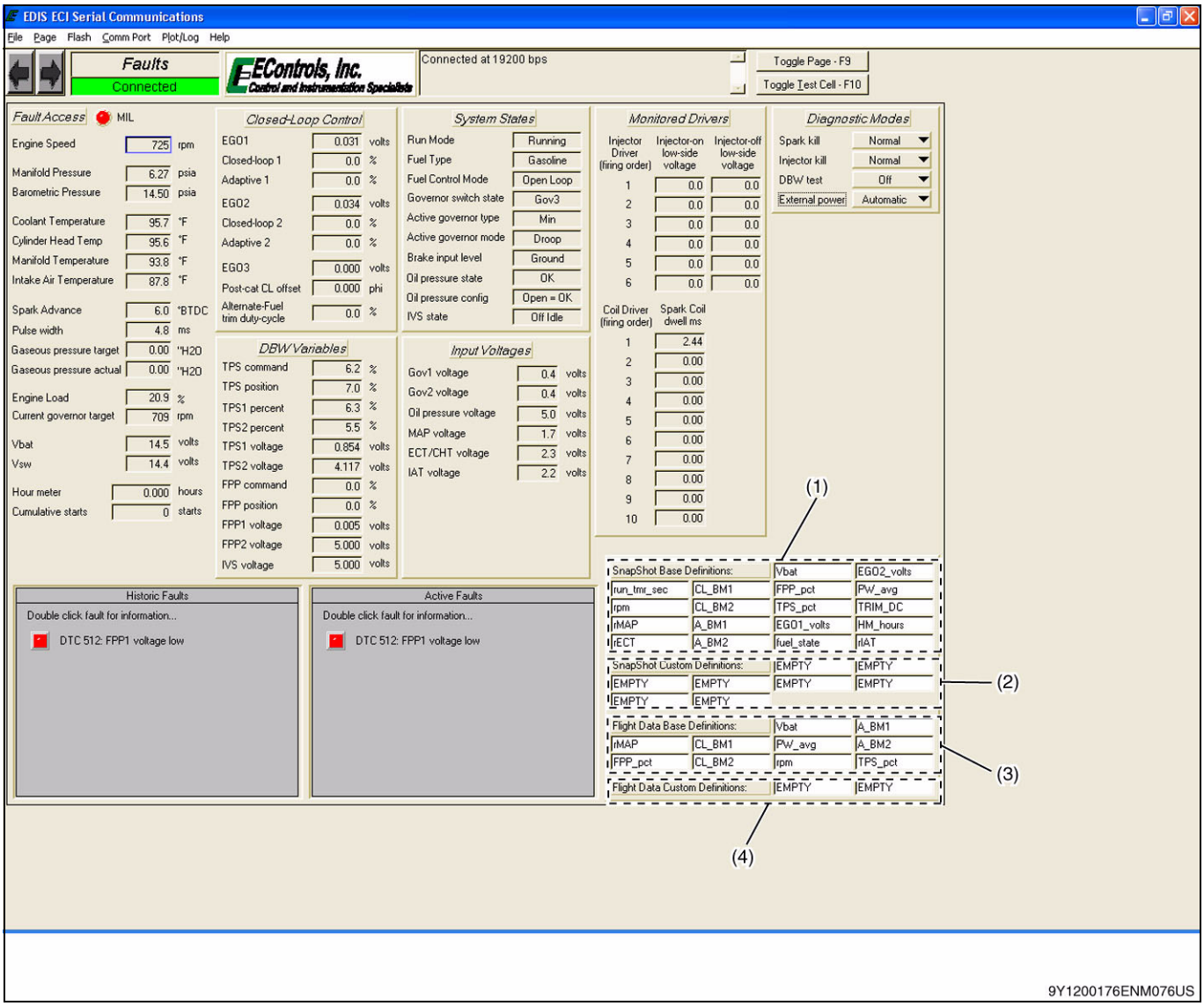


Figure 1: Custom Flight Data Recorder variable definitions (User Defined)

(1) Base Fault snapshot variable definitions (CAN NOT be altered)

(2) Custom Fault Snapshot variable definitions (User Defined)

(3) Base Flight Data Recorder variable definitions (CAN NOT be altered)

(4) Custom Flight Data Recorder variable definitions (User Defined)

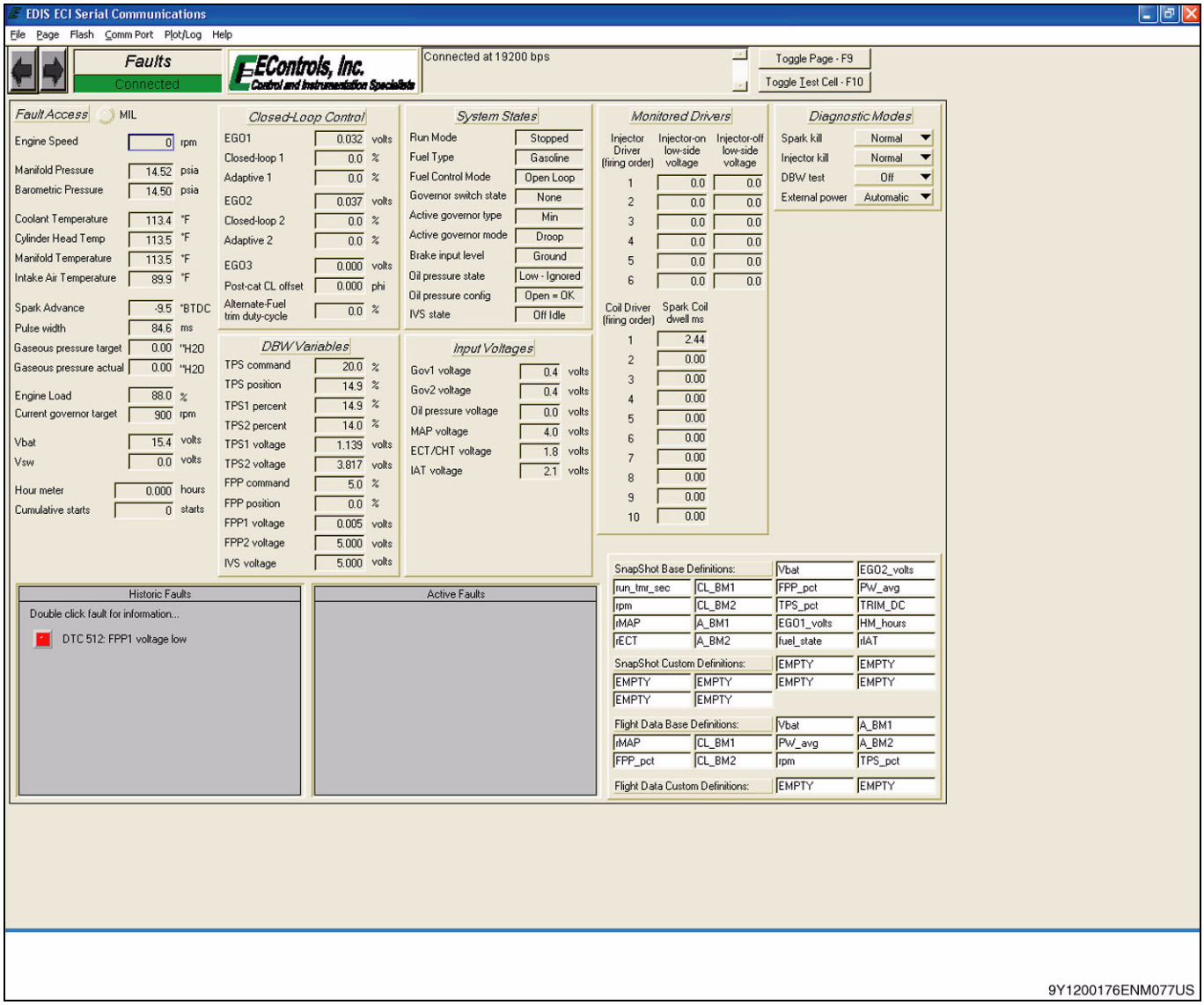


Figure 2: Faults Page with Historic Fault Message

Once an active fault has occurred two sets of data are recorded, fault snapshot and flight data recorder. The fault snapshot (FSS) is a sample of data taken at the instance the fault triggered. Variables included in the FSS are defined in the Snapshot Base and Snapshot Custom Definition fields found on the Faults Page. A FSS is saved with each of the first eight (8) faults for the first time the fault becomes active. Conversely, the flight data recorder (FDR) is a ten-second stream of data that includes eight-seconds prior and two-seconds after triggering the fault. An FDR is saved for each of the first two (2) faults for the first time the fault becomes active. Variables included in the FDR are defined in the Flight Data Base and Flight Data Custom Definition fields found on the Faults Page.

The memory location of the FDR is RAM, therefore this data is only available if the ECM has not lost battery power. In addition, if there is a "Dirty Flash Page" in the ECM, the FDR data will not be available. The memory location of the FSS data is EEPROM and is retained when the ECM loses battery power.

Both sets of data are accessed from the Historic Fault Information interface and can be saved to the PC upon retrieval. Base variables for FSS and FDR are generally defined by the Kubota to include variables most often referenced during fault diagnosis. The base definitions are not fault dependent. Additional variables may be selected for capture during a fault occurrence through a single, left-click of the custom table and selecting the desired variables from a list. An example of custom fault variable definitions is shown in Figure 3.

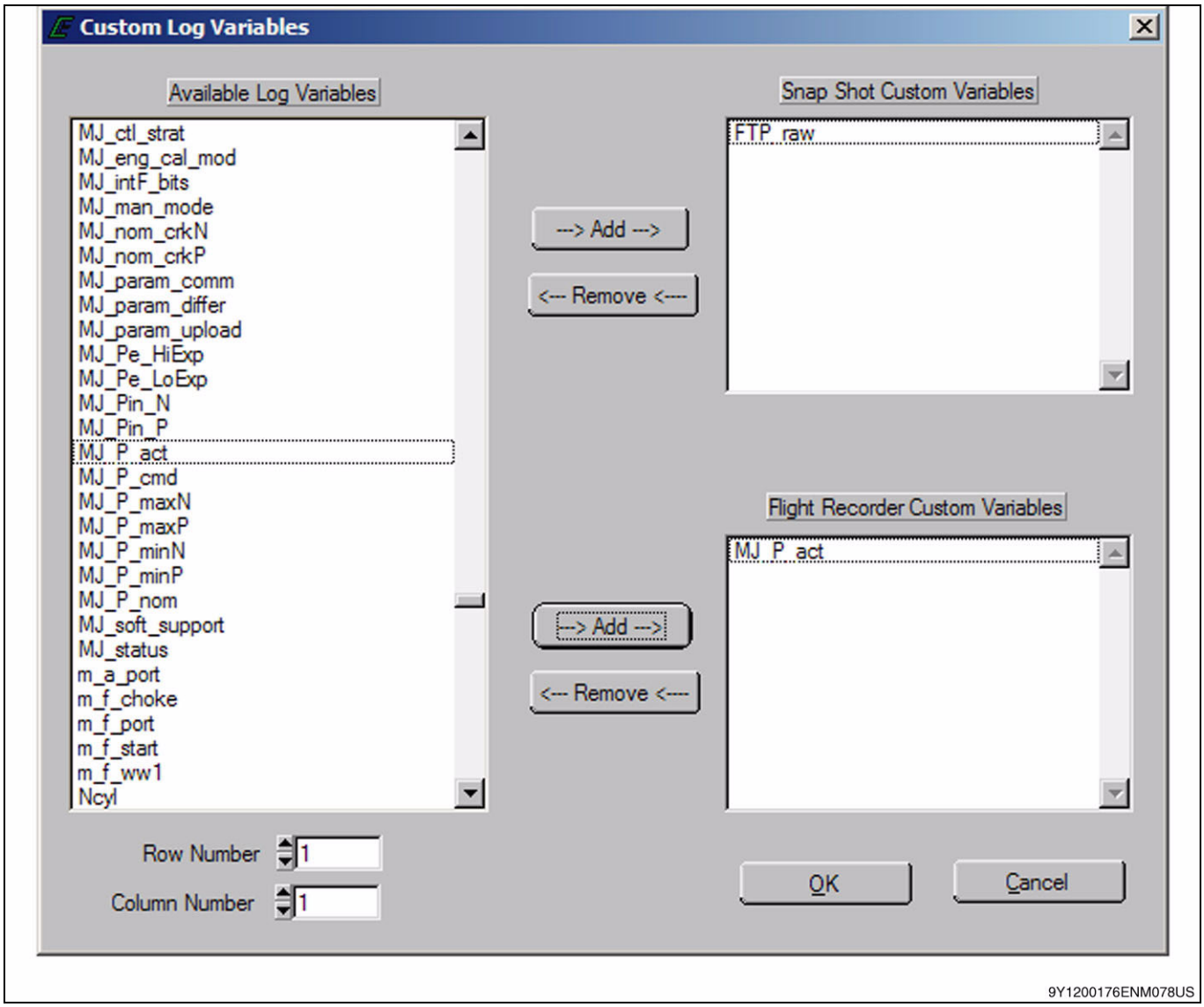


Figure 3: Custom Fault Variable Interface

Accessing fault information is accomplished through a double left-click of the fault LED in the historic fault list. This produces the Historic Fault Information interface shown in Figure 4. From this interface the user can interpret a diagnostic trouble code (DTC) message, identify whether or not the fault occurred during the current key cycle, identify if the fault caused the engine to shutdown, determine how many key cycles have occurred since the fault was last active, clear selected or all historic faults, and view snapshot and flight data.

Table 3 outlines the options displayed in the Historic Fault Information screen. Historic faults are not overwritten if the same fault becomes active, storing data from the original active fault.

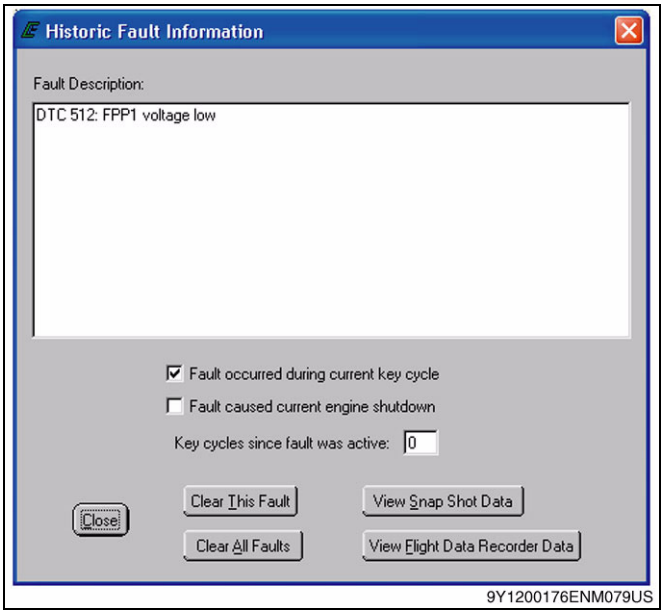


Figure 4: Historic Fault Information Interface

Historic Fault Information Interface Functions

Fault Description Message Box	Customized text that references the DTC flash code and describes the fault.
Fault During Key Cycle Checkbox	Informs that the fault occurred during the current key-on event.
Fault Caused Engine Shutdown Checkbox	Informs that the fault caused the engine to shutdown.
Key Cycles Since Fault Active Indicator	Displays the amount of key-on events since the fault was last active.
Clear This Fault Button*	Erases the selected historic fault from the ECM.
Clear All Faults Button*	Erases all historic faults from the ECM.
View Snap Shot Data Button	Retrieves a data “snap shot” from the ECM for variables defined in the base and custom snapshot variable definition lists. An example of a fault snap shot is shown in Figure 5.
View Flight Data Recorder Data Button	Retrieves a 10-second data strip chart (8 seconds prior, 2 seconds after fault trigger) from the ECM for variables defined in the base and custom flight data recorder definition lists. An example of a fault snap shot is shown in Figure 6.
Close Button	Exits the Historic Fault Information interface. DOES NOT cancel or clear any faults.
* Snapshot and flight data recorder data for historic faults is erased after the prompt shown in Figure 7 is satisfied.	

Figure 5 is an example of a fault snapshot after View Fault Snapshot is selected. Data is presented in two columns, base and custom variables.

Once retrieved, the FSS data may be saved to the PC in text format with an .fss extension. A FSS saved to a PC may be reviewed in any ASCII based software program.

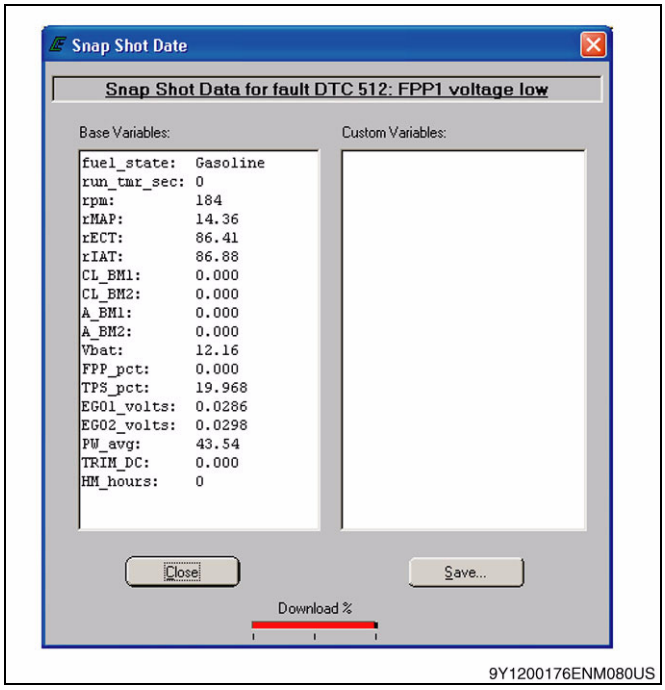


Figure 5: Snapshot Data Interface

Figure 6 shows the Flight Data Recorder interface after View Flight Data Recorder is selected. The FDR captures a ten second (eight seconds prior and two seconds after generating the fault) strip of data for base and custom variables. FDR data is presented in an interface similar to the Plot interface for a quick graphical presentation.

From this interface, the FDR data may be saved to the PC in text, tab-delimited format with an .fdr file extension. Once saved to PC, FDR data may be reviewed using any graphical post-processing software capable of handling tab-delimited formatting.

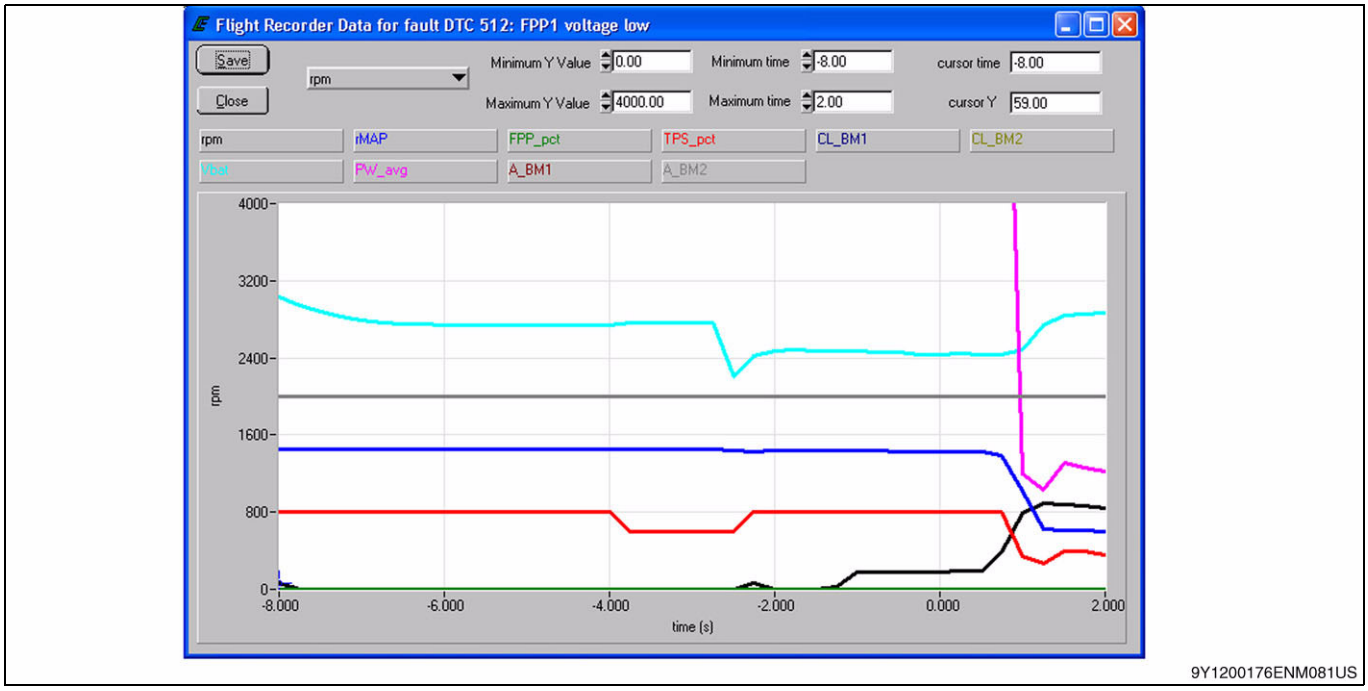


Figure 6: Flight Data Recorder Interface

Fault information may be manually erased using the "Clear" button functions. Once a "Clear" function has been selected, the dialog prompt shown in Figure 7 will be displayed. Choosing YES deletes all fault information from the ECM.

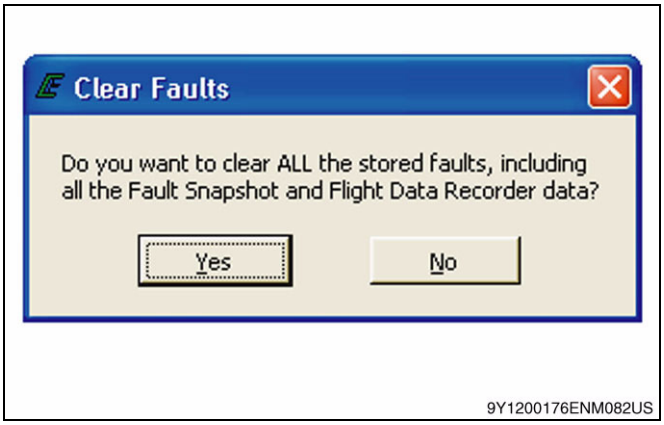


Figure 7: Clear Faults Prompt

[4] DIAGNOSTIC TESTS

The GCP engine control module for spark-ignited engine applications incorporates a set of four (4) diagnostic tests that perform specific functions used as an aid for verifying proper engine control. This section describes the tests supported, test states, and operating criteria for each test.

Diagnostic tests is software which can be initiated via CAN using CCP.

Spark Kill Test

"Coil X" disables individual cylinders at any operating condition for the duration defined in calibration or until released through software. 'Spark Kill' may be used in conjunction with 'Injector Kill' to disable two cylinders at any given time. Upon a state change from one cylinder to another, the test sequence will automatically re-enable the first coil prior to disabling the selected coil. This test reverts to normal operation if "Normal" state is selected, ignition voltage is cycled from high to low, or the calibrated time-out expires.

■ **NOTE**

- **This test should not be initiated prior to the "Injector Kill" test when the engine is attached with a catalyst. If performed while the injector for the selected cylinder is firing, raw-unburned fuel and air will be present in the exhaust and will react in the catalyst resulting in extremely high catalyst substrate temperatures which can cause wash coat or substrate damage and failure.**

States

1) Normal: State of normal operation
2) Coil 1: Disables coil or spark for cylinder 1 in block order
3) Coil 2: Disables coil or spark for cylinder 2 in block order
4) Coil 3: Disables coil or spark for cylinder 3 in block order
5) Coil 4: Disables coil or spark for cylinder 4 in block order

Monitored Status

1) Test not started
2) Test is running
3) Test finished (time-out achieved)
8) Cannot start test

Injector Kill Test

"Inj X" disables individual cylinders at any operating condition for the duration defined in calibration or until released through software. 'Injector Kill' may be used in conjunction with 'Spark Kill' to disable two cylinders at any given time. Upon a state change from one cylinder to another, the test sequence will automatically re-enable the first injector prior to disabling the selected injector. Reverts to normal operation if "Normal" state is selected, ignition voltage is cycled from high to low, or the calibrated time-out expires.

■ **NOTE**

- **This test should not be initiated at high loads or for more than five (5) seconds if the engine is attached with a catalyst. If done so, a large quantity of oxygen will fuel undesirable reactions in the catalyst resulting in extremely high catalyst substrate temperatures which can cause wash coat or substrate damage and failure.**

States

1) Normal: State of normal operation
2) Inj 1: Disables injector 1 in block order
3) Inj 2: Disables injector 2 in block order
4) Inj 3: Disables injector 3 in block order
5) Inj 4: Disables injector 4 in block order

Monitored Status

1) Test not started
2) Test is running
3) Test finished (time-out achieved)
8) Cannot start test

DBW Test

Permits full-authority operation of an electronic throttle via the throttle command input while the engine is in the "Stopped" state only. Reverts to normal operation if "Off" state is selected, ignition voltage is lost, or engine speed is sensed.

■ **NOTE**

- **Ensure that the foot pedal position sensor/electronic throttle control input is at 0 % or idle prior to starting/operating the engine. While this test mode will revert to disabled when engine speed is sensed, the throttle command will follow the FPP % commanded by the sensor causing the engine to accelerate.**

States

1) Off: State of normal operation
2) Enabled: Enables full authority control of an electronic throttle

Monitored Status

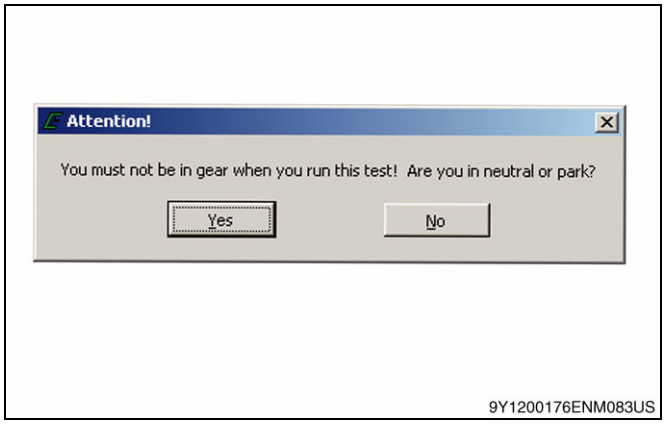
1) Test not started
2) Test is running
3) Test finished
8) Cannot start test (speed is sensed)

Closed-Loop Test

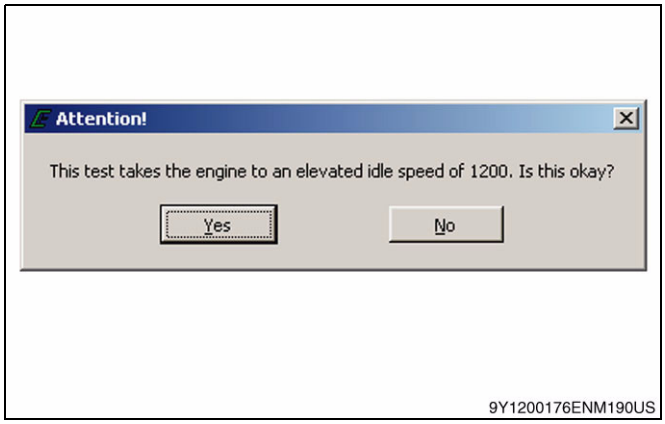
Tests the closed-loop fueling feedback system to verify that exhaust gas oxygen sensors are properly functioning and are providing reliable information. The test runs in the order defined below and aborts if at any time an error/fault is identified, the throttle input is elevated, or the operator requests the test to STOP. Aborting the test due to identification of an error/fault requires that the service technician addresses the identified error and then repeats the test to fully validate the system.

1. Enable Strategy and HEGO Sensors (CL Test State= Pre-cat init test)

a. The test mode is entered by selecting START from EDIS. Once initiated, the user must acknowledge two prompts prior to the test running. These prompts require that the vehicle be in neutral or park and notify the user that the engine speed will increase to run the test. Answering YES to both of these prompts will initiate the test.



9Y1200176ENM083US



9Y1200176ENM190US

a. Govern engine to X RPM as defined in the calibration.

■ **NOTE**

- **Test disables if FPP % exceeds the % used in Idle Speed Command Test (TidIspd_FPP_max)**

b. Turn all configured EGO heaters on according to 'EGOZ Heater-Control Target Impedance / Voltage Limit Schedule'.

■ **NOTE**

- **EGO heater control during this phase uses the run time and heater impedance target schedule, including the heater voltage limits, until the heaters are operating at the final impedance target.**

c. CL pre-cat test status will indicate "Test Running" through steps 2-3.

2. Pre-Catalyst EGO Heater Diagnosis (CL Test State= Pre-cat heater & pre-cat power test)

- The purpose of this portion of the test is:

1. To validate that the pre-catalyst EGO heater element(s) are capable of heating the sense element(s) to a useable state.
2. To validate that the pre-catalyst sense element(s) are operating at the desired temperature.
   a) Monitor EGO impedance feedback and verify impedance ≤ 'EGO impedance active threshold'; this stage runs up to the maximum run time in the 'EGOZ Heater-Control Target Impedance / Voltage Limit Schedule' + 'EGO Heater Additional Wait Time'. If this check fails for any of the pre-catalyst sensors the CL pre-cat test status will indicate "Pre or Post-cat EGO Lazy" and the appropriate EGO Lazy fault for the sensor(s) is set.
   b) In addition, the system monitors EGO impedance feedback and verifies that impedance is equal to the fully warm 'EGOZ Impedance Target' + 'EGO Heater Impedance Max Error'. If any EGO impedance fails to reach the final target plus the impedance error tolerance the heater power is deemed low, the CL pre-cat test status "Pre-cat EGO Power Low" is generated, and the appropriate EGO Lazy fault for the sensor(s) is set. Once all pre-catalyst EGOs have reached the active threshold ('Pre-cat EGO impedance active threshold) the closed-loop system is activated and fueling perturbation begins at the nominal fueling target defined in the test setup parameters.

(To be continued)

(Continued)

3. Pre-Catalyst EGO Sensor Check (CL Test State= Pre-cat voltage test & Pre-cat BM test)

- The purpose of this portion of the test is:

1. To validate that the pre-catalyst EGO sensor feedback is perturbating and providing feedback that correlates to commanded fueling excursions.
2. Attempt to identify leaks within the pre-catalyst sensor assembly and/or the exhaust system and/or identify significant fuel delivery problems.
   a) Once all pre-catalyst EGOs have reached the active threshold ('Pre-cat EGO impedance active threshold') closed-loop is activated and fueling perturbation begins at the nominal fueling target defined in the test setup parameters. During this time, adaptive learn is disabled and the fueling error is monitored (CL_BM). Once the closed-loop system validates a certain number of EGO switches, the total fueling correction (CL_BM+A_BM) is compared to allowable fueling correction limit for the test ('CL+ adapt multiplier max value').
   b) If the fueling correction is within the limits defined in the calibration, the CL pre-cat test status will indicate "Test Finished: Passed".
   c) This portion of the test will fail if the EGO fails to generate the required number of switching cycles or if the fueling correction is outside of the acceptable limits. The CL pre-cat test status will indicate "Pre-cat EGO non-responsive" or "Pre-cat EGO fueling error" status, respectively. In addition, the appropriate "Closed-Loop High/Low" fault will be generated if this check fails.

4. Post-Catalyst EGO Heater Diagnosis (CL Test State= Post-cat heater test & post-cat power test)

- The purpose of this portion of the test is:

1. To validate that the post-catalyst EGO heater element(s) are capable of heating the sense element(s) to a useable state.
2. To validate that the post-catalyst sense element(s) are operating at the desired temperature.
   a) Upon successful completion of the pre-catalyst EGO test checks, the system begins to monitor the post-catalyst sensor(s). The first check is to monitor EGO impedance feedback and verify impedance ≤ 'EGO impedance active threshold'; this stage runs up to the maximum run time in the 'EGOZ Heater-Control Target Impedance / Voltage Limit Schedule' + 'EGO Heater Additional Wait Time'. If this check fails for any of the post-catalyst sensors the CL post-cat test status will indicate "Post-cat EGO Lazy" and the appropriate EGO Lazy fault for the sensor(s) is set.
   b) In addition, the system monitors EGO impedance feedback and verifies that impedance is equal to the fully warm 'EGOZ Impedance Target' + 'EGO Heater Impedance Max Error'. If any EGO impedance fails to reach the final target plus the impedance error tolerance the heater power is deemed low, the CL post-cat test status "Post-cat EGO Power Low" is generated, and the appropriate EGO Lazy fault for the sensor(s) is set. Once all post-catalyst EGOs have reached the active threshold ('Post-cat EGO impedance active threshold) the rich/lean test is run on the post-catalyst sensors.

5. Post-Catalyst EGO Sensor Check (CL Test State= Post-cat rich test & Post-cat lean test)

- The purpose of this portion of the test is:

1. To validate that the post-catalyst EGO sensor feedback is changing as a result of significant changes in pre-catalyst fueling.
   a) Command nominal fueling while applying the fueling multiplier(s) generated during the 'CL pre-cat voltage test' mode (step 3a).
   b) Command a rich open-loop fueling command as defined in the calibration and monitor the post-catalyst EGO voltage feedback to verify that the sensor's rich feedback is within tolerance.
   c) Command a lean open-loop fueling command as defined in the calibration and monitor the post-catalyst EGO voltage feedback to verify that the sensor's lean feedback is within tolerance.
   d) If the post-catalyst EGO voltage feedback is within the limits defined in the calibration, the CL post-cat test status will indicate "Test Finished: Passed" and the CL Test State will indicate "Finished". If post-cat voltage(s) fall outside of the rich/lean limits, CL post-cat test status will indicate "Post-cat EGO Rich Failure" or "Post-cat EGO Lean Failure" and the EGO Lazy fault will be set for the appropriate sensor, respectively.

The engine will return to idle upon completion or abortion of the of the closed-loop diagnostic test.

■ **NOTE**

- **Be sure to check CL Test State, CL pre-cat test status, and CL post-cat test status to determine if the test was successful. If the test failed for ANY reason, faults will be displayed and configured system alarm(s) (soft warning, hard warning, or MIL) will be generated. Technicians should clear faults after running the Closed-Loop Test.**

(To be continued)

(Continued)

States (CL Test State)

1) Inactive
2) Pre-cat init test
3) Pre-cat heater test
4) Pre-cat power test
5) Pre-cat voltage test
6) Pre-cat BM test
7) Post-cat heater test
8) Post-cat power test
9) Post-cat rich test
10) Post-cat lean test
11) Finished
12) Invalid

Pre-Catalyst Monitored Status (CL Pre-Cat Test Status)

1) Test Not Started
2) Test Running
3) Test Finished: Passed
4) Pre-cat EGO Lazy (generates appropriate EGO Lazy fault)
5) Pre-cat EGO Power Low
6) Pre-cat EGO non-responsive
7) Pre-cat EGO fueling error
8) Cannot start test (FPP or TCP % above limit is detected)

Post-Catalyst Monitored Status (CL Post-Cat Test Status)

1) Test Not Started
2) Test Running
3) Test Finished: Passed
4) Post-cat EGO Lazy (generates appropriate EGO Lazy fault)
5) Post-cat EGO Power Low
6) Post-cat EGO Rich Failure
7) Post-cat EGO Lean Failure
8) Cannot start test (FPP or TCP % above limit is detected)

4. BASIC SYSTEM INFORMATION

[1] FUEL SYSTEM

KUBOTA FUEL SYSTEMS

Kubota LSI engines use EControls fuel system. In this section of the manual, Kubota fuel system will be explained further to provide the technician the ability to understand how each system operates and the general layout of each system. A typical installation schematic has been included to identify where in the system the components are located, and how the component communicates to other fuel system components, and the EControls ECM.

FUEL METERING SYSTEMS

In all cases where EControls has supplied the fuel metering system for Kubota, EControls has designed the system for peak engine performance, durability, precise fuel metering and control of the exhaust emission. Each design has been tested and developed in conjunction with Kubota. When servicing an EControls system, you should always follow the prescribed service instructions and procedures, to repair the engine fuel system. When replacing parts within the fuel metering system you should use only Kubota replacement parts. Failure to do so may result in improper performance, an unsafe conditions, and lack of emissions control.

ENGINE CONTROL MODULE

Kubota fuel system will utilize an EControls Engine Control Module (ECM), to control fueling and control emissions output, in the exhaust. In some cases the ECM provides signal output to the vehicle instrument panel. The ECM will utilize signal inputs, from the engine sensors, to control the fuel metering and speed control, while the engine is running. As well, the ECM will provide diagnostic control, over the fuel system.

The diagnostics within the ECM, continually monitor the fuel system performance, by measuring sensor voltage, and if the ECM determines that a sensor value has exceeded the high or low threshold value, the ECM will make changes in the fuel metering system operation, to protect the engine fuel system. These changes were developed during the EControls calibration activities, and during the design of the system. To assist the technician, in determining the fault condition, in the EControls fuel system, Diagnostic Trouble Codes (DTC), are used, to identify the fault conditions. These fault codes can be identified, by using the EControls Global Control Platform laptop diagnostic tool (GCP). To determine fault codes and corrective action to be taken, the technician will use the GCP and the Diagnostic Trouble Code section, of this manual, to determine the root cause of the failure, the effective changes in the EControls fuel system, as well as what repairs must be made, to correct the fault in the fuel system.

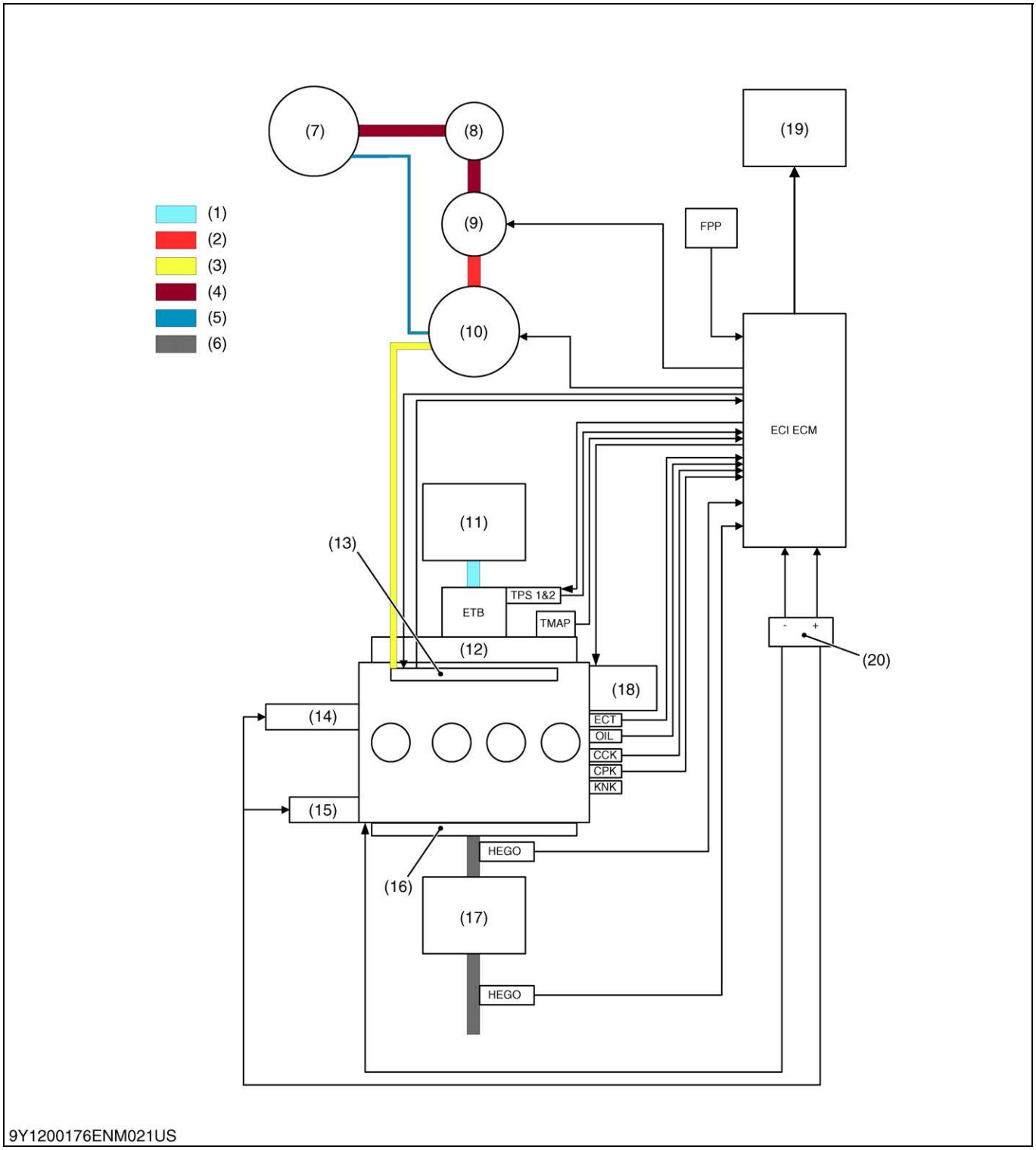


Figure 8: WG1605-G (Gasoline) Schematic

(1) FRESH AIR
(2) LIQUID FUEL HIGH PRESSURE
(3) REGULATED PRESSURE FUEL
(4) SUCTION FUEL
(5) RETURN FUEL
(6) EXHAUST GASES
(7) GASOLINE TANK
(8) FUEL FILTER
(9) ELECTRIC FUEL PUMP
(10) RETURNLESS FUEL PRESSURE REGULATOR
(11) AIR FILTRATION SYSTEM
(12) INTAKE MANIFOLD
(13) GASOLINE FUEL RAIL
(14) ALTERNATOR
(15) STARTER
(16) EXHAUST MANIFOLD
(17) MUFFLER
(18) IGNITION COIL PACK
(19) INSTRUMENT PANEL
(20) BATTERY

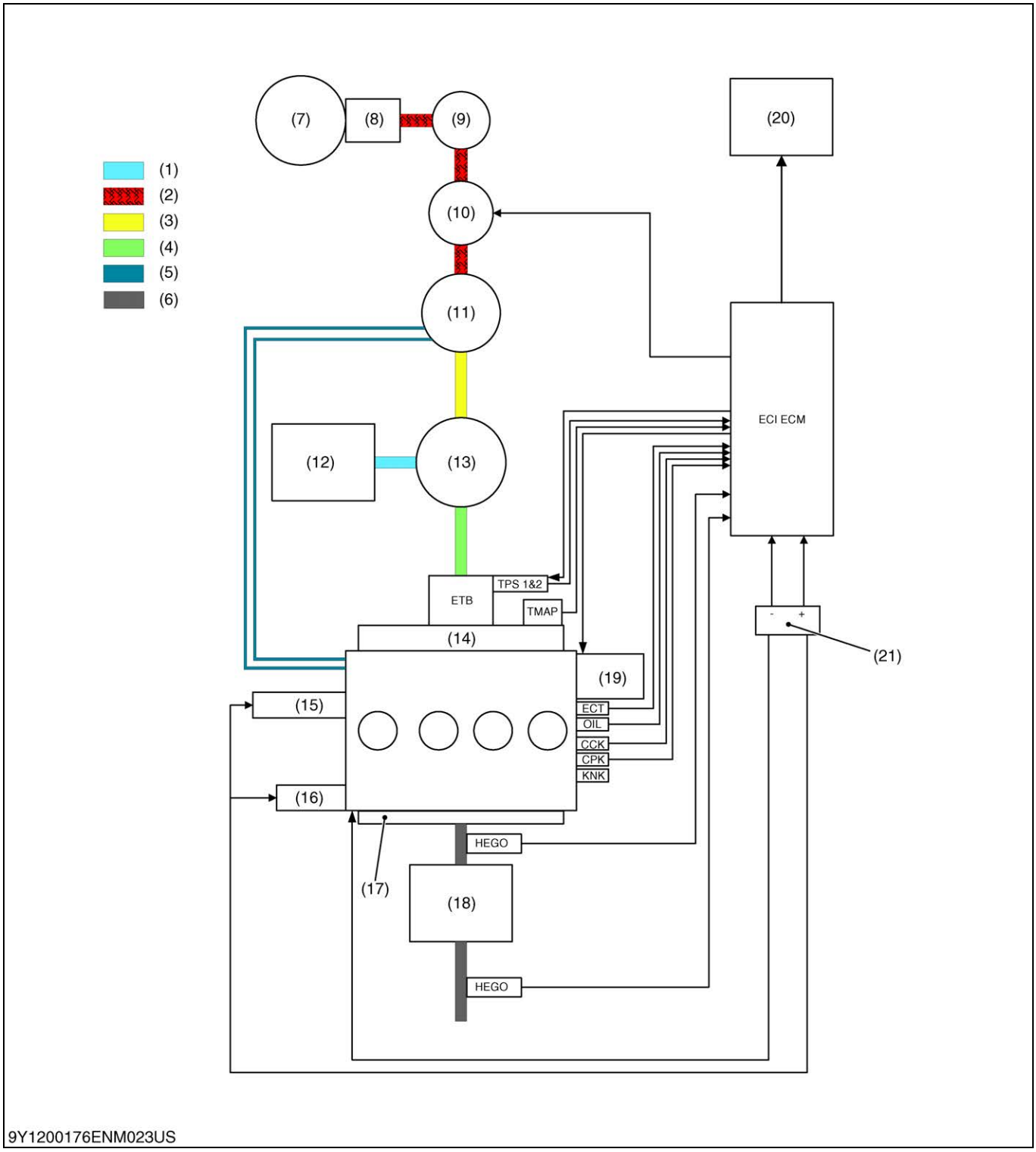


Figure 9: WG1605-L (LPG) Schematic

(1) FRESH AIR
(2) LIQUID FUEL HIGH PRESSURE
(3) LOW PRESSURE FUEL
(4) AIR FUEL MIXTURE
(5) ENGINE COOLANT
(6) EXHAUST GASES
(7) LPG TANK
(8) MANUAL VALVE
(9) FUEL FILTER
(10) ELECTRIC LOCK OFF
(11) DUAL STAGE REGULATOR
(12) AIR FILTRATION SYSTEM
(13) MIXER
(14) INTAKE MANIFOLD
(15) ALTERNATOR
(16) STARTER
(17) EXHAUST MANIFOLD
(18) MUFFLER
(19) IGNITION COIL PACK
(20) INSTURMENT PANEL
(21) BATTERY

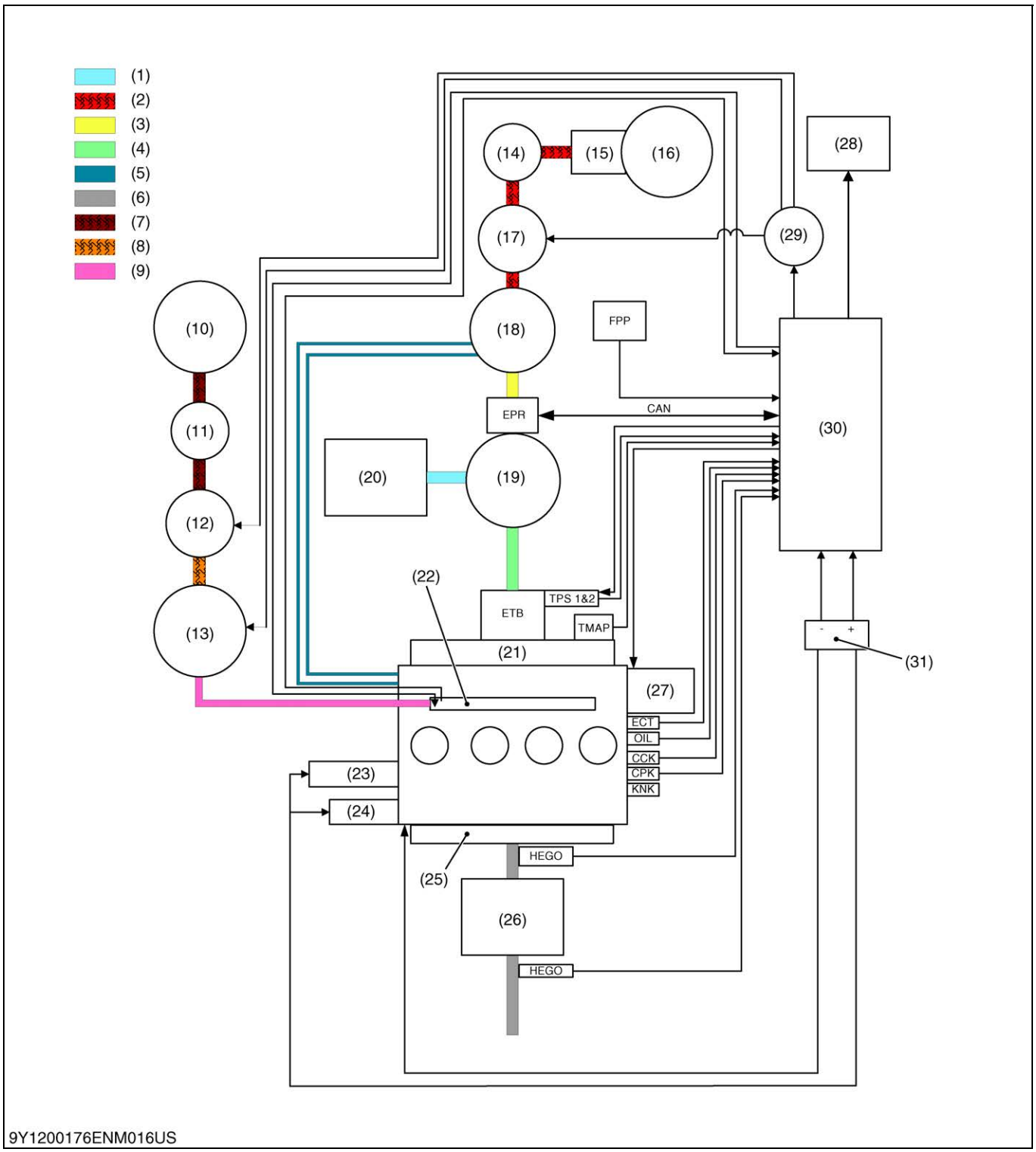


Figure 10: WG1605-GL (Bi-fuel) Schematic

(1) FRESH AIR
(2) LIQUID LPG FUEL HIGH PRESSURE
(3) LPG LOW PRESSURE FUEL
(4) LPG AIR FUEL MIXTURE
(5) ENGINE COOLANT
(6) EXHAUST GASES
(7) GASOLINE SUCTION
(8) GASOLINE PRESSURE
(9) GASOLINE REGULATED
(10) GASOLINE TANK
(11) FUEL FILTER
(12) ELECTRIC FUEL PUMP
(13) RETURNLESS FUEL PRESSURE REGULATOR
(14) FUEL FILTER
(15) MANUAL VALVE
(16) LPG TANK
(17) ELECTRIC LOCK OFF
(18) DUAL STAGE REGULATOR
(19) MIXER
(20) AIR FILTRATION SYSTEM
(21) INTAKE MANIFOLD
(22) GASOLINE FUEL RAIL
(23) ALTERNATOR
(24) STARTER
(25) EXHAUST MANIFOLD
(26) CATALYST
(27) IGNITION COIL PACK
(28) INSTRUMENT PANEL
(29) SELECT SWITCH
(30) ECI ECM
(31) BATTERY

ELECTRIC GASOLINE FUEL PUMP (G, GL)

To supply gasoline to the fuel system, the Kubota bi-fuel system will utilize an external electric gasoline fuel pump. The pump will be mounted in the chassis of the vehicle, or equipment near the fuel tank. Gasoline rated fuel hose and securing devices supplied by Kubota, will be used to transfer the pumped fuel to the Gasoline Fuel Pressure Manifold assembly. Kubota have installed a fuel filtration device ahead of the electric pump, which may be located in the tank or an external filter. Most industrial equipment will be exposed to dusty and dirty environments, therefore use caution when opening the gasoline tank, to prevent dirt and debris from falling in the tank. For filter maintenance, refer to the Recommended Maintenance Chart.

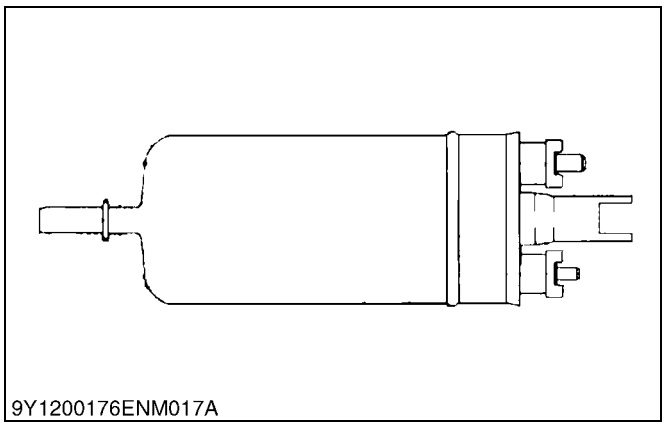


Figure 11: Electric Gasoline Fuel Pump

GASOLINE FUEL PRESSURE MANIFOLD (G, GL)

The Kubota gasoline fuel system, utilizes a Fuel Pressure Manifold assembly, to control the delivery pressure to the gasoline injector rail. The manifold is mounted to the chassis, between the electric fuel pump and the gasoline injector rail. The manifold is attached with a sensor, which provides the ECM with the gasoline fuel temperature, and pressure being regulated to the gasoline injector rail. The ECM uses the fuel temperature and pressure, to calculate the precise amount of gasoline, to be injected to the engine during operation. The manifold is designed into the system, to control pressure, as well as the amount of gasoline, to be returned to the fuel tank. In normal gasoline delivery systems, the electric fuel pump, delivers a constant pressure to the injector rails, and allows a significant amount of fuel to be recycled to the tank, thus causing the gas to heat and vaporize, and requiring the use of a vapor recovery system to control the excess vapor. The Kubota system manages the fuel pressure at the manifold and minimizes the amount of returned fuel, thus reducing the vapor fuel in the tank.

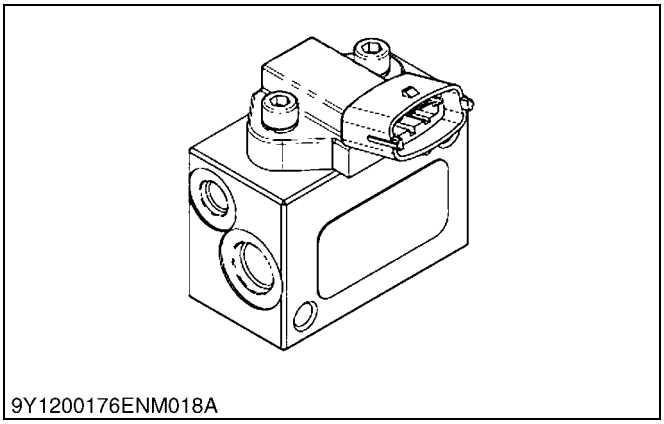


Figure 12: Gasoline Fuel Pressure Manifold

GASOLINE INJECTORS AND INJECTOR RAIL (G, GL)

Kubota gasoline fuel delivery system, utilizes a fuel rail, mounted with injectors, for each cylinder. The fuel rail and injectors, are attached by Kubota. During the design and calibration phase, the ECM gasoline fuel delivery calibrations are developed. The EControls ECM will utilize these calibrations, to pulse width modulate each injector, to deliver the correct amount of gasoline, for optimized performance, and reduced tail pipe emissions. The injector pulsing or "firing", is accomplished by supplying a 12.0 V supply to the positive side of the injector coil, and switching the ground circuit side, using the injector drivers, internal to the ECM.

Because Kubota gasoline fuel system, utilizes the Fuel Pressure Manifold, to control fuel delivery to the rail, Kubota fuel system does not use a separate return line, from the fuel rail assembly. Gasoline injectors are an emissions control device, and do not require periodic adjustment. When serving or placing injectors, use only Kubota replacement injectors, to insure the fuel system operates as designed.

WARNING

NEVER CUT OR WELD ON EITHER THE LPG OR GASOLINE FUEL TANK. REPAIRS TO THE FUEL TANK SHOULD ONLY BE MADE BY A CERTIFIED TANK REPAIR FACILITY.
FAILURE TO OBSERVE THIS WARNING COULD RESULT IN SERIOUS BODILY INJURY AND OR DEATH AND COULD RESULT IN SERIOUS PROPERTY DAMEGE.

WARNING

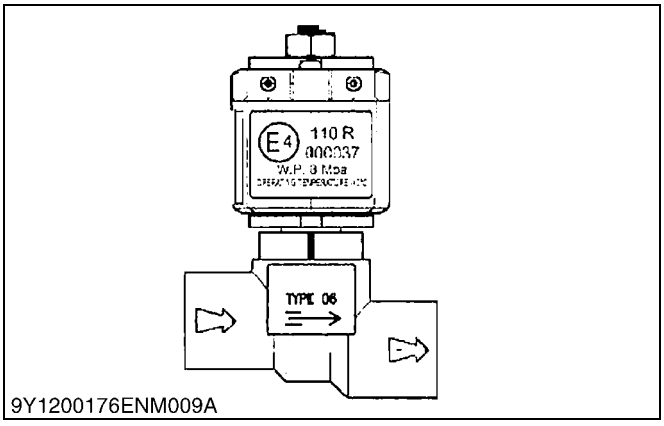
ALWAYS WEAR PROTECTIVE EYEWESR AND GLOVES WHEN PERFORMING MAINTENANCE ON THE LPG OR GASOLINE FUEL SYSTEMS, TO PREVENT SERIOUS INJURY. ALWAYS PERFORM MAINTENACE PROCEDURES IN A WELL VENTILATED AREA AND INSURE THAT THERE ARE NO EXTERNAL SOURSES OF IGNITION.

SERVICE LINE (L, GL)

Propane flows from the fuel tank to the electric lock, via the service line. The service line is most commonly connected to the tank, utilizing a quick coupler. The other end of the service line is connected to a "bulkhead connector" which is used to allow the service line, to pass through the metal enclosure, vehicle body panels, or hoods. This hose is made of special material, which protects the inner core of the hose, from chemicals contained within the LPG, which could result in a failure of the hose. The hose should never be kinked or allowed to come into contact with the chassis, or other engine components, and electrical connection or wiring. When replacing the fuel line, use care as there may be fuel retained in the line between the tank manual valve connection, and the electric lock off device.

LPG FUEL LOCK OFF (L, GL)

The LPG Fuel Lock Off device is an integrated assembly. The electric lock assembly is a 12.0 V, normally closed valve. The solenoid is mounted to the valve body. When energized the solenoid opens the pilot valve, within the lock off, which uses the tank pressure, to assist in opening the valve. By using the pilot valve, to help open the valve, the service life of the valve, is extended, and requires less electrical energy, to open the valve. The valve opens, during cranking, and remains open, during the run cycles of the engine. The lock off supply voltage is controlled by the Engine Control Module (ECM), or may be energized by a relay, which supplies battery voltage, when energized.



9Y1200176ENM009A

Figure 13: Typical In-line LPG Fuel Lock Off device

DUAL STAGE REGULATOR (DSR) (L, GL)

The DSR is a combination vaporizer, pressure regulating device. The DSR is a two stage regulator that is normally closed, when the engine is not running. When the engine is cranking or running, a partial vacuum is created in the fuel line, which connects the regulator to the Direct Electronic Pressure Regulators (DEPR), and mixer. This partial vacuum opens the second stage regulator, permitting fuel to flow to the DEPR, and mixer.

Propane fuel enters the primary port of the DSR, and passes through the primary jet, and into the primary/exchanger chamber. As the propane passes through the heat exchanger, the fuel expands, and creates pressure inside the chamber. The pressure rises as the fuel expands, when the pressure rises above 10 kPa (0.11 kgf/cm^2, 1.5 psi); sufficient pressure is exerted on the primary diaphragm, to cause the diaphragm plate to pivot, and press against the primary valve pin, thus closing off the flow of fuel. This action causes the flow of fuel, into the regulator to be regulated. When the engine is cranking, sufficient vacuum will be introduce into the secondary chamber, from the EPR/mixer, drawing the secondary diaphragm down onto the spring loaded lever, and opening the secondary valve, allowing vaporized fuel, to pass to the mixer. Increased vacuum, in the secondary chamber, increases the downward action on the secondary lever, causing it to open wider, allowing more fuel to flow to the mixer.

The DSR requires a connection to the engine coolant, to prevent freezing in the regulator, during the pressure reduction phase, within the regulator. Coolant connections on the DSR are fitted with "Push In" fittings. These fitting are designed with an o-ring seal, which allows the fitting to be pushed into the water connection on the DSR, and are then lock by spring locks, and retained by screws.

The DSR is connected to the DEPR, by a low pressure flexible hose. Like the other fuel hoses used in the fuel system, the low pressure hose is designed with a special inner core, and is usually wire reinforced, to prevent collapse of the hose, during high demand fueling operations. The low pressure hose should only be replaced, with the recommended Kubota hose replacement.

The packaging of the regulator, into the engine and chassis, must be approved by Kubota, to insure continued long term operation, of the fuel delivery and emission control system. You should never relocate the regulator, or any of the fuel system components, as doing so, may cause excess build up of oil in the regulator, improper coolant flow, or improper fuel delivery.

In certain regions, fuel supplies may be made up of much different chemicals and during the heating of the fuel, in the heat exchange section of the regulator, "heavy end" or petroleum oils, may accumulate over time. To drain the DSR, remove the fuel outlet hose and pour the oils out of the regulator. To determine the frequency, for draining the regulators, refer to the Recommended Maintenance Schedule.

The regulator utilized on USA emission certified engines, are a critical part of the certified emissions system, and does not require any periodic adjustment.

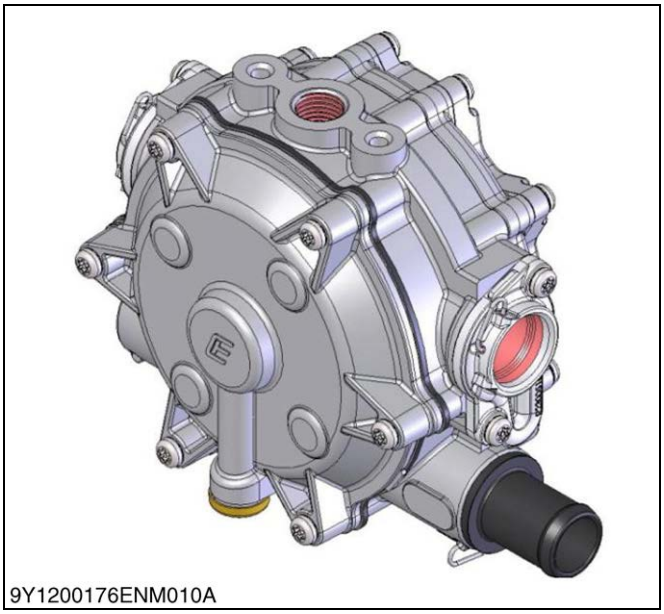


Figure 14: Dual Stage Regulator (DSR)

DIRECT ELECTRONIC PRESSURE REGULATOR (DEPR) (L, GL)

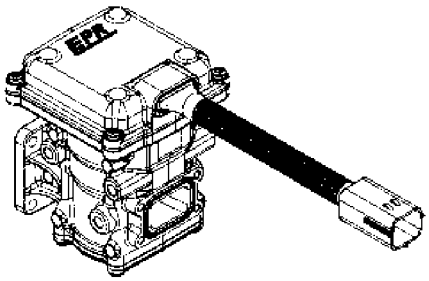
The Direct Electronic Pressure Regulator (DEPR) is the primary fuel control device, used to maintain both performance and emissions control. The DEPR contains an internal computer, which communicates to the EControls Engine Control Module (ECM), via a Communications Area Network (CAN), high speed connection.

The DEPR precisely controls the fuel flow required to insure Stoichiometric (correct air/fuel mixture for complete burn) fuel delivery to the engine combustion chambers. The DEPR also contains internally mounted fuel pressure and temperature sensors, which provide input across the CAN link, to the ECM, for fuel calculation. The ECM will process this information and command changes back across the CAN link, to the DEPR, to adjust fueling.

The DEPR internal computer also maintains certain levels of diagnostics within the system, to ensure emissions control is always maintained. If the DEPR detects a fault within the regulator or fuel delivery system, the DEPR will send that fault information across the CAN link to the ECM. The ECM will then activate the Malfunction Indicator Light (MIL), in the operator control panel. Depending on the type of fault, and its effect on fuel control, or engine performance, the ECM may command the DEPR to change fueling, limit fuel delivery, or in some cases shut down the engine.

The DEPR is connected directly to the mixer on all certified engines. A special designed inlet fitting, is mounted to the DEPR, which allows for the connection, to the DSR. The outlet connection is bolted directly to the mixer.

The DEPR utilized on USA emission certified engines is a critical part of the certified emissions system, and do not require any periodic adjustment.



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Figure 15: Direct Electronic Pressure Regulator (DEPR)

MIXER ASSEMBLY (L, GL)

The air valve mixer is an air-fuel metering device, and is completely self-contained. The mixer is an air valve design, utilizing a relatively constant pressure drop, to draw fuel into the mixer from cranking, to full load. The mixer is mounted in the air stream, ahead of the throttle control device.

When the engine begins to crank, it draws in air, with the air valve covering the inlet, negative pressure begins to build. This negative pressure signal is communicated to the top of the air valve chamber, through 4 vacuum ports, in the air valve assembly. A pressure/force imbalance begins to build, across the air valve diaphragm, between the air valve vacuum chamber, and the atmospheric pressure, below the diaphragm. The air valve vacuum spring is calibrated, to generate from 101.6 mm (4.0 inches) of water column at start, to as high as 355.60 mm (14.0 inches) of water column, at full throttle. The vacuum being created is referred to as Air Valve Vacuum (AVV). As the air valve vacuum reaches 101.6 mm (4.0 inches) of water column, the air valve begins to lift against the air valve spring. The amount of AVV generated is a direct result of the throttle position. At low engine speed, the air valve vacuum is low and the air valve position is low, thus creating a small venturi, for the fuel to flow. As the engine speed increases, the AVV increases, and the air valve is lifted higher, thus creating a much larger venturi. This air valve vacuum is communicated from the mixer venture, to the DSR secondary chamber, via DEPR and the low pressure fuel supply hose. As the AVV increases in the secondary chamber, the secondary diaphragm is drawn further down, forcing the secondary valve lever to open wider.

The DEPR maintains the precise fuel control to the mixer, despite the air valve position, and AVV being sent to the DSR secondary chamber. The mixer acts as the secondary fuel metering device, and delivery device, in the EControls emission control systems. The mixer is attached to the Electronic Throttle Body (ETB), via an adapter. The adapter is fitted with specific spacers and o-rings, to insure a seal tight fit, with the ETB.

The Mixer is designed such that the air valve diaphragm assembly can be replaced, should the diaphragm be damaged, during operation, from fuel contaminants. Refer to Mixer Diaphragm Replacement section in this manual. The Mixer utilized on USA emission certified engines are a critical part of the certified emissions system, and do not require any periodic adjustment. The mixer does not have any external nor internal adjustments.

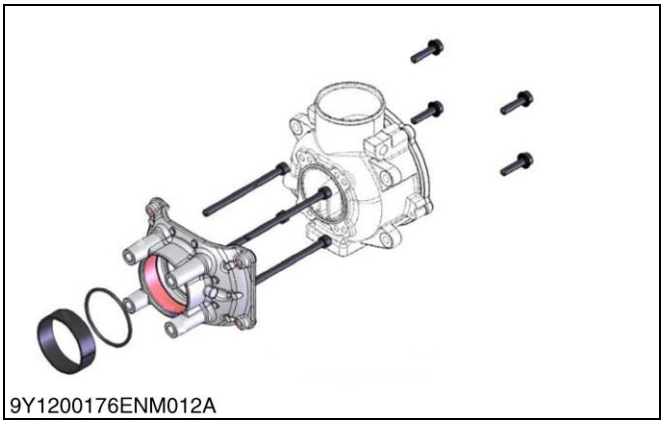

9Y1200176ENM012A

Figure 16: Mixer and ETB Adapter

ELECTRONIC THROTTLE BODY (ETB) (ALL)

The Kubota fuel systems utilize Drive By Wire (DBW), to control engine speed, in this type of application. There is no direct connection between the operator pedal, and the throttle shaft. Speed and load control are determined by the ECM. Defaults programmed into the ECM software, and throttle position sensors, allow the ECM, to maintain safe operating control, over the engine.

In a drive by wire application, the Electronic Throttle Body (ETB) device, or "throttle body assembly", is connected to the intake manifold of the engine. The electronic throttle control device, utilizes an electric motor, connected to the throttle shaft. In addition, a Foot Pedal Position sensor (FPP) is located in the operator's compartment. When the engine is running, electrical signals are sent from the foot pedal position sensor, to the engine ECM, when the operator depresses or release the foot pedal. The ECM then sends an electrical signal to the motor, on the electronic throttle control, to increase or decrease the angle of the throttle blade, thus increasing or decreasing the air flow to the engine.

The electronic throttle control device also incorporates two internal Throttle Position Sensors (TPS), which provide output signals to the ECM, as to the location of the throttle shaft and blade. The TPS information is used by the ECM, to correct for speed and load control, as well as emission control, and engine protection.

The ETB utilized on USA emission certified engines do not require any periodic adjustment.

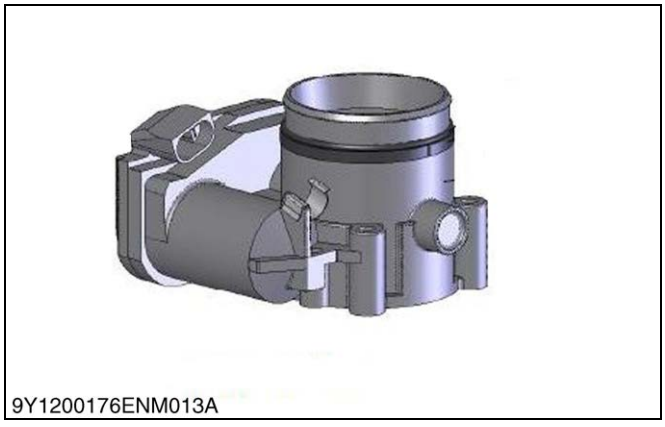


Figure 17: Electronic Throttle Body ETB

THREE WAY CATALYST (ALL)

The emission certified engine has been designed and calibrated, to meet the emission standards in effect for 2010. To help meet the emission requirements, the vehicle has been attached with a Three Way Catalyst (TWC). Kubota has designed and supplied the catalyst in a separate unit. The catalyst function is the final treatment, of the exhaust gases, which are created from the combustion process. The three-way catalyst consists of a honeycomb, coated with a mixture of platinum, palladium, and rhodium. As the hot gases flow through the catalyst section, an oxidation and reduction reactions takes place. This chemical reaction reduces the amount of CO, HC and NOx, in the engines exhaust. The Exhaust gas then flows through the outlet.

HEATED EXHAUST GAS OXYGEN SENSOR (HEGO) (ALL)

The Heated Exhaust Gas Oxygen Sensor (HEGO) is mounted in the exhaust system, downstream of the engine, but before the catalyst, referred to as the "Pre Catalyst" sensor. The ECM continuously monitors the HEGO sensor output if a rich or lean condition is present for an extended period of time, and if the ECM cannot correct the condition, the ECM will set a diagnostic code, and turn on the MIL light in the dash.

The HEGO is used to measure the amount of oxygen, present in the exhaust stream, and communicate that to the ECM, via an electrical signal. The amount of oxygen, present in the exhaust stream, indicates whether the fuel air ratio is too rich or too lean. If the HEGO sensor signal indicates that the exhaust stream is too rich, the ECM will decrease or lean the fuel mixture, during engine operation. If the mixture is too lean, the ECM will richen the mixture.

When the air/fuel mixture is rich, and there is little oxygen in the exhaust, the difference in oxygen levels, across the sensing element, generates a voltage through the sensor's electrodes: typically 0.800 to 0.900 V. When the air/fuel mixture is lean and there is more oxygen in the exhaust, the sensor's voltage drops to 0.100 to 0.300 V. When the air/fuel mixture is perfectly balanced and combustion is cleanest, the sensor's output voltage is around 0.450 V.

The oxygen sensor's voltage signal is monitored by the EControls ECM, to regulate the fuel mixture. When the ECM sees a rich signal (high voltage), from the O_2 sensor, it commands the fuel mixture to go lean. When the computer receives a lean signal (low voltage) from the O_2 sensor, it commands the fuel mixture to go rich. The continued cycling, back and forth from rich to lean, averages out the overall air/fuel mixture, to minimize emissions, and to help the catalytic converter operate at peak efficiency, which is often referred to as the "duty cycle".

The speed with which the oxygen sensor reacts to oxygen changes in the exhaust is very important for accurate fuel control, peak fuel economy, and low emissions. Aging of the sensor due to exposure to contaminants in the fuel, will occur over time, and may cause the sensor to slow down.

On all USA Emission certified engines, the exhaust system is attached with a second HEGO, located after the catalyst, referred to as the "Post Catalyst" sensor. The function of the second HEGO is to monitor the efficiency of the catalyst and fuel control. The operation of the HEGO is the same as the Pre Catalyst sensor; it provides an output voltage to the ECM, to determine the level of oxygen, in the exhaust stream after the catalyst. This type of monitoring is referred to as the On Board Diagnostic, in which additional sensors are installed in the system, to monitor the fuel control systems.

The ECM continuously monitors the HEGO sensors output, if a rich or lean condition is present for an extended period of time and the ECM cannot correct the condition, the ECM will set a diagnostic code and turn on the MIL light in the dash.

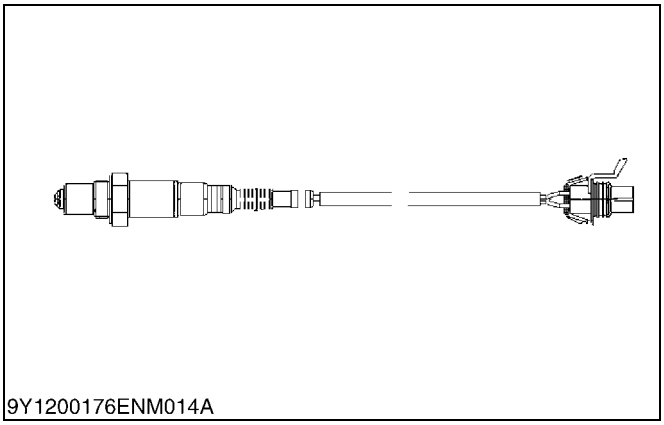


Figure 18: Heated Exhaust Gas Oxygen Sensor (HEGO)

CAUTION

The Heated Exhaust Gas Oxygen Sensor is an emissions control component. If the HEGO fails to operate, replace only with Kubota replacement part. The HEGO sensor is sensitive to silicone based products and can become contaminated. Avoid using silicone sealers or hoses, treated with silicone lubricant, in the air stream or fuel supply lines.

FUEL SYSTEM SELECT SWITCH (GL)

As explained earlier, there are two complete fuel systems, included in Kubota bi-fuel system. To adequately protect the engine from damage caused by introducing two fuels simultaneously, the Kubota has designed a Fuel System Select switch which signals the ECM to change fuels. The switch is typically either a two position, or three positioned switch. When using a three position switch in the center position neither the gasoline fuel pump nor the electric lock off, can be energized. Rotating the switch in one direction or the other will activate the fuel system, the operator has chosen.

ENGINE CONTROL MODULE (ECM)

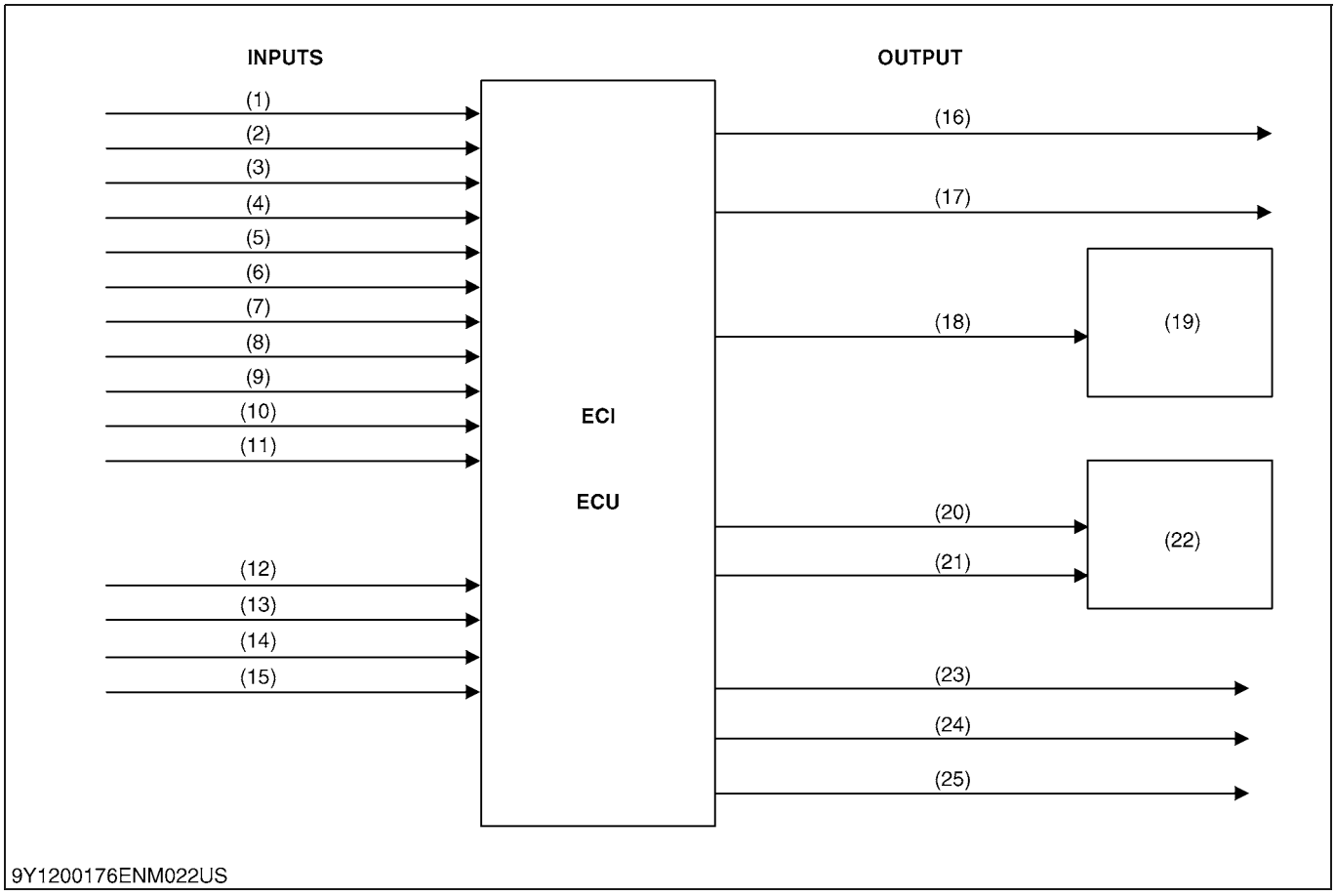


Figure 19: WG1605-G (Gasoline) ECM Input and Outputs

(1) BATTERY PLUS
(2) BATTERY MINUS
(3) ENGINE RPM
(4) ENGINE COOLANT
(5) ENGINE OIL
(6) CRANK SHAFT SENSOR
(7) INTAKE AIR TEMP
(8) MANIFOLD PRESSURE
(9) THROTTLE POSITION 1
(10) THROTTLE POSITION 2
(11) FOOT PEDAL POSITION
(12) KNOCK SENSOR
(13) PRE CAT HEGO
(14) POST CAT HEGO
(15) GASOLINE RETURNLESS RAIL
(16) SPARK CONTROL TO IGNITION COILS
(17) THROTTLE SPEED CONTROL
(18) DATA LINK CONNECTION
(19) DIAGNOSTIC TOOL
(20) MIL LIGHT
(21) GAGE OUTPUT
(22) INSTURMENT PANEL
(23) GASOLINE FUELPUMP CONTROL
(24) GASOLINE RETURNLESS RAIL
(25) GASOLINE INJECTORS

ENGINE CONTROL MODULE (ECM)

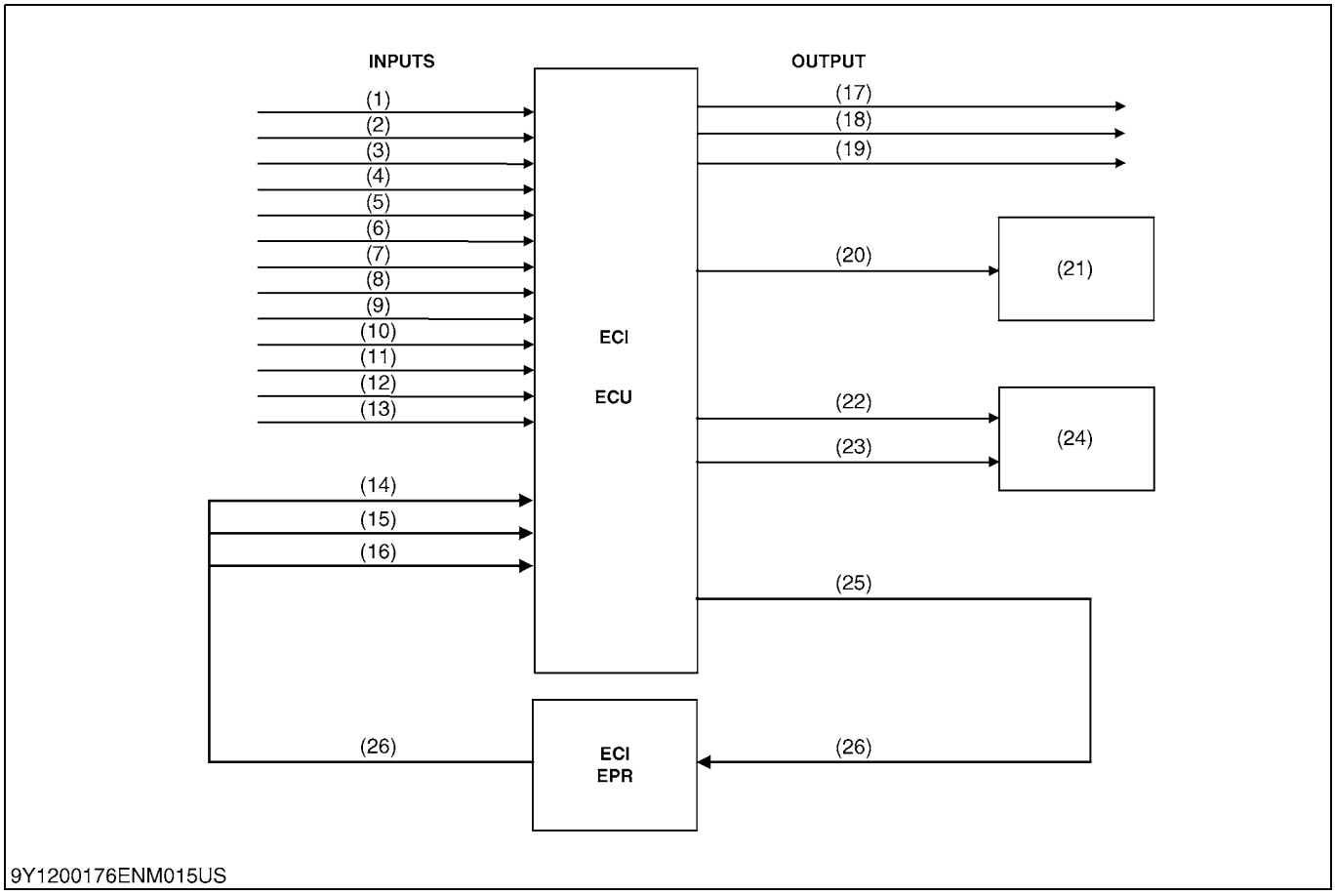


Figure 20: WG1605-L (LPG) ECM Input and Outputs

(1) BATTERY PLUS
(2) BATTERY MINUS
(3) ENGINE RPM
(4) ENGINE COOLANT
(5) ENGINE OIL
(6) CRANK SHAFT SENSOR
(7) INTAKE AIR TEMP
(8) MANIFOLD PRESSURE
(9) THROTTLE POSITION 1
(10) THROTTLE POSITION 2
(11) FOOT PEDAL POSITION
(12) PRE CAT HEGO
(13) POST CAT HEGO
(14) FUEL PRESSURE
(15) FUEL TEMP
(16) FUEL CONTROL LOCATION
(17) SPARK CONTROL TO IGNITION COILS
(18) LPG LOCK OFF CONTROL
(19) THROTTLE SPEED CONTROL
(20) DATA LINK CONNECTION
(21) DIAGNOSTIC TOOL
(22) MIL LIGHT
(23) GAGE OUTPUT
(24) INSTURMENT PANEL
(25) FUEL METERING CORRECTION
(26) HIGH SPEED CAN LINK

ENGINE CONTROL MODULE (ECM)

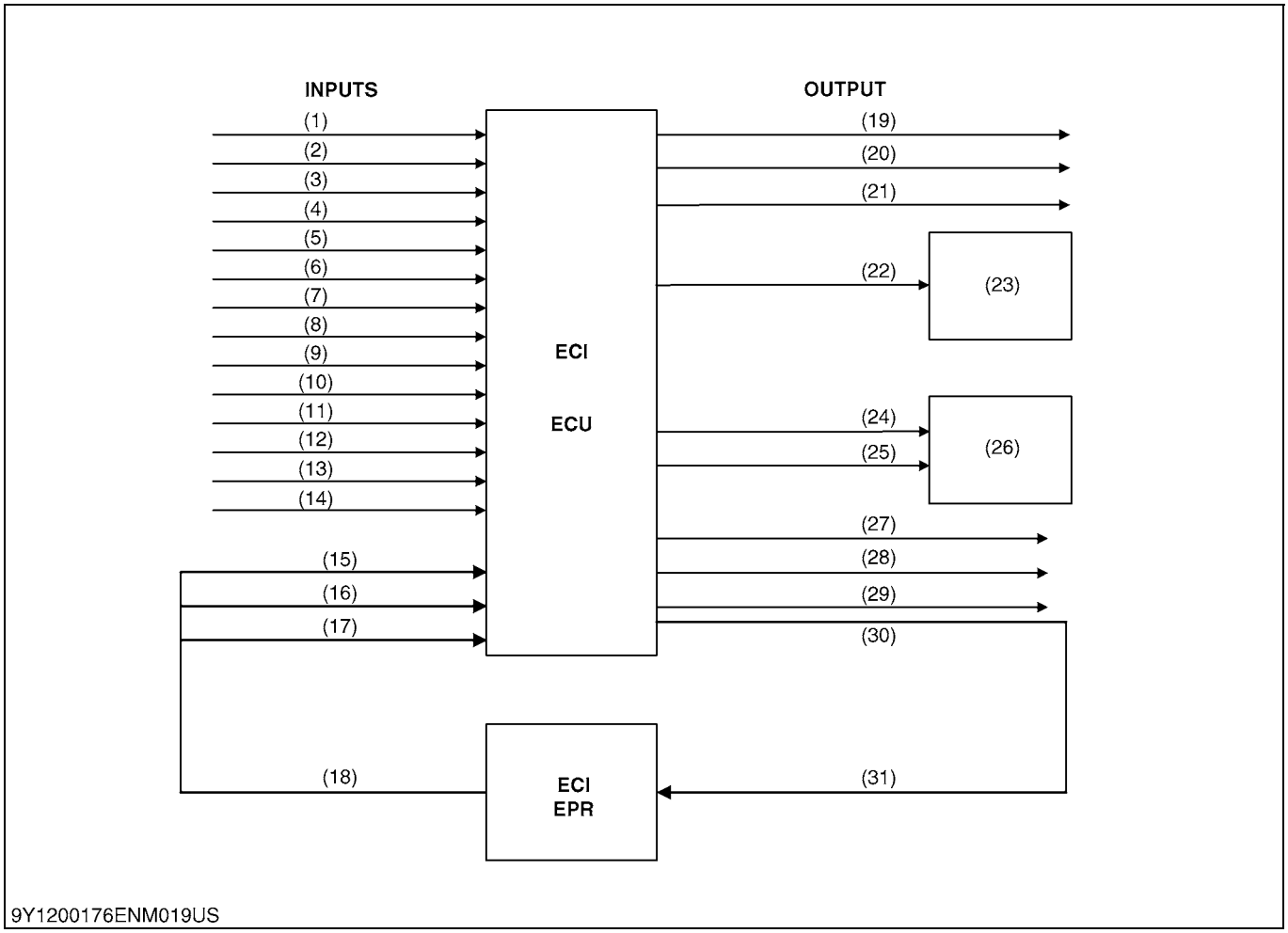


Figure 21: WG1605-GL (Bi-Fuel) ECM Input and Outputs

(1) BATTERY PLUS
(2) BATTERY MINUS
(3) ENGINE RPM
(4) ENGINE COOLANT
(5) ENGINE OIL
(6) CRANK SHAFT SENSOR
(7) INTAKE AIR TEMP
(8) MANIFOLD PRESSURE
(9) THROTTLE POSITION 1
(10) THROTTLE POSITION 2
(11) FOOT PEDAL POSITION
(12) PRE CAT HEGO
(13) POST CAT HEGO
(14) GASOLINE RETURNLESS RAIL
(15) LPG FUEL PRESSURE
(16) LPG FUEL TEMP
(17) FUEL CONTROL LOCATION
(18) HIGH SPEED CAN LINK
(19) SPARK CONTROL TO IGNITION COILS
(20) LPG LOCK OFF CONTROL
(21) THROTTLE SPEED CONTROL
(22) DATA LINK CONNECTION
(23) DIAGNOSTIC TOOL
(24) MIL LIGHT
(25) GAGE OUTPUT
(26) INSTURMENT PANEL
(27) GASOLINE FUELPUMP CONTROL
(28) GASOLINE RETURNLESS RAIL
(29) GASOLINE INJECTORS
(30) FUEL METERING CORRECTION
(31) HIGH SPEED CAN LINK

In Kubota fuel systems, the Engine Control Module (ECM) provides total control, of the engine, fuel control, ignition spark control, and auxiliary features. The ECM depends on Kubota designed wire harness, to receive the required input data, from sensors, and sends the appropriate outputs. The harness is specifically designed to provide the necessary electrical supply, to the engine, through the life of the equipment. All electrical connectors utilize sealed connectors, to prevent damage from moisture intrusion, necessary shielding, when required, and protective covering, to protect the wiring.

To obtain maximum effect from the catalyst and accurate control of the air fuel ratio, the emissions certified engine is attached with an onboard computer known as the ECM. The ECM is a 32 bit controller, which receives input data from sensors, fitted to the engine and fuel system, and then outputs various signals, to control engine operation.

Engine sensors are used for fuel calculation and control, and are also used for the gasoline diagnostics. Those sensors are defined in the sensor group, in this section.

ENGINE SENSOR GROUP

To maintain fuel control, and insure the system provides the optimum performance, the ECM depends on sensors installed in the engine and fuel system, to provide input to the ECM, for calculating fuel delivery, as well as fuel system diagnostics. This section will provide the technician, with the understanding of the function of each sensor.

TEMPERATURE MANIFOLD ABSOLUTE PRESSURE (TMAP)

The TMAP sensor is a combination sensor, and provides the ECM with the Intake Air Temperature (IAT), and the Manifold Absolute Pressure (MAP). The ECM uses the intake air temperature to correct fueling based on the density of the air.

The MAP portion of the TMAP sensor provides the ECM with a measurement of the pressure in the intake manifold. During the start up, the MAP provides the ECM with the barometric pressure, to allow the ECM to adjust fueling, based on barometric pressure. Once the engine has started, the ECM uses the MAP to measure the load on the engine, and make fuel and RPM corrections, to compensate for changing load conditions.

In Kubota fuel system design, the TMAP is mounted to the intake manifold, The TMAP is a 5.00 V reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be a 0 to 5.00 V which is supplied by the engine. During the development phase of the system, the minimum and maximum thresholds of operation are determined, and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point at which the ECM will set the MIL light, to indicate that a fault has been detected in the fuel system.

ENGINE COOLANT TEMPERATURE (ECT)

The ECM monitors the engine coolant temperature, through the ECT sensor mounted in the engine. The ECM uses this sensor input to make corrections in fueling, and to protect the engine from overheating during normal operation.

In Kubota fuel system designs, the ECT is mounted in the water flange, and is usually supplied by Kubota. The ECT is a 5.00 V reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be a 0 to 5.00 V which is supplied by the engine. During the development phase of the system, the minimum and maximum threshold of engine temperature, during normal operation, are determined and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point at which the ECM will set the MIL light, to indicate that a fault has been detected in the fuel system. Should the temperature be exceeded, the ECM will first reduce the engine performance capabilities, often referred to as "limp home", which allows the operator to move the equipment to a facility for repair, or safely shut down the system. In the event the temperature continues to rise, the ECM will shut down the engine in a specified period of time, after the "limp home" strategy has been activated.

ENGINE OIL PRESSURE (EOP)

The ECM monitors the engine oil pressure, through the EOP sensor, mounted in the engine. The ECM uses this sensor input, to protect the engine from damage, from the lack of oil in the crank case.

In Kubota fuel system designs, the EOP is mounted in the cylinder block, and is supplied by Kubota. The EOP is a 5.00 V reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be a 0 to 5.00 V which is supplied by the engine. During the development phase of the system, the minimum and maximum threshold of engine temperature, during normal operation are determined, and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point, at which the ECM will set the MIL light, to indicate that a fault has been detected in the engine. Should the pressure be exceeded or fall below the minimum pressure, the ECM will shut down the engine in a specified period of time.

THROTTLE POSITION SENSORS 1 & 2 (TPS 1&2)

Kubota fuel systems use an Electronic Throttle Body (ETB) for speed and load control. Internal to the ETB, are two Throttle Position Sensors (TPS), which provide an "actual position" of the throttle plate. During the calibration development, the throttle blade variation, from actual to command, is defined. A maximum variation threshold is determined and included in the calibration, this threshold insures that the variation between actual and command do not vary above this threshold. In the event the variation exceeds the threshold, the ECM will command the ETB to idle, or shutdown the engine. The ECM will also set a diagnostic code, and turn on the MIL light

FOOT PEDAL POSITION SENSORS (FPP)

Kubota fuel systems, utilize a "drive by wire" technique, to allow the operator to accelerate the engine. This type of technique does not use a physical connection, between the operator foot pedal and the throttle body. Therefore control of the engine is managed by electrical signals, using a Foot Pedal Position Sensor (FPP), to determine the location, or how much the pedal is being depressed or released, which is relative to the command, that the operator desires. The FPP is a reference voltage sensor, therefore changing the voltage output level up or down, indicates a different desired position to the ECM. The ECM then changes the output signal, to the ETB, thus changing the throttle blade position, to correspond to the desired foot pedal command. The FPP is generally integrated, in the foot pedal mechanism, mounted in the operator's platform.

GASOLINE PRESSURE SENSORS (GPS)

The Gasoline Pressure Sensor (GPS) provides a reference voltage signal to the ECM. The ECM reads the voltage signal and determines the pressure of the gasoline in the Fuel Pressure Manifold. The ECM uses this value to maintain the precise amount of gasoline pressure for injection, to maintain engine performance and emission control. Thresholds of operation are determined during the development of the calibrations; these thresholds are used to provide diagnostics, of the fuel delivery system. If the GPS output voltage is outside the threshold, either high or low, the ECM will detect the condition and either correct the fuel delivery, or set an engine code, and utilize a "limp home" strategy, or shut down the engine. The sensor is located in the Fuel Pressure Manifold, and is serviceable as a separate part.

GAS TEMPERATURE SENSORS (GTS)

The EControls ECM adjusts gasoline fuel delivery to the engine, by utilizing a Gasoline Temperature Sensor (GTS), which provides a reference voltage signal, to the ECM. The ECM reads the voltage signal, and determines the temperature of the gasoline, in the Fuel Pressure Manifold, and uses this value, to correct the precise amount of gasoline, required for injection, to maintain engine performance, and emissions control. Thresholds of operation are determined during the development of the calibrations; these thresholds are used to provide diagnostics, of the fuel delivery system. If the GTS output voltage is outside the threshold, either high or low, the ECM will detect the condition, and either correct the fuel delivery, or set an engine code, and utilize a "limp home" strategy, or shut down the engine. The sensor is located in the Fuel Pressure Manifold, and is serviceable as a separate part.

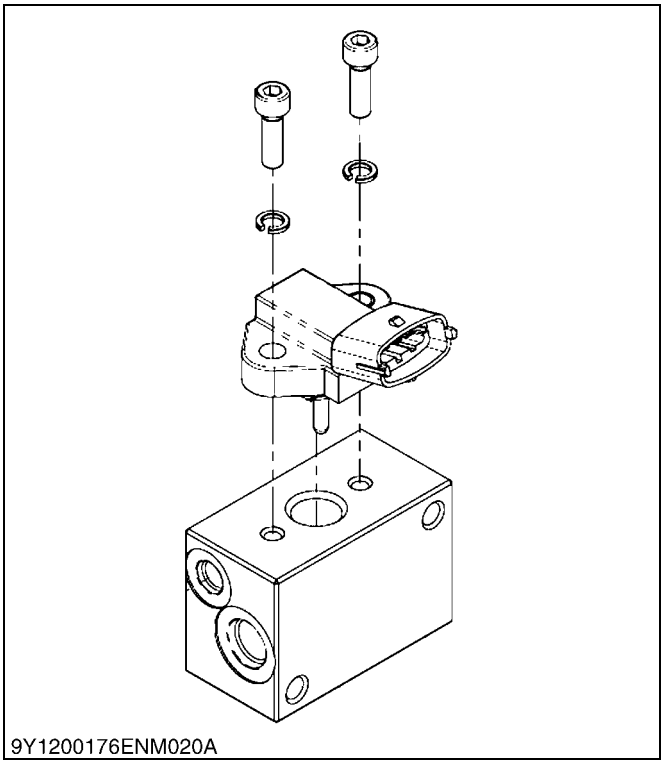


Figure 22: Gasoline Temperature and Pressure Sensor

CRANKSHAFT POSITION SENSOR (CKP)

To determine the engine RPM and piston position of number one cylinder, the ECM receives this information from the Crankshaft Sensor. The CKP is located near the flywheel at the rear of the engine, and is supplied by the engine. CKPs vary in design, depending on the signal that the sensor produces. Induction sensors produce a sine wave signal, where as the pick-up crank position sensor, which reads a notched metal "interrupter" ring, on the back of the harmonic balancer, creates a square wave pattern.

CAMSHAFT POSITION SENSOR (CMP)

The cam shaft sensor is used to determine which stroke of the engine cycle the engine is running on for control of the fuel and spark. The sensor is mounted at the front of the engine (gear case side) and reads a pick up wheel mounted internally within the engine. The pick up wheel can be of vary design and number of pulses.

KNOCK SENSOR (KCS)

To prevent engine "knock", which occurs when the fuel air mixture does not burn smoothly, during this condition timing is generally decreased, to assist with the fuel burn process. Kubota gasoline fuel system, utilizes a Knock Sensor, which is installed to the engine block, and attached by Kubota. The Knock Sensor is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The knock sensor sends a base or "no knock" signal to the EControls ECM, when knocking does occur the sensor detects the increased vibration, and increases the voltage output to the ECM. When the ECM receives the voltage change, the ECM will slightly retard the timing, until such time, the knocking no longer exists.

[2] Electrical System

INTRODUCTION

This section of the Kubota's manual has been designed to allow the technician to be able to select the section of the electrical system which is applicable to the fuel system being used. EControls systems are designed such that variation in fuel, engine size and auxiliary control feature are controlled by only several variations of Engine Control Modules (ECM). During the design of each of Kubota fuel systems Kubota defines the components that will interface with the EControls ECM and what options and auxiliary system are to be controlled by the ECM. Kubota fuel system wire harness varies slightly not only in circuits but in length and connector end. However each of the EControls ECM has identical 90 pin connectors. Variations in each ECM will dictate what the individual pin function is however there are many of the pins which have the same function regardless of fuel system or engine size. Some pins may not be used in certain Kubota fuel system and are blanked in the connector.

SYSTEM WIRING DIAGRAM

This section has shown the detail specific wire harness diagram for Kubota fuel system and electrical circuit. It is shown a connection to the vehicle side and engine side each for each specification.

CONNECTOR VIEWS

For those circuits which are not likely to vary, the individual circuits are documented in the harness section of this manual. Also included are the standard connector mating views which define the pin location in each connection. The view display is from mating connector perspective. Each connector in the overall wire harness has a connector number which begins with the prefix **CO**- followed by a three (3) digit number.

CIRCUIT IDENTIFICATION

Circuit numbers are not identified and wire colors may vary slightly as Kubota request specific wire colors for certain circuits. Standard circuit descriptions are used to identify each circuit. (example: Injector #1+)

WIRE DESCRIPTION

Each of the individual circuit diagrams contains the wiring information necessary for the technician to make repairs to that circuit without causing future damage to any electrical component or the wiring harness itself. All components use a crimped connector unless otherwise defined.

REPAIR OF WIRING HARNESS

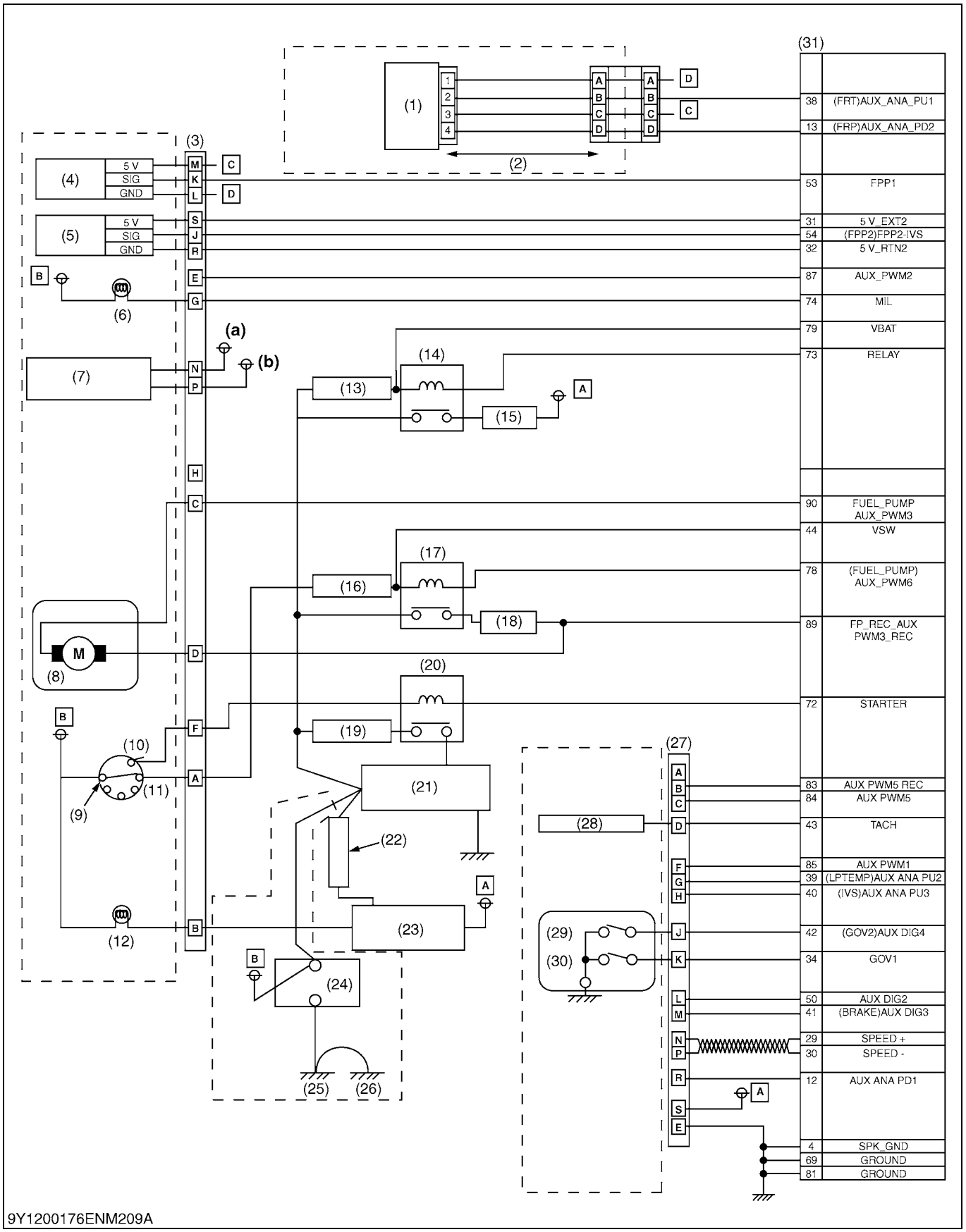
EControls recognizes that through normal wear or improper handling of the main wire harness damage can occur over time. Wires, connector ends, and pins may become damaged and require replacement or repair. EControls has provided in this manual a section which described the proper repair procedures when making repairs to any wire harness. Use this section and the proper tools when making splices or repairs to the harness.

■ **NOTE**

- **BEFORE DIAGNOSING ANY ELECTRICAL PROBLEM CHECK THE MAIN ECM CONNECTOR TO IDENTIFY WHAT PINS ARE BLANKED.**
- **BEFORE MAKING HARNESS REPAIRS BE SURE TO USE THE CORRECT WIRE HARNESS REPAIR TOOLS SUCH AS CRIMPING TOOLS, WIRE STRIPPING TOOLS, AND ELECTRICAL DIAGNOSTIC TOOLS**
- **BEFORE ADDING ANY OPTIONAL ELECTRICAL EQUIPMENT TO THE VEHICLE FITTED WITH AN ECONTROLS SYSTEM CONSULT WITH KUBOTA OF THE EQUIPMENT TO VERIFY THAT THE ELECTRICAL SYSTEM CAN SUSTAIN THE NEW ELECTRICAL LOADS AND WHERE TO CONNECT THE ADDITIONAL LOAD.**
- **WHEN ADDING OPTIONAL ELECTRICAL EQUIPMENT BE SURE TO USE A IN-LINE FUSE OF THE PROPER ELECTRICAL LOAD TO PROTECT THE VEHICLE ELECTRICAL SYSTEM.**

(1) System Wiring Diagram

[A] VEHICLE SIDE OF SYSTEM WIREING DIAGRAM (WG1605-G (GASOLINE))



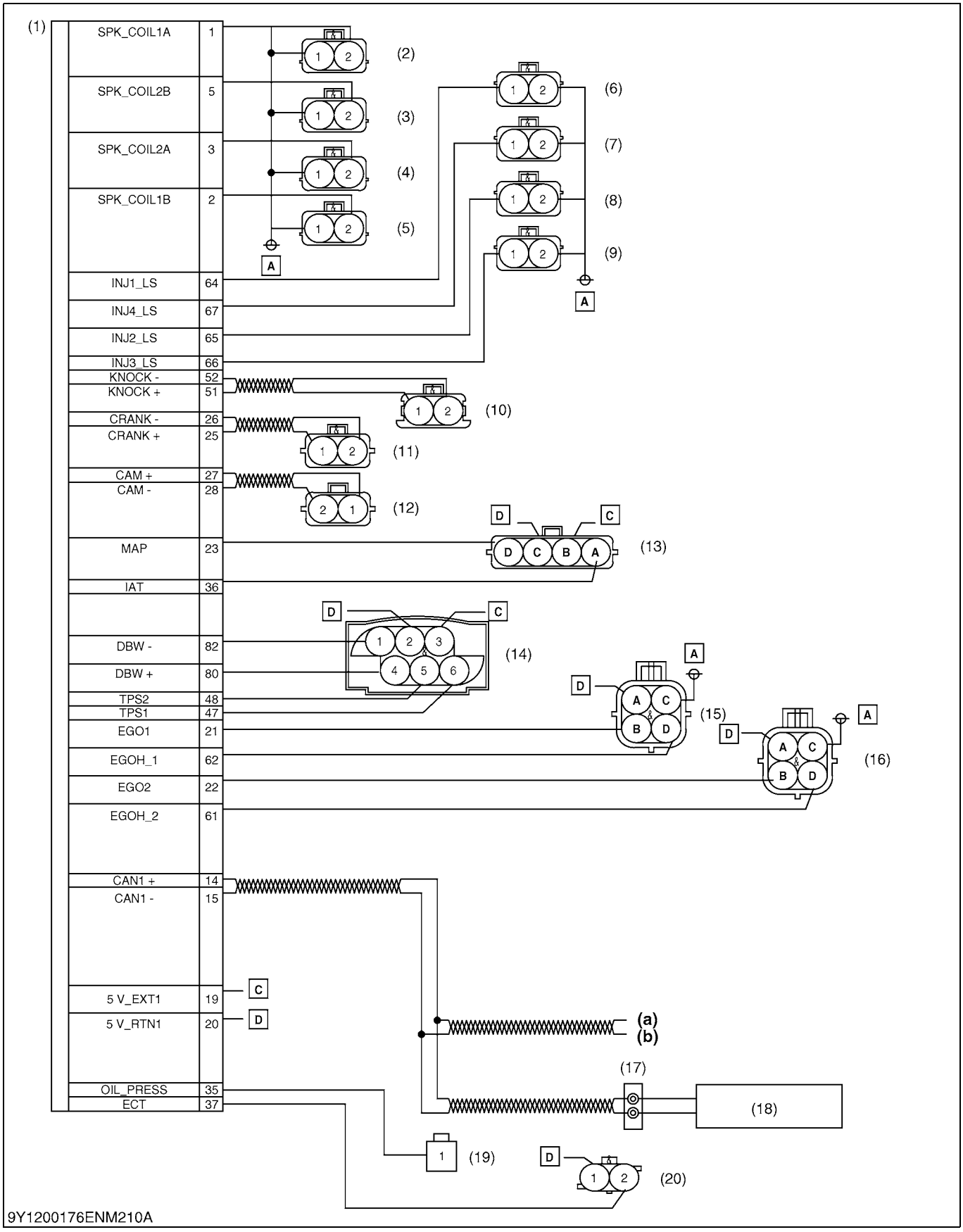
9Y1200176ENM209A

JOINT POINTS (A, B, C, D)

- **A: The points below are jointed.**
  IGNITION_FUSE (15A)
  ALTERNATOR_PIN_2
  VIC2_PIN_S
  COIL_CYL_#1,2,3,4_PIN_1
  INJ_CYL_#1,2,3,4_PIN_2
  O_2_SENSOR_PRE_CATALYST_PIN_C
  O_2_SENSOR_POST_CATALYST_PIN_C
- **B: The points below are jointed.**
  BATTERY +
  KEY_SWITCH_PIN_OFF
  ALTERNATOR_CHARGE_INDICATION_LAMP
  FUEL_SEL_PIN_NG
  MIL_LAMP
- **C: The points below are jointed.**
  ECM_PIN_19 (5 V_EXT1)
  THROTTLE_ACTUATOR_PIN_3
  TMAP (BOOST) PIN_B
  FPM_PIN_C
  VIC1_PIN_M
- **D: The points below are jointed.**
  ECM_PIN_20 (5 V_RTN1)
  COOLANT_TEMPERATURE_SENSOR_PIN_1
  O_2_SENSOR_PRE_CATALYST_PIN_A
  O_2_SENSOR_POST_CATALYST_PIN_A
  THROTTLE_ACTUATOR_PIN_2
  TMAP (BOOST)_PIN_C
  FPM_PIN_A
  VIC1_PIN_L

(1) FPM
(2) FPM Intermediate Harness
(3) VIC1 Connector
(4) ACCEL SENSOR1
(5) ACCEL SENSOR2
(6) MIL
(7) CAN for Vehicle
(8) FEED_PUMP
(9) KEY OFF
(10) KEY ST
(11) KEY IG
(12) Charge Indication
(13) ECM 10A FUSE
(14) Power Relay
(15) IGNITION 15A FUSE
(16) VSW 5A FUSE
(17) Fuel_pump Relay
(18) FUEL_PUMP 15A FUSE
(19) STARTER 15A FUSE
(20) Starter Relay
(21) STARTER
(22) 60A FUSE
(23) ALTERNATOR
(24) BATTERY
(25) BODY EARTH
(26) ENG. BODY
(27) VIC2 Connector
(28) SPEED_METER
(29) GOV_SEL2
(30) GOV_SEL1
(31) ECM (1/2)
(a) to ECM_PIN_14 (CAN1 +)
(b) to ECM_PIN_15 (CAN1 –)

[B] ENGINE SIDE OF SYSTEM WIREING DIAGRAM (WG1605-G (GASOLINE))



JOINT POINTS (A, B, C, D)

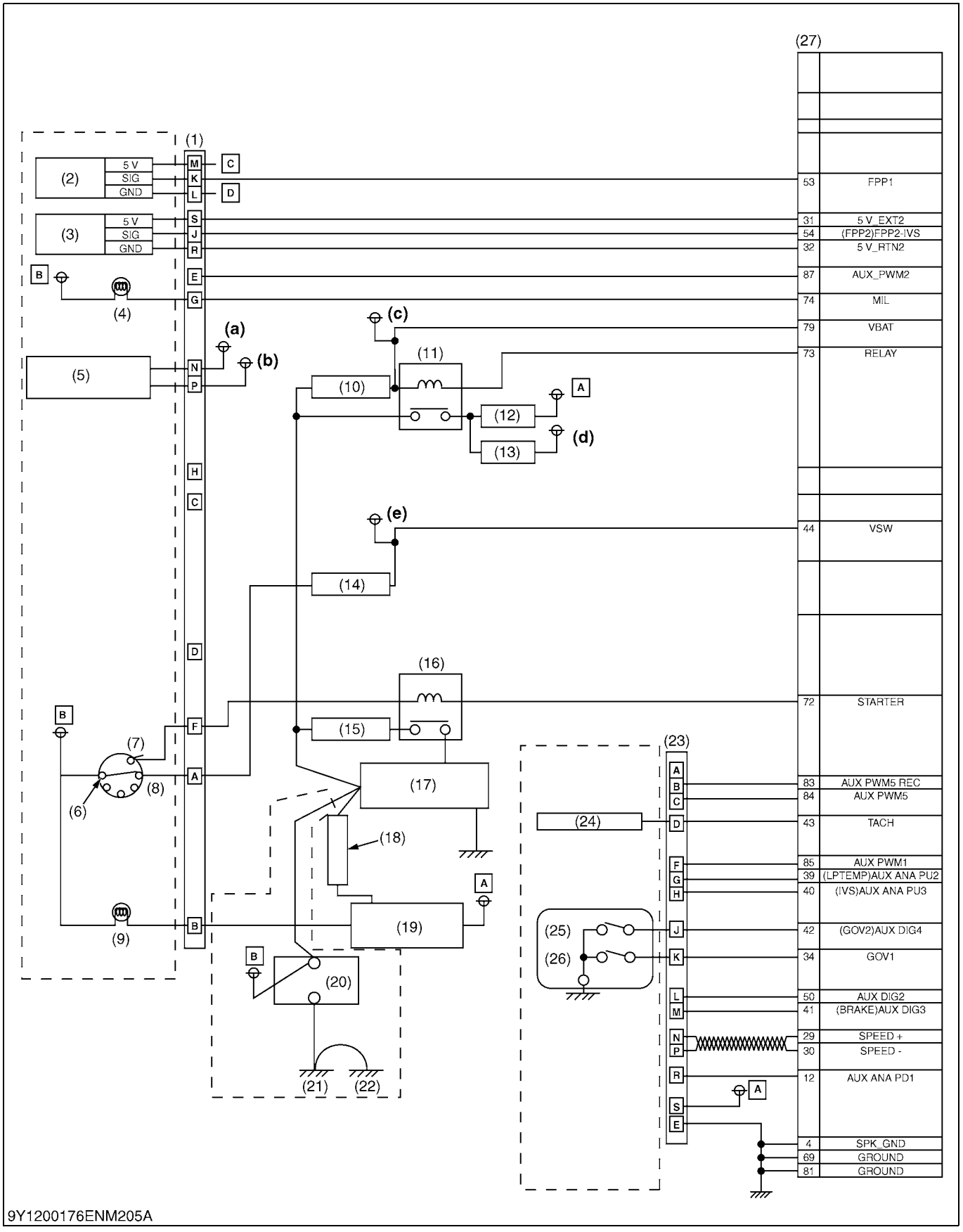
- **A: The points below are jointed.**
  IGNITION_FUSE (15A)
  ALTERNATOR_PIN_2
  VIC2_PIN_S
  COIL_CYL_#1,2,3,4_PIN_1
  INJ_CYL_#1,2,3,4_PIN_2
  O_2_SENSOR_PRE_CATALYST_PIN_C
  O_2_SENSOR_POST_CATALYST_PIN_C
- **B: The points below are jointed.**
  BATTERY +
  KEY_SWITCH_PIN_OFF
  ALTERNATOR_CHARGE_INDICATION_LAMP
  FUEL_SEL_PIN_NG
  MIL_LAMP
- **C: The points below are jointed.**
  ECM_PIN_19 (5 V_EXT1)
  THROTTLE_ACTUATOR_PIN_3
  TMAP (BOOST) PIN_B
  FPM_PIN_C
  VIC1_PIN_M
- **D: The points below are jointed.**
  ECM_PIN_20 (5 V_RTN1)
  COOLANT_TEMPERATURE_SENSOR_PIN_1
  O_2_SENSOR_PRE_CATALYST_PIN_A
  O_2_SENSOR_POST_CATALYST_PIN_A
  THROTTLE_ACTUATOR_PIN_2
  TMAP (BOOST)_PIN_C
  FPM_PIN_A
  VIC1_PIN_L

■ **NOTE**

- **The picture shows the pin arrangement of the connector housing viewed from the harness connector mating side.**

(1) ECM (2/2)
(2) COIL_CYL_#1
(3) COIL_CYL_#2
(4) COIL_CYL_#3
(5) COIL_CYL_#4
(6) INJ_SYL_#1
(7) INJ_SYL_#2
(8) INJ_SYL_#3
(9) INJ_SYL_#4
(10) Knock sensor
(11) Crank sensor
(12) Cam sensor
(13) TMAP (BOOST)
(14) Throttle Actuator
(15) O_2 sensor Pre Catalyst
(16) O_2 sensor Post Catalyst
(17) DIAG_TOOL Connector
(18) CAN Tool
(19) Oil SW
(20) Coolant temperature sensor
(a) to VIC1_PIN_N
(b) to VIC1_PIN_P

[C] VEHICLE SIDE OF SYSTEM WIREING DIAGRAM (WG1605-L (LPG))

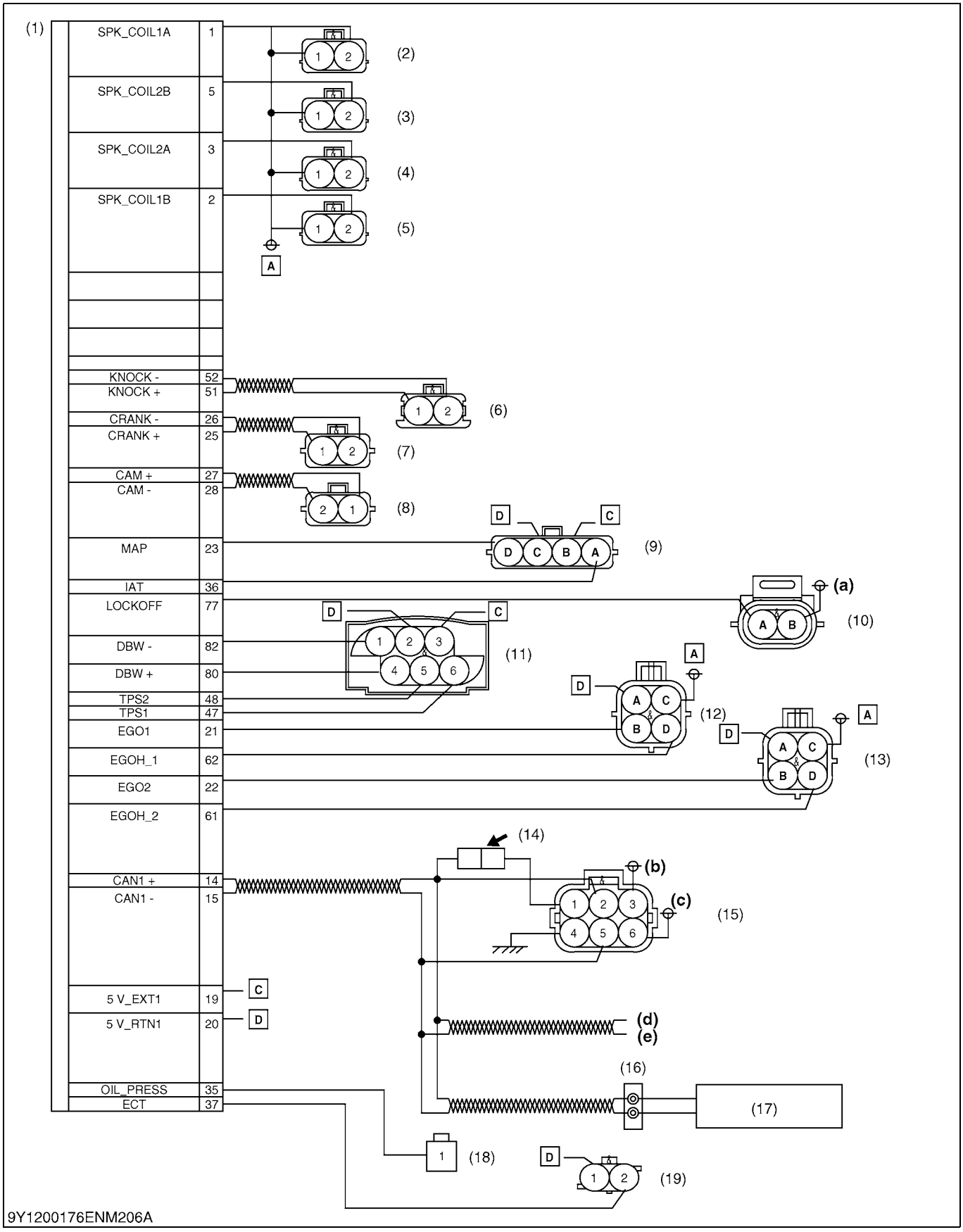


JOINT POINTS (A, B, C, D)

- **A: The points below are jointed.**
  IGNITION_FUSE (15A)
  ALTERNATOR_PIN_2
  VIC2_PIN_S
  COIL_CYL_#1,2,3,4_PIN_1
  INJ_CYL_#1,2,3,4_PIN_2
  O_2_SENSOR_PRE_CATALYST_PIN_C
  O_2_SENSOR_POST_CATALYST_PIN_C
- **B: The points below are jointed.**
  BATTERY +
  KEY_SWITCH_PIN_OFF
  ALTERNATOR_CHARGE_INDICATION_LAMP
  FUEL_SEL_PIN_NG
  MIL_LAMP
- **C: The points below are jointed.**
  ECM_PIN_19 (5 V_EXT1)
  THROTTLE_ACTUATOR_PIN_3
  TMAP (BOOST) PIN_B
  FPM_PIN_C
  VIC1_PIN_M
- **D: The points below are jointed.**
  ECM_PIN_20 (5 V_RTN1)
  COOLANT_TEMPERATURE_SENSOR_PIN_1
  O_2_SENSOR_PRE_CATALYST_PIN_A
  O_2_SENSOR_POST_CATALYST_PIN_A
  THROTTLE_ACTUATOR_PIN_2
  TMAP (BOOST)_PIN_C
  FPM_PIN_A
  VIC1_PIN_L

(1) VIC1 Connector
(2) ACCEL SENSOR1
(3) ACCEL SENSOR2
(4) MIL
(5) CAN for Vehicle
(6) KEY OFF
(7) KEY ST
(8) KEY IG
(9) Charge Indication
(10) ECM 10A FUSE
(11) Power Relay
(12) IGNITION 15A FUSE
(13) DEPR 5A FUSE
(14) VSW 5A FUSE
(15) STARTER 15A FUSE
(16) Starter Relay
(17) STARTER
(18) 60A FUSE
(19) ALTERNATOR
(20) BATTERY
(21) BODY EARTH
(22) ENG. BODY
(23) VIC2 Connector
(24) SPEED_METER
(25) GOV_SEL2
(26) GOV_SEL1
(27) ECM (1/2)
(a) to ECM_PIN_14 (CAN1 +)
(b) to ECM_PIN_15 (CAN1 −)
(c) to DEPR_PIN_6
(d) to DEPR_PIN_3
(e) to LOCKOFF VALVE_PIN_B

[D] ENGINE SIDE OF SYSTEM WIREING DIAGRAM (WG1605-L (LPG))



JOINT POINTS (A, B, C, D)

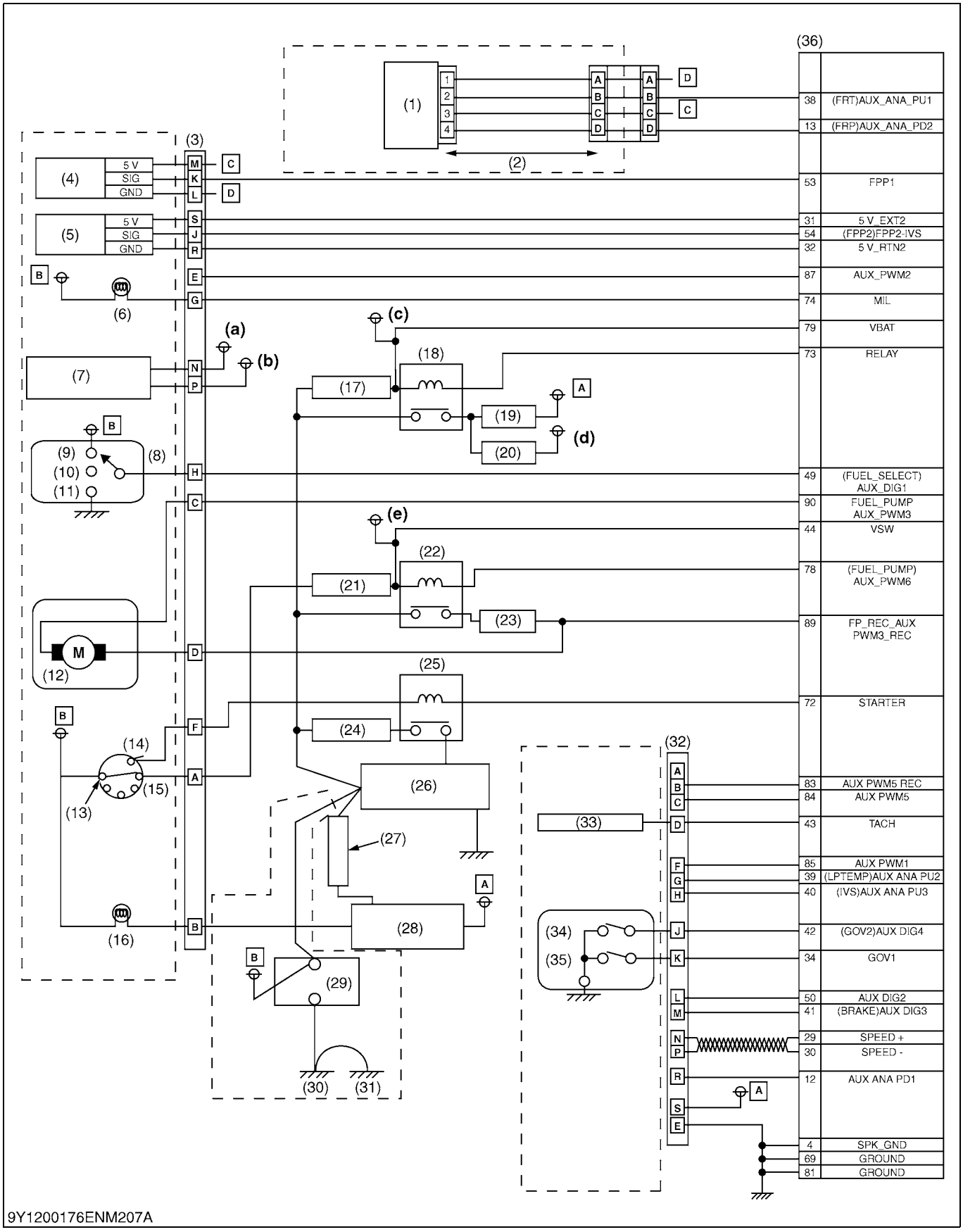
- **A: The points below are jointed.**
  IGNITION_FUSE (15A)
  ALTERNATOR_PIN_2
  VIC2_PIN_S
  COIL_CYL_#1,2,3,4_PIN_1
  INJ_CYL_#1,2,3,4_PIN_2
  O_2_SENSOR_PRE_CATALYST_PIN_C
  O_2_SENSOR_POST_CATALYST_PIN_C
- **B: The points below are jointed.**
  BATTERY +
  KEY_SWITCH_PIN_OFF
  ALTERNATOR_CHARGE_INDICATION_LAMP
  FUEL_SEL_PIN_NG
  MIL_LAMP
- **C: The points below are jointed.**
  ECM_PIN_19 (5 V_EXT1)
  THROTTLE_ACTUATOR_PIN_3
  TMAP (BOOST) PIN_B
  FPM_PIN_C
  VIC1_PIN_M
- **D: The points below are jointed.**
  ECM_PIN_20 (5 V_RTN1)
  COOLANT_TEMPERATURE_SENSOR_PIN_1
  O_2_SENSOR_PRE_CATALYST_PIN_A
  O_2_SENSOR_POST_CATALYST_PIN_A
  THROTTLE_ACTUATOR_PIN_2
  TMAP (BOOST)_PIN_C
  FPM_PIN_A
  VIC1_PIN_L

■ **NOTE**

- **The picture shows the pin arrangement of the connector housing viewed from the harness connector mating side.**

(1) ECM (2/2)
(2) COIL_CYL_#1
(3) COIL_CYL_#2
(4) COIL_CYL_#3
(5) COIL_CYL_#4
(6) Knock sensor
(7) Crank sensor
(8) Cam sensor
(9) TMAP (BOOST)
(10) Lockoff Valve
(11) Throttle Actuator
(12) O_2 sensor Pre Catalyst
(13) O_2 sensor Post Catalyst
(14) Can termination Connector
Open: termination OFF
Close: termination ON
(15) DEPR
(16) DIAG_TOOL Connector
(17) CAN Tool
(18) Oil SW
(19) Coolant temperature sensor
(a) to VSW_FUSE (5A)
(b) to DEPR_FUSE (5A)
(c) to ECM_FUSE (10A)
(d) to VIC1_PIN_N
(e) to VIC1_PIN_P

[E] VEHICLE SIDE OF SYSTEM WIREING DIAGRAM (WG1605-GL (Bi-Fuel))



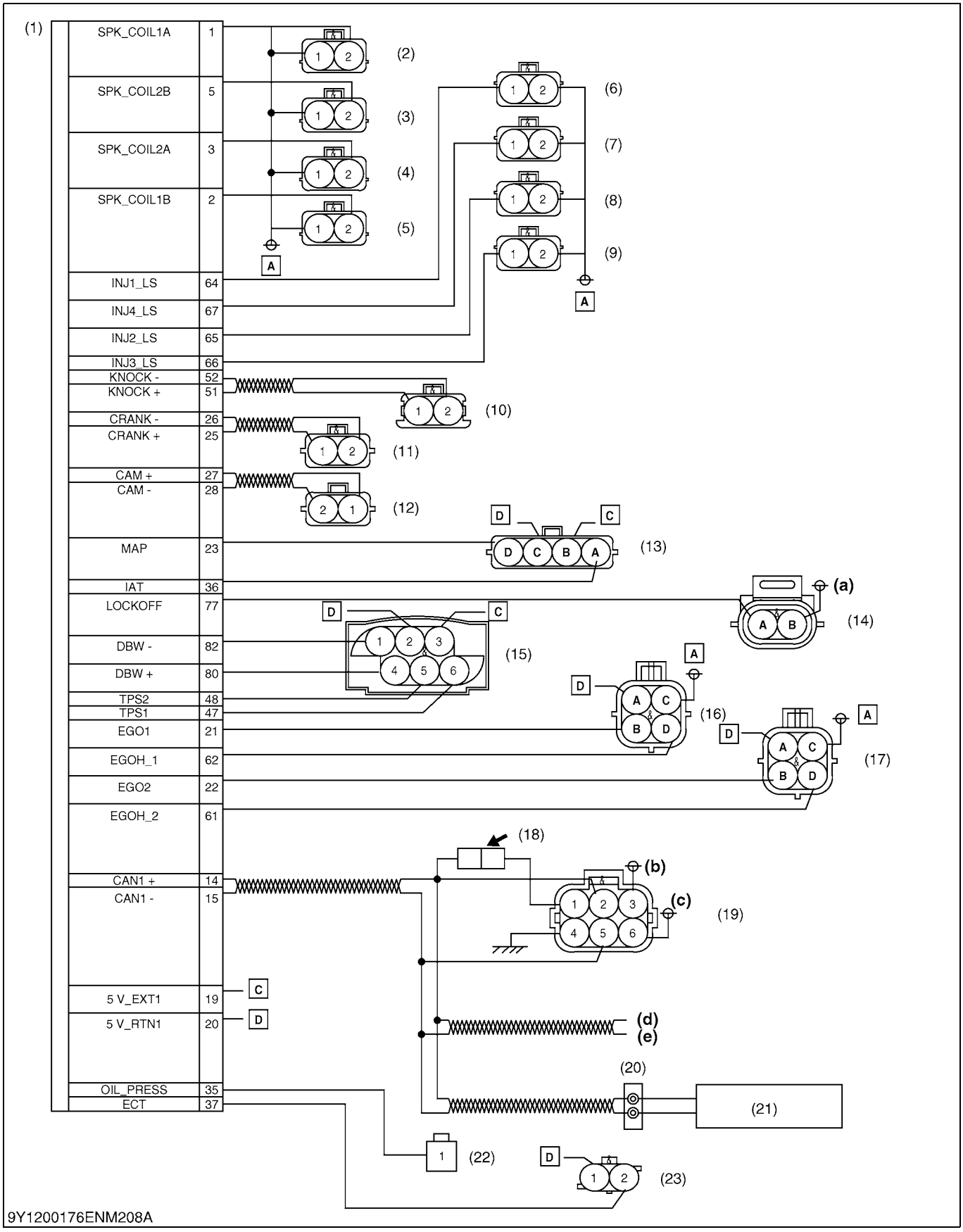
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JOINT POINTS (A, B, C, D)

- **A: The points below are jointed.**
  IGNITION_FUSE (15A)
  ALTERNATOR_PIN_2
  VIC2_PIN_S
  COIL_CYL_#1,2,3,4_PIN_1
  INJ_CYL_#1,2,3,4_PIN_2
  O_2_SENSOR_PRE_CATALYST_PIN_C
  O_2_SENSOR_POST_CATALYST_PIN_C
- **B: The points below are jointed.**
  BATTERY +
  KEY_SWITCH_PIN_OFF
  ALTERNATOR_CHARGE_INDICATION_LAMP
  FUEL_SEL_PIN_NG
  MIL_LAMP
- **C: The points below are jointed.**
  ECM_PIN_19 (5 V_EXT1)
  THROTTLE_ACTUATOR_PIN_3
  TMAP (BOOST) PIN_B
  FPM_PIN_C
  VIC1_PIN_M
- **D: The points below are jointed.**
  ECM_PIN_20 (5 V_RTN1)
  COOLANT_TEMPERATURE_SENSOR_PIN_1
  O_2_SENSOR_PRE_CATALYST_PIN_A
  O_2_SENSOR_POST_CATALYST_PIN_A
  THROTTLE_ACTUATOR_PIN_2
  TMAP (BOOST)_PIN_C
  FPM_PIN_A
  VIC1_PIN_L

(1) FPM
(2) FPM Intermediate Harness
(3) VIC1 Connector
(4) ACCEL SENSOR1
(5) ACCEL SENSOR2
(6) MIL
(7) CAN for Vehicle
(8) FUEL_SEL
(9) NG
(10) Gasoline
(11) LPG
(12) FEED_PUMP
(13) KEY OFF
(14) KEY ST
(15) KEY IG
(16) Charge Indication
(17) ECM 10A FUSE
(18) Power Relay
(19) IGNITION 15A FUSE
(20) DEPR 5A FUSE
(21) VSW 5A FUSE
(22) Fuel_pump Relay
(23) FUEL_PUMP 15A FUSE
(24) STARTER 15A FUSE
(25) Starter Relay
(26) STARTER
(27) 60A FUSE
(28) ALTERNATOR
(29) BATTERY
(30) BODY EARTH
(31) ENG. BODY
(32) VIC2 Connector
(33) SPEED_METER
(34) GOV_SEL2
(35) GOV_SEL1
(36) ECM (1/2)
(a) to ECM_PIN_14 (CAN1 +)
(b) to ECM_PIN_15 (CAN1 –)
(c) to DEPR_PIN_6
(d) to DEPR_PIN_3
(e) to LOCKOFF VALVE_PIN_B

[F] ENGINE SIDE OF SYSTEM WIREING DIAGRAM (WG1605-GL (Bi-Fuel))



JOINT POINTS (A, B, C, D)

- **A: The points below are jointed.**
  IGNITION_FUSE (15A)
  ALTERNATOR_PIN_2
  VIC2_PIN_S
  COIL_CYL_#1,2,3,4_PIN_1
  INJ_CYL_#1,2,3,4_PIN_2
  O_2_SENSOR_PRE_CATALYST_PIN_C
  O_2_SENSOR_POST_CATALYST_PIN_C
- **B: The points below are jointed.**
  BATTERY +
  KEY_SWITCH_PIN_OFF
  ALTERNATOR_CHARGE_INDICATION_LAMP
  FUEL_SEL_PIN_NG
  MIL_LAMP
- **C: The points below are jointed.**
  ECM_PIN_19 (5 V_EXT1)
  THROTTLE_ACTUATOR_PIN_3
  TMAP (BOOST) PIN_B
  FPM_PIN_C
  VIC1_PIN_M
- **D: The points below are jointed.**
  ECM_PIN_20 (5 V_RTN1)
  COOLANT_TEMPERATURE_SENSOR_PIN_1
  O_2_SENSOR_PRE_CATALYST_PIN_A
  O_2_SENSOR_POST_CATALYST_PIN_A
  THROTTLE_ACTUATOR_PIN_2
  TMAP (BOOST)_PIN_C
  FPM_PIN_A
  VIC1_PIN_L

■ **NOTE**

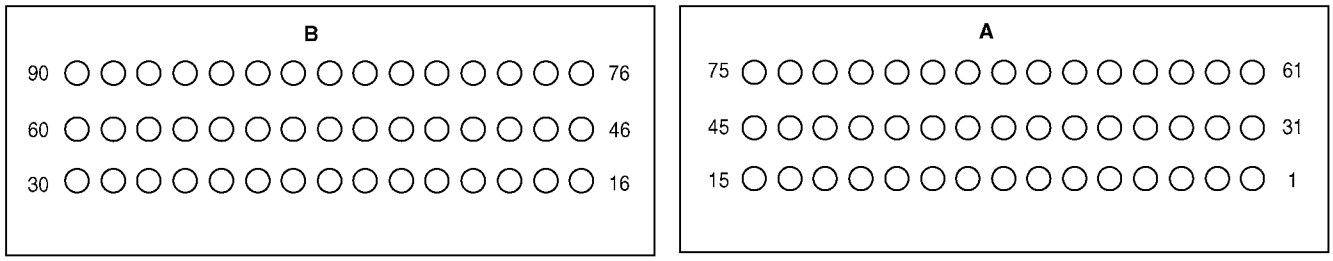
- **The picture shows the pin arrangement of the connector housing viewed from the harness connector mating side.**

(1) ECM (2/2)
(2) COIL_CYL_#1
(3) COIL_CYL_#2
(4) COIL_CYL_#3
(5) COIL_CYL_#4
(6) INJ_SYL_#1
(7) INJ_SYL_#2
(8) INJ_SYL_#3
(9) INJ_SYL_#4
(10) Knock sensor
(11) Crank sensor
(12) Cam sensor
(13) TMAP (BOOST)
(14) Lockoff Valve
(15) Throttle Actuator
(16) O_2 sensor Pre Catalyst
(17) O_2 sensor Post Catalyst
(18) Can termination Connector
Open: termination OFF
Close: termination ON
(19) DEPR
(20) DIAG_TOOL Connector
(21) CAN Tool
(22) Oil SW
(23) Coolant temperature sensor
(a) to VSW_FUSE (5A)
(b) to DEPR_FUSE (5A)
(c) to ECM_FUSE (10A)
(d) to VIC1_PIN_N
(e) to VIC1_PIN_P

(2) ECU Terminal Layout

Connector Number: C001
Name: ECM CONNECTOR

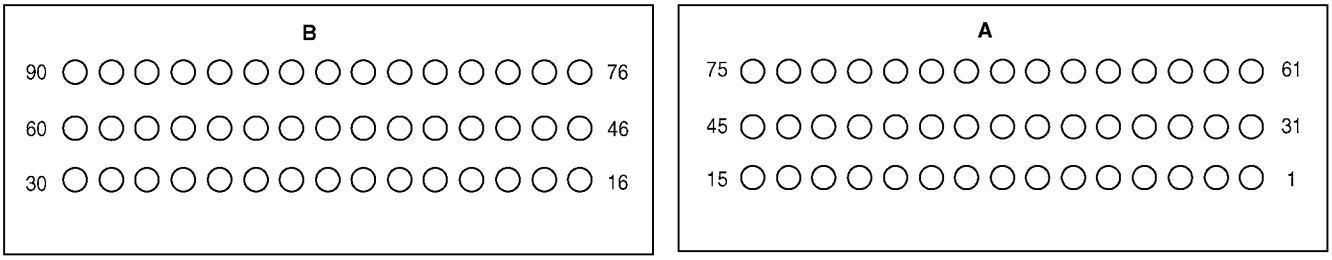
ECM PIN LOCATIONS



9Y1200176ENM047A

PIN	DISCRIPTION		PIN	DISCRIPTION		PIN	DISCRIPTION	
1	SPK_COIL1A	YELLOW 18	**31**	5 V EXT 2	LT_GREEN/ PURPLE 18	**61**	EGOH 2	BLACK/ YELLOW 18
2	SPK_COIL1B	YELLOW/ BLACK 18	**32**	5 V RTN 2	LT_GREEN/ BLACK 18	**62**	EGOH 1	BLACK/ WHITE 18
3	SPK_COIL2A	YELLOW/ RED 18	**33**	PULSE_IN	BLANK	**63**	INJ HS	BLANK
4	SPK_GRND	BLACK 16	**34**	GOV 1	GRAY/ DK_BLUE 18	**64**	INJ1 LS	BROWN/ LT_BLUE 18
5	SPK_COIL2B	YELLOW/ WHITE 18	**35**	OIL PRESSURE	LT_BLUE 18	**65**	INJ2 LS	BROWN/ LT_GREEN 18
6	SPK_COIL3A	BLANK	**36**	IAT	YELLOW/ GRAY 18	**66**	INJ3 LS	BROWN/ YELLOW 18
7	SPK_COIL3B	BLANK	**37**	ECT	TAN/WHITE 18	**67**	INJ4 LS	BROWN/ WHITE 18
8	UEGOS	BLANK	**38**	(FRP) AUX ANA PU1	LT_GREEN/ WHITE 18	**68**	INJ5 LS	BLANK
9	UEGOC	BLANK	**39**	(LPTEMP) AUX ANA PU2	YELLOW/ DK_BLUE 18	**69**	GROUND	BLACK 16
10	UEGOP	BLANK	**40**	(IVS) AUX ANA PU3	DK_BLUE/ YELLOW 18	**70**	INJ6 LS	BLANK
11	UEGPR	BLANK	**41**	BRAKE AUX DIG 3	TAN/ DK_GREEN 18	**71**	AUX PWM8	BLANK
12	AUX ANA PD1	ORANGE/ YELLOW 18	**42**	(GOV2) AUX DIG 4	GRAY/RED 18	**72**	STARTER	PINK/BLACK 18
13	(FRP) AUX ANA PDI	WHITE/ LT_GREEN 18	**43**	TACH	GRAY 18	**73**	RELAY	WHITE/ LT_BLUE 18
14	CAN 1 +	Dk Blue/Pink 18	**44**	VSW	PINK/TAN 18	**74**	MIL	GREEN/ YELLOW 18
15	CAN 1 –	BULE/WHITE 18	**45**	AUX ANA PUD 2	BLANK	**75**	UEGO H	BLANK
16	CAN 2 +	BLANK	**46**	AUX ANA PUD 1	BLANK	**76**	AUX PWM7	BLANK
17	CAN 2 –	BLANK	**47**	TPS 1	PURPLE/ LT_BLUE 18	**77**	LOCK OFF	WHITE/ BLACK 18
18	AUX ANA PUD3	BLANK	**48**	TPS 2	LT_BLUE/ DK_BLUE 18	**78**	FUEL PUMP AUX PWM6	TAN/BLACK 18
19	5 V EXT 1	LT_GREEN/ RED 18	**49**	FUEL SELECT AUX DIG 1	DK_GREEN/ PURPLE 18	**79**	VBAT	RED/TAN 16
20	5 V RTN 1	BLACK/ LT_GREEN 18	**50**	AUX DIG 2	TAN/RED 18	**80**	DBW +	PINK/WHITE 18
21	EGO 1	DK_GREEN/ ORANGE 18	**51**	KNOCK +	BLACK/ YELLOW 18	**81**	GROUND	BLACK 16
22	EGO 2	DK_GREEN/ WHITE 18	**52**	KNOCK –	BLACK 18	**82**	DBW –	TAN/ ORANGE 18

ECM PIN LOCATIONS

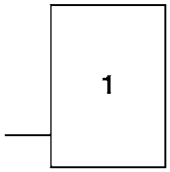


9Y1200176ENM047A

PIN	DISCRIPTION		PIN	DISCRIPTION		PIN	DISCRIPTION	
23	MAP	LT_GREEN 18	**53**	FPP1	DK_BLUE/ ORANGE 18	**83**	AUX PWM5 REC	WHITE/ BROWN 16
24	AUX ANA PUD3	BLANK	**54**	(FPP2) FPP2 IVS	PURPLE/ YELLOW 18	**84**	AUX PWM5	BROWN/ WHITE 16
25	CRANK +	PURPLE/ WHITE 18	**55**	PC TX	BLANK	**85**	AUX PWM1	TAN 16
26	CRANK –	WHITE/ PURPLE 18	**56**	PC RX	BLANK	**86**	AUX PWM4	BLANK
27	CAM +	GRAY/ BROWN 18	**57**	KNOCK 2 +	BLANK	**87**	AUX PWM2	DK_BLUE 18
28	CAM –	PURPLE/ ORANGE 18	**58**	KNOCK 2 –	BLANK	**88**	AUX PWM4 REC	BLANK
29	SPEED +	RED/WHITE 18	**59**	VBAT PROT	BLANK	**89**	FP REC AUX PWM3 REC	PINK/ YELLOW 16
30	SPEED –	RED/BLACK 18	**60**	VBAT	RED/TAN 16	**90**	FUEL PUMP AUX PWM3	BLACK/RED 16

(3) Connector Views

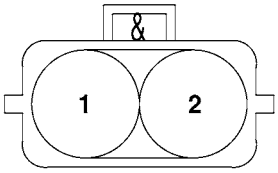
Connector Number: C002*1
Name: Starter Solenoid



9Y1200176ENM049A

Pin Number	Description	Wire Color
1	Starter Solenoid	WHITE

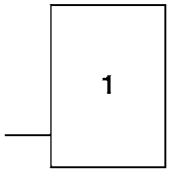
Connector Number: C003*1
Name: Crankshaft Sensor



9Y1200176ENM197A

Pin Number	Description	Wire Color
1	CRANK +	PURPLE/WHITE
2	CRANK –	WHITE/PURPLE

Connector Number: C004*1
Name: Oil Pressure Switch

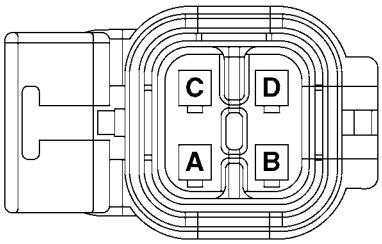


9Y1200176ENM049A

Pin Number	Description	Wire Color
1	Oil Pressure	LT_BLUE

■ **NOTE**
- ***1: All connector views are the mating connector view.**

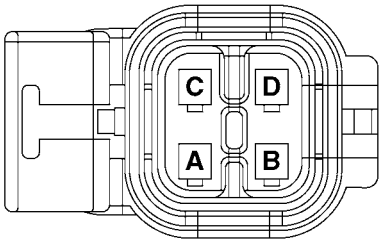
Connector Number: C005*1
Name: Heated O_2 Sensor (Pre-Cat)



9Y1200176ENM051A

Pin Number	Description	Wire Color
A	5 V_RTN 1	BLACK/LT_GREEN
B	EGO 1	DK_GREEN/ORANGE
C	12 V_RELAYED_POWER	PINK/DK_GREEN
D	EGOH 1	BLACK/WHITE

Connector Number: C006*1
Name: Heated O_2 Sensor (Post-Cat)

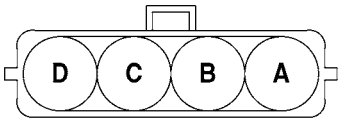


9Y1200176ENM051A

Pin Number	Description	Wire Color
A	5 V_RTN 1	BLACK/LT_GREEN
B	EGO 2	DK_GREEN/WHITE
C	12 V_RELAYED_POWER	PINK/DK_GREEN
D	EGOH 2	BLACK/YELLOW

■ **NOTE**
- ***1: All connector views are the mating connector view.**

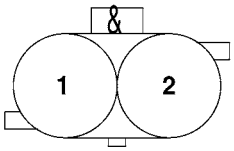
Connector Number: C007*1
Name: TMAP



9Y1200176ENM198A

Pin Number	Description	Wire Color
A	MAP	LT_GREEN
B	5 V_RTN 1	BLACK/LT_GREEN
C	5 V_EXT 1	LT_GREEN/RED
D	IAT	YELLOW/GRAY

Connector Number: C008*1
Name: Engine Coolant Temperature

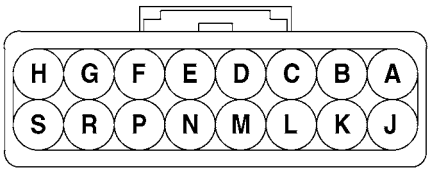


9Y1200176ENM199A

Pin Number	Description	Wire Color
1	5 V_RTN 1	BLACK/LT_GREEN
2	ECT	TAN/WHITE

■ **NOTE**
- ***1: All connector views are the mating connector view.**

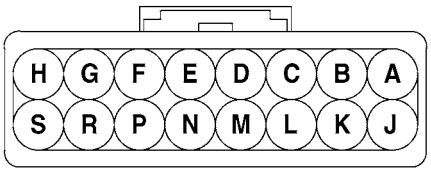
Connector Number: C009*[1]
Name: Vehicle Interface Connector1



9Y1200176ENM200A

Pin Number	Description	Wire Color
A	VSW	PINK 18
B	CHARGE_INDICATION	PURPLE 18
C	FUEL_PUMP –	BLACK/RED 16
D	FUEL_PUMP +	PINK/YELLOW 16
E	AUX_PWM2	DK_BLUE 18
F	START_COMMAND	LT_BLUE/PINK 18
G	MIL	GREEN/YELLOW 18
H	AUX_DIG1 (FUEL_SELECT)	DK_GREEN/PURPLE 18
J	(FPP 2) FPP 2_IVS	PURPLE/YELLOW 18
K	FPP1	DK_BLUE/ORANGE 18
L	5 V_RTN	BLACK/LT_GREEN 18
M	5 V_EXT	LT_GREEN/RED 18
N	CAN1 +	BLUE/PINK 18
P	CAN1 –	BULE/WHITE 18
R	5 V_RTN2	LT_GREEN/BLACK 18
S	5 V_EXT2	LT_GREEN/PURPLE 18

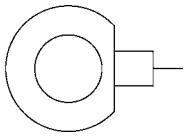
Connector Number: C010*1
Name: Vehicle Interface Connector2



9Y1200176ENM200A

Pin Number	Description	Wire Color
A	NOT_USE	
B	AUX_PWM5_RECIRC	WHITE/BROWN 16
C	AUX_PWM5	BROWN/WHITE 16
D	TACH	GRAY 18
E	GROUND	BLACK 16
F	AUX_PWM1	TAN 16
G	AUX_ANA_PU3	YELLOW/DK_BLUE 18
H	AUX_ANA_PU1	DK_BLUE/YELLOW 18
J	GOV_SELECT2	GRAY/RED 18
K	GOV_SELECT1	GRAY/DK_BLUE 18
L	AUX_DIG2	TAN/RED 18
M	AUX_DIG3	TAN/DK_GREEN 18
N	VS +	RED/WHITE 18
P	VS –	RED/BLACK 18
R	AUX_ANA_PD1	ORANGE/YELLOW 18
S	12 V_RELAYED_POWER	PINK/DK_GREEN 16

Connector Number: C011
Name: System Ground Connection

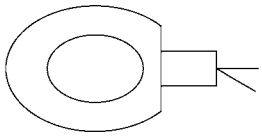


9Y1200176ENM055A

Pin Number	Description	Wire Color
1	Sys Ground	BLACK

■ **NOTE**
- ***1: All connector views are the mating connector view.**

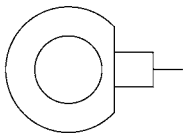
Connector Number: C012
Name: 12 Volt Battery + Connection



9Y1200176ENM056A

Pin Number	Description	Wire Color
1	Battery 12 V +	RED

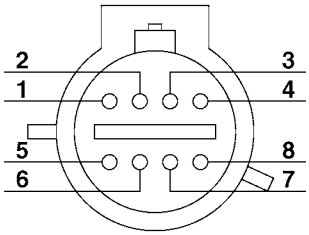
Connector Number: C013
Name: Alternator Battery +



9Y1200176ENM055A

Pin Number	Description	Wire Color
1	Battery 12 V +	RED

Connector Number: C014*1
Name: Diagnostic Tool Connector



9Y1200176ENM057A

Pin Number	Description	Wire Color
1	ANA_RTN	
2	5 V_REF	
3	PC TX	
4	PC RX	
5	VBAT	
6		
7	CAN 1 +	BLUE/PINK
8	CAN 1 –	BLUE/WHITE

Connector Number: C015*1
Name: Alternator Connector

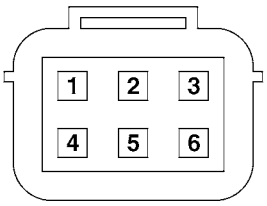


9Y1200176ENM058A

Pin Number	Description	Wire Color
1	Not Used	
2	12 V_RELAYED_POWER	PINK/DK_GREEN
3	Charge Indication	PURPLE

■ **NOTE**
- ***1: All connector views are the mating connector view.**

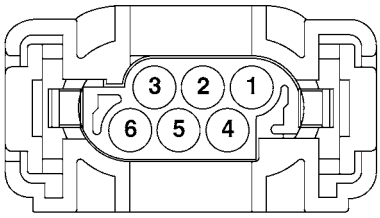
Connector Number: C016*1
Name: DEPR Connector



9Y1200176ENM059A

Pin Number	Description	Wire Color
1	CAN Termination	WHITE
2	CAN 1 +	DK_BLUE/PINK
3	VRELAY	PINK/DK_GREEN
4	Ground	BLACK
5	CAN –	DK_BLUE/WHITE
6	V_{BAT} (12 V)	RED/TAN

Connector Number: C017*1
Name: Bosch Throttle Connector

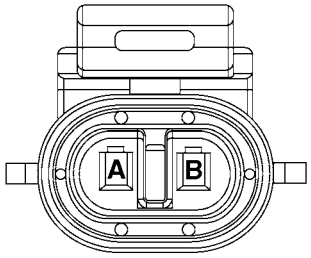


9Y1200176ENM060A

Pin Number	Description	Wire Color
1	DBW –	TAN/ORANGE
2	5 V_RTN 1	BLACK/LT_GREEN
3	5 V_EXT 1	LT_GREEN/RED
4	DBW +	PINK/WHITE
5	TPS 2	LT_BLUE/DK_BLUE
6	TPS 1	PURPLE/LT_BLUE

■ **NOTE**
- ***1: All connector views are the mating connector view.**

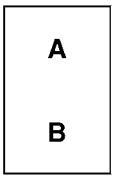
Connector Number: C018*1
Name: LPG Fuel Lock Off Connector



9Y1200176ENM062A

Pin Number	Description	Wire Color
A	Lock Off	WHITE/BLACK
B	12 V	PINK/TAN

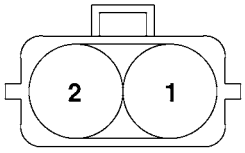
Connector Number: C019*1
Name: Knock Sensor Connector



9Y1200176ENM063A

Pin Number	Description	Wire Color
1	Knock +	BLACK/YELLOW
2	Knock –	BLACK

Connector Number C020*1
Name: Camshaft Position Sensor Connector

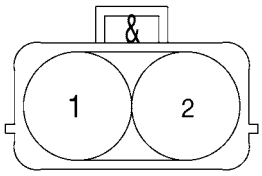


9Y1200176ENM201A

Pin Number	Description	Wire Color
1	CAM +	GRAY/BROWN
2	CAM –	PURPLE/ORANGE

■ **NOTE**
- ***1: All connector views are the mating connector view.**

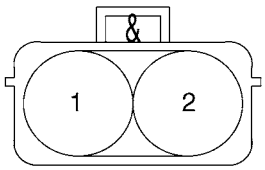
Connector Number C021*1
Name: Ignition Coil Connector



9Y1200176ENM203A

Cylinder Number	Pin Number	Description	Wire Color
1 to 4 (All)	1	12 V_RELAYED_POWER	PINK/DK_GREEN
1	2	SPK_COIL1A	YELLLOW
2	2	SPK_COIL2B	YELLLOW/WHITE
3	2	SPK_COIL2A	YELLLOW/RED
4	2	SPK_COIL1B	YELLLOW/BLACK

Connector Number C022*1
Name: Injector Connector

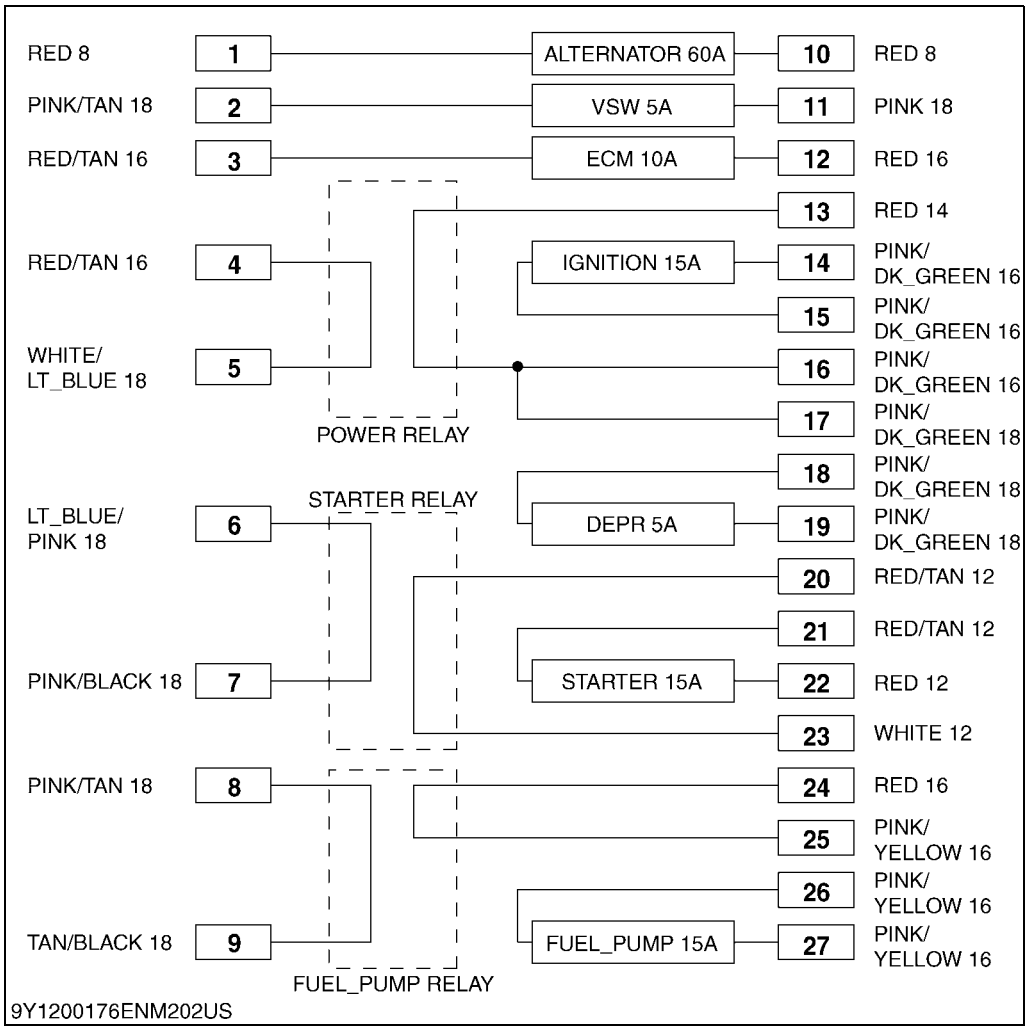


9Y1200176ENM204A

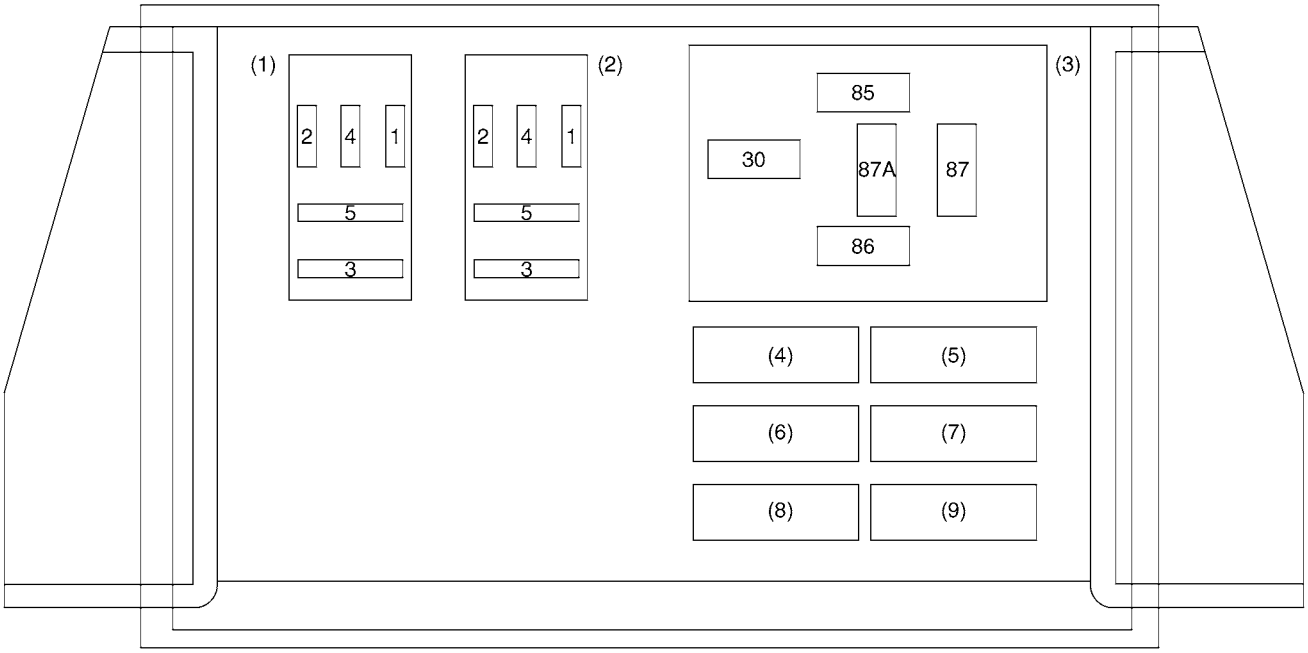
Cylinder Number	Pin Number	Description	Wire Color
1	1	INJ1_LS	BROWN/LT_BLUE
2	1	INJ4_LS	BROWN/WHITE
3	1	INJ2_LS	BROWN/LT_GREEN
4	1	INJ3_LS	BROWN/YELLOW
1 to 4 (All)	2	12 V_RELAYED_POWER	PINK/DK_GREEN

■ **NOTE**
- ***1: All connector views are the mating connector view.**

Connector Number C023
Name: FUSE BOX



Connector Number C024
Name: FUSE BOX (LAYOUT)



9Y1200176ENM211A

- WG1605-G (Gasoline)

(1) Fuel Pump Relay
(2) Power Relay
(3) Starter Relay
(4) 15 A FUSE
(5) 15 A FUSE
(6) 15 A FUSE
(7) BLANK
(8) 10 A FUSE
(9) 5 A FUSE

- WG1605-L (LPG)

(1) BLANK
(2) Power Relay
(3) Starter Relay
(4) 15 A FUSE
(5) BLANK
(6) 15 A FUSE
(7) 5 A FUSE
(8) 10 A FUSE
(9) 5 A FUSE

- WG1605-GL (Bi-Fuel)

(1) Fuel Pump Relay
(2) Power Relay
(3) Starter Relay
(4) 15 A FUSE
(5) 15 A FUSE
(6) 15 A FUSE
(7) 5 A FUSE
(8) 10 A FUSE
(9) 5 A FUSE

(4) Repair of Wiring Harness

INTRODUCTION

The EControls ECM for both certified and non-certified fuel system relies on precise voltage input and outputs to maintain precise fuel control during normal operation. The ECM utilizes reference voltage signals to calculate fuel control, command throttle and engine speed and provide data to the operator through the instrument cluster.

When diagnosing faults in the system often the technician is required to disconnect the electrical connectors in the wire harness. Technicians should always use care when working on the wire harness. Special care should be given to the following items:

- When disconnecting connectors always grasp the connector at its base **DO NOT PULL ON THE WIRES** this make cause extreme stress on the crimped or solder joints
- Always depress or unlatch the connector **DO NOT USE A SCREW DRIVER TO PRY THE CONNECTOR APART** as damage to the connector or mating electrical device can occur
- When disconnecting a electrical connector always check the connector for corrosion in the connector pins, moisture in the connector, missing or damage water seals.
- **DO NOT PUSH THE ELECTRICAL PROBES INTO THE PINS WHEN TESTING CIRCUITS** as this will cause the pin to become enlarged and result in intermittent electrical problems
- When reconnecting an electrical connector "PUSH" the connector together until you here the "CLICK" then "PULL" on the connector base to make sure it is seated and locked.
- Make sure to route the harness in the original fashion and secure the harness using straps, wire ties or clips to prevent the harness from contact with hot surfaces, rotating devices or damage for external elements

Because the critical sensor control circuits operate at low voltage it is always best to use solder to make joints and replace connector pins. Refer to next page "REPAIR OF WIRING HARNESS". If a connector is the "Molded" type and requires repair the complete connector must be replaced using a "pig tail" replacement.

CONNECTORS AND TERMINALS

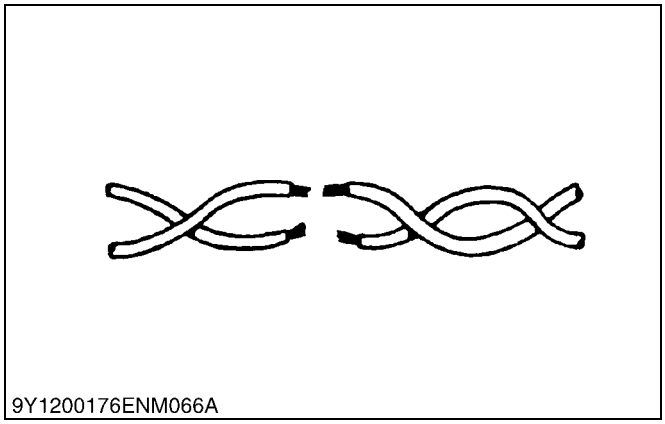
As stated earlier always use care when probing a connector or replacing terminals in a connector housing. Improper repair of a connector can resulting in shorts at the connector and can damage critical electrical components. Always use a jumper wire between the terminal when checking circuits. **NEVER USE A SHARP POINTED OBJECT TO PROBE THROUGH THE WEATHER TIGHT SEALS,** doing so will allow water to intrude into the circuit and will result in future electrical faults in the system or may deter system performance.

Using the proper tools when working on the wire harness is essential to making proper and durable repairs. Use of an improper tool may result in damaging other electrical components and will result in needless repair costs. When working with the use proper wire stripping and cutting tools, use a fuse removal tool when replacing or check fuses, use a small screw driver to unlock connector latches, use electrical probes when testing wires, it is often best to find mating connectors to the EControls wire harness connectors for testing circuits as this will ensure a positive connection when reading ohms or voltage. Use the proper "Pin Removal Tool" when removing a connector terminal from its housing.

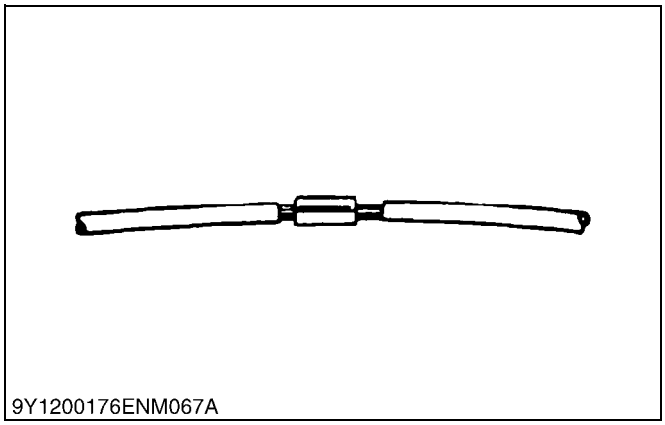
When diagnosing intermittent shorts in the electrical system is often easy to find the fault by wiggling the wires in a connector while the engine is operating as this may cause the misalignment, or corrosion to negatively affect the connection. Corrosion is a primary cause of electrical faults within the system, always look for visible signs of corrosion when diagnosing an electrical fault.

REPAIR OF WIRING HARANESS

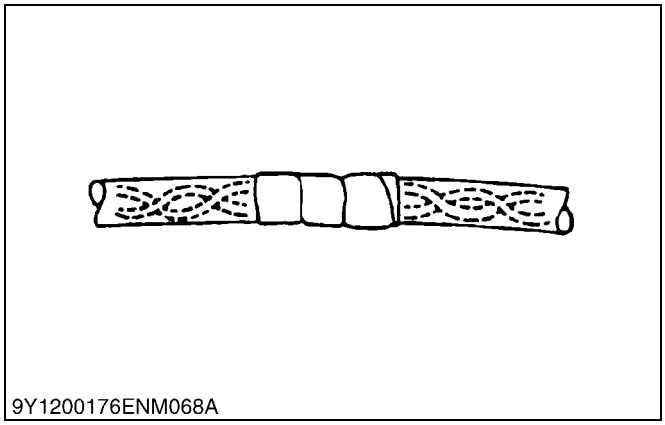
TWISTED LEADS


9Y1200176ENM066A

1. Locate the damaged wire remove only sufficient insulation to allow for a complete sealing of the wire in the connector splice.


9Y1200176ENM067A

2. Place a proper sized heat shrink tube over one of the cut end and slide back from the splice area.
3. position each of the stripped wire ends into the splice and ensure there is no bare wire exposed.
4. Solder the connection using a Rosin Core solder
5. Slide the heat shrink tube over the splice and use heat to shrink the tube over the connection to create a water tight seal.


9Y1200176ENM068A

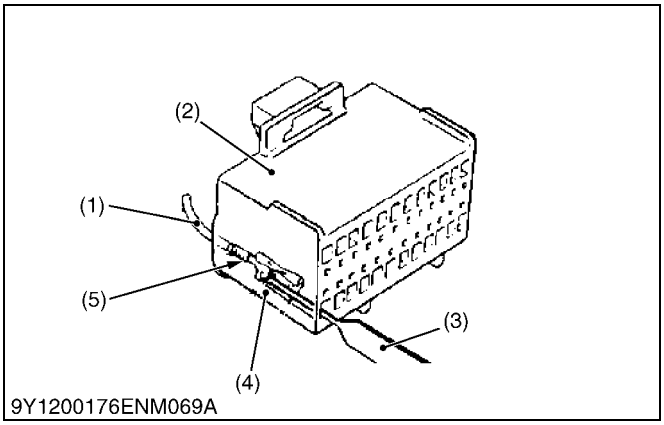
6. Re-twist the wire and secure the splice are with electrical tape to tightly seal the area.

CONNECTOR END REPAIR OR REPLACEMENT

Before making a connector repair, be certain of the type of connector for example Weather-Pack connectors and Compact Three connectors look very similar but are service differently.

MICRO-PACK CONNECTOR

Refer to Figure 2 for the repair procedure for the repair of a MICRO-PACK connector



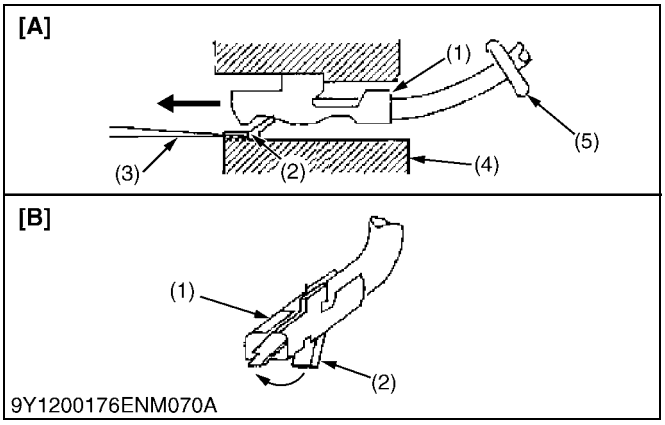
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Figure 23: MICRO PACK CONNECTOR REPAIR

(1) Connector Housing
(2) Cable
(3) Pin Removal Tool J33095, BTB234-A
(4) Locking Tang
(5) Terminal

METRI-PACK CONNECTORS

Some electrical connectors on the harness may utilize a METRI-PACK connector. Refer to Figure 3 for removal and repair of the terminal.



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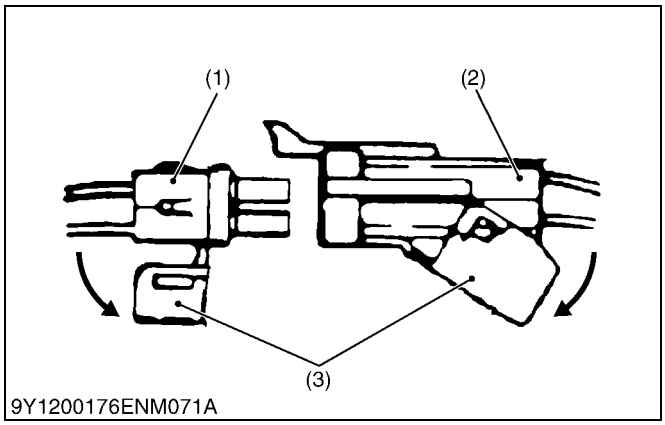
Figure 24: METRI-PACK Terminal Repair

(1) METRI-PACK Series 150 Female Terminal
(2) Locking Tang
(3) Tool J35689, or Bt-8446
(4) Connector Body
(5) Seal

[A] Cut image of connector
[B] End of Wire harness

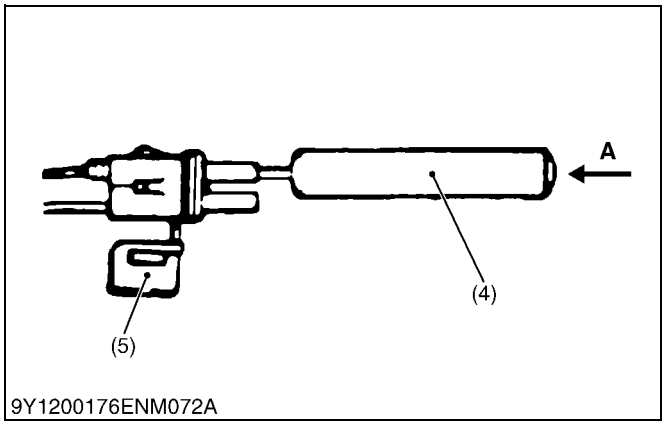
WEATHER PACK CONNECTOR

A Weather-Pack connector can be identified by a rubber seal installed to the wire at the rear of the connector. This type of connector is use in the engine compartment to protect against moisture intrusion into the connector. Refer to Figure 4 for terminal removal and repair.



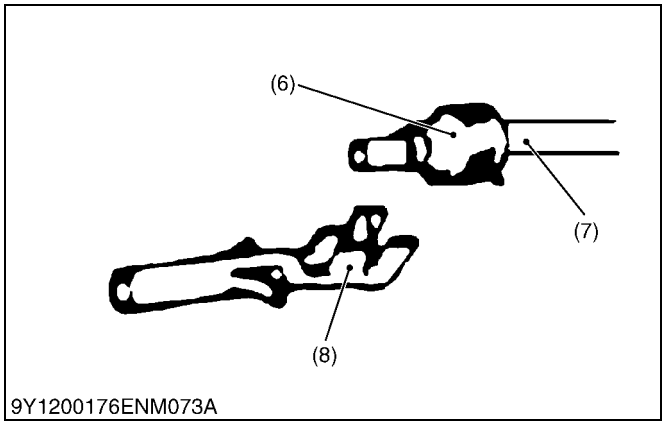
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1. Open the secondary lock hinge to the female connector and separate the connectors.



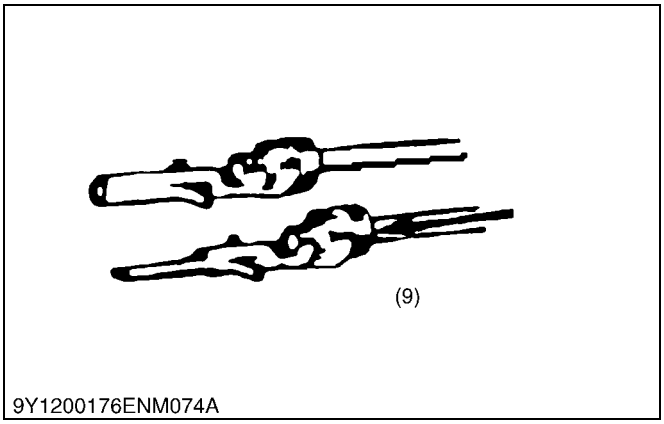
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2. Remove the terminal using the pin tool.



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3. Cut the wire immediately behind the cable seal.



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4. Replace the terminal
   a) Slip the new seal onto the wire.
   b) Strip 5 mm (0.2 in.) of insulation from the wire.
   c) Crimp the terminal over the wire and seal.
5. Push the terminal back into the connector until the locking tangs are seated.
6. Connect the male and female terminals.
7. Close the secondary locks.

(1) Male Connector
(2) Female Connector
(3) Secondary Lock Hinge
(4) Tool J-28742 / BT8234-A
(5) Terminal
(6) Seal
(7) Wire
(8) Terminal
(9) Wire harness terminal

5. DIAGNOSIS

[1] FUEL SYSTEM CHECKS

INTRODUCTION

The maintenance of the engine fitted with Kubota LPG and Gasoline fuel systems, and its related components, is critical to the life of the engine and optimum performance, during its useful life. All engines require a certain amount of maintenance. The suggested maintenance requirements are contained in this section. Industrial engines operate in various environmental conditions, and various temperature ranges.

■ **NOTE**

- **This is a recommended guide line only; each user must assess the daily operational usage and environmental conditions, and determine an appropriate schedule.**

In addition, the owner may have installed additional equipment to the vehicle, which may also increase the requirements for service on certain components. Therefore, the owner and the service agent, should review the operating condition of the equipment, and determine if more frequent inspections, and maintenance cycles maybe required.

This section of the service manual supplement, covers the maintenance items of both the LPG and Gasoline fuel systems, which are designed and supplied by EControls, and general information on those items which are supplied by Kubota, and requires regularly scheduled maintenance. For maintenance of the base engine and or chassis, refer to the Kubota manual which covers the maintenance of the equipment.

GENERAL LPG FUEL TANK MAINTENANCE

LPG TANKS

The typical LPG fuel storage cylinder should be inspected daily or at the beginning of each shift for any of the following.

- External leaks, external damage
- Manual service valve is fully open
- Securely mounted; inspect the securing straps for damage, and that the securing devices are closed and locked.
- Insure that the fuel storage cylinder is properly positioned in the locating pin, in the tank collar, on all horizontally mounted tanks. This will insure that the tank pressure relief device will always be in the correct position, to function if required.

When refueling or exchanging a cylinder, check the following:

- Quick fill valve for thread damage
- Insure that the o-ring seal is in place
- Check the o-ring for cracks, separation or chunking;
- Replace the o-ring if necessary before refueling
- Check the service line quick coupler for any thread damage
- Check the coupler o-ring for cracks, separation, or chunking
- Replace the o-ring if necessary, before refueling.

■ **IMPORTANT**

- **When refueling the cylinder, clean both the fill hose and the tank connector with a clean cloth to remove any dust, dirt or debris to prevent contamination of the fuel system.**

⚠ WARNING

NEVER CUT OR WELLD ON EITHER THE LPG OR GASOLINE FUEL TANK. REPAIRS TO THE FUEL TANL SHOULD ONLY BE MADE BY A CREATIFIED TANK REPAIR FACILITY. FAILURE TO OBSERVE THIS WARNING COULD RESULT IN SERIOUS BODILY INJURY AND OR DEATH AND COULD RESULT IN SERIOUS PROPERETY DAMAGE.

FUEL FILTER MAINTENANCE

Kubota fuel systems will be designed with a specification, which requires filtration of the system. With the EControls designed fuel system; the filter have been attached with additional filtration, (Refer to Kubota Base engine section).

To determine the recommended maintenance intervals, refer to the EControls Recommended Maintenance Schedule at the end of this section. However, engines which operate in extremely dirty environment will require more frequent maintenance.

When inspecting the fuel filtration systems, check the following:

- Check for any fuel leaks at the inlet and outlet fittings.
- Check to make sure the filter is securely mounted.
- Check for any external damage or distortion; if damaged replace the filter element.

To replace the filters use the following steps:

1. Move the equipment to a well ventilated area and insure there are no external ignition sources.
2. On LPG systems start the engine and close the manual valve on the cylinder, and run the engine until the engine runs out of fuel.
3. Remove and replace the fuel filter.
4. Leak check the connections with a soapy solution, or electronic leak detector.
5. On Gasoline fuel pumps with integrated fuel filters or screens located in the tank, follow the procedures for pump removal.
6. On externally mounted filters, close the manual valve at the gasoline tank to prevent fuel from draining from the tank.
7. Drain any excess fuel into an approved container and replace the filter.
8. After replacing the filter, start the engine and leak check all connections.

WARNING

ALWAYS WEAR PROTECTIVE EYEWEAR AND GLOVES WHEN PERFORMING MAINTENANCE ON THE LPG OR GASOLINE FUEL SYSTEMS, TO PREVENT SERIOUS INJURY. ALWAYS PERFORM MAINTENANCE PROCEDURES IN A WELL VENTILATED AREA AND INSURE THAT THERE ARE NO EXTERNAL SOURCES OF IGNITION

FUEL SUPPLY AND RETURN LINE MAINTENANCE

Kubota LPG and Gasoline fuel system utilize fuel supply and return lines that are attached by Kubota. These lines are made of special rubber or metal material, which meet the design working pressures, regional requirements, and provide the proper protection from chemicals found in the fuels. It is recommended that all the fuel line connections be leak checked annually at a minimum, or anytime the lines have been removed. The routing of the lines should also be inspected annually, to insure that the lines have not come into contact with any rotating devices, hot surfaces, or are located in a position in which they may be impacted by debris.

LPG PRESSURE REGULATORS

LPG DUAL STAGE REGULATOR (DSR)

The EControls LPG DSR is a two stage mechanical regulator with an integral vaporizer which reduces the fuel inlet or tank pressure to a specific lower pressure and adds heat to the fuel for vaporization. You should check the following items at a minimum of once per year:

- Check for any fuel leaks at the inlet and outlet fittings.
- Check for any fuel leaks at the connecting seams of the regulator body.
- Check the inlet and outlet coolant fittings at the regulator body.
- Check the inlet and outlet coolant lines for hardening, cracking, chaffing or splits. If any of these conditions exist replace the coolant lines.
- Check the inlet and outlet coolant line hose clamps at each connection, tighten if necessary.
- Check the mounting bracket to insure the regulator is securely mounted, tighten if necessary.
- Check any of the rubber isolators used for mounting for cracking, hardening or separation.
- Check the regulator for a buildup of oil in the second stage chamber of the regulator. Drain the oil by opening the drain plug located at the bottom of the secondary chamber.

■ **NOTE**

- **Certain Kubota LPG systems may be fitted with a Direct Electronic Pressure Regulator (DEPR) which is downstream of the DSR. Check these items when inspecting the DEPR:**
- Check the harness connection on the electronic control section, to insure it is seated and locked.
- Check to make sure the DEPR assembly is securely mounted.

■ **NOTE**

- **All EControls LPG systems are fitted with an LPG Fuel Lock Off device which is typically mounted to the inlet of the DSR. These are the additional items when inspecting the regulator:**
- Check for any fuel leaks at the inlet and outlet fittings.
- Check the Lock Off electrical connector, to insure it is seated and locked.
- Check to insure the solenoid retaining nut is tightened and fully seated.

GASOLINE FUEL PRESSURE MANIFOLD

On Bi-fuel and dedicated gasoline engines, fuel is delivered to the gasoline injector rails via an electric fuel pump. The ECM controls fuel delivery pressure via a PWM low side drive circuit connected to the ground terminal of the pump. The ECM increases or decreases the fuel pump's voltage to achieve the desired pressure using pressure feedback information from the gasoline fuel pressure manifold assembly. This manifold assembly also measures the gasoline fuel temperature and provides this information to the ECM. This manifold, along with the electric fuel pump, will be located on the chassis. By closely maintaining the target fuel pressure using minimum pump current flow, a minimal amount of fuel is returned to the tank. The fuel pressure manifold and fuel pump do not require adjustment. The following items must be inspected once per year.

- Check the mounting bracket for the fuel pressure manifold and fuel pump, for cracks or breakage.
- Check the securing method for the fuel pressure manifold and fuel pump to insure the devices are firmly attached.
- Check the electrical connection at both the fuel pressure manifold and fuel pump.

INJECTOR RAIL AND INJECTORS

The injector rail and injectors require no periodic adjustment. You should annually inspect the following items on the fuel rails and injectors.

- Check to make sure the rail bracket is securely attached to the engine.
- Check to make sure the rail brackets have no cracking or breaking.
- Check to make sure that each injector is securely attached to the rail bracket.
- Check each injector electrical connection to insure the connector is securely attached.
- Leak check all the connections on the manifold at each injector connector, and the inlet and outlet fitting at the rail, using an electronic leak detector or a soapy solution.
- Check the injector delivery hose (if used) for any cracking, kinky, cuts, or deformation, and replace if necessary.

ELECTRICAL SYSTEM CHECKS

The electrical system, sensors, wiring harness, and ECM do not require any periodic adjustments. You should annually inspect the following items.

BATTERY

- Check and clean the battery terminal connections and insure the connections are tight.
- Check the battery for any cracks or damage to the case.
- Check the Positive and Negative battery cables for any corrosion build up, rubbing or chaffing, and check ground connections on chassis, to insure they are tight.

ECM CHECKS

- Check the mounting bracket for the EControls ECM, for cracks or breaking.
- Check the controller mounting bracket, securing bolts to insure they are securely fastened.
- Check the rubber isolators for cracks or deterioration.
- Check the electrical connector and insure the connector is securely attached, locked and the secondary lock is in position. Check the connector for any corrosion in the connector, or on the pins. Clean if observed.

WIRE HARNESS CHECKS

- Check the wire harness routing, under the hood, to insure the main harness and injector harness have not come into contact with any rotating devices, hot surfaces, or have come loose from their securing points, and are hanging in an unsafe location.
- Check all wire ties and / or clamps used to secure the harness for cracking, splitting, or breakage, replace if necessary.
- Check the harness routing and insure the harness is securely attached to the frame and protected from any hot surfaces, rotating devices or road debris, repair any unsafe condition.

SENSORS

- While inspecting the wire harness connector for each sensor, check for any damage to the sensor.
- If the sensor is retained by threads or by fasteners, insure the retaining device is fully secured.

IGNITION SYSTEM

- Check ignition coil and spark plug cables for hardening, cracking, chaffing, separation, split boot covers and properly fitted.
- Replace spark plugs at the proper intervals, as prescribed in the recommended maintenance.
- Check to make sure all electrical components are fitted securely.

MISCELLANEOUS ELECTRICAL

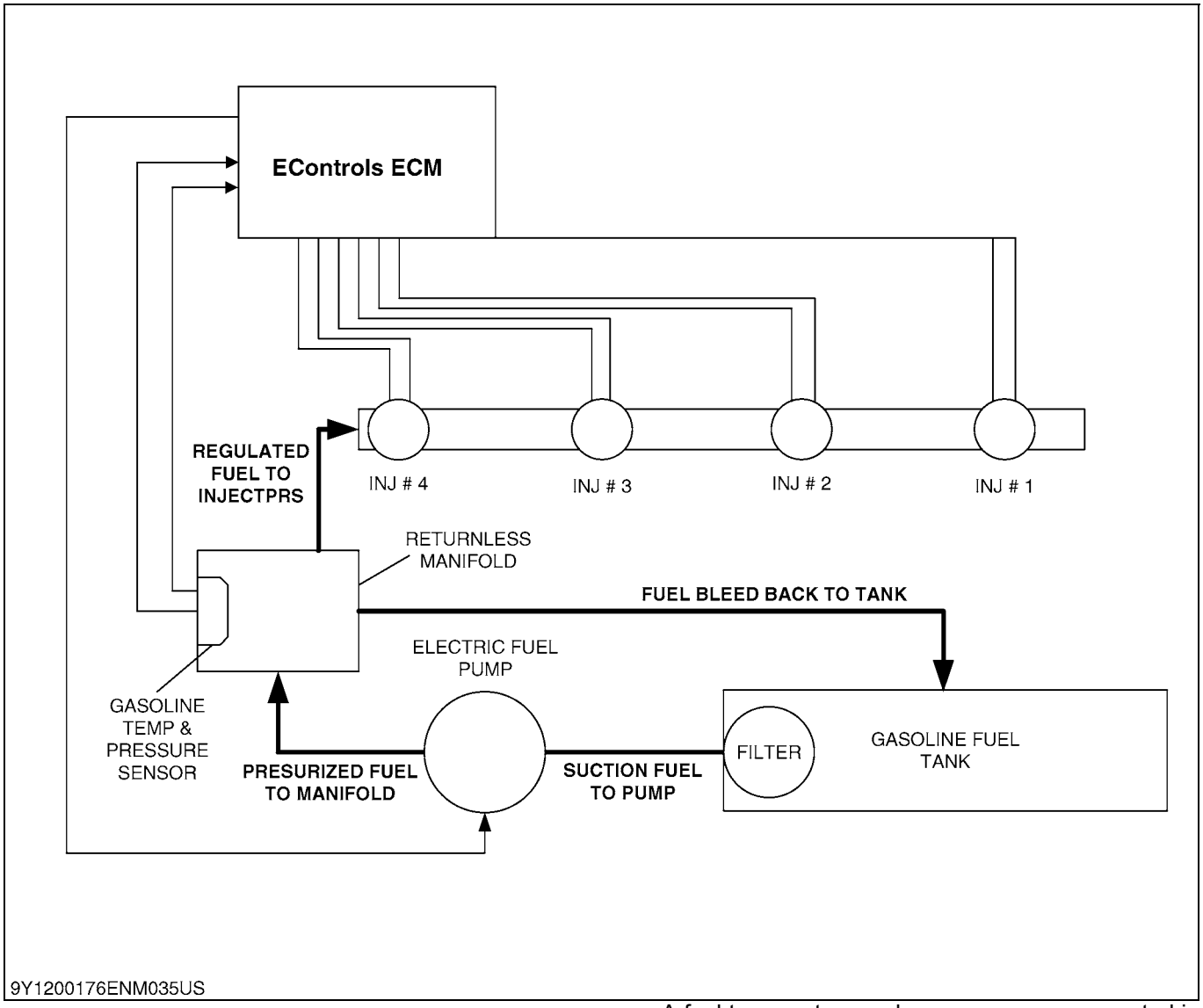
- Check the instrument panel to insure all warning lights are functioning, MIL, oil pressure and temperature gauges are registering
- Check the ignition switch and electrical connectors to insure the connections are fully seated and locked and the tumbler mechanism is working properly

RECOMMEDNED MAINTENANCE

The maintenance schedule represents manufacturers recommended maintenance intervals to maintain proper engine/equipment function. Specific state and federal regulations may require equipment operators to conduct comprehensive engine/equipment inspections at more periodic intervals than those specified above.

[2] FUEL SYSTEM DIAGNOSIS

Gasoline Fuel System Diagnosis



Fuel System Description

Engines which use the EControls gasoline fuel injection system will utilize a gasoline fuel tank which is either part of the chassis or a standalone vessel for the storage of the gasoline. On EControls USA emissions certified engines fuel tanks will not have a vented gasoline tank as the design of the system does not require the use of any vapor recovery from the fuel tank.

When the engine is operating the fuel is being drawn from the tank by the suction created from the fuel pump. A inline fuel filter will be installed either in-line or in the tank to filter out the small contaminants which may be in the fuel prior to reaching the fuel pump.

The EControls ECM controls the fuel pump by varying the supplied voltage to control the outlet pressure. The pump subsequently "pulses", sending pressurized fuel to the Fuel Pressure Manifold.

A fuel temperature and pressure sensor mounted in the manifold measures the gasoline temperature and pressure for feedback to the ECM. By controlling the fuel pump outlet pressure, excess fuel is not being sent to the injector rail and therefore the rail does not have a return line back to the tank. Any excess pressure is allowed to "bleed back" to the tank from the Fuel Pressure Manifold. This method of fuel delivery prevents large amounts of hot fuel from being returned to the tank from the injector rail which would normally cause a vapor build up in the fuel tank and subsequently requiring the need for a vapor recovery system on the engine.

The fuel pressure is controlled by the ECM and therefore to properly measure the pressure, the EControls GCP Display SW is required. On engines where a test port in the fuel rail has been installed, a gauge method can be used to measure pressure.

Diagnostic Aids

This procedure is intended to diagnose a vehicle operating on Gasoline. If the vehicle will not continue to run on Gasoline, refer to Hard Start for preliminary checks. Before proceeding with this procedure, verify that the vehicle has a sufficient quantity of fuel.

Tools Required:

Diagnostic Scan Tool

- EControls GCP Display SW tool.

CAUTION

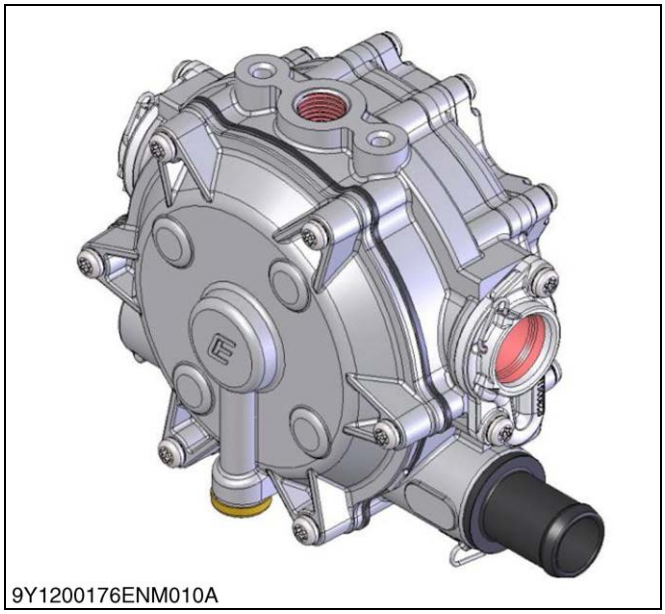
- **To reduce the risk of fire or personal injury that may result form fuel spray on the engine, make sure fuel rails is positioned over injector port and injector retaining clips are intact.**

Gasoline Fuel System Diagnosis

Step	Action	Value(s)	Yes	No
G1	Were you referred to this procedure by a DTC diagnostic chart?	–	Go to Step G3	Go to Step G2
G2	Connect the EControls GCP Display SW tool Perform the On Board Diagnostic (OBD) System Check. Key On Engine Off. System Stopped Mode. Check for DTC 87, 88, 91,92, 627,628,629. Are any fuel pump DTCs present in the ECM? If codes are present follow those procedures first.	–	Go to the applicable DTC Table	Go to Step G3
G3	Verify that the Gasoline fuel tank has a minimum of 1/4 tank of fuel. Does the vehicle have fuel?	–	Go to Step G4	Put fuel into the fuel tank
G4	Check the fuel supply line from the tank to the fuel pump for leakage, crimping, kinks or restriction. Was there a problem found?	–	Go to Step G2	Go to Step G5
G5	Check the electrical connections at the fuel pump and insure they are secured and tightened. Was there a problem found?	–	Go to Step G2	Go to Step G6
G6	Check the Fuel Temperature and Pressure electrical connectors at the Fuel Pressure Manifold. Was there a problem found?	–	Go to Step G2	Go to Step G7
G7	Check the fuel delivery lines, to and from, the Fuel Pressure Manifold for kinks, crimps or blockage of fuel flow. Was there a problem found?	–	Go to Step G2	Go to Step G8
G8	Key Off Engine Off. Remove the fuel inlet hose to the injector rail. Place the hose end into a container Key On Engine Off. Did fuel flow from the hose during the prime sequence?	–	Go to Step G2	Go to Step G9
G9	Key Off Engine Off. Using a volt meter place one probe on the VBAT connector to the fuel pump and ground Key On. Engine Off. Was the voltage > 80 % of VBAT?	> 80 % of VBAT	Go to Step G16	Go to Step G10
G10	Check the 10 Amp fuel pump fuse. Was there a problem found?	–	Go to Step G2	Go to Step G11
G11	Check the fuel pump relay power supply. Key off Engine Off. Using a DVOM place the positive probe on Pin 5 at the fuel pump relay and battery ground Key On. Engine Off. Was the voltage > 80 % of VBAT?	> 80 % of VBAT	Go to Step G16	Go to Step G12
G12	Check the supply voltage to the relay. Using a DVOM place the positive lead on Pin 3 at the relay and battery ground. Was the voltage > 80 % of VBAT?	> 80 % of VBAT	Go to Step G13	Repair Supply voltage wiring

Step	Action	Value(s)	Yes	No
G13	Check the fuel pump signal circuit at the ECM. Using DVOM place the Positive probe at the relay and ground. Key On Engine Off. Was the voltage present?	–	Go to Step G14	Go to Step G15
G14	Replace fuel pump relay. Is this action Complete?	–	Go to Step G2	–
G15	Replace the ECM. Is this action Complete?	–	Go to Step G2	–
G16	Check for restricted fuel pump strainer. Check for plugged fuel filter. Was a problem found?	–	Go to Step G2	–
G17	Replace fuel pump. Is this action Complete?	–	Go to Step G2	–

LPG Fuel System Diagnosis (Open & Closed Loop Systems)


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DUAL STAGE REGULATOR (DSR)

This section of the manual has been prepared to allow the technician to check the mechanical functions, of the regulator and fuel delivery devices, of the EControls "closed loop" fuel control delivery system. The design of the EControls closed loop system is such that, Diagnostic Trouble Codes (DTC) are employed to monitor the fuel delivery system. To properly diagnose fuel delivery system faults, you should first install the EControls GCP diagnostic laptop tool to check for any DTC present in the ECM first, and refer to the proper DTC chart, prior to utilizing this diagnostic section.

The DSR is a combination vaporizer, pressure regulating device. The DSR is a two stage regulator that is a positive pressure regulator that is normally open in the secondary chamber, when the engine is not running. When the engine is cranking or running, pressure from the secondary chamber passes from the regulator to Direct Electronic Pressure Regulators (DEPR), and mixer.

Propane fuel enters the primary port of the DSR, and passes through the primary jet, and into the primary/exchanger chamber. As the propane passes through the heat exchanger, the fuel expands and creates pressure inside the chamber. The pressure rises as the fuel expands. When the pressure rises above 10 kPa (0.11 kgf/cm^2, 1.5 psi), sufficient pressure is exerted on the primary diaphragm, to cause the diaphragm plate, to pivot and press against the primary valve pin, thus closing off the flow of fuel. This action causes the flow of fuel into the regulator, to be regulated. The secondary diaphragm is spring loaded on top of the secondary diaphragm, causing the secondary lever to be pressed down, which opens the secondary seat. When the pressure in the primary chamber enters the secondary chamber, the diaphragm is forced in an upward motion, thus closing the secondary lever against the valve seat. When commanded by the ECM, the DEPR will open, which causes a pressure drop in the secondary seat, and allows the secondary seat to open, and allow fuel to flow to the DEPR. The DEPR regulates the fuel delivery to the mixer, based on the calibration required, for the specific engine load and speed, determined during engine fuel system development.

The DSR requires a connection to the engine coolant, to prevent freezing in the regulator, during the pressure reduction phase, within the regulator. Coolant connections on the DSR are fitted with "Push In" fittings. These fitting are designed with an o-ring seal, which allows the fitting to be pushed into the water connection on the DSR, and are then locked by spring locks, and retained by screws.

The DSR is connected to the DEPR, by a low pressure flexible hose. Like the other fuel hoses used in the fuel system, the low pressure hose is designed with a special inner core and may also be wire reinforced, to prevent collapse of the hose, during high demand fueling operations. The low pressure hose should only be replaced with the recommended Kubota hose replacement.

The packaging of the regulator, into the engine and chassis, has been approved by EControls, to insure continued long term operation, of the fuel delivery and emissions control system.

■ **NOTE**

- **You should never relocate the regulator or any of the fuel system components, as doing so may cause excess build up of oil in the regulator, improper coolant flow, or improper fuel delivery.**

In certain regions, fuel supplies may contain different chemicals and may employ different manufacturing processes to make the LPG, which during the heating of the fuel in the heat exchange section of the regulator, may cause "heavy ends", to accumulate over time. The DSR is attached with a drain plug, to allow the technician to drain excess oil and other contaminants from the regulator. To determine the frequency for draining the regulators, refer to the Recommended Maintenance Schedule.

The regulator utilized on USA emissions certified engines, are a critical part of the certified emissions system, and do not require any periodic adjustment.

(To be continued)

(Continued)

Tools Required:

- 7/16 Open end wrench (for test port plugs)
- Straight Blade screw driver
- DVOM

Diagnostic Scan Tool

- GCP Display Software (laptop)

Pressure Gauges

- 0 to 69 kPa (0 to 0.70 kgf/cm^2, 0 to 10 psi) Gauge

Test Description

The numbers below refer to step numbers, on the diagnostic table which identify faulty components.

1. This step will determine if the DSR primary fuel pressure regulation is correct.
2. This step determines if the LPG Fuel Lock Off is functioning properly
3. This step checks for Plugged filters if attached
4. This step determines if fuel is available, from the fuel tank & supply system.

LPG Fuel System Diagnosis

Step	Action	Value(s)	Yes	No
L1	Were you referred to this procedure by a DTC diagnostic chart?	–	Go to Step L3	Go to Step L2
L2	Connect the EControls GCP display SW (EDIS). Key On Engine Off System Mode Stopped Are any DTCs present in the ECM?	–	Go to the applicable DTC Table	Go to Step L3
L3	Verify that the LPG fuel tank has a minimum 1/4 tank of fuel, and that the manual valve is open. Is the tank valve open and fuel in the tank?	–	Go to Step L4	Refuel tank and Open Valve
L4	Connect a 0 to 69 kPa (0 to 0.70 kgf/cm^2, 0 to10 psi) gauge to the primary test port of the dual stage regulator (DSR). Key On Engine Running System Running Mode Observe the pressure reading, for the DSR primary pressure. Is the fuel pressure **ABOVE** the specified value?	14 to 24 kPa (0.14 to 0.24kgf/cm^2, 2.0 to 3.5 psi)	Go to Step L13	Go to Step L5
L5	Turn OFF the ignition. Disconnect the LPG Fuel lock Off electrical connector. Install a test light between the 12 V supply pin of the LPG Fuel lock-off connector and battery ground, or connect a DVOM between the two pins. Crank the engine. The test light should illuminate or 12 V should be present. Does the test light illuminate?	12 V	Go to Step L6	Go to Step L12
L6	Using a DVOM, check the resistance of the LPG fuel lock-off. Is the resistance within the specified range?	12 to 24 W	Go to Step L7	Go to Step L14
L7	Turn the ignition OFF. Close the manual shut-off valve on the LPG tank. **CAUTION** • **When disconnecting LPG fuel lines, liquid LPG may be present. Perform this step in a well ventilated area.** Slowly loosen the fuel inlet hose fitting, at the inlet of the LPL. Was fuel present, when the fitting was loosened?	–	Go to Step L8B	Go to Step L8A
L8A	Engines fitted with a LPG in-line fuel filter: Slowly loosen the inlet to the fuel filter. Was fuel present, when the fitting was loosened?	–	Go to Step L11	Go to Step L9
L8B	Engines fitted with a integrated filter to the LPL. Remove the filter from the LPL. Empty the contents, of the inlet side of the LPG fuel filter, onto a clean surface. Inspect the contents of the LPG fuel filter, for an excessive amount of foreign material or water. If necessary, locate and repair the source of contamination. Verify if the LPG fuel filter is not restricted or plugged. Was a problem found?	–	Go to Step L11	Go to Step L9

Step	Action	Value(s)	Yes	No
L9	With the fuel line loose at the fuel filter inlet (in-line filter) or at the LPL inlet. Slowly open and close the manual valve. Did fuel begin to flow when the manual valve was opened?	–	Go to Step L14	Go to Step L10
L10	Check the fuel supply system, the hoses are plugged or restricted or the tank valve is not opening. Locate and repair the problem. Is the action complete?	–	Go to Step L16	–
L11	Replace the fuel filter. Refer to Fuel Filter Replacement. Is the action complete?	–	Go to Step L16	–
L12	Repair the open or short, in the lock-off circuit. Is the action complete?	–	Go to Step L16	–
L13	Replace the dual stage regulator (DSR). Refer to Dual Stage Regulator Replacement. Is the action complete?	–	Go to Step L16	–
L14	Replace the lock-off. Refer to Low Pressure Lock-off (LPL) Replacement. Is the action complete?	–	Go to Step L16	–
L15	The fuel supply system is operating normally. Install the test plug, in the DSR secondary chamber. If you were sent to this routine by another diagnostic chart, return to the previous diagnostic procedure. Is the action complete?	–	System OK	–
L16	Disconnect all test equipment. Install the primary and secondary test port plugs, if removed. Start the engine. Using SNOOP® ? or equivalent, leak check the test port plugs, if removed. Is the action complete?	–	System OK	–

(1) Restricted Exhaust System Diagnosis

Exhaust System Description

The emission certified engine has been designed and calibrated to meet the emission standards in effect for 2010. To help meet the emission requirements the vehicle has been attached with a three way catalyst. The catalyst is a three way catalyst, sound damping and spark arresting unit. Besides controlling the noise created from the combustion process, and preventing sparks from escaping from the exhaust system the most important function is treating the exhaust gases which are created from the combustion process. The three-way catalyst consists of a honeycomb core coated with a mixture of precious metals. The hot gases flow through the catalyst honeycomb core where an oxidation and reduction reactions take place. These chemical reactions reduce the amount of CO, HC and NOX in the engines exhaust. The Exhaust gas then flows through the tailpipe outlet.

During normal operation the exhaust system could become damaged. Damage which reduces the flow of the exhaust gas will create increased back pressure in the engine. Reduction in exhaust flow can result from crushed muffler outlets or melted catalyst brick inside the converter.

It may be necessary to measure the back pressure in the exhaust system. To determine if the back pressure in the engine is correct use the following procedure.

Diagnostic Aids

Tools Required:

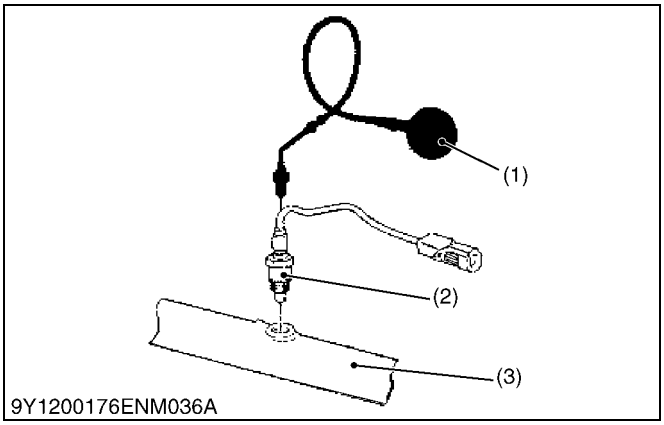
- Back pressure gage 0 to 69 kPa (0 to 0.70 kgf/cm^2, 0 to 10 psi)

Diagnostic Scan Tool:

- EControls GCP Display SW Tool

Check at Heated Exhaust Gas Oxygen Sensor (HEGO)

1. Carefully remove the HEGO.
2. Install exhaust back pressure gage in place of the HEGO Refer to Figure 1.
3. With the engine idling at normal operating temperature, observe the exhaust system back pressure reading on the gage. Reading should not exceed 8.6 kPa (0.088 kgf/cm^2, 1.25 psi).
4. Increase engine speed to 2000 RPM and observe gage. Reading should not exceed 20.7 kPa (0.21 kgf/cm^2, 3 psi).
5. If the back pressure at either speed exceeds specification, a restricted exhaust system is indicated.
6. Inspect the entire exhaust system for a collapsed pipe, heat distress or possible internal muffler failure.
7. If there are no obvious reasons for the excessive back pressure, the catalytic converter is suspected to be restricted and should be replaced using the recommended procedures.



(1) Back Pressure Gage
(2) Oxygen Sensor (O_2S)
(3) Exhaust Manifold

[3] DTC LIST

DTC		16	87	88
Name		Cam/Crank Sensors	FP	FP
DTC Name		Crank and/or Cam Could Not Synchronize During Start	Fuel pressure low	Fuel pressure high
J1939	SPN	636	94	94
	FMI	8	1	0
MIL		ON	ON	ON
Detected Item		• Mechanical misalignment between cam and crank	• Fuel presure abnomality (Low side)	• Fuel presure abnomality (High side)
DTC Set Preconditions		• Engine Cranking or Running	• Engine Running	• Engine Running
DTC Set Conditions		• Cranking revs without sysnc > 4.0 revs • and RPM > 90 min^{-1} (rpm)	• FP fault mode Gasoline only • run time wait for fuel pressure low faults 5.0 sec • FP pressure < 345 kPa (3.52 kgf/cm^2, 50.0 psi)	• FP fault mode Gasoline only • run time wait for fuel pressure high faults 5.0 sec • FP pressure > 448 kPa (4.57 kgf/cm^2, 65.0 psi)
Period for Judgment or Number of Occurrence for Judgment		• 2 sec	• 2 sec	• 2 sec
System Action		• None	• AL Disable KC • Low Rev Limit	• AL Disable KC • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		91	92	107
Name		FP	FP	MAP
DTC Name		FP Low Voltage	FP High Voltage	MAP Low Voltage
J1939	SPN	94	94	106
	FMI	4	3	4
MIL		ON	ON	ON
Detected Item		• Sensor/wiring harness open/short to ground • Sensor malfunction	• Sensor/wiring harness short to power • Sensor malfunction	• Sensor/wiring harness open/short to ground • Sensor malfunction
DTC Set Preconditions		• Engine Running	• Engine Running	• Engine Cranking or Running
DTC Set Conditions		• FP voltage < 0.100 V	• FP voltage > 4.90 V	• MAP voltage < 0.050 V • and TPS > 5.0 % • and RPM < 4000 min^{-1} (rpm)
Period for Judgment or Number of Occurrence for Judgment		• 1 sec	• 5 sec	• 1 sec
System Action		• AL Disable KC • Low Rev Limit	• AL Disable KC • Low Rev Limit	• AL Disable KC • Power derate 1
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		108	111	112
Name		MAP	IAT	IAT
DTC Name		MAP high pressure	IAT Higher Than Expected Stage 1	IAT Low Voltage
J1939	SPN	106	105	105
	FMI	16	15	4
MIL		ON	OFF	OFF
Detected Item		• Sensor/wiring harness short to power • Sensor malfunction	• Intake air temperature abnormality (High side stage 1)	• Sensor/wiring harness short to ground • Sensor malfunction
DTC Set Preconditions		• Engine Cranking or Running	• Engine Running	• Engine Running
DTC Set Conditions		• MAP pressure > 110.3 kPa (1.125 kgf/cm^2, 16.00 psi) • and TPS < 3.0 % • and RPM > 1000 min^{-1} (rpm)	• rum-time wait for all IAT HiExp faults 0.0 sec • IAT > 71 degC (160 degF) • and RPM > 1000 min^{-1} (rpm)	• IAT voltage < 0.100 V
Period for Judgment or Number of Occurrence for Judgment		• 2 sec	• 60 sec	• 1 sec
System Action		• AL Disable KC • Power derate 1	• AL Disable • Power derate 1	• AL Disable • Power derate 1
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		113	116	117
Name		IAT	ECT/CHT	ECT/CHT
DTC Name		IAT High Voltage	ECT Higher Than Expected Stage 1	ECT/CHT Low Voltage
J1939	SPN	105	110	110
	FMI	3	15	4
MIL		OFF	OFF	OFF
Detected Item		• Sensor/wiring harness open/short to power • Sensor malfunction	• Engine coolant temperature abnormality (High side stage 1)	• Sensor/wiring harness short to ground • Sensor malfunction
DTC Set Preconditions		• Engine Running	• Engine Running	• Engine Running
DTC Set Conditions		• IAT voltage > 4.90 V	• run time wait for ECT HiExp faults 30.0 sec • ECT > 110 degC (230 degF) • and RPM > 600 min^{-1} (rpm)	• ECT voltage < 0.100 V
Period for Judgment or Number of Occurrence for Judgment		• 1 sec	• 20 sec	• 1 sec
System Action		• AL Disable • Power derate 1	• AL Disable • Power derate 1	• AL Disable • Power derate 1
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		118	121	122
Name		ECT/CHT	TPS	TPS
DTC Name		ECT/CHT High Voltage	TPS1 % Lower Than TPS2 %	TPS1 Signal Voltage Low
J1939	SPN	110	51	51
	FMI	3	1	4
MIL		OFF	ON	ON
Detected Item		• Sensor/wiring harness open/short to power • Sensor malfunction	• TPS malfunction	• TPS circuit in the harness short to ground • TPS malfunction
DTC Set Preconditions		• Engine Running	• Key-On, Engine Cranking, or Running	• Key-On, Engine Cranking, or Running
DTC Set Conditions		• ECT voltage > 4.90 V	• (TPS1% – TPS2%) < –20.0 %	• TPS1 voltage < 0.200 V
Period for Judgment or Number of Occurrence for Judgment		• 1 sec	• 1 sec	• 0.5 sec
System Action		• AL Disable • Power derate 1	• Shutdown	• Shutdown
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		123	127	134
Name		TPS	IAT	EGO Sensors
DTC Name		TPS1 Signal Voltage High	IAT Higher Than Expected Stage 2	EGO1 Open/Lazy (HO2S1)
J1939	SPN	51	105	3217
	FMI	3	0	5
MIL		ON	OFF	ON
Detected Item		• TPS circuit in the harness short to power • TPS malfunction	• Intake air temperature abnormality (High side stage 2)	• Open feed circuit to O_2 heater • Open heater ground circuit • Open or shorted to ground O_2 signal wire • open sensor ground (5Vrtn1) • inoperative sensor
DTC Set Preconditions		• Key-On, Engine Cranking, or Running	• Engine Running	• Engine Running
DTC Set Conditions		• TPS1 voltage > 4.80 V	• rum-time wait for all IAT HiExp faults 0.0 sec • IAT > 93 degC (200 degF) • and RPM > 1000 min^{-1} (rpm)	• EGO cold persistently > 120.0 sec
Period for Judgment or Number of Occurrence for Judgment		• 0.5 sec	• 120 sec	• 5 sec
System Action		• Shutdown	• AL Disable • Force idle	• CL Disable • AL Disable KC
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		154	171	172
Name		EGO Sensors	Adaptive Learn	Adaptive Learn
DTC Name		EGO2 Open/Lazy (HO2S2)	Adaptive Learn Bank 1 High (Gasoline)	Adaptive Learn Bank1 Low (Gasoline)
J1939	SPN	3227	4237	4237
	FMI	5	0	1
MIL		ON	ON	ON
Detected Item		• Open feed circuit to O_2 heater • Open heater ground circuit • Open or shorted to ground O_2 signal wire • open sensor ground (5Vrtn1) • inoperative sensor	• exhaust leaks upstream or near the HEGO sensor • reduced fuel supply pressure to the fuel injection system • a inoperative sensor • an injector that is stuck closed or dirty • weak spark or lack of spark to a cylinder • a MAP sensor that indicates pressure that is lower than ture pressure	• an inoperative O_2 sensor • high fuel supply pressure or temperature • internal mechanical engine damage • an injector that is stuck open or leaking
DTC Set Preconditions		• Engine Running	• Engine Running, Adaptive Mode	• Engine Running, Adaptive Mode
DTC Set Conditions		• EGO cold persistently > 120.0 sec	• AL_BM > 30 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)	• AL_BM < –30 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)
Period for Judgment or Number of Occurrence for Judgment		• 5 sec	• 3 updates	• 3 updates
System Action		• CL Disable • AL Disable KC	• CL Disable • AL Disable KC	• CL Disable • AL Disable KC
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		182	183	217
Name		FT	FT	ECT/CHT
DTC Name		FT gasoline low	FT gasoline high	ECT Higher Than Expected 2
J1939	SPN	174	174	110
	FMI	4	3	0
MIL		ON	ON	OFF
Detected Item		• Operating in a frigid atmosphere • Sensor out of calibration	• Operating in a hot environment • Sensor out of calibration	• Engine coolant temperature abnormality (High side stage 2)
DTC Set Preconditions		• Engine Running	• Engine Running	• Engine Running
DTC Set Conditions		• FT fault mode Temp only • fuel temp < –37.0 degC (–35.0 degF)	• FT fault mode Temp only • fuel temp > 60.0 degC (140.0 degF)	• run time wait for ECT HiExp faults 30.0 sec • ECT > 116 degC (240 degF) • and RPM > 600 min^{-1} (rpm)
Period for Judgment or Number of Occurrence for Judgment		• 1 sec	• 1 sec	• 30 sec
System Action		• None	• Power derate 2	• Power derate 2
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		219	221	222
Name		Engine Speed	TPS	TPS
DTC Name		RPM Higher Than Max Allowed Governed Speed	TPS1 % Higher Than TPS2 %	TPS2 Signal Voltage Low
J1939	**SPN**	515	51	3673
	FMI	15	0	4
MIL		OFF	ON	ON
Detected Item		• Engine over speed condition, stuck throttle, large vacuum leak into intake manifold after throttle blade	• TPS malfunction	• TPS circuit in the harness short to ground • TPS malfunction
DTC Set Preconditions		• Engine Running	• Key-On, Engine Cranking, or Running	• Key-On, Engine Cranking, or Running
DTC Set Conditions		• RPM > 3800 min^{-1} (rpm)	• (TPS1% – TPS2%) > 20.0 %	• TPS2 voltage < 0.200 V
Period for Judgment or Number of Occurrence for Judgment		• 1 sec	• 1 sec	• 0.5 sec
System Action		• reduce throttle to limit speed	• Shutdown	• Shutdown
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		223	261	262
Name		TPS	Injectors	Injectors
DTC Name		TPS2 Signal Voltage High	Injector Driver #1 Open/Short-To-Ground	Injector Driver #1 Short-To-Power
J1939	**SPN**	3673	651	651
	FMI	3	5	6
MIL		ON	ON	ON
Detected Item		• TPS circuit in the harness short to power • TPS malfunction	• Loss of 12.0 V feed to injector • open injector coil • open or shorted to ground injector driver circuit in engine harness	• Injector coil shorted internally • Injector driver circuit shorted to voltage between injector and ECM
DTC Set Preconditions		• Key-On, Engine Cranking, or Running	• Key-On, Engine Running	• Key-On, Engine Running
DTC Set Conditions		• TPS2 voltage > 4.80 V	• Injector1 off-state low-side < 4.00 V • and battery voltage > 9.00 V	• Injector1 on-state low-side > 4.00 V • and battery voltage < 16.0 V
Period for Judgment or Number of Occurrence for Judgment		• 0.5 sec	• 10 samples	• 10 samples
System Action		• Shutdown	• CL Disable • AL Disable KC • Low Rev Limit	• CL Disable • AL Disable KC • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		264	265	267
Name		Injectors	Injectors	Injectors
DTC Name		Injector Driver #2 Open/Short-To-Ground	Injector Driver #2 Short-To-Power	Injector Driver #3 Open/Short-To-Ground
J1939	SPN	652	652	653
	FMI	5	6	5
MIL		ON	ON	ON
Detected Item		• Loss of 12.0 V feed to injector • open injector coil • open or shorted to ground injector driver circuit in engine harness	• Injector coil shorted internally • Injector driver circuit shorted to voltage between injector and ECM	• Loss of 12.0 V feed to injector • open injector coil • open or shorted to ground injector driver circuit in engine harness
DTC Set Preconditions		• Key-On, Engine Running	• Key-On, Engine Running	• Key-On, Engine Running
DTC Set Conditions		• Injector2 off-state low-side < 4.00 V • and battery voltage > 9.00 V	• Injector2 on-state low-side > 4.00 V • and battery voltage < 16.0 V	• Injector3 off-state low-side < 4.00 V • and battery voltage > 9.00 V
Period for Judgment or Number of Occurrence for Judgment		• 10 samples	• 10 samples	• 10 samples
System Action		• CL Disable • AL Disable KC • Low Rev Limit	• CL Disable • AL Disable KC • Low Rev Limit	• CL Disable • AL Disable KC • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		268	270	271
Name		Injectors	Injectors	Injectors
DTC Name		Injector Driver #3 Short-To-Power	Injector Driver #4 Open/Short-To-Ground	Injector Driver #4 Short-To-Power
J1939	SPN	653	654	654
	FMI	6	5	6
MIL		ON	ON	ON
Detected Item		• Injector coil shorted internally • Injector driver circuit shorted to voltage between injector and ECM	• Loss of 12.0 V feed to injector • open injector coil • open or shorted to ground injector driver circuit in engine harness	• Injector coil shorted internally • Injector driver circuit shorted to voltage between injector and ECM
DTC Set Preconditions		• Key-On, Engine Running	• Key-On, Engine Running	• Key-On, Engine Running
DTC Set Conditions		• Injector3 on-state low-side > 4.00 V • and battery voltage < 16.0 V	• Injector4 off-state low-side < 4.00 V • and battery voltage > 9.00 V	• Injector4 on-state low-side > 4.00 V • and battery voltage < 16.0 V
Period for Judgment or Number of Occurrence for Judgment		• 10 samples	• 10 samples	• 10 samples
System Action		• CL Disable • AL Disable KC • Low Rev Limit	• CL Disable • AL Disable KC • Low Rev Limit	• CL Disable • AL Disable KC • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		326	327	336
Name		Knock	Knock	Cam/Crank Sensors
DTC Name		Knock 1 Excessive or Erratic Signal	Knock 1 Sensor Open or Not Present	Crank Input Signal Noise
J1939	**SPN**	731	731	636
	FMI	2	4	2
MIL		ON	ON	ON
Detected Item		• Knock signal abnormality (High side) • Sensor malfunction	• Sensor/wiring harness open/short to power • Sensor malfunction	• Crank+ or Crank– circuits in wrong connector terminal slot
DTC Set Preconditions		• Key On, Engine On	• Key On, Engine On	• Key On, Engine On
DTC Set Conditions		• KNK1 sensor input > 0.500 V • MAP < 55.2 kPa (0.562 kgf/cm^2, 8.00 psi)	• KNK1 sensor input < 0.005 V • and RPM > 2000 min^{-1} (rpm) • and MAP > 82.7 kPa (0.844 kgf/cm^2, 12.00 psi)	• Number of invalid cam re-syncs 3 re-syncs • within a time window of <= 800 ms
Period for Judgment or Number of Occurrence for Judgment		• 3 sec	• 10 sec	• 1 sec
System Action		• Power derate 1 • Retard Fault KNK	• Power derate 1 • Retard Fault KNK	• AL Disable KC
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		337	341	342
Name		Cam/Crank Sensors	Cam/Crank Sensors	Cam/Crank Sensors
DTC Name		Loss of Crankshaft Input Signal	Camshaft Input Signal Noise	Loss of Camshaft Input Signal
J1939	**SPN**	636	723	723
	FMI	4	2	4
MIL		ON	ON	ON
Detected Item		• Loss of sensor feed • open sensor ground • open or shorted to ground signal wire	• Cam+ or Cam– circuits in wrong connector terminal slot	• Loss of feed voltage to Cam sensor • loss of signal or ground circuits • faulty sensor
DTC Set Preconditions		• Key On, Engine On	• Key On, Engine On	• Key On, Engine On
DTC Set Conditions		• Cam pulsed without crank activity > 3 cam pulses	• Number of invalid cam re-syncs 3 re-syncs • within a time window of <= 700 ms	• No cam pulse in 2.0 cycles • and RPM > 150 min^{-1} (rpm)
Period for Judgment or Number of Occurrence for Judgment		• 1 sec	• 1 sec	• 1 sec
System Action		• None	• AL Disable KC	• AL Disable KC
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		359	420	524
Name		Lockoff/Fuel Diagnostics	Catalyst	Oil Pressure
DTC Name		Fuel run-out longer than expected	Catalyst Monitor	Oil Pressure Low
J1939	**SPN**		3050	100
	FMI		11	1
MIL		ON	OFF	ON
Detected Item				• Low Oil Pressure
DTC Set Preconditions		• Key Off, Engine On	• Engine Running	• Key On, Engine On
DTC Set Conditions		• Fuel run-out engine run time > 20000 ms	• EGO3/4 RMS > 0.008 phi • and EGO3/4 RMS > EGO1/2 RMS 50 % • and EGO3/4 RMS > CL waveform RMS 50 % • and mass flow at ports >= 10.0 g/sec and <= CBT −CBT_ss +/− 50.0 degF	• run time wait for oil pressure low faults 4.0 sec • RPM lower limit for oil pressure low faults 300 min^{-1} (rpm) • Oil pressure pulled-up input less than a threshold voltage of 2.50 V
Period for Judgment or Number of Occurrence for Judgment		• N/A	• 100 updates	• 1 sec
System Action		• Shutdown	• Shutdown • CL Disable • AL Disable • Hard Warning	• Shutdown
Engine Warning Light		OFF	ON	ON Hard Warning

DTC		562	563	601
Name		Battery Voltage	Battery Voltage	Internal Processor Diagnostics
DTC Name		Battery Voltage (VBAT) Low	Battery Voltage (VBAT) High	Microprocessor Failure-FLASH
J1939	**SPN**	168	168	628
	FMI	17	15	13
MIL		ON	ON	ON
Detected Item		• Wiring harness open/short/damage • Battery abnormality	• System voltage abnormality (High side)	• Faulty ECU
DTC Set Preconditions		• Key On, Engine On	• Key-On, Engine Cranking, or Running	• Key on
DTC Set Conditions		• Voltage < 9.00 V • and RPM > 1000 min^{-1} (rpm)	• Voltage > 16.00 V	• Internal microprocessor error
Period for Judgment or Number of Occurrence for Judgment		• 5 sec	• 3 sec	• N/A
System Action		• AL Disable KC • Power derate 2	• AL Disable KC • Low Rev Limit	• Never Forget • AL Disable KC • Power derate 2
Engine Warning Light		ON Hard Warning	ON Hard Warning	OFF

DTC		604	606	627
Name		Internal Processor Diagnostics	Internal Processor Diagnostics	Fuel Pump Relay Control/Coil
DTC Name		Microprocessor Failure-RAM	Microprocessor Failure-COP	Fuel Pump Relay Coil Open
J1939	SPN	630	629	1348
	FMI	12	31	5
MIL		ON	ON	ON
Detected Item		• Faulty ECU	• Faulty ECU	• Open coil in relay • Open in relay driver circuit in engine harness
DTC Set Preconditions		• Key on	• Key on	• Key On, Engine Off
DTC Set Conditions		• Internal ECM microprocessor memory access failure	• Internal microprocessor error	• Fuel Pump relay coil output open circuit
Period for Judgment or Number of Occurrence for Judgment		• N/A	• N/A	• 10 samples
System Action		• Never Forget • AL Disable KC • Power derate 2	• Never Forget • AL Disable KC • Power derate 2	• None
Engine Warning Light		OFF	OFF	ON Hard Warning

DTC		628	629	642
Name		Fuel Pump Relay Control/Coil	Fuel Pump Relay Control/Coil	5 V External
DTC Name		Fuel Pump Relay Ground Short	Fuel Pump Relay Coil Short-To-Power	Sensor Supply Voltage 1 Low (5Vext1)
J1939	SPN	1347	1347	1079
	FMI	5	6	4
MIL		ON	ON	ON
Detected Item		• Relay pull in coil shorted internally • relay driver circuit shorted to ground in wire harness	• Shorted relay pull in coil • relay driver circuit shorted to voltage in wire harness	• Wiring harness short to ground • ECM malfunction
DTC Set Preconditions		• Key On, Engine Off	• Key On, Engine Off	• Key-On, Engine OFF, or Running
DTC Set Conditions		• Fuel Pump relay coil output shorted to ground	• Fuel Pump relay coil output short to power/voltage	• 5VE1 < 4.60 V
Period for Judgment or Number of Occurrence for Judgment		• 10 samples	• 10 samples	• 1 sec
System Action		• None	• None	• AL Disable • Power derate 1
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		643	652	653
Name		5 V External	5 V External	5 V External
DTC Name		Sensor Supply Voltage 1 High (5Vext1)	Sensor Supply Voltage 2 Low (5Vext2)	Sensor Supply Voltage 2 High (5Vext2)
J1939	SPN	1079	1080	1080
	FMI	3	4	3
MIL		ON	ON	ON
Detected Item		• Wiring harness short to 12.0 V power • ECM malfunction	• Wiring harness short to ground • ECM malfunction	• Wiring harness short to 12.0 V power • ECM malfunction
DTC Set Preconditions		• Key-On, Engine OFF, or Running	• Key-On, Engine OFF, or Running	• Key-On, Engine OFF, or Running
DTC Set Conditions		• 5VE1 > 5.40 V	• 5VE2 < 4.60 V	• 5VE2 > 5.40 V
Period for Judgment or Number of Occurrence for Judgment		• 1 sec	• 1 sec	• 1 sec
System Action		• AL Disable • Power derate 1	• AL Disable • Power derate 1	• AL Disable • Power derate 1
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		686	687	1111
Name		Power Relay Control/Coil	Power Relay Control/Coil	Engine Speed
DTC Name		Power Relay Ground Short	Power Relay Coil Short-To-Power	RPM Above Fuel Rev Limit Level
J1939	SPN	1485	1485	515
	FMI	4	3	16
MIL		ON	ON	ON
Detected Item		• Short to ground in relay pull in coil • short to ground in relay driver circuit in wire harness	• Shorted relay pull in coil • relay driver circuit shorted to voltage in wire harness	• Engine overspeed condition, faulty Crank sensor or input
DTC Set Preconditions		• Key On, Engine Off	• Key On, Engine Off	• Engine Running
DTC Set Conditions		• Power relay coil output shorted to ground	• Power relay coil output short to power/voltage	• RPM > 4200 min^{-1} (rpm)
Period for Judgment or Number of Occurrence for Judgment		• 10 samples	• 10 samples	• 1 sec
System Action		• None	• None	• disable fuel injectors or gaseous fuel control actuator
Engine Warning Light		OFF	OFF	ON Hard Warning

DTC		1112	1151	1152
Name		Engine Speed	Closed Loop	Closed Loop
DTC Name		RPM Above Spark Rev Limit Level	Closed Loop High (LPG)	Closed Loop Low (LPG)
J1939	SPN	515	4236	4236
	FMI	0	0	1
MIL		ON	ON	ON
Detected Item		• Engine overspeed condition, faulty Crank sensor or input	• exhaust leaks upstream or near the HEGO sensor • reduced fuel supply pressure to the gaseous fuel control system • a fuel supply or manifold leak • a non-responsive HEGO sensor	• high fuel supply pressure to the gaseous fuel control or faulty pressure regulator • a non-responsive HEGO sensor
DTC Set Preconditions		• Engine Running	• Engine Running, Closed Loop Mode	• Engine Running, Closed Loop Mode
DTC Set Conditions		• RPM > 4300 min^{-1} (rpm)	• CL_BM > 35 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)	• CL_BM < –35 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)
Period for Judgment or Number of Occurrence for Judgment		• 1 sec	• 5 updates	• 5 updates
System Action		• disable ignition coils	• CL Disable • AL Disable KC	• CL Disable • AL Disable KC
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		1153	1154	1155
Name		Closed Loop	Closed Loop	Closed Loop
DTC Name		Closed Loop High (NG)	Closed Loop Low (NG)	Closed Loop Bank 1 High (Gasoline)
J1939	SPN	4236	4236	4236
	FMI	0	1	0
MIL		ON	ON	ON
Detected Item		• exhaust leaks upstream or near the HEGO sensor • reduced fuel supply pressure to the gaseous fuel control system • a fuel supply or manifold leak • a non-responsive HEGO sensor	• high fuel supply pressure to the gaseous fuel control or faulty pressure regulator • a non-responsive HEGO sensor	• exhaust leaks upstream or near the HEGO sensor • reduced fuel supply pressure • an injector that is stuck closed
DTC Set Preconditions		• Engine Running, Closed Loop Mode	• Engine Running, Closed Loop Mode	• Engine Running, Closed Loop Mode
DTC Set Conditions		• CL_BM > 35 % • and RPM <= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)	• CL_BM < –35 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)	• CL_BM > 35 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)
Period for Judgment or Number of Occurrence for Judgment		• 5 updates	• 5 updates	• 5 updates
System Action		• CL Disable • AL Disable KC	• CL Disable • AL Disable KC	• CL Disable • AL Disable KC
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		1156	1161	1162
Name		Closed Loop	Adaptive Learn	Adaptive Learn
DTC Name		Closed Loop Bank 1 Low (Gasoline)	Adaptive Learn High (LPG)	Adaptive Learn Low (LPG)
J1939	**SPN**	4236	4237	4237
	FMI	1	0	1
MIL		ON	ON	ON
Detected Item		• high fuel supply pressure to the fuel injection system • a non-responsive HEGO sensor • an injector that is stuck open	• exhaust leaks upstream or near the HEGO sensor • reduced fuel supply pressure to the gaseous fuel control system • a fuel supply or manifold leak • a non-responsive HEGO sensor	• high fuel supply pressure to the gaseous fuel control or faulty pressure regulator • a non-responsive HEGO sensor
DTC Set Preconditions		• Engine Running, Closed Loop Mode	• Engine Running, Adaptive Mode	• Engine Running, Adaptive Mode
DTC Set Conditions		• CL_BM < −35 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)	• AL_BM > 30 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)	• AL_BM < −30 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)
Period for Judgment or Number of Occurrence for Judgment		• 5 updates	• 3 updates	• 3 updates
System Action		• CL Disable • AL Disable KC	• CL Disable • AL Disable KC	• CL Disable • AL Disable KC
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		1163	1164	1165
Name		Adaptive Learn	Adaptive Learn	Catalyst
DTC Name		Adaptive Learn High (NG)	Adaptive Learn Low (NG)	Catalyst inactive on LPG
J1939	**SPN**	4237	4237	3050
	FMI	0	1	11
MIL		ON	ON	OFF
Detected Item		• exhaust leaks upstream or near the HEGO sensor • reduced fuel supply pressure to the gaseous fuel control system • a fuel supply or manifold leak • a non-responsive HEGO sensor	• high fuel supply pressure to the gaseous fuel control or faulty pressure regulator • a non-responsive HEGO sensor	
DTC Set Preconditions		• Engine Running, Adaptive Mode	• Engine Running, Adaptive Mode	• Engine Running
DTC Set Conditions		• AL_BM > 30 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)	• AL_BM < –30 % • and RPM >= 0 min^{-1} (rpm) • and RPM <= 9999 min^{-1} (rpm) • and MAP >= 0.0 kPa (0.0 kgf/cm^2, 0.0 psia) • and MAP <= 682 kPa (6.96 kgf/cm^2, 99.0 psia)	• EGO3/4 RMS > 0.008 phi • and EGO3/4 RMS > EGO1/2 RMS 50 % • and EGO3/4 RMS > CL waveform RMS 50 % • and mass flow at ports >= 10.0 g/sec and <= CBT –CBT_ss +/– 50.0 degF
Period for Judgment or Number of Occurrence for Judgment		• 3 updates	• 3 updates	• 100 updates
System Action		• CL Disable • AL Disable KC	• CL Disable • AL Disable KC	• Shutdown • CL Disable • AL Disable • Hard Warning
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON

DTC		1166	1173	1612
Name		Catalyst	Megajector	Internal Processor Diagnostics
DTC Name		Catalyst inactive on NG	Megajector comm lost	Microprocessor Failure-RTI 1
J1939	SPN	3050	520620	629
	FMI	11	31	31
MIL		OFF	OFF	ON
Detected Item				• Faulty ECU
DTC Set Preconditions		• Engine Running	• Engine Running	• Key on
DTC Set Conditions		• EGO3/4 RMS > 0.008 phi • and EGO3/4 RMS > EGO1/2 RMS 50 % • and EGO3/4 RMS > CL waveform RMS 50 % • and mass flow at ports >= 10.0 g/sec and <= CBT −CBT_ss +/− 50.0 degF		• Internal microprocessor error
Period for Judgment or Number of Occurrence for Judgment		• 100 updates		• N/A
System Action		• CL Disable • AL Disable KC	• CL Disable • AL Disable KC	• Shutdown • CL Disable • AL Disable • Hard Warning
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON

DTC		1613	1614	1615
Name		Internal Processor Diagnostics	Internal Processor Diagnostics	Internal Processor Diagnostics
DTC Name		Microprocessor Failure-RTI 2	Microprocessor Failure-RTI 3	Microprocessor Failure-A/D
J1939	SPN	629	629	629
	FMI	31	31	31
MIL		ON	ON	ON
Detected Item		• Faulty ECU	• Faulty ECU	• Faulty ECU
DTC Set Preconditions		• Key on	• Key on	• Key on
DTC Set Conditions		• Internal microprocessor error	• Internal microprocessor error	• Internal microprocessor error
Period for Judgment or Number of Occurrence for Judgment		• N/A	• N/A	• N/A
System Action		• Never Forget • AL Disable KC • Power derate 2	• Never Forget • AL Disable KC • Power derate 2	• Never Forget • AL Disable KC • Power derate 2
Engine Warning Light		OFF	OFF	OFF

DTC		1616	2111	2112
Name		Internal Processor Diagnostics	TPS	TPS
DTC Name		Microprocessor Failure-Interrupt	Unable to Reach Lower TPS	Unable to Reach Higher TPS
J1939	SPN	629	51	51
	FMI	31	7	7
MIL		ON	ON	ON
Detected Item		• Faulty ECU	• TPS malfunction	• TPS malfunction
DTC Set Preconditions		• Key on	• Cranking or Running	• Cranking or Running
DTC Set Conditions		• Internal microprocessor error	• target TPS-actual TPS < –20.0 % • persistently longer than 200 ms while battery voltage > 9.00 V and battery voltage < 16.0 V	• target TPS-actual TPS > 20.0 % • persistently longer than 200 ms while battery voltage > 9.00 V and battery voltage < 16.0 V
Period for Judgment or Number of Occurrence for Judgment		• N/A	• 1 sec	• 1 sec
System Action		• Never Forget • AL Disable KC • Power derate 2	• Shutdown	• Shutdown
Engine Warning Light		OFF	ON Hard Warning	ON Hard Warning

DTC		2115	2116	2122
Name		FPP	FPP	FPP
DTC Name		FPP1 higher than IVS	FPP2 higher than IVS	FPP1 Voltage High
J1939	SPN	51	29	91
	FMI	0	0	3
MIL		ON 2Hz	ON 2Hz	ON 2Hz
Detected Item		• Wiring harness open/short/damage • FPP malfunction • IVS malfunction	• Wiring harness open/short/damage • FPP malfunction • IVS malfunction	• Wiring harness open/short/damage • FPP malfunction
DTC Set Preconditions		• Engine Cranking or Running	• Engine Cranking or Running	• Key On
DTC Set Conditions		• IVS at-idle when FPP1 >1.20 V	• IVS at-idle when FPP2 >1.20 V	• FPP1 voltage > 4.80 V
Period for Judgment or Number of Occurrence for Judgment		• 0.5 sec	• 0.5 sec	• 0.5 sec
System Action		• Power derate 2 • Low Rev Limit	• Power derate 2 • Low Rev Limit	• Power derate 1 • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		2123	2127	2128
Name		FPP	FPP	FPP
DTC Name		FPP1 Voltage Low	FPP2 voltage low	FPP2 voltage high
J1939	SPN	91	29	29
	FMI	4	4	3
MIL		ON 2Hz	ON 2Hz	ON 2Hz
Detected Item		• Wiring harness open/short/damage • FPP malfunction	• Wiring harness open/short/damage • FPP malfunction	• Wiring harness open/short/damage • FPP malfunction
DTC Set Preconditions		• Key On, Engine Off	• Key On	• Key On
DTC Set Conditions		• FPP1 voltage < 0.200 V	• FPP1 voltage < 0.200 V	• FPP1 voltage > 4.80 V
Period for Judgment or Number of Occurrence for Judgment		• 0.5 sec	• 0.5 sec	• 0.5 sec
System Action		• Power derate 1 • Low Rev Limit	• Power derate 1 • Low Rev Limit	• Power derate 1 • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

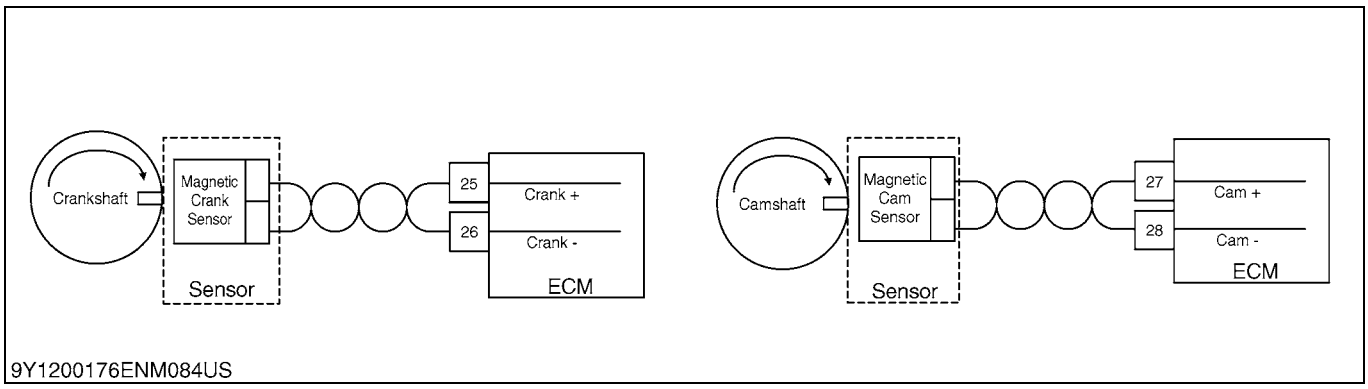
DTC		2135	2139	2140
Name		TPS	FPP	FPP
DTC Name		TPS1/2 Simultaneous Voltages out of range	FPP1 lower than IVS	FPP2 lower than IVS
J1939	SPN	51	91	29
	FMI	31	1	1
MIL		ON	ON 2Hz	ON 2Hz
Detected Item		• TPS malfunction	• Wiring harness open/short/damage • FPP malfunction • IVS malfunction	• Wiring harness open/short/damage • FPP malfunction • IVS malfunction
DTC Set Preconditions		• Key On, Engine On	• Engine Cranking or Running	• Engine Cranking or Running
DTC Set Conditions		• User same parameter as individual TPS1/2 voltage fault detection above	• IVS off-idle when FPP1 < 0.600 V or • IVS off-idle if FPP1 @idle fault and FPP1<FPP1 learned idle + 0.050 V (Disabled)	• IVS off-idle when FPP2 < 0.600 V or • IVS off-idle if FPP2 @idle fault and FPP2 < FPP2 learned idle+0.050 V (Disabled)
Period for Judgment or Number of Occurrence for Judgment		• 0.5 sec	• 0.5 sec	• 0.5 sec
System Action		• Shutdown	• Power derate 2 • Low Rev Limit	• Power derate2 • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		2300	2301	2303
Name		Spark Coil Primary	Spark Coil Primary	Spark Coil Primary
DTC Name		Spark Coil #1 Primary Open/Short-to-Ground	Spark Coil #1 Primary Short-to-Power	Spark Coil #2 Primary Open/Short-to-Ground
J1939	SPN	1268	1268	1269
	FMI	5	6	5
MIL		ON	ON	ON
Detected Item		• a short to ground or open circuit in the harness • an open internal to the primary coil	• a short to power in the harness • a short internal to the primary coil	• a short to ground or open circuit in the harness • an open internal to the primary coil
DTC Set Preconditions		• Key On, Engine On	• Key On, Engine On	• Key On, Engine On
DTC Set Conditions		• Adaptive dwell adjustment >= 2.0 ms • or total dwell >= 14.0 ms • and battery voltage > 11.0 V	• Adaptive dwell adjustment <= −2.0 ms • or total dwell <= 4.0 ms • and battery voltage < 16.0 V	• Adaptive dwell adjustment >= 2.0 ms • or total dwell >= 14.0 ms • and battery voltage > 11.0 V
Period for Judgment or Number of Occurrence for Judgment		• 10 sparks	• 10 sparks	• 10 sparks
System Action		• CL Disable • AL Disable • Low Rev Limit	• CL Disable • AL Disable • Low Rev Limit	• CL Disable • AL Disable • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		2304	2306	2307
Name		Spark Coil Primary	Spark Coil Primary	Spark Coil Primary
DTC Name		Spark Coil #2Primary Short-to-Power	Spark Coil #3 Primary Open/Short-to-Ground	Spark Coil #3 Primary Short-to-Power
J1939	SPN	1269	1270	1270
	FMI	6	5	6
MIL		ON	ON	ON
Detected Item		• a short to power in the harness • a short internal to the primary coil	• a short to ground or open circuit in the harness • an open internal to the primary coil	• a short to power in the harness • a short internal to the primary coil
DTC Set Preconditions		• Key On, Engine On	• Key On, Engine On	• Key On, Engine On
DTC Set Conditions		• Adaptive dwell adjustment <= −2.0 ms • or total dwell <= 4.0 ms • and battery voltage < 16.0 V	• Adaptive dwell adjustment >= 2.0 ms • or total dwell >= 14.0 ms • and battery voltage > 11.0 V	• Adaptive dwell adjustment <= −2.0 ms • or total dwell <= 4.0 ms • and battery voltage < 16.0 V
Period for Judgment or Number of Occurrence for Judgment		• 10 sparks	• 10 sparks	• 10 sparks
System Action		• CL Disable • AL Disable • Low Rev Limit	• CL Disable • AL Disable • Low Rev Limit	• CL Disable • AL Disable • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning	ON Hard Warning

DTC		2309	2310
Name		Spark Coil Primary	Spark Coil Primary
DTC Name		Spark Coil #4 Primary Open/Short-to-Ground	Spark Coil #4 Primary Short-to-Power
J1939	**SPN**	1271	1271
	FMI	5	6
MIL		ON	ON
Detected Item		• a short to ground or open circuit in the harness • an open internal to the primary coil	• a short to power in the harness • a short internal to the primary coil
DTC Set Preconditions		• Key On, Engine On	• Key On, Engine On
DTC Set Conditions		• Adaptive dwell adjustment >= 2.0 ms • or total dwell >= 14.0 ms • and battery voltage > 11.0 V	• Adaptive dwell adjustment <= −2.0 ms • or total dwell <= 4.0 ms • and battery voltage < 16.0 V
Period for Judgment or Number of Occurrence for Judgment		• 10 sparks	• 10 sparks
System Action		• CL Disable • AL Disable • Low Rev Limit	• CL Disable • AL Disable • Low Rev Limit
Engine Warning Light		ON Hard Warning	ON Hard Warning

[4] Diagnosis Procedure by DTC
(1) Crank/Cam Sensors (DTC 16, 336, 337, 341, 342)



9Y1200176ENM084US

DTC 16-Crank and/or Cam Could Not Synchronize During Start

- Hardware: Crankshaft Position Sensor/Camshaft Position Sensor Input Circuits
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: Engine cranking longer than 4 revolutions above 90 min^{-1} (rpm) without crank and/or cam synchronization
- Corrective Action(s): Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp
- Emissions related fault
- Possible causes: Mechanical misalignment between cam and crank, CMP or CKP signal (+)/ground (–) wires misplaced in connectors, bad ECM

The crankshaft position sensor is a magnetic pick-up sensor installed in the engine block adjacent to a "coded" trigger wheel located on the flywheel. The sensor-trigger wheel combination is used to determine crankshaft position (with respect to TDC cylinder #1 compression) and the rotational engine speed. Determination of the crankshaft position and speed is necessary to properly activate the ignition, fuel injection, and throttle governing systems for precise engine control.

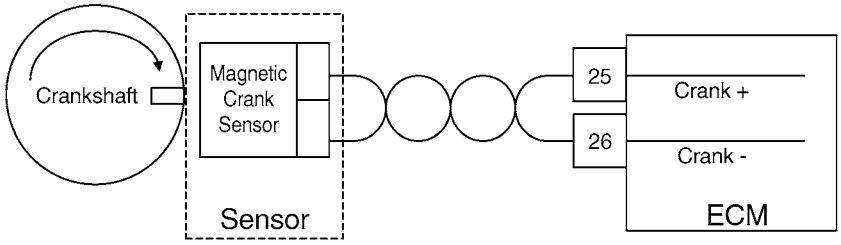
The camshaft position sensor is a magnetic pick-up sensor installed in the engine block or valve train adjacent to a "coded" trigger wheel located on or off of the camshaft. The sensor-trigger wheel combination is used to determine cam position (with respect to TDC cylinder #1 compression). Determination of the camshaft position is necessary to identify the stroke (or cycle) of the engine to properly activate the fuel injection system and ignition (for coil-on-plug engines) for precise engine control.

Typically, this fault will result in an engine that will not start or run.

DTC 16-Crank and/or Cam Could Not Synchronize During Start

Diagnostic Aids

- If there are any other CMP or CKP DTC's, diagnose them first
- Ensure that all 3 terminals are in the correct slot in the connector for both the CMP and the CKP sensors
- Ensure that the cam and crank are properly installed and timed
- Check that crankshaft and/or camshaft position sensor(s) is/are securely connected to harness
- Check that crankshaft and/or camshaft position sensor(s) is/are securely installed into engine block
- Check crankshaft and/or camshaft position sensor(s) circuit(s) wiring for open circuit
- Connect a 2 channel oscilloscope, scope CMP and CKP inputs and compare to known good waveforms



9Y1200176ENM127US

DTC 336-Crank Input Signal Noise

- Hardware: Crankshaft Position sensor
- Enabling Conditions: Key On, Engine On
- Set Conditions: Electrical noise or irregular crank pattern detected causing more than 1 crank re-synchronization events in less than 800 ms
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn function for the rest of the key cycle.
- Emissions related fault
- Possible Causes: CKP+ or CKP– circuits in wrong connector terminal slot, improper CKP signal due to sensor air gap too large, excessive metal on sensor tip, improper wiring, intermittent connection in sensor circuitry, intermittent sensor internal problem

The crankshaft position sensor is a magnetic pick-up sensor installed in the engine block adjacent to a "coded" trigger wheel located on the flywheel. The sensor-trigger wheel combination is used to determine crankshaft position (with respect to TDC cylinder #1 compression) and the rotational engine speed. Determination of the crankshaft position and speed is necessary to properly activate the ignition, fuel injection, and throttle governing systems for precise engine control.

The ECM must see a valid crankshaft position signal while running. If no signal is present, the signal amplitude is too high (due to improper air gap with respect to trigger wheel), or an irregular crank pattern is detected causing the ECM to resynchronize x times for y ms or longer as defined in the diagnostic calibration (see set conditions above), this fault will set. Irregular crank patterns can be detected by the ECM due to electrical noise, poor machining of trigger wheel, or trigger wheel run out and/or gear lash.

Ensure crank circuit used with VR/magnetic pick-up sensors are properly twisted.

DTC 337-Loss of Crankshaft Input Signal

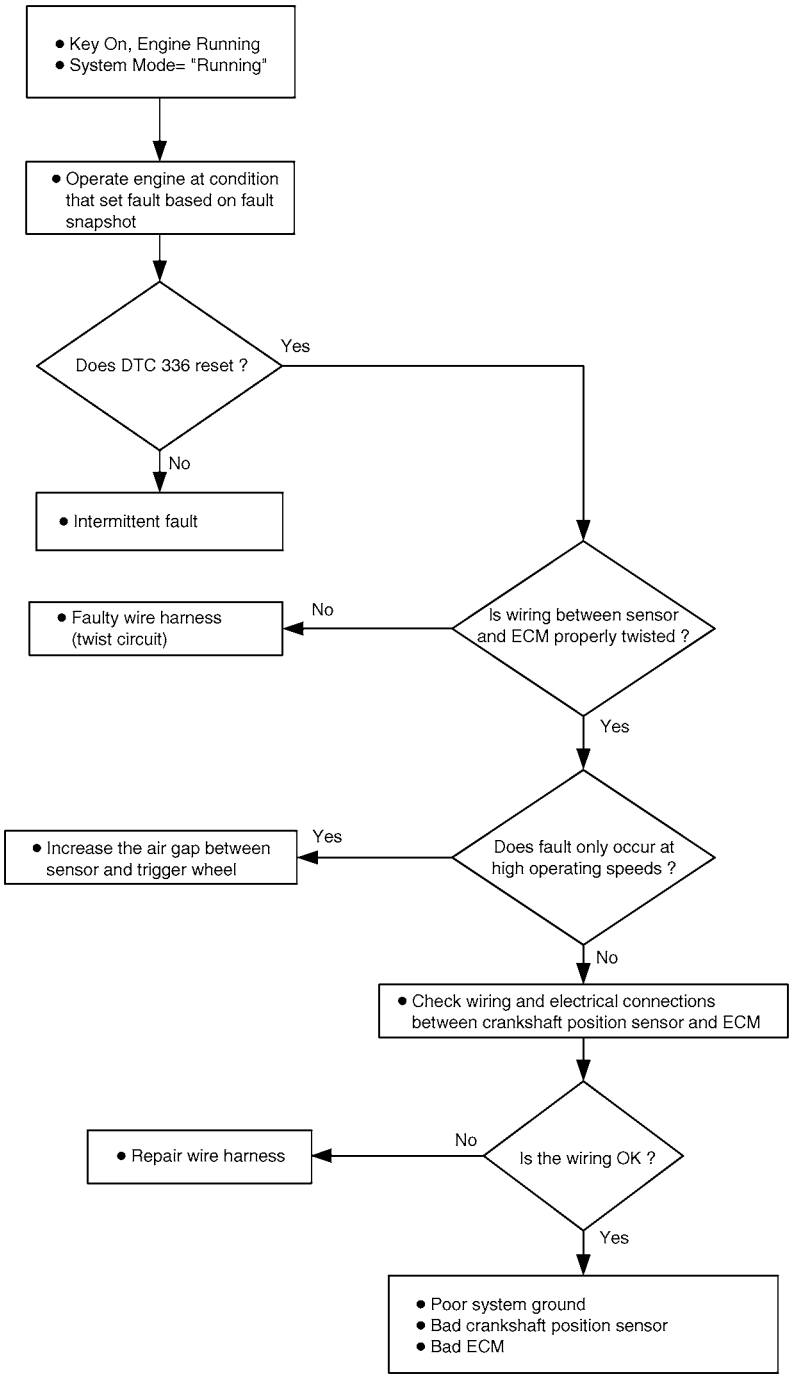
- Hardware: Crankshaft Position sensor
- Enabling Conditions: Key On, Engine On
- Set Conditions: Loss of crankshaft position signal (CKP) with more than 6 cam pulses from the camshaft position sensor (CMP).
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: Loss of sensor feed, open sensor ground (5 Vrtn1 and CKP–), open or shorted to ground signal wire

The crankshaft position sensor is a magnetic pick-up sensor installed in the engine block adjacent to a "coded" trigger wheel located on the flywheel. The sensor-trigger wheel combination is used to determine crankshaft position (with respect to TDC cylinder #1 compression) and the rotational engine speed. Determination of the crankshaft position and speed is necessary to properly activate the ignition, fuel injection, and throttle governing systems for precise engine control.

The ECM must see a valid crankshaft position signal while running. The engine typically stalls or dies as a result of this fault condition due to the lack of crankshaft speed input resulting in the inability to control ignition timing.

DTC 336-Crank Input Signal Noise

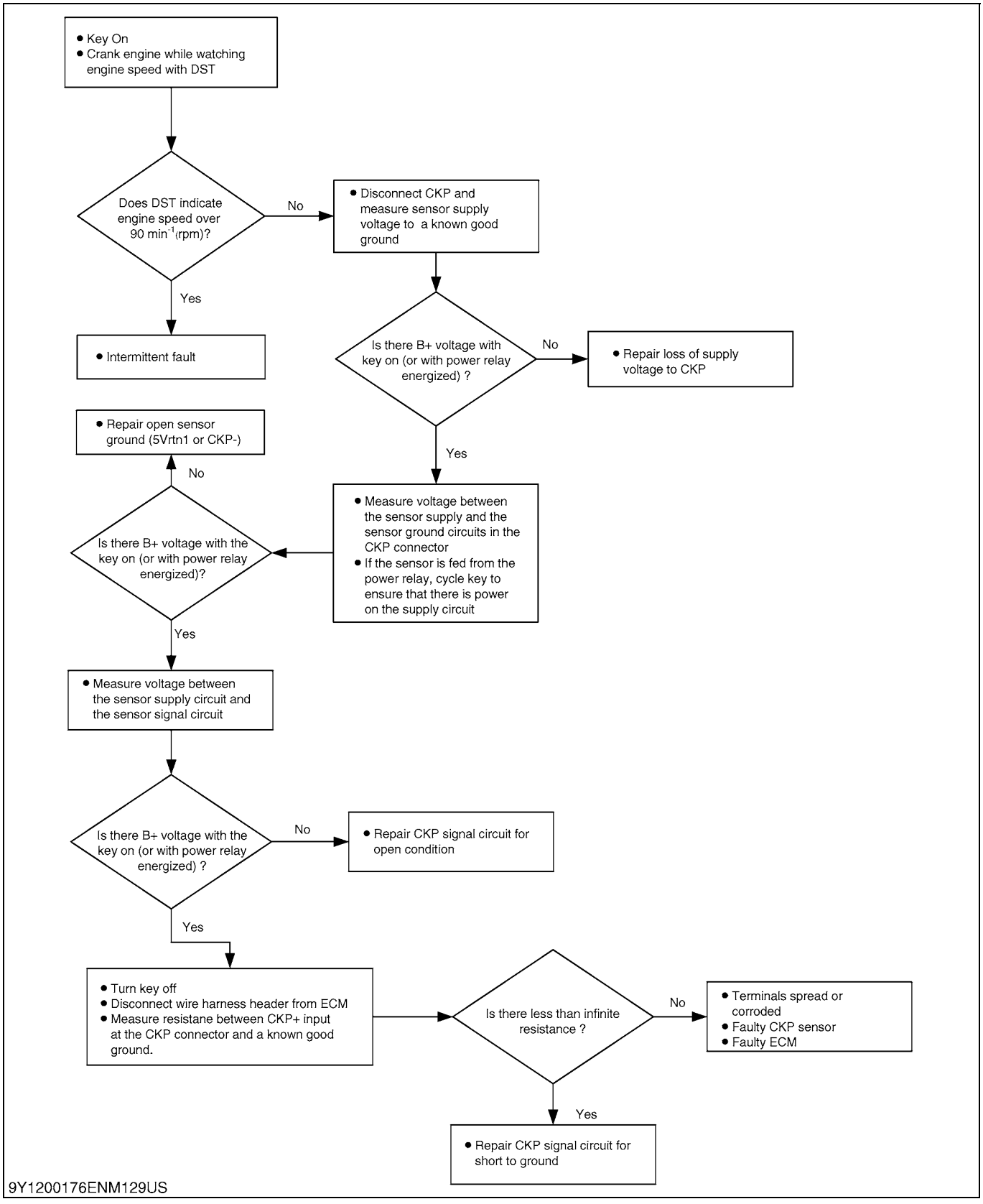
Diagnostic Aids Chart

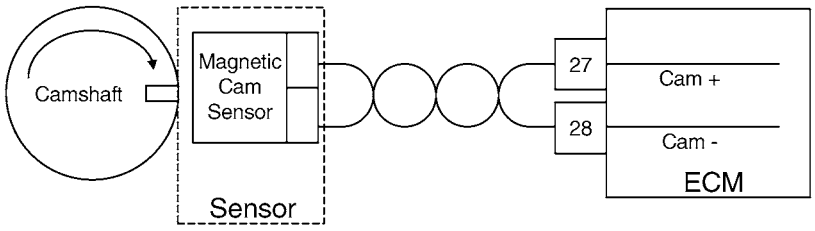


9Y1200176ENM128US

DTC 337-Loss of Crankshaft Input Signal

Diagnostic Aids Chart





9Y1200176ENM130US

DTC 341-Camshaft Input Signal Noise

- Hardware: Camshaft Position sensor
- Enabling Conditions: Key On, Engine Running
- Set Conditions: Electrical noise or irregular cam pattern detected causing more than 1 cam re-synchronization events in less than 700 ms.
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for remainder of key-cycle.
- Emissions related fault
- Possible Causes: CMP+ or CMP− circuits in wrong connector terminal slot, improper CMP signal due to sensor air gap too large, excessive metal on sensor tip, improper wiring, intermittent connection in sensor circuitry, intermittent sensor internal problem

The camshaft position sensor is a magnetic pick-up sensor installed in the engine block or valve train adjacent to a "coded" trigger wheel located on or off of the camshaft. The sensor-trigger wheel combination is used to determine cam position so the ECM can determine which piston is coming up on TDC. Determination of the camshaft position is necessary to identify the stroke (or cycle) of the engine to properly activate the fuel injection system and ignition (for coil-on-plug engines) for precise engine control.

For a cam synchronized engine, the ECM must see a valid camshaft position signal while running. If no signal is present, the signal amplitude is too high (due to improper air gap with respect to trigger wheel), or an irregular cam pattern is detected causing the ECM to resynchronize this fault will set. Irregular cam patterns can be detected by the ECM and can be caused by: electrical noise, poor machining of trigger wheel, or trigger wheel run out and/or gear lash. In some instances this fault can cause rough engine operation and can cause the engine to stall or die if attached with coil-on-plug ignition engines.

Ensure cam circuit used with VR/magnetic pick-up sensors are properly twisted.

DTC 342-Loss of Camshaft Input Signal

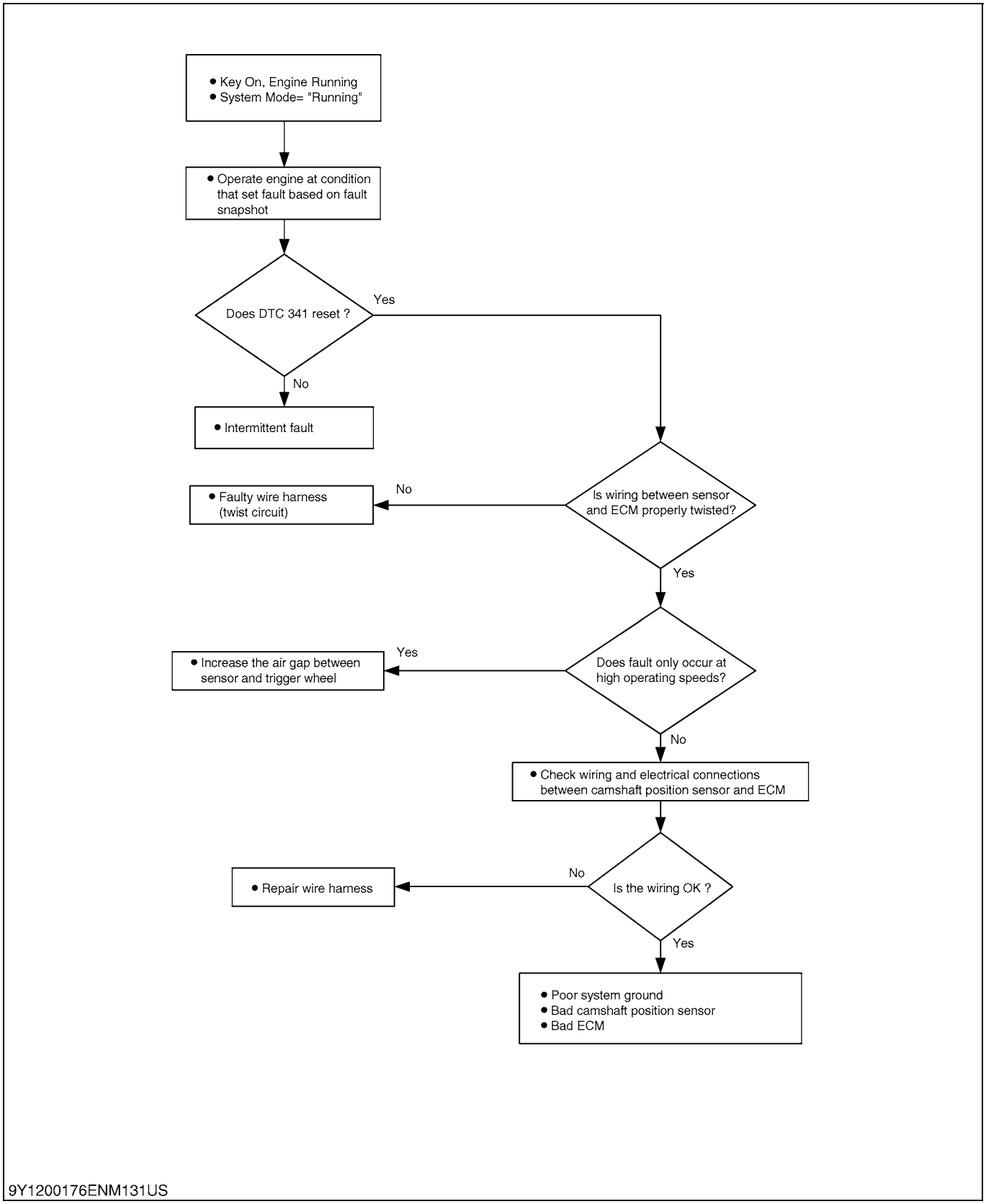
- Hardware: Camshaft Position sensor
- Enabling Conditions: Key On, Engine Running above 1000 min^{-1} (rpm)
- Set Conditions: Loss of camshaft position signal while valid crankshaft position signals continue for 2.5 engine cycles for longer than 1 second
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: Loss of feed voltage to CMP sensor, loss of signal or ground circuits, faulty sensor, faulty ECM or damaged engine components

The camshaft position sensor is a magnetic sensor (hall-effect) installed in the engine block or valve train adjacent to a "coded" trigger wheel located on or off of the camshaft. The sensor-trigger wheel combination is used to determine cam position (with respect to TDC cylinder #1 compression). Determination of the camshaft position is necessary to identify the stroke (or cycle) of the engine to properly activate the fuel injection system and ignition (for coil-on-plug engines) for precise engine control.

For a cam synchronized engine, the ECM must see a valid camshaft position signal while running. In some instances this fault can cause rough engine operation and can cause the engine to stall or die if attached with coil-on-plug ignition engines.

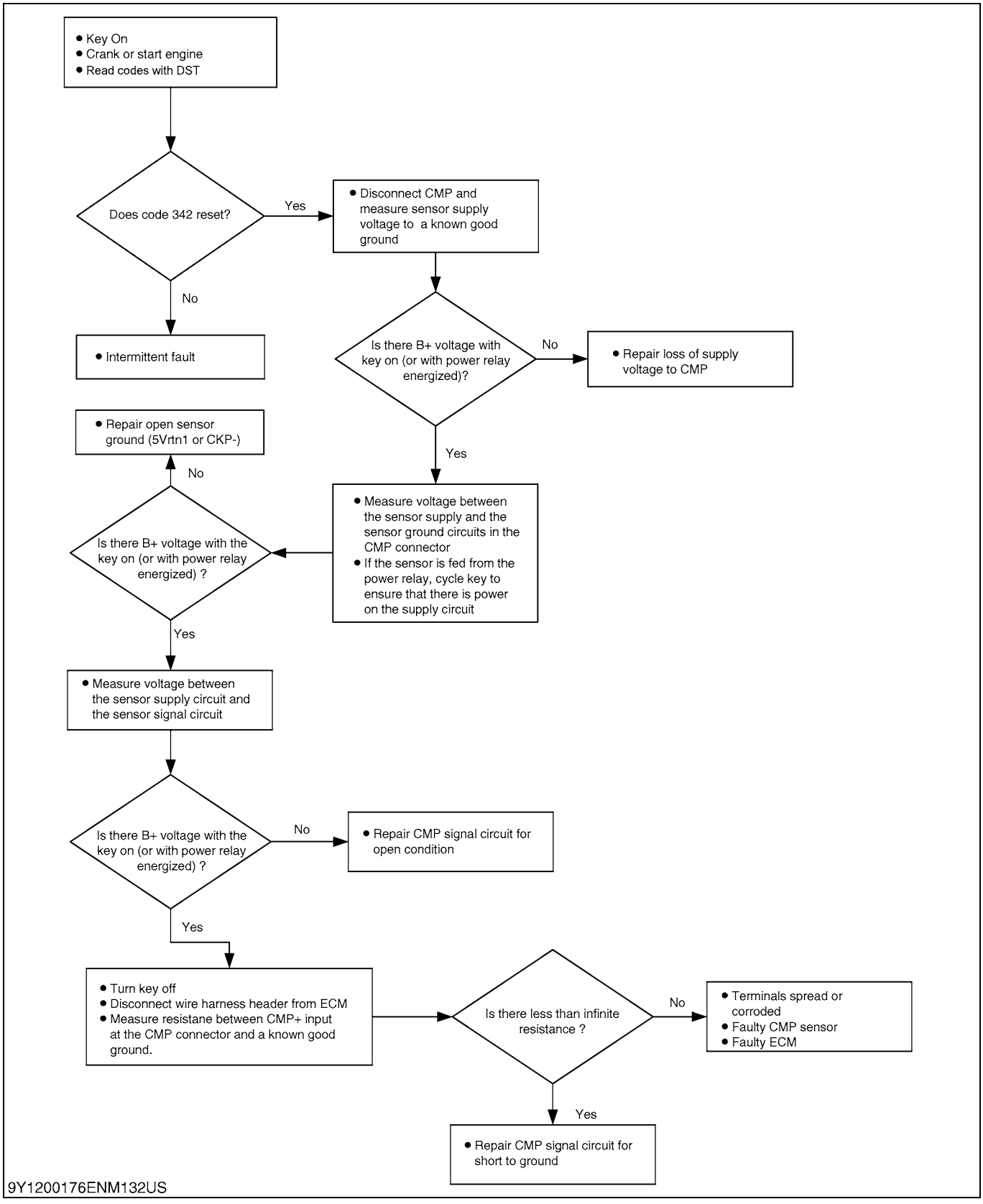
DTC 341-Camshaft Input Signal Noise

Diagnostic Aids Chart

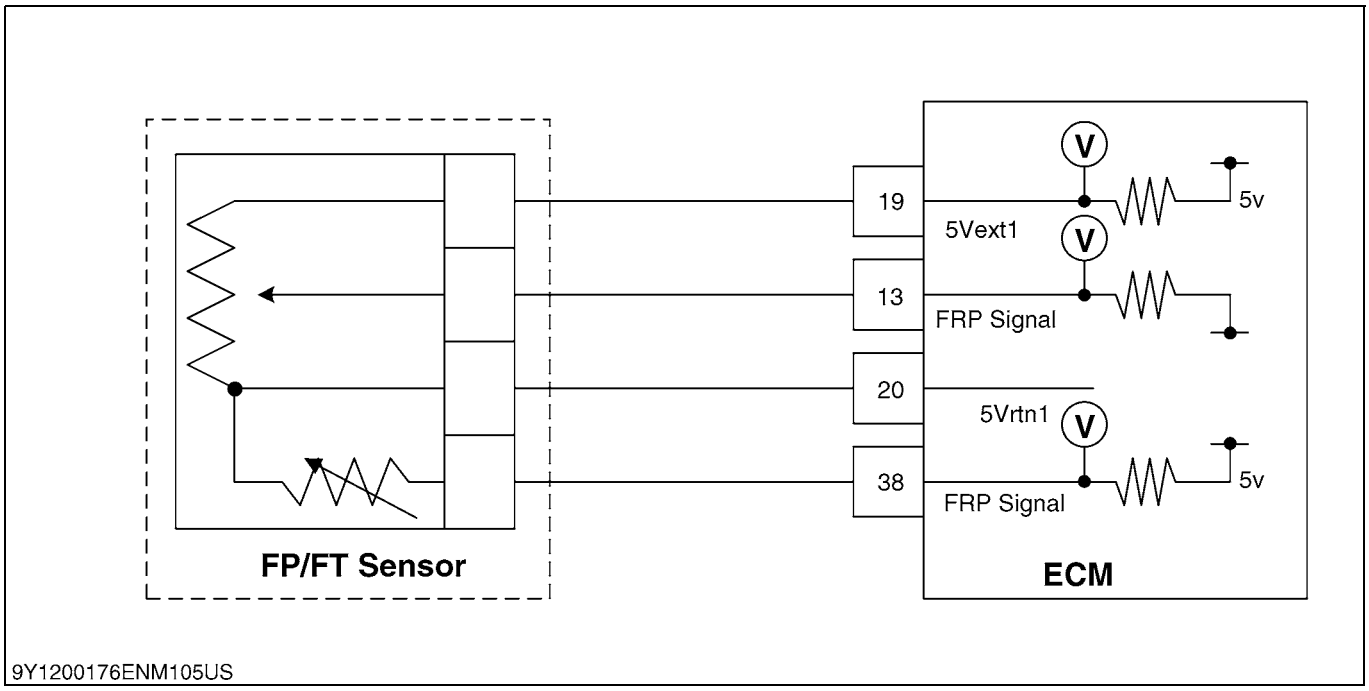


DTC 342-Loss of Camshaft Input Signal

Diagnostic Aids Chart



(2) FP (Fuel Pressure Sensor) (DTC 91, 92)



DTC 91-FP (Fuel Pressure Sensor) Low Voltage

- Hardware: Liquid Fuel Pressure and Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: Fuel pressure feedback voltage lower than 0.200 V for longer than 6 seconds
- Corrective Action(s): Illuminate the MIL and disable adaptive learn fueling correction for the rest of the key-cycle.
- Emissions related fault
- Possible Causes: FP sensor connector disconnected, an open-circuit or short-to-ground of the FP signal circuit in the wiring harness, a loss of sensor reference voltage, or a failure of the sensor.

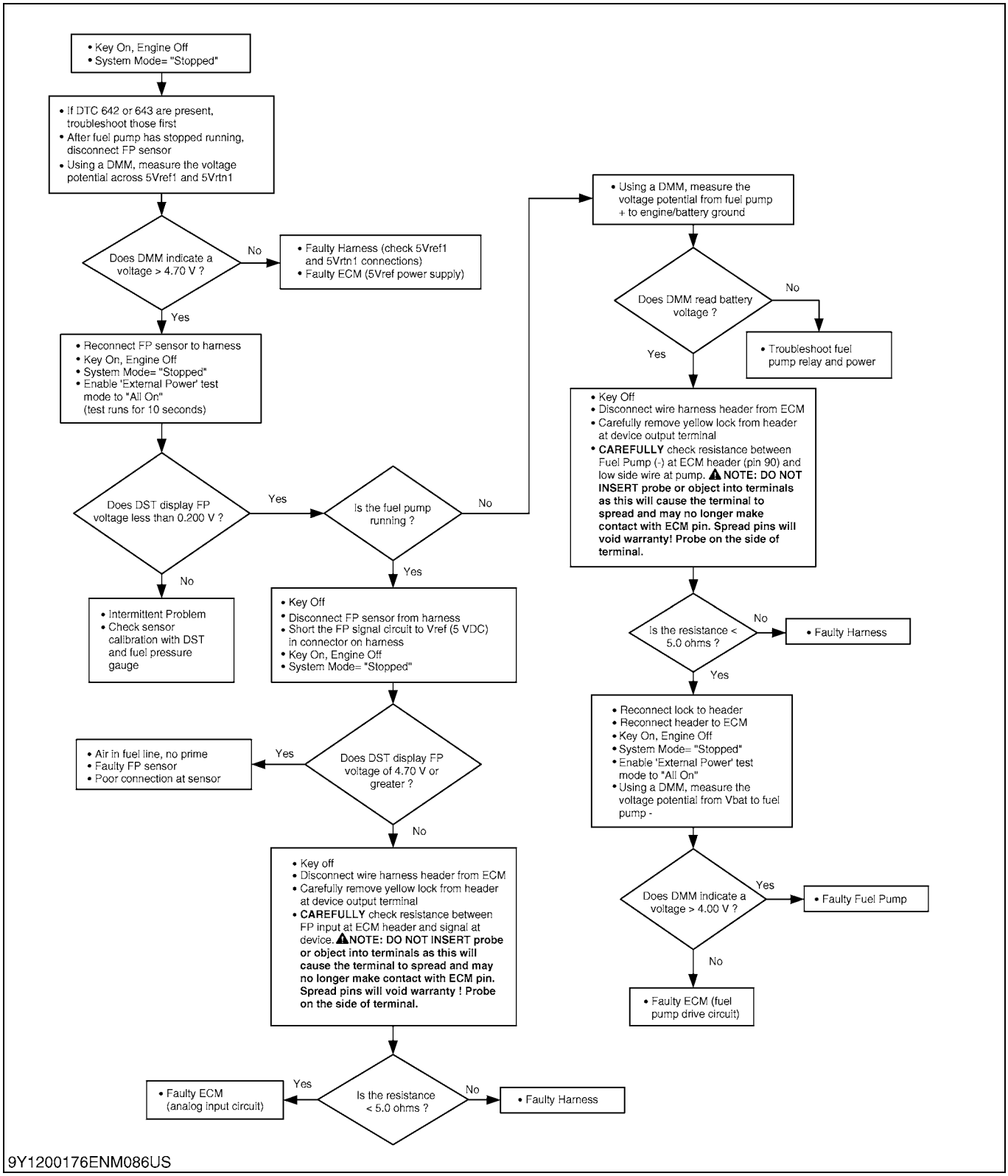
DTC 92-FP (Fuel Pressure Sensor) High Voltage

- Hardware: Liquid Fuel Pressure and Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: Fuel pressure feedback voltage higher than 4.80 V for longer than 2 seconds.
- Corrective Action(s): Illuminate MIL and disable adaptive learn fueling correction for the rest of the key-cycle.
- Emissions related fault
- Possible Causes: FP signal circuit or 5 V rtn1 open, open sensor or sensor signal shorted to voltage

The fuel pressure sensor is installed inline in the gasoline fuel supply line and is used to provide fuel pressure feedback to the ECM. The ECM sets a target rail pressure based on running conditions and then the fuel pump is PWM controlled through a low side driver in the ECM. The fuel pressure sensor feedback is used to determine when the actual rail pressure has reached the target rail pressure.

DTC 91-FP (Fuel Pressure) Low Voltage

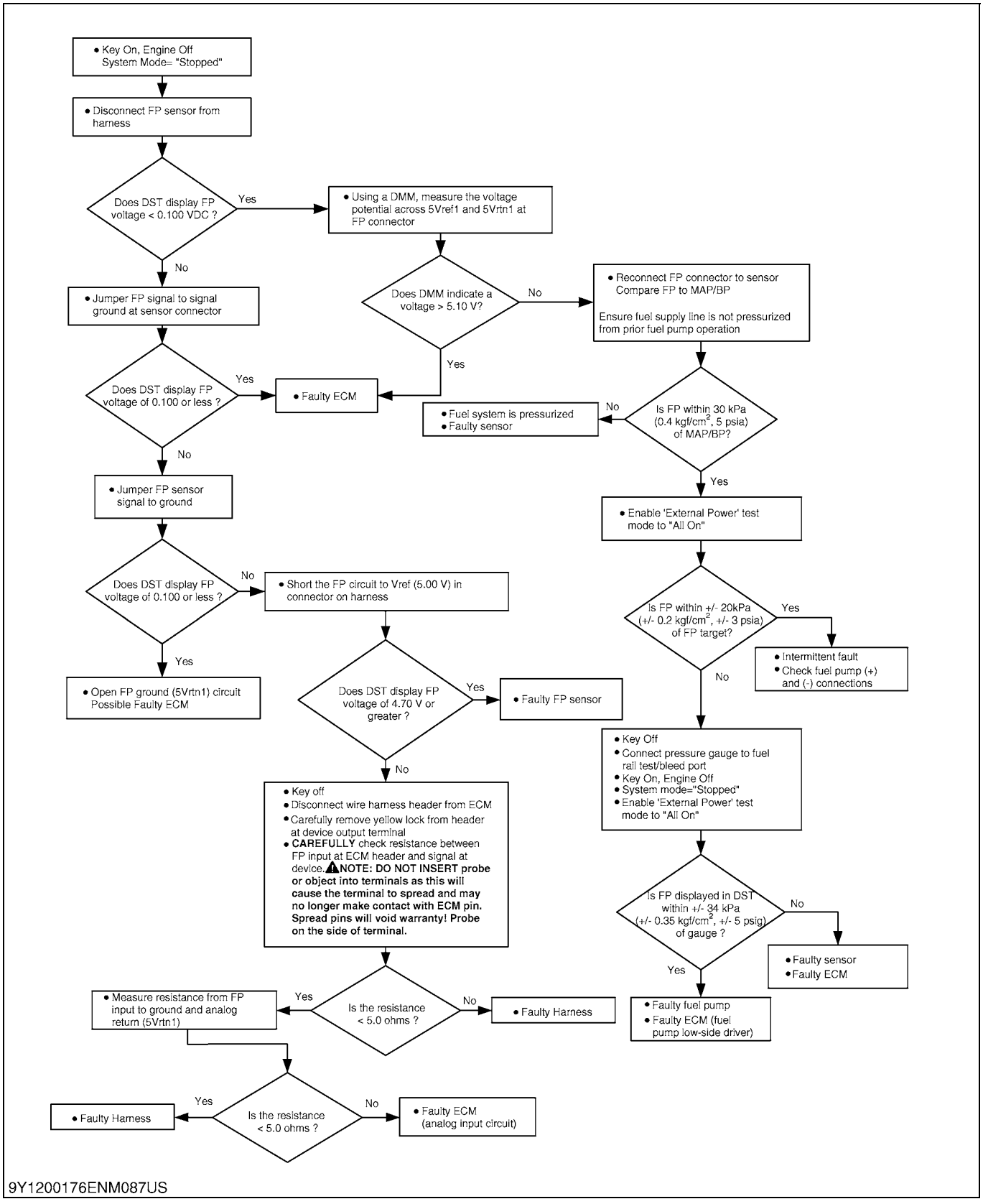
Diagnostic Aids Chart



9Y1200176ENM086US

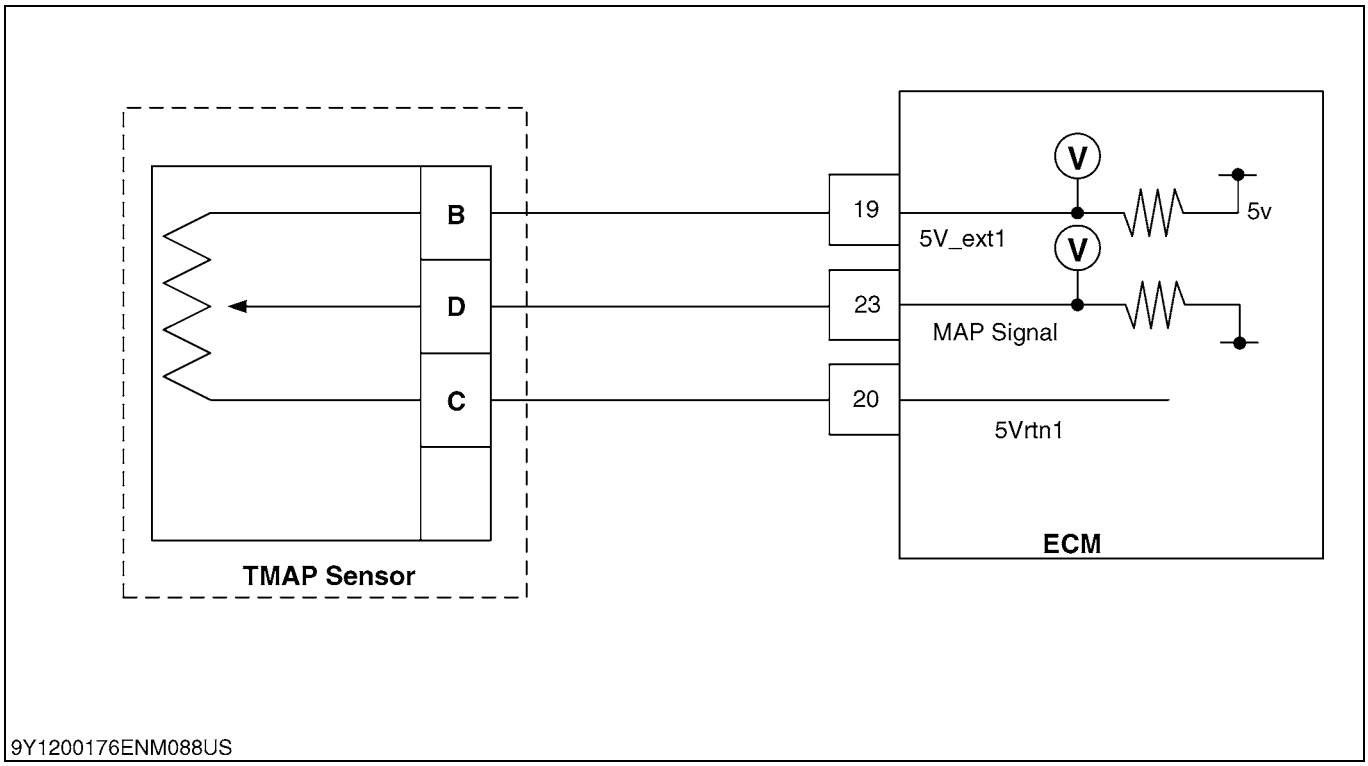
DTC 92-FP (Fuel Pressure Sensor) High Voltage

Diagnostic Aids Chart



9Y1200176ENM087US

(3) MAP (Manifold Absolute Pressure Sensor) (DTC 107, 108)



DTC 107-MAP Low Voltage

- Hardware: Manifold Absolute Pressure Sensor
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: MAP sensor voltage feedback less than 0.050 V when throttle position is greater than 5 % and engine speed is less than 4000 min^{-1} (rpm).
- Corrective Action(s): Illuminate MIL and disable adaptive learn fueling correction for the rest of the key-cycle.
- Emissions related fault
- Possible Causes: Loss of 5.00 V reference feed to sensor, open or shorted to ground sensor signal wire, faulty sensor or faulty ECM.

DTC 108-MAP High Pressure

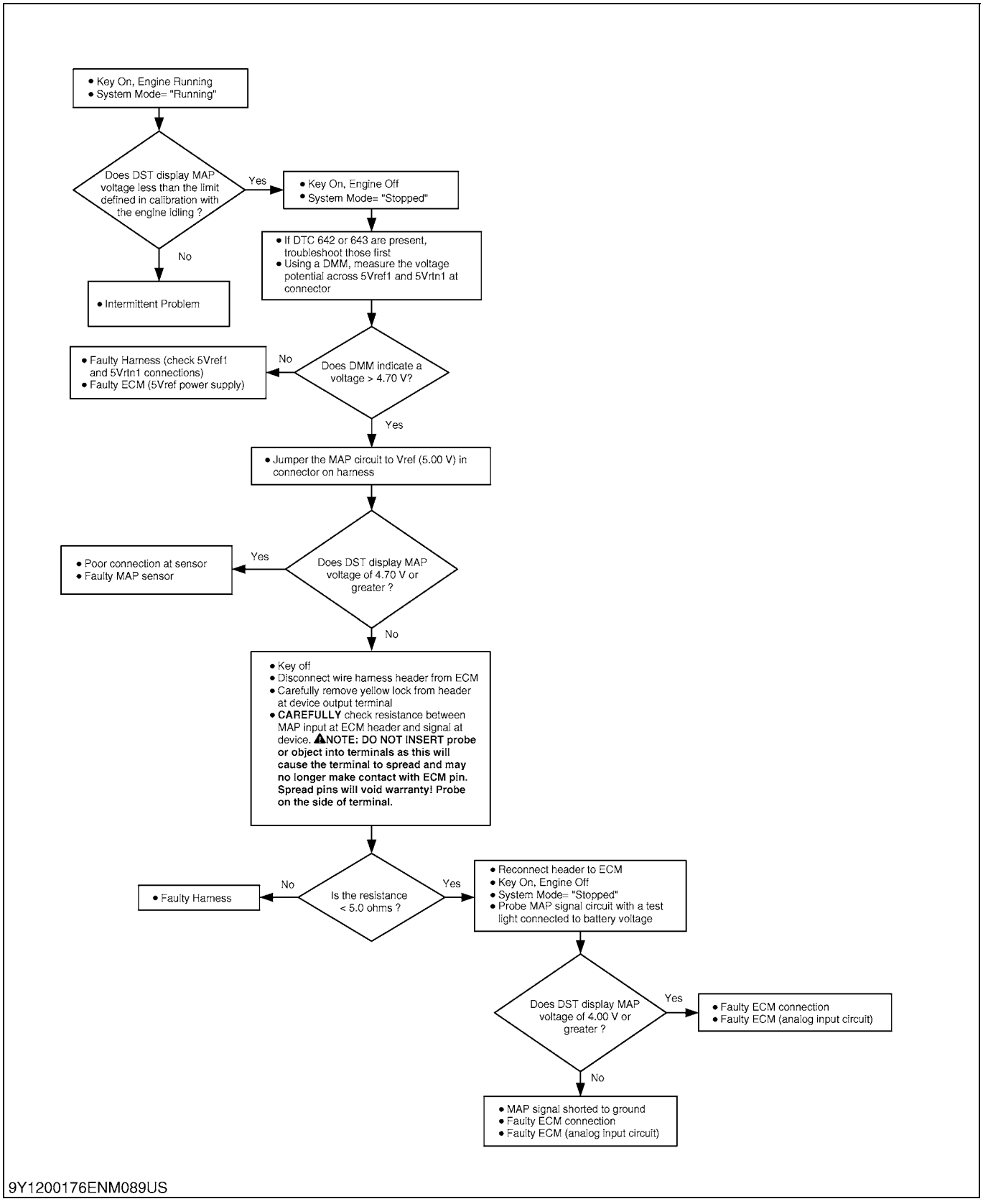
- Hardware: Manifold Absolute Pressure Sensor
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: MAP is higher than 110 kPa (1.1 kgf/cm^2, 16 psi) when throttle position is less than 3 % and engine speed is greater than 1000 min^{-1} (rpm).
- Corrective Action(s): Illuminate MIL and disable adaptive learn fueling correction for the rest of the key-cycle.
- Emissions related fault
- Possible Causes: 5.00 V reference feed shorted to voltage, signal circuit shorted to voltage, open 5 Vrtn1 (sensor ground), faulty sensor or faulty ECM.

The Manifold Absolute Pressure sensor is a pressure transducer connected to the intake manifold. It is used to measure the pressure of air in the manifold prior to induction into the engine. The pressure reading is used in conjunction with other inputs to determine the rate of airflow to the engine. The rate of airflow into the engine is used to determine the required fuel flow rate.

When these fault are active, the ECM operates in a limp home mode in which an estimated MAP based on TPS feedback is used to fuel the engine.

DTC 107-MAP Low Voltage

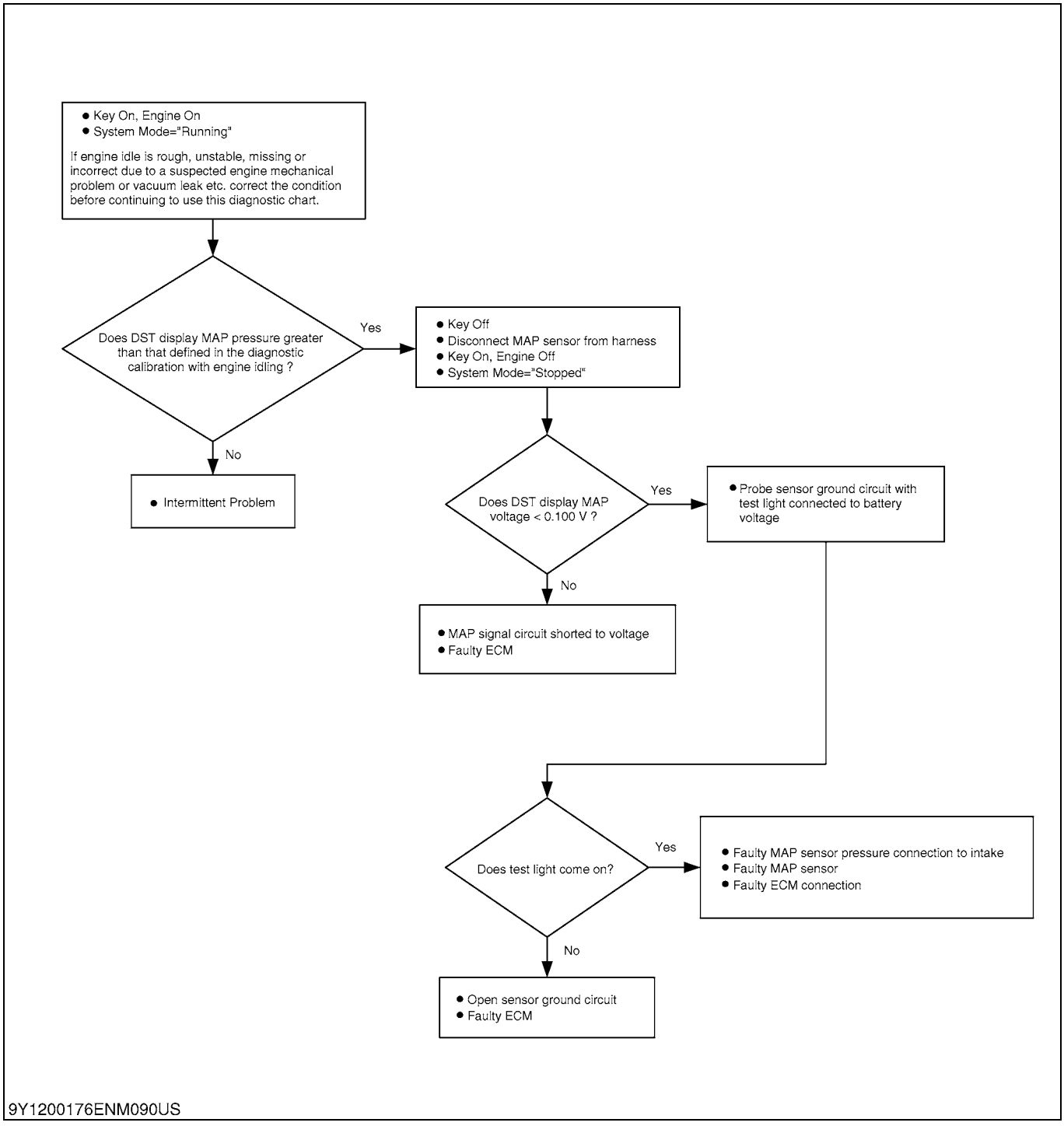
Diagnostic Aids Chart



9Y1200176ENM089US

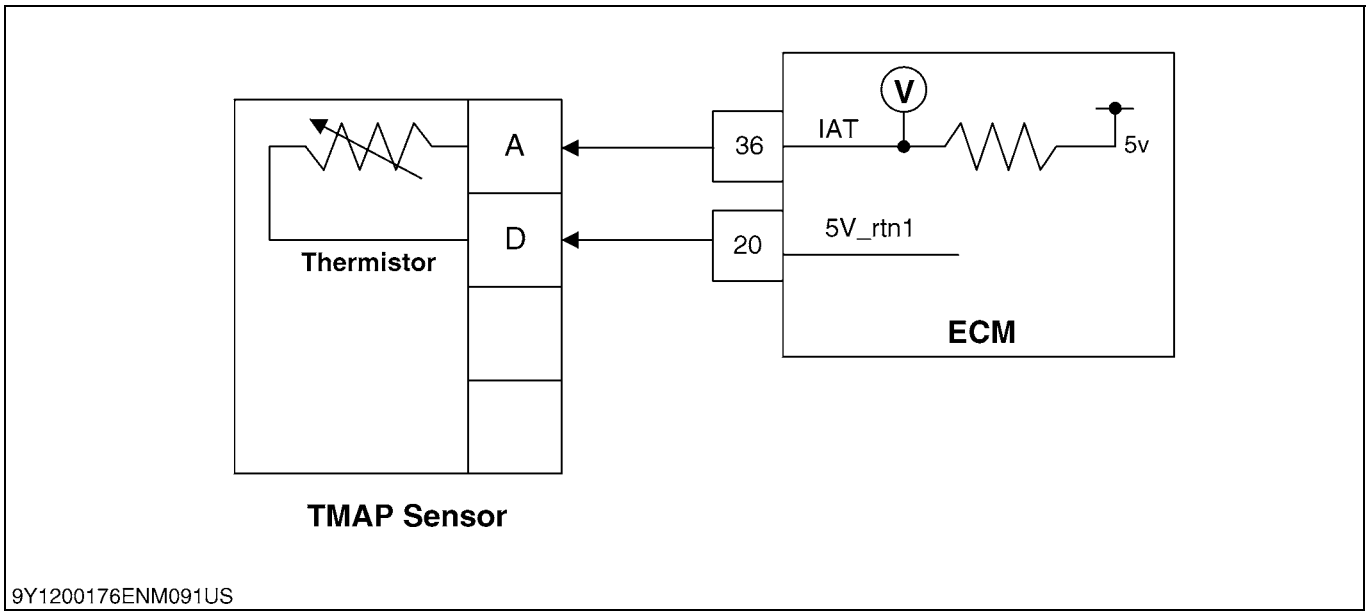
DTC 108-MAP High Pressure

Diagnostic Aids Chart



9Y1200176ENM090US

(4) IAT (Intake Air Temperature Sensor) (DTC 111, 112, 113, 127)



DTC 111-IAT Higher Than Expected Stage 1

- Hardware: Intake Air Temperature Sensor
- Enabling Conditions: Engine Running higher than 1000 min^{-1} (rpm)
- Set Conditions: Intake Air Temperature greater than stage 1 limit (93 °C (200 °F)) for longer than 60 seconds when rpm is above 1000 min^{-1} (rpm).
- Corrective Action(s): Activate power derate 1 (max 50 % throttle angle)
- Non-emissions related fault
- Possible Causes: Damaged inlet air system allowing hotter than normal air into engine intake system

DTC 112-IAT Low Voltage

- Hardware: Intake Air Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: IAT sensor voltage less than 0.050 V for longer than 1 second
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learning while the code is active.
- Emissions related fault
- Possible Causes: Faulty ECM (no voltage on signal wire), signal wire shorted to ground or sensor internally shorted

DTC 113-IAT High Voltage

- Hardware: Intake Air Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: IAT sensor voltage greater than 4.95 V for longer than 1 second
- Corrective Action(s)-Disable fuel adaptive learn while code is active
- Emissions related fault
- Possible Causes: Signal wire shorted to 12.0 V, signal wire open, sensor open internally or open 5 Vrtn1 (sensor ground)

DTC 127-IAT Higher Than Expected Stage 2

- Hardware: Intake Air Temperature
- Enabling Conditions: Engine Running higher than 1000 min^{-1} (rpm)
- Set Conditions: Intake Air Temperature greater than stage 2 limit (99 °C (210 °F)) for longer than 2 minutes
- Corrective Action(s)-Illuminate MIL, disable fuel adaptive learning while code is active
- Emissions related fault
- Possible Causes: Damaged inlet air system allowing hotter than normal air into engine intake system

The Intake Air Temperature sensor is a thermistor (temperature sensitive resistor) located in the intake manifold of the engine. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine. The ECM provides a voltage divider circuit so that when the air is cool, the signal reads higher voltage, and lower when warm.

The Manifold Air Temperature is a calculated value based mainly on the IAT sensor at high airflow and influenced more by the ECT/CHT at low airflow. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine, and ignition timing.

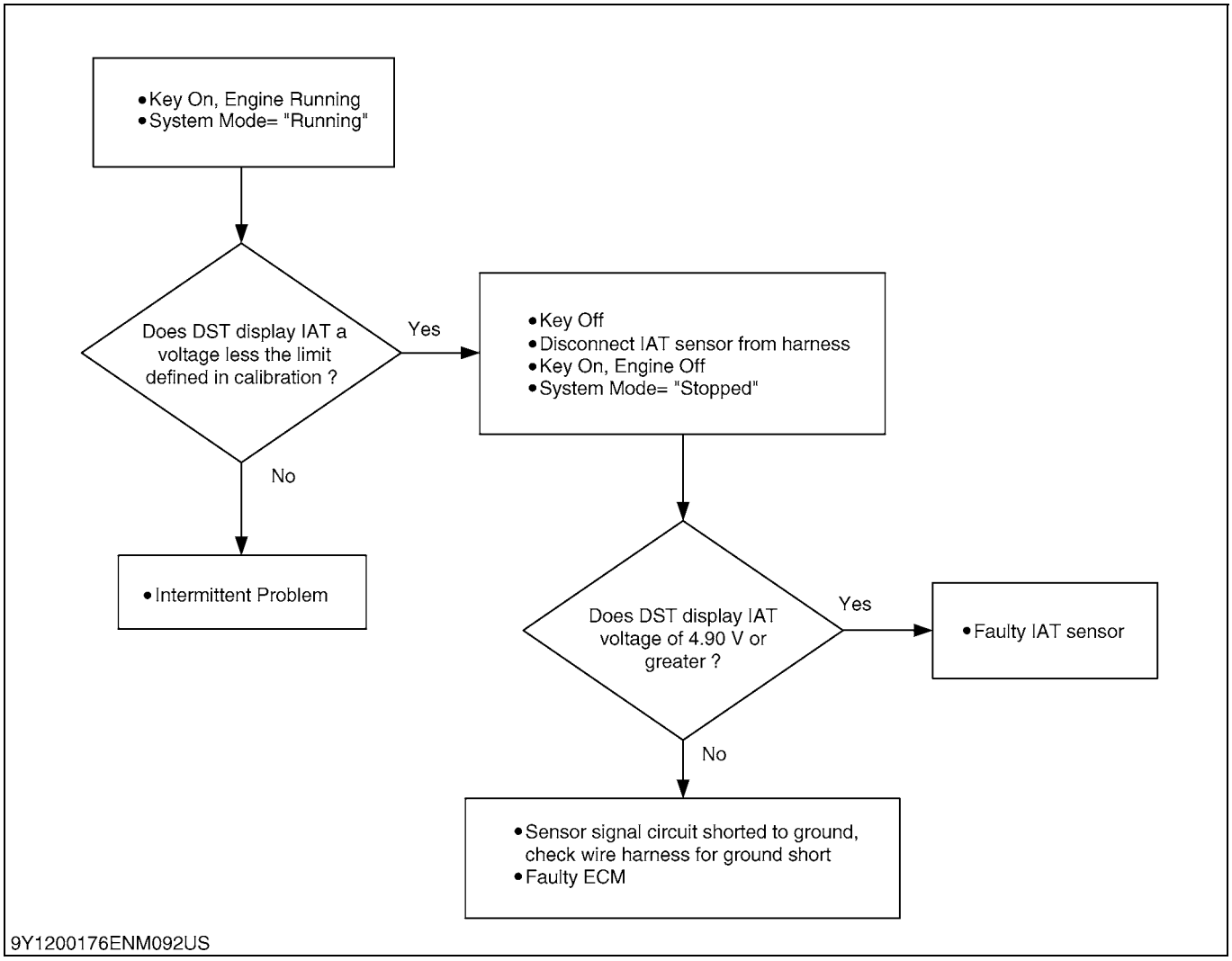
DTC 111-IAT Higher Than Expected Stage 1

Diagnostic Aids

- This fault will set when inlet air is hotter than normal. The most common cause of high inlet air temperature is a result of a problem with routing of the inlet air. Ensure inlet plumbing sources are external, is cool, and is not too close to the exhaust at any point.
- Inspect the inlet air system for cracks or breaks that may allow unwanted underhood air to enter the engine.
- If no problem is found, replace the IAT sensor with a known good part and retest.

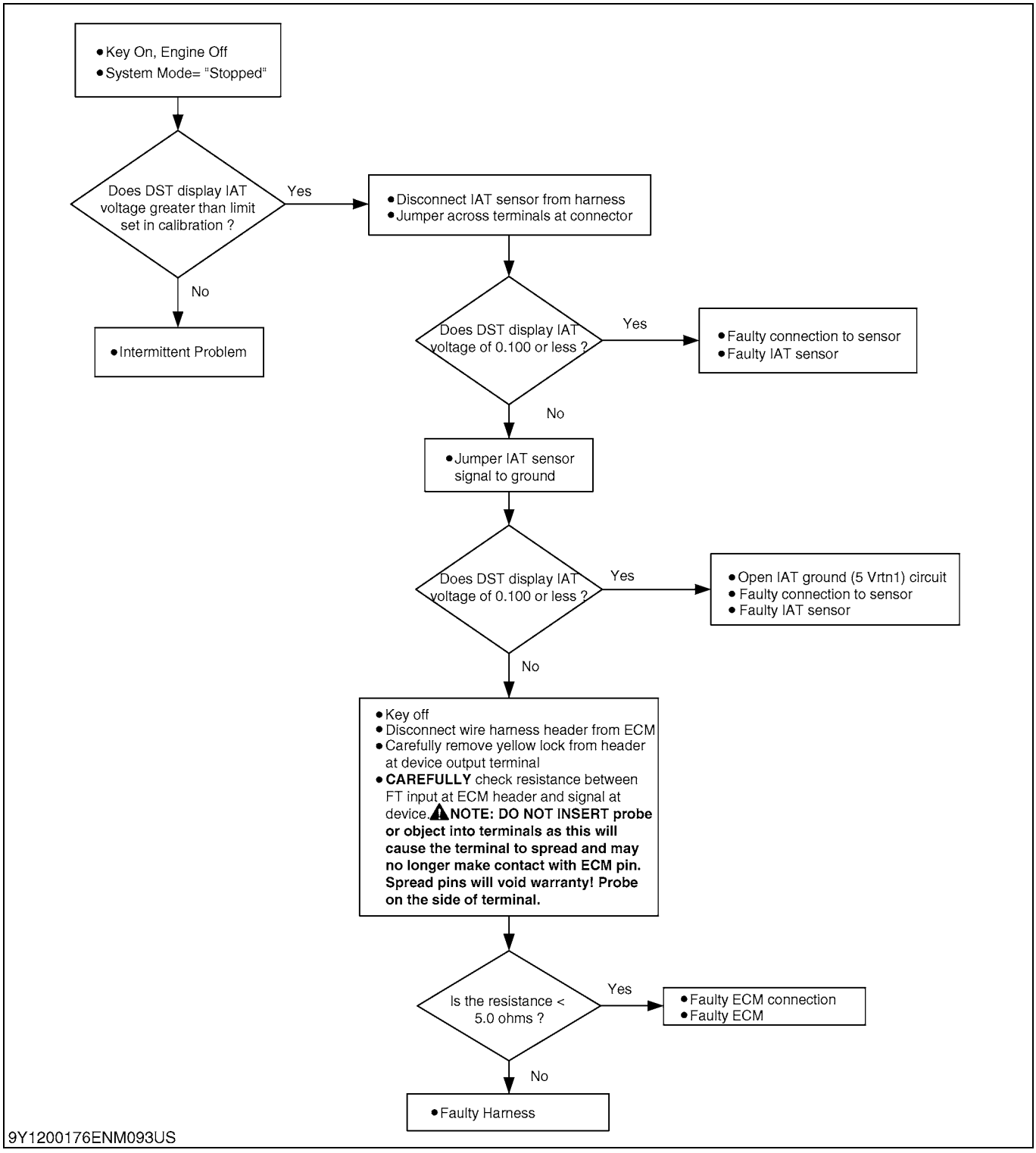
DTC 112-IAT Low Voltage

Diagnostic Aids Chart



DTC 113-IAT High Voltage

Diagnostic Aids Chart

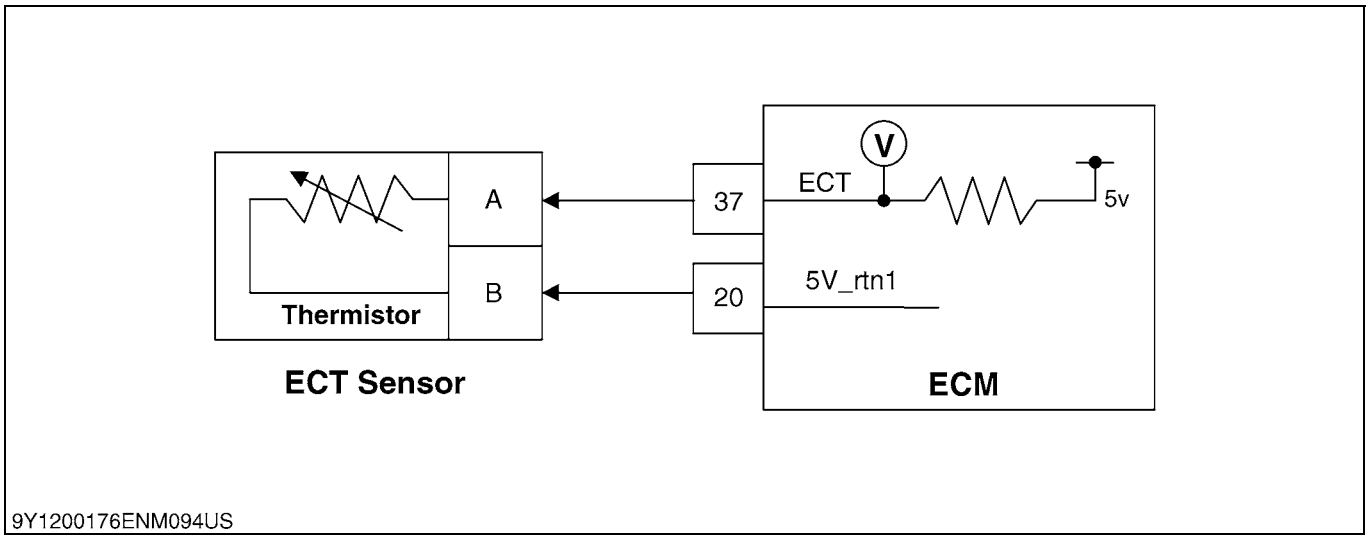


DTC 127-IAT Higher Than Expected Stage 2

Diagnostic Aids

- This fault will set when inlet air is hotter than normal. The most common cause of high inlet air temperature is a result of a problem with routing of the inlet air. Ensure inlet plumbing sources are external, is cool, and is not too close to the exhaust at any point.
- Inspect the inlet air system for cracks or breaks that may allow unwanted underhood air to enter the engine.
- If no problem is found, replace the IAT sensor with a known good part and retest.

(5) ECT (Engine Coolant Temperature) (DTC 116, 117, 118, 217)



DTC 116-ECT Higher Than Expected Stage 1

- Hardware: Engine Coolant Temperature Sensor
- Enabling Conditions: Engine Running above 500 min^{-1} (rpm)
- Set Conditions: Engine Coolant Temperature reading or estimate greater than the stage 1 limit (110 °C (230 °F)) for longer than 30 seconds
- Corrective Action(s): Illuminate MIL, active power derate 1
- Non-emissions related fault
- Possible Causes: Overheating engine, sensor out of calibration, signal wire partially shorted to ground or faulty ECM

DTC 117-ECT Low Voltage

- Hardware: Engine Coolant Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: ECT sensor voltage less than 0.100 V for longer than 1 second
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn while code is active
- Emissions related fault
- Possible Causes: Faulty ECM (no voltage on signal wire), signal wire shorted to ground or sensor internally shorted

DTC 118-ECT High Voltage

- Hardware: Engine Coolant Temperature Sensor
- Enabling Conditions: Engine Running
- Set Condition: ECT sensor voltage greater than 4.90 V for longer than 1 second
- Corrective Action(s): Turn on MIL, disable fuel adaptive learn while code is active.
- Emissions related fault
- Possible Causes: Signal wire shorted to 12.0 V, signal wire open, sensor open internally or open 5 Vrtn1 (sensor ground)

DTC 217-ECT Higher Than Expected Stage 2

- Hardware: Engine Coolant Temperature Sensor
- Enabling Conditions: Engine Running above 500 min^{-1} (rpm)
- Set Conditions: Engine Coolant Temperature reading or estimate greater than the stage 1 limit (120 °C (248 °F)) for longer than 10 seconds
- Corrective Action(s): Illuminate MIL, active power derate 2
- Emissions related fault
- Possible Causes: Overheating engine, sensor out of calibration, signal wire partially shorted to ground or faulty ECM

The Engine Coolant Temperature sensor is a thermistor (temperature sensitive resistor) located in the engine coolant. The ECT is used for engine fuel calculation (cold engine), ignition timing control, to enable certain features, and for engine protection (overheats). The ECM provides a voltage divider circuit so when the sensor reading is cool the sensor reads higher voltage, and lower when warm.

The fault of DTC 116 and DTC 217 will help protect the engine in the event of over temperature.

The ECM will use a default value for the ECT sensor in the event of the faults of DTC 117 or DTC 118.

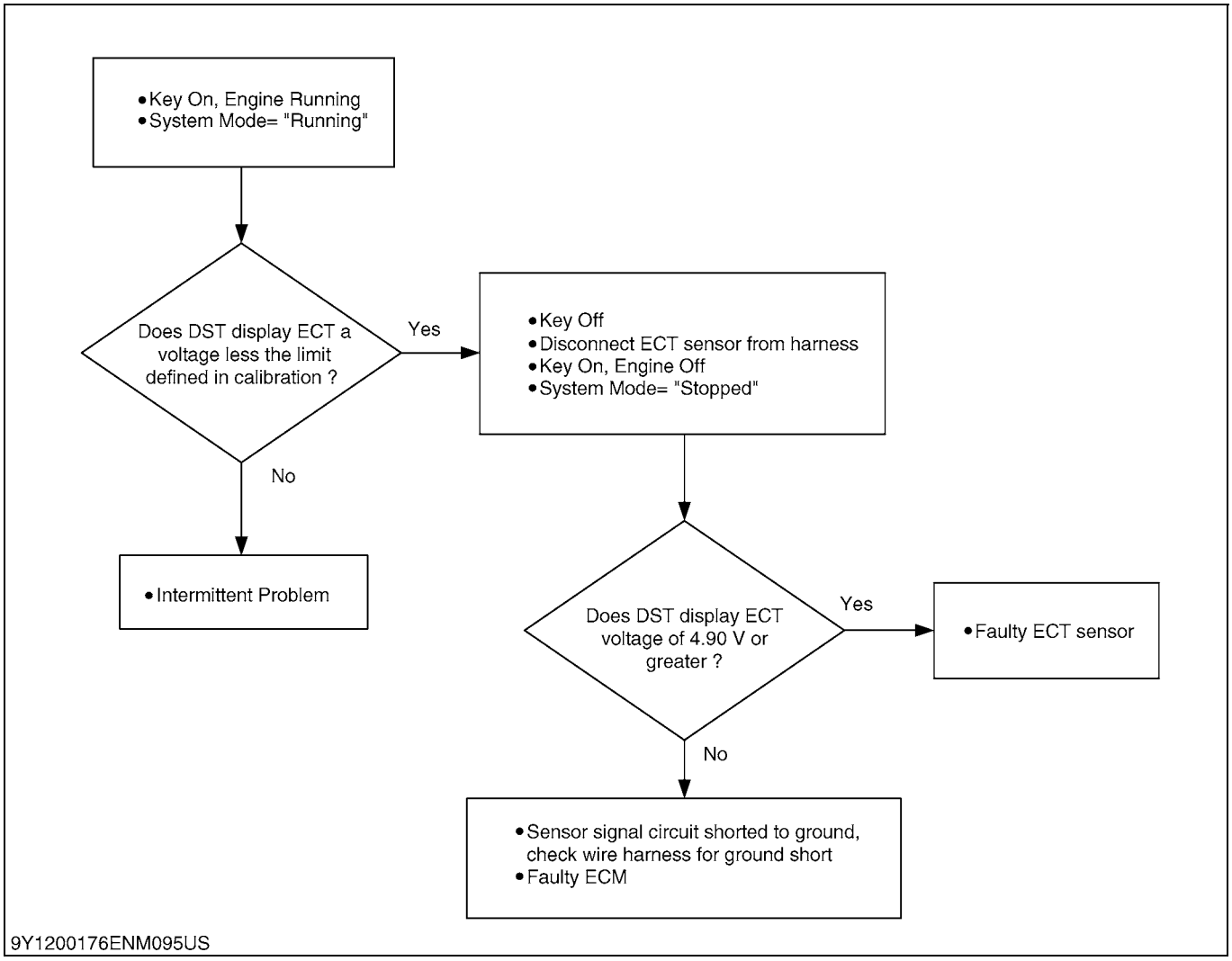
DTC 116-ECT Higher Than Expected Stage 1

Diagnostic Aids

- If the "ECT High Voltage" fault is also present, follow the troubleshooting procedures for that fault as it may have caused "ECT Higher Than Expected 1".
- If the cooling system utilizes an air-to-water heat exchanger (radiator) and fan:
  - Check that the radiator has a proper amount of ethylene glycol/water and that the radiator is not leaking
  - Ensure that there is no trapped air in the cooling path
  - Inspect the cooling system (radiator and hoses) for cracks and ensure connections are leak free
  - Check that the fan is operating properly
  - Check that the thermostat is not stuck closed
- If the cooling system utilizes a water-to-water heat exchanger:
  - Check that the heat exchanger has a proper amount of ethylene glycol/water and that the heat exchanger is not leaking
  - Ensure that there is no trapped air in the cooling path
  - Inspect the cooling system (radiator and hoses) for cracks and ensure connections are leak free
  - Check that the raw water pickup is not blocked/restricted by debris and that the hose is tightly connected
  - Check that the thermostat is not stuck closed
  - Check that the raw water pump/impeller is tact and that it is not restricted

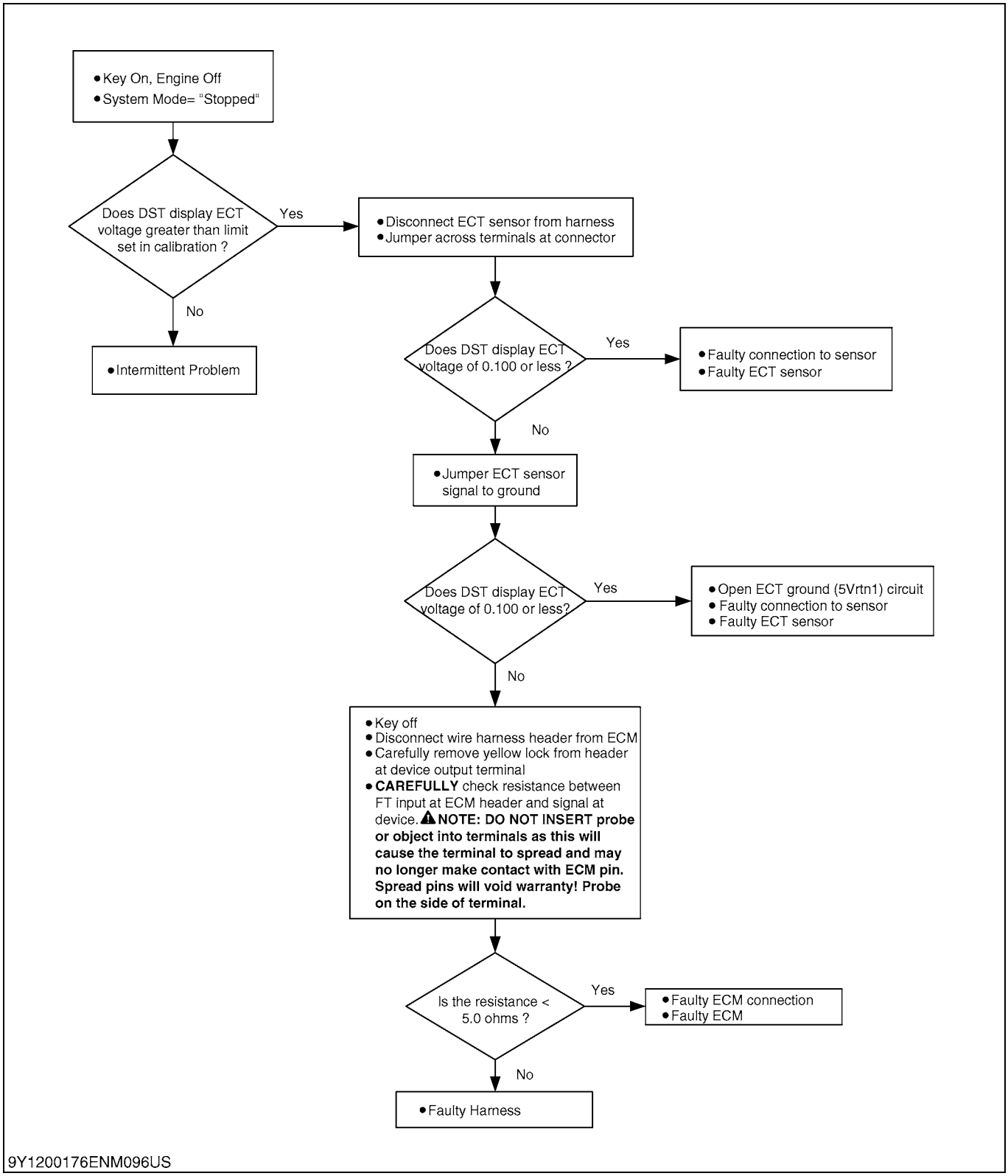
DTC 117-ECT Low Voltage

Diagnostic Aids Chart



DTC 118-ECT High Voltage

Diagnostic Aids Chart



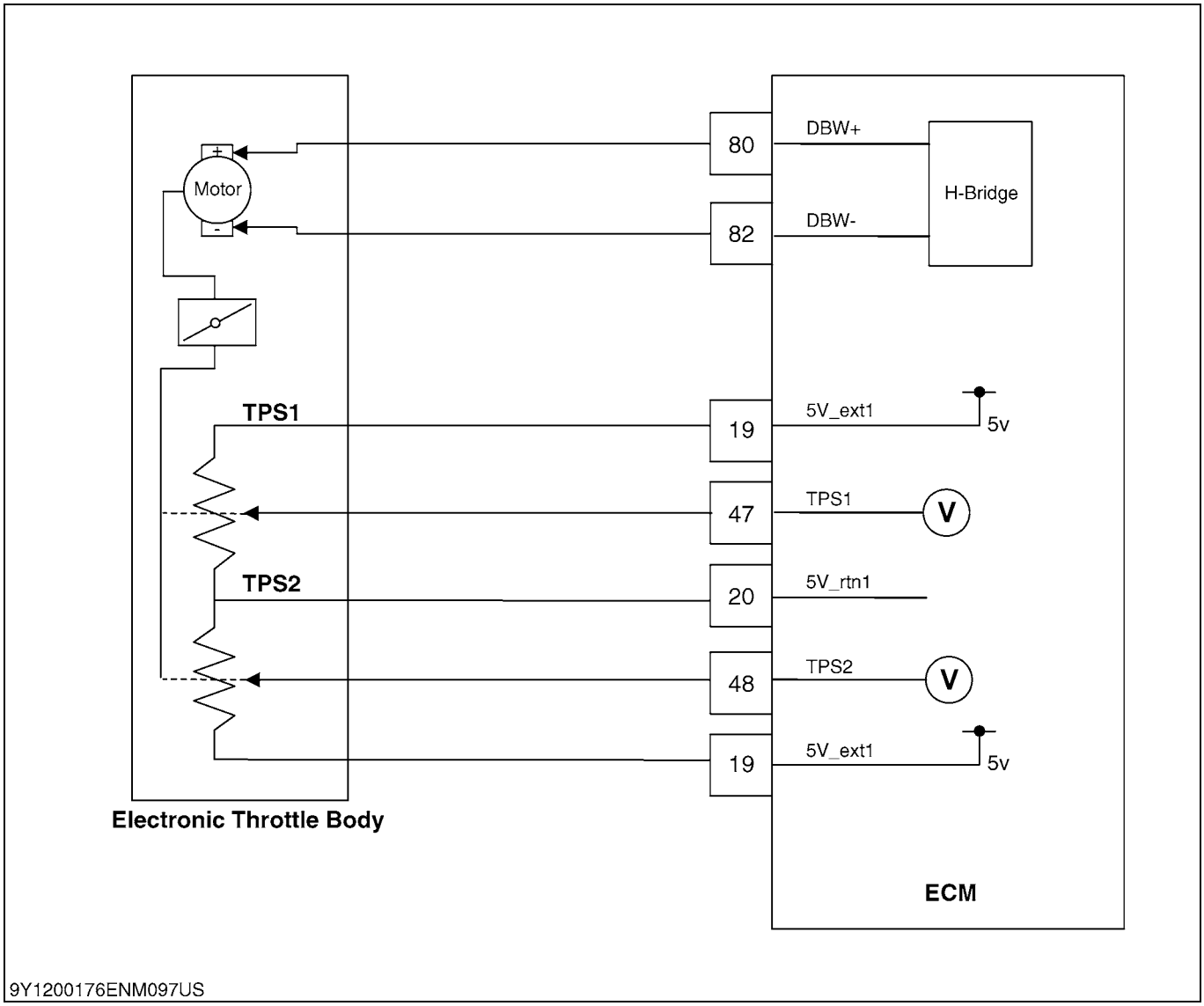
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DTC 217-ECT Higher Than Expected Stage 2

Diagnostic Aids

- If the "ECT High Voltage" fault is also present, follow the troubleshooting procedures for that fault as it may have caused "ECT Higher Than Expected 2".
- If the cooling system utilizes an air-to-water heat exchanger (radiator) and fan:
  - Check that the radiator has a proper amount of ethylene glycol/water and that the radiator is not leaking
  - Ensure that there is no trapped air in the cooling path
  - Inspect the cooling system (radiator and hoses) for cracks and ensure connections are leak free
  - Check that the fan is operating properly
  - Check that the thermostat is not stuck closed
- If the cooling system utilizes a water-to-water heat exchanger:
  - Check that the heat exchanger has a proper amount of ethylene glycol/water and that the heat exchanger is not leaking
  - Ensure that there is no trapped air in the cooling path
  - Inspect the cooling system (radiator and hoses) for cracks and ensure connections are leak free
  - Check that the raw water pickup is not blocked/restricted by debris and that the hose is tightly connected
  - Check that the thermostat is not stuck closed
  - Check that the raw water pump/impeller is tact and that it is not

(6) TPS (Throttle Position Sensor) (DTC 121 to 123, 221 to 223, 2111, 2112, 2135)



9Y1200176ENM097US

DTC 121-TPS1 % Lower Than TPS2 %

- Hardware: Throttle Body-Throttle Position Sensors 1 & 2 relationship
- Enabling Conditions: Key-On, Engine Cranking, or Running
- Set Conditions-TPS1 % lower than TPS2 % by more than 20 % for longer than 1 second
- Corrective Action(s): Turn on MIL, **activate engine shutdown mode**
- Emissions related fault
- Possible Causes: TPS1 or TPS2 out of calibration in throttle body, unwanted resistance in either TPS1 or TPS2 signal circuits, unwanted resistance in either the shared reference feed (5 V_ext1) or shared sensor ground (5 Vrtn1), bad ECM

DTC 122-TPS1 Signal Voltage Low

- Hardware: Throttle Body-Throttle Position Sensor 1
- Enabling Conditions: Engine running
- Set Conditions: TPS1 sensor voltage lower than 0.200 V for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, shutdown engine
- Emissions related fault
- Possible Causes: Loss of 5.00 V reference feed, open or shorted to ground signal circuit, open or shorted to ground TPS in throttle body, bad ECM

DTC 123-TPS1 Signal Voltage High

- Hardware: Throttle Body-Throttle Position Sensor 1
- Enabling Conditions: Engine running
- Set Conditions: TPS1 sensor voltage higher than 4.80 V for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, shutdown engine
- Emissions related fault
- Possible Causes: 5.00 V reference feed (5 V_ext1) shorted to voltage, Open sensor ground (5 Vrtn1) circuit, signal wire shorted to voltage or bad TPS in throttle body

DTC 221-TPS1 % Higher Than TPS2 %

- Hardware: Throttle Body-Throttle Position Sensor 1 & 2 relationship
- Enabling Conditions: Key-On, Engine Cranking, or Running
- Set Conditions: TPS1 % higher than TPS2 % by more than 20 % for longer than 1 second
- Corrective Action(s): Illuminate MIL, **activate engine shutdown**
- Non-emissions related fault
- Possible Causes: TPS1 or TPS2 out of calibration in throttle body, unwanted resistance in either TPS1 or TPS2 signal circuits, unwanted resistance in either the shared reference feed (5 V_ext1) or shared sensor ground (5 vrtn1), bad ECM

DTC 222-TPS2 Signal Voltage Low

- Hardware: Throttle Body-Throttle Position Sensor 2 (electronic throttle body only)
- Enabling Condition: Key-On, Engine Off
- Set Condition: TPS2 sensor voltage lower 0.200 V for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, **activate engine shutdown**
- Emissions related fault
- Possible Causes: Loss of 5.00 V reference feed, open or shorted to ground signal circuit, open or shorted to ground TPS in throttle body, bad ECM

DTC 223-TPS2 Signal Voltage High

- Hardware: Throttle Body-Throttle Position Sensor 2 (electronic throttle body only)
- Enabling Conditions: Engine running
- Set Conditions: TPS2 sensor voltage higher than 4.80 V for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, **activate engine shutdown**
- Emissions related fault
- Possible Causes: 5.00 V reference feed (5 V_ext1) shorted to voltage, Open sensor ground (5 Vrtn1) circuit, signal wire shorted to voltage or bad TPS in throttle body

The throttle controls the airflow through the engine, directly affecting the power output of the engine. When the throttle is electronically controlled in an Electronic Throttle Body it can be used to control the idle stability and limit engine speed based on operating conditions.

Each Throttle Position Sensor uses a variable resistor and voltage divider circuit to determine throttle plate position, and is located within the throttle body. The output of the TPS is linear with angular position. The TPS input(s) provide angular position feedback of the throttle plate. In an Electronic Throttle Body multiple position feedback sensors (usually two counteracting potentiometers) are used to perform speed governing with improved safety and redundancy.

DTC 2111: Unable to Reach Lower TPS

- Hardware: Throttle Position Sensor
- Enabling Conditions: Cranking or Running
- Set Conditions: Throttle command is 20 % less than throttle position for 0.2 seconds or longer
- Corrective Action(s): Turn on MIL, activate engine shut down
- Emissions related fault
- Possible Causes: Follow at DTC 2112

DTC 2112: Unable to Reach Higher TPS

- Hardware: Throttle Position Sensor
- Enabling Conditions: Cranking or Running
- Set Conditions: Throttle command is 20 % more than actual throttle position
- Corrective Action(s): MIL-On during active fault, Adaptive-Enabled, Closed Loop-Enabled, Engine Shut Down
- Emissions related fault
- Possible Causes:

There are 2 Throttle Position Sensors located within the throttle which use variable resistors to determine signal voltage based on throttle plate position. TPS1 will read low voltage when closed and TPS2 will read high voltage when closed. The TPS1 and TPS2 % ages are calculated from these voltages. Although the voltages are different, the calculated values for the throttle position % ages should be very close to the same. The TPS values are used by the ECM to determine if the throttle is opening as commanded.

The DBW motor is a 2 wire DC motor that is PWM controlled by the ECM. Neither of these wires is watched by the ECM for electrical problems. DTCs 2111 and 2112 usually indicate that the ECM has lost control of the motor due to an electrical problem with the motor or a mechanical problem with the motor.

This fault of DTC 2111 will set if the throttle command is 20 % lower or more than the actual throttle position. During this active fault the MIL light will be on and the engine will shut down.

This fault of DTC 2112 will set if the throttle command is 20 % lower or more than the actual throttle position. During this active fault the MIL light will be on and the engine will shut down.

DTC 2135-TPS1/2 Simultaneous Voltages Out-of-Range

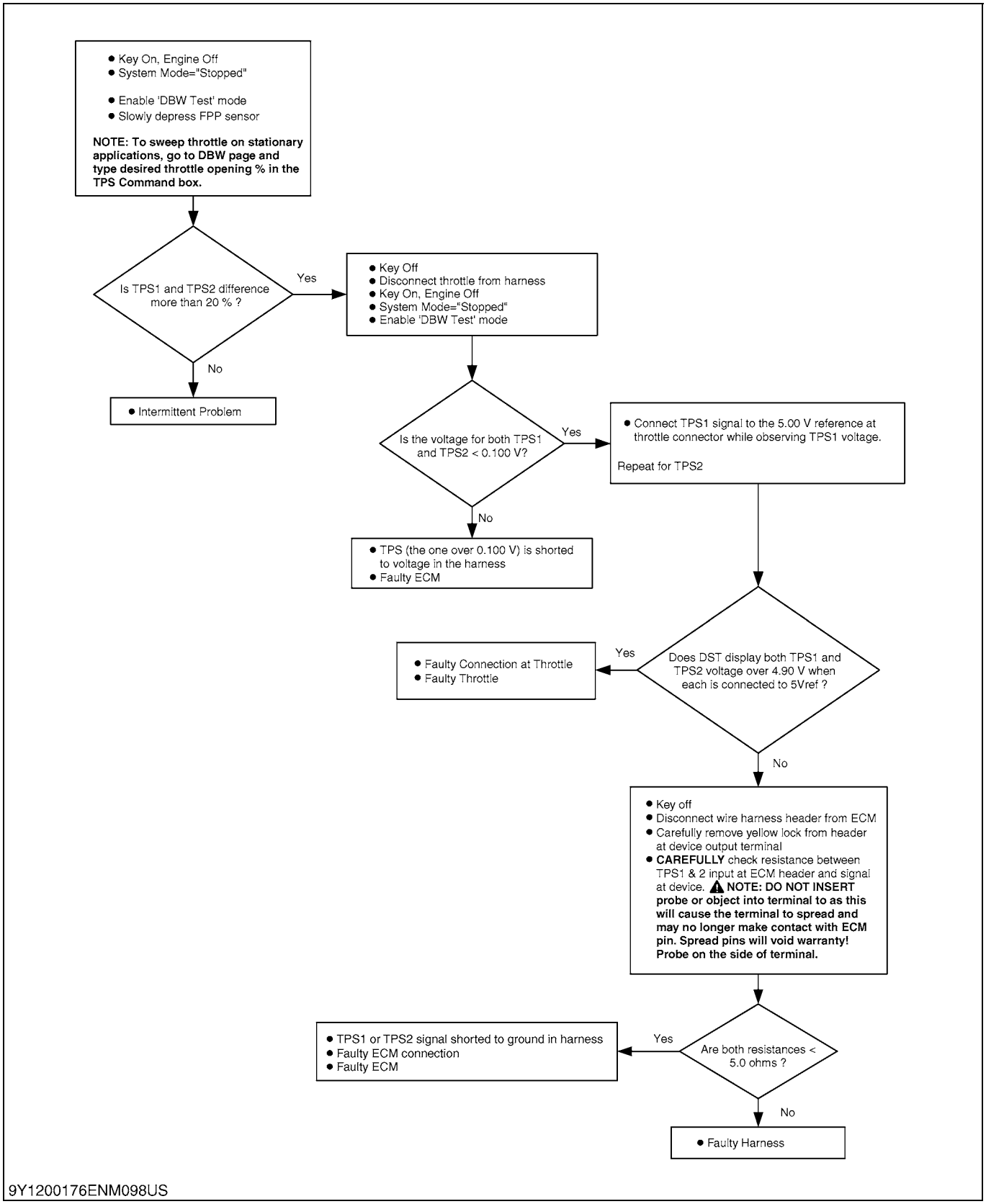
- Hardware: Electronic throttle body
- Enabling Conditions: Key On, Engine Cranking or Running
- Set Condition: TPS1 and TPS2 voltages are both simultaneously out-of-range for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL and shutdown engine
- Non-emissions related fault
- Possible Causes: Loss of 5.00 V feed to both sensors, loss of ground (5 V_rtn1) to both sensors, problem with both TPSs at the same time

The throttle is an air valve used to control the amount of air available to the engine for combustion and thereby the engine's power output. An electronic throttle simply means that a motor is controlled electronically through an electronic control system to actuate the throttle valve. Electronic throttle control is advantageous because it tends to offer improved starting, improved idle governing, improved maximum speed governing, excellent load acceptance and steady-state speed governing, permits engine synchronization, and offers flexibility to protect the engine during certain fault conditions.

This fault is generated when both feedback sensors in the ETB (TPS1 and TPS2) simultaneously produce out-of-range faults. This fault indicates that there is no feedback of the throttle valve and as a result throttle control cannot take place.

DTC 121-TPS1 % Lower Than TPS2 %

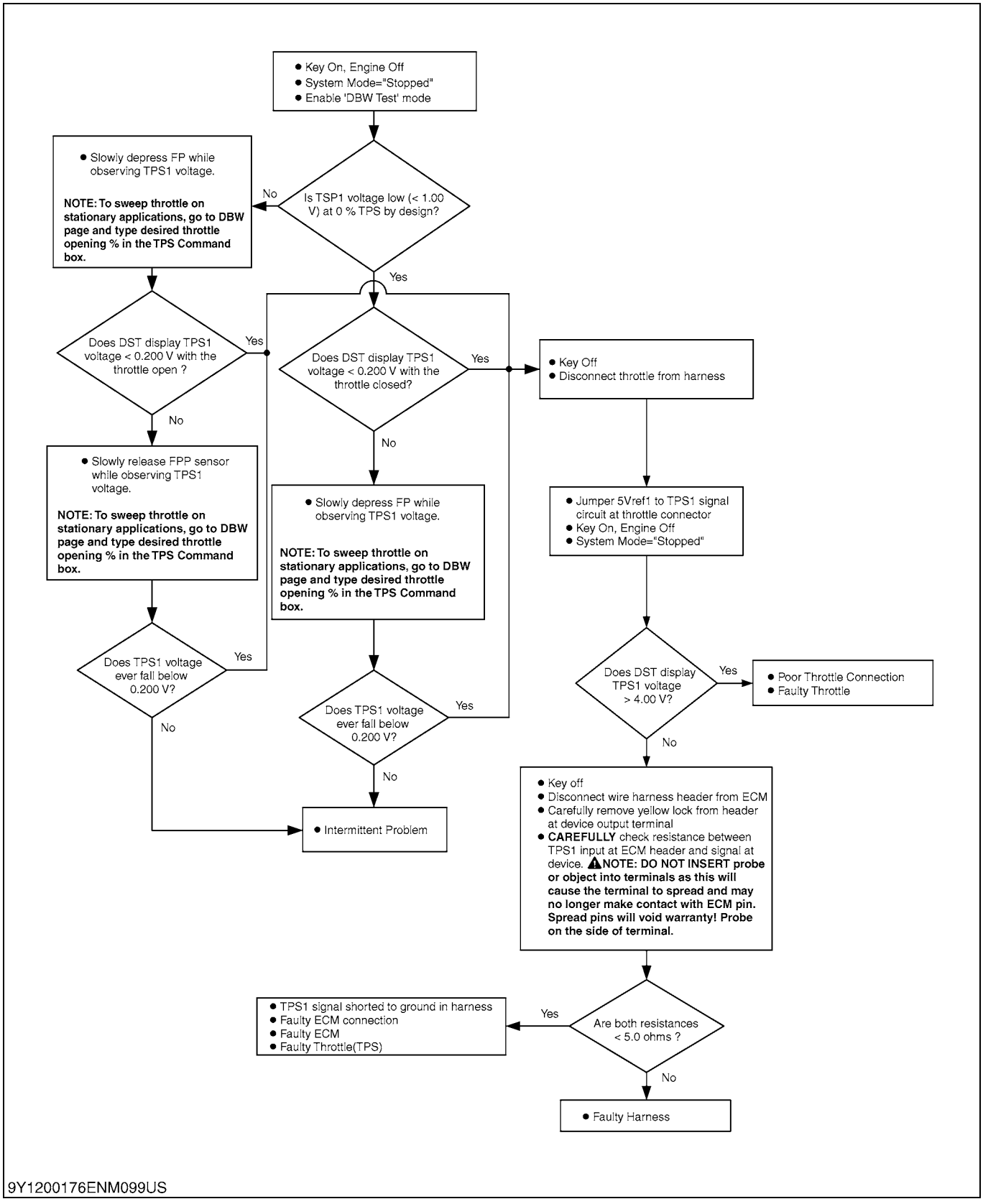
Diagnostic Aids Chart



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DTC 122-TPS1 Signal Voltage Low

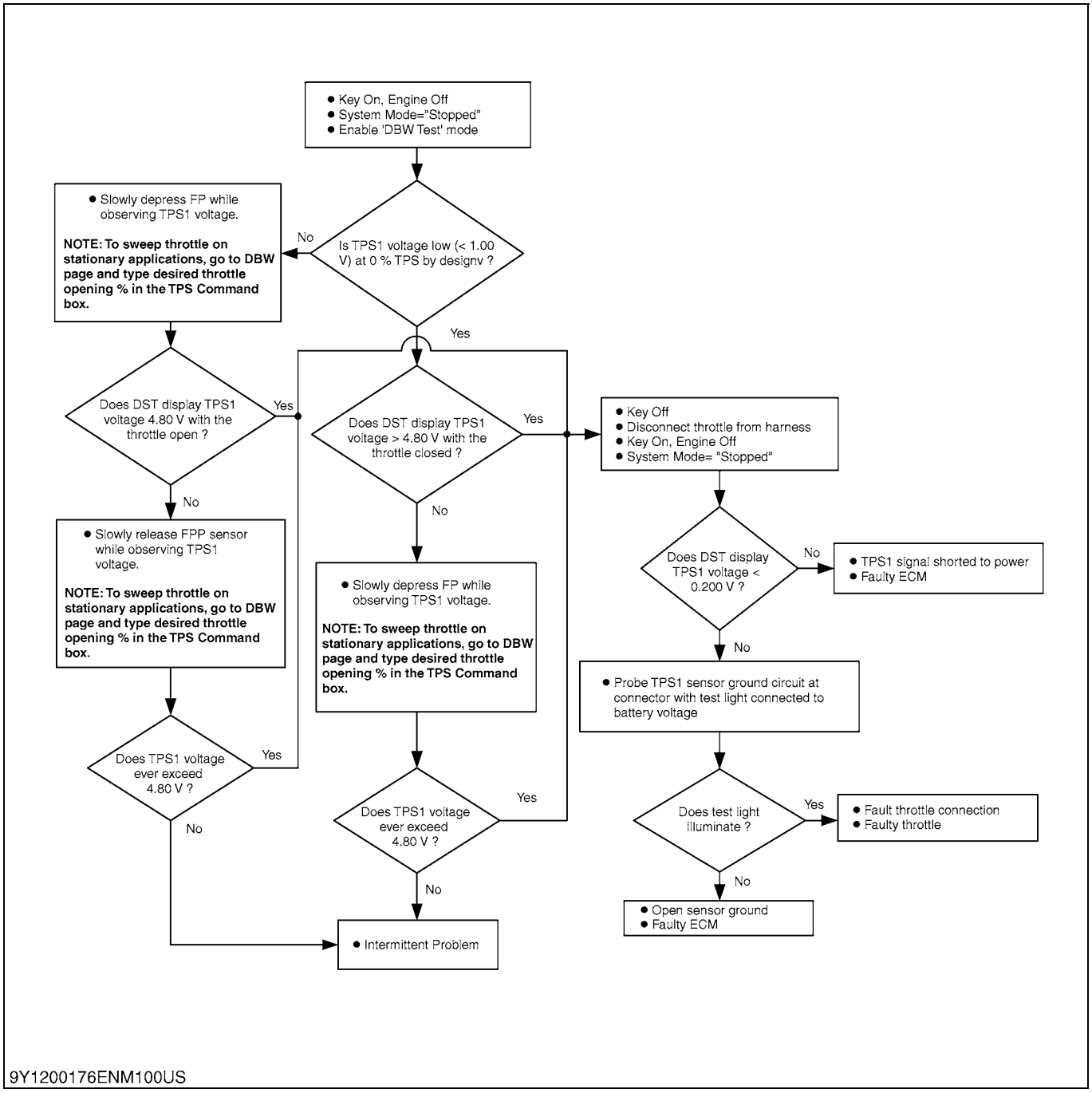
Diagnostic Aids Chart



9Y1200176ENM099US

DTC 123-TPS1 Signal Voltage High

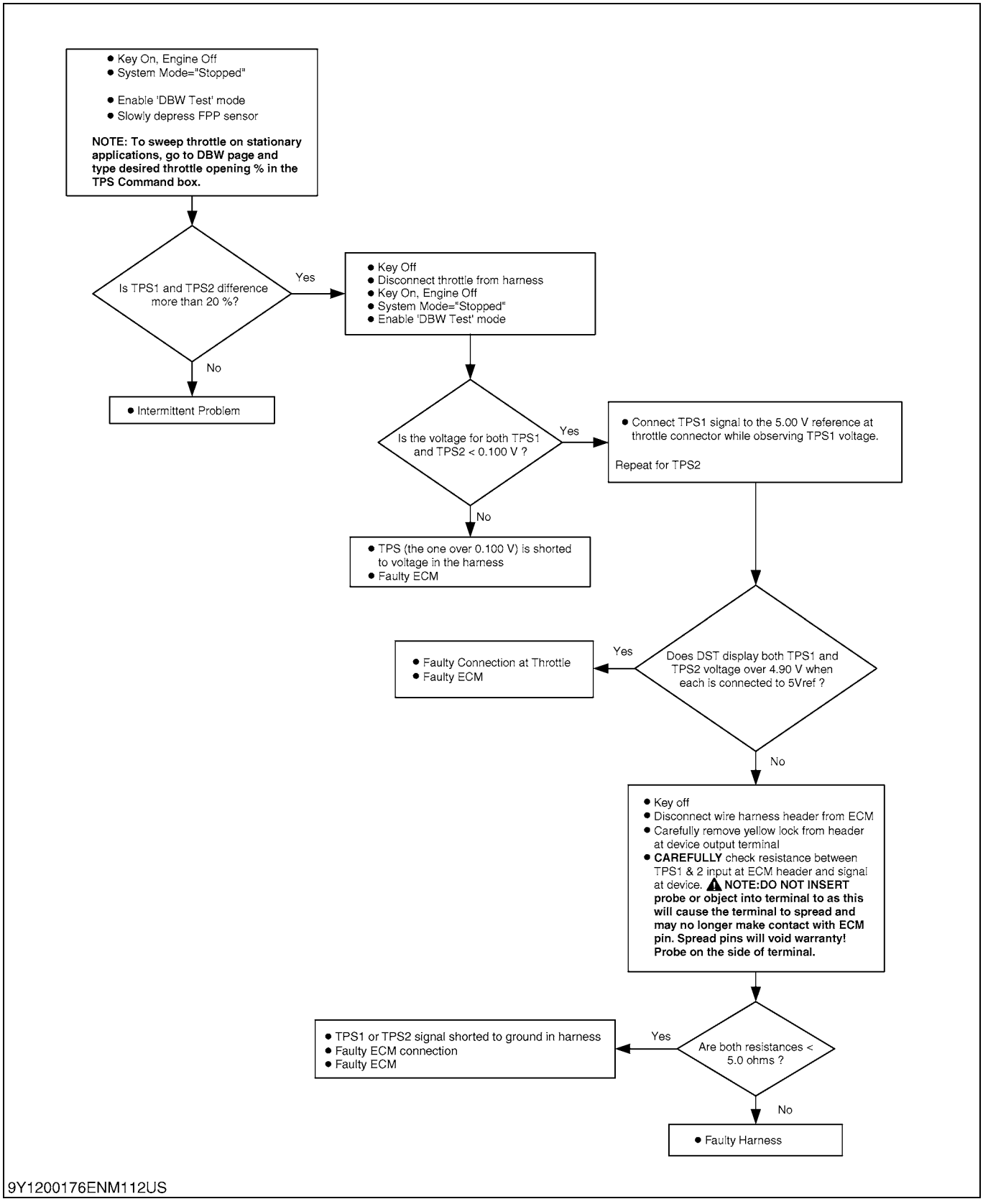
Diagnostic Aids Chart



9Y1200176ENM100US

DTC 221-TPS1 % Higher Than TPS2 %

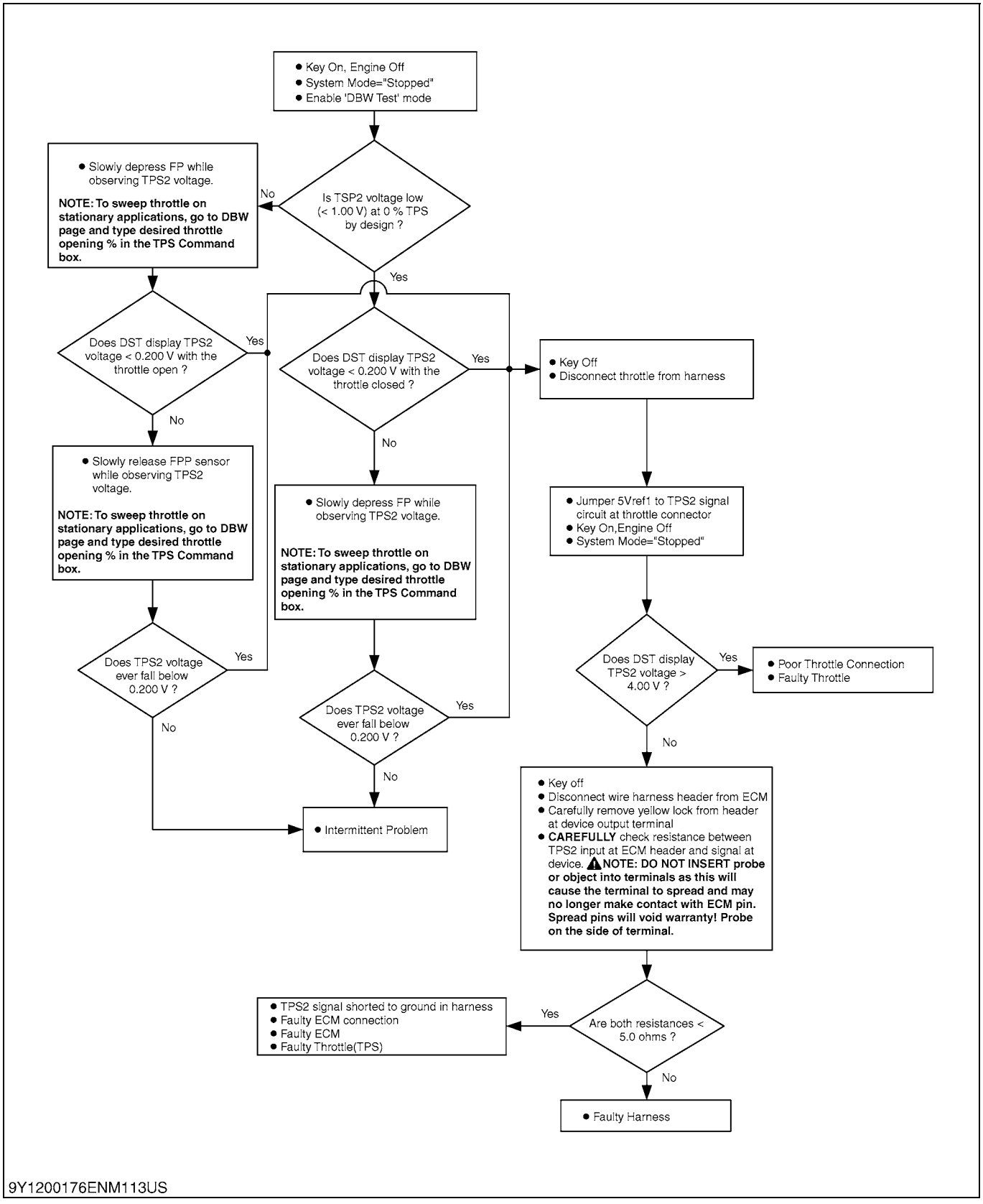
Diagnostic Aids Chart



9Y1200176ENM112US

DTC 222-TPS2 Signal Voltage Low

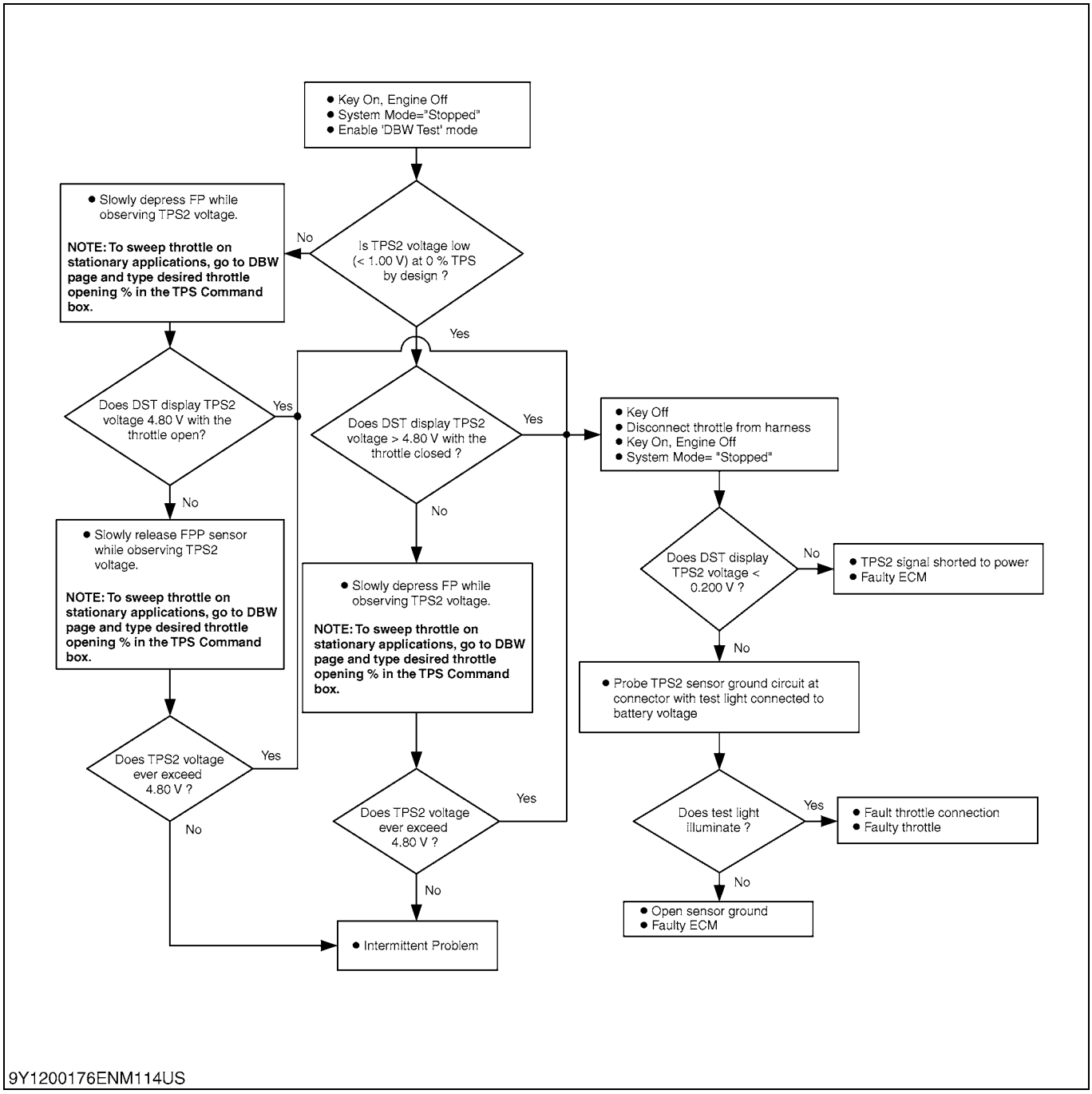
Diagnostic Aids Chart



9Y1200176ENM113US

DTC 223-TPS2 Signal Voltage High

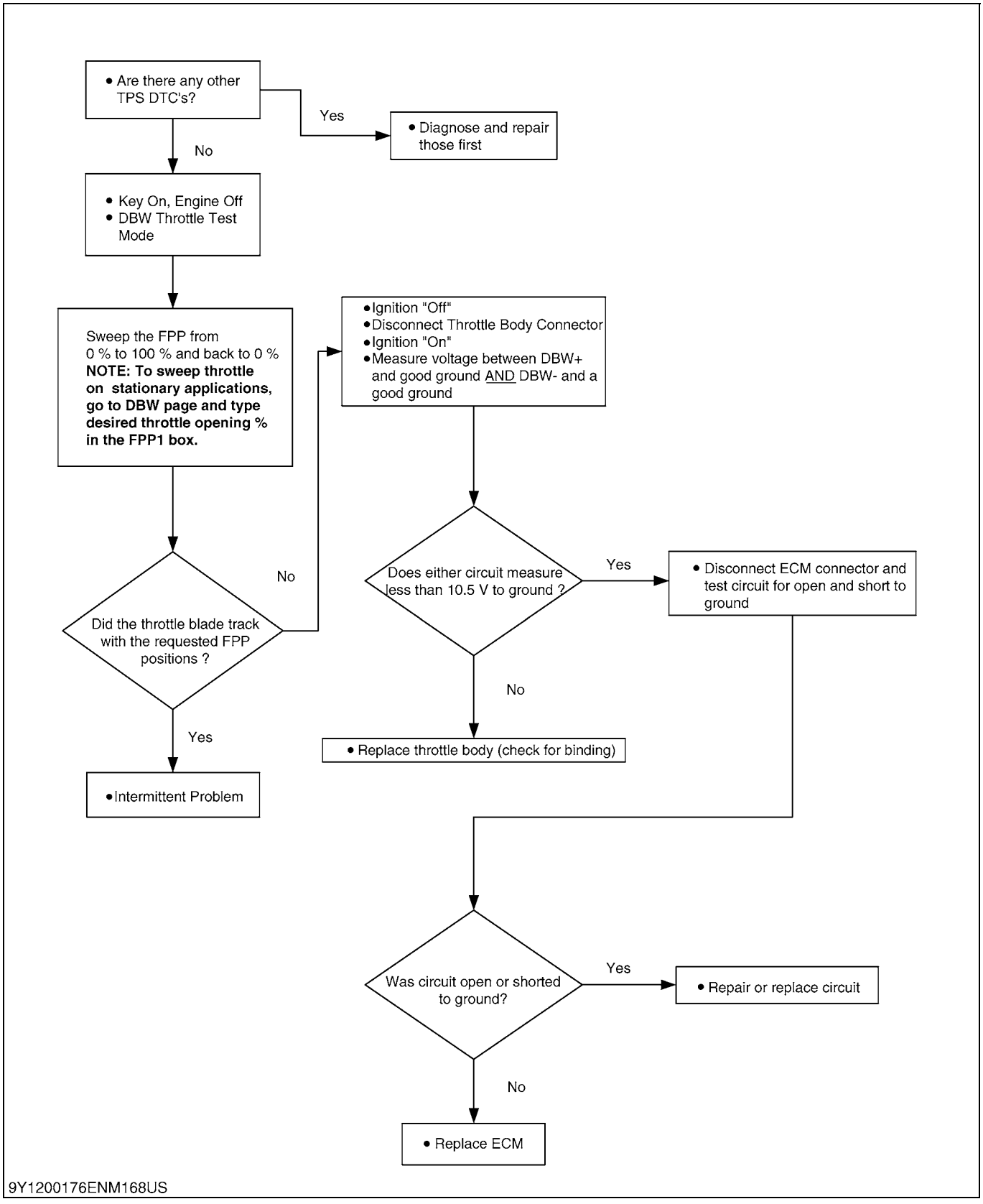
Diagnostic Aids Chart



9Y1200176ENM114US

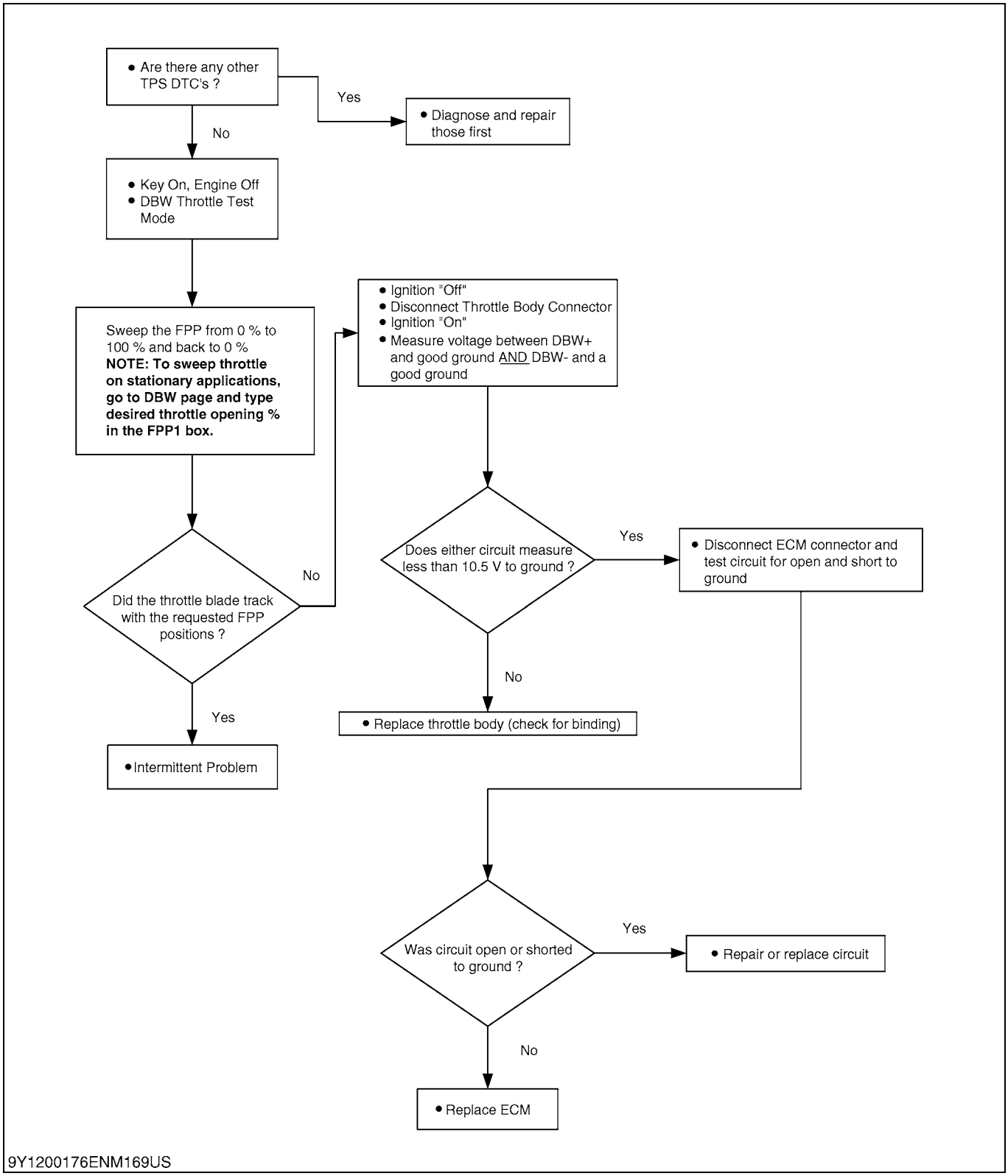
DTC 2111: Unable to Reach Lower TPS

Diagnostic Aids Chart



DTC 2112: Unable to Reach Higher TPS

Diagnostic Aids Chart

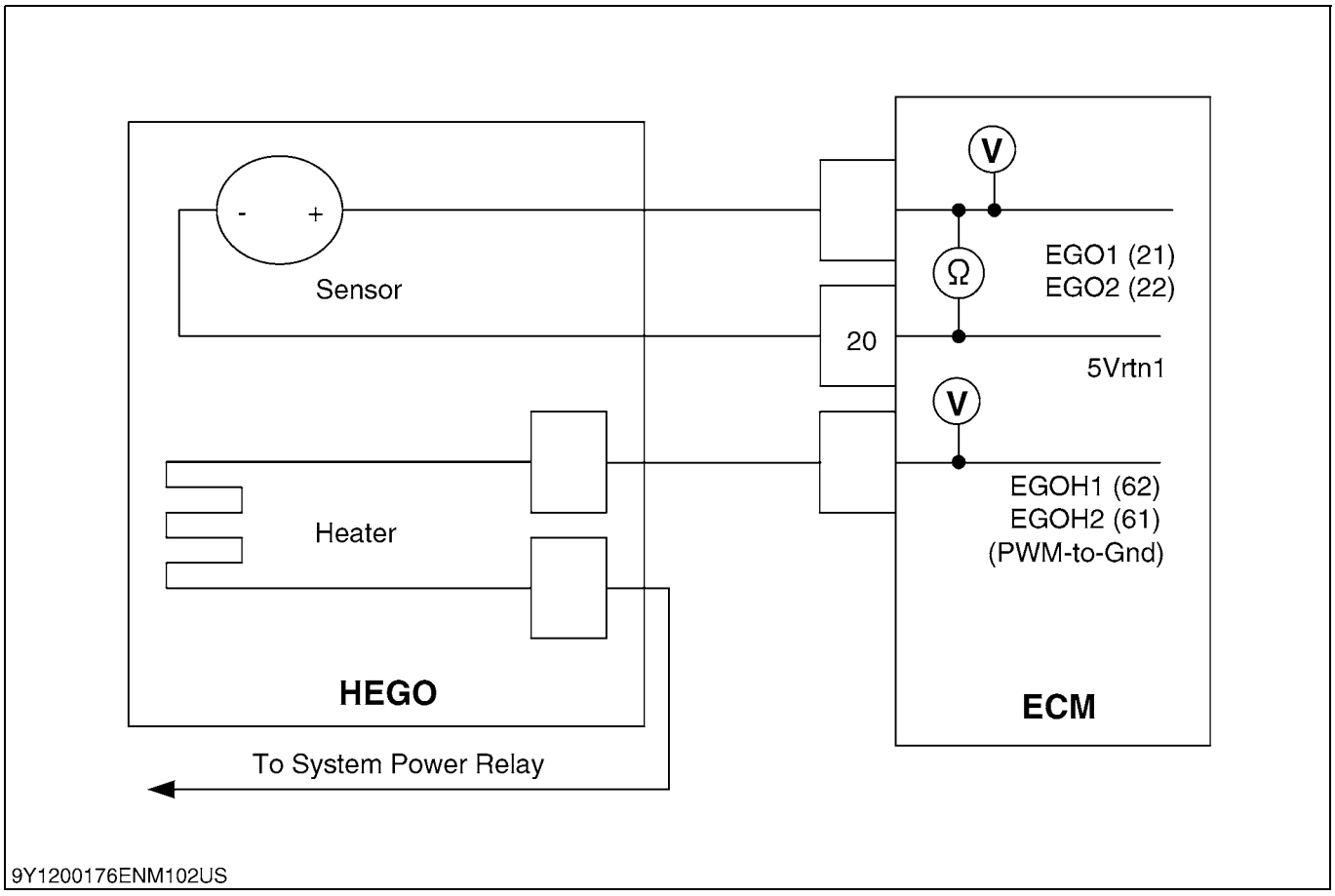


DTC 2135-TPS1/2 Simultaneous Voltages Out-of-Range

Diagnostic Aids

Troubleshoot according to TPS1 voltage out-of-range following DTC 122 and 123 procedures.
Troubleshoot according to TPS2 voltage out-of-range following DTC 222 and 223 procedures.

(7) EGO Sensors ((Exhaust Gas Oxygen) Sensors) (DTC 134, 154)



DTC 134-EGO1 Open/Lazy (HO_2S1)

- Hardware: Heated Exhaust Gas Oxygen Sensor (Pre-Catalyst)
- Enabling Conditions: Engine Running
- Set Conditions: HEGO/HO_2S cold or non-responsive for longer than 120 seconds
- Corrective Action(s): Illuminate MIL, disable closed loop operation and fuel adaptive learn correction (both) while the code is active.
- Emissions related fault
- Possible Causes: Open feed circuit to O_2 heater, Open heater ground circuit, Open or shorted to ground O_2 signal wire, open sensor ground (5 Vrtn1), inoperative sensor

The HEGO/HO_2S sensor is a switching-type sensor about stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. If there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted using the Closed Loop multiplier and then "learned" with the Adaptive multiplier. The multipliers only update when the system is in either "CL Active" or "CL + Adapt" control modes.

Cold or non-responsive is defined as the actual impedance of the sensor heater not reaching the target impedance.

DTC 154-EGO2 Open/Lazy (HO_2S2)

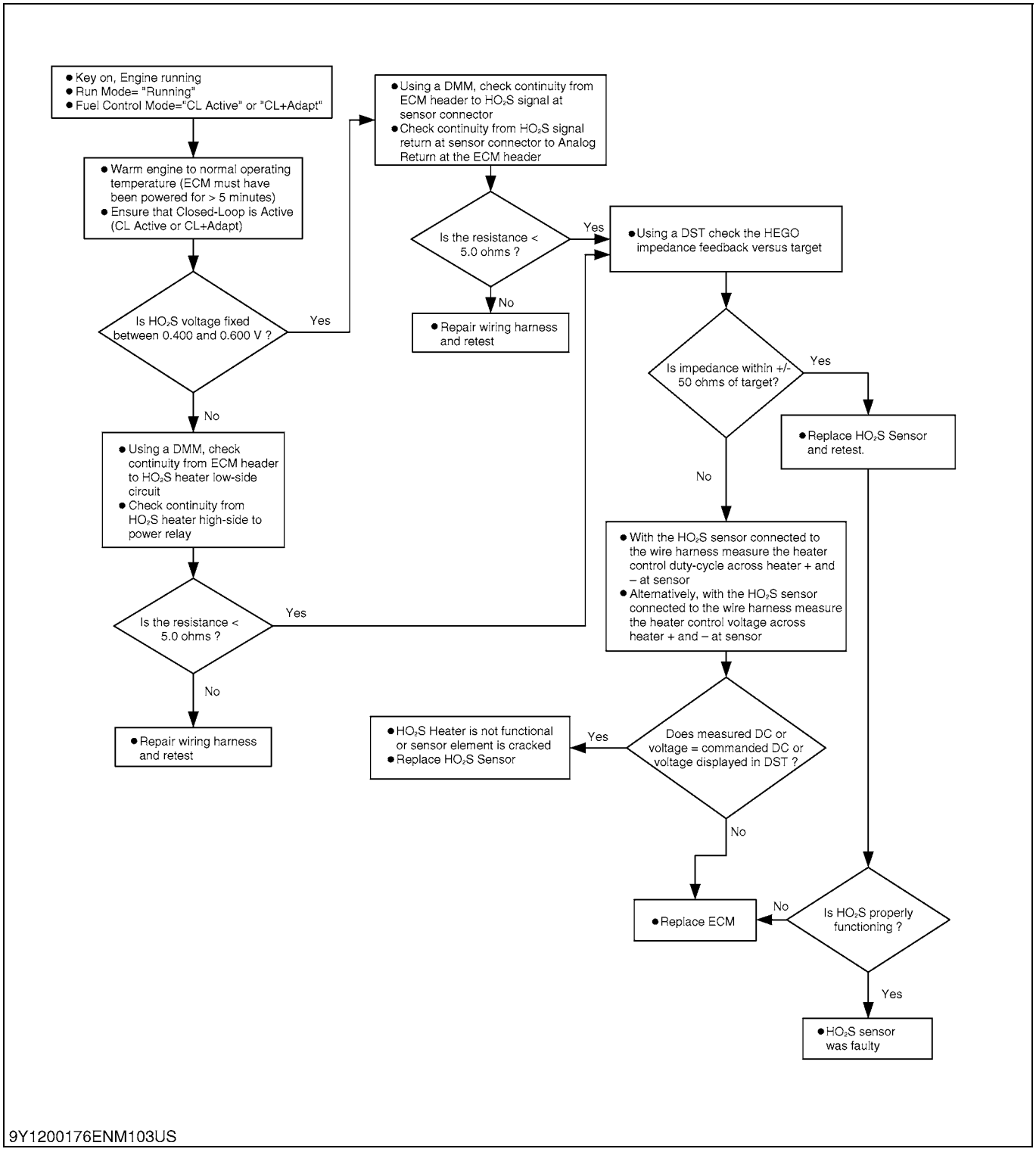
- Hardware: Heated Exhaust Gas Oxygen Sensor (Post-Catalyst)
- Enabling Conditions: Engine Running
- Set Conditions: HEGO/HO_2S cold or non-responsive longer than 120 seconds
- Corrective Action(s): Illuminate MIL.
- Emissions related fault
- Possible Causes: Open feed circuit to O_2 heater, Open heater ground circuit, Open or shorted to ground O_2 signal wire, open sensor ground (5 Vrtn1), inoperative sensor

In a post-catalyst configuration the HEGO/HO_2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content downstream of the catalyst for two main functions: 1) to compare it to the oxygen content upstream of the catalyst to determine how efficiently the catalyst is using oxygen to determine its effectiveness and 2) trim the commanded equivalence ratio target to maximize the catalyst conversion efficiency. The post-catalyst strategy and diagnostic is only active when the system is in either "CL Active" or "CL + Adapt" control modes.

Cold or non-responsive is defined as the actual impedance of the sensor heater not reaching the target impedance.

DTC 134-EGO1 Open/Lazy (HO_2S1)

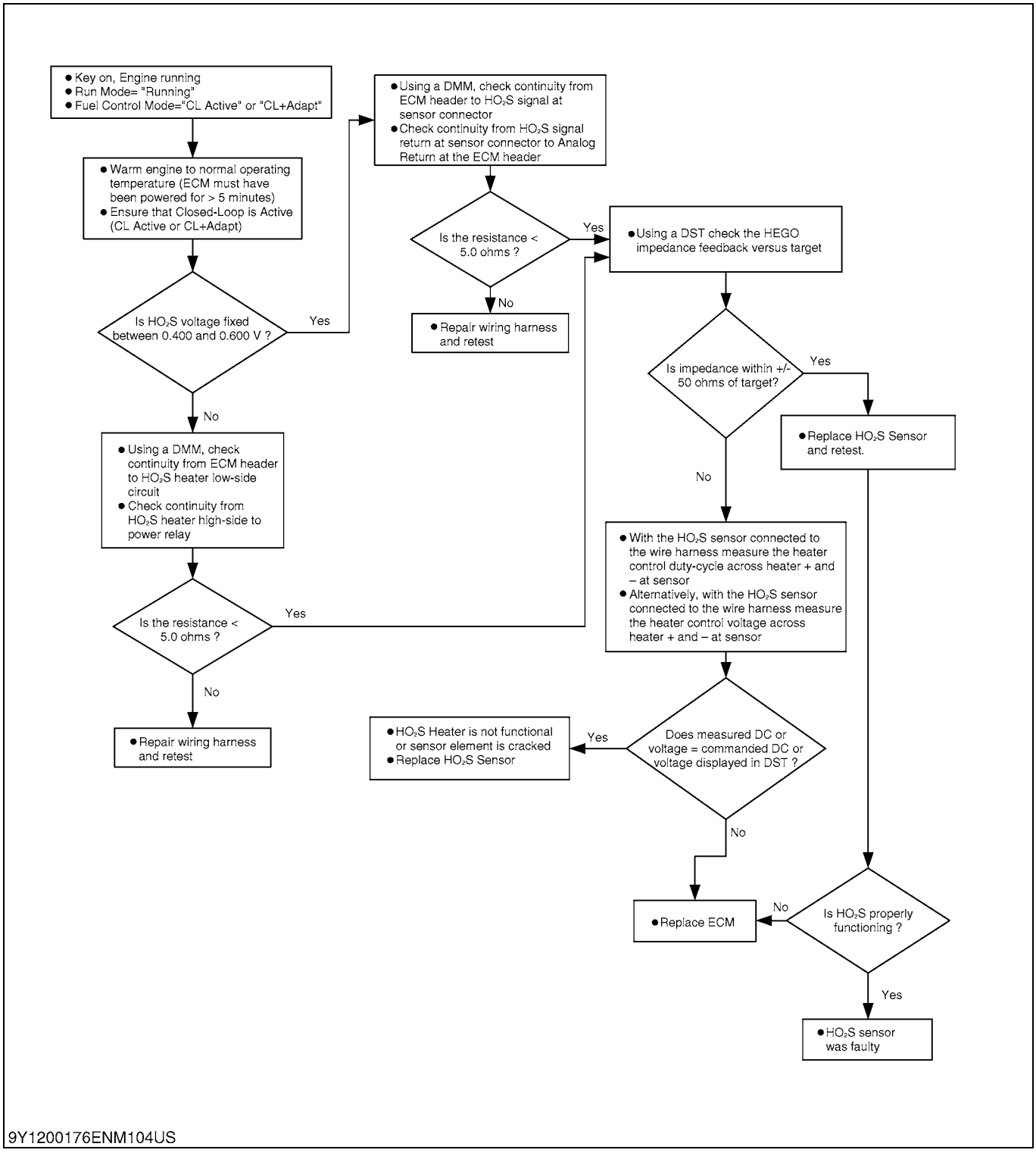
Diagnostic Aids Chart



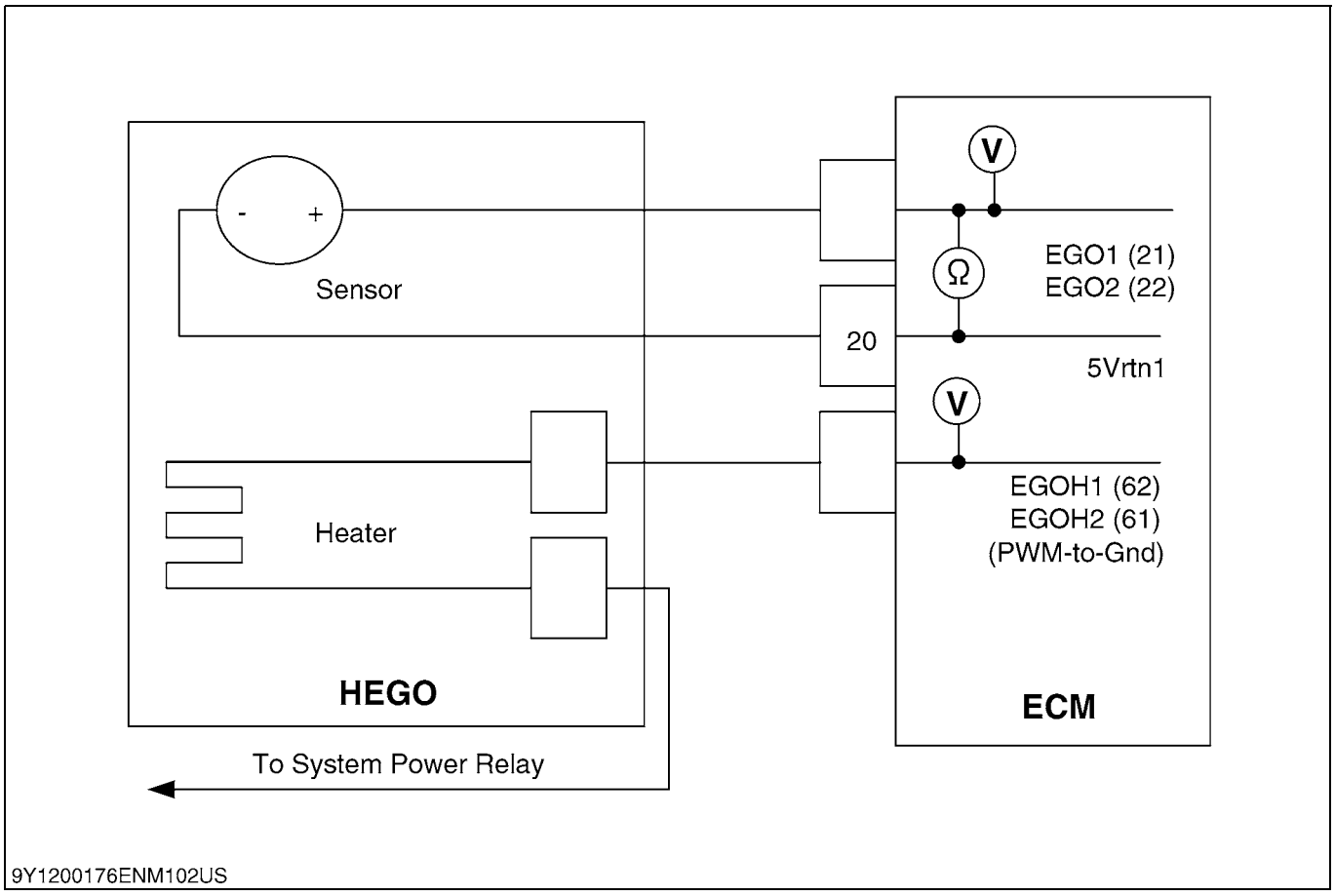
9Y1200176ENM103US

DTC 154-EGO2 Open/Lazy (HO_2S2)

Diagnostic Aids Chart



(8) Adaptive Learn (DTC 171, 172, 1161 to 1164)



DTC 171-Adaptive Learn Bank 1 High (Gasoline)

- Hardware: HEGO Sensor (Pre-Catalyst) rich-lean switch rate
- Enabling Conditions: Engine Running in closed loop active mode updating adaptive learn multiplier (CL+Adap mode)
- Set Conditions: Bank 1 adaptive learn multiplier ≥ +30 % for longer than 3 updates (see below)
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: See Diagnostic aids below and on next page

DTC 172-Adaptive Learn Bank1 Low (Gasoline)

- Hardware: HEGO Sensor (Pre-Catalyst) rich-lean switch rate
- Enabling Conditions: Engine Running in closed loop active mode updating adaptive learn multiplier (CL+Adap mode)
- Set Condition: Bank 1 adaptive learn multiplier ≤ 30 % for longer than 3 updates (see below)
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: See Diagnostic aids below and on next page

The purpose of the Adaptive Learn Multiplier is to adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation. The Adaptive Learn multiplier values are held in a table and are remembered between key cycles. Adaptive memory tables are erased at battery disconnects and with the DST.

An "update" (from Set Conditions above) can be thought of as a "variable timer", one that takes longer to set a fault at low engine speeds than at higher speeds.

This fault of DTC 171 sets if the Adaptive multiplier exceeds the high limit of normal operation indicating that the engine is operating lean (excess oxygen) and requires more fuel than allowed by corrections. Often high positive fueling corrections are a function of one or more of the following conditions: 1) exhaust leaks upstream or near the HEGO sensor, 2) reduced fuel supply pressure to the fuel injection system, 3) a inoperative sensor, 3) an injector that is stuck closed or dirty, 4) weak spark or lack of spark to a cylinder and/or 5) a MAP sensor that indicates pressure that is lower than true pressure.

This fault of DTC 172 sets if the Adaptive multiplier exceeds the low limit of normal operation indicating that the engine is operating rich (low oxygen content) and requires less fuel than allowed by corrections. Often high negative fueling corrections are a function of one or more of the following conditions: 1) an inoperative O_2 sensor, 2) high fuel supply pressure or temperature, 3) internal mechanical engine damage, 3) an injector that is stuck open or leaking, and/or 4) improper airflow through the engine due to things such as valve timing problems, collapsed lifters/followers, worn cam lobes or bent pushrods.

To test the O_2 sensor run the CL test. This test tests both pre-cat and post-cat O_2 sensor functionality.

DTC 171-Adaptive Learn Bank 1 High (Gasoline)

Diagnostic Aids

■ **NOTE**

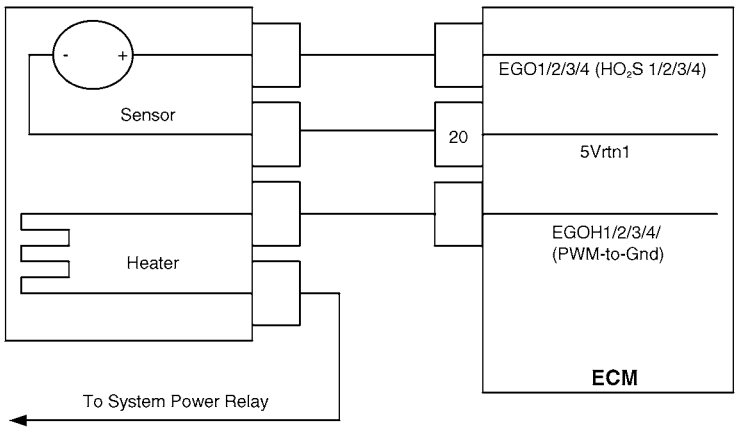
- **If any other DTCs are present, diagnose those first.**
- Oxygen Sensor Wire-Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- Inoperative Oxygen Sensor-sensor may be damaged internally and unable to switch resulting in a system that over fuels or under fuels the engine.
- Weak Spark or Lack of Spark to a Cylinder-improper burning of the fuel/air mixture in a cylinder results in excess unburned oxygen exiting the cylinder causing the pre-cat O_2 sensor to see a lean condition
- Vacuum Leaks-Large vacuum leaks and crankcase leaks can cause a lean exhaust condition at light load.
- Injectors-System will be lean if an injector driver or driver circuit fails. The system will also be lean if an injector fails in a closed manner or is dirty.
- Fuel Pressure-System will be lean if fuel pressure is too low. Check fuel pressure in the fuel rail during key-on, engine off and during normal operating conditions.
- Air in Fuel - If the fuel return hose/line is too close to the fuel supply pickup in the fuel tank, air may become entrapped in the pump or supply line causing a lean condition and driveability problems.
- Exhaust Leaks - If there is an exhaust leak, outside air can be pulled into the exhaust and past the O_2 sensor causing a false lean condition.
- Fuel Quality - A drastic variation in fuel quality may cause the system to be lean including oxygenated fuels.
- System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- If all tests are OK, replace the HO_2S sensor with a known good part and retest.

DTC 172-Adaptive Learn Bank1 Low (Gasoline)

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- Injectors - System will be rich if an injector driver or driver circuit fails shorted-to-ground. The system will also be rich if an injector fails in an open position or leaks.
- Fuel Pressure - System will be rich if fuel pressure is too high. Check fuel pressure in the fuel rail during key-on, engine off and during normal operating conditions.
- System Electrical Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems (causing sensors to provide bad information to the ECM).
- Internal mechanical engine damage causing lower than normal intake manifold vacuum
- MAP sensor that indicates pressure higher than true pressure
- Coolant Temperature Sensor - A sensor that indicates the engine is colder than actual engine temperature
- If all tests are OK, replace the HO_2S sensor with a known good part and retest.



9Y1200176ENM133US

DTC 1161-Adaptive Learn High (LPG)

DTC 1163-Adaptive Learn High (NG)

- Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- Enabling Conditions: Engine Running in closed loop and with fuel adaptive learn active
- Set Conditions: Adaptive fuel multiplier higher than 30 % for longer than 3 updates
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes:

The HEGO/HO_2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. A UEGO sensor measures the exhaust content across a wide-range of air-fuel ratios with a linear output proportional to lambda/equivalence ratio/air-fuel ratio. In either case, if there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted for each bank using the Closed Loop multiplier and then "learned" with the Adaptive multiplier. The multipliers only update when the system is in either "CL Active" or "CL + Adapt" control modes. The purpose of the Adaptive Learn fuel multiplier is to adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation.

This fault sets if the Adaptive multiplier exceeds the high limit of normal operation indicating that the engine is operating lean (excess oxygen) and requires more fuel than allowed by corrections. Often high positive fueling corrections are a function of one or more of the following conditions: 1) exhaust leaks upstream or near the HEGO sensor, 2) reduced fuel supply pressure to the gaseous fuel control system, 3) a fuel supply or manifold leak, 4) a non-responsive HEGO/UEGO sensor, and/or 5) a defective gaseous fuel control component (actuator/valve and/or mixer). This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

DTC 1162-Adaptive Learn Low (LPG)

DTC 1164-Adaptive Learn Low (NG)

- Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- Enabling Conditions: Engine Running in closed loop and with fuel adaptive learn active
- Set Conditions: Adaptive fuel multiplier lower than –30 % for longer than 3 updates
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes:

The HEGO/HO_2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. A UEGO sensor measures the exhaust content across a wide-range of air-fuel ratios with a linear output proportional to lambda/equivalence ratio/air-fuel ratio. In either case, if there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted for each bank using the Closed Loop multiplier and then "learned" with the Adaptive multiplier. The multipliers only update when the system is in either "CL Active" or "CL + Adapt" control modes. The purpose of the Adaptive Learn fuel multiplier is to adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation.

This fault sets if the Adaptive multiplier exceeds the low limit of normal operation indicating that the engine is operating rich (excess fuel) and requires less fuel than allowed by corrections. Often high negative fueling corrections are a function of one or more of the following conditions: 1) high fuel supply pressure to the gaseous fuel control or faulty pressure regulator and/or 2) a non-responsive HEGO/UEGO sensor. This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

DTC 1161-Adaptive Learn High (LPG)

DTC 1163-Adaptive Learn High (NG)

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor sense signal.
- Vacuum Leaks - Large vacuum leaks and crankcase leaks can cause a lean exhaust condition at light load.
- Fuel Pressure - System will be lean if fuel pressure is too low. Ensure fuel tank pressure is not too low and that gaseous fuel control actuator/regulator has proper fuel pressure under all operating conditions.
- Exhaust Leaks - If there is an exhaust leak, outside air can be pulled into the exhaust and past the O_2 sensor causing a false lean condition.
- Fuel Quality - A drastic variation in fuel quality may cause the system to be lean including fuels with high inert gas content.
- System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- If all tests are OK, replace the HO_2S or UEGO sensor with a known good part and retest.

DTC 1162-Adaptive Learn Low (LPG)

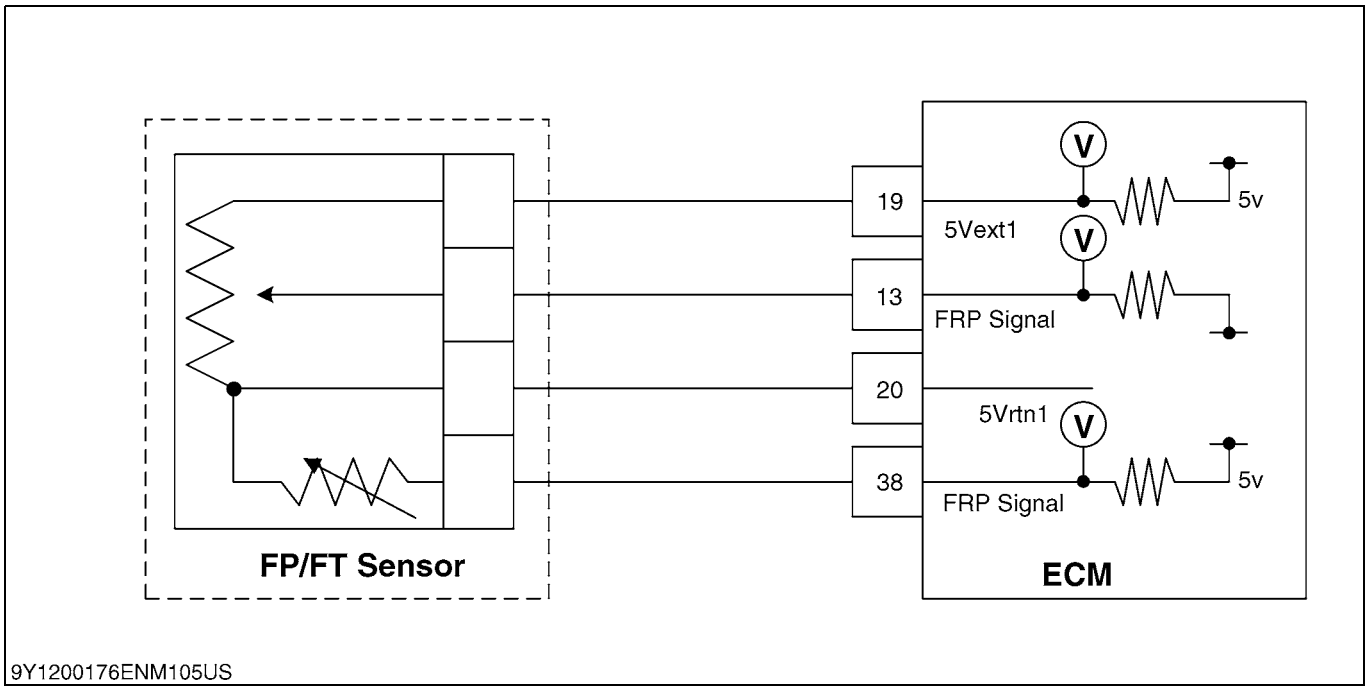
DTC 1164-Adaptive Learn Low (NG)

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- Fuel Pressure - System will be rich if fuel delivery pressure is too high to gaseous control system. Check fuel pressure at the control actuator/valve under all operating conditions.
- System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- If all tests are OK, replace the HO_2S or UEGO sensor with a known good part and retest.

(9) Fuel Temp (Fuel Temperature Sensor) (DTC 182, 183)



DTC 182-Fuel Temp (Gasoline) Low Voltage/Low Temp

- Hardware: Liquid Fuel Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: FT sensor voltage less than 0.050 V **OR** indicated temperature below −37 °C (−35 °F) for longer than 1 second
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for the rest of the key cycle
- Emissions related fault (evaporative emissions)
- Possible causes:
  - Voltage Low: Sensor signal wire shorted to ground, sensor shorted internally, faulty ECM
  - Temperature Low: Operating in a frigid atmosphere, Sensor out of calibration, partial short to ground in signal circuit causing circuit to indicate a very cold temp (below −37 °C (−35 °F)) but not high enough to set a high voltage fault

The Fuel Temperature sensor is a thermistor (temperature sensitive resistor) integrated into the fuel pressure located in the fuel supply line between the fuel pump and the fuel rail. It is used to monitor the fuel temperature exiting the fuel pump to set a fault if the fuel temperature is too high resulting in increased fuel vapor from the fuel tank causing excessive evaporative emissions (for emissions regulations compliance). The ECM provides a voltage divider circuit so that when the fuel is cool, the signal reads higher voltage, and lower when warm.

This fault will set if the signal voltage is less than 0.050 V anytime that the engine is running **OR** the indicated temperature from the sensor is below −37 °C (−35 °F) for longer than 1 second.

DTC 183-Fuel Temp (Gasoline) High Voltage/High Temp

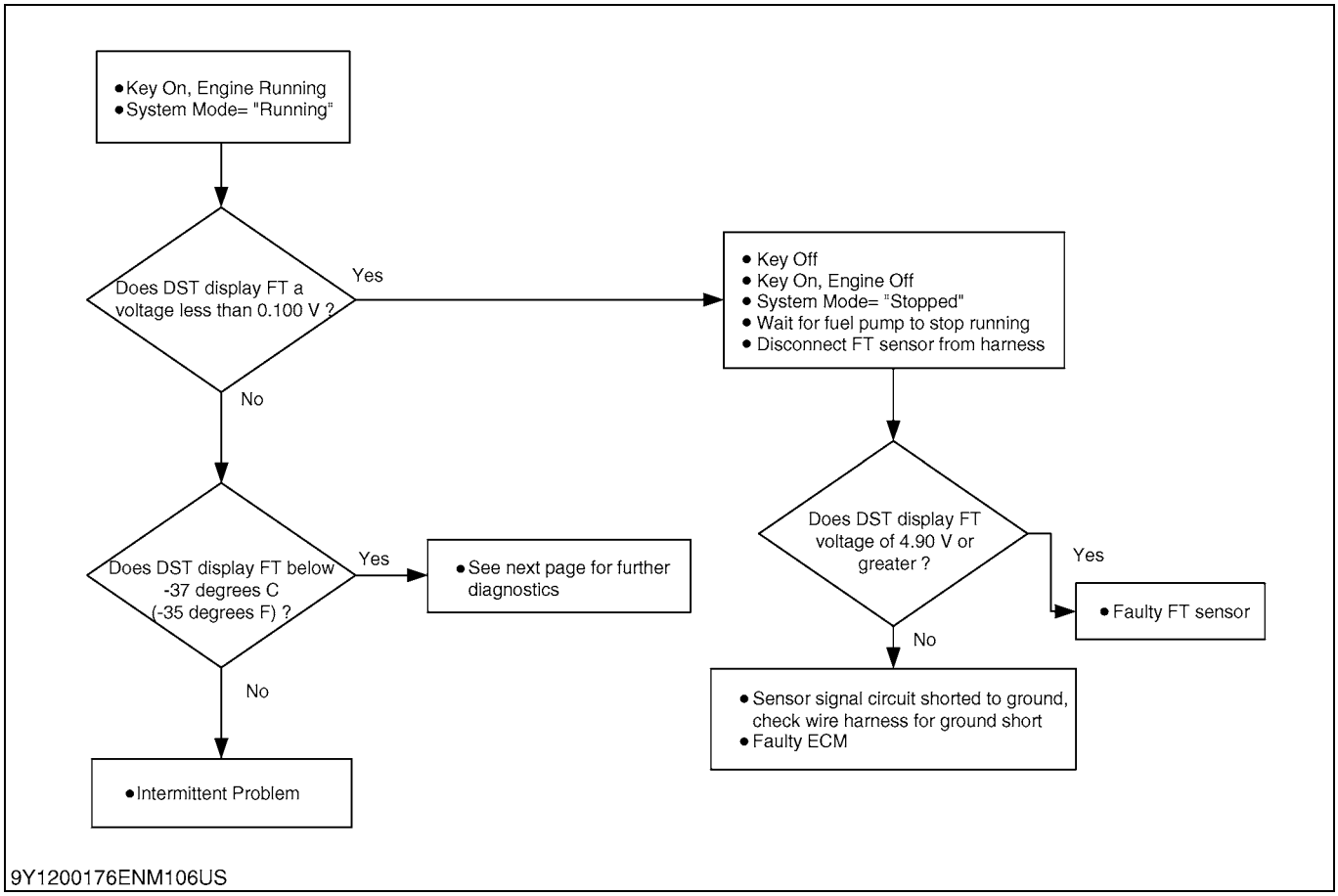
- Hardware: Liquid Fuel Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: FT sensor voltage higher than 4.90 V **OR** indicated temperature above 59 °C (138 °F) for longer than 2 minutes
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for the rest of the key cycle
- Emissions related fault
- Possible Causes:
  - Voltage High: Sensor signal wire shorted to voltage, sensor open, signal circuit open or faulty ECM
  - Temperature High: Operating in a hot environment, Sensor out of calibration, unwanted resistance in signal circuit causing circuit to indicate a very hot temp (above 59 °C (138 °F)) but voltage not low enough to set a low voltage fault

The Fuel Temperature sensor is a thermistor (temperature sensitive resistor) integrated into the fuel pressure located in the fuel supply line between the fuel pump and the fuel rail. It is used to monitor the fuel temperature exiting the fuel pump to set a fault if the fuel temperature is too high resulting in increased fuel vapor from the fuel tank causing excessive evaporative emissions. The ECM provides a voltage divider circuit so that when the fuel is cool, the signal reads higher voltage, and lower when warm.

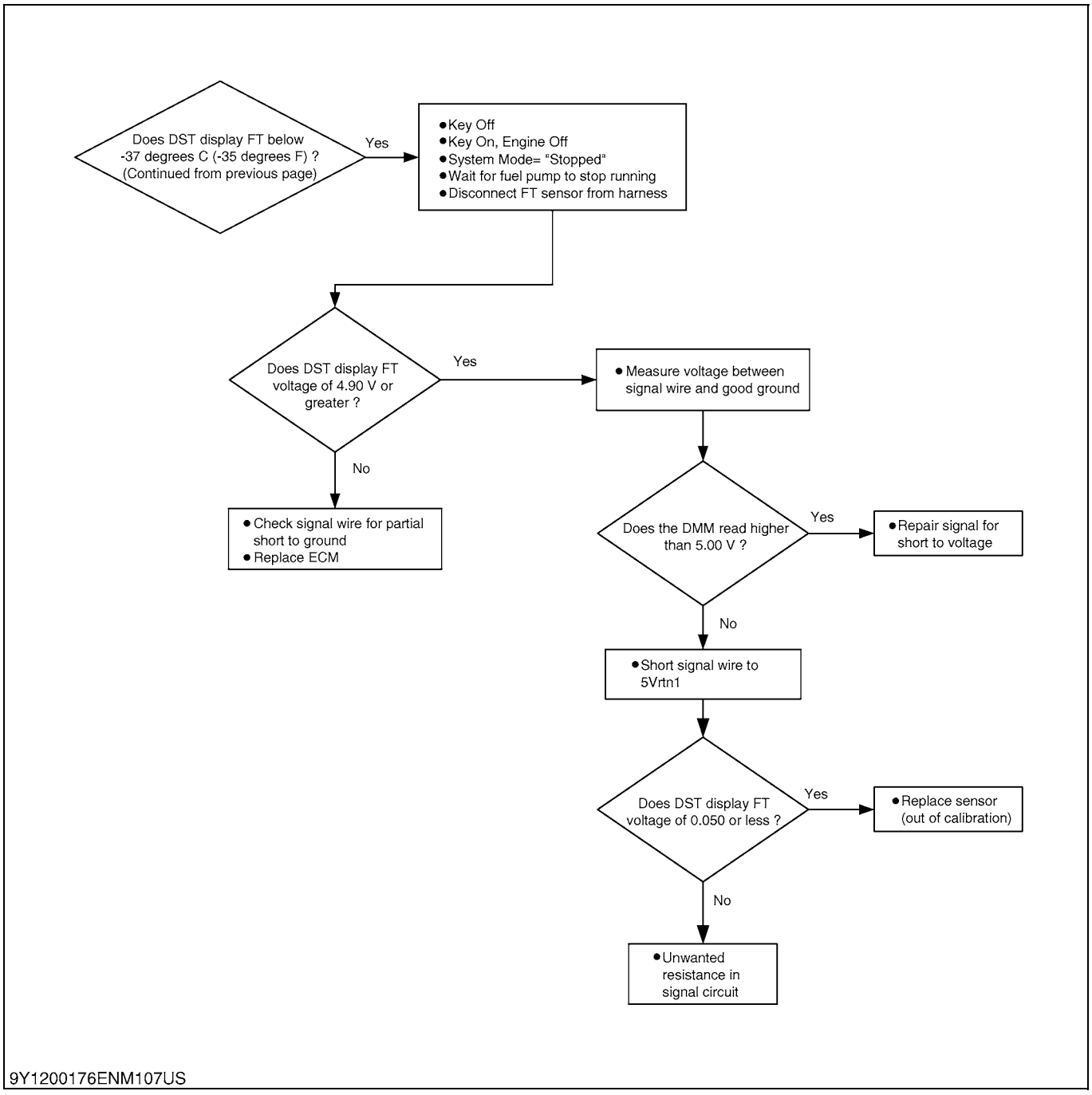
This fault will set if the signal voltage is higher than 4.90 V anytime that the engine is running **OR** the indicated temperature from the sensor is above 59 °C (138 °F) for longer than 1 second.

DTC 182-Fuel Temp (Gasoline) Low Voltage/Low Temp

Diagnostic Aids Chart (Low Voltage/Low Temp)

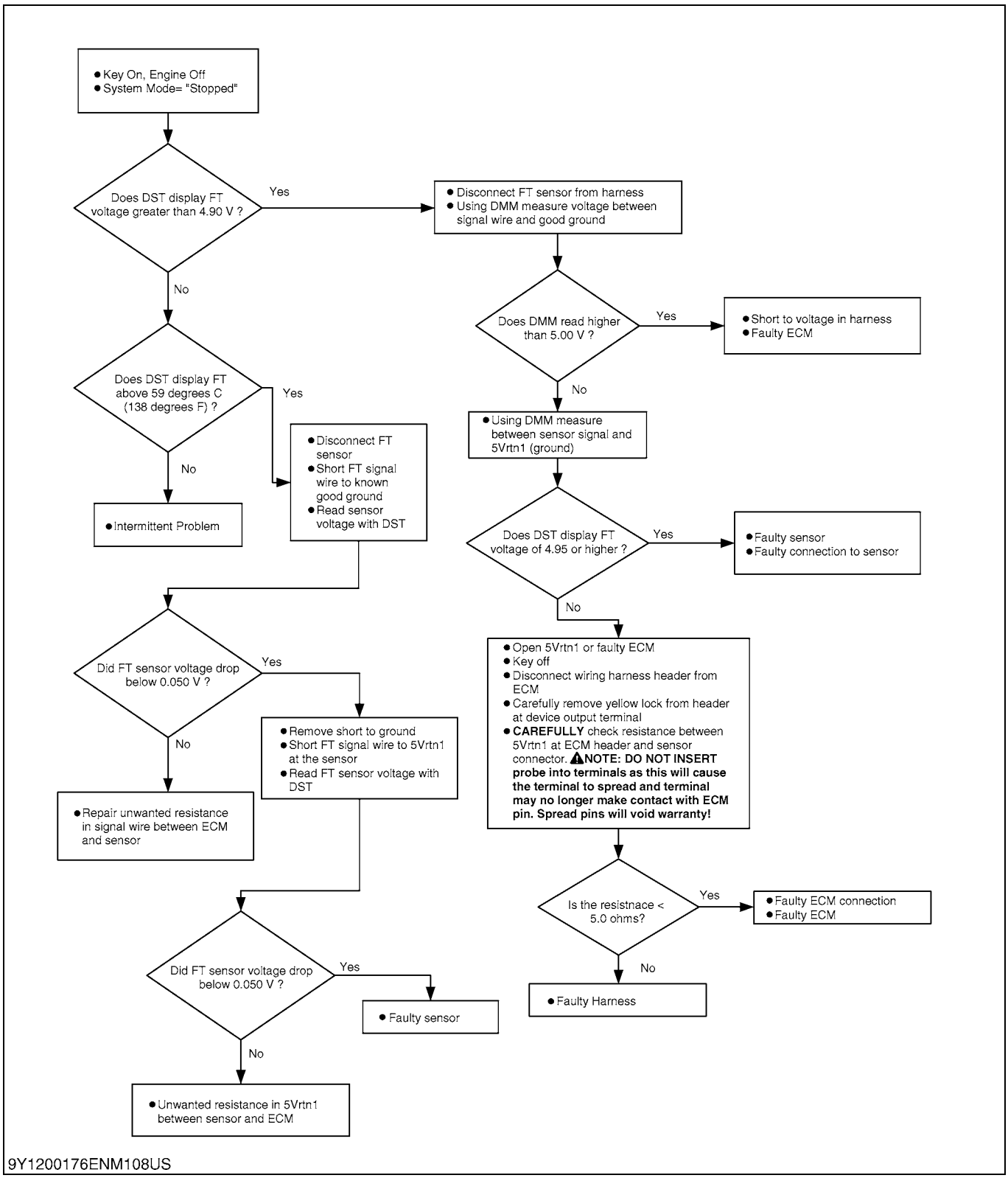


Diagnostic Aids Chart (Low Voltage/Low Temp)



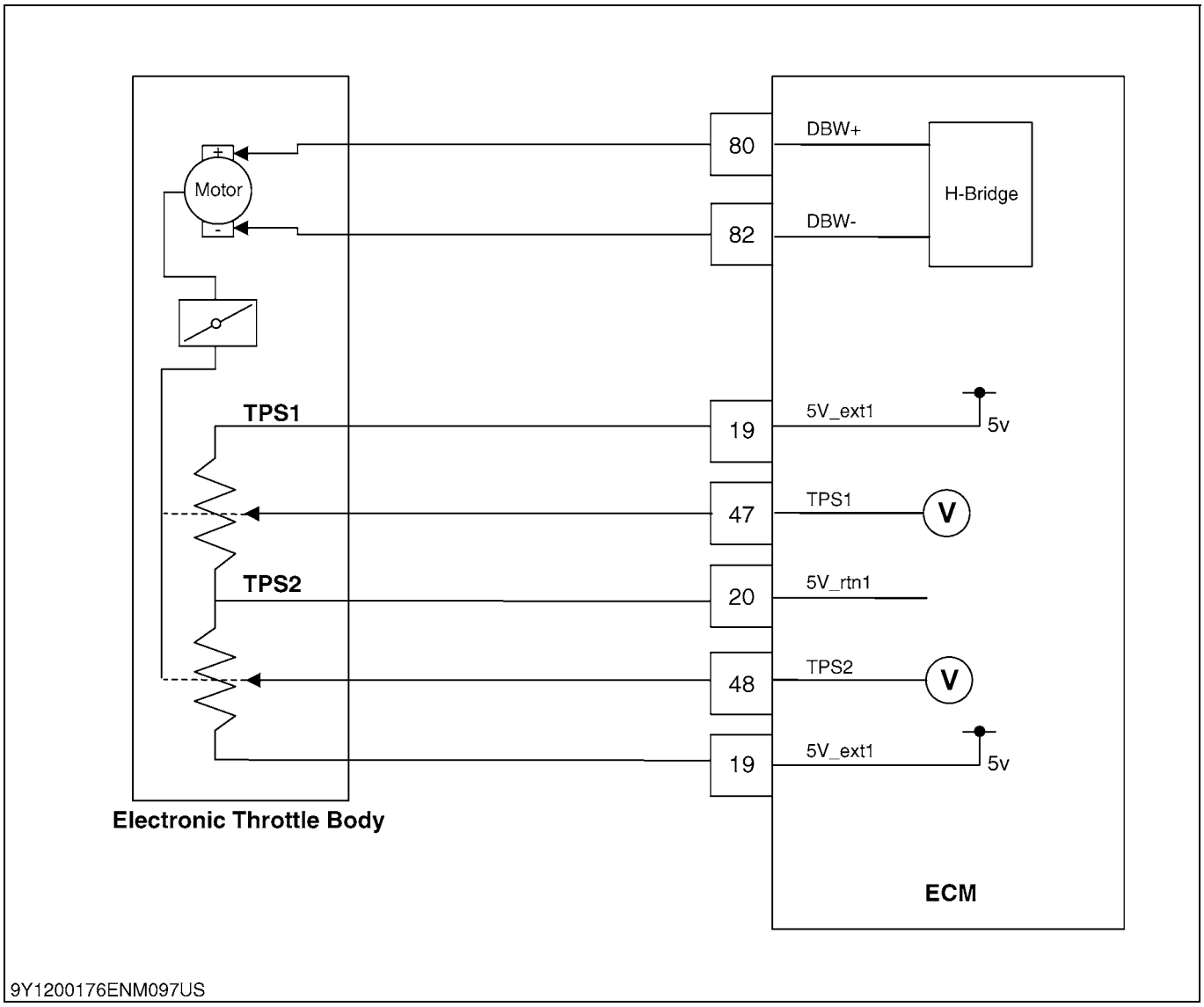
DTC 183-Fuel Temp (Gasoline) High Voltage/High Temp

Diagnostic Aids Chart



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(10) Engine Speed (DTC 219, 1111, 1112)



DTC 219-RPM Higher Than Max Allowed Governed Speed

- Hardware: Max Govern Speed Override- Crankshaft Position Sensor
- Enabling Conditions: Engine Running
- Fault Condition-Engine speed greater 3900 min^{-1} (rpm) for longer than 1 second
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Engine over speed condition, stuck throttle, large vacuum leak into intake manifold after throttle blade

DTC 1111-RPM Above Fuel Rev Limit Level

- Hardware: Fuel Rev Limit- Crankshaft Position Sensor
- Enabling Conditions: Engine Running
- Set Conditions: Engine speed greater than the Fuel Rev Limit speed (4000 min^{-1} (rpm)) for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Engine over speed condition, faulty CKP sensor or input

DTC 1112-RPM Above Spark Rev Limit Level

- Hardware: Spark Rev Limit- Crankshaft Position Sensor
- Enabling Conditions: Engine Running
- Set Conditions: Engine speed greater than the Spark Rev Limit speed (4200 min^{-1} (rpm)) for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Engine over speed condition, faulty CKP sensor or input

The fault of DTC 219 will set anytime the engine RPM exceeds 3900 min^{-1} (rpm) for longer than 1 second. This fault is designed to help prevent engine or equipment damage. The throttle will be lowered in order to govern the engine to the speed set in the diagnostic calibration.

The fault of DTC 1111 will set anytime the engine RPM exceeds the limit set in the diagnostic calibration for the latch time or more. This speed overrides any higher max governor speeds programmed by the user. This fault is designed to help prevent engine or equipment damage and will disable fuel injectors or gaseous fuel actuator to reduce engine speed. The throttle will also be lowered in order to govern the engine to the speed set in the diagnostic calibration for Max Gov Override.

The fault of DTC 1112 will set anytime the engine RPM exceeds the limit set in the diagnostic calibration for the latch time or more. This speed overrides any higher max governor speeds programmed by the user. This fault is designed to help prevent engine or equipment damage and will disable the ignition coils to reduce engine speed. In addition, the throttle will be lowered in order to govern the engine to the speed set in the diagnostic calibration for Max Gov Override and the fuel injectors or gaseous fuel control actuator will be disabled to reduce the engine speed below the speed set in the diagnostic calibration for Fuel Rev Limit.

DTC 219-RPM Higher Than Max Allowed Governed Speed

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Ensure that no programmed governor speeds exceed the limit set in the diagnostic calibration for Max Gov Override Speed
- Check mechanical operation of the throttle
- Check the engine intake for large air leaks downstream of the throttle body

DTC 1111-RPM Above Fuel Rev Limit Level

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Ensure that no programmed governor speeds exceed the limit set in the diagnostic calibration for Max Gov Override Speed
- Check mechanical operation of the throttle
- Check the engine intake for large air leaks downstream of the throttle body

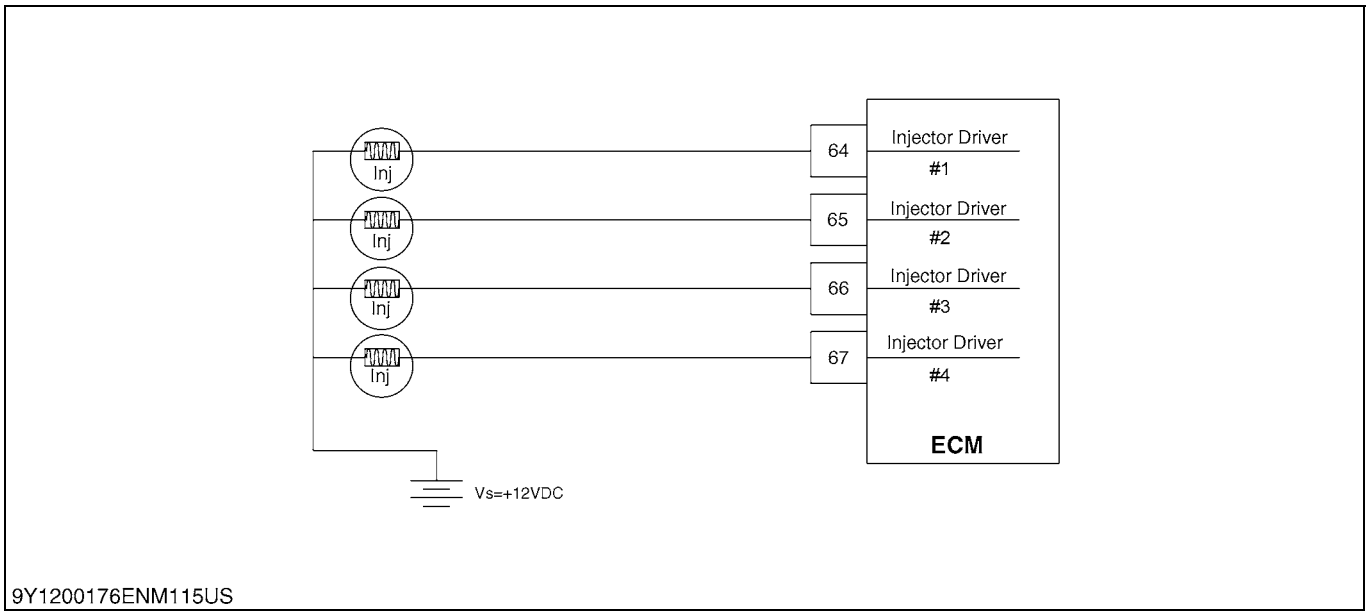
DTC 1112-RPM Above Spark Rev Limit Level

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Ensure that no programmed governor speeds exceed the limit set in the diagnostic calibration for Max Gov Override Speed
- Check mechanical operation of the throttle
- Check the engine intake for large air leaks downstream of the throttle body

(11) Injectors (DTC 261, 262, 264, 265, 267, 268, 270, 271)



DTC 261-Injector Driver #1 Open/Short-To-Ground

DTC 264-Injector Driver #2 Open/Short-To-Ground

DTC 267-Injector Driver #3 Open/Short-To-Ground

DTC 270-Injector Driver #4 Open/Short-To-Ground

- Hardware: Each Injector Driver (**each cylinder in the block order**)
- Enabling Conditions: Key-On, Engine Running
- Set Conditions: Battery voltage at ECM greater than 9.00 V and each injector driver off voltage less than 4.00 V for 10 samples
- Corrective Action(s): Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Loss of 12.0 V feed to injector, open injector coil, open or shorted to ground injector driver circuit in engine harness, bad ECM

DTC 262-Injector Driver #1 Short-To-Power

DTC 265-Injector Driver #2 Short-To-Power

DTC 268-Injector Driver #3 Short-To-Power

DTC 271-Injector Driver #4 Short-To-Power

- Hardware: Each Injector Driver (**each cylinder in the block order**)
- Enabling Conditions: Key-On, Engine Running
- Set Conditions: Battery voltage at ECM less than 16.0 V and each injector driver on voltage greater than 4.00 V for 10 samples
- Corrective Action(s): Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Injector coil shorted internally, injector driver circuit shorted to voltage between injector and ECM, bad ECM

The fuel injector is an electronically controlled valve and nozzle that is controlled to deliver a precise quantity of fuel to a cylinder. Each fuel injector is supplied 12.0 V from the power relay and is operated by the ECM through a low side driver (LSD) circuit that is monitored for the correct voltage for the current state of the injector (on or off).

DTC 261-Injector Driver #1 Open/Short-To-Ground

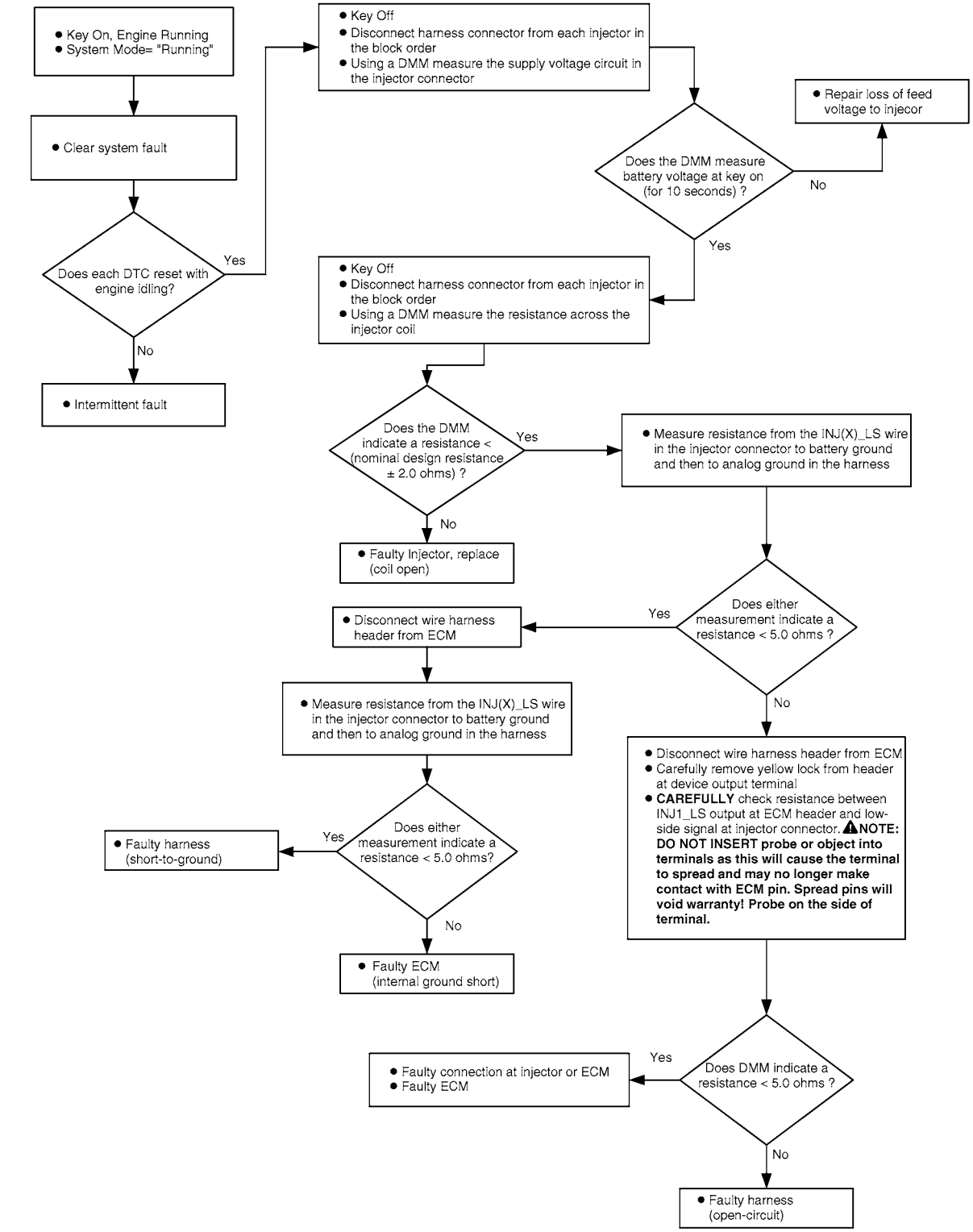
DTC 264-Injector Driver #2 Open/Short-To-Ground

DTC 267-Injector Driver #3 Open/Short-To-Ground

DTC 270-Injector Driver #4 Open/Short-To-Ground

Diagnostic Aids Chart

Firing Order Example



9Y1200176ENM116US

DTC 262-Injector Driver #1 Short-To-Power

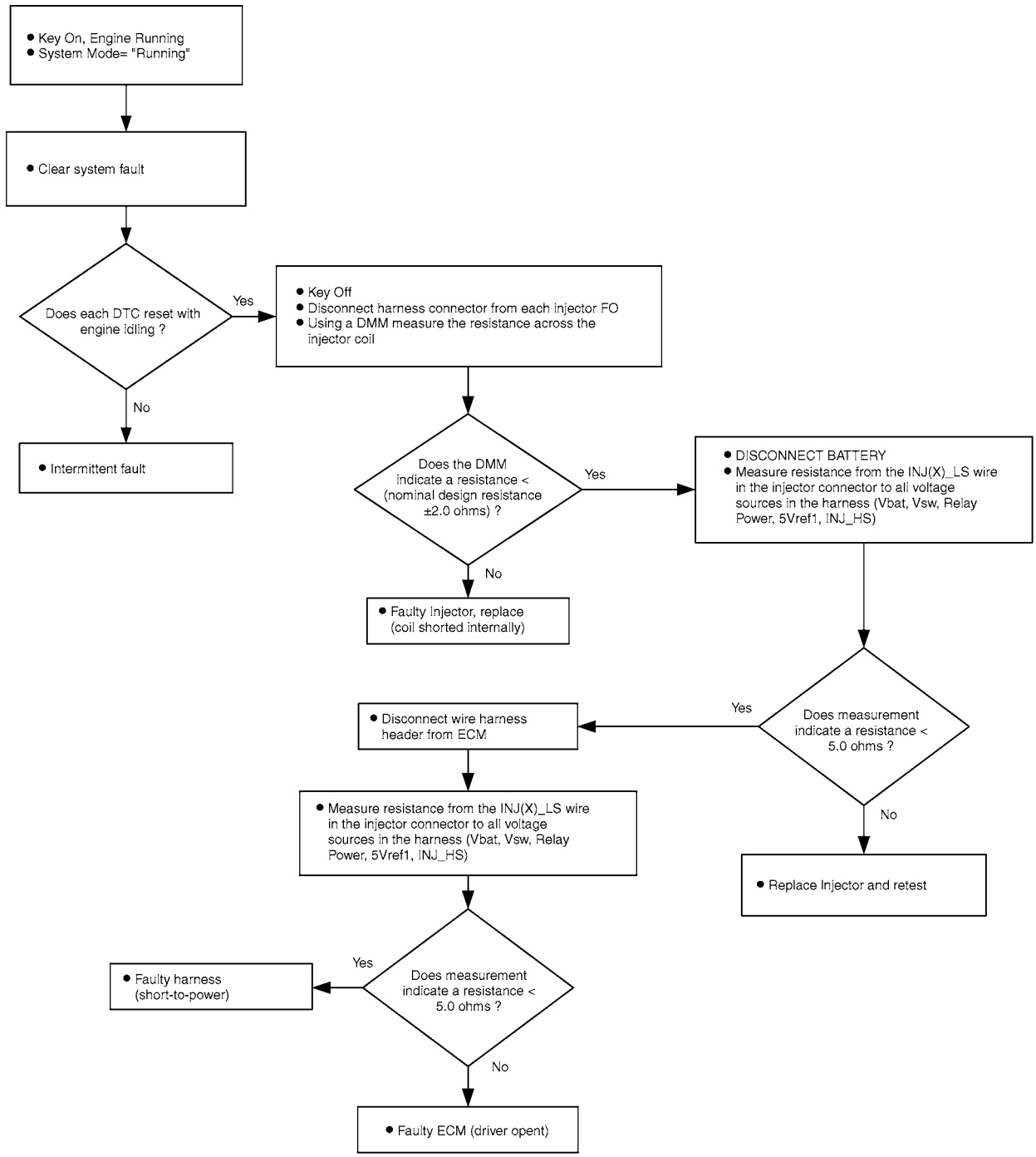
DTC 265-Injector Driver #2 Short-To-Power

DTC 268-Injector Driver #3 Short-To-Power

DTC 271-Injector Driver #4 Short-To-Power

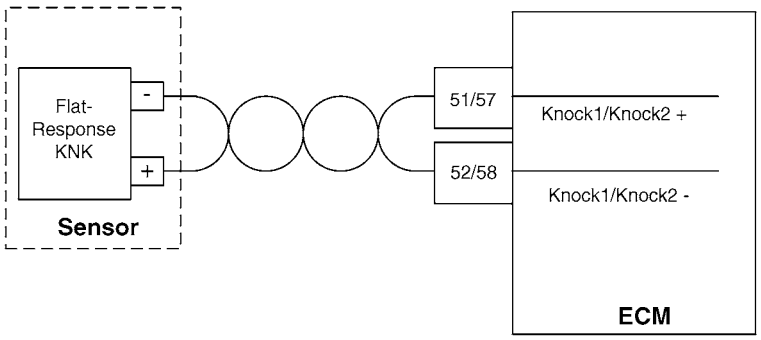
Diagnostic Aids Chart

Firing Order Example



9Y1200176ENM117US

(12) Knock Sensor (DTC 326, 327)



9Y1200176ENM124US

DTC 326-Knock 1 Excessive or Erratic Signal

- Hardware: Knock sensor #1
- Enabling Conditions: Key On, Engine On
- Set Conditions: Knock sensor 1 voltage above 2.00 V with MAP less than 62 kPa (0.63 kgf/cm^2, 9 psi) and knock retard is a maximum retard value for longer than 3 seconds.
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: Internal engine damage causing audible noise, knock sensor signal wire routed too close to spark plug wire, bad sensor, bad ECM

The knock sensor is used to detect detonation through mechanical vibration in the engine block and/or cylinder heads and provide feedback for the ignition system to retard spark to reduce knock intensity. The knock sensor is used to protect the engine from damage that can be caused from detonation or knock based on fixed spark advance.

This fault sets if the signal from knock sensor 1 is higher than expected for low load operation as defined in calibration. If this fault sets, spark is lowered by the amount defined in calibration for Faulted KNK Retard.

DTC 327-Knock 1 Sensor Open or Not Present

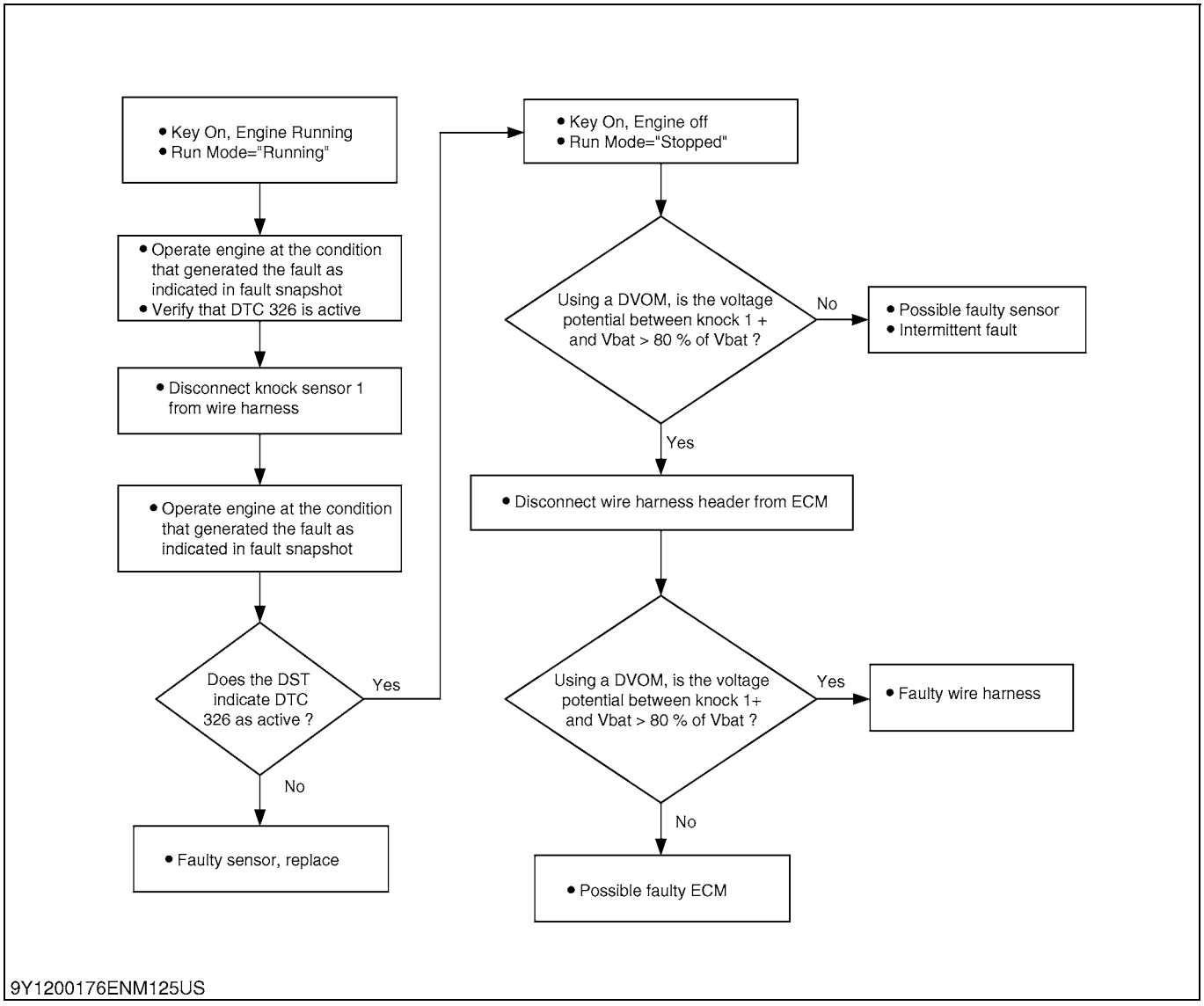
- Hardware: Knock sensor #1
- Enabling Conditions: Key On, Engine On
- Set Conditions: Knock sensor 1 signal below 0.005 V, rpm above 2000 min^{-1} (rpm) and MAP above 83 kPa (0.84 kgf/cm^2, 12 psi) for longer than 3 seconds.
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: Knock sensor open internally, signal circuit open or shorted to ground or bad ECM

The knock sensor is used to detect detonation through mechanical vibration in the engine block and/or cylinder heads and provide feedback for the ignition system to retard spark to reduce knock intensity. In most applications the knock sensor is used to protect the engine from damage that can be caused from detonation or knock based on fixed spark advance. In other applications, the knock sensor is used to optimize spark advance and "learn" between spark tables based on fuel quality.

This fault sets if the signal from knock sensor 1 is lower than expected for higher speed and load operation as defined in calibration. If this fault sets, spark is lowered by the amount defined in calibration for Faulted KNK Retard.

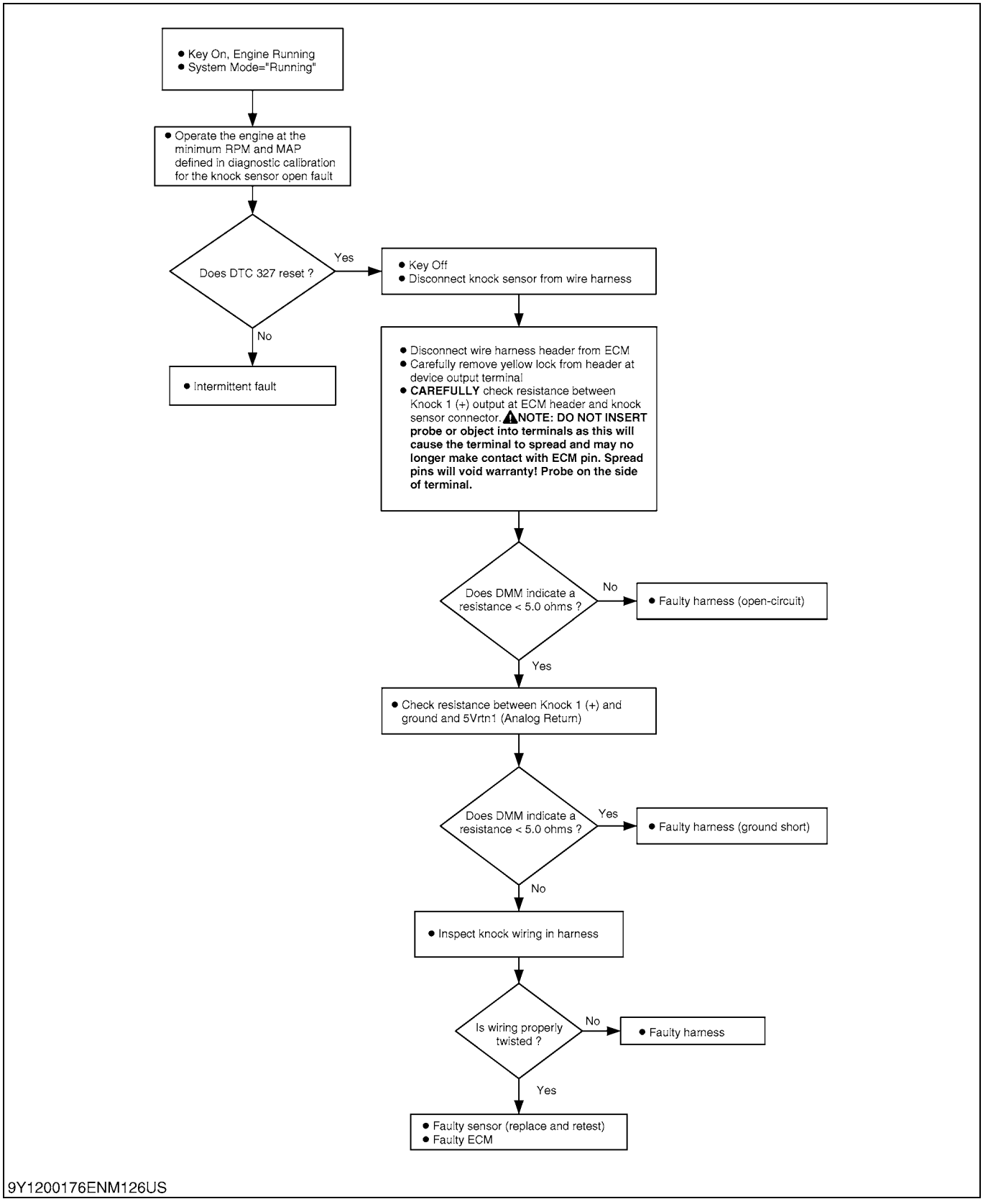
DTC 326-Knock 1 Excessive or Erratic Signal

Diagnostic Aids Chart



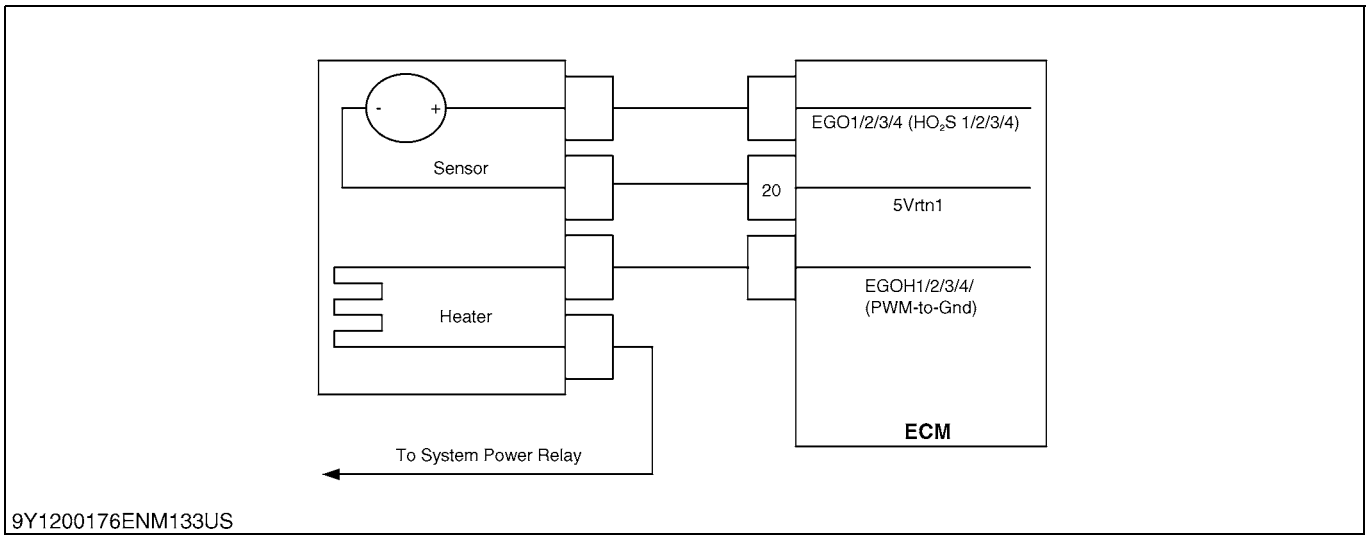
DTC 327-Knock 1 Sensor Open or Not Present

Diagnostic Aids Chart



9Y1200176ENM126US

(13) Catalyst Monitor (DTC 420, 1165, 1166)



9Y1200176ENM133US

DTC 420-Catalyst Inactive on Gasoline (Bank1)

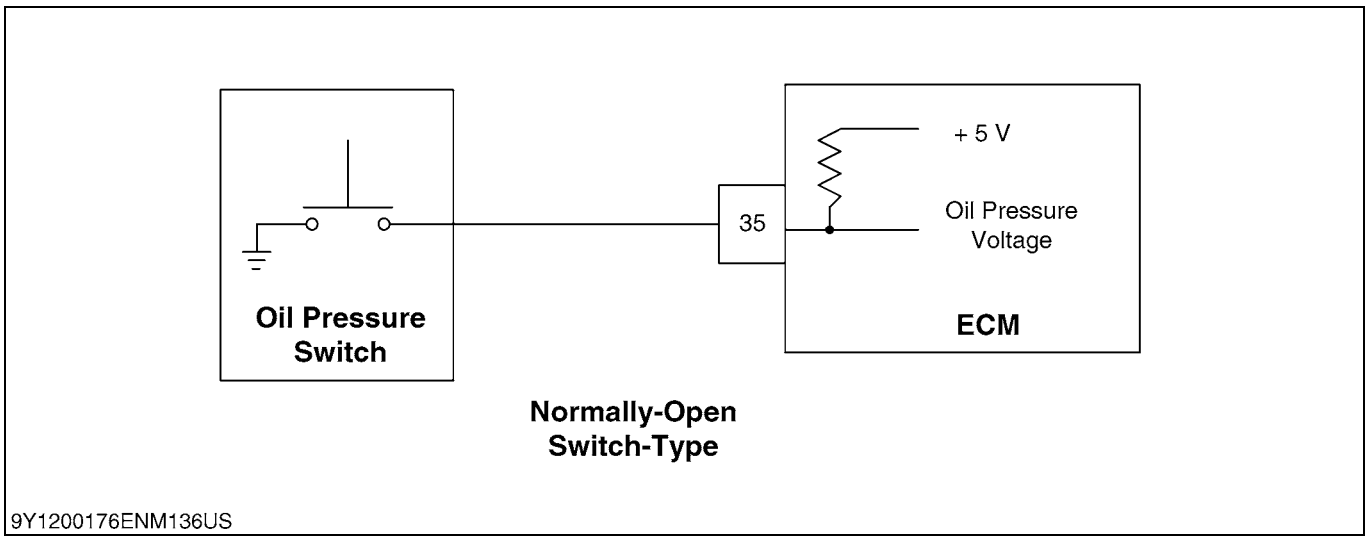
- Hardware: Bank 1 Pre-Catalyst Exhaust Gas Oxygen Sensor and Bank 1 Post-Catalyst Exhaust Gas Oxygen Sensor
- Enabling Conditions: Engine Running
- Set Conditions: Bank 1 catalyst inactive on gasoline or LPG engine
- Corrective Action(s): Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp.
- Emissions related fault
- Possible Causes: Physically damaged catalyst element, contaminated catalyst element or post catalyst oxygen sensor signal circuit shorted to pre-catalyst oxygen sensor signal circuit

DTC 1165-Catalyst Inactive on LPG

DTC 1165-Catalyst Inactive on NG

- Hardware: Bank 1 Catalyst, Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 2-After Catalyst)
- Enabling Conditions: Engine Running
- Set Conditions: Catalyst inactive on LPG (NG)
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn and closed loop while fault is active
- Emissions related fault
- Possible Causes: Physically damaged catalyst element, contaminated catalyst element

(14) Oil Pressure Sensor (DTC 524)



DTC 524-Oil Pressure Low

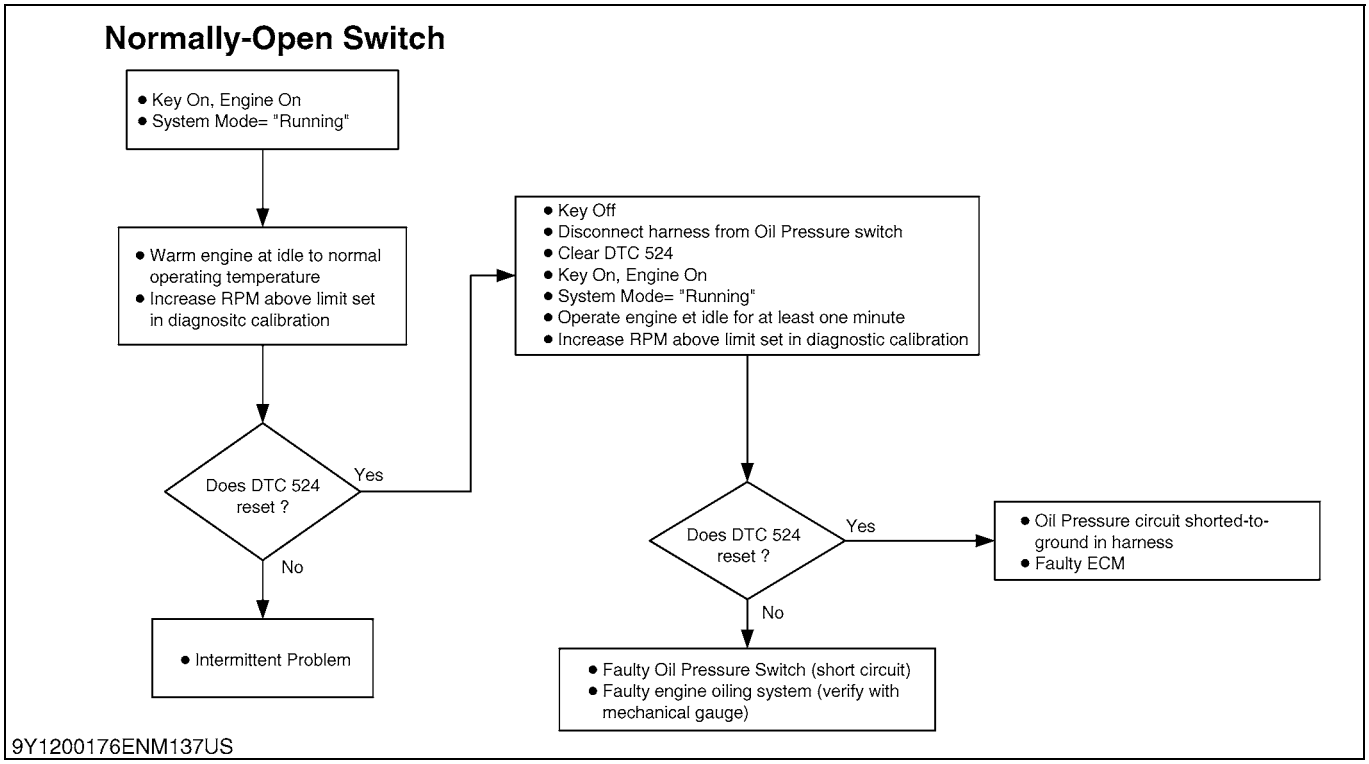
- Hardware: Engine Oil Pressure Sensor or Switch
- Enabling Conditions: Key on, Engine Running longer than 15 seconds and running higher than 1300 min^{-1} (rpm)
- Set Conditions: Engine oil pressure switch circuit < 2.50 V for longer than 3 seconds
- Corrective Action(s): Illuminate MIL and initiate an engine shutdown
- Non-emissions related fault
- Possible Causes: Oil pressure problem with engine, oil pressure switch failure, oil pressure switch circuit shorted to ground, faulty ECM

The ECM can be configured to monitor oil pressure through a switch. Oil pressure monitoring is important to prevent engine damage due to low oil pressure resulting in higher friction and lack of lubrication. In addition, high oil pressure can be undesirable because it can cause oil to leak past seals and rings, can be a result of a restriction in the oil flow path, or can be a sign of a malfunctioning oiling system.

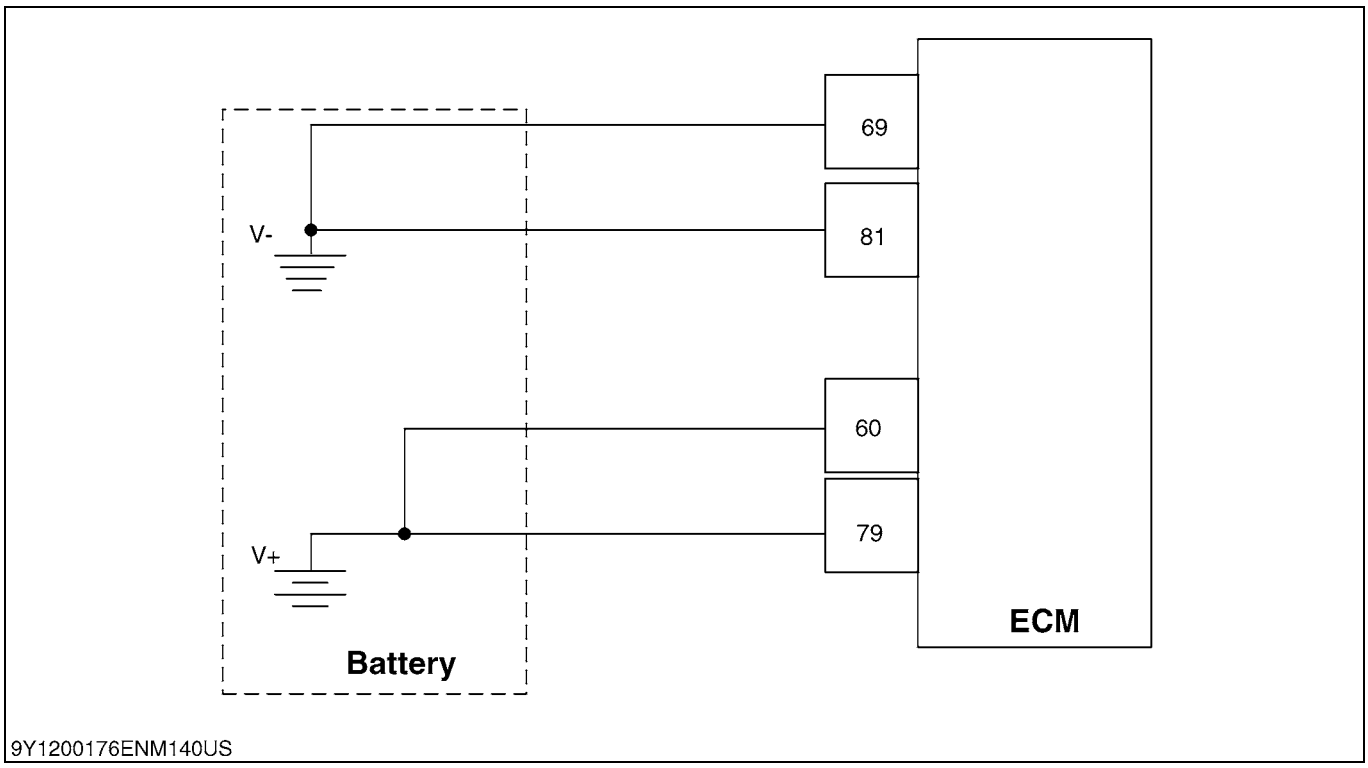
If the switch is normally open, the fault will set if the circuit becomes grounded. Go to the Faults page in EDIS to determine how the input is configured. ("Open=OK" is normally open). The engine will should be configured to derate or force idle and/or shut down in the event of this fault to help prevent possible damage.

DTC 524-Oil Pressure Low

Diagnostic Aids Chart



(15) Battery Voltage (DTC 562, 563)



DTC 562-Battery Voltage (VBat) Low

- Hardware: System voltage to ECM
- Enabling Conditions: Key on, Engine running above 1000 min^{-1} (rpm)
- Set Conditions: Battery voltage to ECM less than 9.00 V for longer than 5 seconds
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for the remainder of key cycle
- Non-emissions related fault
- Possible Causes: Low charging system output, low voltage input into ECM, faulty battery

DTC 563-Battery Voltage (VBat) High

- Hardware: System voltage to ECM
- Enabling Conditions: Key on, Engine running
- Set Conditions: Battery voltage to ECM greater than 16.0 V for longer than 3 seconds while the engine is running
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for remainder of key cycle
- Non-emissions related fault
- Possible Causes: Charging system overcharging

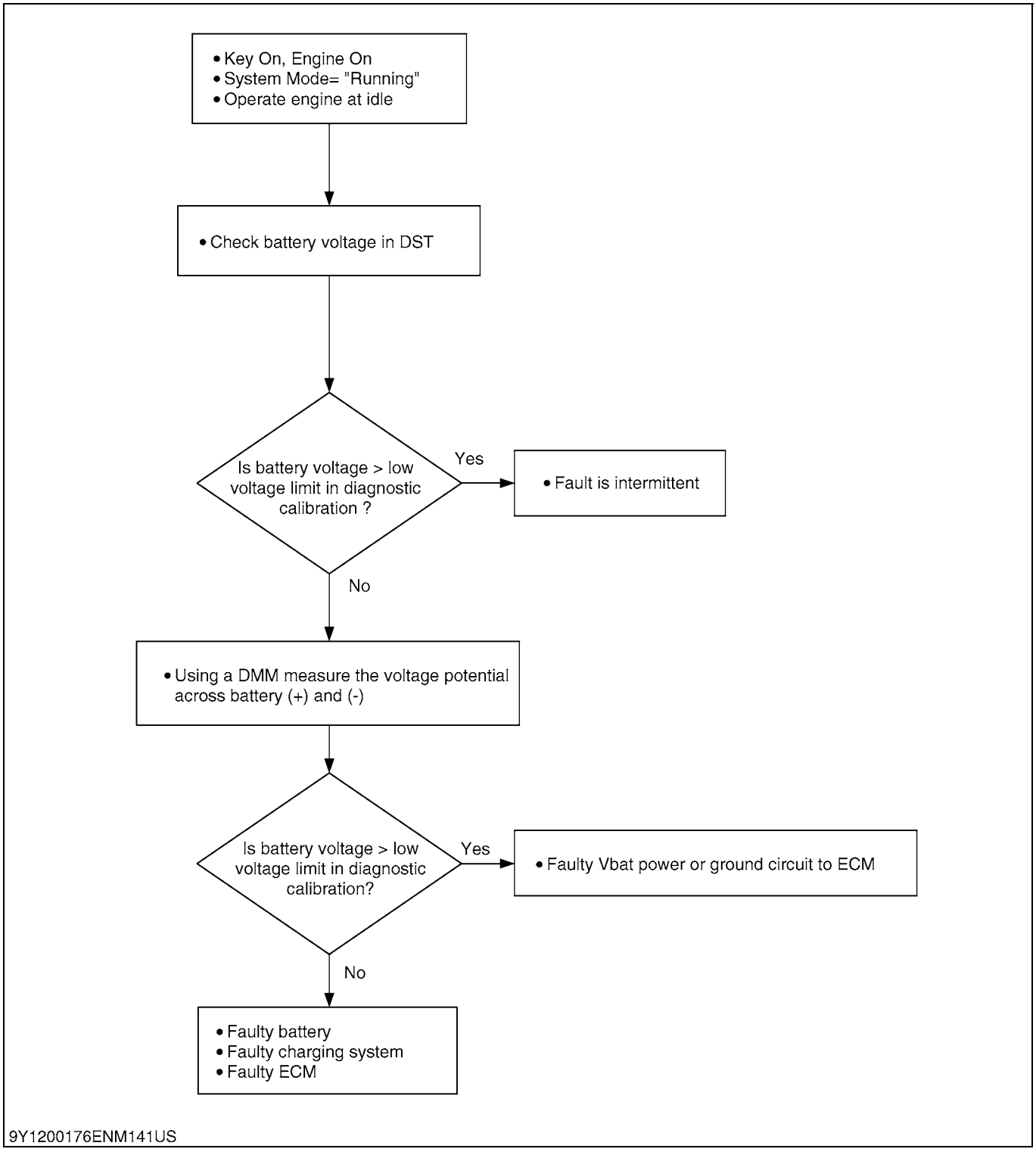
The battery voltage powers the ECM and must be within limits to correctly operate injector drivers, ignition coils, throttle, power supplies, and other powered devices that the ECM controls.

The fault of DTC 562 will set if the ECM detects system voltage less than 9.00 V while the engine is operating at above 1000 min^{-1} (rpm) as defined in the diagnostic calibration as the alternator should be charging the system. The adaptive learn is disabled to avoid improper adaptive learning due to the inability to correctly time injector firings.

The fault of DTC 563 will set if the ECM detects system voltage greater than 16.0 V for longer than 3 seconds while the engine is running. The adaptive learn is disabled to avoid improper adaptive learning.

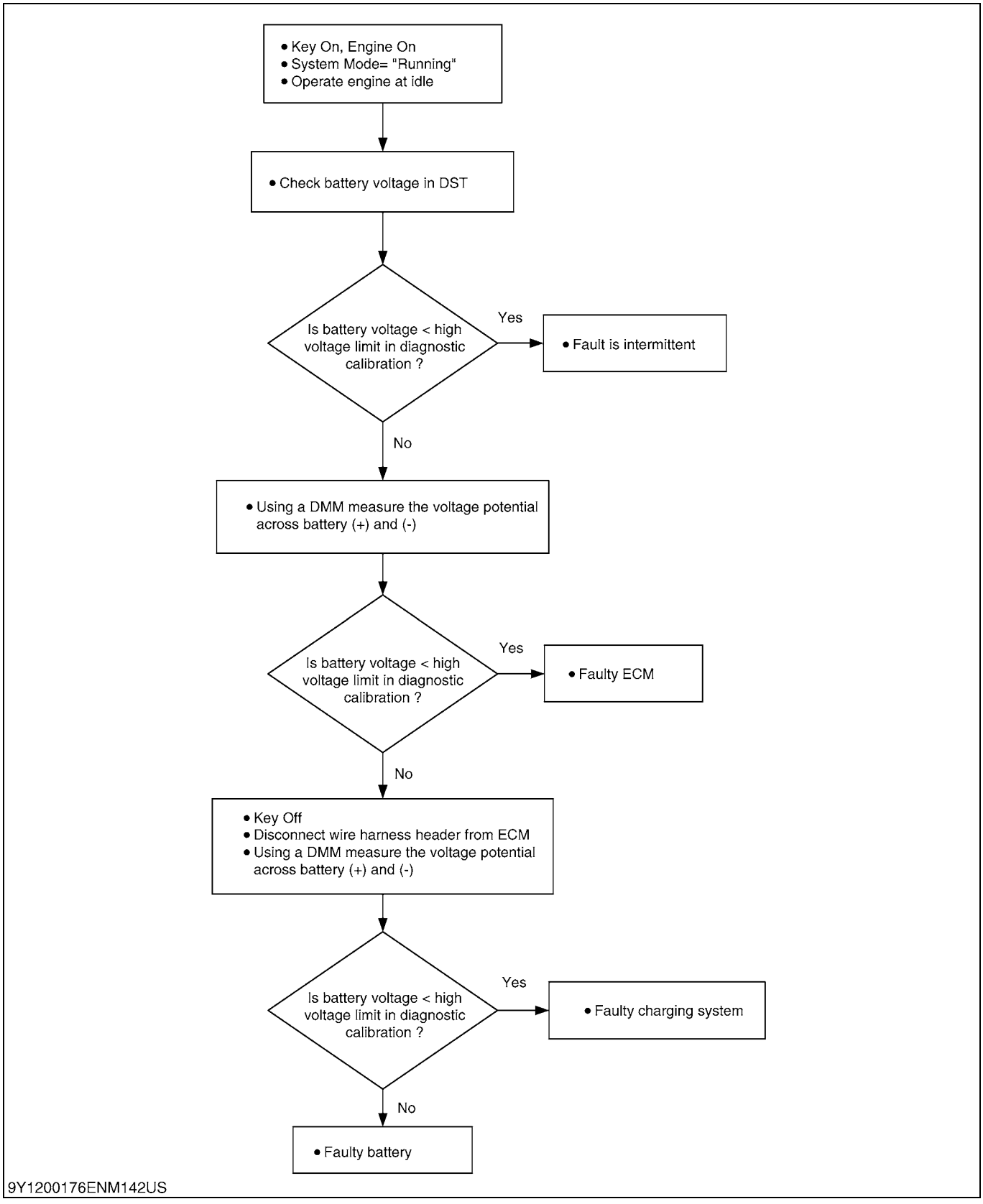
DTC 562-Battery Voltage (VBat) Low

Diagnostic Aids Chart

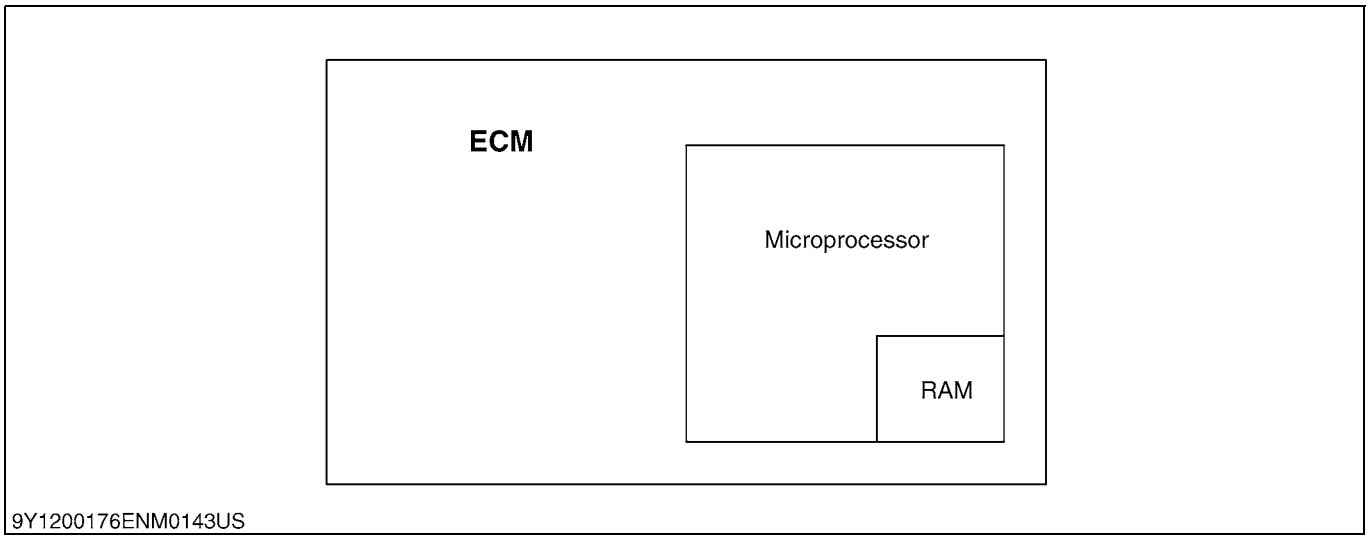


DTC 563-Battery Voltage (VBat) High

Diagnostic Aids Chart



(16) Internal Processor Diagnostics (DTC 601, 604, 606, 1612 to 1616)



DTC 601-Microprocessor Failure-FLASH

- Hardware: Engine Control Module-Flash Memory
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn for remainder of key cycle, activate power derate 2 and never forget code (code must be manually erased by technician with DST)
- Non-emissions related fault
- Possible Causes: Faulty ECM

The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault.

If this fault sets, the ECM will reset itself and log the code. A fault of flash memory can occur for any calibration variable set and thus could cause undesirable operation.

DTC 604-Microprocessor Failure-RAM

- Hardware: Engine Control Module-Random Access Memory
- Enabling Conditions: Key on
- Set Conditions: Internal ECM microprocessor memory access failure
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn for remainder of key cycle, activate power derate 2 and never forget code (code must be manually erased by technician with a DST)
- Non-emissions related fault
- Possible Causes: Faulty ECM

Random Access Memory is located within the microprocessor and can be read from or written to at any time. Data stored in RAM include DTCs (when fault configuration is set to "Battery Power Retained"), adaptive fuel learn tables, octane adaptation table, misfire adaptaion tables, and closed loop fuel multipliers. The ECM has checks that must be satisfied each time an instruction is executed.

This fault will set if the ECM detects a problem accessing or writing information to RAM. If this fault sets, the ECM will reset itself and log the code. This fault should be erased by a technician after diagnostics are performed.

DTC 606-Microprocessor Failure-COP

- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn for remainder of key cycle, activate power derate 2 and never forget code (code must be manually erased by technician with a DST)
- Non-emissions related fault
- Possible Causes: Faulty ECM

The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault.

If this fault sets, the ECM will reset itself and log the code.

DTC 1612-Microprocessor Failure-RTI 1

- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes: Faulty ECM

The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30 %.

DTC 1613-Microprocessor Failure-RTI 2

- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes: Faulty ECM

The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30 %.

DTC 1614-Microprocessor Failure-RTI 3

- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes: Faulty ECM

The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30 %.

DTC 1615-Microprocessor Failure-A/D

- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes: Faulty ECM

The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30 %.

DTC 1616-Microprocessor Failure-Interrupt

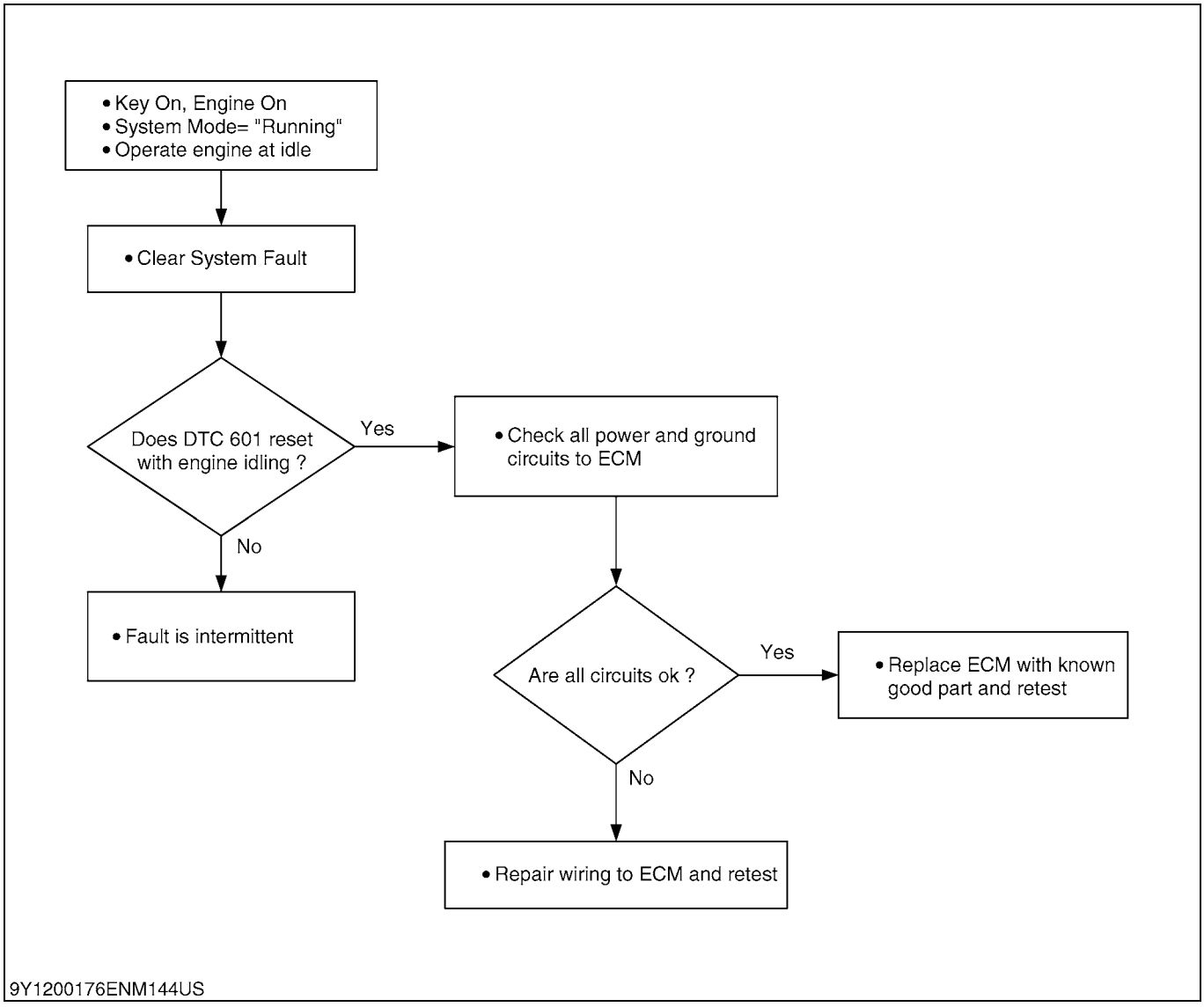
- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes: Faulty ECM

The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30 %.

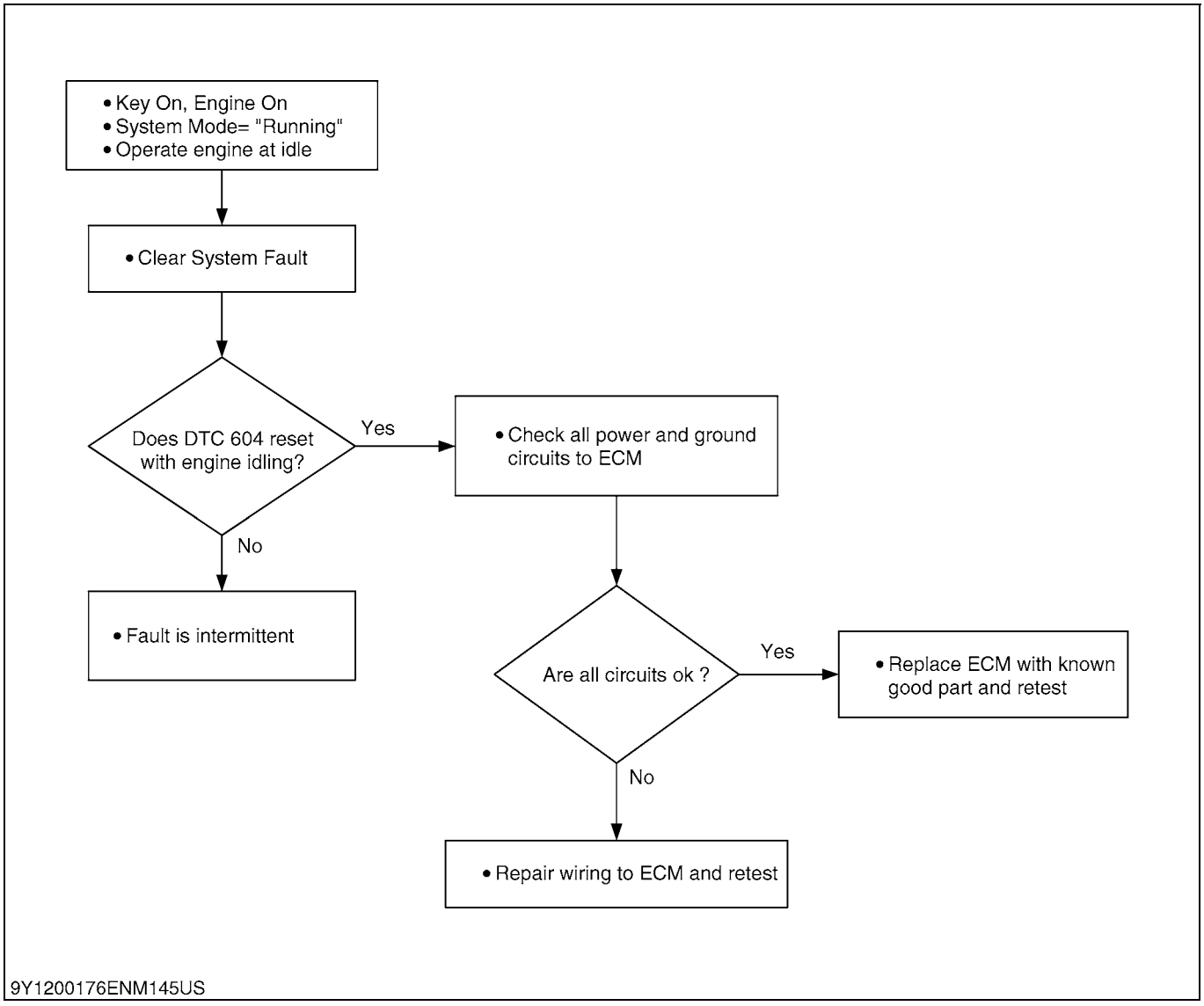
DTC 601-Microprocessor Failure-FLASH

Diagnostic Aids Chart



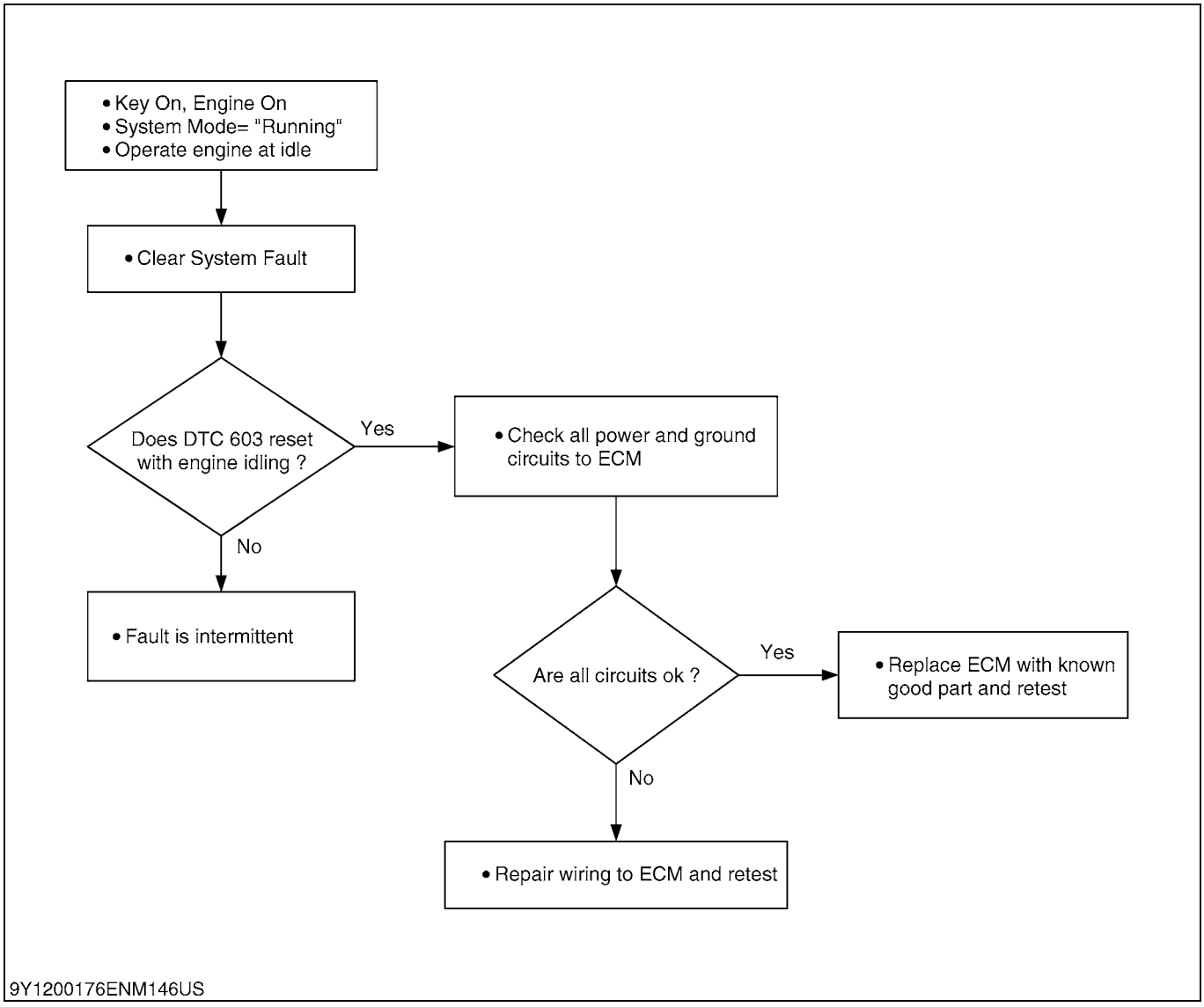
DTC 604-Microprocessor Failure-RAM

Diagnostic Aids Chart



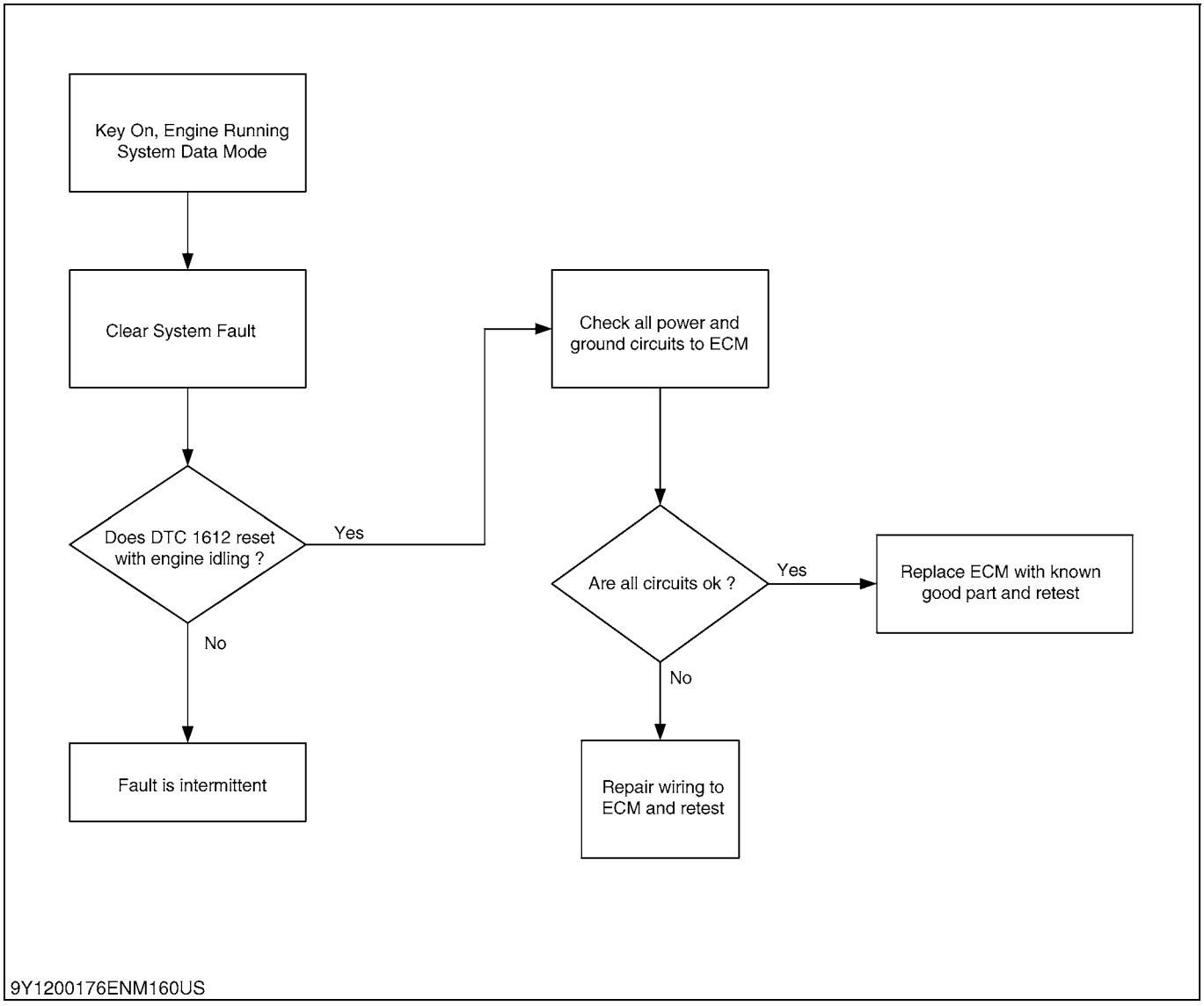
DTC 606-Microprocessor Failure-COP

Diagnostic Aids Chart



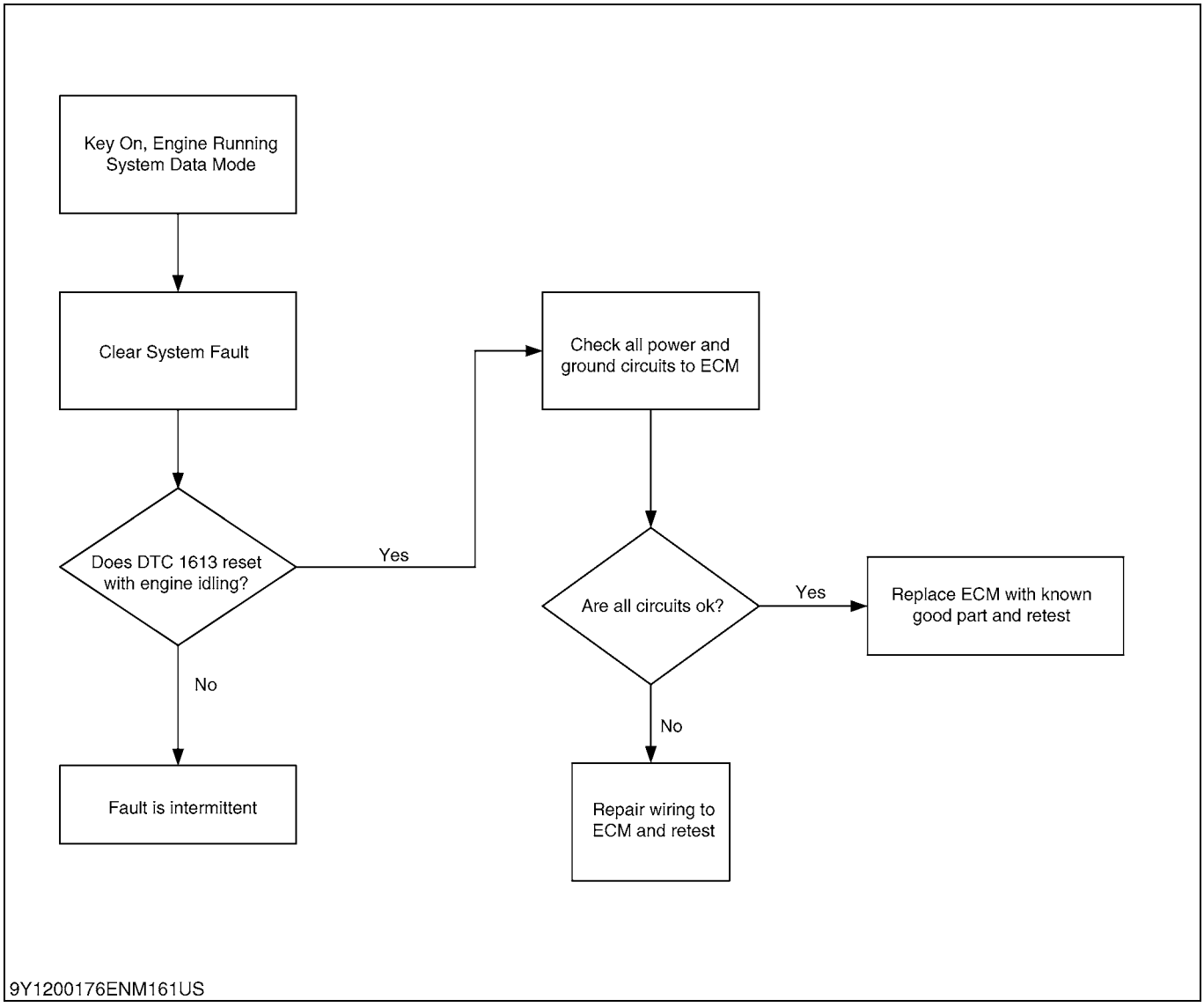
DTC 1612-Microprocessor Failure-RTI 1

Diagnostic Aids Chart



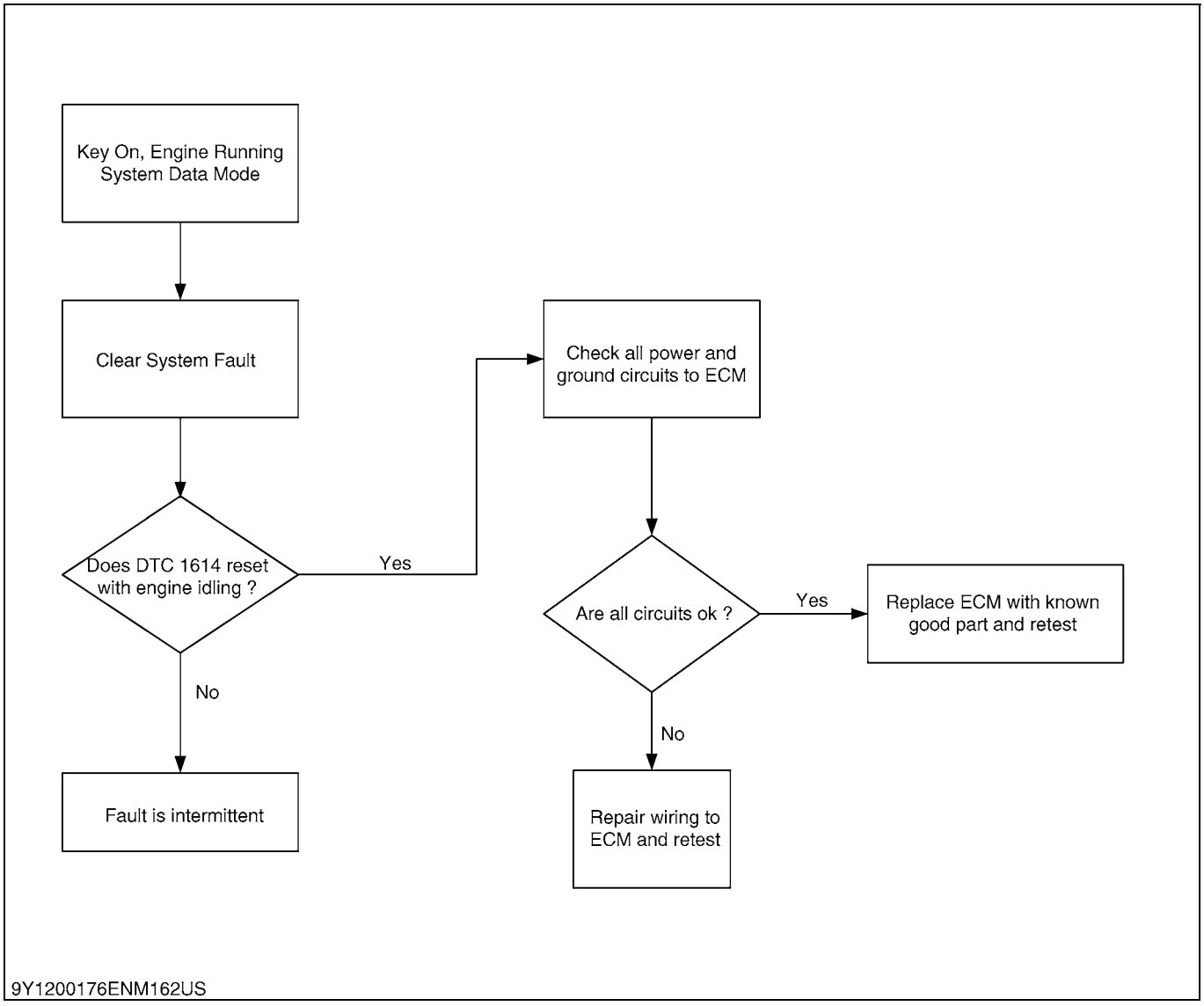
DTC 1613-Microprocessor Failure-RTI 2

Diagnostic Aids Chart



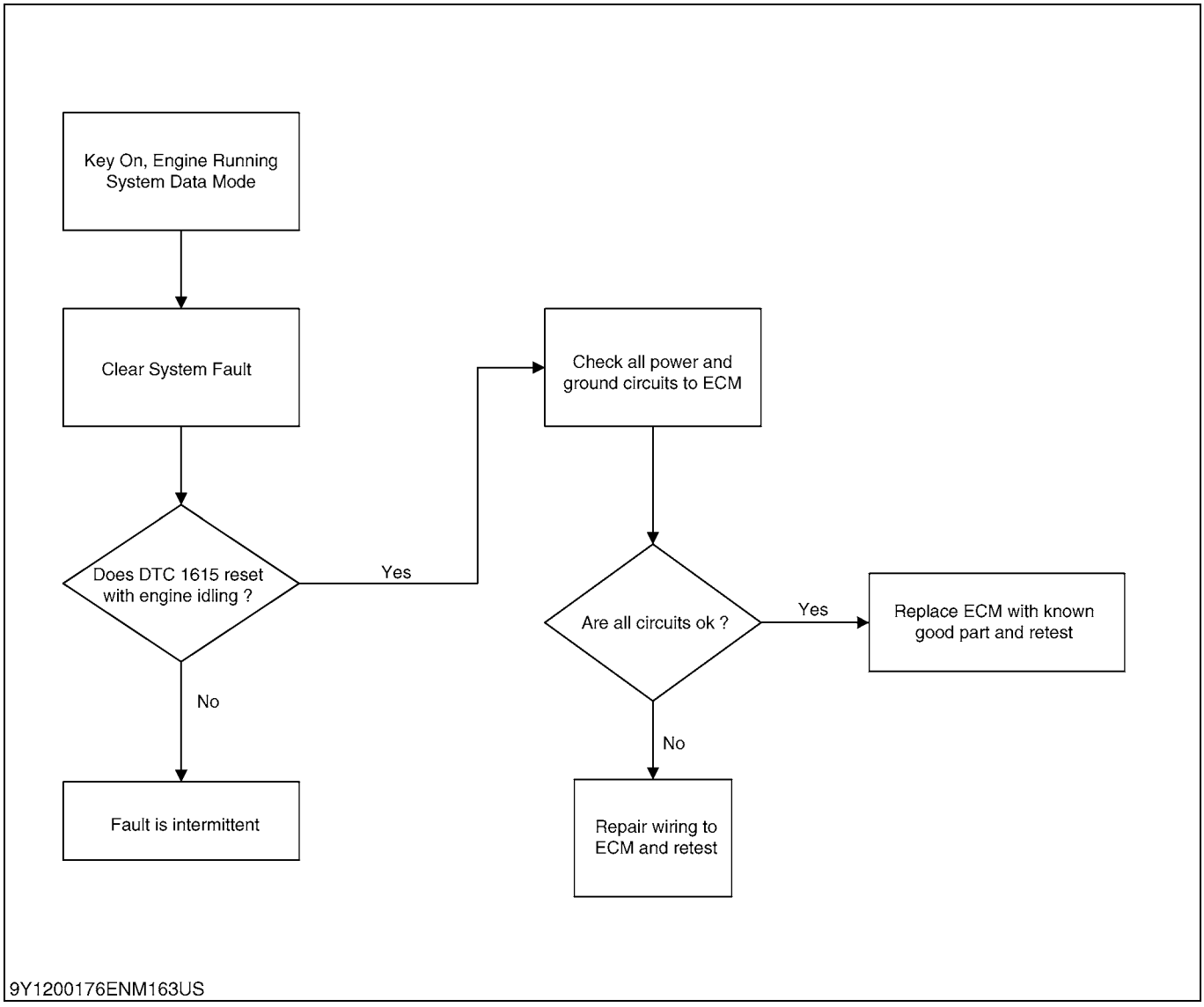
DTC 1614-Microprocessor Failure-RTI 3

Diagnostic Aids Chart



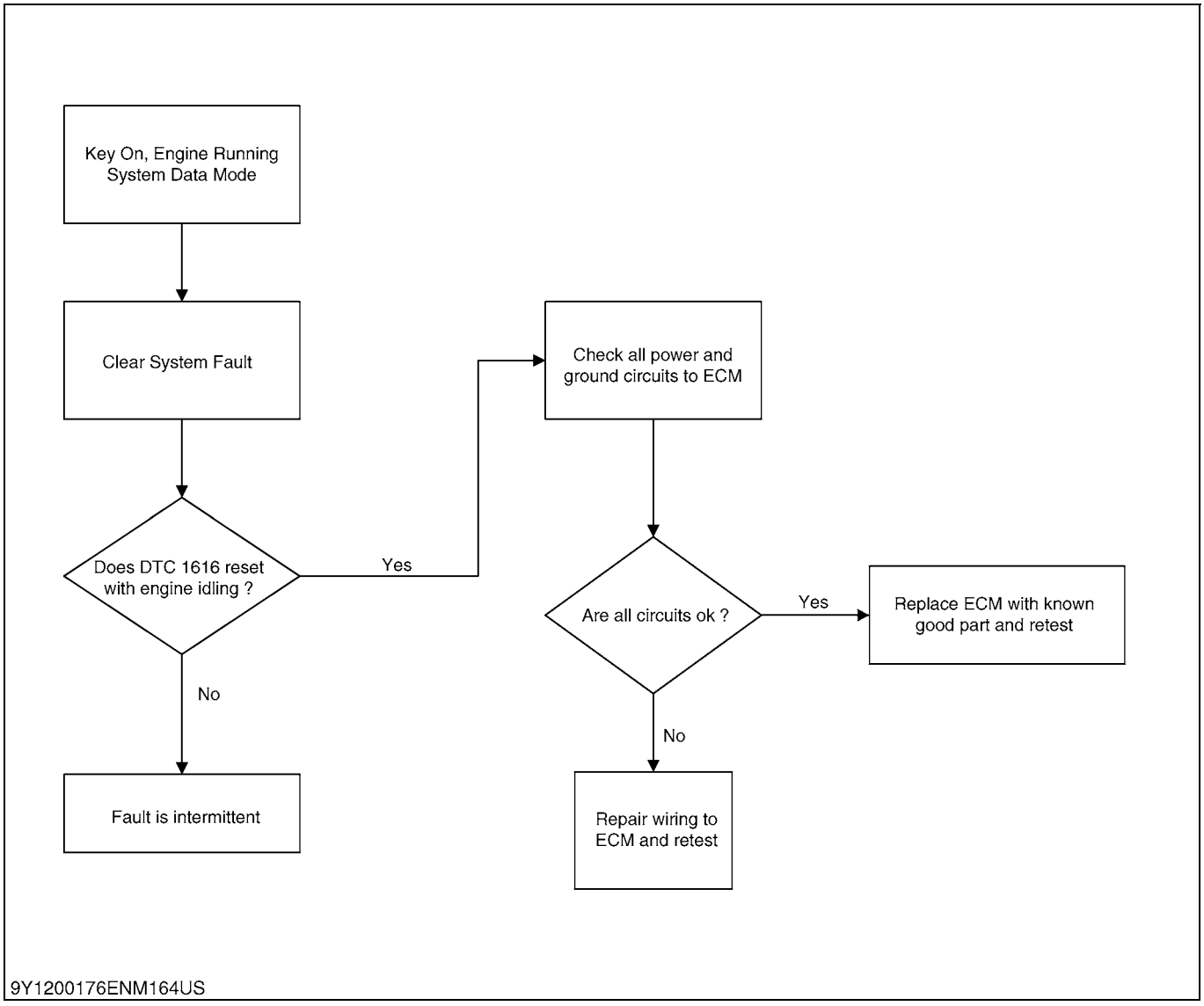
DTC 1615-Microprocessor Failure-A/D

Diagnostic Aids Chart

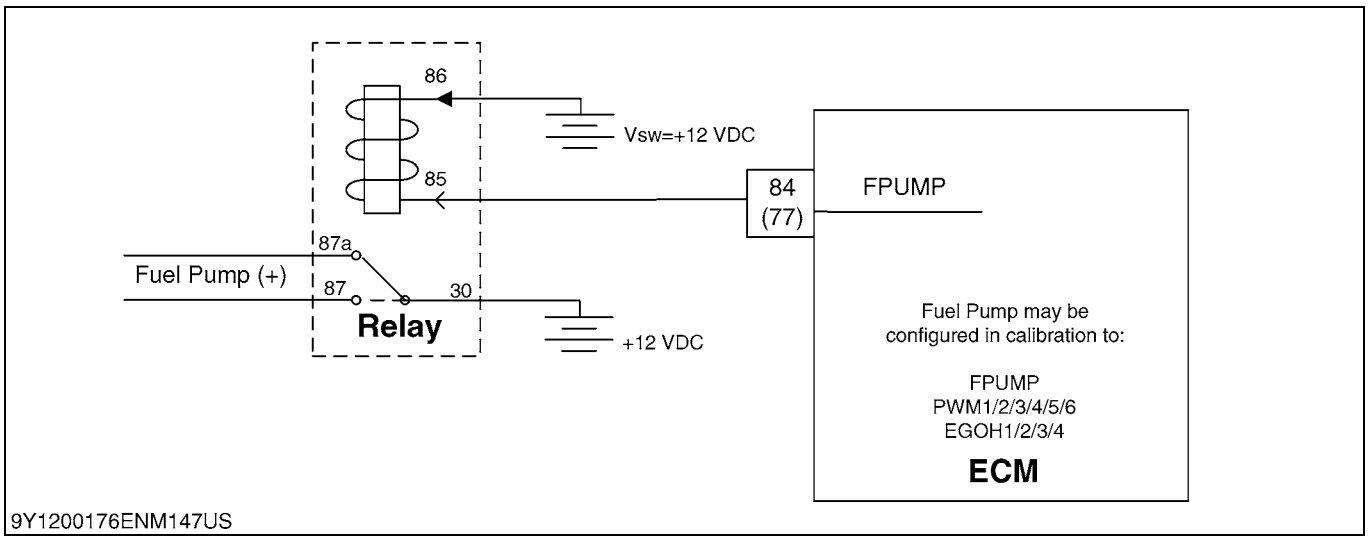


DTC 1616-Microprocessor Failure-nterrupt

Diagnostic Aids Chart



(17) Fuel Pump Relay Control/Coil (DTC 627 to 629)



DTC 627-Fuel Pump Relay Coil Open

- Hardware: Fuel Pump Relay Pull in Coil
- Enabling Conditions: Key On
- Set Conditions: Fuel Pump relay coil output open circuit for more than 10 samples of the circuit
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Open coil in relay, Open in relay driver circuit in engine harness or faulty ECM

DTC 628-Fuel Pump Relay Ground Short

- Hardware: Fuel Pump Relay Pull in Coil
- Enabling Conditions: Key On, Engine Off
- Set Conditions: Fuel Pump relay coil output shorted to ground for more than 10 samples of the circuit
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Relay pull in coil shorted internally, relay driver circuit shorted to ground in wire harness, faulty ECM

DTC 629-Fuel Pump Relay Coil Short-To-Power

- Hardware: Fuel Pump Relay Pull in Coil
- Enabling Conditions: Key On, Engine Off
- Set Conditions: Fuel Pump relay coil output short to power/voltage
- Corrective Action(s): Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp
- Non-emissions related fault
- Possible Causes: Shorted relay pull in coil, relay driver circuit shorted to voltage in wire harness

The ECM has auxiliary low-side drivers that can turn on warning devices or ground electromagnetic relay coils to control power to devices connected to the engine.

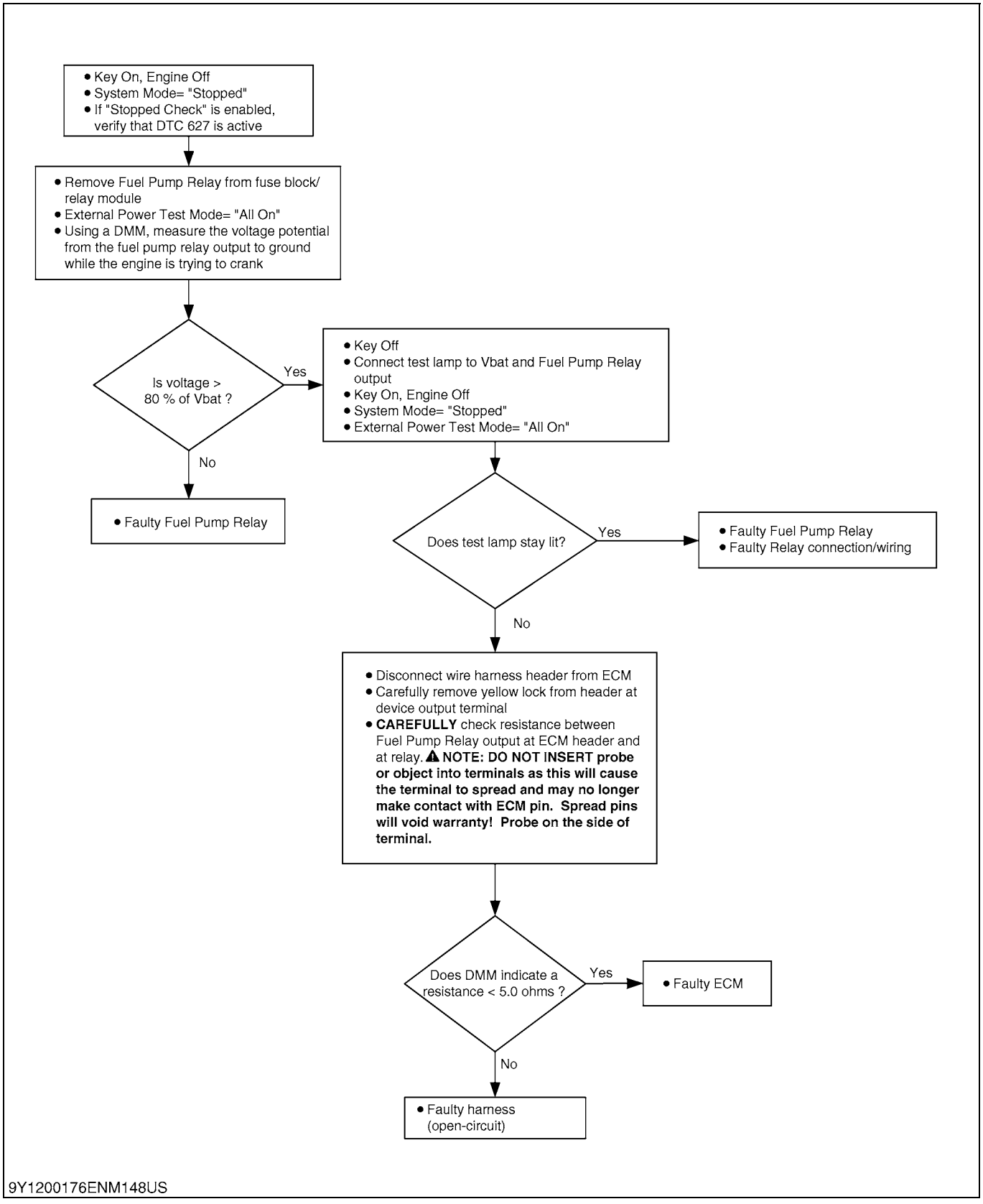
The fault of DTC 627 sets if the output for the fuel pump relay is detected as an open circuit. If this fault is active the fuel pump will not receive power and the engine will not run on gasoline.

The fault of DTC 628 sets if the output for the fuel pump relay is detected as being shorted to ground. If this fault is active and the high-side of the fuel pump relay is supplied, the fuel pump will run until the relay or high-side power is removed.

The fault of DTC 629 sets if the output for the fuel pump relay is detected as shorted to power. If this fault is active the fuel pump will not receive power and will not run.

DTC 627-Fuel Pump Relay Coil Open

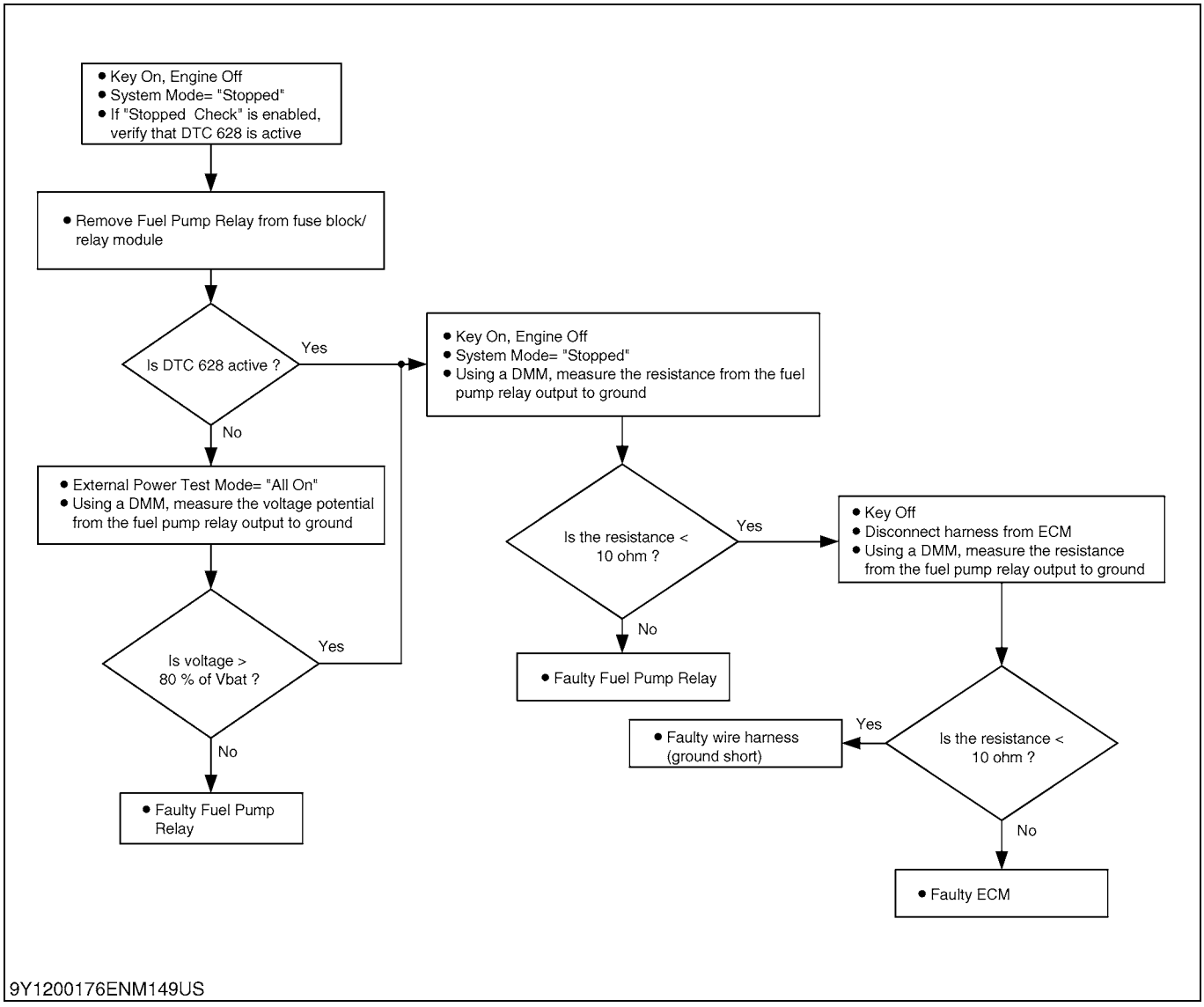
Diagnostic Aids Chart



9Y1200176ENM148US

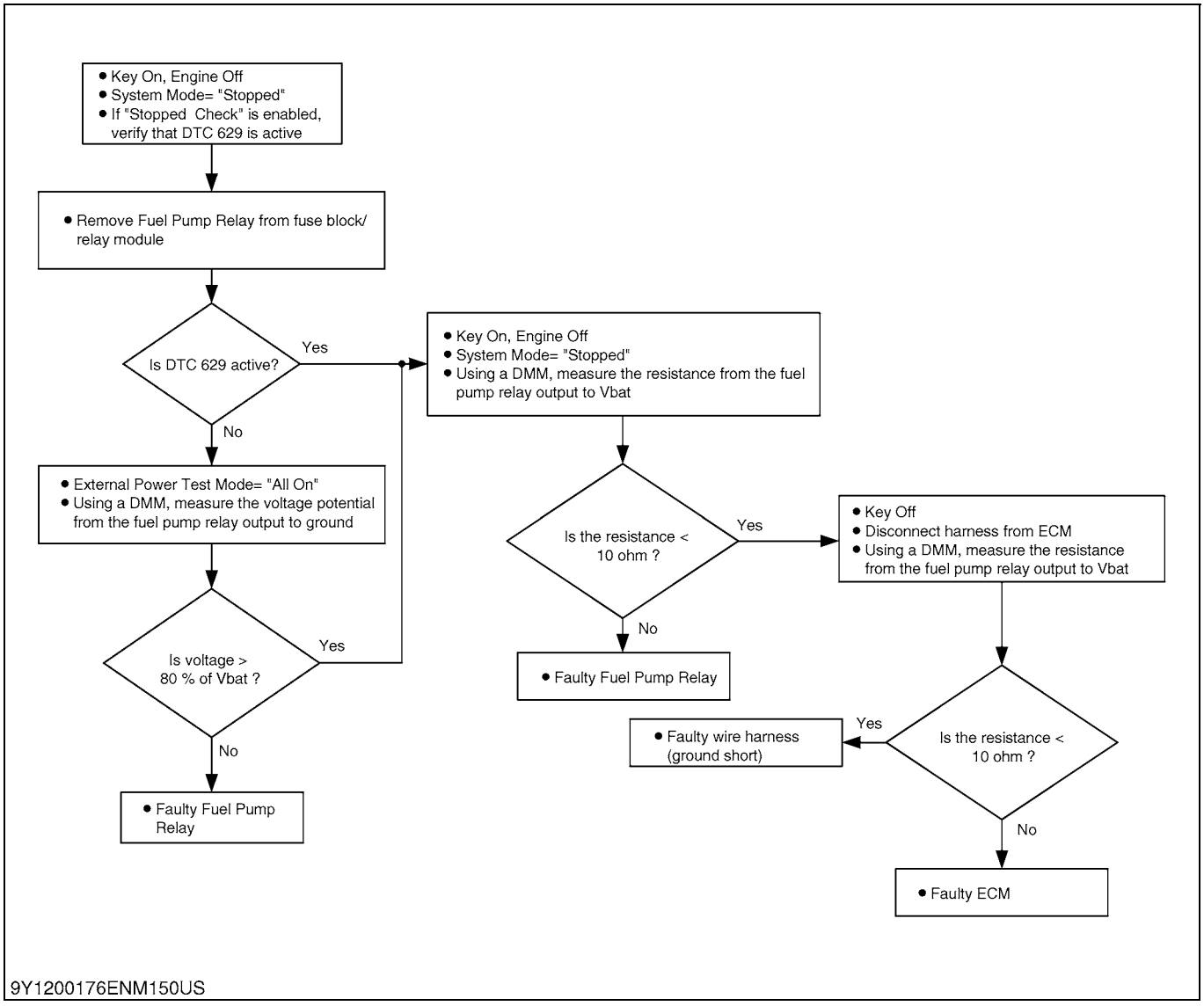
DTC 628-Fuel Pump Relay Ground Short

Diagnostic Aids Chart

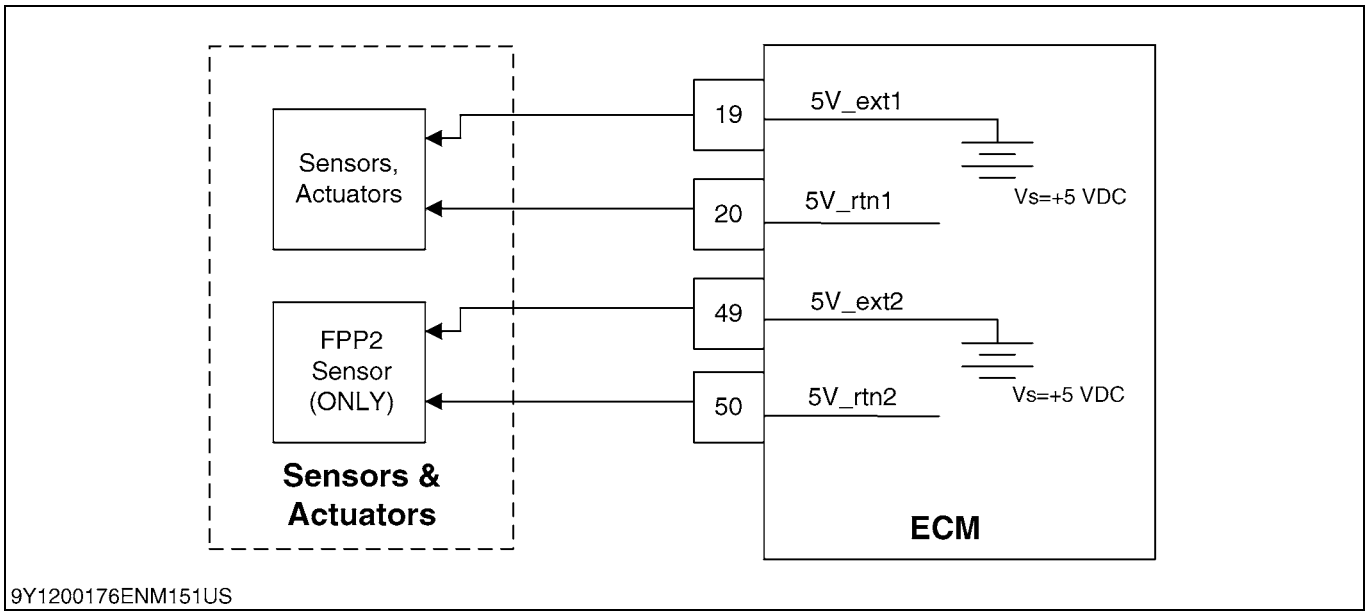


DTC 629-Fuel Pump Relay Coil Short-To-Power

Diagnostic Aids Chart



(18) 5 V External (DTC 642, 643, 652, 653)



DTC 642-Sensor Supply Voltage 1 Low (5 Vext1)

- Hardware: External Sensor Supply Voltage Regulator 1
- Enabling Conditions: Key On, Engine Off or Running
- Fault Condition- Voltage feedback on sensor supply circuit #1 below 4.60 V for longer than 1 second
- Corrective Action(s)- Illuminate MIL and disable fuel adaptive learn while code is active
- Non-emissions related fault
- Possible Causes: Internal short to ground in any sensor fed by 5 Vext1 supply, 5 Vext1 shorted to ground in wire harness, faulty ECM (no 5 V output on 5 Vext1)

DTC 643-Sensor Supply Voltage 1 High (5 Vext1)

- Hardware: External Sensor Supply Voltage Regulator 1
- Enabling Conditions: Key On, Engine Off and Running
- Set Conditions: Voltage feedback on sensor supply circuit #1 is greater than 5.40 V for longer than 1 second
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn while code is active
- Non-emissions related fault
- Possible Causes: 5 Vext1 circuit shorted to 12.0 V in wire harness

DTC 652-Sensor Supply Voltage 2 Low (5 Vext2)

- Hardware: External Sensor Supply Voltage Regulator 2
- Enabling Conditions: Key On, Engine Off or Running
- Fault Condition- Voltage feedback on sensor supply circuit #2 below 4.60 V for longer than 1 second
- Corrective Action(s)- Illuminate MIL and disable fuel adaptive learn while code is active
- Non-emissions related fault
- Possible Causes: Internal short to ground in any sensor fed by 5 Vext2 supply, 5 Vext2 shorted to ground in wire harness, faulty ECM (no 5 V output on 5 Vext2)

DTC 653-Sensor Supply Voltage 2 High (5 Vext2)

- Hardware: External Sensor Supply Voltage Regulator 2
- Enabling Conditions: Key On, Engine Off and Running
- Set Conditions: Voltage feedback on sensor supply circuit #2 is greater than 5.40 V for longer than 1 second
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn while code is active
- Non-emissions related fault
- Possible Causes: 5 Vext2 circuit shorted to 12.0 V in wire harness

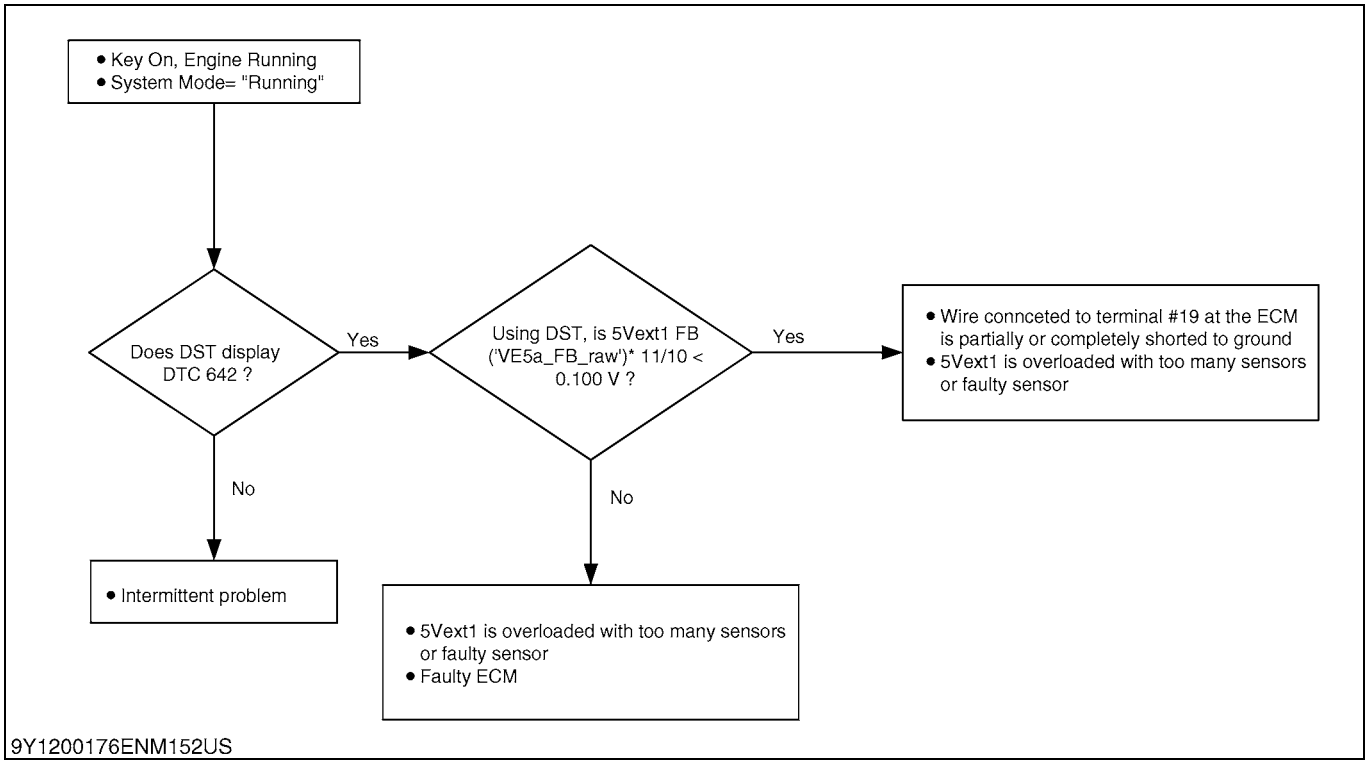
The external 5-volt supply powers sensors and other components in the engine control system. The accuracy of this supply is critical to the accuracy of the sensors' feedback, therefore, it is supplied from a precision regulator whose output is internally monitored by the ECM. The ECM monitors the 5-volt supply to ratio metrically correct sensor feedback and determine if the circuit is overloaded, shorted, or otherwise out of specification.

The fault of DTC 642 and DTC 652 will set if the internally measured voltage feedback of the regulator output is lower than the low voltage limit as defined in the diagnostic calibration anytime the engine is running or stopped at key-on (if applicable).

The fault of DTC 643 and DTC 653 will set if the internally measured voltage feedback of the regulator output is higher than the high voltage limit as defined in the diagnostic calibration anytime the engine is running or stopped at key-on (if applicable).

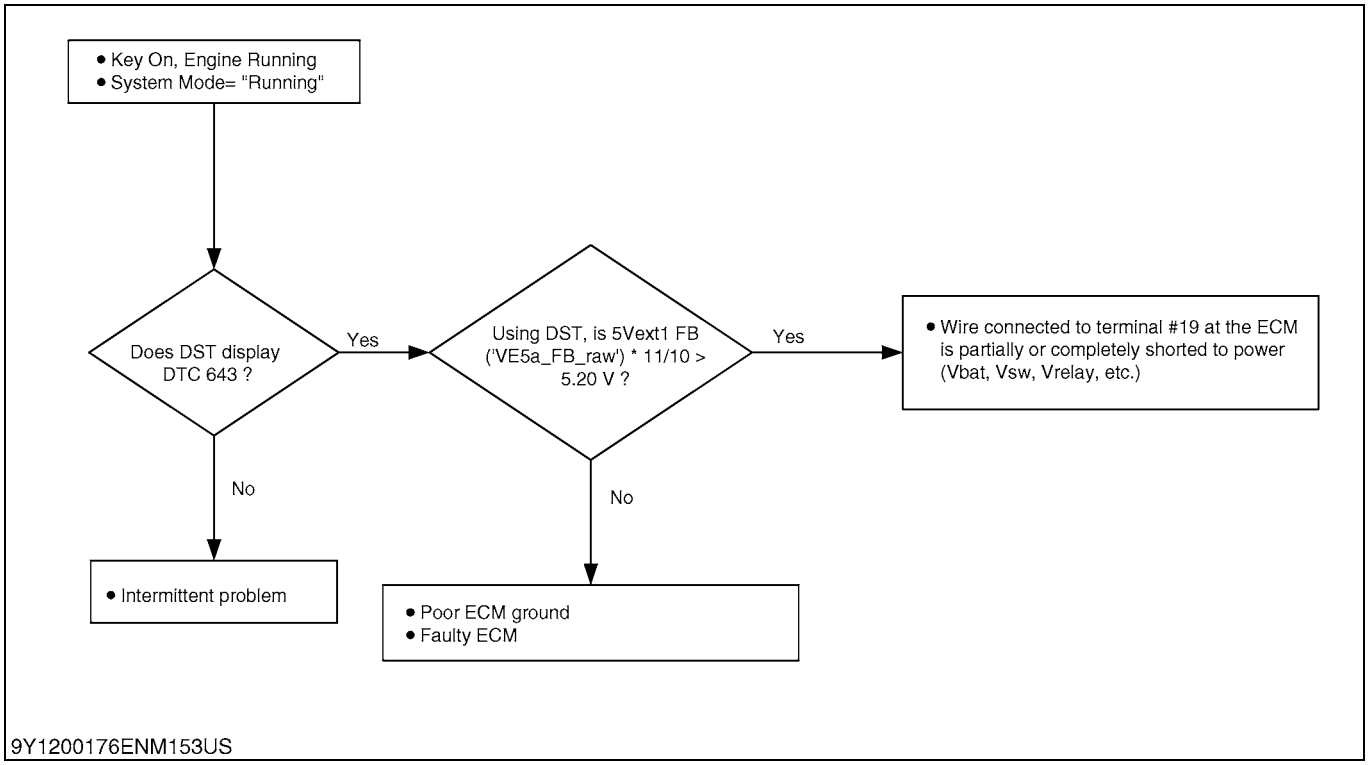
DTC 642-Sensor Supply Voltage 1 Low (5 Vext1)

Diagnostic Aids Chart



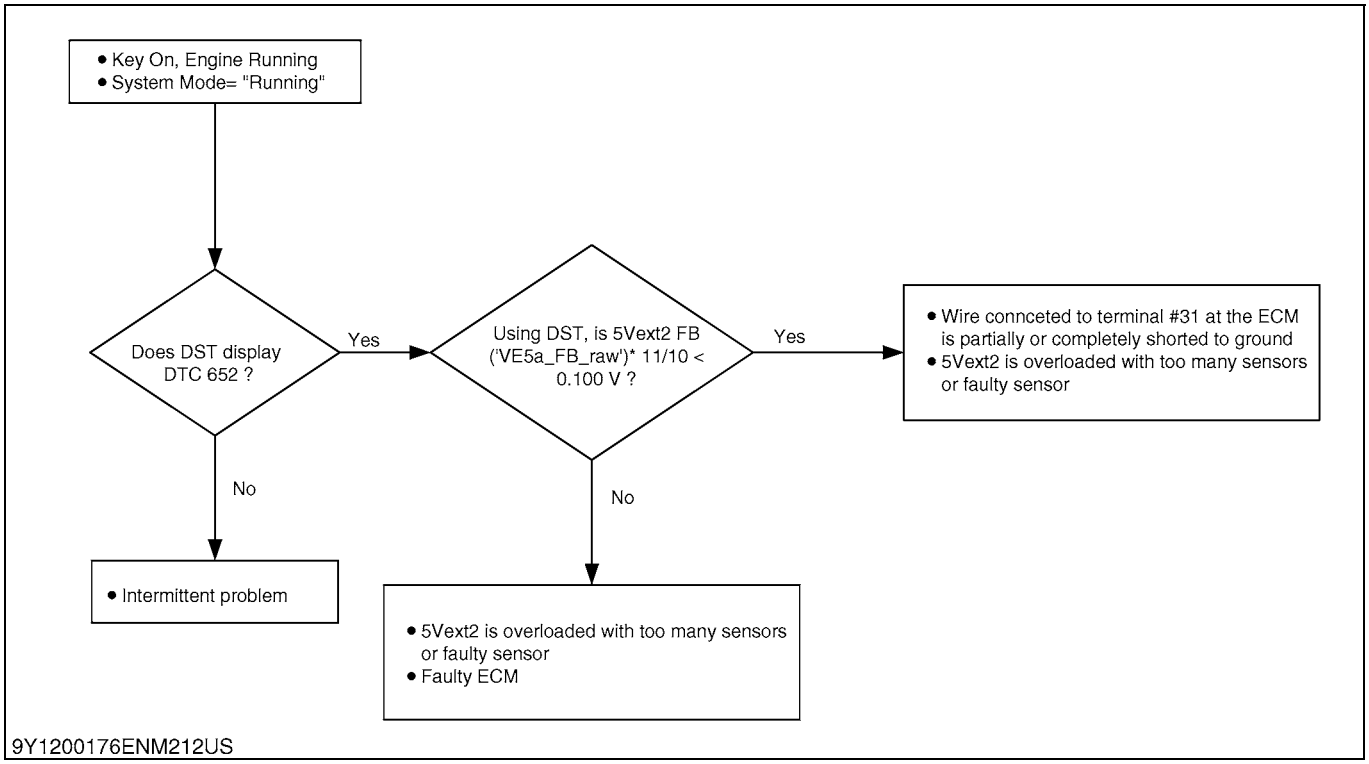
DTC 643-Sensor Supply Voltage 1 High (5 Vext1)

Diagnostic Aids Chart



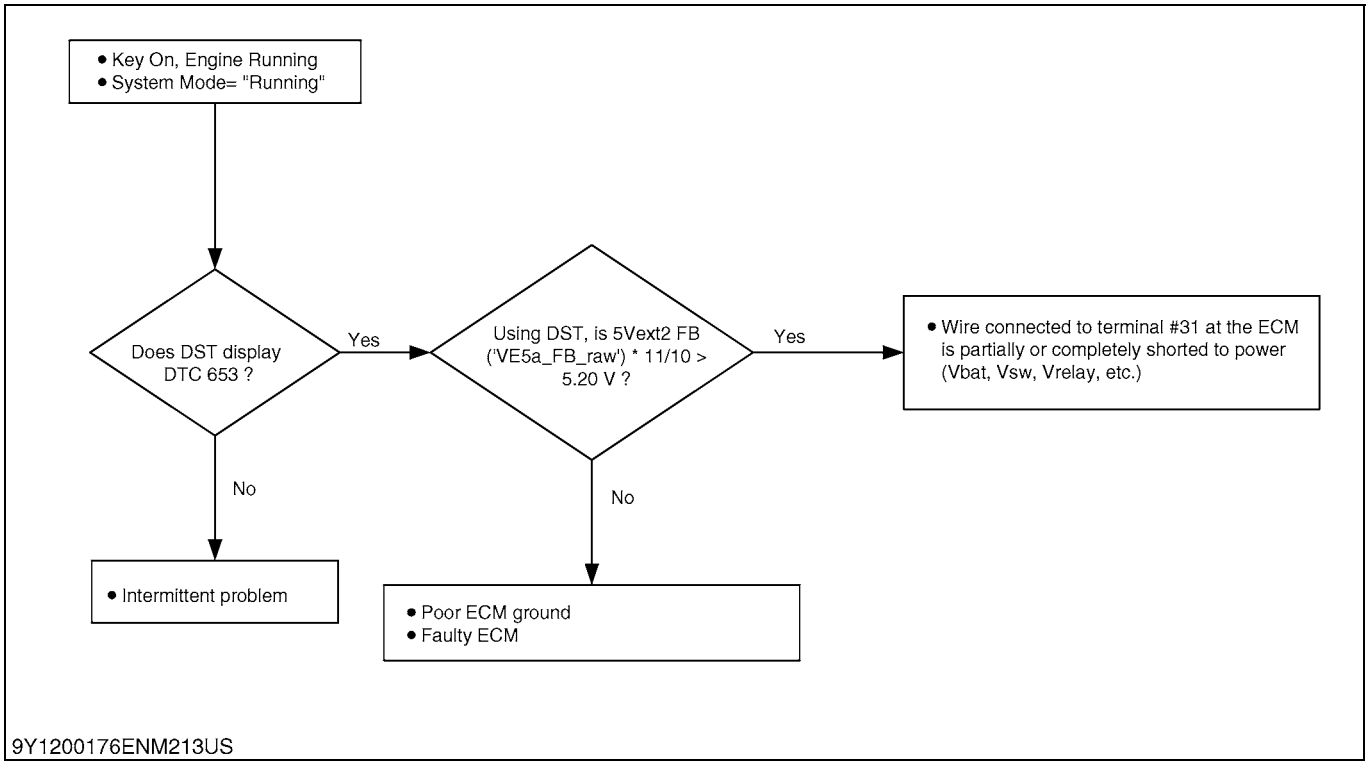
DTC 652-Sensor Supply Voltage 2 Low (5 Vext2)

Diagnostic Aids Chart

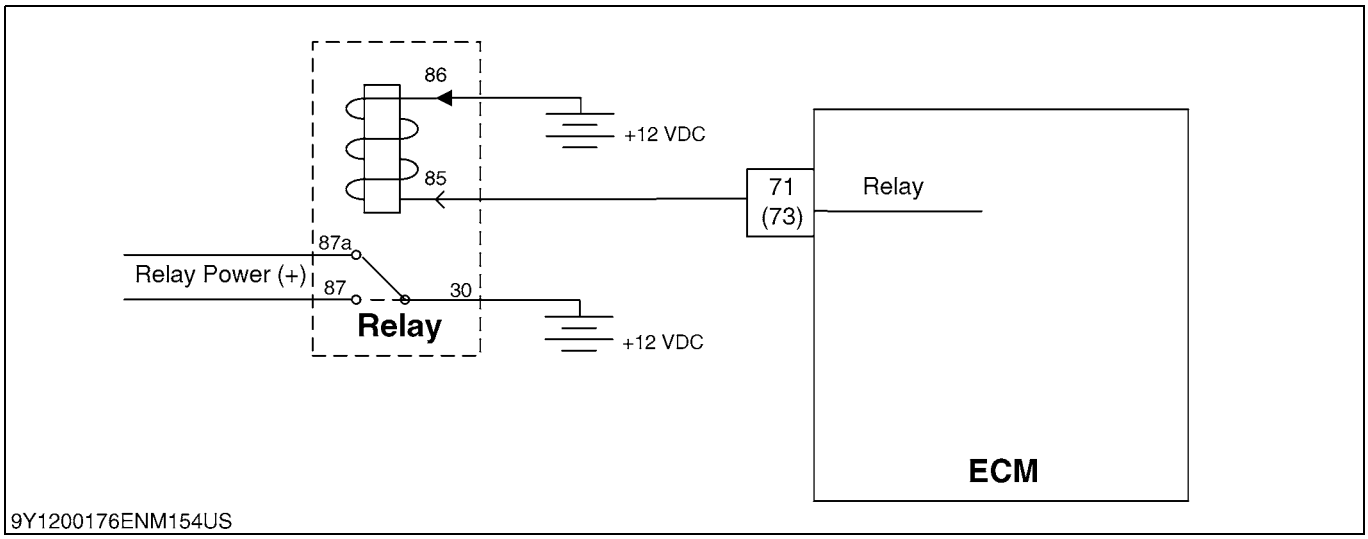


DTC 653-Sensor Supply Voltage 2 High (5 Vext2)

Diagnostic Aids Chart



(19) Power Relay Control / Coil (DTC 686, 687)



DTC 686-Power Relay Ground Short

- Hardware: Power Relay Pull in Coil
- Enabling Conditions: Key On, Engine Off
- Set Conditions: Power relay coil output shorted to ground for more than 10 samples of circuit
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Short to ground in relay pull in coil, short to ground in relay driver circuit in wire harness, faulty ECM

DTC 687-Power Relay Coil Short-To-Power

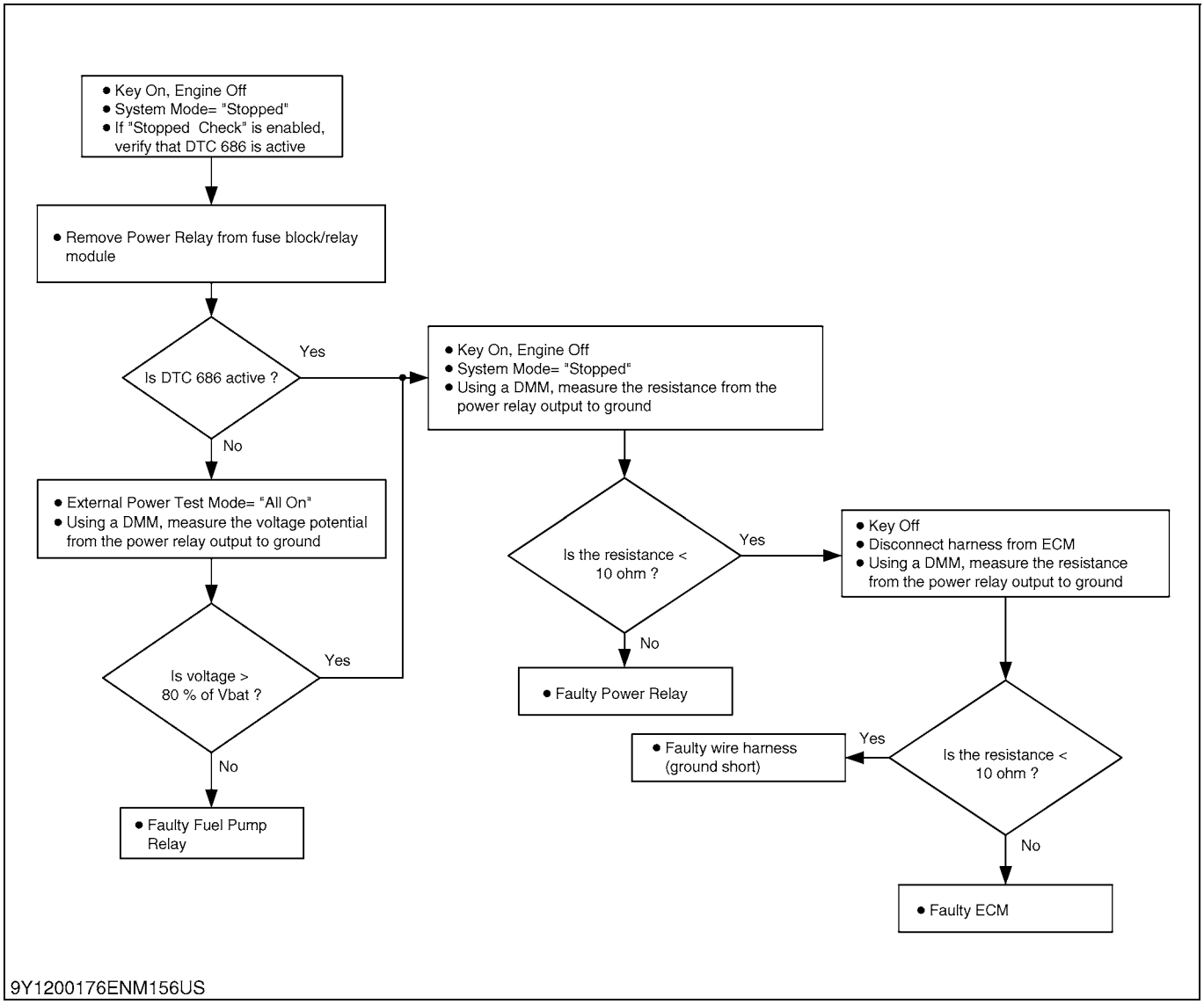
- Hardware: Power Relay Pull in Coil
- Enabling Conditions: Key On, Engine Off
- Set Conditions: Power relay coil output short to power/voltage
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Shorted relay pull in coil, relay driver circuit shorted to voltage in wire harness

The fault of DTC 686 sets if the output for the power relay is detected as being shorted to ground. If this fault is active and the high-side of the power relay is supplied, the following components will have power until the relay or high-side power is removed: CMP sensor, CKP sensor, both O2 sensors, the DEPR (if attached) and all fuel injectors (gasoline engines).

The fault of DTC 687 sets if the output for the power relay is detected as shorted to power.

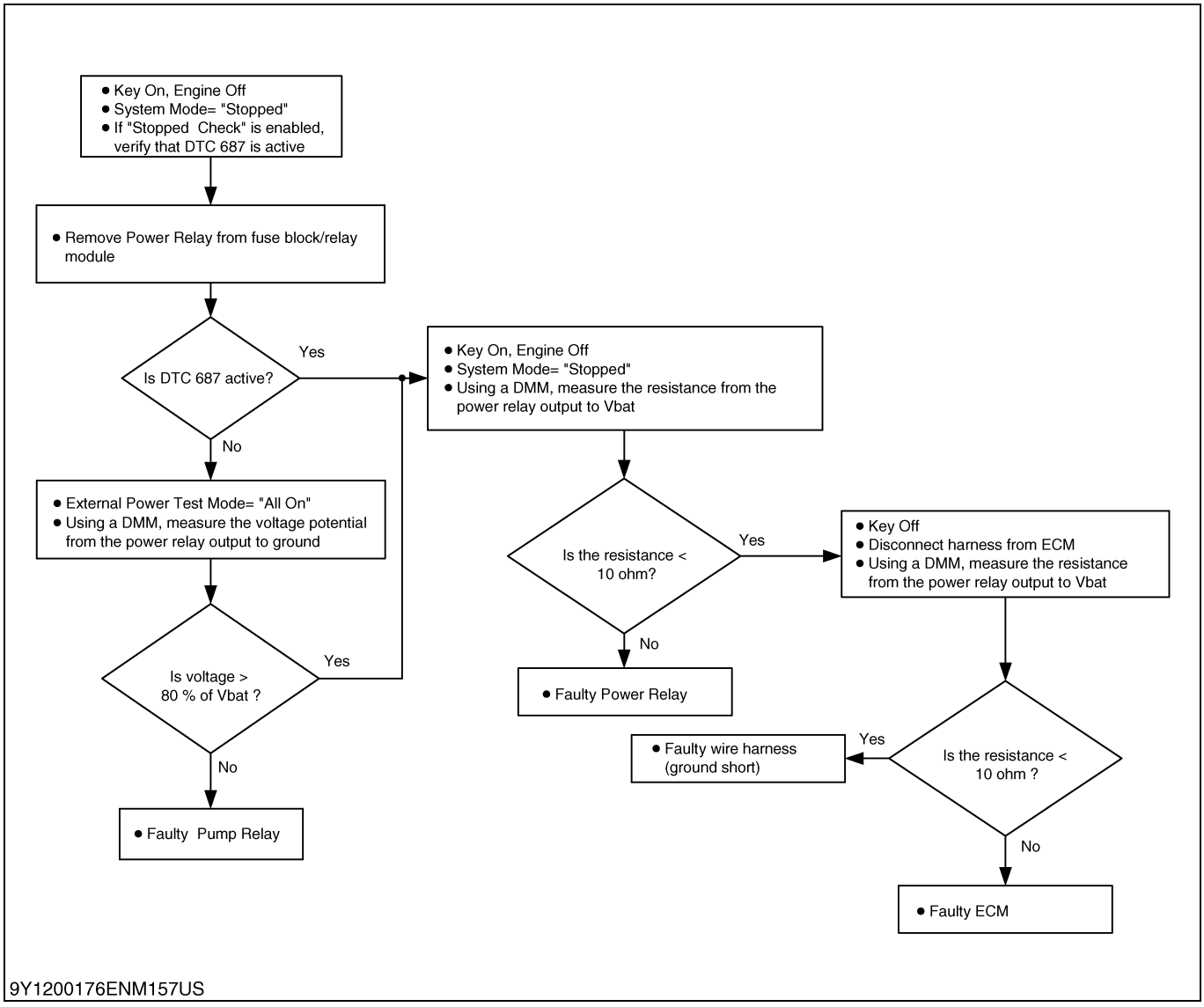
DTC 686-Power Relay Ground Short

Diagnostic Aids Chart



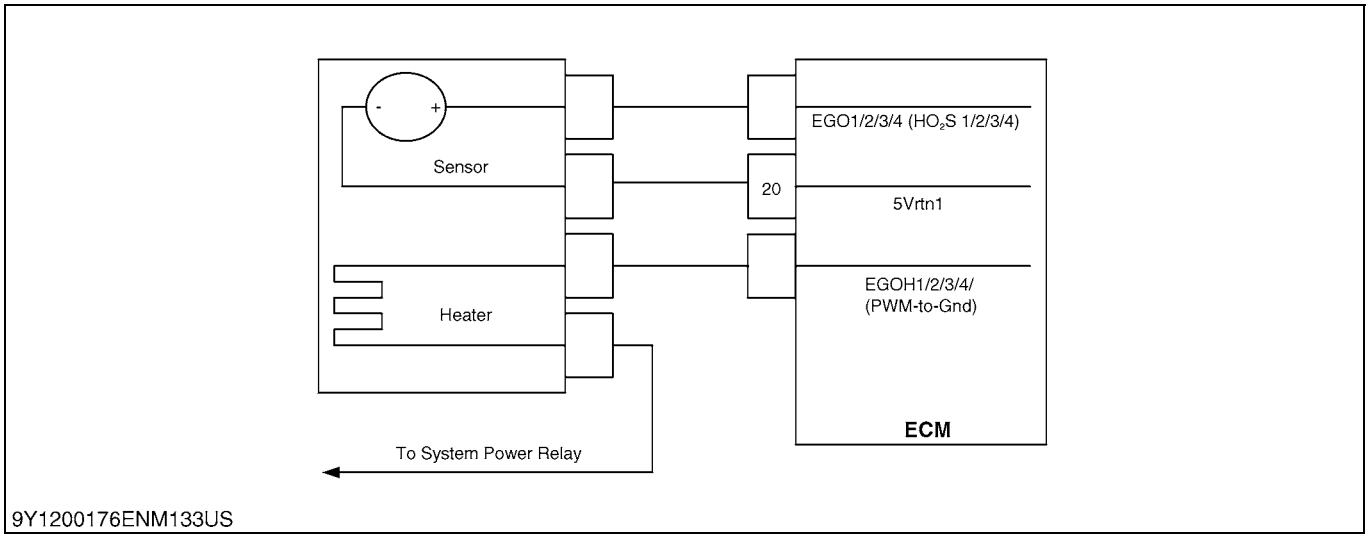
DTC 687-Power Relay Coil Short-To-Power

Diagnostic Aids Chart



9Y1200176ENM157US

(20) Closed Loop (DTC 1151 to 1156)



DTC 1151-Closed Loop High (LPG)

DTC 1153-Closed Loop High (NG)

DTC 1155-Closed Loop Bank 1 High (Gasoline)

- Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- Enabling Conditions: Engine Running in closed loop
- Set Conditions: Closed Loop fuel multiplier higher than 35 % for longer than 5 updates
- Corrective Action(s): Illuminate MIL
- Emissions related fault

DTC 1152-Closed Loop Low (LPG)

DTC 1154-Closed Loop Low (NG)

DTC 1156-Closed Loop Bank 1 Low (Gasoline)

- Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- Enabling Conditions: Engine Running in closed loop
- Set Conditions: Closed Loop fuel multiplier lower than −35 % for longer than 5 updates
- Corrective Action(s): Illuminate MIL
- Emissions related fault

The HEGO/HO_2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. A UEGO sensor measures the exhaust content across a wide-range of air-fuel ratios with a linear output proportional to lambda/equivalence ratio/air-fuel ratio. In either case, if there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted for each bank using the Closed Loop multiplier and then "learned" with the Adaptive multiplier. The multipliers only update when the system is in either "CL Active" or "CL + Adapt" control modes. The purpose of the closed loop fuel multiplier is to quickly adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation prior to adaptive learn fueling correction "learning" the fueling deviation.

The fault of DTC 1151 and DTC 1153 sets if the Closed Loop multiplier exceeds the high limit of normal operation indicating that the engine is operating lean (excess oxygen) and requires more fuel than allowed by corrections. Often high positive fueling corrections are a function of one or more of the following conditions: 1) exhaust leaks upstream or near the HEGO sensor, 2) reduced fuel supply pressure to the gaseous fuel control system, 3) a fuel supply or manifold leak, 4) a non-responsive HEGO/UEGO sensor, and/or 5) a defective gaseous fuel control component (actuator/valve and/or mixer). These faults should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

The fault of DTC 1152 and DTC 1154 sets if the Closed Loop multiplier exceeds the low limit of normal operation indicating that the engine is operating rich (excess fuel) and requires less fuel than allowed by corrections. Often high negative fueling corrections are a function of one or more of the following conditions: 1) high fuel supply pressure to the gaseous fuel control or faulty pressure regulator and/or 2) a non-responsive HEGO/UEGO sensor. These faults should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

The fault of DTC 1155 sets if the closed loop multiplier exceeds the high limit of normal operation indicating that the engine is operating lean (excess oxygen) and requires more fuel than allowed by corrections. Often high positive fueling corrections are a function of one or more of the following conditions: 1) exhaust leaks upstream or near the HEGO sensor, 2) reduced fuel supply pressure to the fuel injection system, 3) a non-responsive HEGO/UEGO sensor, and/or 3) an injector that is stuck closed. This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

The fault of DTC 1156 sets if the closed loop multiplier exceeds the low limit of normal operation indicating that the engine is operating rich (excess fuel) and requires less fuel than allowed by corrections. Often high negative fueling corrections are a function of one or more of the following conditions: 1) high fuel supply pressure to the fuel injection system, 2) a non-responsive HEGO/UEGO sensor, and/or 3) an injector that is stuck open. This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

DTC 1151-Closed Loop High (LPG)

DTC 1153-Closed Loop High (NG)

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor sense signal.
- Vacuum Leaks - Large vacuum leaks and crankcase leaks can cause a lean exhaust condition at light load.
- Fuel Pressure - System will be lean if fuel pressure is too low. Ensure fuel tank pressure is not too low and that gaseous fuel control actuator/regulator has proper fuel pressure under all operating conditions.
- Exhaust Leaks - If there is an exhaust leak, outside air can be pulled into the exhaust and past the O_2 sensor causing a false lean condition.
- Fuel Quality - A drastic variation in fuel quality may cause the system to be lean including fuels with high inert gas content.
- System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- If all tests are OK, replace the HO_2S or UEGO sensor with a known good part and retest.

DTC 1152-Closed Loop Low (LPG)

DTC 1154-Closed Loop Low (NG)

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- Fuel Pressure - System will be rich if fuel delivery pressure is too high to gaseous control system. Check fuel pressure at the control actuator/valve under all operating conditions.
- System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- If all tests are OK, replace the HO_2S or UEGO sensor with a known good part and retest.

DTC 1155-Closed Loop Bank 1 High (Gasoline)

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- Vacuum Leaks - Large vacuum leaks and crankcase leaks can cause a lean exhaust condition at light load.
- Injectors - System will be lean if an injector driver or driver circuit fails. The system will also be lean if an injector fails in a closed manner or is dirty.
- Fuel Pressure - System will be lean if fuel pressure is too low. Check fuel pressure in the fuel rail during key-on, engine off and during normal operating conditions.
- Air in Fuel - If the fuel return hose/line is too close to the fuel supply pickup in the fuel tank, air may become entrapped in the pump or supply line causing a lean condition and driveability problems.
- Exhaust Leaks - If there is an exhaust leak, outside air can be pulled into the exhaust and past the O_2 sensor causing a false lean condition.
- Fuel Quality - A drastic variation in fuel quality may cause the system to be lean including oxygenated fuels.
- System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- If all tests are OK, replace the HO_2S sensor with a known good part and retest.

DTC 1156-Closed Loop Bank 1 Low (Gasoline)

Diagnostic Aids

■ **NOTE**

- **If any other DTCs are present, diagnose those first.**
- Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- Injectors - System will be rich if an injector driver or driver circuit fails shorted-to-ground. The system will also be rich if an injector fails in an open.
- Fuel Pressure - System will be rich if fuel pressure is too high. Check fuel pressure in the fuel rail during key-on, engine off and during normal operating conditions.
- System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- If all tests are OK, replace the HO_2S sensor with a known good part and retest.

(21) Megajector/EPR (DTC 1173)

DTC 1173-Megajector/EPR Comm Lost

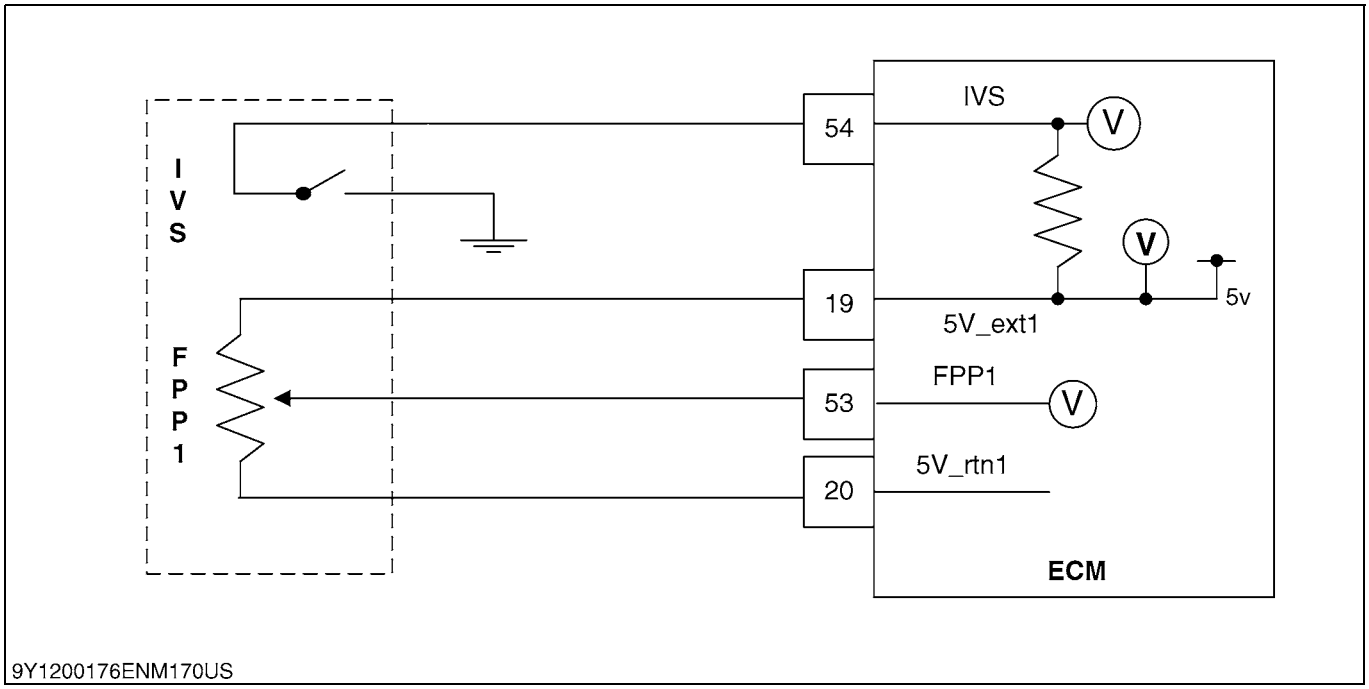
- Hardware: Megajector or EPR
- Enabling Conditions: Engine Running
- Set Conditions: ECM lost CAN communication with Megajector/EPR
- Corrective Action(s): Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp, disable closed loop fueling correction while the fault is active and adaptive fueling correction for the remainder of the key-cycle
- Emissions related fault
- Possible Causes:

The Megajector is the first generation of EControls Inc. Electronic Pressure Regulators (EPR) found in many industrial applications. The Megajector is a "smart" actuator that is installed in the gaseous fuel flow path as a secondary stage regulator that receives fuel pressure commands from the ECM and precisely modulates fuel pressure to the gaseous fuel carburetor/mixer. The Megajector allows for fast and accurate gaseous fuel control to provide a combustible mixture to the engine.

The EPR (Cobra EPR and HD EPR) is the second generation of EControls Inc. Electronic Pressure Regulators found in many industrial and heavy-duty on-highway applications. The 2nd generation EPR is a "smart" actuator integrated with the primary stage regulator that is designed to control gaseous fuel pressure in the secondary stage regulator. The EPR receives fuel pressure commands from the ECM and quickly and precisely modulates fuel pressure to the gaseous fuel mixer. The EPR allows for very fast and very accurate gaseous fuel control to provide a combustible mixture to the engine in a smaller package.

This fault sets if the ECM loses CAN communication with the EPR. This fault indicates that the ECM is no longer receiving CAN packets from the EPR which also results in the EPR not receiving communication from the ECM. This is often a result of a power loss at the EPR or improper CAN termination or wiring. Adaptive fueling correction should be disabled for the key-cycle to avoid improper learning of the fuel correction table.

(22) FPP (Foot Pedal Position Switch) (DTC 2115, 2116, 2139, 2140, 2122, 2123, 2127, 2128)



9Y1200176ENM170US

DTC 2115-FPP1 Higher Than IVS

- Hardware: Foot Pedal Position/Idle Validation Switch
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: IVS at idle (open) and FPP voltage greater than 1.00 V for longer than 1 second
- Corrective Action(s): MIL-On during active fault and activate power derate 2 (max 30 % throttle blade opening)
- Non-emissions related fault
- Possible Causes: IVS switch sticking, unwanted or incorrect resistance in FPP1 circuitry

DTC 2116-FPP2 Higher Than IVS

- Hardware: Foot Pedal Position/Idle Validation Switch
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: IVS at idle (open) and FPP voltage greater than 1.00 V for longer than 1 second
- Corrective Action(s): MIL-On during active fault and activate power derate 2 (max 30 % throttle blade opening)
- Non-emissions related fault
- Possible Causes: IVS switch sticking, unwanted or incorrect resistance in FPP2 circuitry

DTC 2139-FPP1 Lower Than IVS

- Hardware: Foot Pedal Position/Idle Validation Switch
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: IVS off idle (closed) and FPP voltage less than 0.850 V for longer than 1 second
- Corrective Action(s): MIL-On during active fault and activate power derate 2 (max 30 % throttle blade opening)
- Non-emissions related fault
- Possible Causes: IVS switch sticking, unwanted or incorrect resistance in FPP1 circuitry

DTC 2140-FPP2 Lower Than IVS

- Hardware: Foot Pedal Position/Idle Validation Switch
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: IVS off idle (closed) and FPP voltage less than 0.850 V for longer than 1 second
- Corrective Action(s): MIL-On during active fault and activate power derate 2 (max 30 % throttle blade opening)
- Non-emissions related fault
- Possible Causes: IVS switch sticking, unwanted or incorrect resistance in FPP2 circuitry

The engine load command to the ECM is determined by operator depression of the electronic foot pedal. The ECM monitors the foot pedal position and controls the throttle to maintain the commanded power level. Because a problem with the foot pedal signal can result in a higher or lower power than intended by the operator, the pedal used with this control system incorporates a sensor with an idle validation switch. Checks and cross checks are constantly conducted by the ECM to determine the validity of the signals. The Idle Validation Switch (IVS) is a normally open switch (idle) that grounds the IVS circuit to the ECM when the pedal is depressed more than the idle position.

DTC 2122-FPP1 Voltage High

- Hardware: Electronic foot pedal/throttle control sensor
- Enabling Conditions: Key On, Engine Off
- Set Conditions: FPP1 voltage > 4.00 V for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, activate low rev limit
- Non-emissions related fault
- Possible Causes: FPP signal shorted to voltage, 5 V_rtn1 open to FPP, FPP open internally

DTC 2127-FPP2 Voltage High

- Hardware: Electronic foot pedal/throttle control sensor
- Enabling Conditions: Key On, Engine Off
- Set Conditions: FPP2 voltage > 4.00 V for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, activate low rev limit
- Non-emissions related fault
- Possible Causes: FPP signal shorted to voltage, 5 V_rtn1 open to FPP, FPP open internally

DTC 2123-FPP1 Voltage Low

- Hardware: Electronic foot pedal/throttle control sensor
- Enabling Conditions: Key On, Engine Off
- Set Conditions: FPP1 voltage < 0.300 V for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, activate low rev limit
- Non-emissions related fault
- Possible Causes: Loss of 5 V supply, FPP1 signal circuit open or shorted to ground, faulty FPP, faulty ECM

DTC 2128-FPP2 Voltage Low

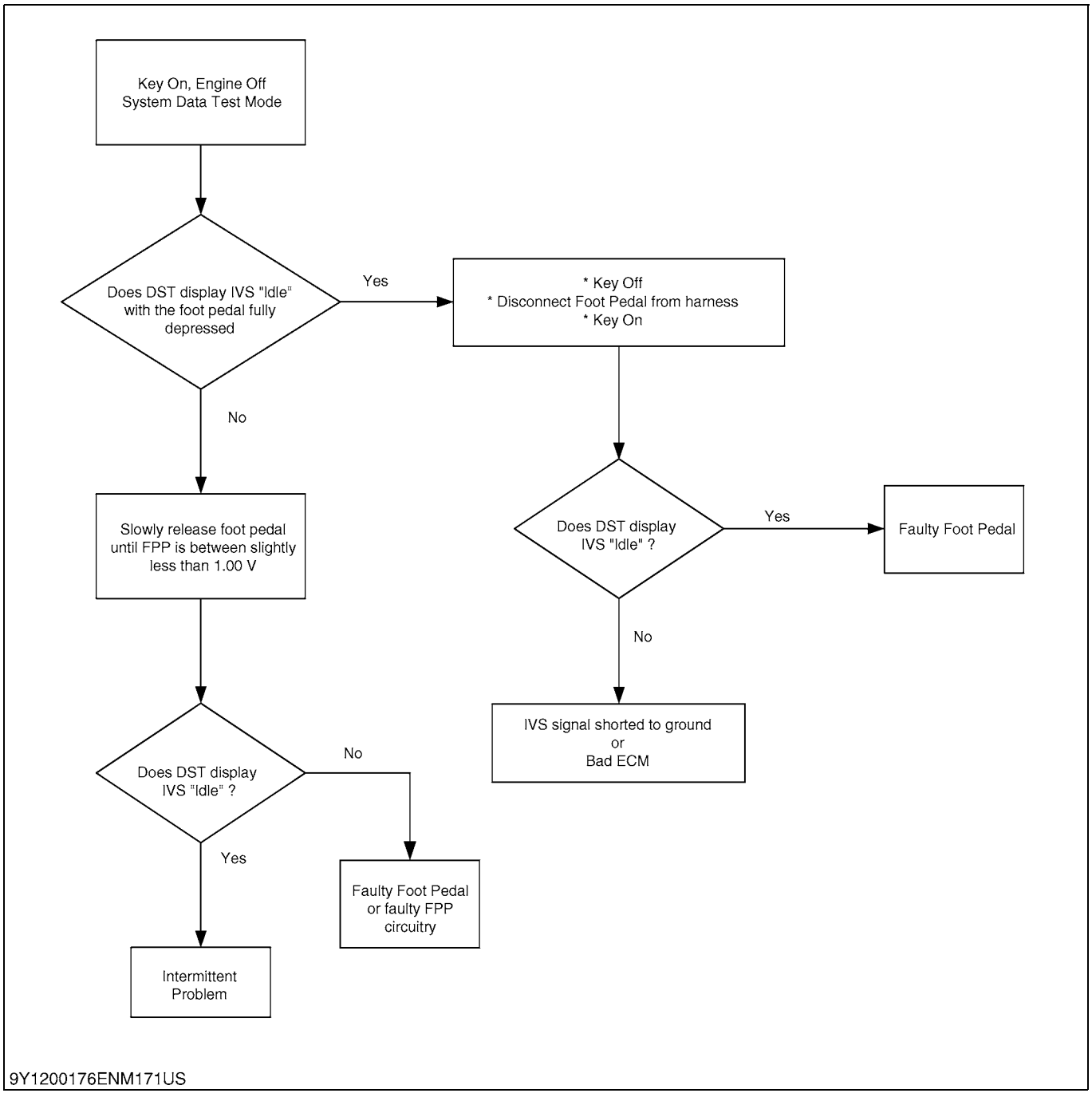
- Hardware: Electronic foot pedal/throttle control sensor
- Enabling Conditions: Key On, Engine Off
- Set Conditions: FPP2 voltage < 0.300 V for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, activate low rev limit
- Non-emissions related fault
- Possible Causes: Loss of 5 V supply, FPP2 signal circuit open or shorted to ground, faulty FPP, faulty ECM

The FPP sensor is an electronic device that is coupled to a mechanically driven input as commanded by the vehicle/engine operator. The FPP sensor output is proportional to the commanded input. The ECM uses the FPP sensor input to control the throttle and adjust the engine's load in order to achieve the requested power. Since the FPP sensor inputs directly affect the engine's power output, redundant sensors are generally used to ensure safe, reliable operation. In electronic throttle control systems the foot pedal position/throttle control position sensor is used by the engine/equipment operator or system to command either throttle position or a governor speed target proportional to the input in order to achieve desired system behavior.

DTC 2115-FPP1 Higher Than IVS

DTC 2116-FPP2 Higher Than IVS

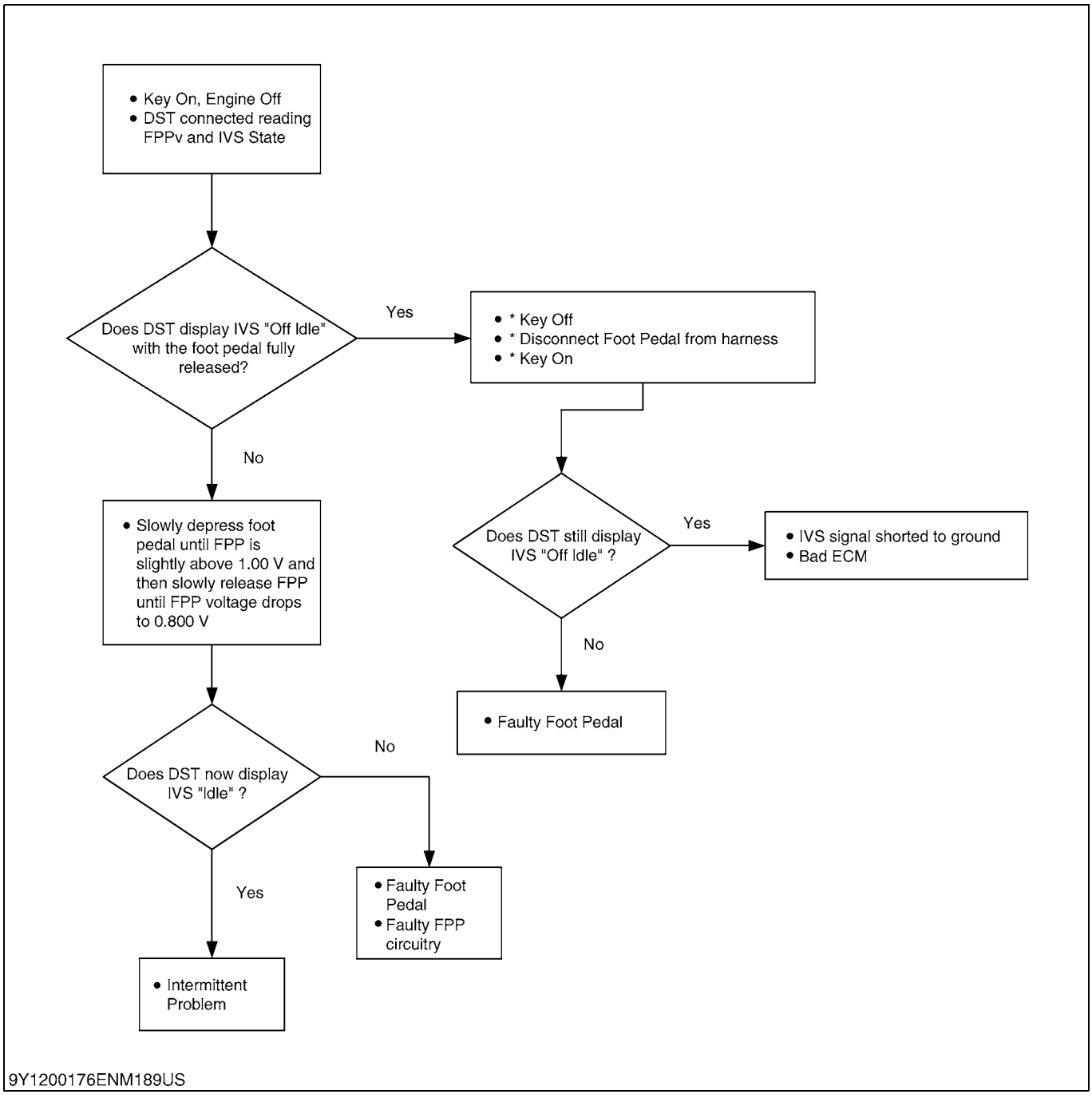
Diagnostic Aids Chart



DTC 2139-FPP1 Lower Than IVS

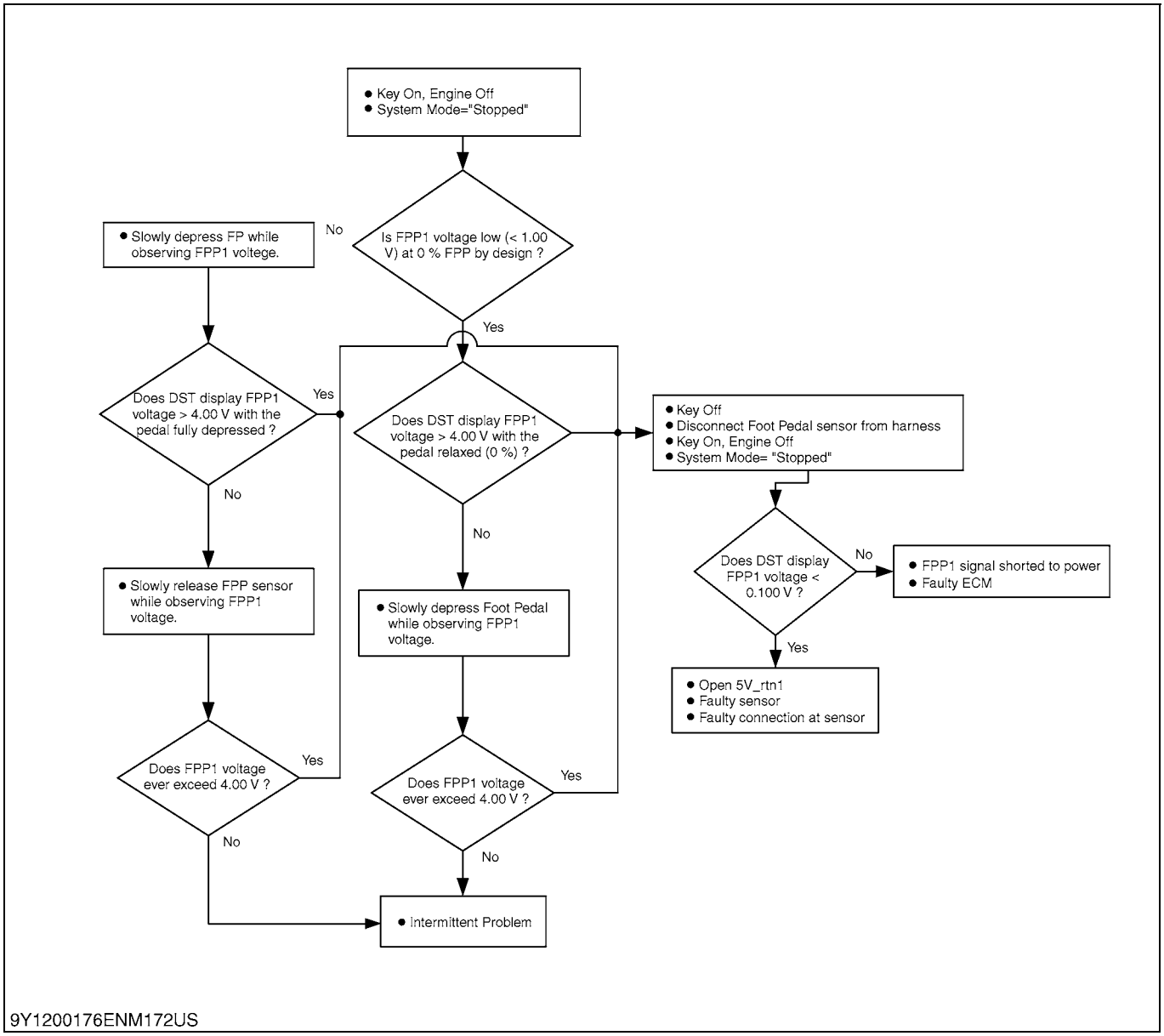
DTC 2140-FPP2 Lower Than IVS

Diagnostic Aids Chart



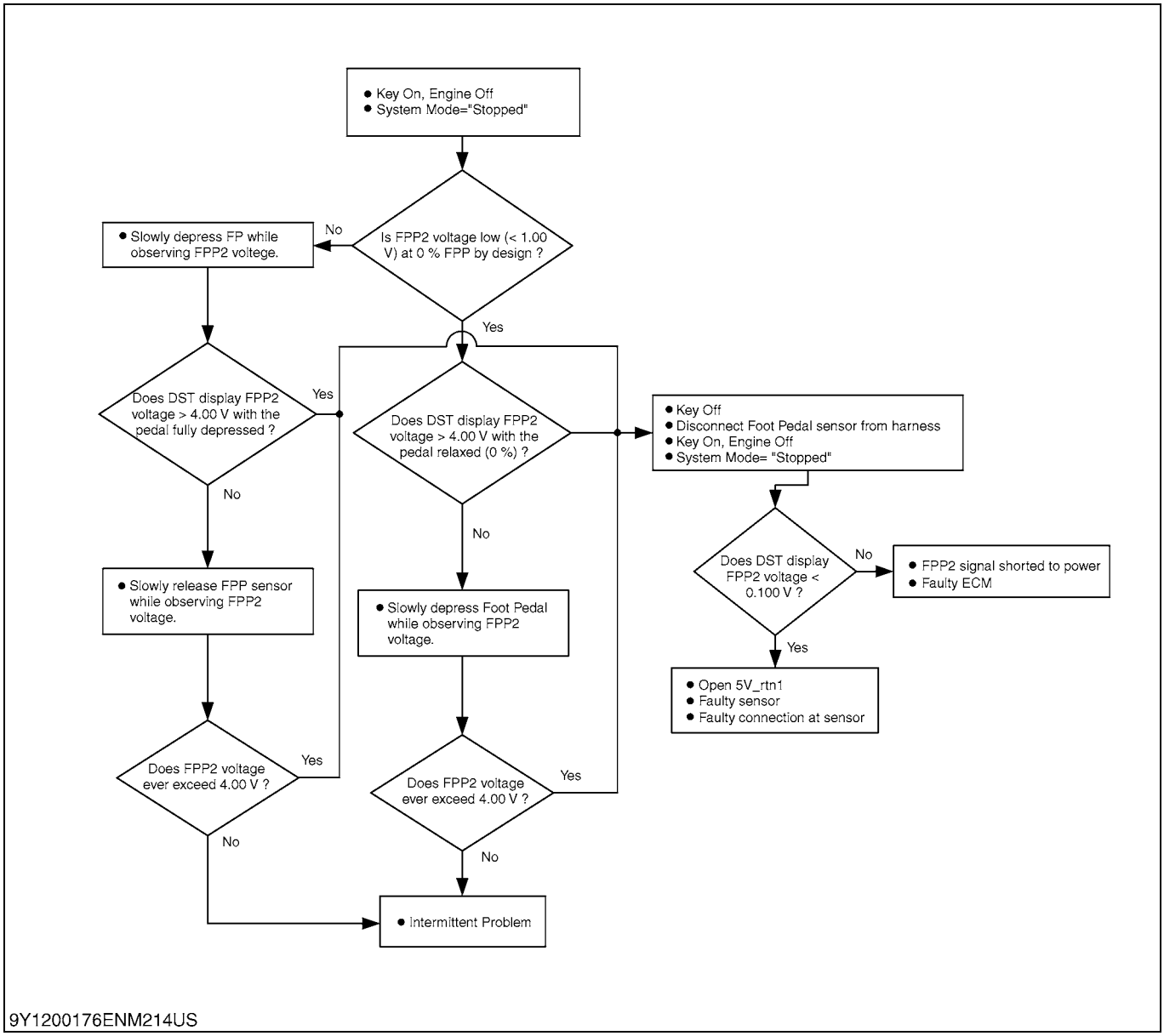
DTC 2122-FPP1 Voltage High

Diagnostic Aids Chart



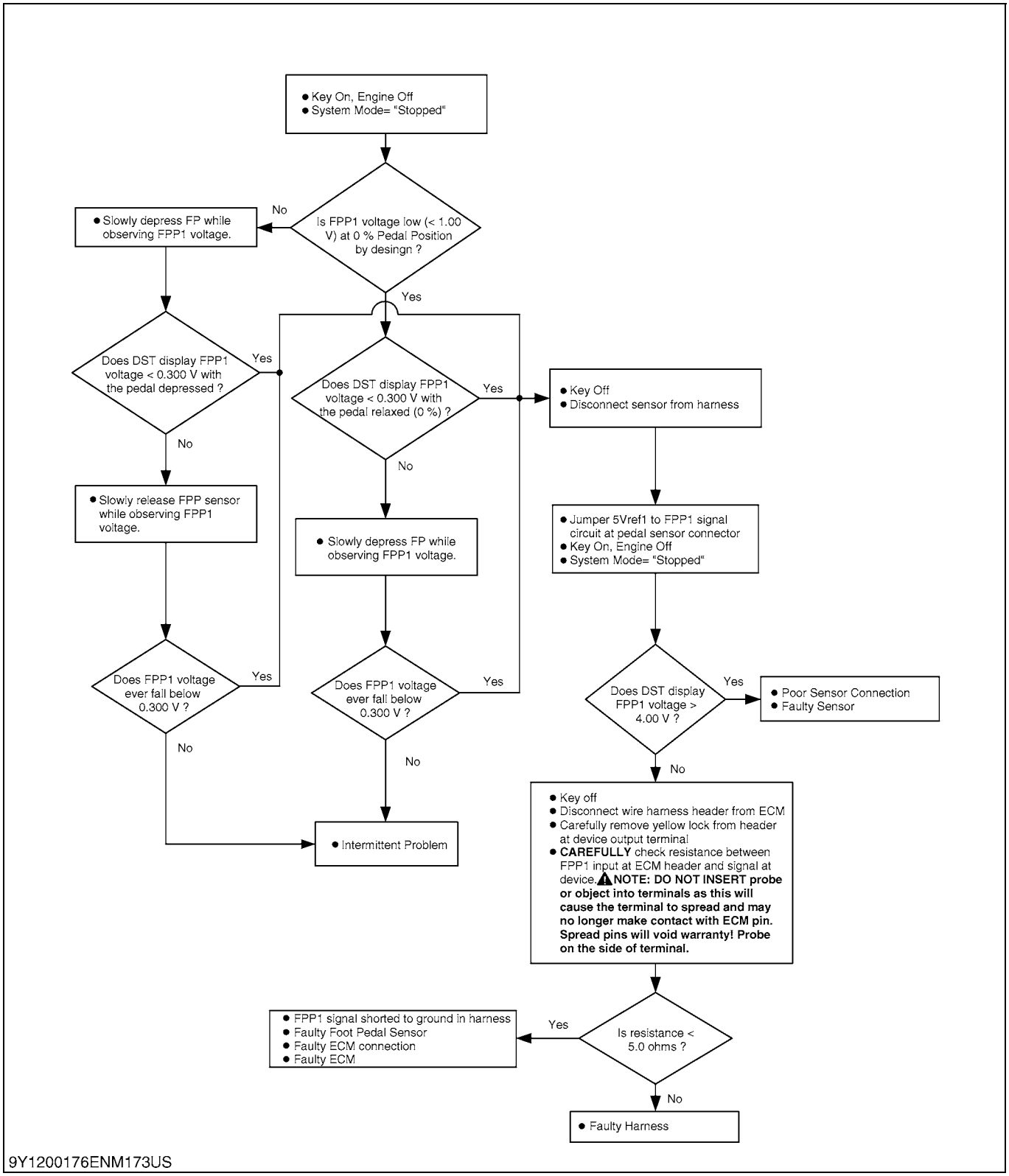
DTC 2127-FPP1 Voltage High

Diagnostic Aids Chart



DTC 2123-FPP1 Voltage Low

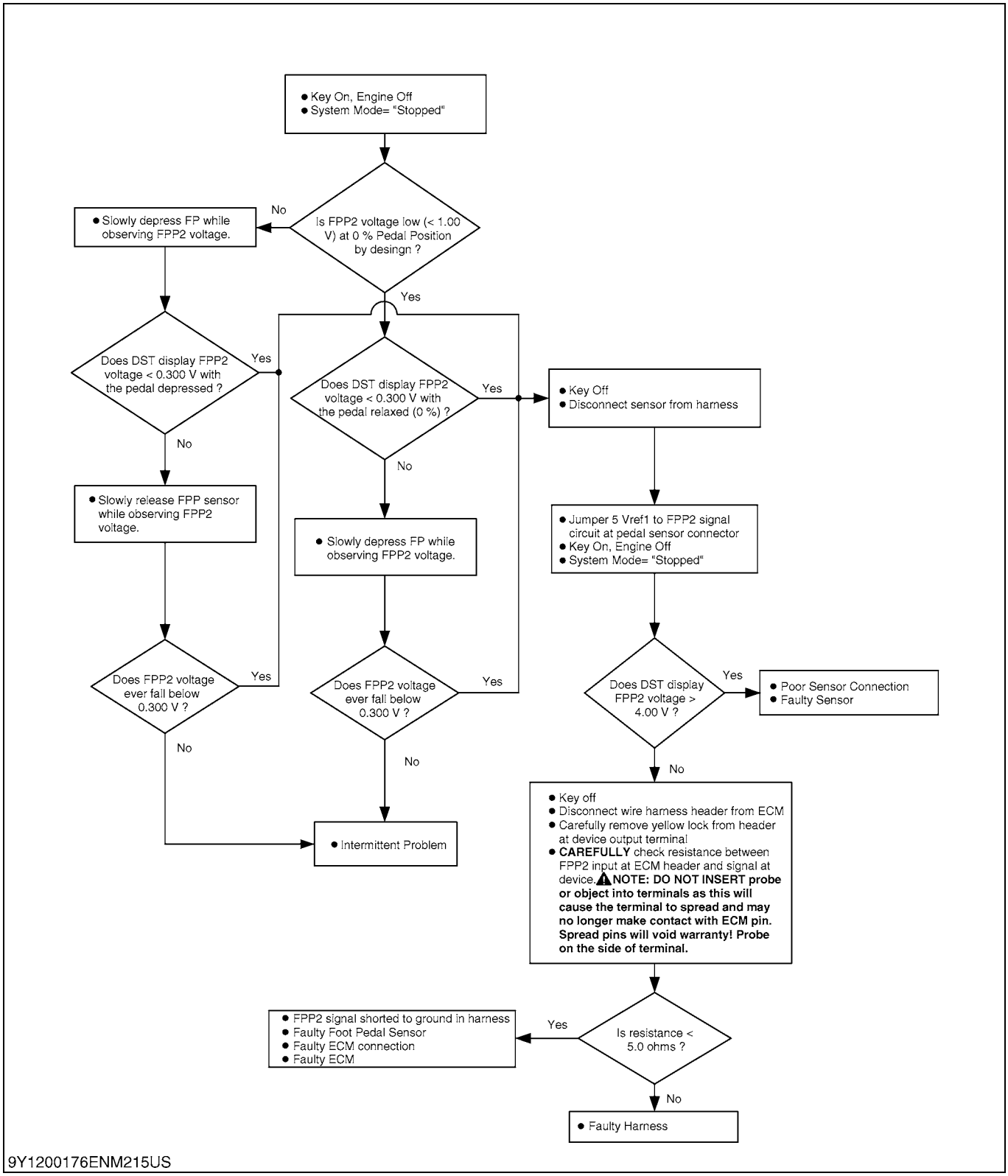
Diagnostic Aids Chart



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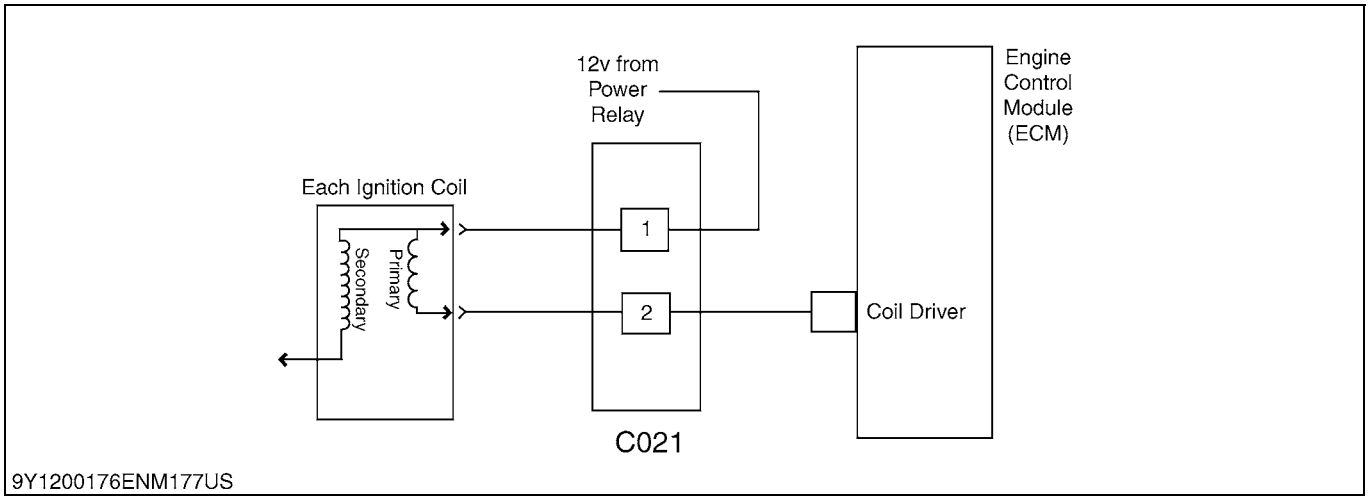
DTC 2128-FPP2 Voltage Low

Diagnostic Aids Chart



9Y1200176ENM215US

(23) Spark Coil Primary (DTC 2300, 2301, 2303, 2304, 2306, 2307, 2309, 2310)



DTC 2300-Spark Coil #1 Primary Open/Short-to-Ground

DTC 2303-Spark Coil #2 Primary Open/Short-to-Ground

DTC 2306-Spark Coil #3 Primary Open/Short-to-Ground

DTC 2309-Spark Coil #4 Primary Open/Short-to-Ground

- Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- Enabling Conditions: Key On, Engine Running, Battery volts > 11.0
- Set Conditions: Primary circuitry of the ignition coil is an open circuit or shorted-to-ground
- Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- Emissions related fault
- Possible Causes:

Each coil driver #1, #2, #3 and #4 fires the corresponding cylinder, the 1st, 2nd, 3rd and 4th cylinder each in the block order.

These faults will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is greater than 2 ms. or the total dwell is greater than 14 ms. and battery voltage is greater than 11.0 V.

The purpose of these faults is to detect a short-to-ground or open circuit in the harness or an open internal to the primary coil.

DTC 2301-Spark Coil #1 Primary Short-to-Power

DTC 2304-Spark Coil #2 Primary Short-to-Power

DTC 2307-Spark Coil #3 Primary Short-to-Power

DTC 2310-Spark Coil #4 Primary Short-to-Power

- Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- Enabling Conditions: Key On, Engine Running, Battery volts < 16.0
- Set Conditions: Primary circuitry of the ignition coil is shorted-to-power
- Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- Emissions related fault
- Possible Causes:

Each coil driver #1, #2, #3 and #4 fires the corresponding cylinder, the 1st, 2nd, 3rd and 4th cylinder each in the block order.

These faults will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is less than –2 ms. or the total dwell is less than 4.0 ms. and battery voltage is less than 16.0 V.

The purpose of these faults is to detect a short-to-power in the harness or internal to the primary coil.

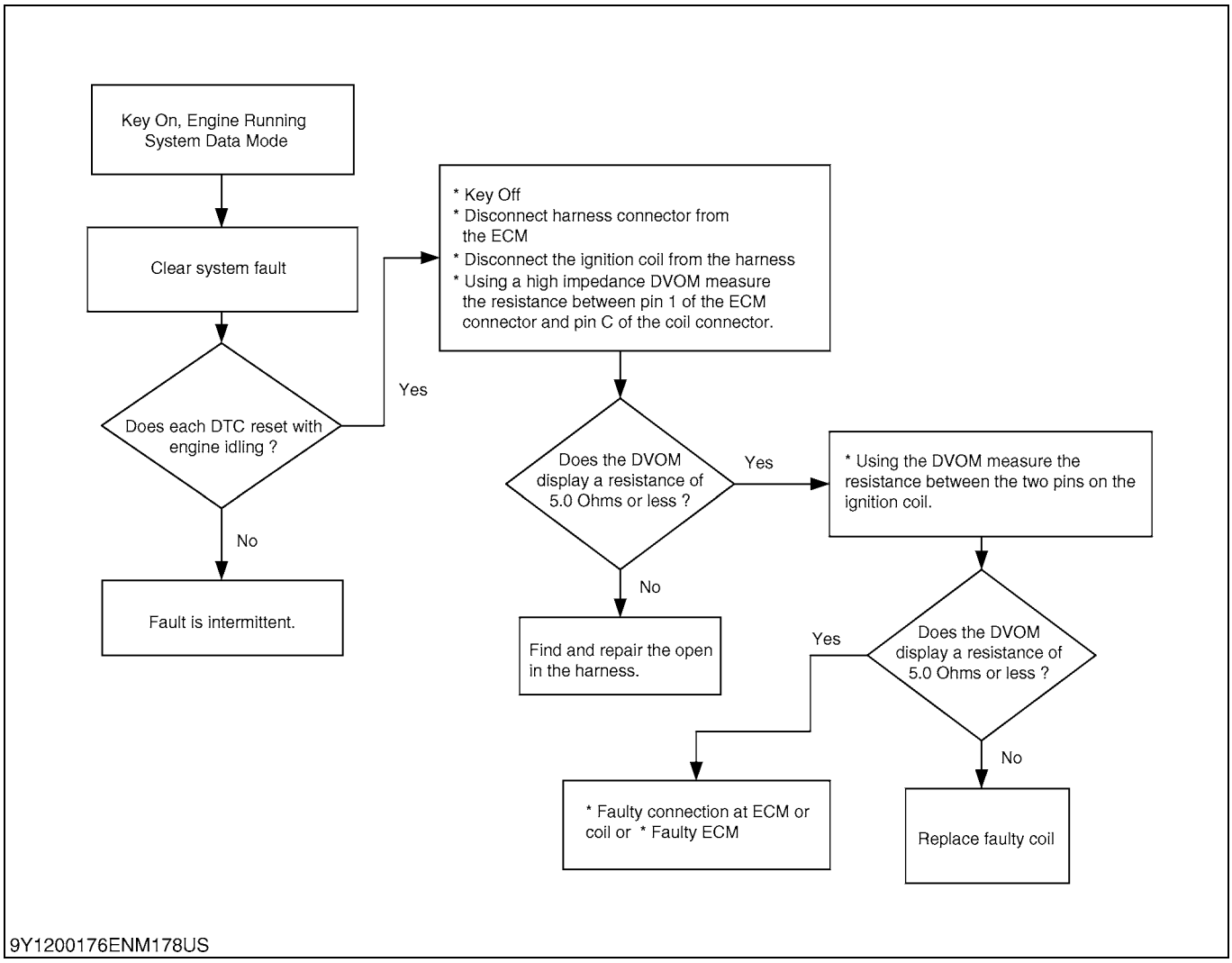
DTC 2300-Spark Coil #1 Primary Open/Short-to-Ground

DTC 2303-Spark Coil #2 Primary Open/Short-to-Ground

DTC 2306-Spark Coil #3 Primary Open/Short-to-Ground

DTC 2309-Spark Coil #4 Primary Open/Short-to-Ground

Diagnostic Aids Chart



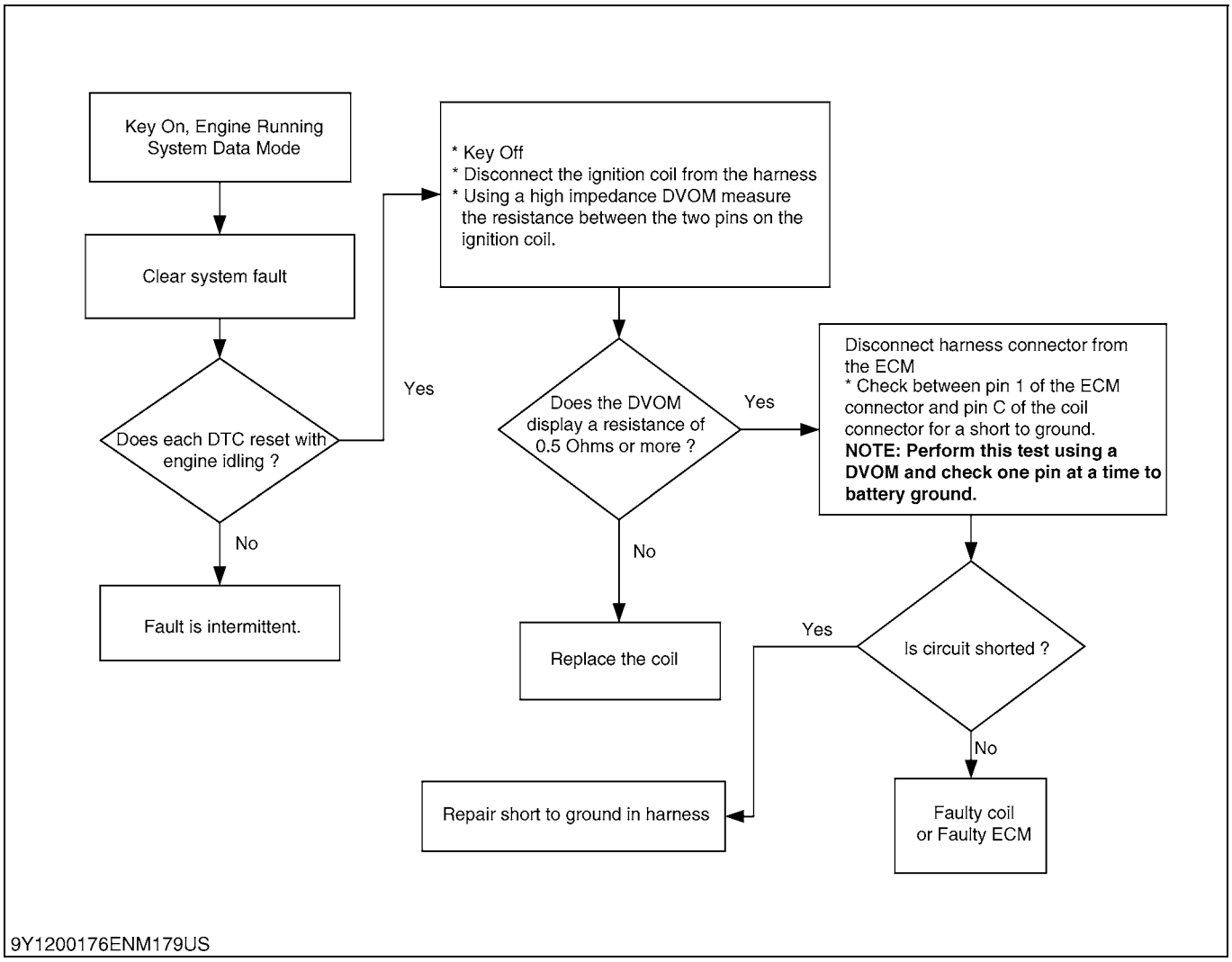
DTC 2301-Spark Coil #1 Primary Short-to-Power

DTC 2304-Spark Coil #2 Primary Short-to-Power

DTC 2307-Spark Coil #3 Primary Short-to-Power

DTC 2310-Spark Coil #4 Primary Short-to-Power

Diagnostic Aids Chart



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KUBOTA Corporation

Printed in Japan 2012. 06, S, EI, EI, engusa Code No.9Y110-01760
2011. 12, S, EI, EI, engusa

KUBOTA ENGINES

APPLICATION MANUAL

(WG1605-E3 MODEL)

First Edition

January, 2012

KUBOTA

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PREFACE

1. This has been prepared so as to enable users to properly and efficiently utilize KUBOTA large SI engines.
2. This manual describes the features of the engines, the cautions and the check items for mounting the engines on various machines.
3. The contents of this manual are roughly divided into the following three items.
   a) General information
   b) Installation instruction
   c) Technical information
4. This manual describes only the content that should be mentioned specially for large SI engines.
5. Phase3 emissions regulations require confirmation of “Emissions-Related Installation Instructions”, “Contractual agreement” etc. between engine and equipment manufactures under 40CFR1068.
6. The specifications and features described in this manual are subject to change without advance notice for technical improvement.
7. If you have any question about this manual, please contact with nearest KUBOTA sales representatives or send e-mail to “k-iss@kubota.co.jp”.

GENERAL INFORMATION

GENERAL

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1. SPECIFICATIONS

Item \ Model			WG1605-G-E3	WG1605-GL-E3	WG1605-L-E3
Type			Vertical, water cooled 4-cycle Gasoline engine	Vertical, water cooled 4-cycle Gasoline / LPG engine	Vertical, water cooled 4-cycle LPG engine
Number of cylinders			4		
Cylinder bore x Stroke		mm (in)	79 x 78.4 (3.11 x 3.09)		
Total displacement		L (cu. in)	1.537 (93.79)		
Brake horse power	SAE J1995 Gross intermittent	kW (HP) / min^{-1} (rpm)	42.5 (57.0) / 3600	41.0 (55.0) / 3600	
	SAE J1349 Net intermittent		38.5 (51.6) / 3600	37.1 (49.8) / 3600	
	SAE J1349 Net continuous		30.8 (41.3) / 3600	29.7 (39.8) / 3600	
	ISO Gross		42.5 (59.0) / 3600	41.0 (55.0) / 3600	
	ISO Continuous		30.8 (41.3) / 3600	29.7 (39.8) / 3600	
	JIS B8002 Net Intermittent		38.5 (51.6) / 3600	37.1 (49.8) / 3600	
	JIS B8002 Continuous		30.8 (41.3) / 3600	29.7 (39.8) / 3600	
Max. torque (SAE J1349)		N·m (lbf-ft) min^{-1} (rpm)	120 (88.5) / 2400	117 (86.3) / 2400	
Maximum engine speed		min^{-1} (rpm)	3600 ±25		
Minimum engine speed		min^{-1} (rpm)	750 ±25		
Compression ratio			9.1		
Firing order			1-3-4-2		
Ignition system			Full transistor battery ignition type		
Ignition timing		deg. BTDC ° / rpm	26 / 3600, 10 / 750	20 / 3600, 10 / 750	
Spark plug type		mm (in.)	NGK IFR6F8DN		
Fuel			Unleaded gasoline	Commercial LPG	
Direction of rotation			Counter-clockwise from flywheel side		
Starting system			Electric starting with cell starter		
Starting motor		V-kW	12 x 1.0		
Alternator output		V-A	12-40 / 12-60		
Lubricating system			Forced lubricating by trochoid pump		
Lubricating oil class		SAE	SAE 10W or SAE 10W-30		
		API	Better than SL class		
Lubricating oil capacity		L (U.S. gal)	6.0 (1.59)		
Catalyst			Three Way Catalyst		
Coolant capacity (with radiator)		L (U.S. gal)	4.0 (1.07)		
Governor type			Electronic governor		
Dimensions (L x B x H)		mm (in)	592.0 x 478.7 x 652.3 (23.31 x 18.85 x 25.68)		
Dry weight		kg (lb)	119 (262.3)	121 (267.0)	120 (264.6)

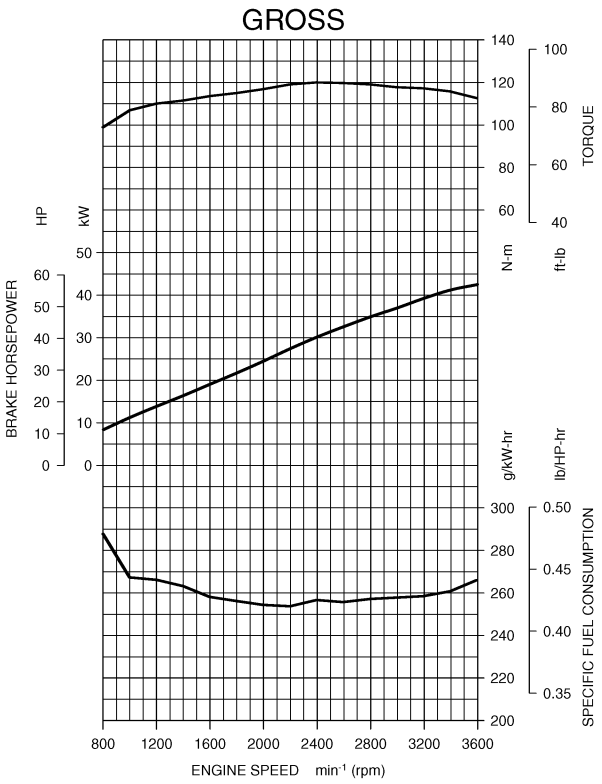
■ **NOTE**

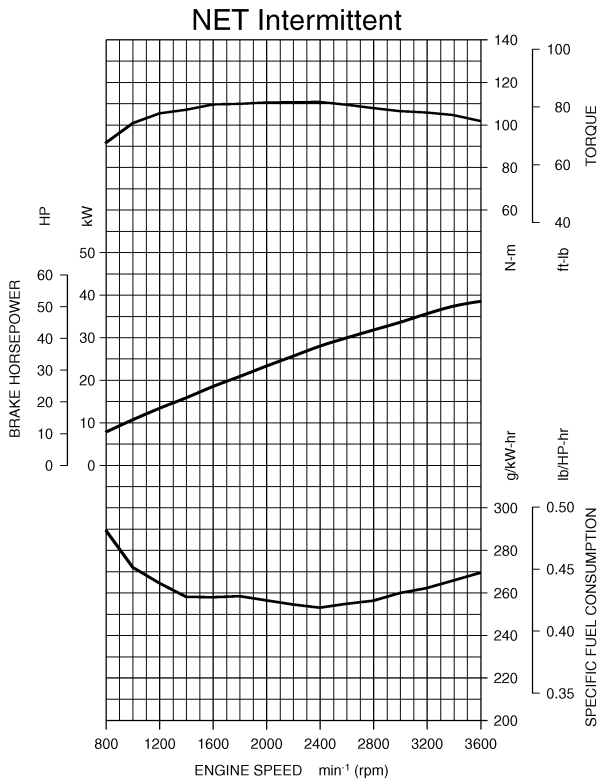
- *** LPG regulator with vaporizer operates on a liquid withdrawal type system.**
- **The descriptions in this application only apply to the basic model shown above.**

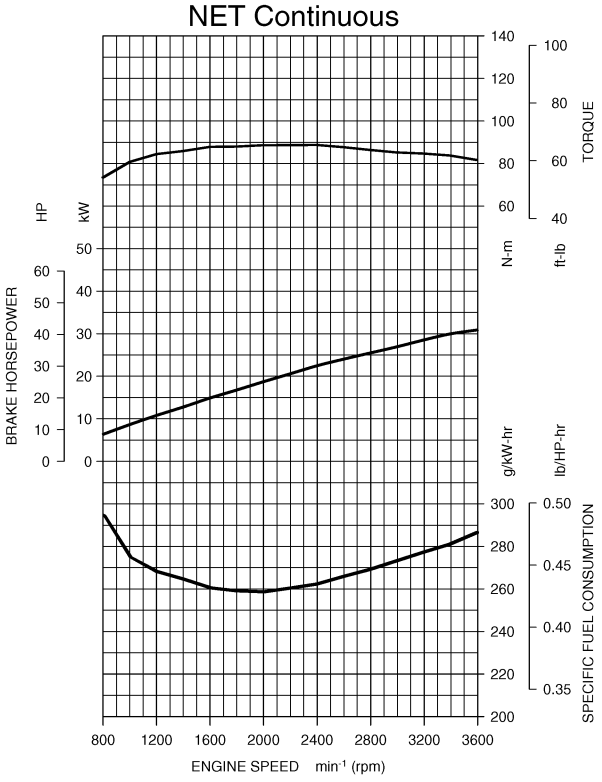
2. PERFORMANCE CURVES

WG1605-G / -GL-E3

Gasoline Use



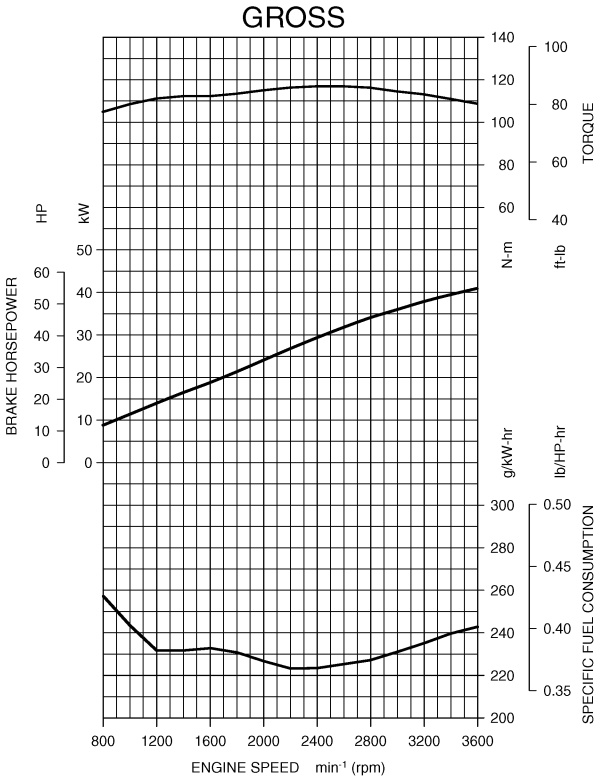


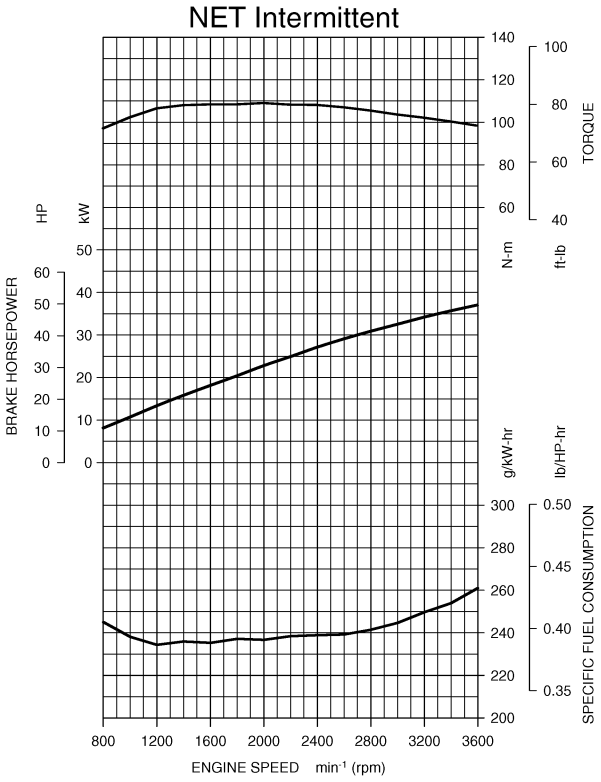


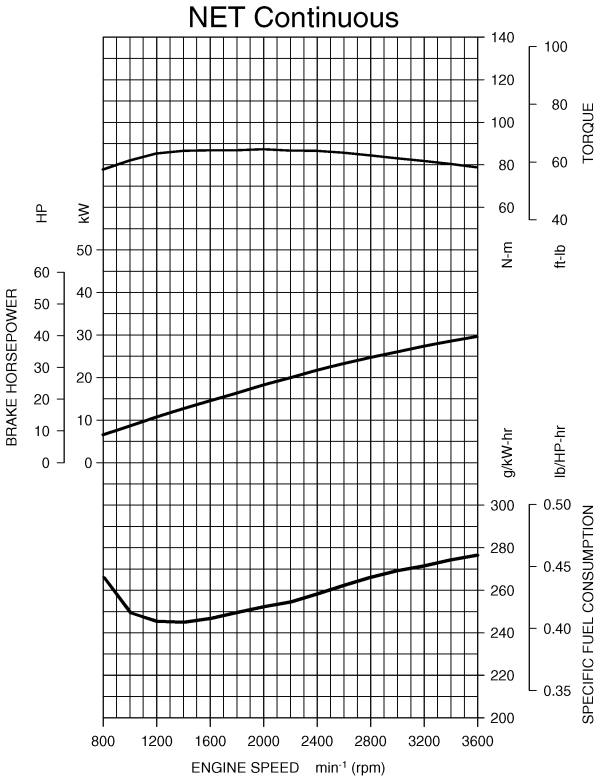
GEN001A

WG1605-L / -GL-E3

LP Gas Use



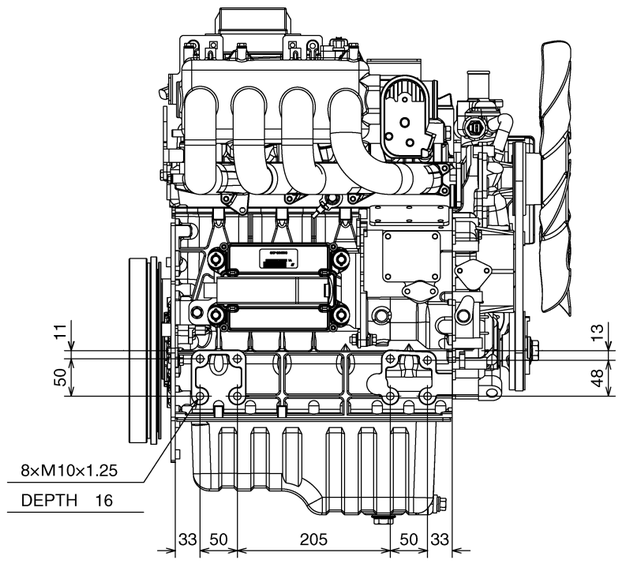


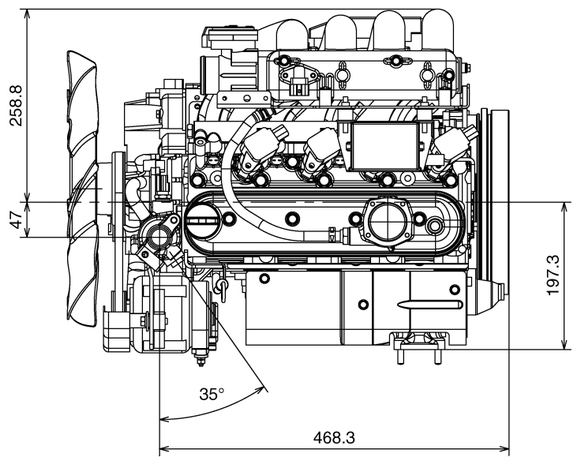


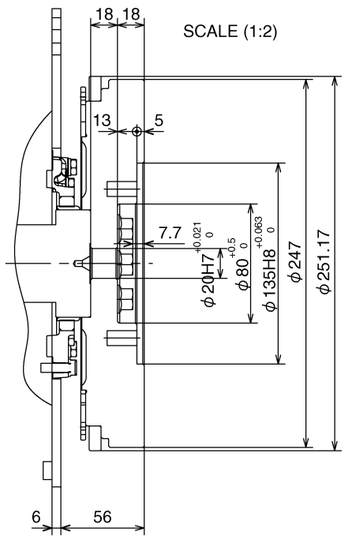
GEN002A

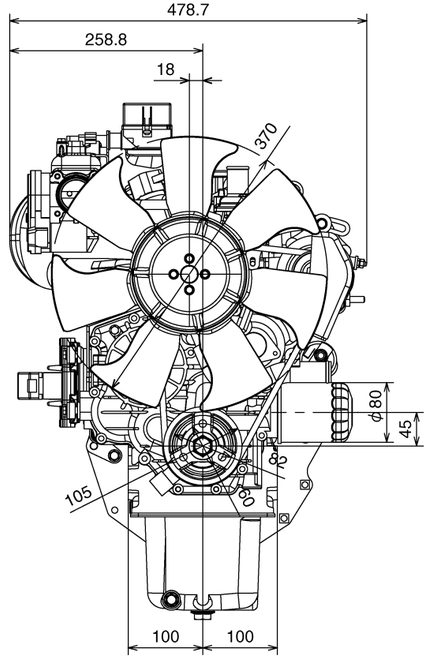
3. DIMENSIONS

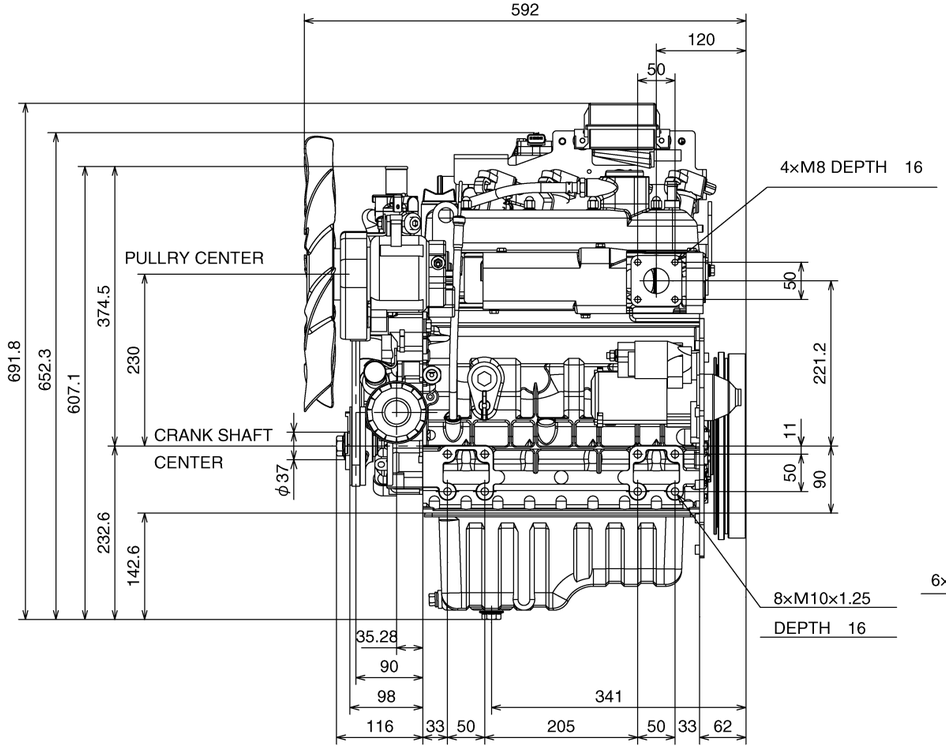
WG1605-G-E3

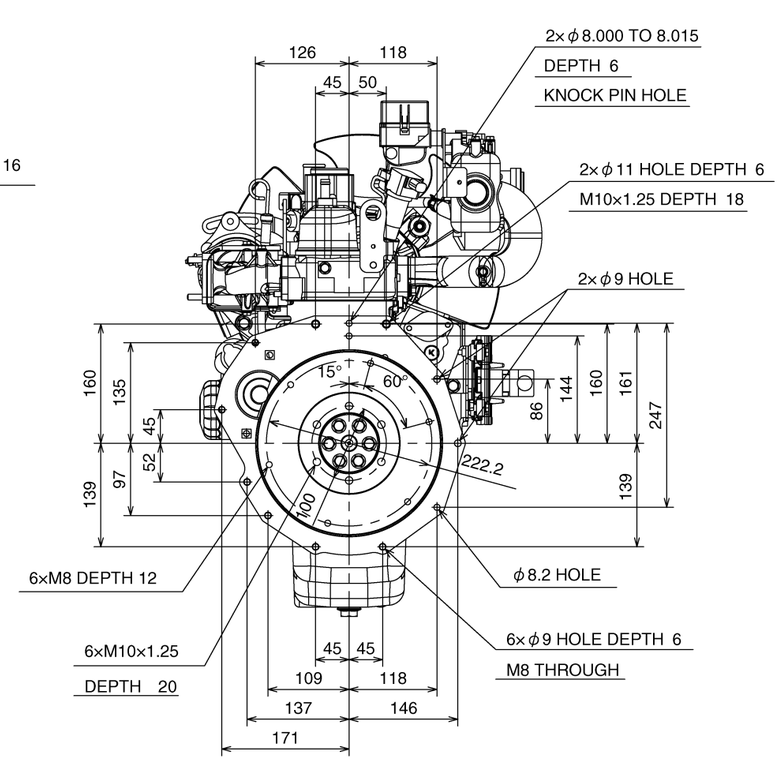






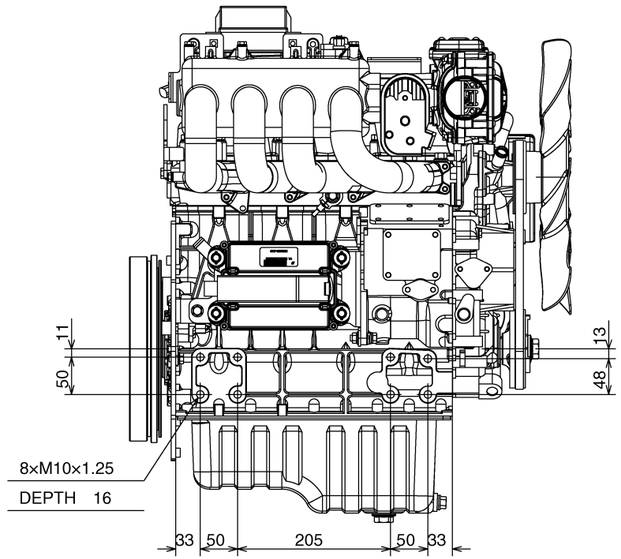


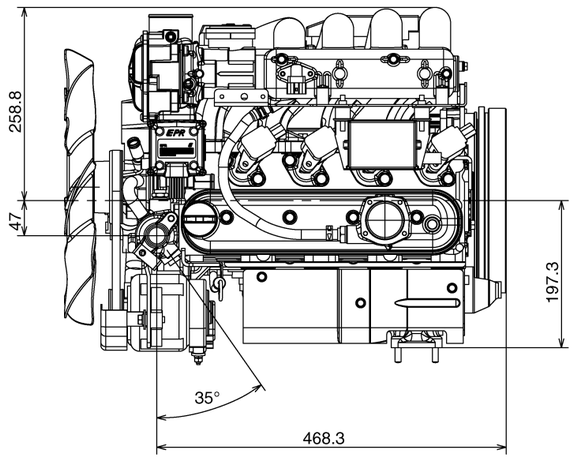


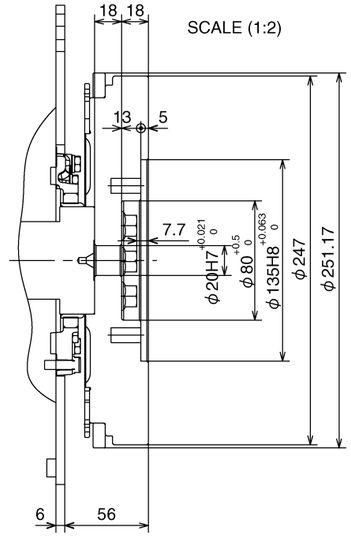


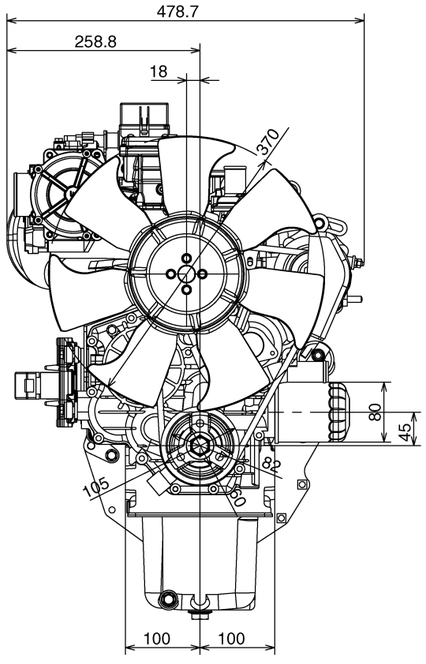
GEN003A

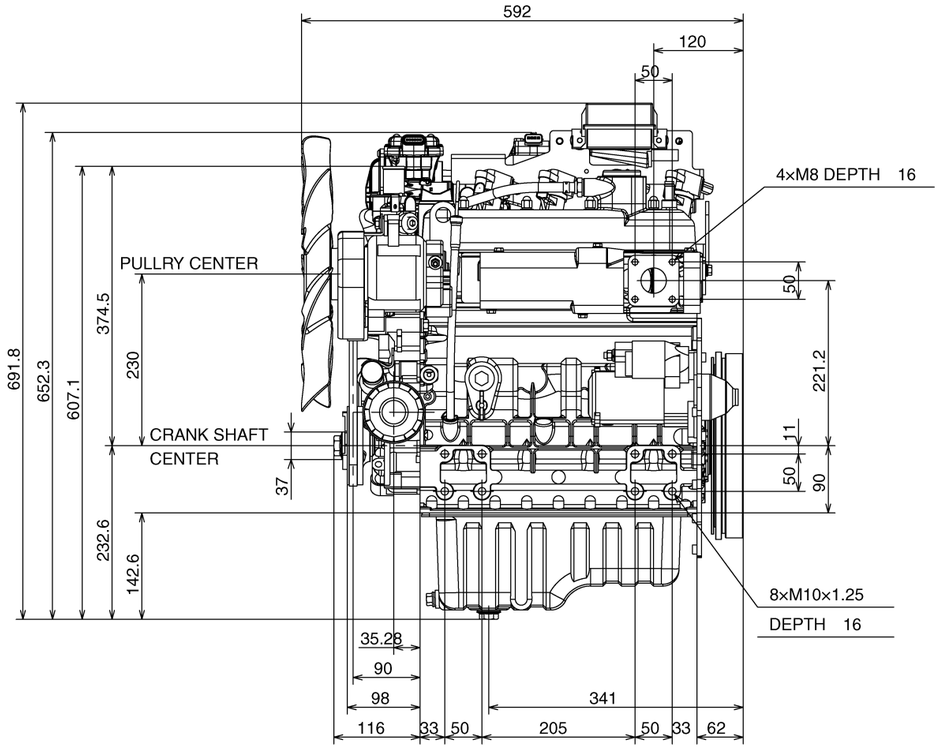
WG1605-L-E3

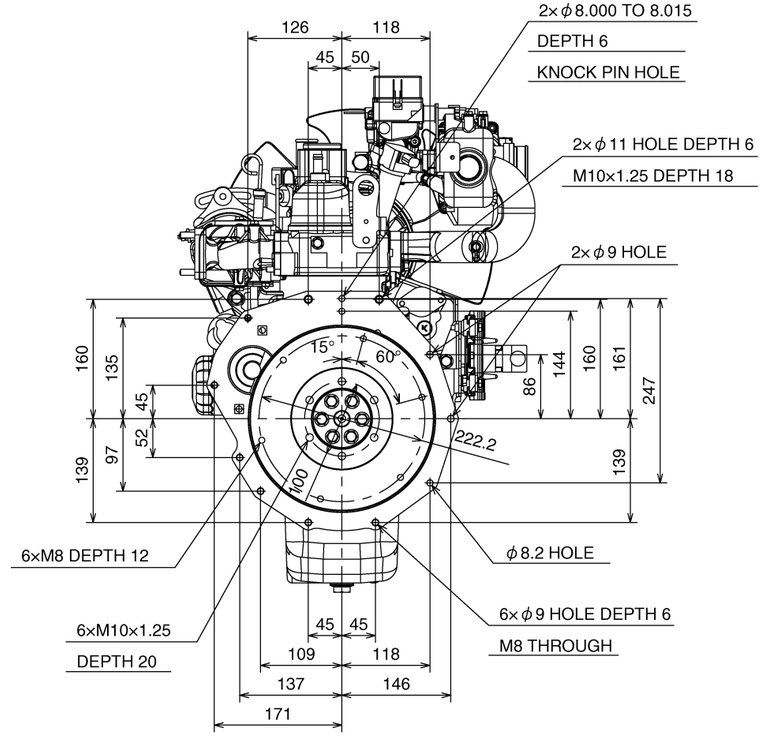




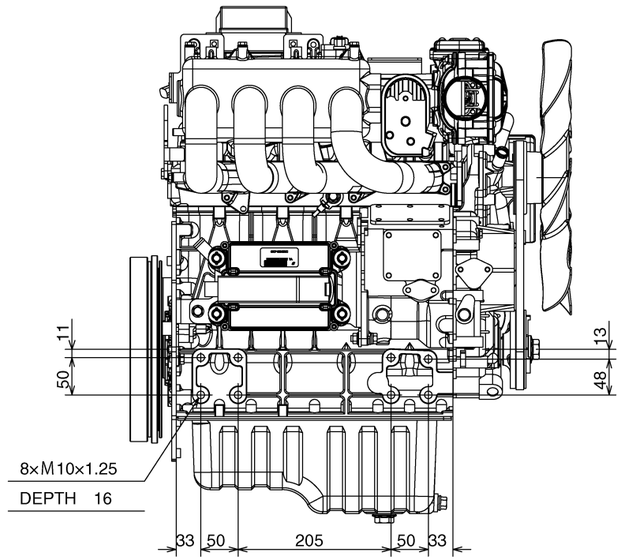


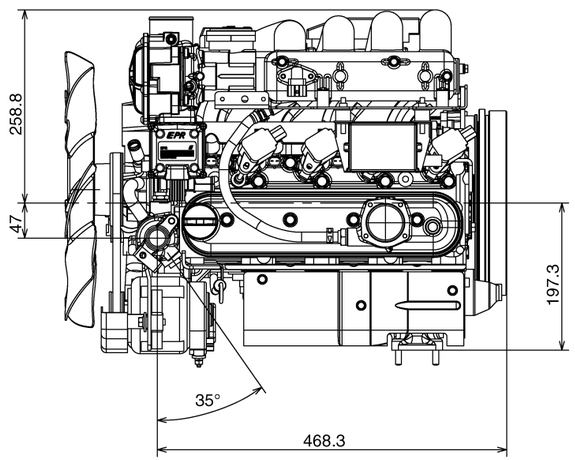


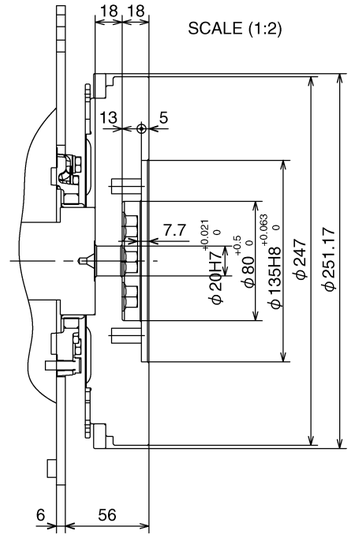


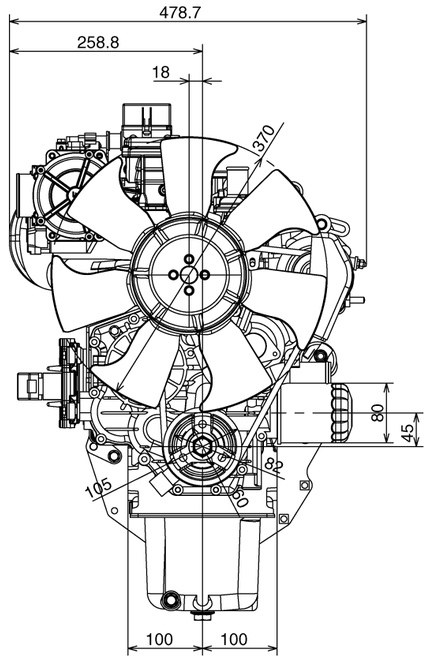


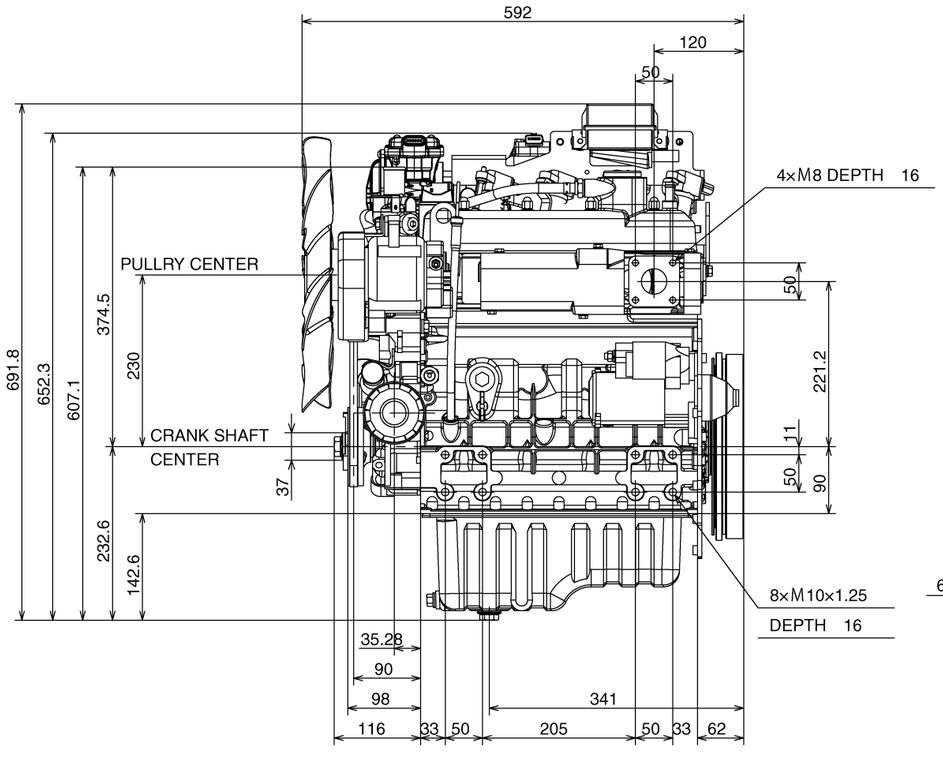
GEN004A

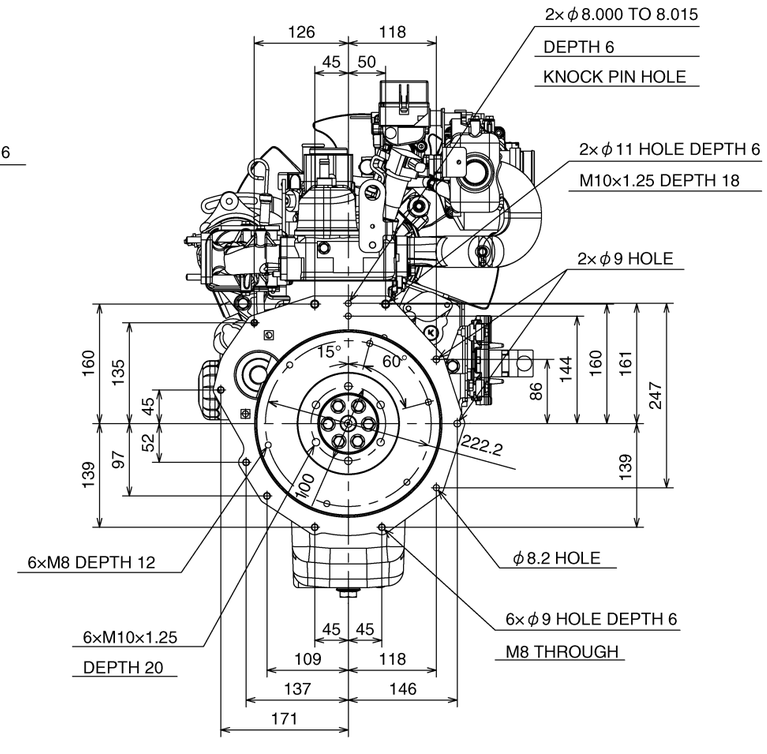

11
50
13
48
8×M10×1.25
DEPTH 16
33 50 205 50 33


258.8
47
197.3
35°
468.3


18 18
SCALE (1:2)
13
5
7.7
φ20H7 +0.021 0
φ80 +0.5 0
φ135H8 +0.063 0
φ247
φ251.17
6
56


478.7
258.8
18
370
80
45
105
100 100


592
120
50
4×M8 DEPTH 16
PULLRY CENTER
691.8
652.3
607.1
374.5
230
CRANK SHAFT
CENTER
37
232.6
142.6
50
221.2
11
50
90
8×M10×1.25
DEPTH 16
35.28
90
98
341
116 33 50 205 50 33 62

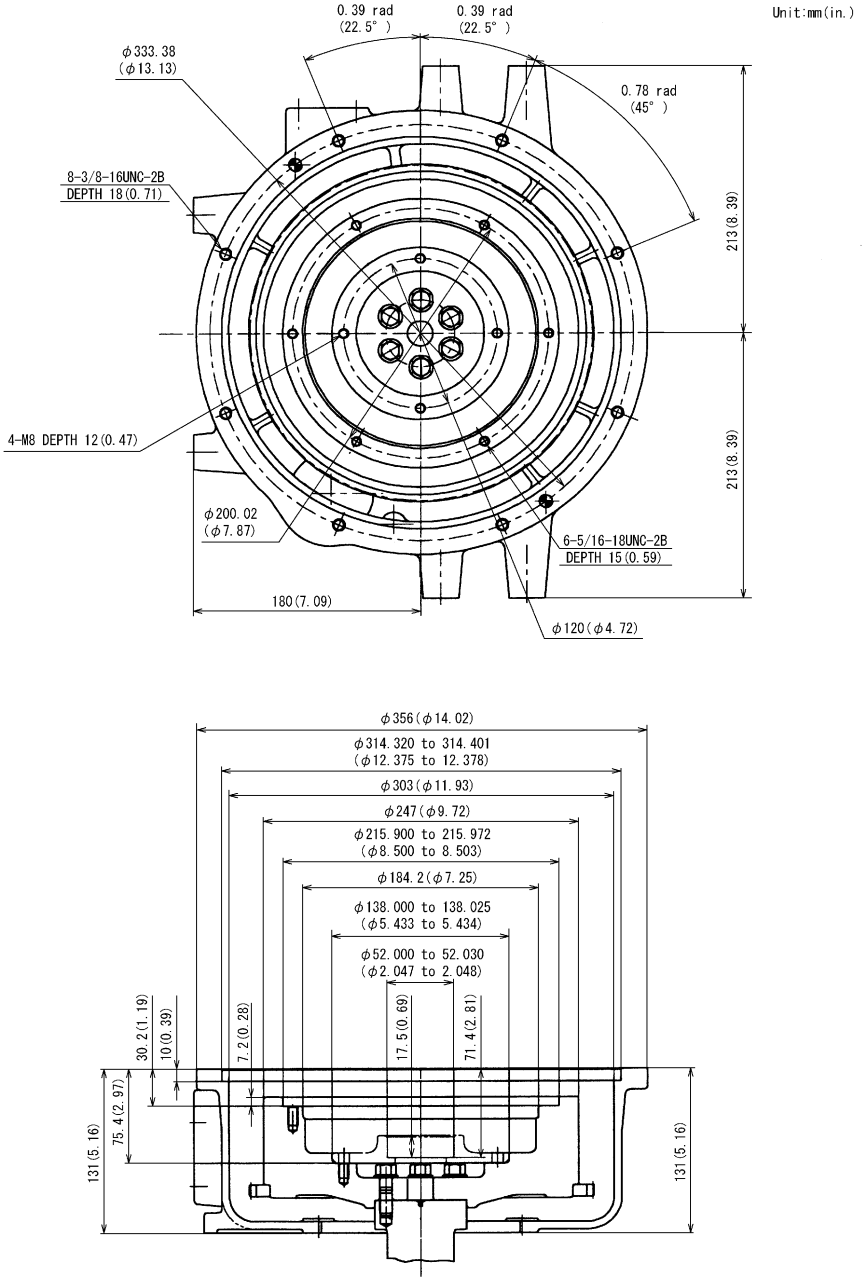

2×φ8.000 TO 8.015
DEPTH 6
KNOCK PIN HOLE
126 118
45 50
2×φ11 HOLE DEPTH 6
M10×1.25 DEPTH 18
2×φ9 HOLE
15°
60°
160
135
45
52
139
97
100
222.2
86
144
160
161
247
139
6×M8 DEPTH 12
φ8.2 HOLE
6×M10×1.25
DEPTH 20
6×φ9 HOLE DEPTH 6
M8 THROUGH
45 45
109 118
137 146
171

GEN005A

WG1605-E3

Flywheel : Normal SAE for Clutch No.6-1/2

Flywheel Housing : Normal SAE No.5



WG1605_153A

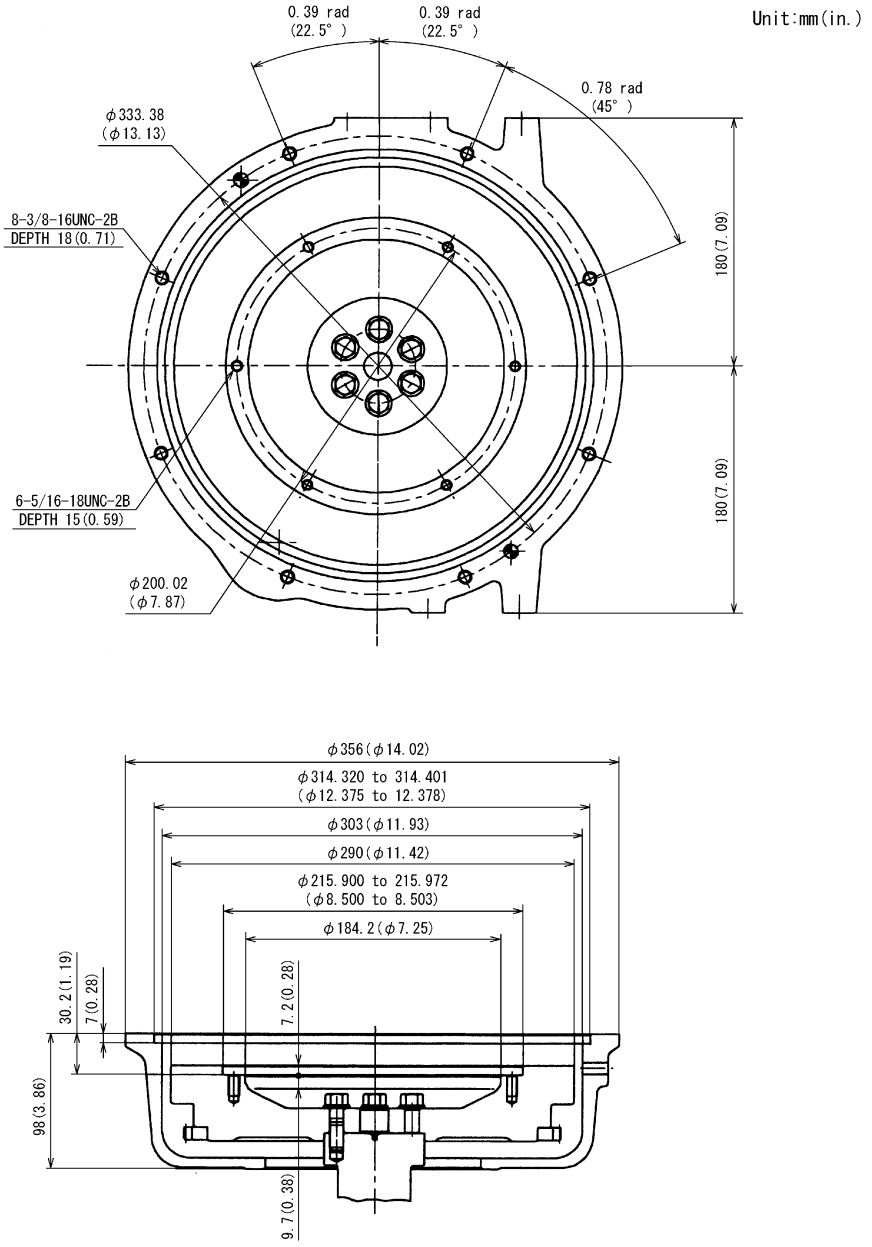
(Below 3000 rpm)

* Please refer to Kubota S.O.S Manual for further information.

WG1605-E3

Flywheel : Short SAE for Clutch No.6-1/2

Flywheel Housing : Short SAE No.5



WG1605_029A

(Below 3000 rpm)

* Please refer to Kubota S.O.S Manual for further information.

EMISSION REGULATION

CONTENTS

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   [2] EMISSION-RELATED INSTALLATION INSTRUCTIONS 1-2
      (1) Exhaust System 1-2
      (2) Intake System 1-2
      (3) Crankcase Ventilation Connections 1-2
      (4) Gasoline Fuel System 1-2
      (5) Gaseous Fuel System 1-2
      (6) Engine Control Unit (ECU) 1-2
      (7) Vehicle Interface Connectors 1-2
      (8) Malfunction Indicator Light (MIL) 1-2
      (9) Tracing Information 1-2
      (10) Certification Labels 1-3
      (11) End of Line (EOL) Test Data 1-3

1. GENERAL

WG1605 is available and unavailable in those countries.

kW, disp.	Model	North America	Europe	Japan
19 < P 1.0 < L	WG1605-G / L / GL	Available	Available	Non-available

Current and future emission regulations.

$HC+NO_X/CO$ (g/kWh)

Countries		kW, disp.	2009	2010	2011	2012	2013	2014	2015	2016
USA	CARB	19 < P < 560 1.0 < L	2.7/4.4 * **	0.8/20.6 *						
	EPA	19 < P < 560 1.0 ≤ L	2.7/4.4 * **							
Canada		19 < P	None							
Japan		19 ≤ P < 560	HC:0.6g/kWh, NOx:0.6g/kWh, CO:20g/kWh							
EU		19 < P	None							

■ **NOTE**

- *** with evaporative emission regulation**
- ****See figure below**

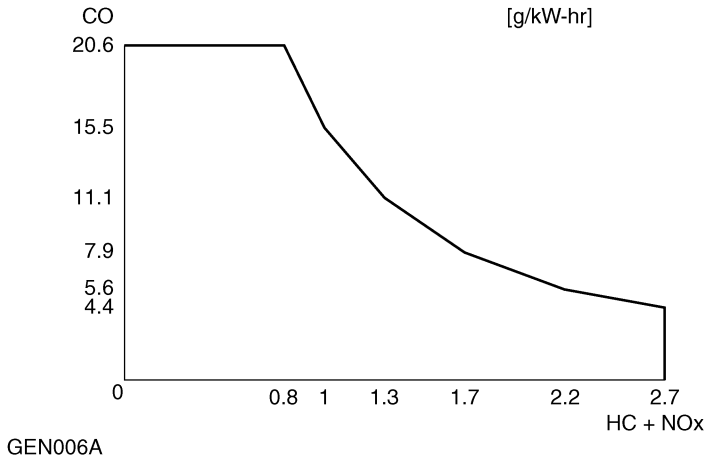


Figure 1-1

2. IMPORTANT ITEMS

[1] IMPORTANT NOTICE

These instructions are provided to the Final Engine Assemblers (FEA) who must ensure the engine, exhaust system (catalyst), fuel system etc, are installed correctly in the engine's certified configuration.

The emission related parts which FEA prepare (for example the exhaust pipe between the exhaust manifold and the catalyst) must be designed to function throughout the useful life without any failure.

Please confirm whether emission-related items are certain on application review

The contractual agreement contract is necessary before mass-production.

(for EPA only)

Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.

[2] EMISSION-RELATED INSTALLATION INSTRUCTIONS

(1) Exhaust System

Kubota supplies a certified catalyst. FEA must use a Kubota certified catalyst and assemble the exhaust system parts according to the instructions.

No other catalyst is certified for use with WG1605 Engine. No Other Catalyst can be used.

FEA may only install the exhaust system parts confirmed at application review.

(2) Intake System

To prevent decreases of engine output performance, intake resistance must be kept below a certain point.

(Refer to page 1-12 of Installation Instruction.)

(3) Crankcase Ventilation Connections

Crankcase emissions may not be discharged directly into the ambient atmosphere throughout its useful life. (40 CFR 1048.115(a))

(4) Gasoline Fuel System

If your equipment uses a volatile liquid fuel (such as gasoline), they must meet the evaporative emission standards of 40 CFR 1048.

(5) Gaseous Fuel System

FEA must use only the vaporizer and the lock-off valve Kubota offers and assemble the LPG fuel system parts according to the instructions.

(6) Engine Control Unit (ECU)

Installation must utilize all 4 of the vibration mounts.

ECU header pins must be horizontal or point downward.

(7) Vehicle Interface Connectors

Vehicle interface connectors shall be connected with your wire harness.

(8) Malfunction Indicator Light (MIL)

When the MIL goes on, it must display "Check Engine," "Service Engine Soon," or a similar message that EPA approve. (40 CFR 1048.110(b))

(9) Tracing Information

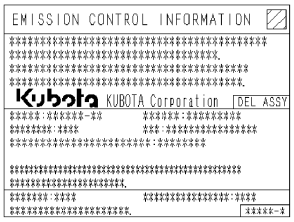
You (FEA) may demonstrate compliance with the requirements of 40 CFR 1068.261 by maintaining a database showing how you (FEA) pair aftertreatment components with the appropriate engines such that the final product is in its certified configuration. (40CFR 1068.261(b))

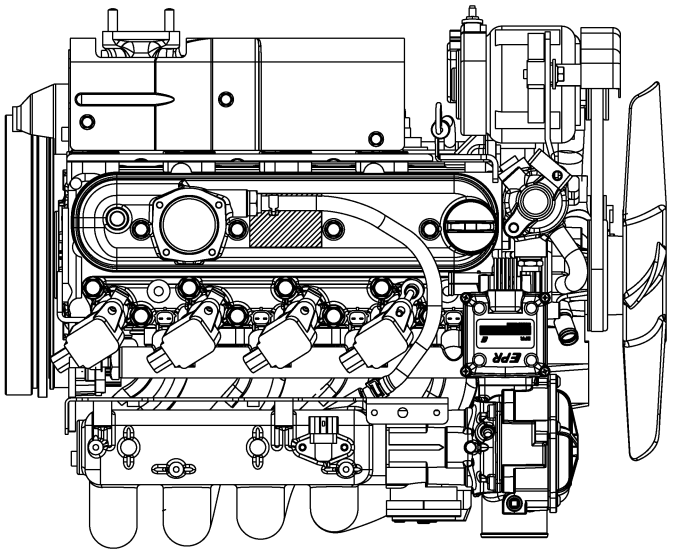
Tracing information of Engine, ECU and Catalyst must be reported.

(10) Certification Labels

Kubota installs the certification label on the cylinder head cover.

If you (FEA) install the engine in a way that makes the engine's emission control information label hard to read during normal engine maintenance, you (FEA) must place a duplicate label on the equipment, as described in 40 CFR 1068.105. (40 CFR 1054.130(b) (7))





LAB001A

Figure 1-2

(11) End of Line (EOL) Test Data

FEA must report a record of End Of Line (EOL) test data.

(Refer to page 1-32 of Installation Instruction.)

RATING

CONTENTS

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3. STANDARD OF JAPAN, USA AND EUROPE 2-2
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   [2] SCOPE, DECLARATIONS OF POWER AND STANDARD REFERENCE CONDITIONS 2-3
   [3] METHOD OF POWER CORRECTION 2-4

1. GENERAL

Engine output indications are standardized in accordance with engine application and type in each country and test methods specified accordingly.

Indications for KUBOTA engine ratings conform to the Japan Industrial Standards (JIS), SAE and ISO.

2. ENGINE TESTING METHODS

Normally, testing methods for engine performance vary according to use. These methods also vary by countries, although in most major respects they are the same.

Engine performance is determined by the following factors and the presence of accessories.

1. Fixed factors -
   Piston displacement, compression ratio, cam timing and other factors that cannot be changed during operation.
2. Variable factors -
   Revolution speed and other factors that can be changed during operation.
3. Environmental factors -
   Atmospheric pressure, temperature, humidity and others.
4. Accessories -
   Fan, muffler, air cleaner, speed change gears and other auxiliary equipment and accessories.

Therefore, engine performance can be determined only after taking into account the setting of variable factors, atmospheric conditions, and use of optional accessories.

It is a common practice to select the annual mean value of the atmospheric conditions of the country in which the engine is used to minimize the error which must be corrected.

Engine performance is usually tested with the minimum number of accessories required for operation only.

3. STANDARD OF JAPAN, USA AND EUROPE

[1] PERFORMANCE TESTING METHODS

Country	Code number	Title
JAPAN	JIS B8002-1	Reciprocating internal combustion engines - Performance - Part 1 :Standard reference conditions, declarations of power, fuel and lubricating oil consumptions, and test methods Part 3 : Test measurements Part 4 : Speed governing Part 5 : Torsional vibrations Part 6 : Overspeed protection Part 7 : Codes for engine power
U.S.A.	SAE J1349	ENGINE POWER TEST CODE - SPARK IGNITION AND COMPRESSION IGNITION - NET POWER RATING
	SAE J1995	ENGINE POWER TEST CODE - SPARK IGNITION AND COMPRESSION IGNITION - GROSS POWER RATING
EUROPE	ISO 3046-1	Reciprocating internal combustion engines - Performance - Part 1 :Standard reference conditions, declarations of power, fuel and lubricating oil consumptions, and test methods Part 3 : Test measurements Part 4 : Speed governing Part 5 : Torsional vibrations Part 6 : Overspeed protection Part 7 : Codes for engine power

[2] SCOPE, DECLARATIONS OF POWER AND STANDARD REFERENCE CONDITIONS

<table>
<tr><th></th><th>JIS B8002-1, ISO 3046-1</th><th>SAE J1995</th><th>SAE J1349</th></tr>
<tr><td rowspan="2">Scope</td><td>JIS B8002 :
All reciprocating internal combustion (R.I.C.) engines excluding engines used to aircraft.</td><td colspan="2" rowspan="2">1. 4 or 2 cycle engine.
2. Spark ignition or compression ignition engine.
3. N/A engine or engine with T/C or S/C and I/C.
4. Excluding engines used to aircraft or marine.</td></tr>
<tr><td>ISO 3046 :
R.I.C engines for land, rail - traction and marine use, excluding engines used to propel agricultural tractors, road vehicles and aircraft.</td></tr>
<tr><td rowspan="3">Declarations of power</td><td>1) Types of statement of power ISO power :
The power determined under the operating conditions of the manufacturer's test bed and adjusted or corrected as determined by the manufacturer to the standard reference conditions.
Service power :
The power delivered under the ambient and operating conditions of an engine application.</td><td rowspan="3">Gross</td><td rowspan="3">Net</td></tr>
<tr><td>2) Types of power application
a) Continuous power
b) Overload power
c) Fuel stop power</td></tr>
<tr><td>3) Types of power
• Indicated power
• Brake power with
a) essential dependent auxiliaries.
b) essential independent auxiliaries.
c) non - essential dependent auxiliaries.</td></tr>
<tr><td rowspan="4">Standard reference conditions</td><td>Total barometric pressure :
Pr=100 kPa</td><td colspan="2">Inlet Air Supply Pressure (absolute) :
Pr=100 kPa</td></tr>
<tr><td>Ambient air temperature :
Tr=25 ° C (77 ° F)</td><td colspan="2">Inlet Air Supply Temperature :
Tr=25 °C (77 °F)</td></tr>
<tr><td>Relative humidity :
ϕr=30%
Relative humidity of 30% at a temperature of 25 °C (77 °F) corresponds to a water?vapour pressure of 1 kPa.</td><td colspan="2">Dry Air Pressure (absolute)
Pb dry=99 kPa</td></tr>
<tr><td>Charge air coolant temperature :
Tcr=25 °C (77 °F)</td><td colspan="2">REFERENCE CI FUEL SPECIFICATIONS
Fuel Density at 15 °C (59 °F) =0.850 kg/L
Fuel Kinematic Viscosity at 40 °C (104 °F) =2.6 mm^2/s
Fuel Inlet Temperature=40 °C (104 °F)</td></tr>
</table>

[3] METHOD OF POWER CORRECTION

<table>
<tr><th></th><th>JIS B8002-1, ISO 3046-1</th><th>SAE J1995</th><th>SAE J1349</th></tr>
<tr><td>Formula of power correction</td><td>Standard power = α x Text power ≈ α x Text power</td><td colspan="2">Standard power = (CA x CF) x Test power
CA ; Air correction factor
CF ; Fuel correction factor</td></tr>
<tr><td>Correction factor</td><td>$\alpha = (fa)^{fm}$</td><td colspan="2">$CA = (fa)^{fm}$
CF = fd x fv</td></tr>
<tr><td>Declarations of power</td><td>0.9 < α <1.1
10 °C (50 °F) ≤ Intake air temperature ≤ 40 °C (104 °F)
80 kPa ≤ Dry air pressure ≤ 110 kPa</td><td colspan="2">15 °C (59 °F) ≤ Intake air temperature ≤ 40 °C (104 °F)
90 kPa ≤ Dry air pressure ≤ 105 kPa</td></tr>
<tr><td rowspan="5">Coefficient</td><td>Atmospheric factor : fa
[For naturally aspirated engines mechanically pressure - charged engines and turbocharged engines with waste - gates operating]
$fa = \left(\frac{99}{Pbdry}\right) \times \left(\frac{Tai + 273}{298}\right)^{0.7}$
[For turbocharged engines without charge air cooling or with charge cooling by air/air cooler]
$fa = \left(\frac{99}{Pbdry}\right)^{0.7} \times \left(\frac{Tai + 273}{298}\right)^{1.2}$
[For turbocharged engines with charge air cooling by engine coolant]
$fa = \left(\frac{99}{Pbdry}\right)^{0.7} \times \left(\frac{Tai + 273}{298}\right)^{0.7}$</td><td colspan="2">1. Calculation of CA
Atmospheric factor : fa
[For naturally aspirated engines mechanically pressure - charged engines.]
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[For turbocharged engines without charge air cooling or with charge cooling by air/air cooler]
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<tr><td>Engine factor : fm
$fm = 0.036 \times \frac{q}{R} - 1.14 \quad (37.2 < q/R < 65)$
$fm = 0.2 \quad (q/R \leqq 37.2)$
$fm = 1.2 \quad (65 \leqq q/R)$</td><td colspan="2">Engine factor : fm
$fm = 0.036 \times \frac{q}{R} - 1.14 \quad (37.2 < q/R < 65)$
$fm = 0.2 \quad (q/R \leqq 37.2)$
$fm = 1.2 \quad (65 \leqq q/R)$</td></tr>
<tr><td>Boost pressure ratio
$R = \frac{PB + Pbc}{PB} \quad (NA ; R=1)$</td><td colspan="2">Boost pressure ratio
$R = \frac{PB + Pbc}{PB} \quad (NA ; R=1)$</td></tr>
<tr><td>Fuel mass per cycle per litre of engine swept volume
$q = \frac{10^2 \times Be}{3 \times Ne \times Ve}$ mg/cyl.l</td><td colspan="2">Fuel mass per cycle per litre of engine swept volume
$q = \frac{10^2 \times Be}{3 \times Ne \times Ve}$ mg/cyl.l</td></tr>
<tr><td></td><td colspan="2">2. Calculation of CA
$fd = 1 + 0.70 \times \frac{0.850 - Sgo}{Sgo}$
$fv = \frac{1 + S/Vo}{1 + S/2.6} = \frac{1 + 0.15/Vo}{1 + 0.15/2.6}$
Sgo : Fuel density at testing (kg/L)
Vo : Fuel viscosity at testing (mm^2/s)</td></tr>
</table>

	JIS B8002-1, ISO 3046-1	SAE J1995	SAE J1349
Engine equipments	ISO standard power With essential dependent auxiliaries	Gross	Net
Intake air system	❍	Option Minimum level restriction	❍
Intake pipe	❍		❍
Air cleaner	❍		❍
Air heater		x	x
Fuel supply system	❍	❍	❍
Fuel filter	❍	Option	Option
Fuel feed pump	❍	❍	❍
	❍	❍:In-use settings	❍:In-use settings
Cooling system	❍	❍	❍
Cooling water pump	❍	❍	❍
Cooling fan	❍	x	❍
Thermostat		Option	Option
Lubricating system	❍	❍	❍
Lubricating pump	❍	❍	❍
Exhaust system	❍	Option Minimum level restriction	❍
Muffler	❍		
			❍
Emission control system	❍	Option	❍
Oil pump	x	x	x
Ventilation fan	x	x	x

ENGINE PERFORMANCE

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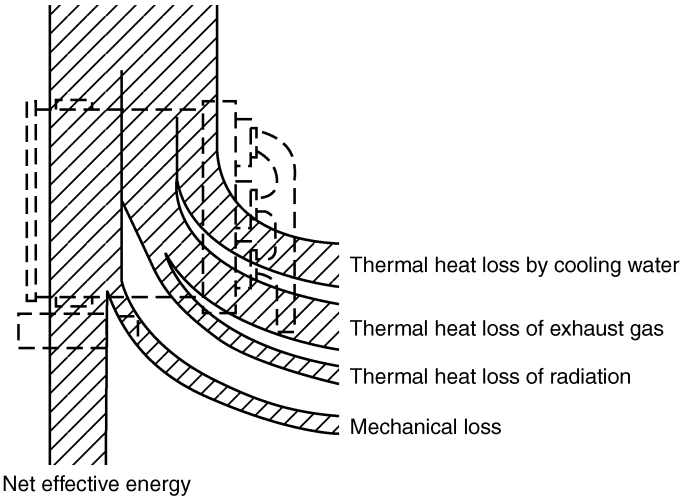
1. OUTPUT

[1] GENERAL

Drawing a balance-sheet, expressing the various forms of energy produced by the engine (e.g., output power, heat to cooling water, and heat unaccounted for) as percentages of the heat supplied from the calorific value of the fuel. As described earlier, about 30 % of heat supplied to the engine is converted into power. A breakdown how heat is used is shown below.

	Gasoline engine	Diesel engine
Heat quantity available as effective work	25 to 28 %	30 to 34 %
Heat loss from cooling system	32 to 34 %	30 to 31 %
Heat loss from exhaust system	33 to 37 %	30 to 33 %
Heat loss from mechnical friction	5 to 6 %	5 to 7 %

This balance-sheet of the calorific values is called “heat balance”. This is shown below, “Thermal equilibrium diagram”.



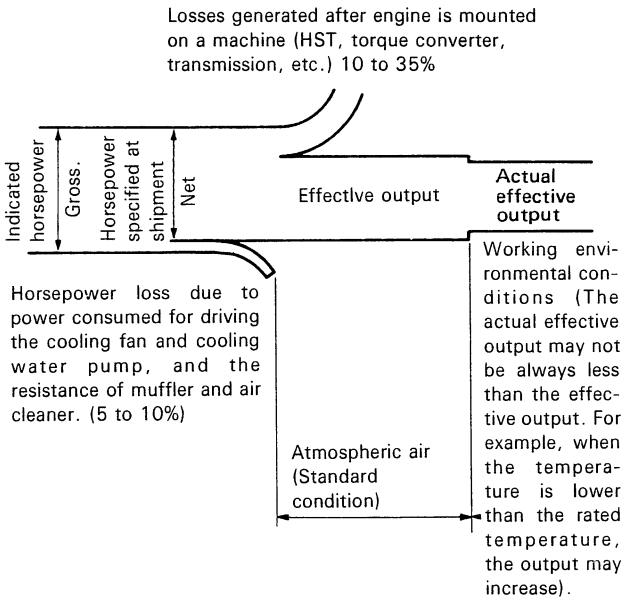
WG1605_028A

Figure 3-1

[2] ACTUAL EFFECTIVE OUTPUT

The final output (actual effective output) of engine varies with various external factors such as horsepower loss due to the power consumed for driving the cooling fan and water pump, resistance of muffler and air cleaner, environmental conditions such as temperature, humidity, and altitude, type of applied fuel, and horsepower loss and transmission efficiency of equipment driven by the engine.

Thus the final output mainly depends upon the horsepower loss. Also the output varies with the time factors such as “aging and wear” and “maintenance”, which depend upon the operating time.



WG1605_030A

Figure 3-2

Fuel supply adjustment and governor setting are adjusted by KUBOTA according to each destination country in conformity with “JIS”, “SAE” and “ISO” standards before shipment.

They may be adjusted to the output characteristic discussed with the Technical Department in case of special OEM requirements.

Engine performance is normally indicated by the output, torque and fuel consumption curves, which are closely related to each other.

[3] OUTPUT CHARACTERISTICS

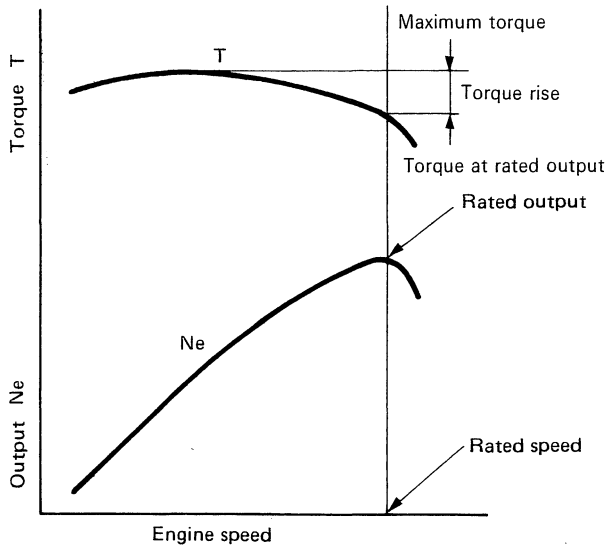
When mounting an engine on a machine, it is risky to select an engine by its standard output alone (as shown in cataloge and other literatures) and comparing it with the required power of the machine. The following factors must be carefully considered when making a selection.

(1) For Large Load Variations

Engines with large torque backup are suitable for frequent use with varying loads which require a broad torque range.

The amount of torque backup is indicated by torque rise (%).

Torque rise = (Max. torque / Torque at rated output) × 100 - 100 (%)



WG1605_031A

Figure 3-3

(2) For Constant Speed Applications

When an engine is to be used with a generator, for example, for which stable revolution characteristics are required, governor setting and inertia effect are needed to maintain the coefficient of revolution fluctuation at a minimum level. Unless these actions are taken, the generator voltage or frequency will vary largely with variation of engine revolution speed, preventing proper operation.

(3) For Reduced Engine Speed Applications

When an engine is to be operated slower than the rated speed in order to reduce the noise level below that of the rating, or due to the transmission unit to which the engine is connected, an optimum adjustment (including fan, pump and other equipment performance check) at that engine speed and output check is necessary.

Conditions for selection further vary with priority factors of the machine to which the engine is mounted. (e.g. emphasis on reduced fuel consumption, or larger output margin due to extremely long periods of operation.) There are many cases in which these factors are combined. It is suggested that careful review be given when determining the correct selection of an engine.

(4) Precautions For Specifying Engine Output

When specifying the engine output characteristics it is necessary to consider the output decrease due to changes of ambient conditions, especially the temperature rise (rise of engine intake-air temperature as well as atmospheric temperature), power consumed by accessories and horsepower loss in the power transmission unit.

[4] FUEL CONSUMPTION

Whether the fuel consumption is efficient or not depends upon the specifications inherent to each engine such as ignition timing, fuel injection timing, valve timing, fuel system, etc., and revolution speed.

The matching of engine and machine directly influences efficiency of fuel consumption.

Therefore sufficient consideration is required to select an engine to be mounted on each machine.

[5] NOISE

Often they are subject to government regulation. One of the major development objectives for KUBOTA engines is a substantial reduction of noise and vibration.

(1) Highly Rigid Crankcase

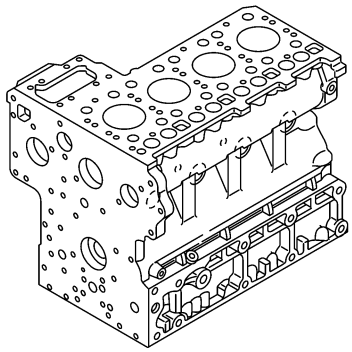
The cylinder block is the main housing of engine and supports the other main parts.

The cylinder block is usually of integrated cast iron construction, and includes complete passages for coolant and lubricating oil.

Three kinds (the tunnel type, the hanger type and ladder frame type) are adopted in Kubota engines.

WG1605 series

The crankcase has tunnel-type integral structure. It is highly rigid.



WG1605_032A

Figure 3-4

[6] VIBRATION

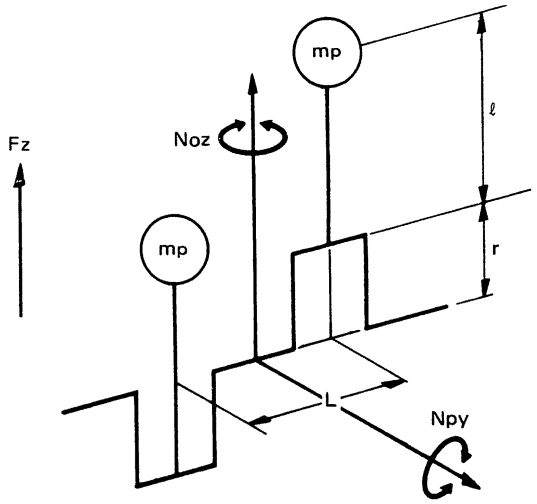
In order to reduce the vibration level as much as possible, special consideration has been taken in designing the crankshafts according to the number of cylinders and rotating parts such as the fan drive pulley, flywheel to minimize unbalanced inertia force and inertia couple of the reciprocating and rotating parts.

The crankshaft is made of a strong special steel alloy to reduce weight of the pin and arm sections. Alternating balance weights are used for each cylinder.

Other main parts are also made of special steel to reduce their weight and provide sufficient strength. The weight of the piston itself is reduced.

Thus, both the reciprocating mass and the rotating mass are reduced. The result is smaller inertia forces and smaller unbalanced inertia couple.

The table in TECHNICAL INFORMATION shows unbalanced forces of standard KUBOTA engines.



Fz : Unbalanced inertia force
Npy,Noz : Unbalanced inertia couple
mp : Reciprocating mass
r : Crankshaft radius
l : Center distance of rod metal
L : Cylinder distance
ω : Angular velocity
$\omega = 2\pi N / 60$
N : Engine speed r/min

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Figure 3-5

Fz : Unbalanced inertia force

No. of cylinders	Order	Fz
2	1	0
	2	$2mp \cdot r \cdot (r/l) \cdot \omega^2$
3	1	0
	2	0
4	1	0
	2	$4mp \cdot r \cdot (r/l) \cdot \omega^2$

Npy : Unbalanced inertia couple

No. of cylinders	Order	Fz
2	1	$(mp/2) \cdot r \cdot L \cdot \omega^2$
	2	0
3	1	$(3mp/2) \cdot r \cdot L \cdot \omega^2$
	2	$3mp \cdot r \cdot (r/l) \cdot \omega^2$
4	1	0
	2	0

Noz : Unbalanced inertia couple

No. of cylinders	Order	Fz
2	1	$(mp/3) \cdot r \cdot L \cdot \omega^2$
	2	0
3	1	$(3mp/2) \cdot r \cdot L \cdot \omega^2$
	2	0
4	1	0
	2	0

2. OPERATING ENVIRONMENT

[1] GENERAL

For the standard engine output performance, the values measured under the standard conditions specified by the world principle standards such as JIS, SAE and ISO are used as the standard. However since engines are used all over the world, their output performance varies with the operating conditions and ambient conditions (altitude, humidity and temperature). If the ambient temperature varies largely, the environment is dusty, or the engine is operated at an unusual installation altitude, the engine performance is directly or indirectly influenced.

It is necessary to consider the balance between the output compensation in accordance with the ambient conditions, and actions to adapt the engine to the operating conditions.

[2] COLD ENVIRONMENTS

In cold environments starting is a major problem. Once the engine is started, the air density becomes larger and the intake efficiency also becomes higher. More output can be expected in cold areas. When the temperature is very low, extra care must be taken regarding fuel and oil changes in their viscosity, freezing of water contained in the piping, or of water adhering on the filter.

At an extremely cold temperature, the viscosity of hydraulic fluid and lubrication oil may increase and the torque of starter may exceed its permissible value, hindering proper starting.

Item		**Cold intensity**
		0 °C to -20 °C (32 °F to -4 °F)
Starter		Standard
Battery		Size up from std.
Lubricating oil	SAE	SAE10W or SAE10W-30
	API	Better than SL class
Cooling		Antifreeze

1) Above table may be changed by application due to the drag torque of various machines.
2) Material of all pipes, resins and rubbers must be cold resistant material in extreme cold condition.

[3] HIGH TEMPERATURES

High compartment temperatures can be caused by high ambient temperatures, small engine room, soundproof cases and other reasons.

Among these the most important factor is the temperature of the intake and cooling air.

Even if the engine is contained in a soundproof case, its output is not affected as long as sufficient cold air is taken in from the outdoor atmosphere. In order to prevent overheating, it is necessary to measure and check the temperature of intake air and exhaust gas. At an extremely hot temperature it is necessary to control the viscosity of lubrication oil, to maintain the cooling performance (prevent overheat) and to care about the temperature rise of electric equipment.

* Output reduction
  Output decreases as ambient temperature increases.
* Radiation of cooling water
  Care must be taken regarding the amount of radiation reduction, when an all seasons antifreeze is used for continuous operation at high temperature, or when a high density antifreeze is used.

Requirements for operation at high temperature

Item		Temperature
Lubrication		**Above 25 °C (77 °F)**
		SAE30 or SAE10W-30, SAE15W-40
		Lower than 120 °C (248 °F)
Cooling	Reserve tank	Necessary to use
	Radiator, fan	When necessary, use larger radiator and fan.
Accessories	Permissible temperature	Starter, Alternator : 80 °C (176 °F) or lower

[4] DUST

When the engine is to be used in extremely dusty areas or used continuously in a dusty environment, special care must be taken with air cleaner and radiator. The intake air must be cleaned with the air cleaner. Lowering of the radiator cooling capacity due to clogging dust must be prevented.

Dust density

A degree of dustiness is hard to express in numbers. Comparative indication of amount of dust contained per $1m^3$ of air is one way to express dustiness.

Below are some examples :

1. Pavement : 0.0002 to 0.0004 g/m^3
2. Unpaved road : 0.005 to 0.01 g/m^3
3. Dusty road (after passing of a car on unpaved road 2) above) : 0.3 to 0.4 g/m^3
4. Construction site : 0.5 to 1.0 g/m^3
5. Extremely dusty operation : Over 1.0 g/m^3

Air cleaner

Air cleaner type and capacity must be chosen according to the dust level in the operating environment and conditions for maintenance.

If an improper selection is made, especially when the capacity is less than needed, intake air resistance becomes higher, resulting in reduced output.

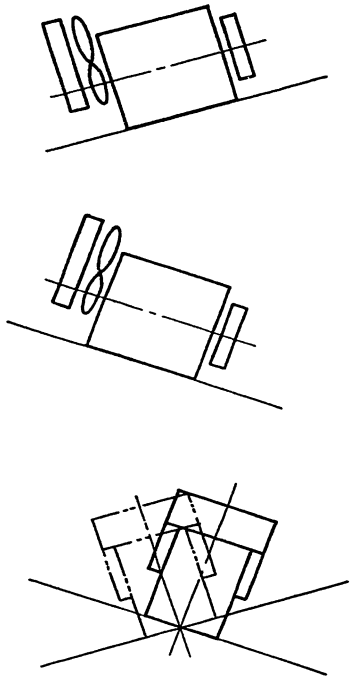
In order to maintain air tighten seals at the joining sections of intake system component parts and thus to prevent foreign matter from entering, it is necessary to ensure the security of the air intake system to prevent the component parts from being damaged.

[5] INCLINATION AND CENTER OF GRAVITY

Engine may be used inclined when it is used in a machine for working on slopes, during oscillation and when the engine is mounted at an angle. The tilted posture may be either momentary or continuous. Mounting the engine at an angle, even a small angle, should be avoided. When using an engine in a tilted posture continuously, the following points must be remembered.

1. If the engine is tilted to the front there is a possibility of an air pocket being created at the back of the cylinder head.
2. The effective volume of the oil pan becomes less, so air suction must be prevented.

Allowable angles for tilted operation are given below for engines with standard specifications.



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	Less than 10 minutes continuous operation	Continuous operation
Front down	0.52 rad (30 °)	0.35 rad (20 °)
Rear down	0.52 rad (30 °)	0.35 rad (20 °)
Left or right side down	0.52 rad (30 °)	0.35 rad (20 °)

Figure 3-6

■ **NOTE**

- **The engine for generator should be mounted level.**

Center of gravity

With reference to tilted engines during operation, it is necessary to know the center of gravity position when checking for machine stability.

[6] DERATION OF ENGINE OUTPUT

Engine output is affected by atmospheric pressure, temperature and humidity.

An engine should be selected with sufficient power to meet the load demands under all operating conditions.

KUBOTA WG1605 series engine performance curves are corrected to standard conditions explained in standards such as JIS, SAE an ISO.

Provided output should be corrected for various atmospheric conditions by above standards.

Deration coefficient table is shown in next page.

Deration of engine output is very important when selecting the proper engine model when using at high ambient temperature and in high altitude location.

3. ATMOSPHERE AND ENGINE OUTPUT

The table below shows output changes ageist changes of atmospheric pressure at a temperature of 25 °C. Watch the engine output when using in an elevated place.

Altitude	Atmospheric pressure		Output
m	mmHg	kPa	%
0	760	101.3	100.00
100	751	100.1	98.82
200	741	98.8	97.50
300	732	97.6	96.32
400	723	96.4	95.13
500	714	95.2	93.95
600	705	94.0	92.76
700	696	92.8	91.58
800	688	91.7	90.53
900	679	90.5	89.34
1000	671	89.4	88.29
1100	662	88.3	87.11
1200	654	87.2	86.05
1300	646	86.1	85.00
1400	638	85.0	83.95
1500	630	84.0	82.89
1600	622	82.9	81.84
1700	614	81.9	80.79
1800	607	80.9	79.87
1900	599	79.9	78.82
2000	592	78.9	77.89
2100	584	77.9	76.84
2200	577	77.0	75.92
2300	570	76.0	75.00
2400	563	75.1	74.08
2500	556	74.1	73.16
2600	549	73.2	72.24
2700	542	72.3	71.32
2800	535	71.4	70.39
2900	529	70.5	69.61
3000	522	69.6	68.68
3100	516	68.8	67.89
3200	509	67.9	66.97
3300	503	67.1	66.18
3400	497	66.2	65.39
3500	491	65.4	64.61
3600	484	64.6	63.68
3700	481	64.1	63.34
3800	475	63.3	62.55
3900	469	62.4	61.66
4000	463	61.6	60.87

4. COLD STARTING AND OPERATION

[1] GENERAL

As explained in the preceding section regarding engines used in cold weather, a standard KUBOTA engine without external load can be started in temperatures as low as -20 °C (4 °F).

When the engine is mounted on a machine, cold starting performance is subject to various conditions, so very careful checks are necessary.

Points regarding, lubricating oil, cooling water, starter and battery are covered below.

[2] LUBRICANT

Oil viscosity changes in cold temperature as crystallization of the wax element contained in oil proceeds, and fluidity is finally lost. Wrong selection of oil cannot only increase resistance for cold starting but also affect lubrication of each part. Oils for low temperature, containing additives for lowering the pour point, should be used.

■ **NOTE**

- **The use of synthetic oil is not recommended.**

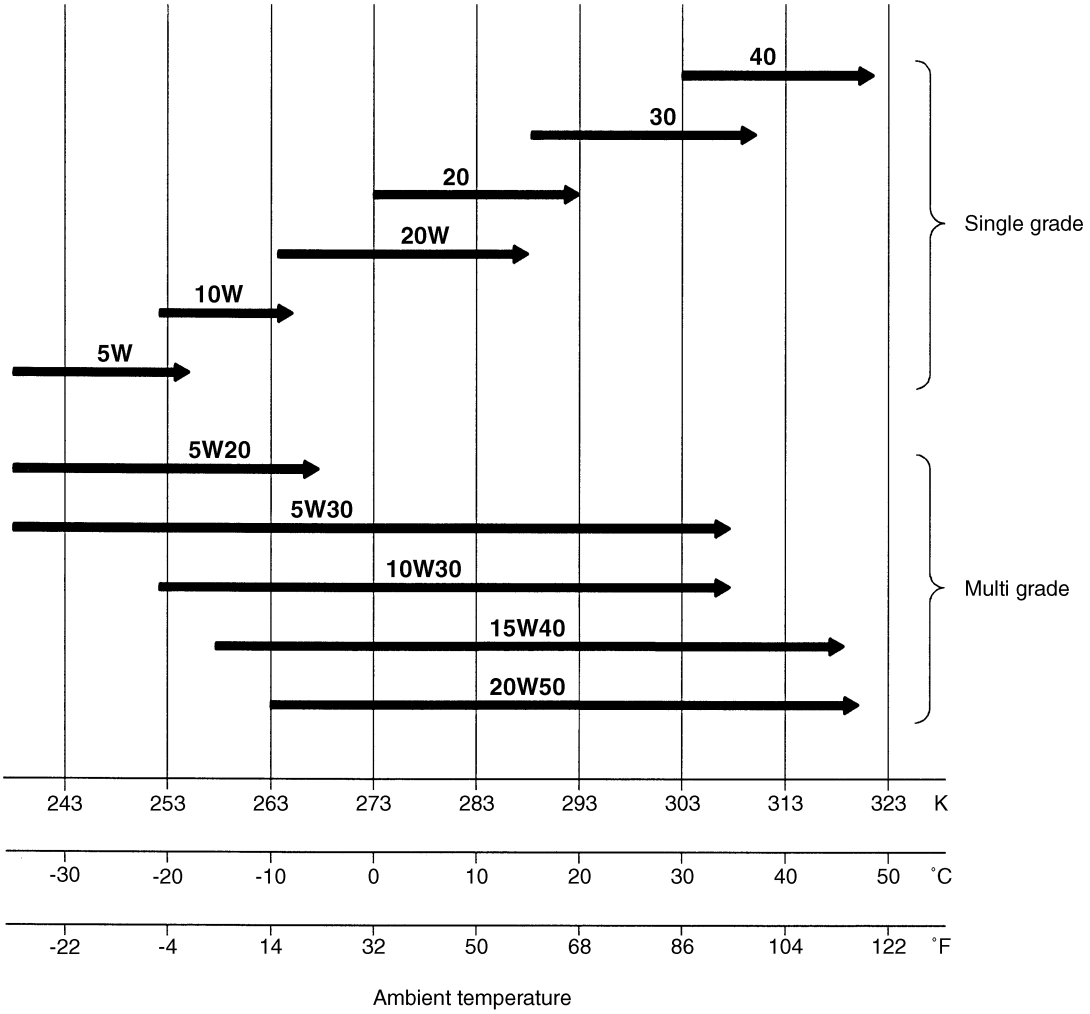


Figure 3-7

[3] COOLANT

High quality antifreeze must be used at all times.

1. Mix antifreeze with soft distilled water to use.
2. Premix the H_2O and antifreeze thoroughly before adding to the engine
3. Use only a 50/50 mix of H_2O and ethylene glycol (antifreeze) at all times.
4. Change antifreeze mix once a year.

[4] STARTER

Starter capacity of WG1605 to 1.0 KW.

Cold starting difficulty depends on the ambient temperature (intense cold or extreme cold) and resistance of transmission.

1. When an ON/OFF clutch is used between the engine and the power transmission, it can be set to OFF during starting and engine can be started as if starting an isolated engine.
2. Even though an ON/OFF clutch is not used, when resistance of the transmission is small, or when resistance is not small but the ambient temperature is not very cold, a standard starter may be sufficient.
3. On the contrary, as resistance increases, or as the ambient temperature becomes extremely cold, a large capacity starter and battery must be used.
4. As the displacement per cylinder increases, a larger capacity starter and battery must be used.

[5] BATTERY

From the viewpoint of startability, the battery capacity should be as high as possible. The capacity however is regulated by the assigned installation space and the balance between battery capacity and charging capacity.

Too much battery capacity imposes too much load on the starter. In the worst case, the starter may be burned up. Therefore, it is necessary to sufficiently examine and decide the battery capacity in accordance with the ambient conditions at starting.

As a principle, however, the battery is prepared and set by the manufacturer of machine to which the battery will be installed.

Battery capacity

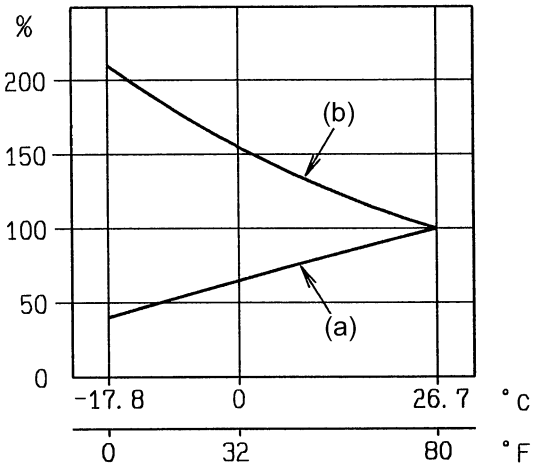
5hr Ratio (AH)	**C. C. R. (A)**
50 to 60	370 to 465

Cold Cranking Amperage

Engine size Total displacement cc (cu.in.)	Cold Cranking Amperage [C.C.A (A)]
800 to 1900 (48.82 to 115.95)	350 to 600

Discharging capacity is reduced by temperature change. The battery discharging capacity varies with the ambient temperature change.

Especially at a low temperature, the decrease of discharging capacity poses a problem. As for the equipment used at an extremely cold temperature, if the load of its hydraulic pump, torque converter, etc. is estimated to increase, it is necessary to increase the battery capacity together with that of the starter.



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Figure 3-8

(a) Comparison of cranking power available from fully charged battery at various temperature.
(b) Comparison of power required to crank engine with S.A.E. 10W-30 oil at various temperature.

[6] BATTERY CABLE

The battery cable size (cross-sectional area) largely influences the starting performance of engine (especially at an extremely cold temperature).

It is necessary to select a cable of appropriate size. The following summarizes the procedures for specifying the battery cable size area.

Current (A)	Cable size (mm^2)	AWG size
380	15	6
440	20	4
550	30	2
630	40	1
710	50	0
800	60	2/0
960	85	3/0
1170	100	4/0

[Ambient temperature : 40 °C (104 °F)]

Procedures for specifying battery cable size

1. Obtain the rated current of starter.
   To obtain the rated current (A), divide the rated output of starter (kW) by the battery voltage (V).

   Ex.
   When a 2.2 kW starter is driven by a 12 V battery : 2200 (W) / 12 (V) = 183.3 (A)

   When a 2.2 kW starter is driven by a 24 V battery : 2200 (W) / 24 (V) = 91.7 (A)

2. Multiply the obtained rated current by three (since the current flow at starting is about three times the rated current).

   Rated current × 3
   Ex. 183.3 × 3 = 549.9 (A)

3. In accordance with the obtained starting current value and above table (Table of maximum current for each cable size in short time operation), select the minimum cable size to withstand the starting current value.

   Ex.
   The above table shows a cable of 30 or 40 mm^2 cross sectional area (low voltage cable for automobiles) must be used.

FUEL SYSTEM

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1. GENERAL

[1] GASOLINE

- Unleaded regular gasoline.
- E10 (10 % ethanol is added to gasoline)

[2] LPG

- Commercial liquid propane gas only.
- Equivalent to propane HD–5 of GPA * standards.
- KUBOTA RECOMMENDED LPG FUEL SPECIFICATIONS

C_3H_8	C_3H_6	C_4H_{10}	Others
≥ 90 %	≤ 5 %	≤ 2.5 %	–

(vol %)

■ **NOTE**

- *** GPA means Gas Processors Association (U.S.A)**

2. CAUTIONS

[1] FOR SAFETY (WG1605-GL, WG1605-L)

- All fuel connections added to this engine must be installed by qualified personnel utilizing recognized procedures and standards.
- The non-KUBOTA installed parts, such as hoses, fittings, piping should be approved for LPG use and conform to UL, CSA, NFPA, MSHA and all other applicable standards.
- The following standards must be followed prior to installation: UL, CSA, NFPA and MSHA standards.

(1) Tightening Torque And Leak Check For Vaporizer

Each fitting must be sealed with approved joint sealant compound, and be tightened to the specified torque using a wrench and leak check must be performed as shown in the below table.

TIGHTENING TORQUE AND LEAK CHECK PRESSURE

Fitting	Qty.	Size	Tightening torque			Leak check pressure		
			Nm	kgfm	ft-lb	kPa	kgf/cm^2	psi
LPG OUT (VAPOR)	1	ϕ19 mm (3/4 in.) Hose Fitting	–	–	–	1730 to 1760	17.65 to 17.95	250.9 to 255.1
LPG IN (LIQUID) *	1	1/4-18 NPTF	19.6 to 39.2	2.0 to 4.0	14.5 to 28.9			
WATER IN/OUT	2	ϕ16 mm (5/8 in.) Hose Fitting	–	–	–	200 to 220	2.0 to 2.2	28.5 to 31.3

* NOT KUBOTA supplied

(2) Setting And Vibration Limits

Mount the vaporizer and lockoff valve according to the Installation Instructions.

[2] FOR EMISSION REGULATIONS (WG1605-GL, WG1605-L)

(1) Vaporizer

In order to conform to applicable EPA and CARB Emissions regulations when operating WG1605–GL, and WG1605-L engine, only a KUBOTA GENUINE vaporizer can be used.

Vaporizer can only be installed by an authorized KUBOTA DISTRIBUTOR or the Final Engine Assembler (FEA) in which this engine is used.

(2) Length Of The Gas Hose

The hose length between the vaporizer and the D-EPR (Electronic Pressure Regulator) must not exceed 700mm (27.6 in).

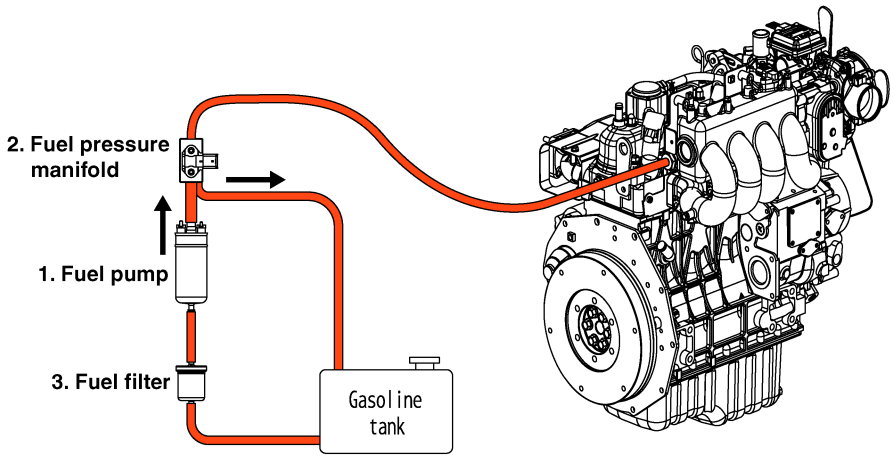
3. EVAPORATIVE EMISSION CONTROLS “GASOLINE FUEL SYSTEM”

1. Fuel pressure manifold must be mounted away from engine compartment heat.
   Must be in cool location, preferably close to the machine fuel tank.
2. FEA supplied non-metallic fuel line must conform to permeation Category 1 of SAE J2260. (40 CFR 1048.105 (a))
3. The gasoline fuel tank must have a self-tethered fuel cap sealed up to a positive pressure of 24.5 kPa (3.5 psig). (40 CFR 1048.245 (e) (1) (i))
   Cap must comply with CARB and EPA regulations.
4. Liquid fuel in the fuel tank may not reach boiling during continuous engine operation in the final installation at an ambient temperature of 30 °C. (40 CFR 1048.105 (d))
5. Note that gasoline with a Reid vapor pressure of 62 kPa (9 psi) begins to boil at about 53 °C at atmospheric pressure, and at about 60 °C for fuel tanks that hold pressure as described in §1048.245 (e) (1) (i). (40 CFR 1048.105 (d))
   FEA must confirm that bulk gasoline in fuel tank will not boil under continuous normal engine operating condition when tested at 30 °C ambient at application review.
6. Nonmetal fuel tanks must also use one of the qualifying designs for controlling permeation emissions specified in 40 CFR 1060.240. (40 CFR 1048.245 (e) (1) (i))
7. FEA must consult Kubota when changes are made to the fuel system after application review.

4. FUEL DIAGRAM

WG1605-G / -GL

- Mark 1, 2 and 3 are supplied by KUBOTA.
  The other parts including hose should be procured by OEM.
- Each pipes should be surely connected by clamp.
- Refer to next page.

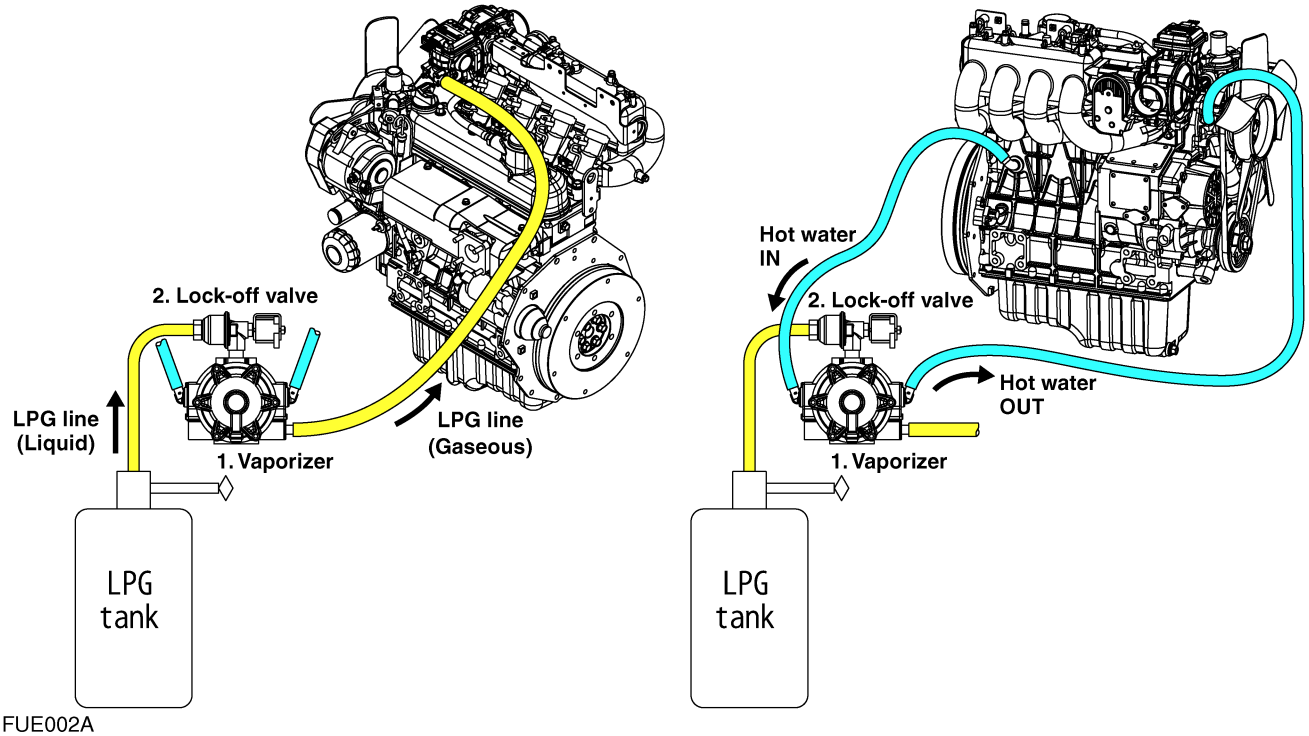


FUE001A

Figure 4-1

WG1605-L / -GL

- Mark 1 and 2 are supplied by KUBOTA.
  The other parts including hose should be procured by OEM.
- Each pipes should be surely connected by clamp.



FUE002A

Figure 4-2

5. ELECTRIC GASOLINE FUEL PUMP

The gasoline system will utilize an external electric gasoline fuel pump. The pump will be mounted in the chassis of the vehicle, or equipment near the fuel tank. Gasoline rated fuel hose and securing devices supplied by the OEM, will be used to transfer the pumped fuel to the Gasoline Fuel Pressure Manifold assembly. Most industrial equipment will be exposed to dusty and dirty environments, therefore use caution when opening the gasoline tank, to prevent dirt and debris from falling in the tank.

The electric gasoline fuel pump, utilized on USA emission certified engines are a critical part of the certified emissions system, and do not require any periodic adjustment.



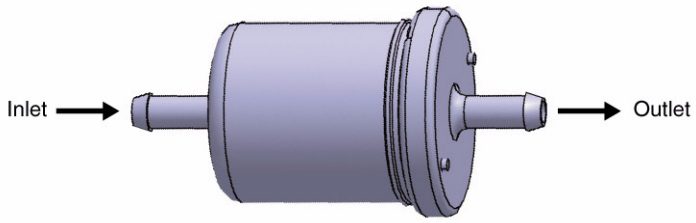
WG1605_026A

Figure 4-3

Fuel Filter

The fuel filter is installed in the fuel line between the fuel tank and the feed pump.

As the fuel flows from the inlet through the filter element, the dirt and impurities in the fuel are filtered,allowing only clean fuel to penetrate the inside of the filter element. The cleaned fuel flows out from the outlet.

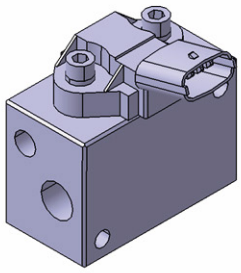


WG1605_048A

Figure 4-4

6. GASOLINE FUEL PRESSURE MANIFOLD

The gasoline fuel system, utilizes a Fuel Pressure Manifold assembly, to control the delivery pressure to the gasoline injector rail. The manifold is mounted to the chassis, between the electric fuel pump and the gasoline injector rail. The manifold is equipped with a sensor, which provides the ECU with the gasoline fuel temperature, and pressure being regulated to the gasoline injector rail. The ECU uses the fuel temperature and pressure, to calculate the precise amount of gasoline, to be injected to the engine during operation. The manifold is designed into the system, to control pressure, as well as the amount of gasoline, to be returned to the fuel tank. In normal gasoline delivery systems, the electric fuel pump, delivers a constant pressure to the injector rails, and allows a significant amount of fuel to be recycled to the tank, thus causing the gas to heat and vaporize, and requiring the use of a vapor recovery system to control the excess vapor. The system manages the fuel pressure at the manifold and minimizes the amount of returned fuel, thus reducing the vapor fuel in the tank.



WG1605_027A

Figure 4-5

7. DIRECT ELECTRONIC PRESSURE REGULATOR (D-EPR)

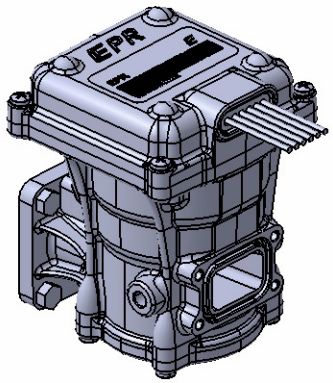
The Direct Electronic Pressure Regulator (D-EPR) is the primary fuel control device, used to maintain both performance and emissions control. The D-EPR contains an internal computer, which communicates to the KUBOTA Engine Control Unit (ECU), via a Communications Area Network (CAN), high speed connection.

The D-EPR precisely controls the fuel flow required to insure Stoichiometric (correct air/fuel mixture for complete burn) fuel delivery to the engine combustion chambers. The D-EPR also contains internally mounted fuel pressure and temperature sensors, which provide input across the CAN link, to the ECU, for fuel calculation. The ECU will process this information and command changes back across the CAN link, to the D-EPR, to adjust fueling.

The D-EPR internal computer also maintains certain levels of diagnostics within the system, to ensure emissions control is always maintained. If the D-EPR detects a fault within the regulator or fuel delivery system, the D-EPR will send that fault information across the CAN link to the ECU. The ECU will then activate the Malfunction Indicator Light (MIL), in the operator control panel. Depending on the type of fault, and its effect on fuel control, or engine performance, the ECU may command the D-EPR to change fueling, limit fuel delivery, or in some cases shut down the engine.

The D-EPR is connected directly to the mixer on all certified engines.

The D-EPR utilized on USA emission certified engines is a critical part of the certified emissions system, and do not require any periodic adjustment.



WG1605_022A

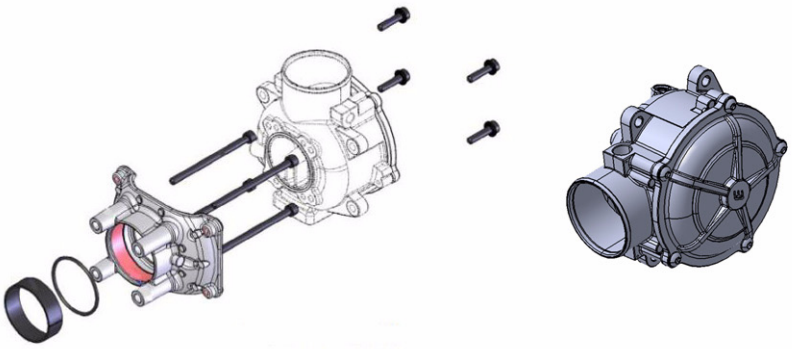
Figure 4-6

8. MIXER ASSEMBLY

The air valve mixer, is an air-fuel metering device, and is completely self-contained. The mixer is an air valve design, utilizing a relatively constant pressure drop, to draw fuel into the mixer, from cranking, to full load. The mixer is mounted in the air stream, ahead of the throttle control device.

When the engine begins to crank, it draws in air, and with the air valve covering the inlet, negative pressure begins to build. This negative pressure signal, is communicated to the top of the air valve chamber, through 4 vacuum ports, in the air valve assembly. A pressure/force imbalance begins to build, across the air valve diaphragm, between the air valve vacuum chamber, and the atmospheric pressure below the diaphragm. The air valve vacuum spring is calibrated, to generate from 101.6 mm (4.0 in.) of water column at start, to as high as 355.60 mm (14.0 in.) of water column, at full throttle. The vacuum being created is referred to as Air Valve Vacuum (AVV). As the air valve vacuum reaches 101.6 mm (4.0 in.) of water column, the air valve begins to lift against the air valve spring. The amount of AVV generated, is a direct result of the throttle position. At low engine speed, the air valve vacuum is low, and the air valve position is low, thus creating a small venturi for the fuel to flow. As the engine speed increases the AVV increases and the air valve is lifted higher, thus creating a much larger venturi.

The mixer is attached to the Electronic Throttle Body (ETB), via an adapter. The adapter is fitted with specific spacers, and o-rings, to insure a seal tight fit with the ETB.



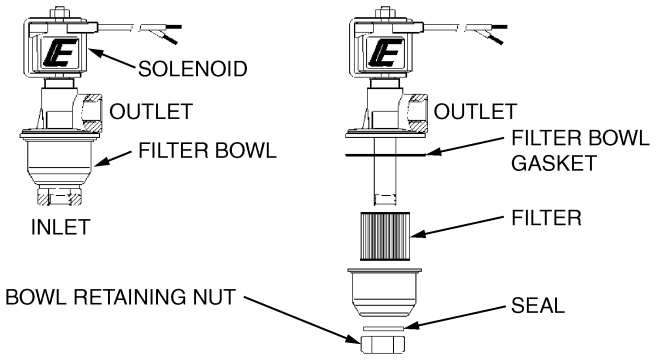
WG1605_023A

Figure 4-7

9. LPG FUEL LOCK-OFF VALVE

Fuel Lock-off Valve is used to isolate the D-EPR and all downstream components from upstream fuel pressure when the engine is shut-off.

The LPG fuel lock-off device is an integrated assembly. The electric lock-off assembly is a 12.0 V, normally closed valve. The solenoid is mounted to the valve body. When energized the solenoid opens the pilot valve, within the lock-off, which uses the tank pressure, to assist in opening the valve. By using the pilot valve, to help open the valve, the service life of the valve is extended, and requires less electrical energy, to open the valve. The valve opens during cranking, and remains open, during the run cycles of the engine. The lock-off supply voltage is controlled by the Engine Control Unit (ECU), or may be energized by a relay, which supplies battery voltage, when energized.

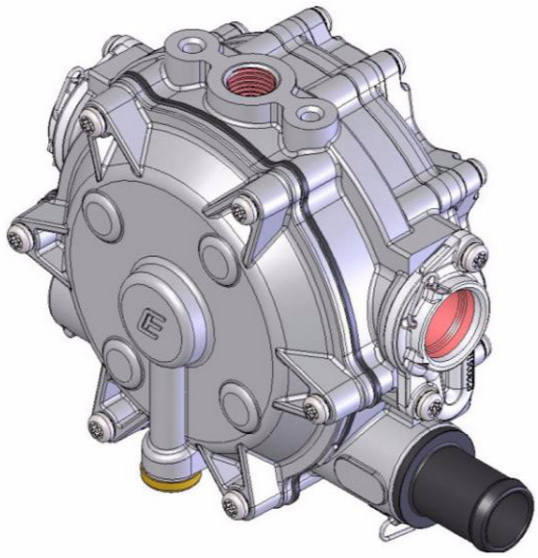


WG1605_024A

Figure 4-8

10. VAPORIZER (DUAL STAGE REGULATOR (DSR))

The DSR is a combination vaporizer, pressure regulating device. The DSR is a two-stage regulator that is normally closed, when the engine is not running. When the engine is cranking or running, a partial vacuum is created in the fuel line, which connects the regulator to the mixer. This partial vacuum opens the second stage regulator, permitting fuel to flow to the mixer.



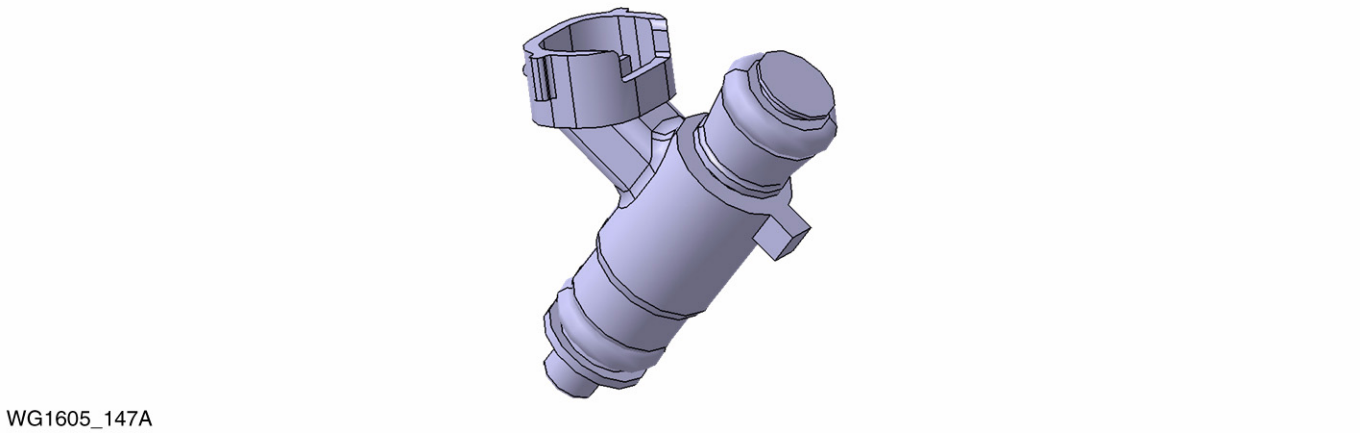
WG1605_025A

Figure 4-9

11. INJECTOR

In the injector, electric currents are applied to a solenoid coil to move the valve with an attached magnetic body up and down. While the valve opens, the fuel is injected from the edge hole of the valve in proportion to the pressure difference before and after the injector.

The fuel injection quantity can be adjusted by the electric current applying time, which is controlled by ECU.



WG1605_147A

Figure 4-10

LUBRICATION SYSTEM

CONTENTS

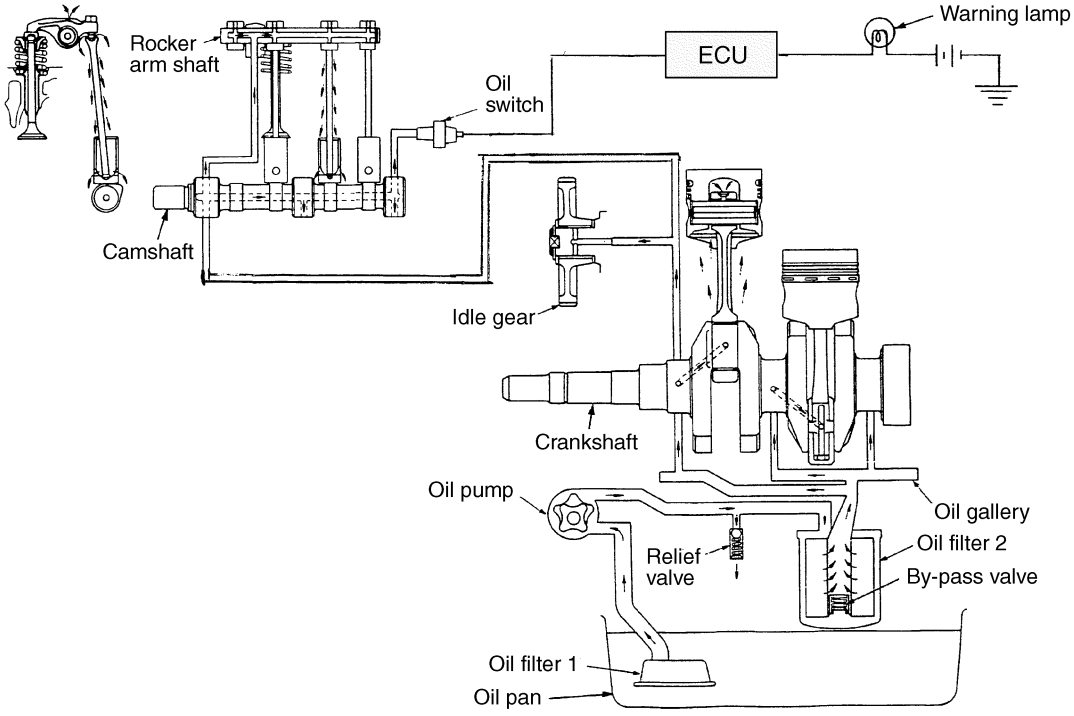
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1. GENERAL

All moving parts of the engine must be lubricated to function properly. For this purpose, the lubricating oil circulating through the engine has a number of functions. In addition to reducing friction, the oil cools down the engine, controls expansion and dispersion of bearing areas, provides a sealing action, prevents rusting, seals out dust, and purifies products generated in the cylinders by incomplete combustion.

A typical lubrication system is shown in below. Lubricating oil in the oil pan is circulated by a pump throughout the system as indicated by the arrows.

Oil pressure is controlled between 196 to 441 kPa (2.00 to 4.49 kgf/cm^2, 28.5 to 63.9 psi) and it is delivered to each section of the engine before returning to the oil pan. There are two main oil passages. One is through the crankshaft to the crank pin metal and the other is in the wall of the crankcase to the rocker arm shaft of valve train. Should oil pressure fall for any reason, parts can become scored or other serious problems will arise. A warning lamp indicates oil pressure drop when it falls below 49.03 kPa (0.5 kgf/cm^2, 7.11 psi).



WG1605_001A

Figure 5-1

The lubrication system of this engine comprises the oil pan, oil filter 1, oil pump, valve, oil filter 2, and oil switch.

Engine oil, after being cooled in the oil pan, passes through oil filter 1 as it is drawn by the oil pump. Oil, pressurised by the trochoid type pump is then filtered by oil filter 2 to remove fine particles. Then it passed through oil gallery (the oil passage in the crankcase) to be forcibly supplied to crankshaft, connecting rod, idle gear, camshaft and rocker arm shaft to lubricate them.

Oil splashed by the crankshaft or oil dripping from the clearances between parts lubricates the pistons, cylinders connecting rod small ends, fuel camshaft, tappets, push rods, intake and exhaust valves and timing gear.

2. LUBRICATING OIL

■ **NOTE**
- **The use of synthetic oil is not recommended.**
- **Poor quality oil will shorten engine life.**
- **Use only the specified lubricating oils.**

[1] FUNCTIONS OF ENGINE OIL

(1) Anti-wear Action

The most important role of engine oil is prevention of seizures and to reduce frictional forces to minimize the wear between moving parts and contact surfaces depending on the reduction of friction force. (Such as cylinder walls and piston rings and both ends of connecting rods, crankshaft bearings, camshaft, tappets, etc.).

(2) Cooling Action

The combustion chamber becomes extremely hot. Oil not only lubricates friction parts of piston but also cools the engine by acting as a heat exchange medium. This prevents seizures and high temperature oxidation of the oil itself. This cooling action is an extremely critical function. Extremely high viscosity or insufficient supply will result in seizures due to inadequate cooling.

(3) Sealing Action

Cylinder walls and compression rings seal the combustion chamber to allow build-up of compression. Oil seals the clearance between the cylinder walls and rings to provide more complete sealing and prevent leakage of the compressed air to maintain the compression pressure. It also prevents combustion gas from blowing back into the crankcase.

The prevents reduction of engine output and contamination of oil by unburned fuel.

(4) Engine Cleaning Action

Oil removes deposits inside the engine to prevent wear due to build-up of deposits.

(5) Corrosion Preventive Action

Oil prevents acid corrosion of metal parts, such as bearing metals, etc.

(6) Rust Prevention Action

Engine oil prevents rusting caused by condensation of acidic gases.

[2] CLASSIFICATION OF ENGINE OIL

SAE (Society of Automotive Engineers) Standards are generally used to classify engine oil viscosities. Viscosity is a principal property of oil, the higher the viscosity, the thicker the oil film formed over the metal surface will be and the lower the viscosity, the thinner the film thickness becomes.

Viscosity varies with temperature. The higher the temperature, the lower the viscosity and vice versa. Engine oil should have the appropriate viscosity and have properties which are not affected by viscosity changes caused by temperature changes. In other words, engine oil must have a high viscosity index. Multi-grade oils having relatively low viscosity (SAE 10W-30) can provide superior lubrication at both low temperature and high temperatures. Such oils are available commercially for all-season use.

*"High viscosity index" means less viscosity change by temperature fluctuation.

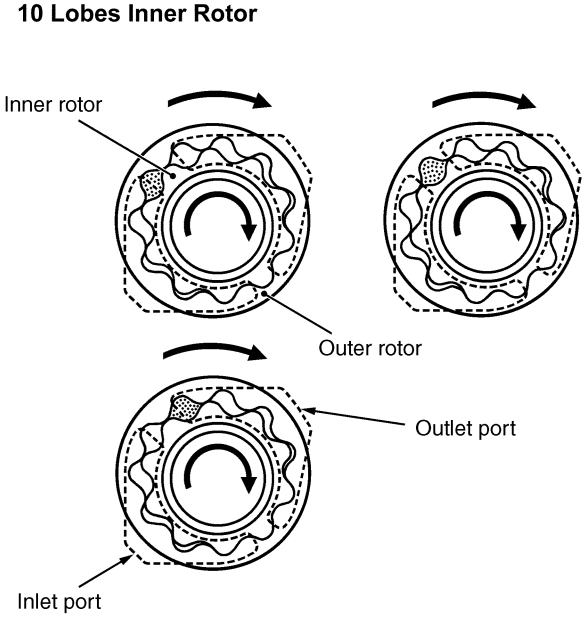
SAE J-300

Vis- cosity No.	*Max. viscosity at each temp. (CP)	**Max.temp. expressing tolerable pump discharge performance °C (°F)	Viscosity at 100 °C (212 °F)	
			Min.	Max.
0 W	3250 at -30 °C (-22 °F)	238 (-35)	3.8	
5 W	3500 at -25 °C (-13 °F)	243 (-30)	3.8	
10 W	3500 at -20 °C (-4 °F)	248 (-25)	4.1	
15 W	3500 at -15 °C (5 °F)	253 (-20)	5.6	
20 W	4500 at -10 °C (14 °F)	258 (-15)	5.6	
25 W	6000 at -5 °C (23 °F)	263 (-10)	9.3	
20	–	–	5.6	< 9.3
30	–	–	9.3	< 12.5
40	–	–	12.5	< 16.3
50	–	–	16.3	< 21.9

* Measured by CCS viscometer (ASTM D-2602).
** Measured by mini rotary viscometer (ASTM D-3829).
When the viscosity is less than 30000 CP, the maximum temperature is measured.

3. LUBRICATING OIL PUMP

A trochoid pump is used to pump oil. It is compact and driven by the crankshaft gear.
It also runs extremely smoothly and quietly.
The casing is made of an aluminum alloy and the rotor of a sintered steel alloy.



WG1605_002A

Figure 5-2

The rotor has a precise clearance of 0.1 mm (0.0039 in.) which requires very careful attention. Make absolutely sure that no dirt or other foreign matter enters into oil pump through the oil filter.

Oil pump specifications

	Type	Trochoid pump
WG1605-G/GL/L	Inner rotor Delivery volume (3000 min^{-1} (rpm))	10 lobes 23.4 L/min 6.18 U.S gals/min
	Delivery pressure (3000 rpm^{-1} (rpm)) (Regulator valve pressure)	196 to 441 kPa 2.00 to 4.49 kgf/cm^2 28.5 to 63.9 psi

4. LUBRICATING OIL FILTER

Oil in the oil pan first passes through filter 1 and is then suctioned by the oil pump. It then flows through filter 2 lubricating the various parts.

Oil filter 1 is installed near the bottom of the oil pan and removes dirt and foreign matter.

Oil filter 2 is installed under the gear case or the side of gear case and is a standard full-flow type cartridge which requires minimum maintenance.

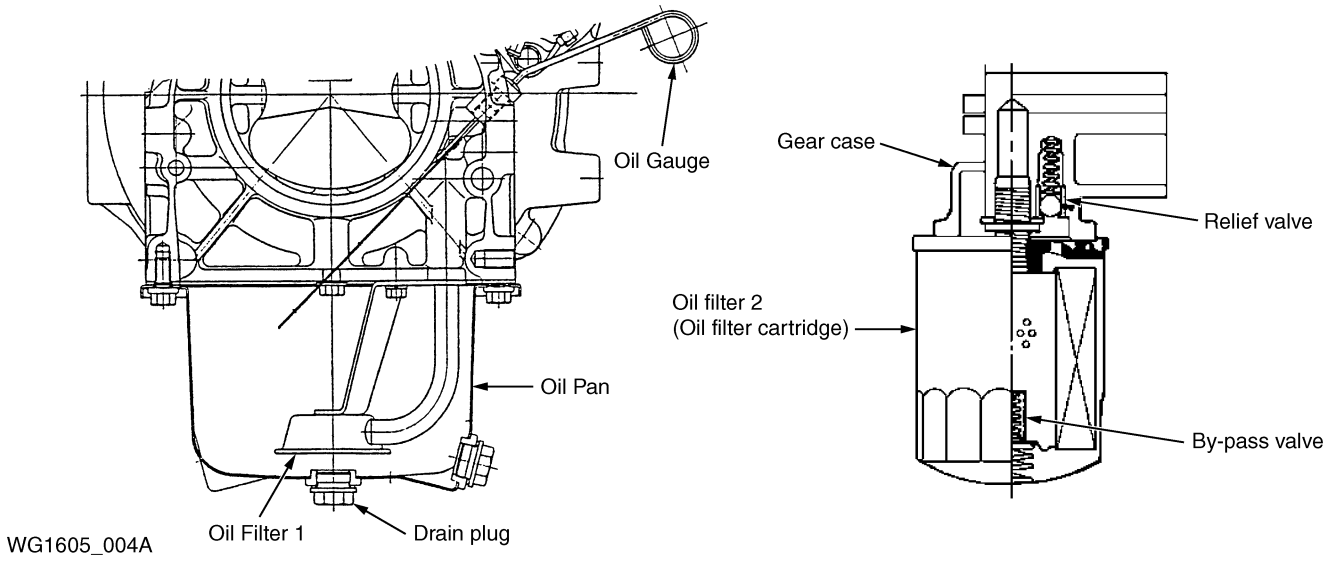


Figure 5-3

- **Function of valves and switches**

Relief valve

Maintains lubricating oil pressure at constant value adjusted to maintain pressure of 200 to 440 kPa (2.0 to 4.5 kgf/cm^2, 28.0 to 64.0 psi).

By-pass valve

By-pass valve is built into oil filter 2, if the filter becomes clogged, insufficient lubrication will result. To prevent this, the by-pass valve opens when the pressure difference before and after the filter exceeds 98.1 kPa (1.0 kgf/cm^2, 14.22 psi) to provide oil to engine parts.

Oil switch

An oil switch is fitted at the camshaft bearing. If oil pressure drops below 49.0 kPa (0.5 kgf/cm^2, 7.11 psi) a lamp connected to the switch lights up, advising the operator to stop engine and investigate the cause of the pressure drop.

- **Remote oil filter**

When remote oil filter is used, the oil pressure at idling is as follows.

98 kPa (1.0 kgf/cm^2, 14 psi) or more

[Oil temperature : 90 to 95 °C (194 to 203 °F)]

5. OIL PAN

The oil pan holds a specified volume of oil, which is drawn up by the pump during operation and returns along the inside walls of the crankcase.

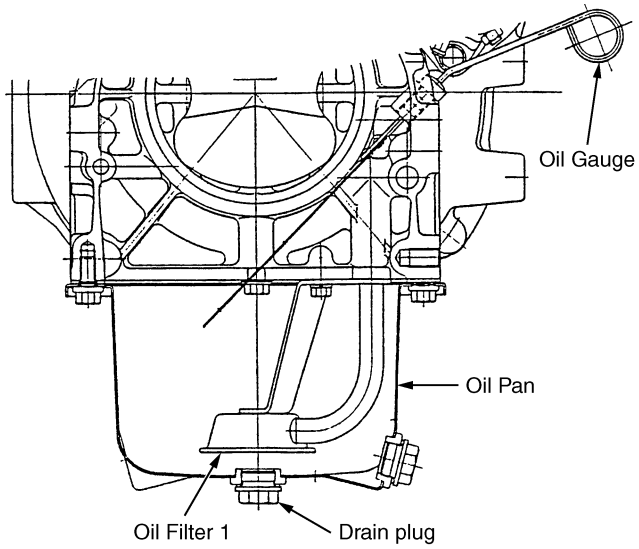
This flow cycle is repeated continuously as the engine runs.

The oil drain is located according to how the engine is installed and positioned for easy access for special drain requirements.

Oil gauge

The standard oil gauge is installed on the side of crankcase. The part which is inserted is made of rubber, which is grooved to release internal pressure during insertion. The oil gauge is stamped with lines indicating upper and lower limits. If oil is supplied far above the top limit, engine output will be reduced and oil temperature will be increased, so watch this point carefully.

Proper oil level is not indicated for a few minutes after the engine is stopped because of the time required for oil to return to the oil pan. Oil level must be measured in level position.



WG1605_035A

Figure 5-4

6. OIL SUPPLY PORT

Oil is supplied to the engine through the oil supply port located on top of the cylinder head cover or on the gear case.

Oil flows through cylinder head and crankcase or gear case to the oil pan. This oil supply port should be easily accessible for servicing, even after the engine has been installed.

Care must be taken to decide the position of oil supply port so that the oil can be easily supplied to the piping installed on the machine.

7. POSITIVE CRANKCASE VENTILATION SYSTEM

During normal compression stroke, a small amount of gases in the combustion chamber escapes past the piston.

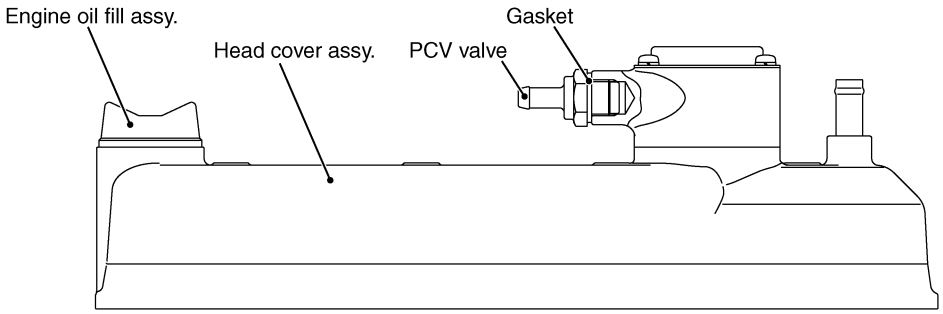
Approximately 70% of these blowby gases are unburned fuel (HC) that can dilute and contaminate the engine oil, cause corrosion to critical parts, and contribute to sludge build up.

The purpose of the Positive Crankcase Ventilation (PCV) system is to remove these harmful gases from the crankcase before damage occurs and combine them with the engine's normal incoming air/fuel charge.

PCV System Using PCV Valve

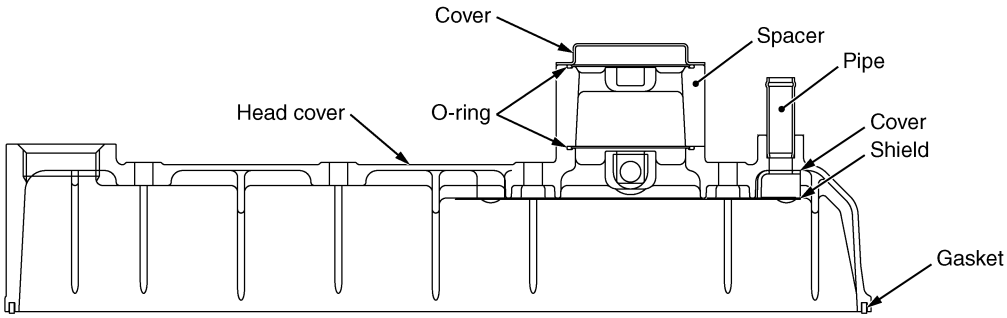
The PCV valve has the main body with a valve and spring incorporated into it and is mounted between the engine main body and intake manifold.

The intake of the blowby gas and the amount of new air introduced are controlled according to the state of engine operation.



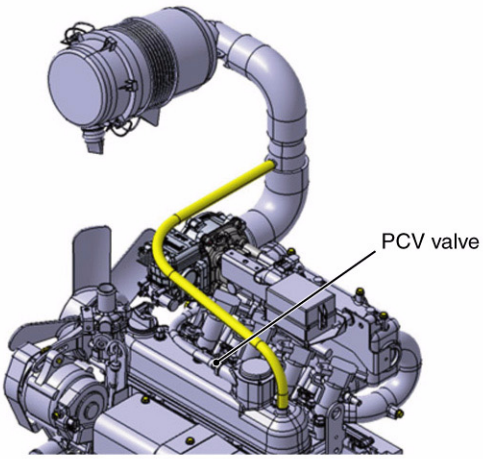
WG1605_049A

Figure 5-5



WG1605_005A

Figure 5-6



WG1605_039A

Figure 5-7

AIR INTAKE SYSTEM

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2. AIR CLEANER 6-2
   [1] GENERAL 6-2
   [2] STRUCTURE OF DRY TYPE AIR CLEANER 6-2
      (1) Structure Of Single Element Air Cleaner 6-3
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1. GENERAL

The intake and exhaust system is very important for engines.

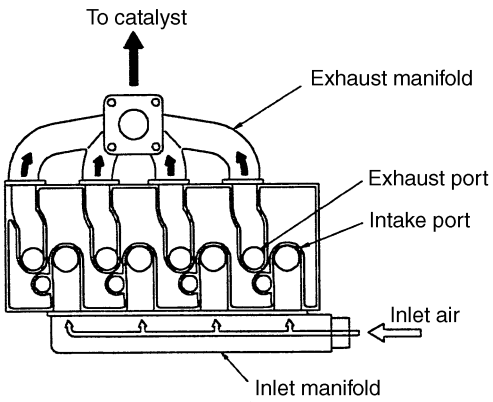
In order to operate an engine smoothly, the intake and exhaust system must be efficient enough for maximizing the functions of highly reliable valve mechanism. It is best to feed clean, low temperature (i.e. high density) air to the engine intake.

The intake system supplies the air required for combustion. Insufficient air intake decreases engine output. If air is not clean, wear increases on the piston, rings and cylinder and lubricating oil smear will tend to shorten engine life.

Crossflow system

Intake air temperature tends to rise if exhaust gas passages are near the intake passage ; this leads to decreased output. To prevent this, KUBOTA engines use a crossflow system.

As shown in the diagram, the KUBOTA engine employs the crossflow system which separates the intake and exhaust systems in opposite side of the cylinder head. This arrangement effectively prevents heating of intake air by exhaust heat which would result in decreased output. The crossflow type cylinder head provides better volumetric efficiency of the intake, alternately placed intake and exhaust ports minimize cylinder head distortion due to exhaust gas heat. The following sections cover important elements of the intake and exhaust systems.



WG1605_007A

Figure 6-1

2. AIR CLEANER

[1] GENERAL

The air cleaner, of which purpose is to purify intake air, has two types, ; the dry type and wet type. The dry-type air cleaner, which is generally used in most cases, uses a filter paper element and therefore dust removing efficiency is very high regardless of the engine speed. (99.5-99.8%)

In KUBOTA engines, the dry-type air cleaner are employed as standard part for all models.

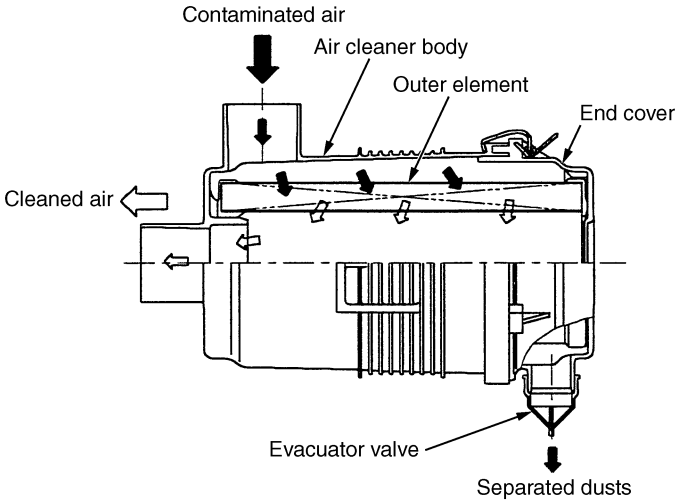
[2] STRUCTURE OF DRY TYPE AIR CLEANER

Dust or air containing moisture will infiltrate into air cleaner through the inlet installed perpendicularly on the bodies outer circumference and direct vortex flow along the guide is created inside the body.

After this, the air passes through the element and will further be purified.

The element is made of high-quality paper filter and can inhibit infiltration of very fine dust (20 μ). Dust separated by the vortex flow will be collected into the rear-side and cover and then passed into the evacuator valve.

This evacuator valve will open and close automatically in accordance with pulsation of suction air and discharge the dust.

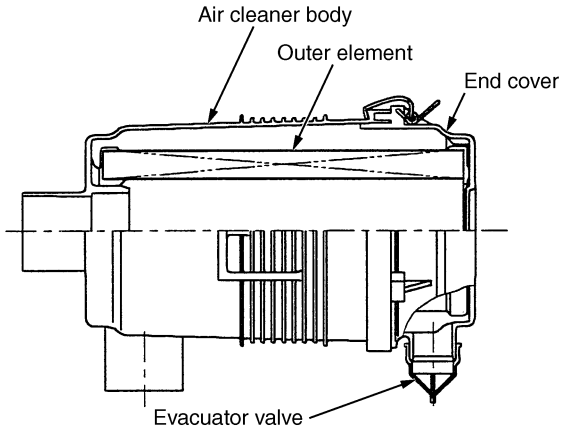


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Figure 6-2

(1) Structure Of Single Element Air Cleaner

This air cleaner is the most popularly used type for the small-size general purpose engine and is composed of the air cleaner body, outer element, rear-side end cover, dust-evacuator valves, etc. The outline of the structure is shown in the Fig. 6-3.

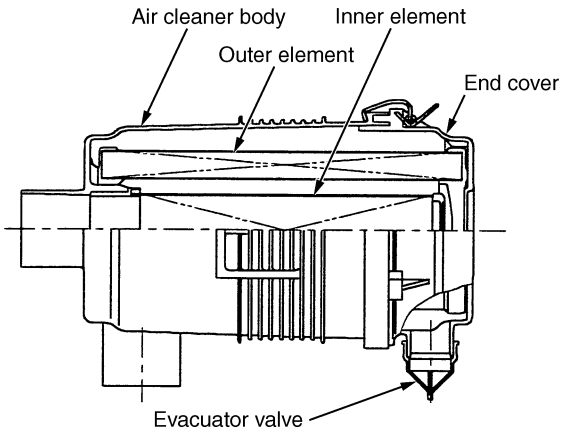


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Figure 6-3

(2) Structure Of Double Element Air Cleaner

The air cleaner of double element structure is used for the engine to be used in more severe environmental conditions such as the case of construction machinery and sweeper where the amount of dust is large. This type is made by adding the inner element to the previously-described single element air cleaner and the structure is shown in the following figure.



WG1605_055A

Figure 6-4

[3] SELECTION OF AIR CLEANER

(1) Conditions For Selection

1) Amount of suction air
2) Environmental conditions of dust
   - Small-amount dust conditions : Generator, forklift, carrier, etc.
   - Large-amount dust conditions : Agricultural machinery, construction machinery
3) Mounting conditions
   Mounting to engine, or mounting to machine
4) Destination
   Use in advanced countries, or to developing countries
5) Use conditions
   Operating hours and quality of maintenance
6) Cost
   Initial cost and maintenance cost

(2) Selection Of Air Cleaner And The Cautionary Items

1) Cautionary items for environment

- In case that an air cleaner is used in high dust concentration areas (high-temperature or high-humidity area), a model of sufficient capacity should be used. (It is required to use the air cleaner of one size higher capacity than those to be used in ordinary areas.)
  The air cleaner should be the double element type.
- Reduction in the life of the air cleaner element (clogging) is often caused by comparatively small-sized dust. However, in the case that there is a possibility that the suction port (air intake) of air cleaner may be clogged by large-size dust (such as fallen leaves and straw dust), it is required to move the suction port to a location with less dust or to install a pre-filter to remove such large-size dust.
- In the case that there is a possibility that the air cleaner may suck in water, a water drain hole or water-separating device should be installed. Be very careful to prevent the water entering engine when washing the machine.

2) Caution items when mounting to engines

- Vibration of air cleaner should not exceed the rated value verified in the field operation of the actual machinery. Large vibration will cause damage to various parts or allow dust leakage of the element (including the element gasket section).
- Be careful so that the suction port of air cleaner is not subjected to the detrimental conditions such as the followings :
  a) Air cleaner should not inhale hot air, such as the hot side cooling air of radiator.
  b) Air cleaner should not inhale exhaust gas.
  Particularly fine carbon will cause to early clogging.
  c) Air cleaner should not inhale the material having viscosity such as mist of crankcase.
- Cautionary items when piping to the air cleaner
  a) Is the inner diameter, length, or bending of pipe appropriate ?
  Be careful so that the intake air resistance should not be too great.
  b) Is the dust seal of piping system complete ?
  If there is even the least gap in the suction air system, it will result in the early wear of the moving parts of engine.

Therefore, checking of the following items is required.

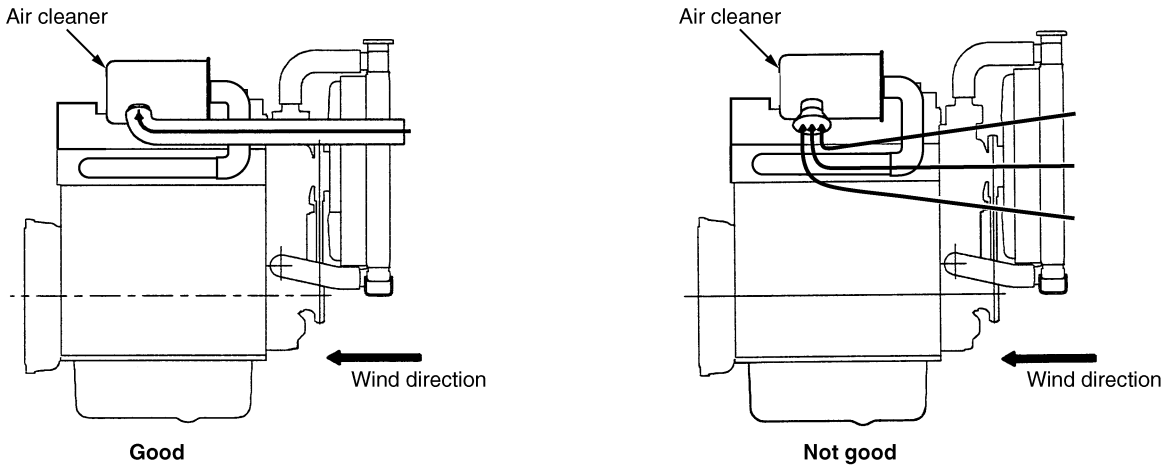
1. Is clamping force of the hose clamp sufficient, and will not the hose clamp be loosened by vibration ?
   Are all hose connection “rubber to metal”.
   Are all rubber hose connections tight on metal connections.
2. Is strength of the hose sufficient ?
   (Will not distortion or damage of the hose be incurred by negative suction pressure or positive suction air pressure ?)
3. Will dust infiltrate through the screw holes ?

c) If an extension pipe is installed to the suction port, or the hose between air cleaner and intake manifold is too long, it may result in an engine output decrease or smoke increase.

3) Cautionary items on maintenance

- Maintain the air cleaner within the time specified in the operators manual. (In the case of the air cleaner provided with a dust indicator, maintainance should be performed after the warning of clogging is indicated.)
  Unnecessary maintenance will be the cause of problems, such as the damage or deformed element.
- Be careful so that dust adhered on the element should not infiltrate to the outlet side of air cleaner when removing the element.
- When cleaning the element, it should be done by blown air or water washing. (Depending on the kind of the element, water washing is allowed, or specified detergent can be used.) In case of blown air remember to blow air from the inside toward the outside.
- When removing the element, stop the engine.
- In case that there is a pin hole on the element, replace it with new one.

Installation example of air cleaners are shown :



WG1605_051A

Figure 6-5

3. REQUIRED AIR VOLUME

The volume of air required during engine operation can be determined by the following formula.

$Q_1 = Vh \times N \times C \times \eta \times 10^{-3}$
where as :
Q_1 = Amount of intake air (m^3/min)
Vh = Total displacement (liter)
N = Engine speed (min^{-1} (rpm))
C = Coefficient 4 cycle ... 0.5
η = Intake efficiency : Gasoline 0.85, LPG 0.81

The air volume required for KUBOTA SI engine is refered to in section. (TECHNICAL INFORMATION)

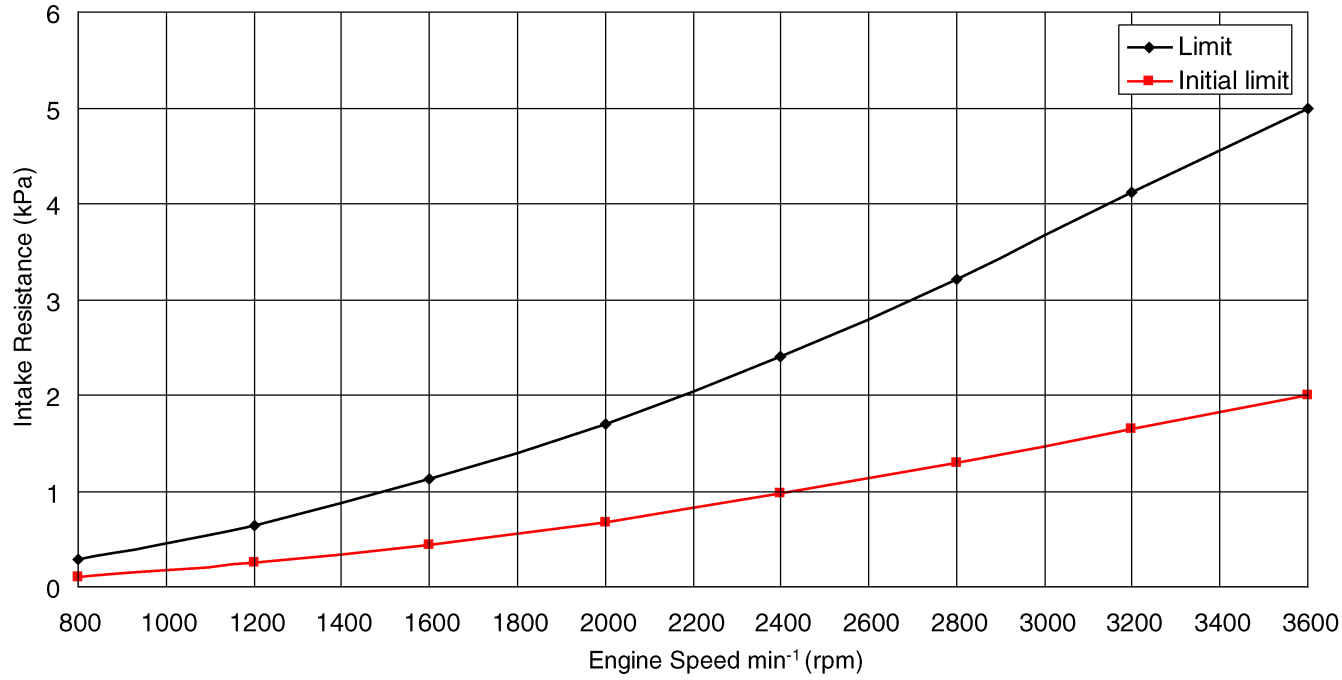
Example Calculation
[Engine model : WG1605-G, Engine speed : 3600 min^{-1} (rpm)]
$Q1 = Vh \times N \times C \times \eta \times 10^{-3}$
Vh = 1.537 lit
N = 3600 min^{-1} (rpm)
C = 0.5
η = 0.85
$Q1 = 1.537 \times 3600 \times 0.5 \times 0.85 \times 10^{-3}$
$= 2.35\ m^3$/min

4. INTAKE RESISTANCE

To prevent decreases of engine output performance, intake resistance must be held within the following data at full load condition.

Measurement point of intake resistance is between the air cleaner and the inlet of the throttle body (-G) or the mixer (-L, -GL).

Engine Speed min^{-1} (rpm)	Intake Resistance	
	Limit w/dirty filter (kPa)	Initial limit w/clean filter (kPa)
700	0.22	0.08
800	0.28	0.10
1200	0.64	0.25
1600	1.12	0.44
2000	1.70	0.67
2400	2.40	0.97
2800	3.21	1.29
3200	4.11	1.65
3600	5.00	2.00



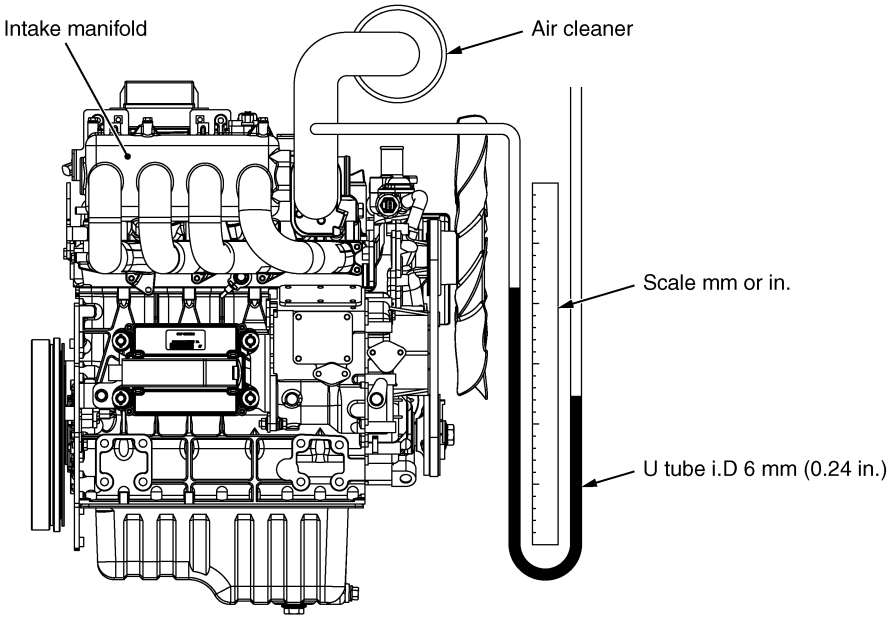
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Figure 6-6

■ **NOTE**

- **The intake restriction is the total system limit.**
- **Intake restriction must be measured at the location that is not affected by pulsation.**
- **The application check must be performed at the Initial limit with clean filter condition.**
- **If OEMs mention the restriction values on their operator manuals for service interval, refer to the above sheet (Limit w/dirty filter).**

The intake piping should be made of a high quality compounded rubber with exceptional resistance to aging, oil and cold to reduce chances of cracking during operation.



WG1605_036A

Figure 6-7

EXHAUST SYSTEM

CONTENTS

1. GENERAL 7-1
2. LIMITATION OF PERMISSIBLE BACK PRESSURE 7-2
3. THREE-WAY CATALYST 7-3
   [1] FEEDBACK CONTROL OF AIR-FUEL RATIO 7-3
   [2] OXYGEN SENSOR 7-4

1. GENERAL

An engine's exhaust system must be able to freely discharge all high temperature exhaust gas after combustion to the outside air.

Exhaust resistance must be as low as possible in order to prevent a decrease in power, however exhaust noise must be kept at an acceptable level. Careful design is required to reconcile these two conflicting factors.

Kubota supplies a certified catalyst. FEA must use a Kubota certified catalyst and assemble the exhaust system parts according to the instructions.

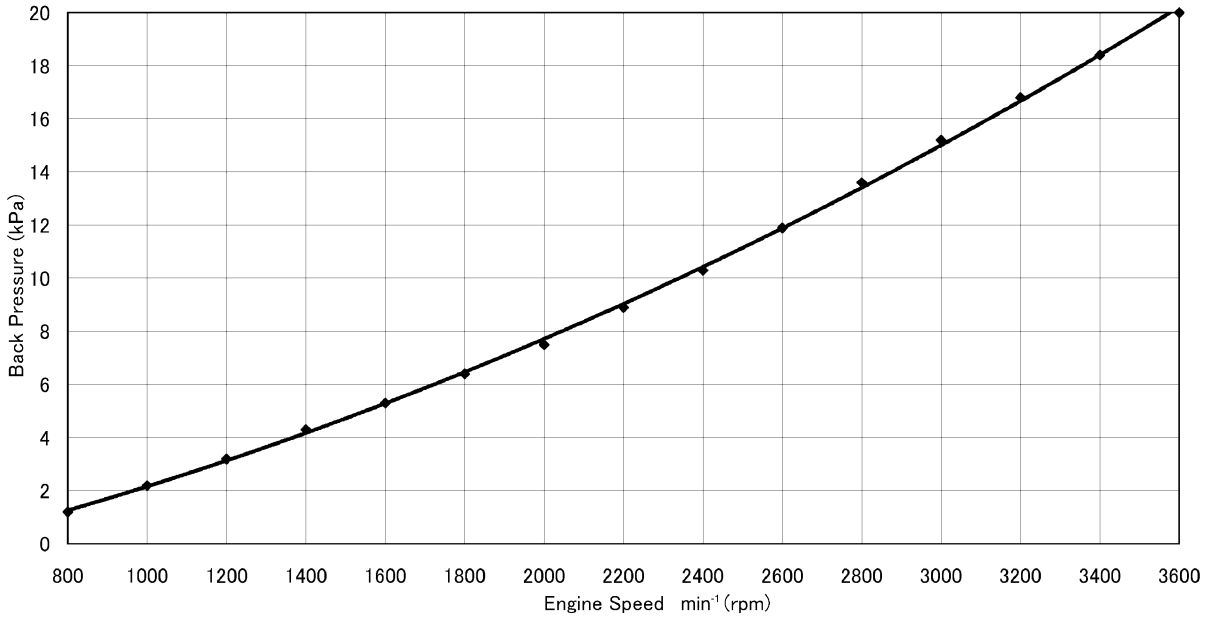
No other catalyst is certified for use with WG1605 Engine. No Other Catalyst can be used.

FEA may only install the exhaust system parts confirmed at application review.

2. LIMITATION OF PERMISSIBLE BACK PRESSURE

Back Pressure of exhaust system must be held within the following data at full load condition.
Measurement point of back pressure of exhaust system is between the exhaust manifold and the catalyst.

Engine Speed min^{-1} (rpm)	Back Pressure (kPa)
800	1.2
1000	2.2
1200	3.2
1400	4.3
1600	5.3
1800	6.4
2000	7.5
2200	8.9
2400	10.3
2600	11.9
2800	13.6
3000	15.2
3200	16.8
3400	18.4
3600	20.0



WG1605_021A

Figure 7-1

Generally speaking,

- Back pressure increases as engine speed increases. The back pressure varies with muffler construction.
- Mufflers with higher back pressures have larger output loss.
- Back pressure increases as exhaust piping has many bends, longer length, many restrictions and smaller muffler volume.

3. THREE-WAY CATALYST

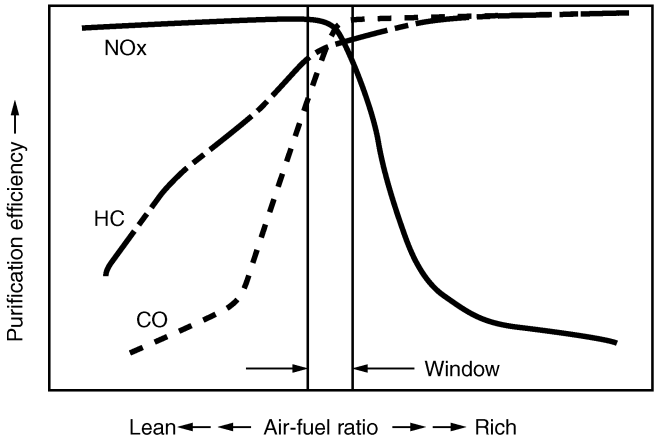
A three-way catalyst is a catalyst that oxidizes HC to CO_2 and H_2O and also CO to CO_2 respectively and at the same time reduces NOx to N_2 near the stoichiometric ratio.

The main basic component of an exhaust gas purification system that uses a three-way catalyst is feedback control of air-fuel ratio by means of an oxygen sensor for the purpose of maximizing the emission purification efficiency characteristic with reference to the intake air-fuel ratio of the three-way catalyst.

[1] FEEDBACK CONTROL OF AIR-FUEL RATIO

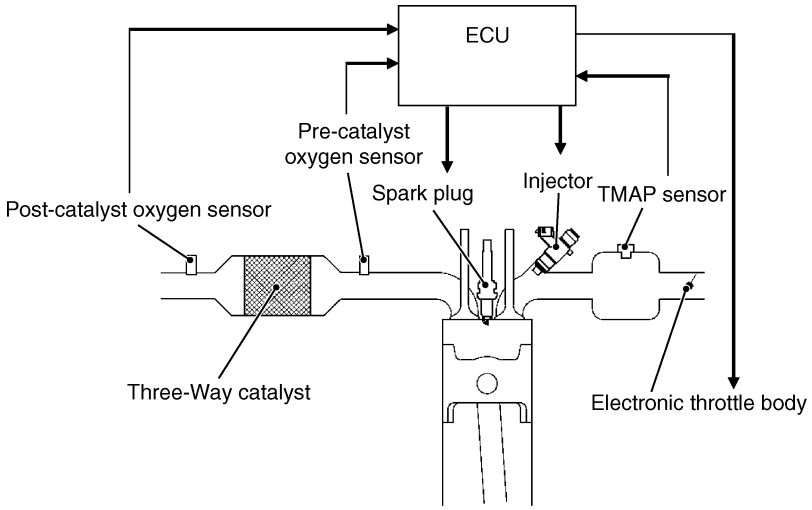
Regarding the exhaust emission purification efficiency characteristic with reference to the air-fuel ratio of a three-way catalyst, three components can be simultaneously purified with an extremely high efficiency in the narrow range near the stoichiometric ratio called the "window," as shown in Figure 7-2. Once out of the window, the purification efficiency suddenly declines.

Figure 7-3 shows an example of electronically-controlled feedback control of air-fuel ratio for maintain the air-fuel ratio within this window. The oxygen sensor provided in the exhaust system detects the oxygen concentration in the exhaust gas, which, together with other information obtained at the same time such as the intake air quantity and water temperature, is sent to the ECU for processing. Then, fuel in an amount corresponding to the intake air for controlling the air-fuel ratio within the window is fed through the electronically-controlled fuel system to the engine.



WG1605_053A

Figure 7-2



WG1605_052A

Figure 7-3

[2] OXYGEN SENSOR

An Oxygen sensor is an essential element of a feedback control of air-fuel ratio. The sensor has a mechanism in which a zirconia tube, which is a solid electrolyte, is exposed into the exhaust gas and the outside of a zirconia tube to an exhaust gas, the inside to an atmosphere with a known oxygen concentration respectively. Any difference produced between the two sides of the zirconia tube causes electromotive force to be generated. Oxygen sensor should be installed at the catalyst inlet and outlet each.

[Pre-Catalyst Oxygen Sensor]

When the air-fuel ratio is rich, HC, CO, H_2, etc. react with the oxygen (O_2) that remains in the exhaust gas. This causes a significant reduction of the concentration of the remaining oxygen, which considerably increases the ratio of it to the concentration of oxygen contained in the atmosphere inside, increasing the electromotive force. When the air-fuel ratio is lean, the process is the other way around, resulting in a significant drop in the electromotive force near the stoichiometric ratio. That is, the feedback control functions as electronic control that makes the air-fuel ratio lean when it is judged to be on the rich side based on the electromotive force and that makes the air-fuel ratio rich when it is on the lean side.

[Post-Catalyst Oxygen Sensor]

A post-catalyst oxygen sensor provides information that can be used 1) to diagnose how efficiently a catalyst is using the available oxygen to react and 2) to adjust or trim pre-catalyst equivalence ratio (air-fuel ratio) to a desired level to optimize catalyst conversion efficiency.

COOLING SYSTEM

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1. GENERAL

Heat generated inside the combustion chamber during combustion and heat generated by friction of moving parts is removed by the cooling system to allow continuous operation in the proper range.

Coolant flow

The cooling system cools the engine while it is running to prevent overheating and maintain a proper operating temperature.

Kubota engines are used pressurised forced-circulation type.

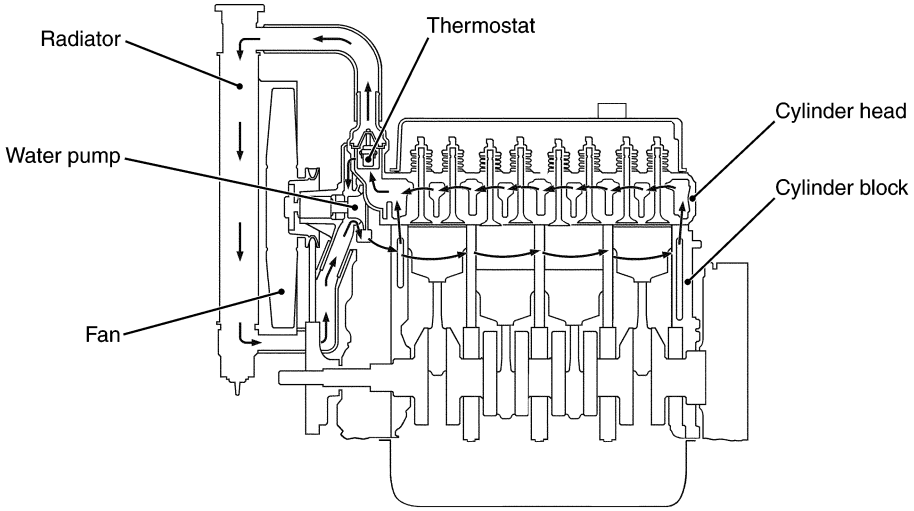
This system consists of a radiator, water pump, cooling fan, thermostat and coolant temperature sensor.

The coolant is cooled through the radiator core, and the fan set behind the radiator pulls cooling air through the core to improve cooling.

When the coolant in the engine is at a low temperature, the thermostat valve is closed so that the coolant is circulated in the engine through the bypass pipe.

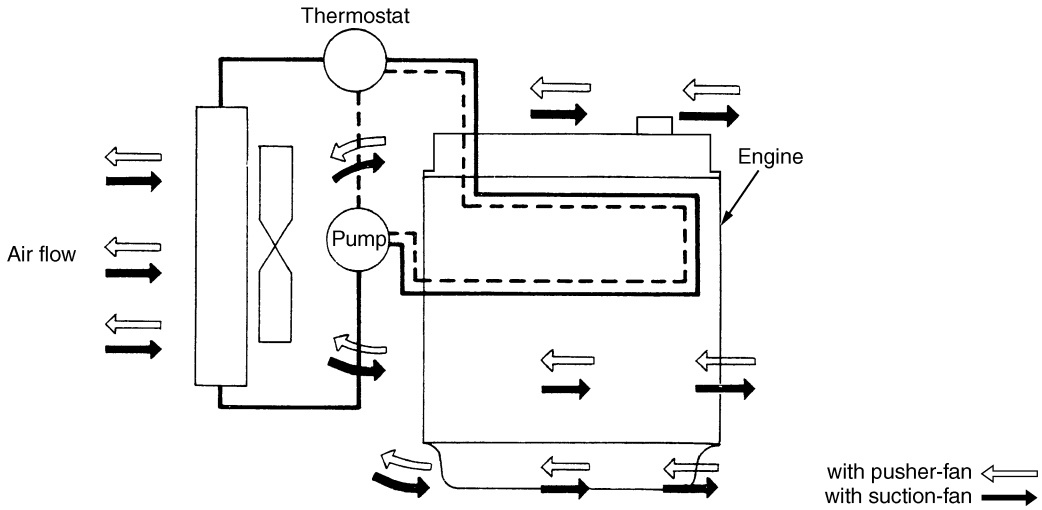
When the temperature of the coolant becomes the valve opening temperature of thermostat, the thermostat opens the valve to return the heated coolant to the radiator.

The water pump sucks the cooled coolant, forces it into the cylinder block and draws out the hot coolant.



WG1605_008A

Figure 8-1



WG1605_009A

Figure 8-2

2. RADIATOR

[1] GENERAL

Heated cooling water, passing through the radiator is cooled when the fan causes air to pass through the radiator and disperse the heat. The standard radiator mounted on KUBOTA engine is a tube-and-corrugated-fin type with a superior cooling effect. Radiator capacity is selected according to rated output (at standard condition) of an engine to prevent overheating extended operation.

Pressurised cooling water inside the radiator is kept less than 88 kPa (0.9 kgf/cm^2, 12.8 psi) by the radiator cap to prevent deformation of radiator due to excessive pressure. Generally, corrugated-fin types come with louver or without louver and with various fin pitches. When selecting a radiator, dust conditions, ambient temperature, load etc. must be considered carefully.

A radiator has many thin copper, brass or aluminium components and requires special care and handling.

Radiators should be installed where they are not subjected to impacts and vibration. Measures should also be taken to prevent engine parts or other objects from contacting radiator.

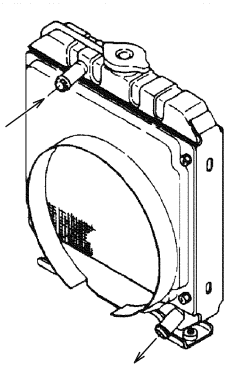
A coolant recovery tank should be installed for all applications.

This helps prevent loss of coolant and overheating resulting from coolant level.

[2] TYPE

In general, there are two kinds of radiators. One is a down flow radiator. The other is a cross flow radiator.

★ Down flow radiator (Conventional)



WG1605_107A

Figure 8-3

★ Cross-flow radiator

In a cross-flow radiator the coolant passageways travel horizontally rather than vertically. Another feature of the cross-flow radiator is that the inlet and outlet tanks are located on the sides of the radiator, rather than on top and bottom. This allows for a “low profile” cooling system.

These radiators offer a compact cooling system, but special attention must be given to key issues associated with a cross-flow radiator.

(1) Cooling System Fill

a) A cooling system should be designed to provide complete filling of the engine, piping, and radiator without air pockets in the system. Due to the nature of the cross-flow radiator design, this can be very difficult.
b) Even with a standard coolant recovery bottle, removing this air can require several warm-up and cool-down cycles.
c) Only cooling system with a pressurised recovery tank will allow proper and quick de-aeration.

(2) De-aeration Capability

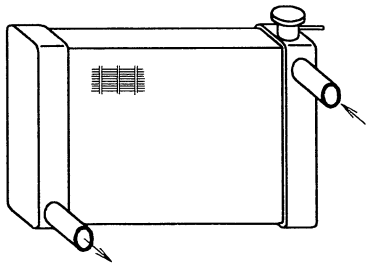
a) De-aeration capability is the ability of a cooling system to get rid of air and gasses entrapped in the cooling system. Air can be introduced into the system during fill or during normal operation.
b) A properly designed down-flow radiator has a top tank with a baffle. The area above the baffle serves as space to isolate entrapped air from the coolant.
c) A cross-flow radiator has no method of separating the entrapped air from the coolant causing the air to constantly be drawn back into the system. Constant splashing as coolant enters the tank causes air and coolant to mix, allowing the cooling system to draw the air in.

* Air retained in the cooling system can cause “hot spots” in the engine, particularly the cylinder head. It can also reduce cooling capacity and possibly cause cavitations of the water pump.

(3) Drawdown Capability

a) Drawdown capability is the ability of a cooling system to correctly function with a given amount of coolant loss.
b) Cross-flow radiators do not provide drawdown capability during operation, Even With A Standard Coolant Recovery Bottle.

* Only at cool-down will coolant from the recovery bottle be allowed back into the radiator.



WG1605_108A

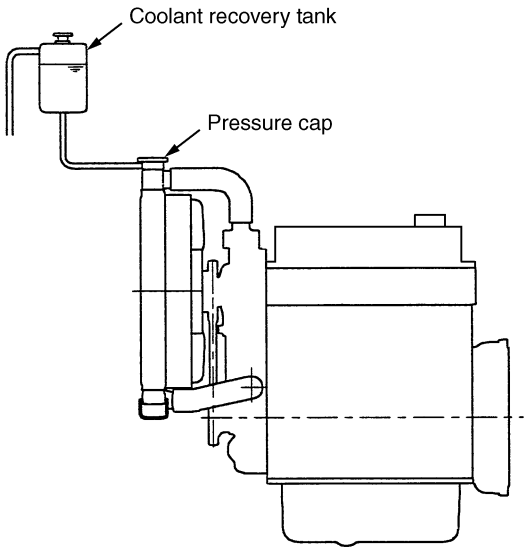
Figure 8-4

[3] RADIATOR POSITION

In case of mounting a radiator parallel to the crankshaft, positioning of other components, such as the fan belt drive system, becomes complicated. Non-standard positioning should be avoided as much as possible.

(1) Basic Arrangement

Basically a fan is installed on the water pump shaft, and a radiator position is shown in below.



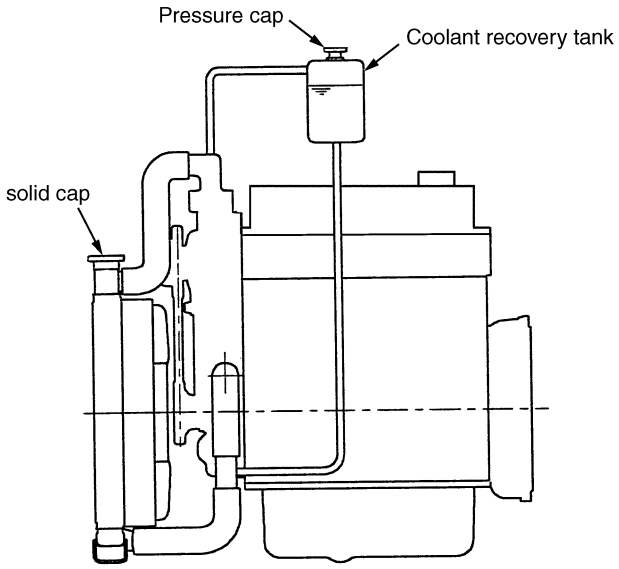
WG1605_056A

Figure 8-5

(2) Top Of Radiator Below Engine Water Outlet

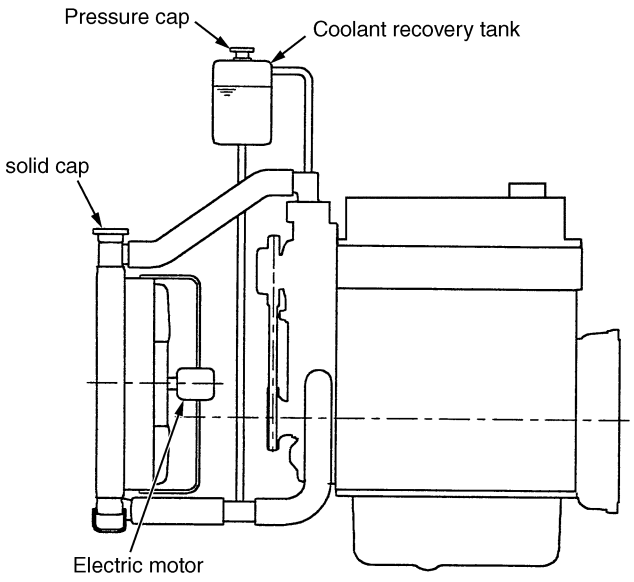
Sometimes a radiator is positioned at a lower level and the pressure cap may be positioned at a lower level than the rest of system. In this case, a special venting/bleed line arrangement is required.

Below are examples.



WG1605_057A

Figure 8-6



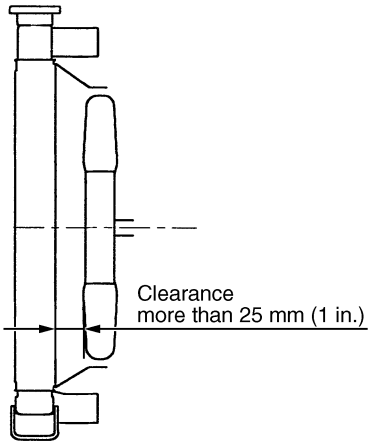
WG1605_058A

Figure 8-7

(3) Distance Between Fan And Radiator Core

Clearance between fan and radiator core should be kept as far as possible, within the space limitation in radiator mounting.

If the clearance between fan and radiator core cannot be maximized due to lack of space, it should be more than 25 mm (1 in.).



WG1605_109A

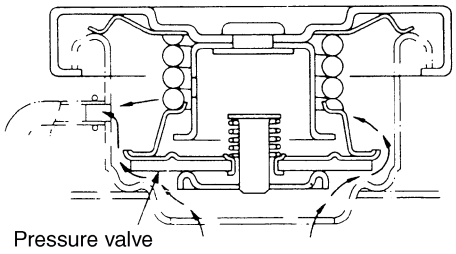
Figure 8-8

[4] RADIATOR CAP

Pressure inside a radiator is slightly higher than atmospheric pressure and is regulated by the radiator cap. [less than 88 kPa (0.9 kgf/cm2,12.8 psi)]

(1) Function Of Radiator Cap

[A] When internal pressure is high

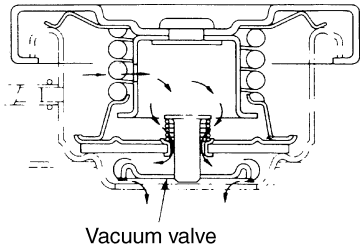


WG1605_011A

Figure 8-9

When temperature in the radiator increases, the coolant volume increases proportionally. This, combined with steam generation, may cause the internal pressure to rise up to 88 kPa (0.9 kgf/cm^2, 12.8 psi). The pressure valve opens, allowing coolant to escape and preventing rise in pressure. This protects the radiator.

[B] When radiator internal pressure is lower than atmospheric pressure



WG1605_010A

Figure 8-10

When coolant temperature drops, coolant volume decreases, reducing internal radiator pressure to below atmospheric pressure.

The vacuum valve opens, equalizing radiator internal pressure and atmospheric pressure, protecting the deformation of radiator.

3. COOLING FAN

A cooling fan moves the air required to disperse radiator heat. The exact type is generally selected after considering the following factors.

[1] AIR DIRECTION (SUCTION/PUSHER FAN)

- A suction type cooling fan is generally used on moving vehicles since air is taken in from the direction in which the vehicle is running.
- When enclosing an engine in a noise-proof case, a suction type fan is used to prevent noise from being discharged.
- A pusher type cooling fan is used for machines working in dusty places to prevent radiator clogging as cooling air passes through machine before entering the radiator.

[2] COOLING FAN DIAMETER

Generally, large diameter cooling fans provide sufficient cooling air at low rpm. However, the same cooling effect can be obtained with a smaller diameter fan by providing higher fan speed or fan blades with a steep-blade angle.

This allows a more compact installation.

[3] COOLING FAN SPEED

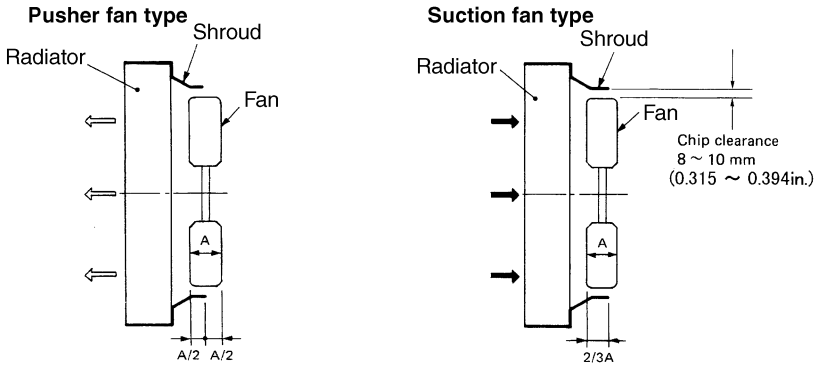
Standard KUBOTA cooling fans are driven by the crankshaft via a V-belt and pulley to rotate approx. 0.9 to 1.4 times faster than engine speed.

[4] SHROUD

A shroud is provided around the cooling fan on the radiator side to increase air flow efficiency.

The relative position of the shroud and fan are closely related to suction efficiency of air flow, but available positions are limited by the surrounding space.

Standard positioning is shown in below.



WG1605_012A

Figure 8-11

[5] AIR DISCHARGE

Generally, a 15 to 20% additional air discharge capacity is provided based on heat dispersion as a margin to ensure efficient cooling under most conditions.

[6] POWER REQUIREMENTS

Power consumed for fan drive is in proportion to air discharge and radiator core air flow resistance. The calculation expressions are as follows.

Ls = Lad / ηad

Ls : Horsepower requirements (PS)

Lad : Adiabatic compression horsepower (PS)

Lad = Pdf•Q / 4500

ηad : Adiabatic efficiency of fan (%)

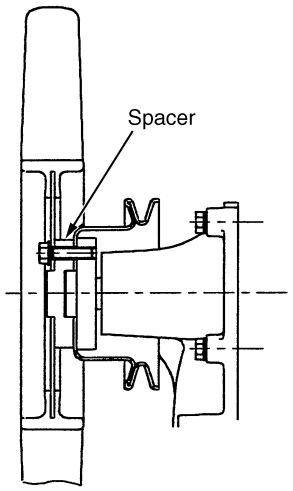
(Generally 50 - 70%)

Q : Suction capacity (m^3/min.)

Pdf : Compression difference between the push side and the suction side (mmAq)

[7] FAN SPACER

Various thickness spacers, which are installed between a fan and a water pump, are available. These are used to properly position the fan in the shroud. If thicker spacers than 21 mm (0.83 in.) are installed, details of the installation should be sent and reviewed with the KUBOTA Engineering Department, in order to avoid excessive loading on the water pump bearings. If larger diameter and heavier fans than the KUBOTA standards are installed, the spacers are not recommended.



WG1605_059A

Figure 8-12

[8] ELECTRIC FAN

Use of electric fans on vehicles for radiator cooling has been increasing recently.

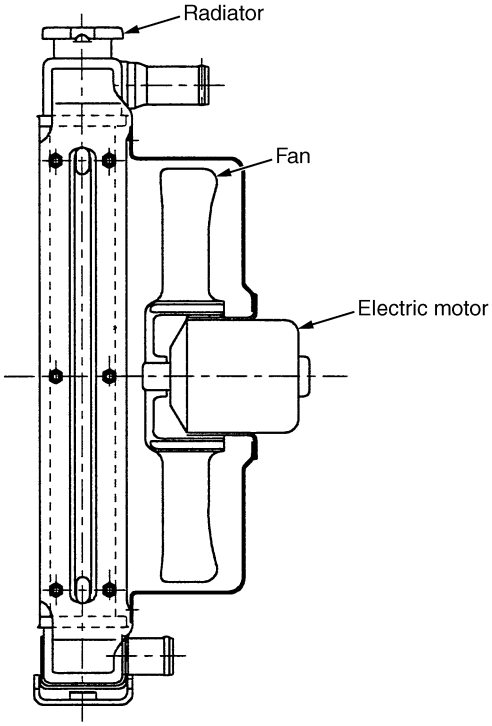
These fans turn at a constant speed regardless of engine speed.

However, in cases where cooling air is not enough due to insufficient vehicle velocity, the cooling effect on engine body, oil pan, etc is sometimes less than that of a direct-driving fan.

For this reason, cooling capacity and air flow around the engine must be examined and thorough tests conducted after the engine is installed.

Also, care must be taken to the capacity of alternator since the DC motor drives the fan.

Great care should be taken of the temperature setting for controlling the operation of the electric fan.



WG1605_060A

Figure 8-13

4. COVERING

Most engines are covered to some extent. Additional design importance is given to system compactness and noise reduction.

Covering encases the engine. The most important factor to be considered in covering the engine is heat radiation.

Air cleaner must be positioned where fresh, clean air is available. Care must also be used to avoid adverse effect on engine output.

[1] RADIATOR FAN

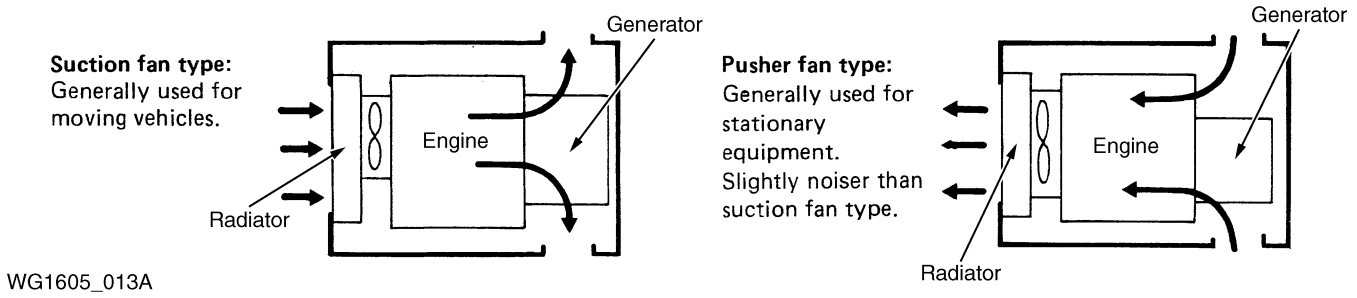


Figure 8-14

[2] HEAT BALANCE

When the engine is covered for noise reduction, check carefully cooling system on running to avoid over heat. It is very important.

[3] MAINTENANCE

Machines must also be designed for easy check, supply or replacement of fuel, lubricating oil, coolant and filter elements.

5. WATER PUMP

A centrifugal water pump with an impeller is mounted on top of the gear case at the front of the engine (radiator side). It pumps heated coolant from the cylinder head to the radiator. A seal is used to prevent leakage from around the pump shaft. The fan driving pulley is connected to the end of the pump shaft and both water pump and fan are driven by the crankshaft via the V-belt.

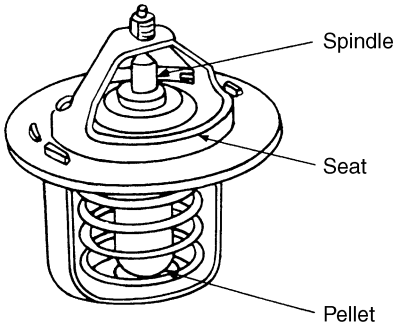
- The performance curves of water pump are in accordance with attached technical information.

6. THERMOSTAT

Coolant is adjusted to the proper temperature by the thermostat located at the upper part of the cylinder head before being fed to the radiator. With thermostat control the coolant does not enter the radiator when engine temperature is low and only circulates inside the engine until it reaches a certain temperature.

For WG1605

Valve opening temperature : 71 °C (159.8 °F)
Valve full open temperature : 85 °C (185 °F)
Valve lift : 8 mm (0.315 in.)

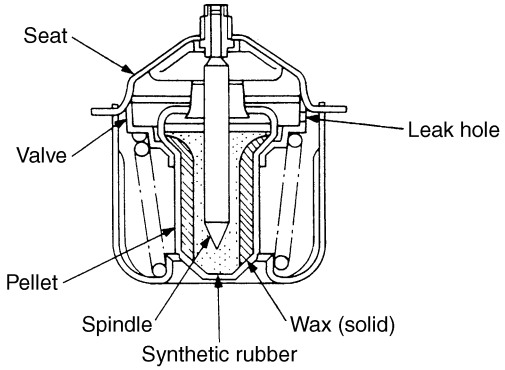


WG1605_014A

Figure 8-15

A wax pellet-type thermostat is controlled by waxed sealed in a pellet. The wax is solid at low temperature but liquefies and expands when heated to open the thermostat valve.

[1] AT LOW TEMPERATURE [BELOW 71 °C (159.8 °F)]

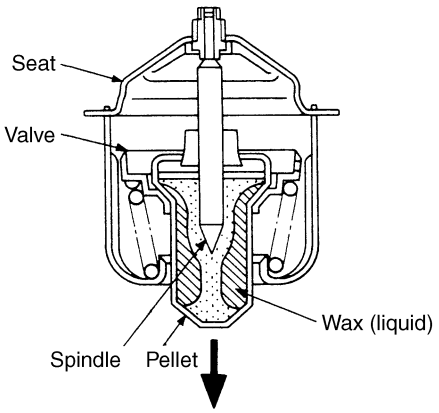


WG1605_015A

Figure 8-16

When the thermostat is closed, cooling water does not enter the radiator but only circulates inside the engine through the water return pipe. Any air remaining in the engine's water jacket escapes to radiator side through the leak hole in the thermostat.

[2] AT HIGH TEMPERATURE [ABOVE 71 °C (159.8 °F)]



WG1605_016A

Figure 8-17

When the coolant temperature exceeds 71 °C (159.8 °F), wax turns from a solid into a liquid and expands.

Since the spindle is fixed, the pellet pushes the valve from its seat, and coolant flows form the cylinder head to the radiator.

[3] COOLANT TEMPERATURE FOR KUBOTA ENGINES

The coolant temperature is under the control of load, engine speed. cooling fan, radiator, water pump, thermostat, type of enclosure, pressure of radiator cap, ambient temperature and so on.

In case that the coolant is the mixture of 50% water and 50% ethylene glycol, the allowable water temperature is as follows :

Allowable coolant temperature	110 °C (230 °F)
Pressure of radiator cap	82 to 96 kPa
	0.84 to 0.98 kgf/cm^2
	12 to 14 psi

■ **NOTE**

- **When a local radiator is procured by customers and pressure of the radiator cap is 48 kPa (0.49 kgf/cm^2, 7 psi), the allowable coolant temperature is 104.4 °C (220 °F).**

The coolant temperature must be under the above temperature at maximum ambient temperature condition [51.7 °C to 54.4 °C (125 °F to 130 °F)].

If an emergency shut down system is used, the temperature switch must be set at the allowable temperature listed in the above table.

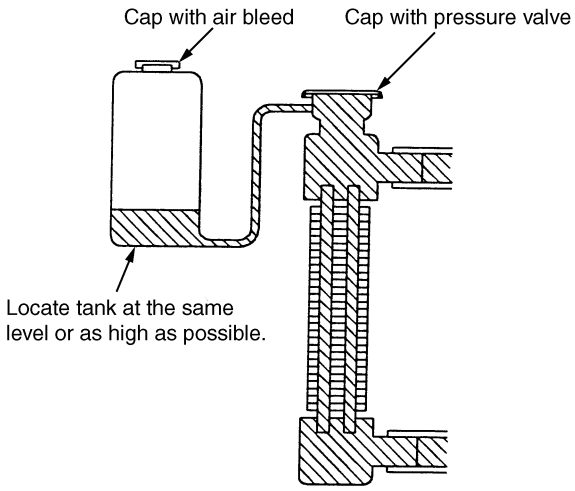
7. COOLANT RECOVERY TANK

The following benefits are provided by installing a coolant recovery tank independently to the radiator.

1. The radiator is always completely full which prevents entrance of air into the cooling system.
2. Any coolant overflow due to heat expansion is transferred to the coolant recovery tank and returns to the radiator when the temperature lowers. This eliminates coolant waste and the need to add coolant periodically.
3. Coolant is replenished to the coolant recovery tank only. Maintenance can be done easily if coolant level is visible.

Types of coolant recovery tanks

1. Semi-sealed type : An open-air type with slight natural evaporation of coolant, but low cost.
2. Actual capacity of a coolant recovery tank should be sized more than about 10% of total cooling system capacity.



WG1605_017A

Figure 8-18

8. COOLING SYSTEM PRECAUTIONS

[1] PREVENTION OF AIR ENTRAPMENT

If air should enter the cooling system at point of connection, it can result in abnormal boiling, reduced pump performance, and overheating locally. This can cause loss of coolant due to air expansion and other problems.

Connections must be carefully checked. The same applies to exhaust gas entering due to faulty cylinder head gaskets.

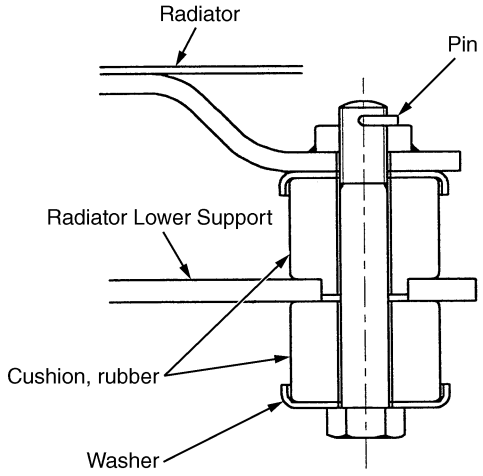
[2] RADIATOR SURFACE CLEANING

The surface of the radiator is important to overall cooling performance. If the surface becomes dirty, overheating will result. A dust net is sometimes provided at the front and a wiper is installed to automatically clean the surface according to circumstances.

[3] RADIATOR SUPPORT

A radiator must be properly supported to prevent vibration and impact if the engine is installed in a moving vehicle.

The Figure 8-19 shows typical radiator installation.



WG1605_110A

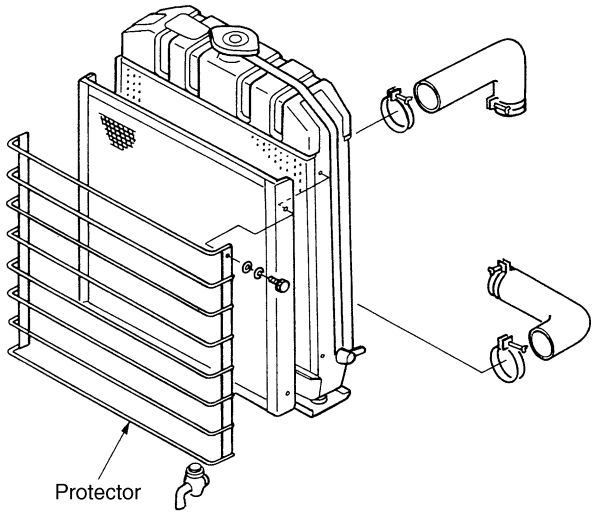
Figure 8-19

■ **NOTE**

- **Use upper support depending on the vibration level.**

[4] PROTECTION OF RADIATOR

If the radiator surface is directly exposed to outside, a protective frame should be installed around it. A typical example is shown in Figure 8-20.



WG1605_018A

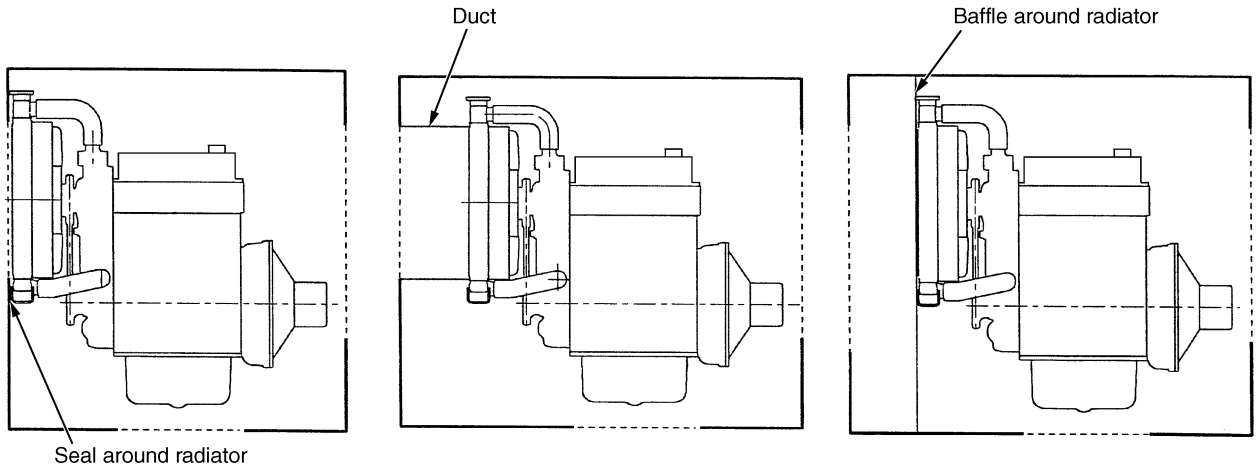
Figure 8-20

[5] PREVENTION OF AIR RECIRCULATION

It is important to take cool air into the radiator in order to get the best cooling effect.

Therefore when engine compartment is designed, suitable barriers and ducting arrangements around the radiator must be considered to prevent hot air recirculation.

Below show examples of compartment designs.

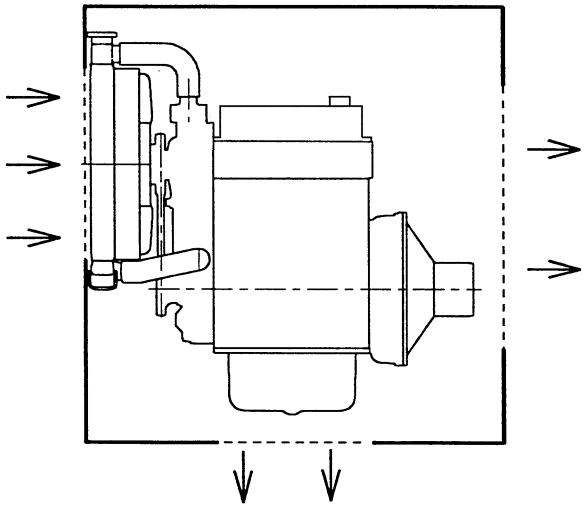


WG1605_020A

Figure 8-21

[6] ENTRANCE AND EXIT OF AIR BLOW

Open area of entrance and exit of air flow should be enough to prevent air flow reduction.
The open area should be at least, the same as radiator core area or more.
Opening the bottom of engine compartment is an effective way to make engine oil temperature lower.



WG1605_061A

Figure 8-22

9. HEAT REJECTION TO COOLANT

The amount of cooling loss, which can be dispersed by coolant in an engine is expressed as follows :

Ho = Hu × Ne × be × i

The amount of heat dispersion by coolant of each engine is in accordance with attached TECHNICAL INFORMATON.

where as ;

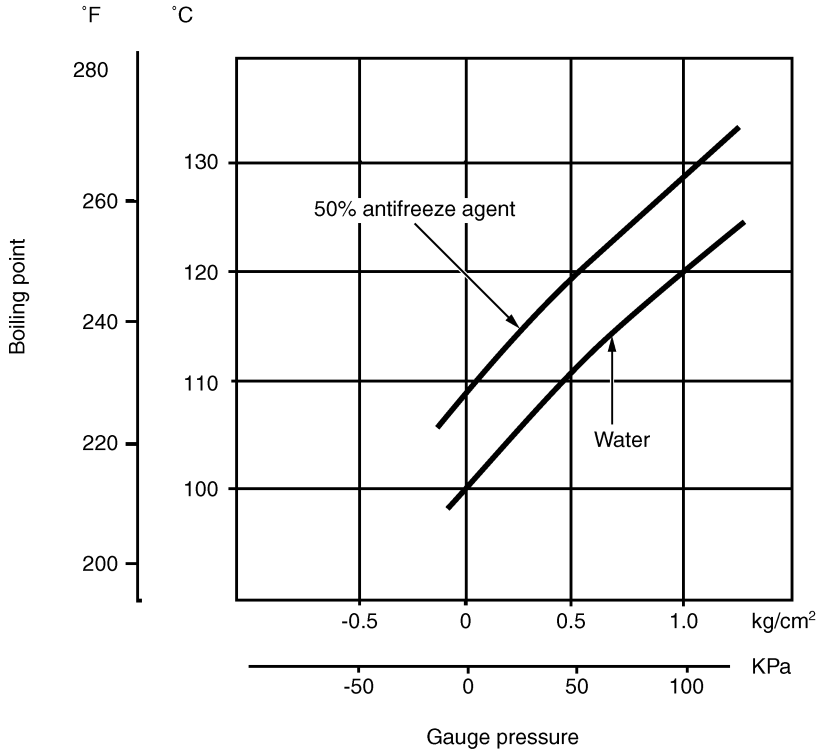
Ho : Heat rejection to cooling water
be : Specific fuel consumption ratio
i : Dispersion ratio to cooling water
Hu : Fuel lower heating value
Ne : Brake horse power

10. RADIATOR CAPACITY

[1] GENERAL

Generally, water at atmospheric pressure boils at 100 °C (212 °F).

As the pressure inside the radiator is raised higher than the atmospheric pressure, the boiling point is also raised, and thereby the coolant temperature in the radiator can be kept lower than the boiling point, thus preventing eventual cavitation inside the pump.



WG1605_111A

Figure 8-23

Rad. cap pressure	% of water / antifreeze	Boiling point	
		°C	°F
0 kPa {0 kgf/cm2 (0 psi) }	100% water	100	212
	50/50	108	226
88.2 kPa {0.9 kgf/cm2 (13 psi) }	100% water	118	244
	50/50	126	259

[2] DETERMINATION OF A RADIATOR SIZE

The final determination of a radiator size is dependent on the load, ambient temperature and whether the engine is in a compartment or not, always select a larger radiator if a severe condition exists.

(1) Factors Of Radiator Size Determination

[Operating condition]

Ambient temperature → Will the engine be open to the air or enclosed ?
Ambient pressure → Will the engine be used at high altitudes ?
Ambient humidity → Will the engine be used in extremely dry areas ?
Dust conditions → Will dust adhere to radiator surface ?
Movement of vehicle → Will the engine be installed in a moving vehicle ?
Load pattern → Will overloads be applied frequently ?
Cooling → Will the oil and/or hydraulic system also be cooled ?

[Construction]

Cooling water → How is it sufficient ?
Air flow → Is surrounding air normally still ?
Type of radiator → Is it readily available ?
Space → How much space is available for radiator installation ?

(2) Step Of Radiator Specification Determination

1. Determine heat load.
2. Determine overheating limit.
3. Determine specifications of cooling system.

[3] COOLING CAPACITY CHECKING METHODS

(1) Air-to-boil (ATB) Test

ATB is a quick and easy method to determine a machines present cooling efficiency and help predict the cooling performance at elevated ambient temperatures.

[Test equipment]

- Temperature meter or data collector and at least 6-thermocouple probes and 4-optional probes
- A 50/50 mixture of Ethylene Glycol anti-freeze must be used in the engine
- 88.2 kPa {0.9 kgf/cm^2 (12.8 psi)} rated radiator cap installed
- Blocked open thermostat
- Engine tachometer

[Test conditions]

(a) Ambient temperature of at least 24 °C (75 °F) is required for accurate testing.
If outside temperature is below 24 °C (75 °F) testing must be completed in a heated room.
  - Testing in temperatures below 24 °C (75 °F) or in high winds might produce inaccurate results.
  - Ambient temperature readings should be taken approximately 3 m (10 ft) from the machine.

(b) Machine must be tested at a duty cycle that represents the worst case scenario that the machine will be used in the field.

(c) All machine enclosure panels, screens and fan shrouding must be in place.

[Test setup]

1. Install blocked open thermostat.
2. Install thermocouples to record the following data.
   a) Radiator coolant in (Top tank)
   b) Radiator coolant out (Optional but recommended)
   c) Air cleaner inlet air
   d) Engine oil
   e) Exhaust gas
   f) Engine speed
   g) Ambient
   h) Radiator air in (Optional)
   i) Compartment air (Optional)
   j) Radiator air out (Optional)
   k) Hydraulic oil (Optional)

■ **NOTE**

- **Engine speed and exhaust temperature is required to estimate the engine loading.**
- **Radiator coolant temperature readings must be taken in the coolant stream.**
- **Ambient temperature readings should be taken 3 m (10 ft) from the unit.**
- **Oil temperature should be taken in the oil sump as close to the center as possible.**

3. Operate the unit at its most severe operating condition until the coolant temperature is stabilized (does not change more than 2 °C (36 °F) in 15 minutes).
   Stabilization usually takes place after operating the engine for 45 minutes to 1.5 hours under loaded condition.
4. Record data in Temperature Measuring Sheet in small time increments until stabilization temperature is reached.
5. To calculate ATB
   88.2 kPa {0.9 kgf/cm^2 (12.8 psi)} radiator cap

   ATB (Air-To-Boil) = (A-B) + C

   A = Theoretical coolant boiling temperature or maximum allowable coolant temperature
   - 110 °C (230 °F) is Kubota's maximum allowable coolant temperature with a 88.2 kPa {0.9 kgf/cm^2 (12.8 psi)} radiator cap.

   B = Top tank or engine coolant out line temperature (Thermostat fully open)
   C = Actual ambient temperature recorded during test

Example :

The radiator cap : 88.2 kPa {0.9 kgf/cm^2 (12.8 psi)}
The top tank coolant temp. : 90 °C (195 °F)
The ambient temp. : 29 °C (85 °F)
ATB = {110 °C (230 °F) - 90 °C (195 °F)} + 29 °C (85 °F)
ATB = 20 °C (35 °F) + 29 °C (85 °F)
ATB = 49 °C (120 °F)

[To evaluate ATB]

Kubota's minimum allowable ATB is 49 °C (120 °F).
An ATB below 49 °C (120 °F) indicates limited cooling reserve.
Using the above example, the ATB of 49 °C (120 °F) means that if the ambient temperature would rise from 29 °C (85 °F) to 49 °C (120 °F) then the top tank coolant temperature would rise to the maximum allowable of 110 °C (230 °F).

- The ATB is the maximum ambient temperature which the machine can operate in and not exceed Kubota's maximum coolant temperature.

The equipment manufacturer should determine the unit's anticipated operating ambient and design the cooling system to provide for proper cooling under all potential operating conditions.
Since it is not always possible to test the application at the highest anticipated ambient, a higher than 49 °C (120 °F) ambient should be the target.

[Summation]

1. ATB test can be used for engineering evaluations and is a part of a standard Application Review.
2. ATB should be **49 °C (120 °F) or higher**.
3. ATB figures higher than 49 °C (120 °F) will provide the greatest cooling reserve and maximum engine life.
4. The radiator inlet air temperature must not be more than -12 °C (10 °F) above ambient temperature, recorded 3m (10 ft) from the machine.
   Higher than -12 °C (10 °F) indicates poor air re-circulation.
5. The difference between the top tank temperature and bottom tank coolant temperature should be approximately -5 °C (10 °F).
   A greater differential might indicate too much restriction in the cooling circuit.
6. If the machine is operated at altitude, the air density and the cooling fan airflow across the radiator will decrease. Therefore, the higher the ATB the more reserve is available.
7. The use of 50/50 mixture of anti-freeze and water only adds about -15 °C (5 °F) to the top tank temperature over pure water.
   However, the boiling point under cap pressure of 88.2 kPa {0.9 kgf/cm^2 (12.8 psi)} increases from 118 °C (244 °F) to 126 °C (259 °F) using a 50/50 mixture.
8. Air filter inlet should be positioned to take in air at or near ambient temperature.
   High inlet temperatures can have a negative effect on ATB and oil temperature.
9. Oil temperature must be below 120 °C (248 °F) Intermittent Duty {110 °C (230 °F) Continuous Duty}.
   Elevated temperatures can increase oil oxidation and must be corrected.
   - Elevated oil temperatures can be a result of high air intake temperatures, high engine compartment temperatures, poor air recirculation or inadequate cooling system capacity.

[Sleeve used to hold thermostat open]

Sleeve length

Series	Length (L)
WG1605 series	14.0 to 14.5 mm (0.55 to 0.57 in.)

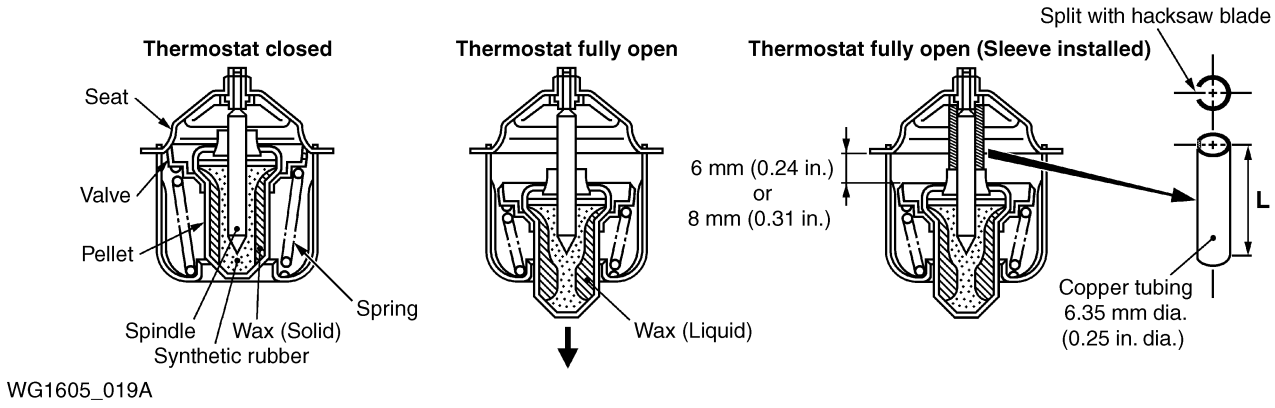


Figure 8-24

(2) Normal heat test

This method can be used instead of the air-to-boil test. Apply the maximum horsepower and torque to the engine at the maximum required operating temperature, and measure the engine water temperature to check for overheating.

11. COOLANT

Quality of coolant is an important factor.

Cooling is adversely affected by corrosion of engine parts. This can reduce engine output and shorten engine life.

[1] NATURE OF WATER

Water is used for cooling since it absorbs heat well and is readly available. Coolant boils at 100 °C (212 °F) freezes at 0 °C (32 °F) and has other disadvantages such as a tendency to leave deposits and corrode metal parts.

These disadvantages can cause cooling system problems. Special measures, such as those listed below, are required :

a) Raising of the boiling point by pressurizing the cooling system (Radiator cap) and using antifreeze.
b) Lowering the freezing point by using antifreeze.
c) Selecting water carefully and using a rust preventive.
d) Don't use hard water.

[2] DEPOSITS AND RUST

Deposits (scale) can be generated wherever water exists and can accumulate easily in the cylinder block and cylinder head where temperature is consistently high and where the radiator temperature varies greatly. Deposits will take the form of brown and sticky tar, and have very poor thermal conductivity. Accumulated deposits restrict water circulation and reduce the overall cooling effect.

Rust, on the other hand, is gathered on metal parts and restricts water circulation if left untreated.

Rust also lowers the overall cooling effect (like deposits), because it has poor thermal conductivity. Rusted metal surfaces become rough and pitted. Metal pieces can become scaled and thick and lose their strength, causing cracks or fatigue failure.

[3] GRADE OF WATER

Clean soft water should be used for the cooling system. Distilled water, tap water, and pure rain are especially recommended. Natural water generally contains minerals and sometimes salt, which can oxdize metal and accelerate corrosion. On the other hand, hard water is liable to create deposits more quickly. If impure water has to be used for cooling, completely flush the cooling system and add a rust preventive.

12. FREEZING AND ANTIFREEZE COOLANT

[1] FREEZING OF COOLANT

Water freezes at 0 °C (32 °F), and its volume expands approximately 9%. This expansion force is so great that water loses its fluidity. When the cooling water freezes in the cooling system, expansion can crack the engine and radiator or lead to other damage.

[2] MAJOR COMPONENTS OF ANTIFREEZE COOLANT

Freezing temperature is lowered to prevent the freezing of coolant by adding ethylene glycol, etc..

Ethylene glycol

Ethylene glycol has no odor, will not evaporate and will not affect paints and coatings. It has a high boiling point, and can be used along with an anti-corrosive agent in the summer.

[3] TYPES AND CHARACTERISTICS OF ANTIFREEZE COOLANT

KUBOTA recommends the use of ethylene glycol base antifreeze coolant of permanent type which is most commonly used.

Characteristics of permanent type antifreeze coolant

[Characteristics of antifreeze]

Main components	Ethylene glycol
Specific gravity 20 °C (68 °F)	Above 1.12
Boiling point	145 °C (293 °F)
Flash point	Flame retardant but burns
Hygroscopicity	Very easily absorbs humidity
Freezing of undiluted solution or mixture	Freezes sometimes below -20 °C (-4 °F)

[Characteristics during use]

Boiling point	100 to 113 °C (212 to 235.4 °F)
Evaporation of main components	Small evaporation
Boiling of during operation	No

[4] CAUTION IN USING ANTIFREEZE COOLANT

(1) Never use poor quality antifreeze coolant

The main components of the antifreeze coolant can corrode metal, gathering rust in the cooling system over an extended period. Corrosion is caused by acids and various kinds of additives which are used to neutralize them. Some additives give the cooling water alkaline properties that can rapidly corrode light metal.

Poor quality antifreeze has poor content of corrosion preventive. The content further becomes less potent with the dilution of water.

For this reason, poor quality antifreeze accelerates metal corrosion.

(2) Do not use antifreeze for extended periods

Except for quality permanent antifreeze coolant which does not require replacement for a long time. Drain the antifreeze coolant mixture when it is not in use and flush the cooling system.

Use of antifreeze coolant for an extended time can result in increased corrosion within the cooling system.

(3) Use permanent type ethylene glycol antifreeze coolant when temperature of coolant exceeds 100 °C (212 °F).

(4) Completely cover the container since the undiluted solution is hygroscopic.

(5) Undiluted solutions of permanent type can freeze below -20 °C (-4 °F) in some cases, so watch the temperature carefully.

(6) Never drink antifreeze coolant, because they are poisonous.

(7) Do not spill antifreeze coolant over painted surfaces since they may dissolve paint.

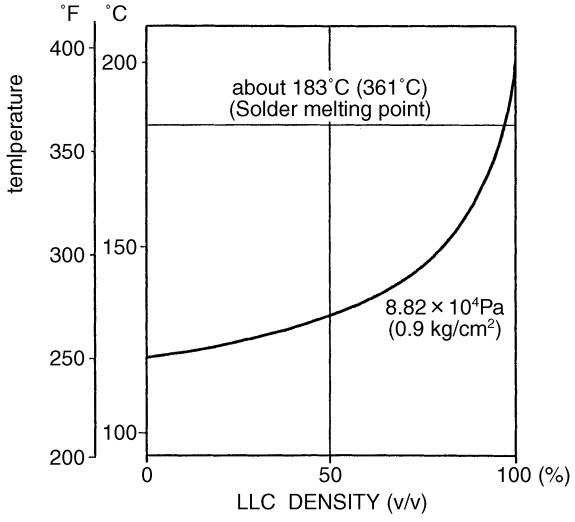
[5] DILUTION RATIONS

Always use a 50/50 mix of ethylene glycol coolant in KUBOTA engines.

Contact KUBOTA concerning coolant for extreme conditions.

When the density becomes too high, the boiling point rises and the solder strength lowers, resulting in a dangerous situation. The following drawing shows the relation between the boiling point and density.

LLC Density and Boiling Point



WG1605_112A

Figure 8-25

[6] ADDING ANTIFREEZE COOLANT

(1) Completely drain the cooling water and flush the cooling system.

(2) Check for leaks or loose connections at the radiator, cylinder head gasket, drain cock, etc..

(3) Mix antifreeze coolant and water at the specified ratio before pouring into engine.

(4) For replenishment, add 50/50 mix to cooling system for permanent types.

■ **NOTE**

- **If antifreeze and water are not mixed thoroughly, before putting into the engine, hot spots may develop leading to engine overheating.**

ELECTRICAL SYSTEM

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1. GENERAL

An electrical system consists of starting device, such as a starter ; charging devices, such as an alternator and battery ; control device, such as an ECU ; sensor devices, such as a water temperature sensor and a TMAP sensor ; actuator devices, such as a throttle body and a fuel pump.

2. STARTING DEVICE

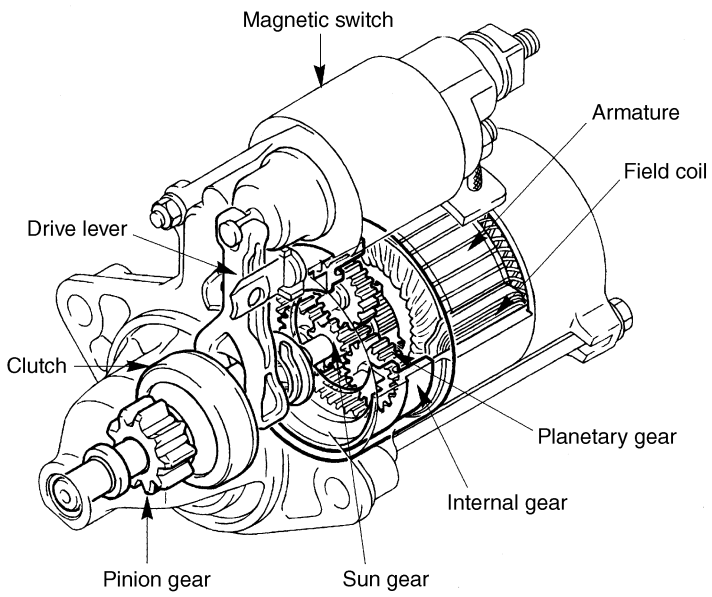
[1] GENERAL

The starting device is composed of the starter, starter switch, fuse, battery etc., and the outline of the basic operation is as the followings ;

1) Voltage from battery is added to the B terminal of starter switch through the fuse.
2) If the starter switch is turned on, B terminal will be connected to AC, and the electrical current will flow to each load.
3) If the starter switch is turned to the starting position, B terminal will be connected to AC, 19, and 50 will be connected to the ST terminal of starter (in case of the type with safety relay, it shall be connected via relay) to start the engine.
4) After the engine is started, if you have let your hand off the starter switch, it automatically returns to ON position.

[2] STARTER

(1) P Type Starters



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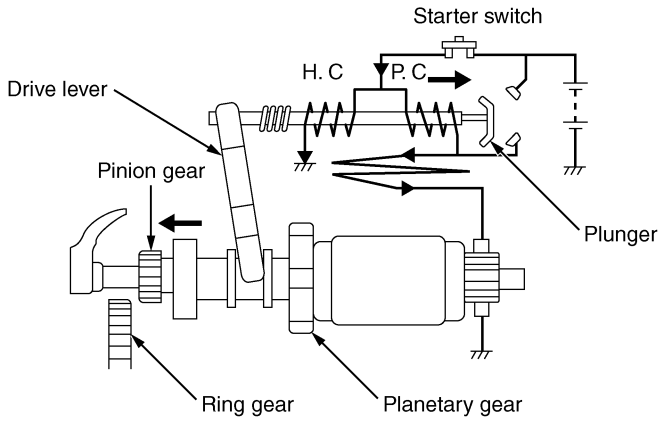
Figure 9-1

- The P type starters are reduction type starters that uses a planetary gears. The P types use the same type of compact, high-speed motor as the reduction type, and have planetary gears between the clutch and armature. As a result, a more compact and lightweight starter design has been achieved.
- To engage with the engine, the magnetic switch moves the clutch forward via the drive lever. The clutch slides along a shaft (planetary carrier shaft) connected to the planetary gears.
- The P type starters are equipped with shock absorbers that reduce the shock generated during starter actuation.

Starter switch on

When the starter switch is on, current flows to both the pull-in coil PC and holding coil HC, and the plunger is pulled in by the electromagnetic force generated in both coils.

The pinion gear is thus pushed out to the left, and engages with the ring gear.



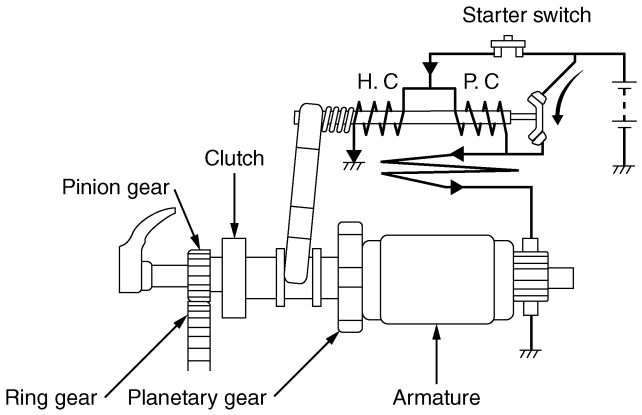
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Figure 9-2

When the pinion gear engages with the ring gear without collision

When the pinion gear engages with the ring gear at a certain position, the magnetic switch main contact closes, and a large current flows through the main contact to the armature.

The force of the armature spiral spline pushes the pinion gear forward, engaging the pinion gear with the ring gear to start the engine.

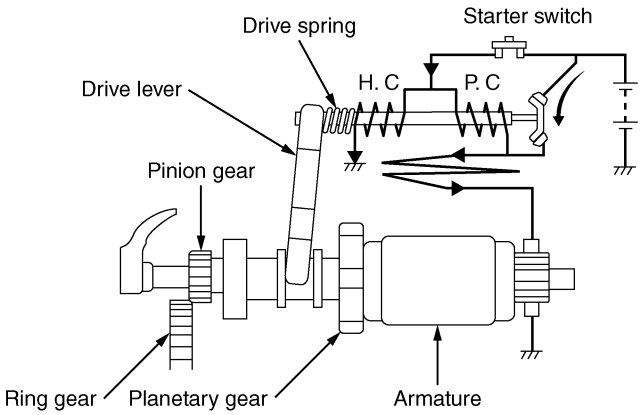


WG1605_117A

Figure 9-3

When the pinion gear and ring gear collide

If the pinion gear and ring gear teeth contact, the pinion gear cannot move any further. If this happens, the magnetic switch drive spring compresses, and the magnetic switch contact closes. As a result, the armature rotates at high torque, and the teeth alignment position slides. The compression force of the drive spring and the force of the armature spiral spline move the pinion gear forward, engaging the pinion gear with the ring gear to start the engine.



WG1605_118A

Figure 9-4

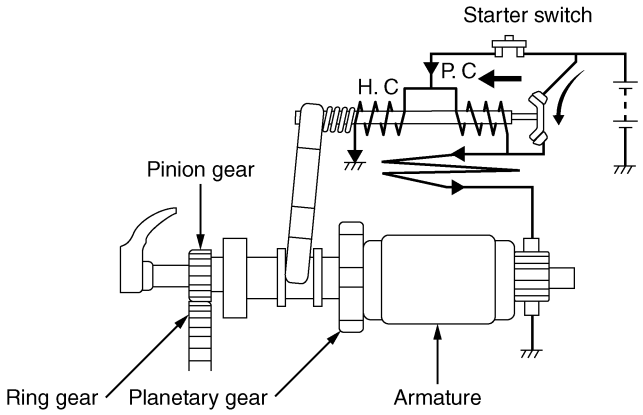
When the engine is started

When the engine starts, the clutch idles to prevent the ring gear from driving the armature in reverse.

Starter switch OFF

When the starter switch is turned OFF, the magnetic switch attraction is cancelled and the pinion gear is returned by the magnetic switch return spring.

The main contact then opens, interrupting the flow of current to the armature.



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Figure 9-5

(2) Overrunning Clutch

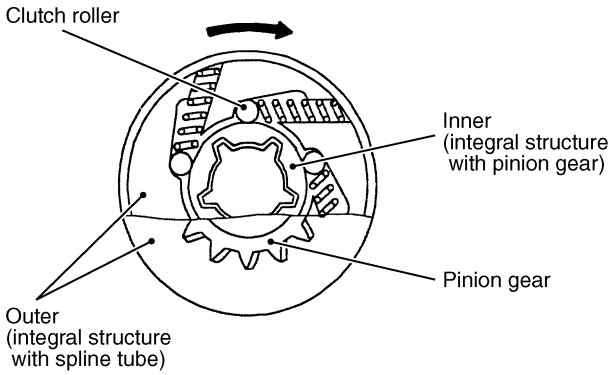
Function

In case that the pinion gear and ring gear are still intermeshed even when the engine is started, the motor will be forced to run in abnormal rotation, and the armature, brush, etc. will be damaged.

In order to prevent such an error, the overrunning clutch will function as the device to let the pinion race against the armature shaft when the engine is started, and to shut off transmission of rotation of the engine to the motor.

Action

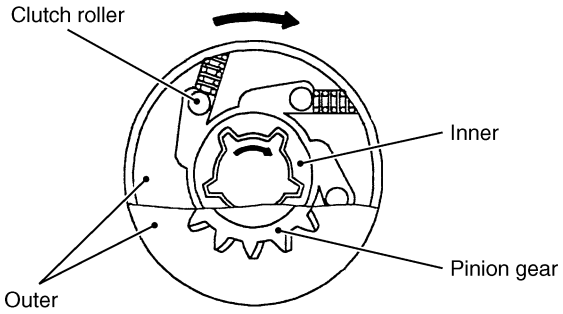
1) When starting:
   If the outer is rotated in the arrow mark direction receiving rotation of the armature, the clutch roller will be pushed toward the narrower side of clearance between the outer concave side and the inner so that the outer and inner will be locked. The roller will function as a wedge between the inner and outer, and will transmit the rotation of the outer to the inner, and both will rotate in the same speed.
2) After the engine is started:
   When the pinion is forced to rotate by the ring gear, rotation of the inner (rotation of engine x gear ratio) will become faster than that of the outer (a number of rotation of armature), and the clutch roller will move toward the direction that compresses the spring.
   Consequently, clearance between the outer concave side and the inner becomes wide to prevent overrunning of the armature.
   (It is required to decrease the contact pressure of the pinion gear and ring gear to realize smooth separation of the pinion gear, and for the sake of this, the pinion gear must be in the state of racing.)



State that the outer and inner are rocked.

WG1605_089A

Figure 9-6



State that the outer and inner are free.

WG1605_090A

Figure 9-7

[3] STARTER SWITCH

Starter switch is an important part comprising of the starting device of engine. Particularly, as seizing of the starter may be incurred due to failure of the starter switch, careful consideration is required for the installation position, place, and direction, so that rain or cleaning water should not directly splash on the starter switch.

Shown in the Figure 9-8 is an example of a starter switch.

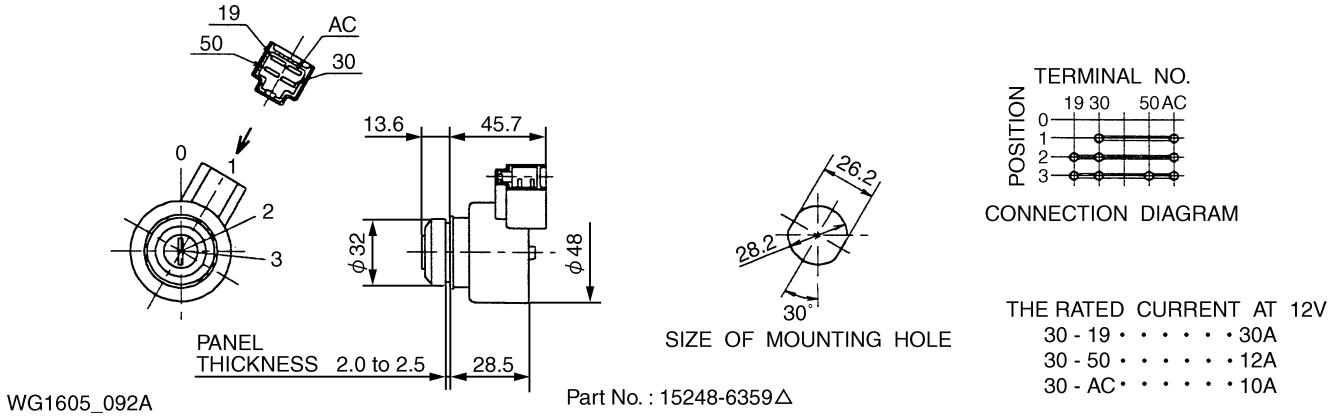


Figure 9-8

[4] STARTER SAFETY SYSTEM

The ECU can be configured for either auto cranking (crank until starting) or crank limiting (maximum crank time and disabling of starter if frequency and number of attempts is too high).

3. CHARGING DEVICE

[1] GENERAL

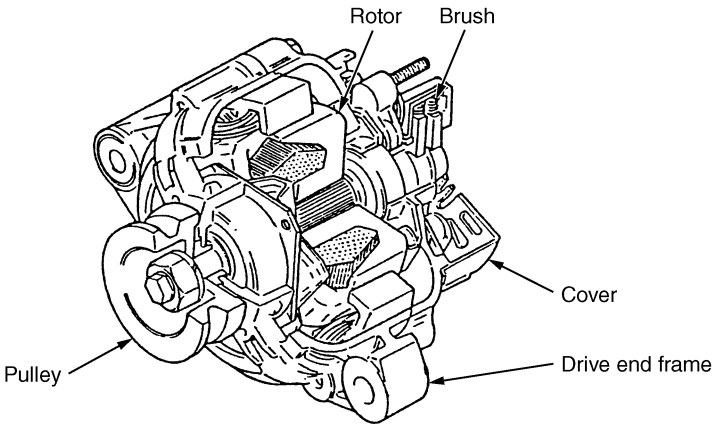
The function of the charging device is to charge batteries.

[2] IC REGULATOR BUILT-IN TYPE ALTERNATOR

The alternator is the incorporated with an IC regulator, this has been made small size and light weight by the semiconductor technique of the IC regulator.

The cooling property and safety is improved by incorporating the cooling fan and roller that is an integral structure.

Further, the serviceability is also improved by facilitating mounting and removal of the rectifier and IC regulator.



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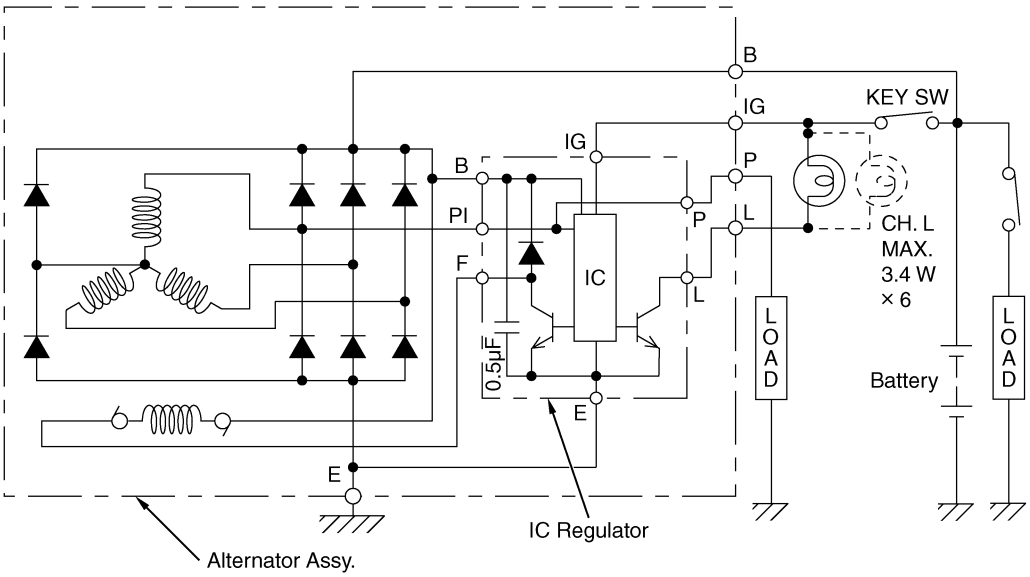
Figure 9-9

D2 Type Regulator

IC regulator has a special feature that makes it possible to interrupt field current by using the transistor or IC instead of the contact-point-type regulator.

IC regulator has the special features as follows :

1) Readjustment for this regulator is unnecessary because the control voltage does not change over time. Further, vibration-proof property and durability is excellent because IC regulator has no moving parts.
2) Since IC regulator has over-temperature compensation property, which makes the control voltage low if the temperature is increased, it makes it possible to properly charge the batteries.
   The circuit inside IC regulator is as shown in the following figure.
   It is composed of the monolithic IC-incorporated hybrid IC. (Since the inside circuit of the monolithic IC is extremely complex, it is described as M.IC circuit.)
   Tr1 has the function as the contact point to control field electrical current, and as the charging lamp relay to light the charging lamp.
   M.IC controls Tr 1 and Tr 2 by detecting decrease of the output voltage of alternator, decrease of the L-terminal voltage, disconnection of the rotor coil, etc.



WG1605_114A

Figure 9-10

Charge Light Control

Turns the charge light ON and OFF in accordance with alternator power generation.

Standard pulley dimensions

Fan drive pulley mm (in.)	Alternator pulley mm (in.)
105 (4.13)	58.5 (2.30)

Specification of alternator with IC (incorporated with) regulator

Nominal voltage	12 V
Maximum output	40 A, 60 A
Rotational direction	Right as seen from pulley side
Armature wiring	3 phase, Y wiring
Rectifying system	Total wave rectification★
min^{-1} (rpm) at no load (when cold)	14 V at 0 A 1050 to 1350 min^{-1} (rpm)
min^{-1} (rpm) at max. output (when cold)	14 V at maximum output below 4000 min^{-1} (rpm)

Generating capacity will be determined by rpm of engine and pulley ratio.

★ Total wave rectification

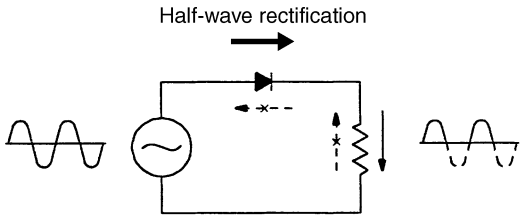
In case of the generator for mobile equipment of which purpose is to charge the batteries, alternating current cannot be used as it is. Because of this, it is required to conduct the action called rectification so that the alternating current can be changed to direct current. Alternator conducts rectification by means of diode.

If the voltage is applied to diode in the normal direction, enough electrical current can flow even by small voltage, however if applied in the reverse direction, it inhibits the reserve flow of electrical current.

Using this property, alternate current generated in the stator coil is changed to the direct current.

As for the rectification using diode, there are two methods, i.e., 'half-wave rectification' that takes out only positive portion of alternate current, and 'total-wave rectification' that rectifies both positive and negative current and change to the direct current.

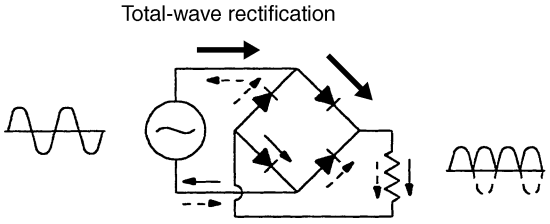
Half-wave Rectification



WG1605_098A

Figure 9-11

Total-wave Rectification

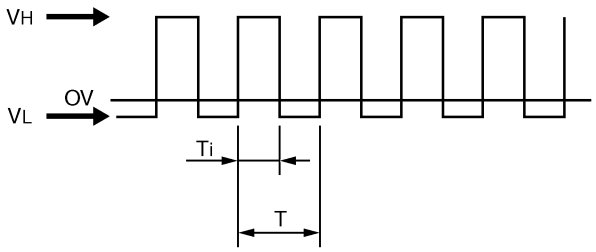


WG1605_099A

Figure 9-12

Alternator P Terminal

(1) P terminal waveform: The alternator P terminal outputs rotation signals required by a tachometer, etc.
The P terminal corresponds with one phase of the alternator stator and the output waveform during power generation is a waveform equivalent to the rectangular wave with a frequency in proportion to the number of revolutions of the alternator.



Reference waveform (outline)

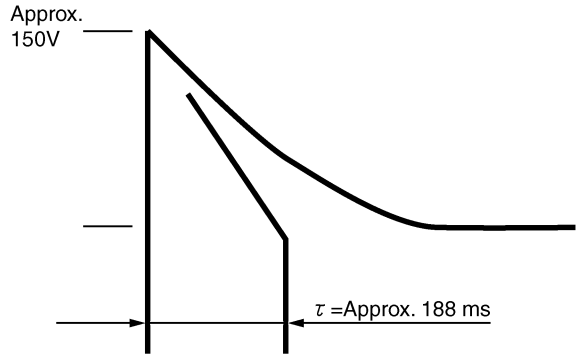
WG1605_100A

Figure 9-13

Frequency (1/T) : Number of revolutions of alternator [rpm] / 10 [Hz]
Duty (Ti/T) : approx. 50 %
VH (average) : about +0 to 2 V with reference to the alternator B terminal voltage (average)
VL : about −2 to 0 V

■ **NOTE**

- **As with the B terminal waveform, the P terminal waveform includes noise, which varies depending on the number of revolutions, output and wiring (see the waveform in a separate material).**
- **Surge voltage may be generated by any charging cable disconnection (especially with high number of revolutions/high output), etc.**



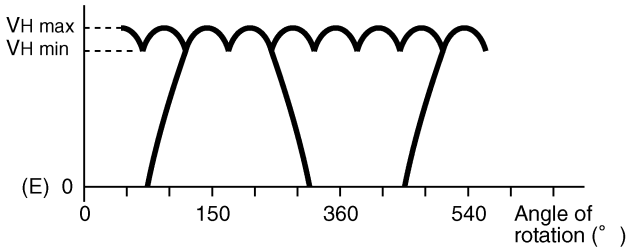
WG1605_101A

Figure 9-14

Surge voltage waveform with any charging cable disconnection. (Alternator : F3A - H, 40 A 15000 rpm, max output)

- **May be VHmin = 6.5 V in high electric load shedding or unloaded condition with the battery fully charged.**

P terminal voltage with reference to the GND (E)



WG1605_102A

Figure 9-15

(2) Load connected to the P terminal
P terminal output current: 0.5 A max (average current)

■ **NOTE**

- **Ensure that there is no load short circuit or wrong wiring.**
- **Do not connect inductive or capacitive load (connection of such load subject to discussion of the specification).**
- **When detecting a waveform, take the noise and VHmin into consideration.**
- **Take the surge voltage into consideration for the input of the load.**
- **Use the actual equipment for sufficient check of the operation of the load.**

4. CONTROLLING DEVICE

[1] ECU

The ECU will utilize signal inputs from the engine sensors, to control the fuel metering and speed control, while the engine is running. As well, the ECU will provide diagnostic control, over the fuel system.

Normal operating temperature range : –40 to 105 °C (–40 to 221 °F)
Maximum allowable vibration : 5 G

Current consumption of WG1605.

Gasoline

Engine Speed (rpm)	Current Consumption (A)	
	AVG.	MAX. (Ignition Coil ON)
800	4.2	11.0
3000	5.6	12.4
3600	5.7	12.4

LPG

Engine Speed (rpm)	Current Consumption (A)	
	AVG.	MAX. (Ignition Coil ON)
800	2.0	8.6
3000	3.0	10.0
3600	4.1	10.8

5. SENSOR DEVICE

[1] WATER TEMPERATURE SENSOR

Ignition timing, fuel rate, and boost levels can be configured to vary with engine coolant temperature. This is typically done at very cold or very hot conditions. Coolant temperature is also used in the airflow models in the ECU.

Operating temperature range : –30 to 120 °C (–22 to 248 °F)
Storage temperature range : –40 to 120 °C (–40 to 248 °F)

Resistance characteristics

Temperature	Resistance
°C	kΩ
–20	13.84 to 16.33
0	5.74
20	2.32 to 2.59
40	1.15
60	0.584
80	0.310 to 0.326
100	0.1836
110	0.1399 to 0.1435

[2] TEMPERATURE AND MANIFOLD ABSOLUTE PRESSURE SENSOR (TMAP SENSOR)

TMAP sensor is mounted in the intake manifold and measures the absolute pressure as well as the temperature of the air/fuel stream. MAP data is used by the ECU for calculating airflow pressure. The temperature information from the TMAP is used for a density correction in the mass air flow calculation.

Operating temperature range : –30 to 120 °C
Storage temperature range : –40 to 120 °C
Performance characteristics

Pressure Sensor

Pressure	Voltage
kPa	**V**
20	0.729 to 0.849
46.66	1.782 to 1.902
101.32	3.94 to 4.06

at -30 to 120 °C
(-22 to 248 °F)

Temperature Sensor

Temperature	Resistance
°C	**kΩ**
0	5.4 to 6.6
80	0.282 to 0.388

[3] CRANKSHAFT POSITION SENSOR

The Crankshaft Position Sensor provides engine speed information.

Operating temperature range : –30 to 120 °C (–22 to 248 °F)
Storage temperature range : –40 to 120 °C (–40 to 248 °F)
Resistance between the terminals : 1850 to 2450 Ω at 20 °C

[4] CAMSHAFT POSITION SENSOR

The Camshaft Position sensor informs the ECU which cylinders are in compression to signal spark timing.

Operating temperature range : –20 to 200 °C (–4 to 392 °F)
Storage temperature range : –30 to 60 °C (–22 to 140 °F)
Resistance between the terminals : 470 to 530 Ω

[5] KNOCK SENSOR

The knock sensor is used to detect detonation through mechanical vibration in the engine block and / or cylinder heads and provide feedback for the ignition system to retard spark to reduce knock intensity.

In most applications the knock sensor is used to protect the engine from damage that can be caused from detonation or knock based on fixed spark advance.

Operating temperature range : –40 to 130 °C (–40 to 266 °F)
Sensitivity at 5kHz (with new sensor) : 18 to 34 mV/g
Change of sensitivity over lifetime : max. –17 % at room temp. 18 to 28 °C, humidity of 45 to 75 % rH



WG1605_145A

Figure 9-16

[6] FUEL PRESSURE MANIFOLD (FPM)

The ECU is equipped to provide Pulse Width Modulation control of the fuel pump. This control feature and fuel pressure manifold combination prevent the build-up of excess heat in the gasoline tank which in turn reduces the evaporative emissions.

Operating temperature range : –40 to 125 °C (–40 to 257 °F)

Pressure Sensor

Pressure	Median Voltage
kPa	**V**
50	0.50
1000	4.50

Temperature Sensor

Rated resistance : 2.35 to 2.65 kΩ at 20 °C (68 °F)

6. ACTUATOR DEVICE

[1] THROTTLE BODY

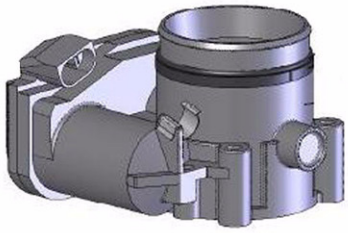
The ETB is connected to the intake manifold of the engine.

The ETB utilizes an electric motor connected to the throttle shaft. In addition, an accelerator position sensor (a foot pedal position sensor) is located in the operator's compartment.

When the engine is running, electrical signals are sent from the accelerator position sensor (the foot pedal position sensor) to the Engine Control Unit (ECU) when the operator depresses or releases the foot pedal.

The ECU then sends an electrical signal to the motor on the ETB to increase or decrease the angle of the throttle blade, thus increasing or decreasing the air flow to the engine.

Environmental temperature range : –40 to 140 °C (–40 to 284 °F)
Storage temperature range : –10 to 50 °C (14 to 122 °F)



WG1605_146A

Figure 9-17

[2] FUEL PUMP

The fuel pump has a roller vane type pumping element driven by an electric motor with permanent magnets. The motor is flown through with fuel without forming an explosive composition. Nominal fuel pressure is 300 kPa.

Storage temperature range :–30 to 60 °C (–22 to 140 °F)
The atmospheric humidity must not exceed 60 % during storage.
Ambient temperature range : –40 to 80 °C (–40 to 176 °F)

Permissible vibrational acceleration : 3 G
Maximum allowable suction pressure : ≤10 kPa (below ambient pressure)

[3] DIRECT ELECTRONIC PRESSURE REGULATOR (D-EPR)

The D-EPR controls the gaseous fuel rate to the engine by regulating the pressure supplied to the air/fuel mixer.

Maximum vibration operating : <15 G
Nominal operating temperature range : –40 to 105 °C (–40 to 221 °F)
Storage temperature range : –40 to 135 °C (–40 to 275 °F)

[4] LOCK-OFF VALVE

Fuel Lock-off Valve is used to isolate the D-EPR and all downstream components from upstream fuel pressure when the engine is shut-off.

Operating temperature range : –20 to 120 °C (–4 to 248 °F)
Coil resistance : 12.15 to 13.15 Ω at 20 °C (68 °F)
Burst pressure : >6.75 MPa

[5] IGNITION COIL

Ignition coil is a transformer to generate high electric voltage necessary for the ignition. Around the iron core of multi-layer thin crude steel plates, secondary coil is wound, on whose outside, in the same direction, primary coil is wound. The empty space in the case is filled with resin for electric insulation and good heat radiation.

The ignition timing is controlled by ECU and the high voltage is applied to the spark plugs by the ECU signals.

Operating ambient temperature : –30 to 120 °C (–22 to 248 °F)
Storage ambient temperature : –40 to 130 °C (–40 to 266 °F)
Primary resistance : 0.63 to 0.77 Ω at 25 °C (77 °F)
Secondary resistance : 7.29 to 8.91 kΩ at 25 °C (77 °F)

7. WIRING

[1] CAUTIONARY ITEMS FOR WIRING

(1) Equipment should be grounded securely. When the grounding is not properly done, necessary amount of electrical current will not flow, and function of electrical equipment will not be exhibited fully. For example, it is possible that insufficient grounding of the starter will cause failure to start, and in addition, after repeating the starting many times, the starter will seize. Therefore, select a clean metal surface for the grounding wire attachment (on the main machine side as well as engine side), and completely remove the paint to make the contact resistance as low as possible.

(2) The wire diameter of wiring and the electrical current capacity of each fuse are shown in the wiring diagram. However, these are only recommended values, and therefore when applying to the actual case, be careful to use the correct sites taking into consideration the length of wiring and the connection form.

(3) Wiring should be routed and secured, be careful so that the insulation will not be worn off due to contact with other parts during operation, and short circuiting will not occur.
Further, it recommended to protect wiring with corrugated protective covers.

(4) In case that wiring is made mistaking the polarity, wiring materials may be burned and damaged, or it may result in personal injury.
It is important that any mistaken wiring never be made, and in addition, attention and care (by changing the colors and length of wire) should be taken not to let workers perform incorrect wiring.

(5) Use low-voltage wires for automobile (AV SS wire, etc.) for wiring. However, in case that the ambient temperature is more than 75 °C (167 °F), use heatresistant wires (AVX wire, etc.).

(6) To protect wiring, use a fuse or slow-blow fuse.

(7) As for the load that may incur when unexpected current comes into the circuit, such as the case of motors, be careful not to directly connect to AC and any wires connected directly to battery '+'.

(8) Attach covers to the terminal on the terminal on the positive side of the battery to prevent sparks due to accidental contact.

[2] SIZE OF WIRING

(1) General

1) The size of wiring shall be determined taking into consideration the various factors such as the length of cable, electrical current value, allowable voltage drop, etc.

2) When electrical current 'A' (Amperes) flows in the circuit, the resistance 'ohms' always exists as the result of electrical power loss in the cable, and the voltage will be decreased.
The difference between the voltage of electrical power source and the voltage at the connection end of the cable of each equipment is the voltage drop leading to poor performance.

3) Excessive electrical power loss in the cable will cause overheating of the cable and drastic voltage drop.
To resolve such a problem, it is important to take into consideration that the cable resistance is the accumulated value of complete circuit and to correctly use the specified cables.

4) The rated value of the cable shall be determined according to the allowable electrical current value. Electrical resistance depends on the total sectional area of the conductive material (wire).
It is possible to minimize the electrical power loss and voltage drop by using correct cables.
It is important to restrain the temperature increase of the cable for the cables that are used together in a harness.

5) All of the voltage drop in the circuit should not exceed 10% of the regular voltage. (For example, 1.2 V in case of 12 V circuit.)
The voltage drop expected to occur in the circuit can be measured by using the simple formula as shown in below :
Voltage drop = Current value Total cable resistance

6) For the cables in which electrical current will flow continuously for a long period of time, attention and care must be taken for both the temperature increase and voltage drop, and on the other hand, as for the circuit to be used for a short time, care must be taken for the voltage drop.

(2) Battery cable

The battery cable is the first 'connection' in the electric system of engine. Attention and care should be taken so that this cable should be of the sufficient size matching the electrical current required, and the length should be as short as possible.

Take care to securely install the battery terminals, and tightly clamp the cables.

Voltage drop against each battery cable should not exceed 0.6 V DC − 0.8 V DC.

Recommended battery cable :

Cable size 20 mm^2 (AWG size 4) or more.

Cable length 2 m or less.

8. BATTERY

The battery makes it possible to store electric energy as chemical energy, and to take it out as electric energy as needed.

Further, a battery is the device that can repeatedly charge and discharge.

[1] FORMULA OF DISCHARGING AMOUNT

Discharging amount (Ah) = Rated capacity (Ah) × (S.G. when fully charged - S.G. when measuring) / (S.G. when fully charged - S.G. when fully discharged)

In general case :
S.G. when fully charged : 1.28 {20 °C (68 °F)}
S.G. when fully discharged : 1.12 {20 °C (68 °F)}

S.G. : Specific Gravity

Battery capacity is indicated by the electricity amount that can be taken out before the voltage reaches the discharging end voltage, after the fully charged battery is continuously discharged with a electrical current.

Capacity (Ah) = Discharging currenct (A) × Time until discharging end voltage (Hr)

[Meaning of 45 Ah / 20 Hr]
45 Ah / 20 Hr = 2.25 A … 20 hour rate current

Capacity is determined when the battery voltage becomes the discharging end voltage, when the battery is discharged for 20 hours at 2.25 A.

[2] TEMPERATURE RECTIFICATION

Temperature compensation should be made for the specific gravity measured by a gravimeter.

This specific gravity value will indicate that “it is low when the temperature is high”, and “it becomes high when the temperature becomes low”.

Generally, the specific gravity of the electrolyte of battery shall be taken using the temperature of 20 °C (68 °F) as the standard, and as for the rate of the change, the specific gravity decreases by 0.0007 against a temperature increase of 1 °C (34 °F), and the specific gravity increases by 0.0007 against the temperature of 1 °C (34 °F).

It is convenient to use the following formula to convert the specific gravity measured at a certain temperature into the standard temperature of 20 °C (68 °F).

S20 = St + 0.0007 (t - 20)
S20 : S.G. at the temperature of 20 °C (68 °F)
St : S.G. at the temperature of t °C

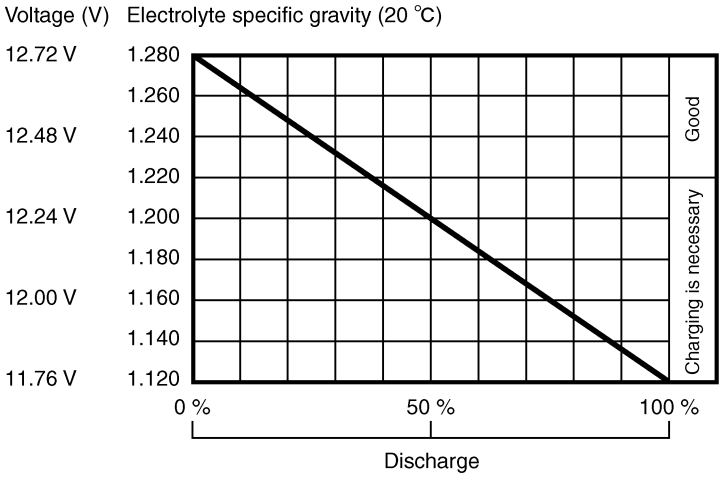
[Example : In case of electrolyte temperature of 40 °C (104 °F)
Reading of gravimeter : 1.240
S20 = 1.240 + 0.0007 (40 - 20) = 1.254

Consequently, the S.G. converted into 20 °C (68 °F) is 1.254. If looked at on the gravimeter, it appears that it is discharged by about 10%, however, if converted into the standard temperature, it is practically near to the state of full charge.

The charged or discharged state of battery can be known by measuring the S.G. of the electrolyte.

When measuring S.G., it can easily be performed comparatively by using a suction gravimeter.

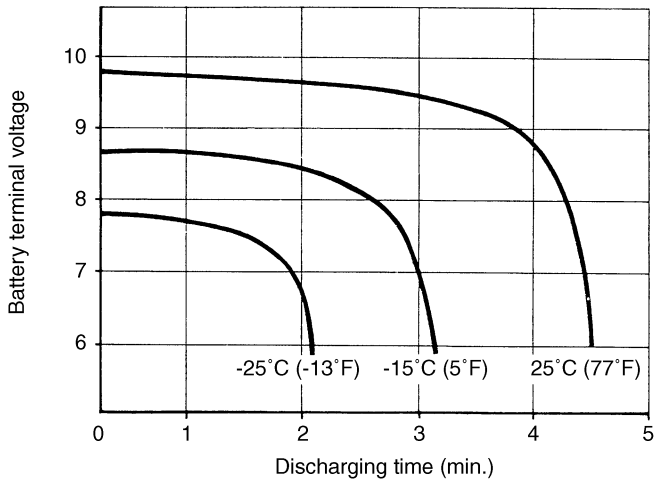
[3] RELATION BETWEEN SPECIFIC GRAVITY OF ELECTROLYTE AND DISCHARGING AMOUNT



WG1605_104A

Figure 9-18

Gravity of electrolyte 20 °C (68 °F)	State of discharging
1.280	100
1.240	75
1.200	50
1.170	25
1.120	Totally discharged

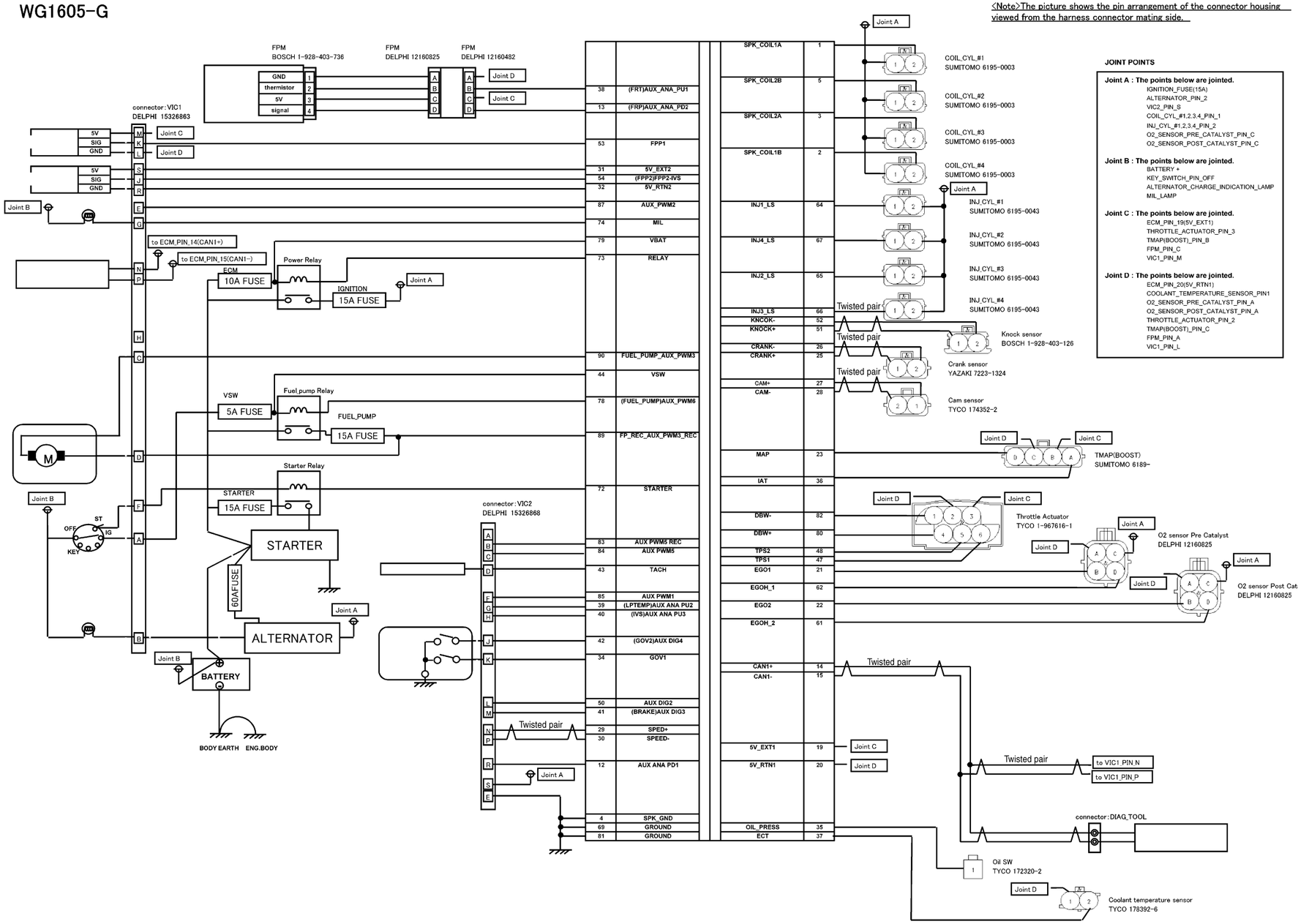


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Figure 9-19

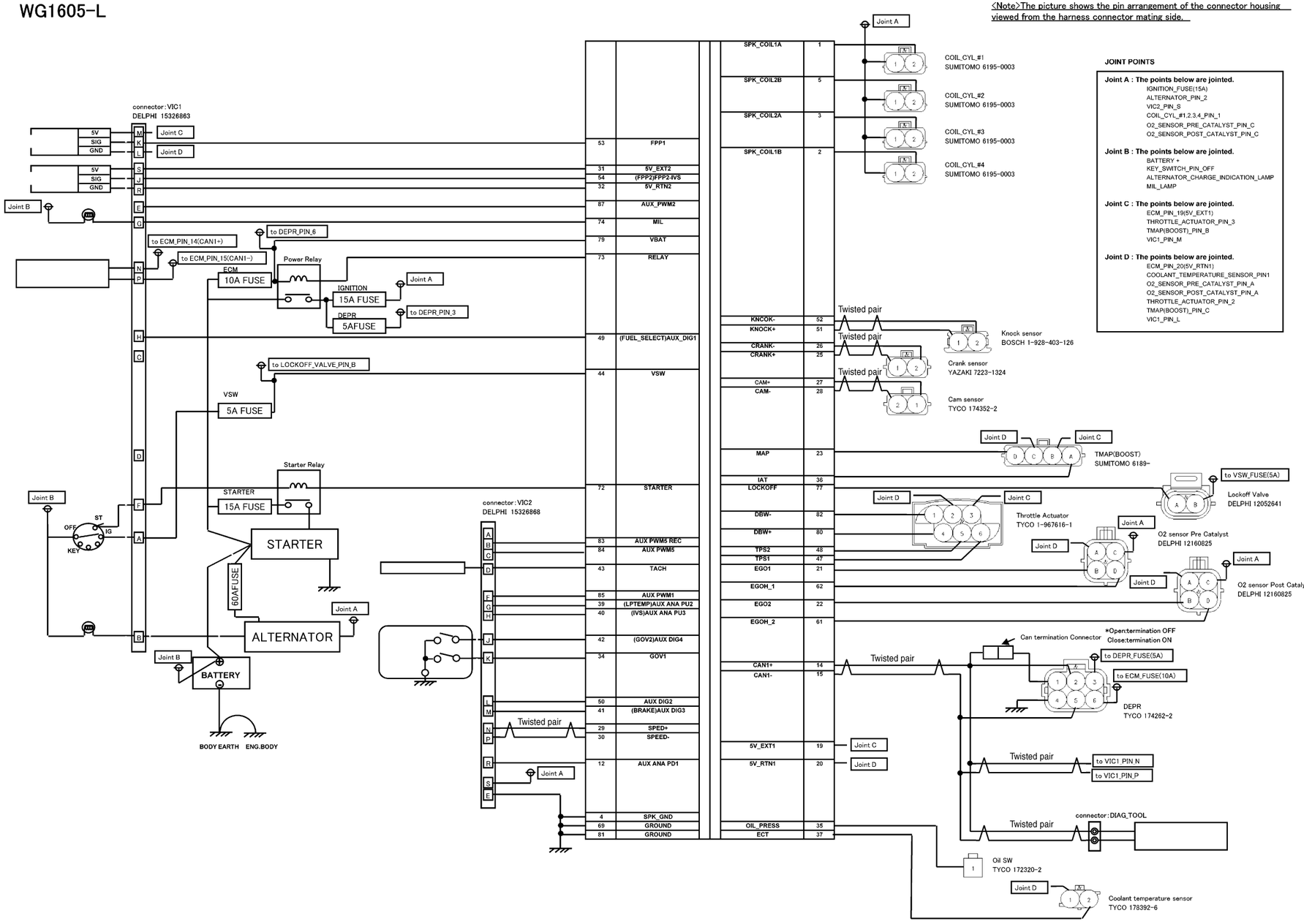
9. WIRING DIAGRAM

WG1605-G



WG1605_142A

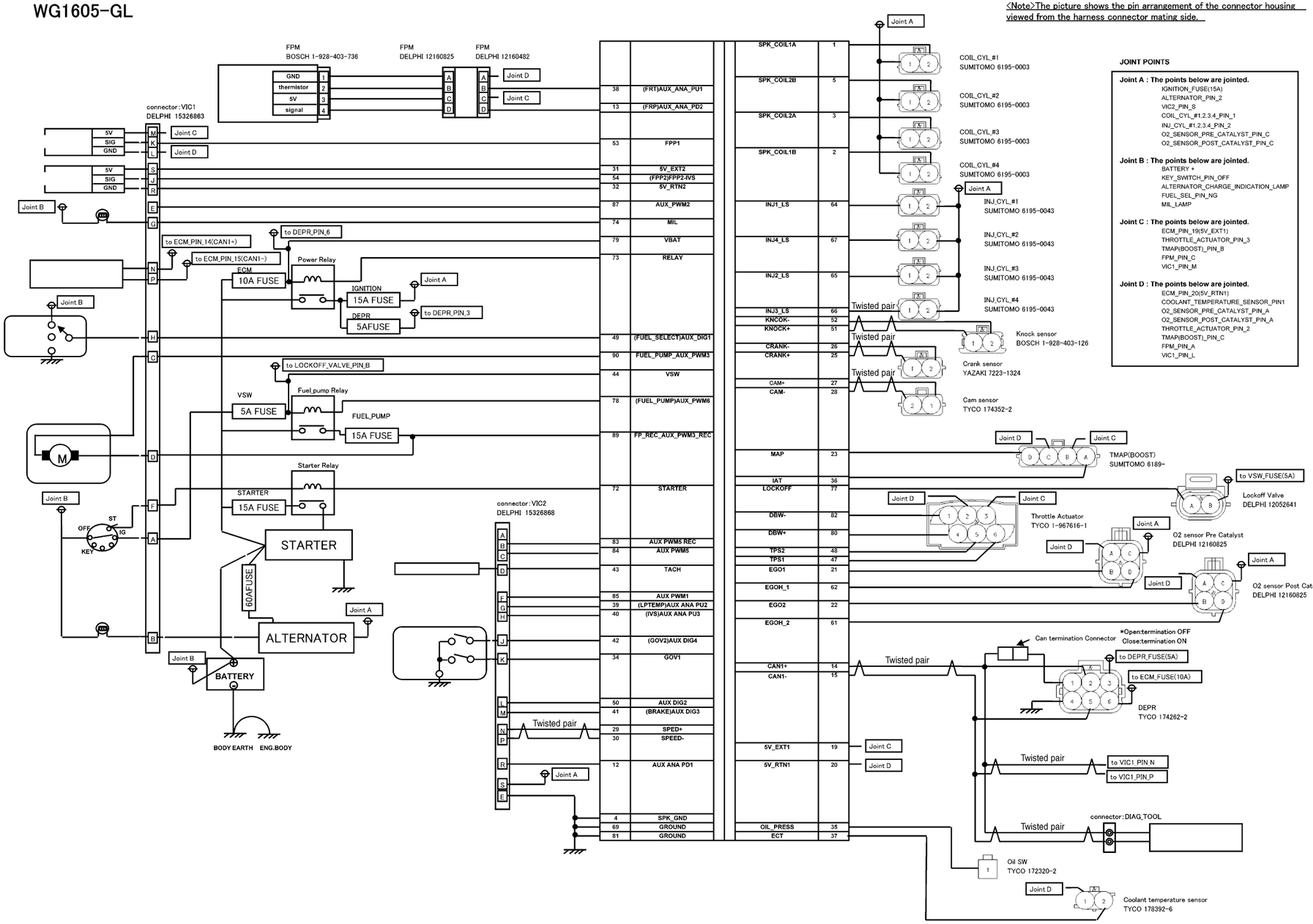
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WG1605-GL

<Note>The picture shows the pin arrangement of the connector housing viewed from the harness connector mating side.



PTO SYSTEM

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1. GENERAL

Power can be taken off a KUBOTA engine from the following points within a certain range dicated by total engine output.

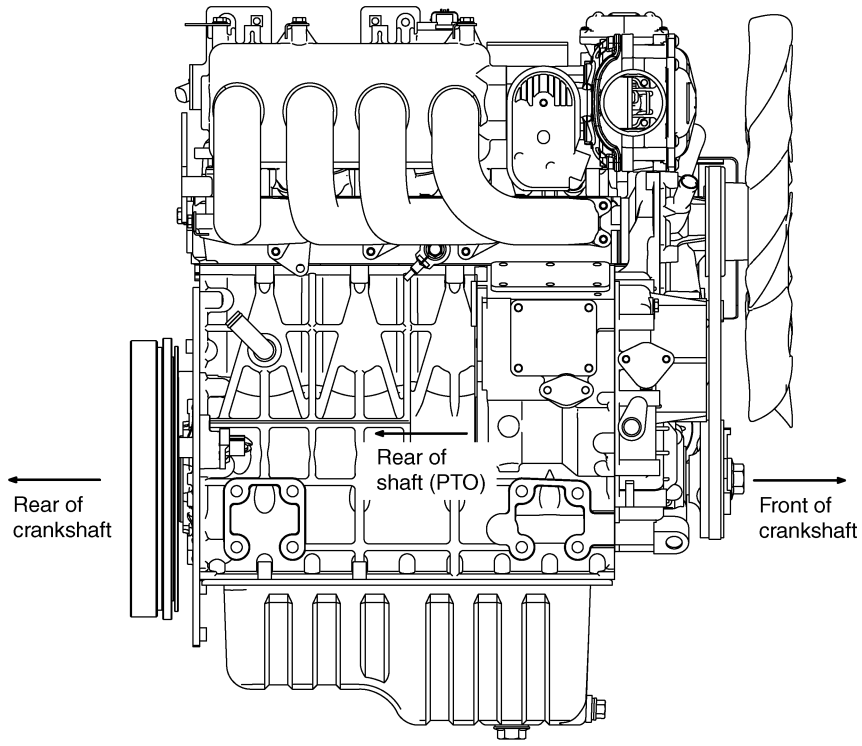
The amount of power that can be taken at a position may be 100% (Full engine horse power) or less than that.

This depends on strength of engine components, type of drive component and direction of power take - off.

To ensure proper engine performance and long life the drive system must be carefully designed.

A review by KUBOTA is recommended.

PTO Usage	
PTO Position	**Notes**
Crank Rear	Main Power
Crank Front	Auxiliary Power
Shaft (PTO) (Governor Shaft)	Hydraulic Pump



WG1605_041A

Figure 10-1

Table of PTO

	Location	Application	Connecting method	Available power (%)	Remarks
1	Rear of crankshaft	Main power	Flange direct-coupling	100	
			Belt drive by pulley	50 to 100	Depending on overhang (See Figure 10-8)
2	Front of crankshaft	Auxiliary power drive	Rotation transmission by concentric shaft	50 to 100	Ex. Air Conditioning
			Belt drive by pulley	30 to 60	Depending on overhang (See Figure 10-8)
3	Shaft (PTO) (Governor Shaft)	Hydraulic pump	Oldham	30 to 50	

■ **NOTE**

- **Rear : Flywheel side**

2. REAR OF CRANKSHAFT (FLYWHEEL SIDE)

[1] FOR DIRECT CONNECTION WITH HOUSING

(1) Housing

Join flange faces and tighten bolts (by pilot dia or knock pin).

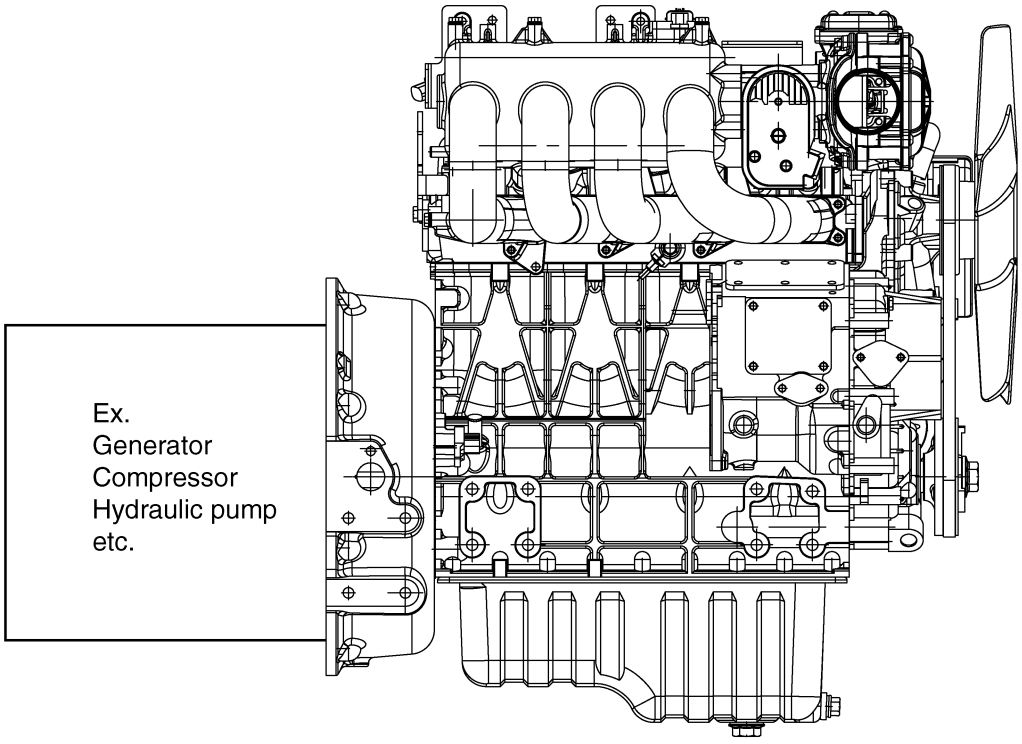
(2) Rotating Body

Join flywheel mounting face with flange face and tighten bolts (by dowel).

(3) Precision Of Case And Rotating Body

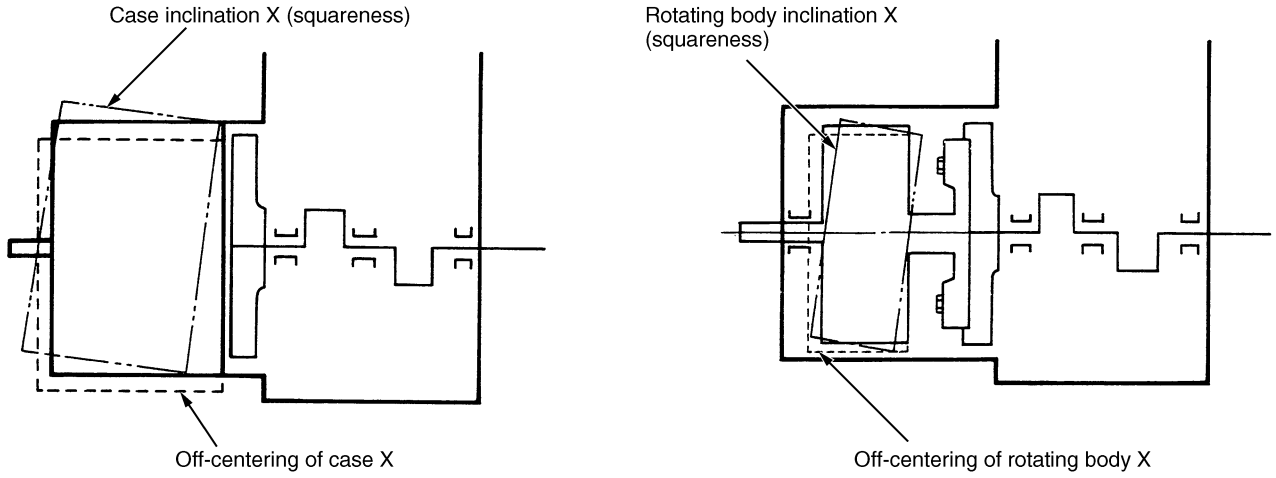
Rigid connection of the PTO, marine gear or transmission to the engine flywheel housing can make the system compact. Special attention should be paid to the assembly precision for this type of conection.

Improper assembly will result in excessive power loss premature parts failure.



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Figure 10-2



WG1605_043A

Figure 10-3

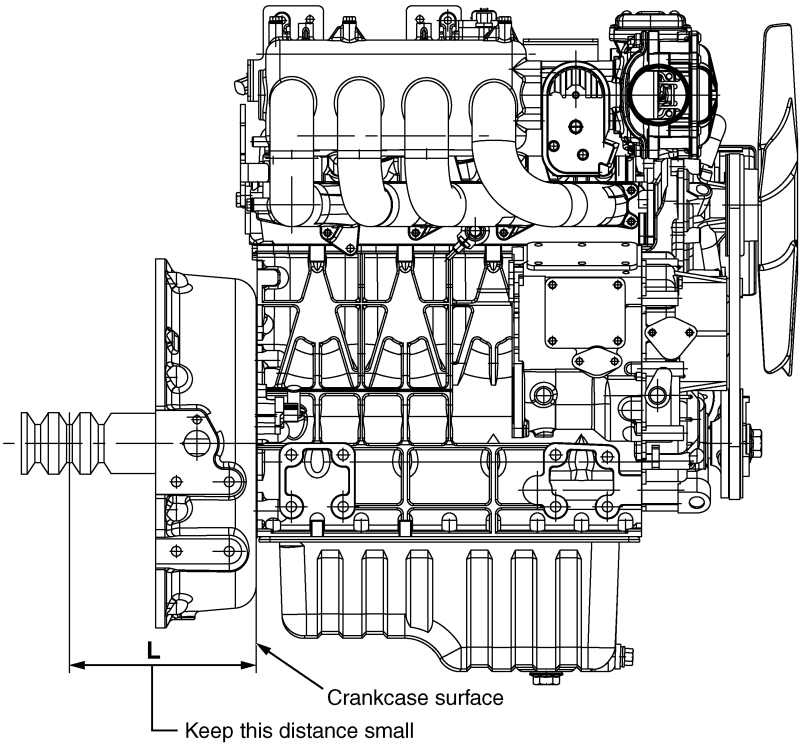
[2] FOR USING BELT

(1) Direction

a) When taking power off in two directions, arrange so that tension is offset.
b) When taking motive power off in one direction, take it off downward. Ensure that side load is within KUBOTA's specs.

(2) Available Load

Determine by referring to Figure 10-4 and page 10-6 to page 10-9.



WG1605_044A

Figure 10-4

(3) When Using Belt

When belt driving is used, careful consideration must be given to the amount of overhang and size of load, allowable load must be strictly observed, belt tension also greatly influences load. Belt must be tightened as specified.

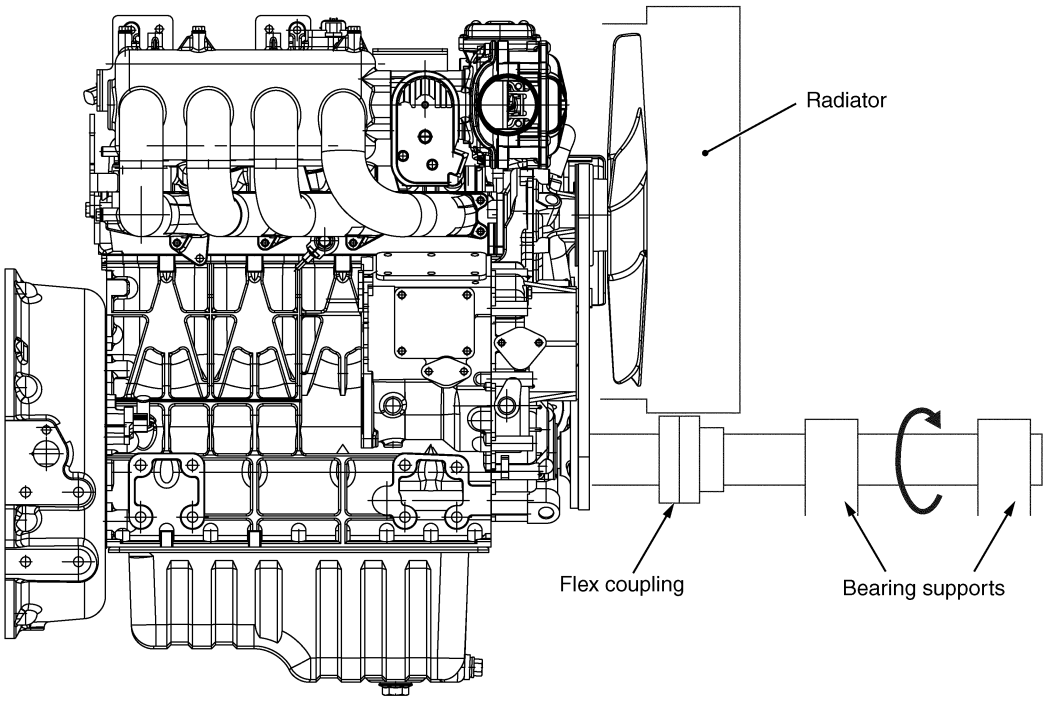
3. FRONT OF CRANKSHAFT (RADIATOR SIDE)

[1] TAKING OFF IN AXIAL DIRECTION

a) Take off from the same shaft center via a flange coupling (concentric).

■ **NOTE**

- **PTO should be able to be dismounted easily when replacing the fan belt.**
- **Since spline is formed at the crancshaft end, an adapter suitable to the spline required.**



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Figure 10-5

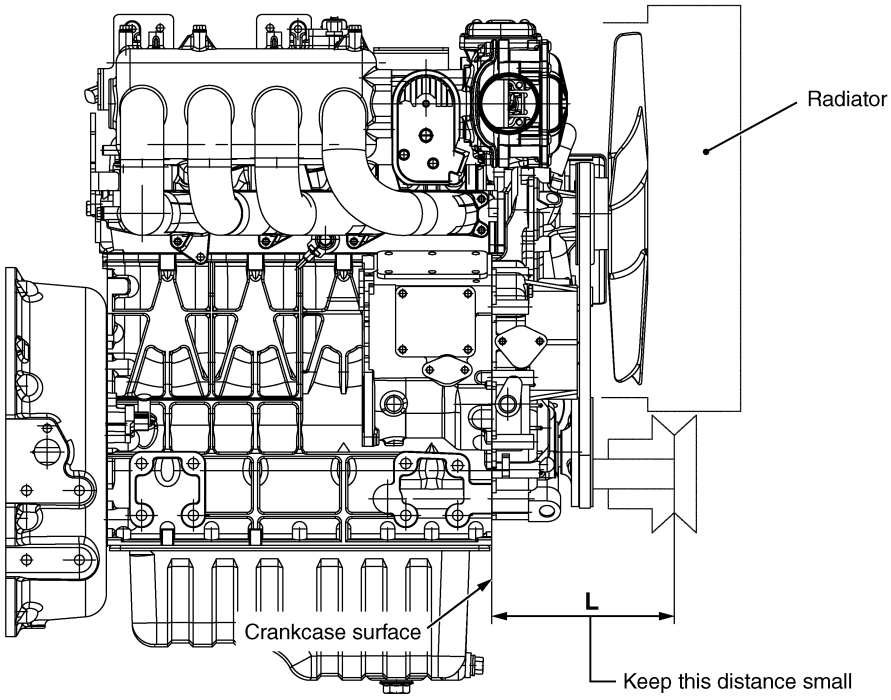
[2] FOR USING BELT

(1) Direction

a) When taking power off in two directions, arrange so that the tension is offset.
b) When taking power off in one directions, take it off downward. Ensure that side load is within KUBOTA's specs.

(2) Available Load

Determine by referring to Figure 10-6 and page 10-6 to page 10-9.



WG1605_046A

Figure 10-6

[Power Take-off Recommendations]

1. If PTO shaft length are too long, an outboard bearing must be added.
2. Flexible couplings allow a little miss alignment between engine and drive device.
   They also dampen inertial loads, they must be used, along with outboard bearing, for front PTO drives.
3. Power disconnects (Clutches, Hydraulic unloader valve, etc.) reduce the load on the engine when being started.
   Using them may eliminate the cost of adding a heavy duty starter.
4. SAE housings allow direct coupling of industry standard generators, clutches and pumps.
5. To minimize the possibility of excessive overhang when driving two separate loads through two separate belts, it is best to place the two loads as directly opposite each other as possible.
6. To reduce overhang, belt drive pulleys must be as close to the engine as possible.

4. SIDE LOAD

[1] SIDE LOAD CALCULATION FOR V-BELT DRIVE APPLICATION

When V-belt pulley is used for PTO according to the following procedure, confirm that the position of the pulley is within the allowable limit.

Even if it is located within the limit, minimize the overhang as much as possible to avoid any side load problems.

Also, tension of the belt is very important for the life of the bearing of the engine and the belt.

Follow the recommendation of the belt manufacture for tensioning the belt.

The following calculation method is only a reference for designing. Therefore, it is important to eventually carry out the actual operation test or the endurance test using the actual machine to check for problems.

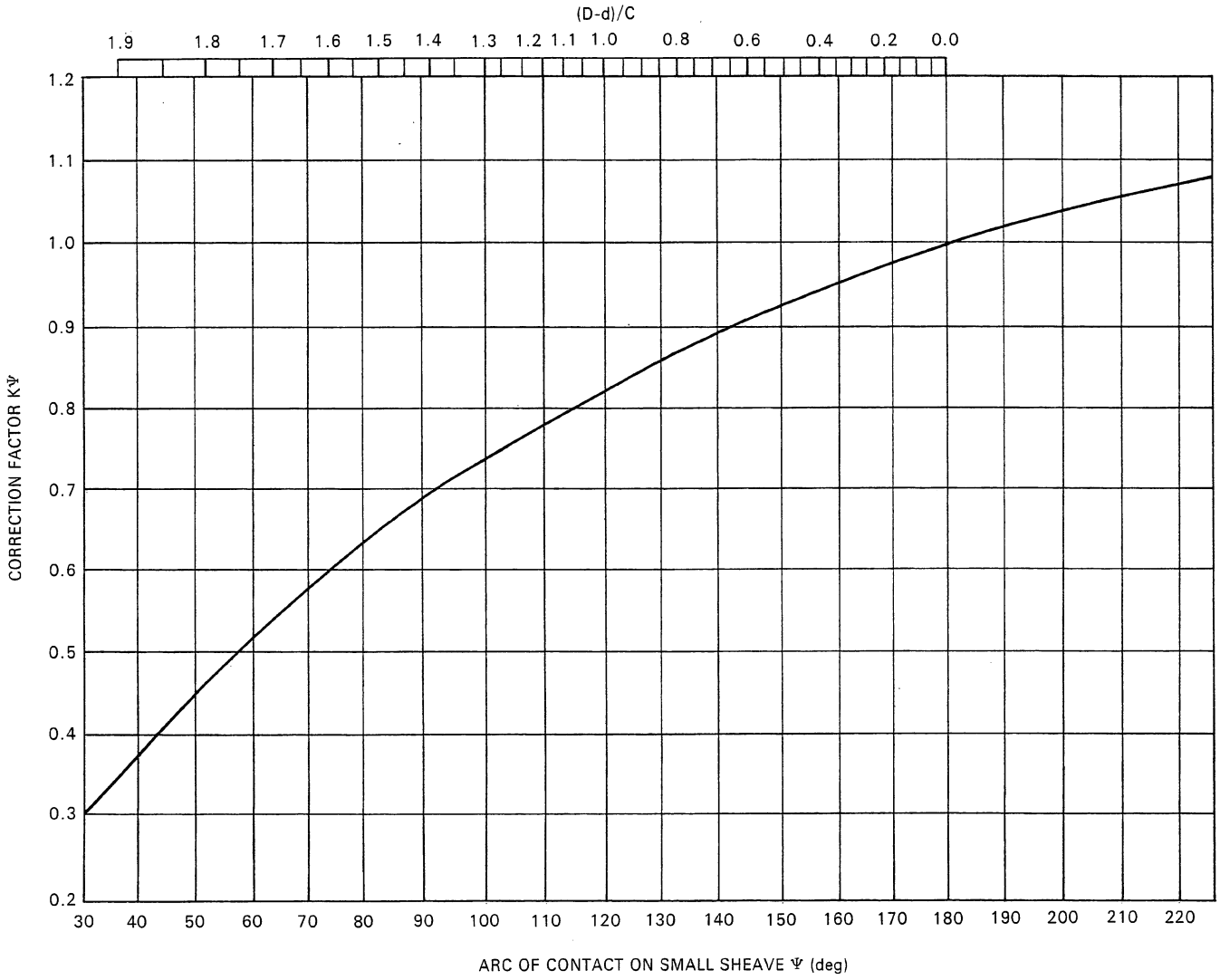
[2] PROCEDURE TO DETERMINE THE ALLOWABLE SIDE LOAD

TABLE NO.1 SERVICE FACTORS

Driven Machine	Type of Service		
	I	II	III
Agitators for Liquids	1.0	1.1	1.2
Blowers and Exhausters			
Centrifugal Pumps & Compressors			
Fans up to 10 Horsepower			
Light Duty Conveyors			
Belt Conveyors for Sand, Grain, etc	1.1	1.2	1.3
Dough Mixers			
Fan Over 10 Horsepower			
Generators			
Line Shafts			
Laundy Machinery			
Machine Tools			
Punches - Presses - Shears			
Printing Machinery			
Positive Displacement Rotary Pumps			
Removing and Vibrating Screens			
Brick Machinery	1.2	1.3	1.4
Bucket Elevators			
Exciters			
Piston Compressors			
Conveyors (Drag - Pan - Screw)			
Hammer Mills			
Paper Mill Beaters			
Piston Rumps			
Positive Displacement Blowers			
Pulverizers			
Saw Mill and Woodworking Machinery			
Textile Machinery			
Crushers (Syratory - Jaw - Roll)	1.3	1.4	1.5
Mills (Ball - Rod - Tube)			
Hoists			
Rubber - Extruders - Mills			

I : Intermittent Service	3-5 Hours Daily or Seasonal
II : Normal Service	8-10 Hours Daily
III : Continuous Service	16-24 Hours Daily

ARC CORRECTION FACTOR KΨ



WG1605_047A

Figure 10-7

(1) Find The Design Horsepower Pd

a) Select the service factor Ks from Table No.1 depending on the type of the driven machine and the service cycle. If can not find you machine on Table No.1 use 1.3 as the service factor.
b) Calculate the Design Horsepower according to Formula No.1.
   Pd = Ks Pr ...(Formula No.1)
   Pd : Design Horsepower (HP)
   Pr : Required Horsepower for the machine (HP)
   Ks : Service Factor

(2) Find The Shaft Load

a) Calculate Ψ or (D-d) / c
   Ψ = 180-57 (D-d) / c...(Formula No.2)
   Ψ : Arc of contact on small sheave (deg)
   D : Diameter of large sheave (mm or in.)
   d : Diameter of small sheave (mm or in.)
   c : Center distance between both sheave (mm or in.)
b) Find the Arc correction factor K Ψ from Figure 10-7.
c) Calculate the belt speed.
   V = (d N) / 3.82...(Formula No.3)
   V : Belt speed (ft/min)
   d : Diameter of small (large) sheave (in.)
   N : Small (large) sheave speed (rpm)
   or
   V = (d N) / 318.3... (Formula No.3)
   V : Belt speed (m/min)
   d : Diameter of small (large) sheave (mm)
d) Calculate the shaft load Fd.
   Fd = 33000 [(2.5-KΨ) / KΨ] (Pd/V) (Formula No.4)
   Fd : Shaft load (lbs)
   or
   Fd = 4500 [(2.5-KΨ) / KΨ] (Pd/V) (Formula No.4)
   Fd : Shaft load (kg)

[3] ALLOWABLE OVERHANG

Find the allowable overhang from the engine according to Figure 10-8 and design the position within the allowable limit.

Available load vs. overhang for using belt

■ **NOTE**

- **Consider the conditions for use and take proper measures if necessary.**

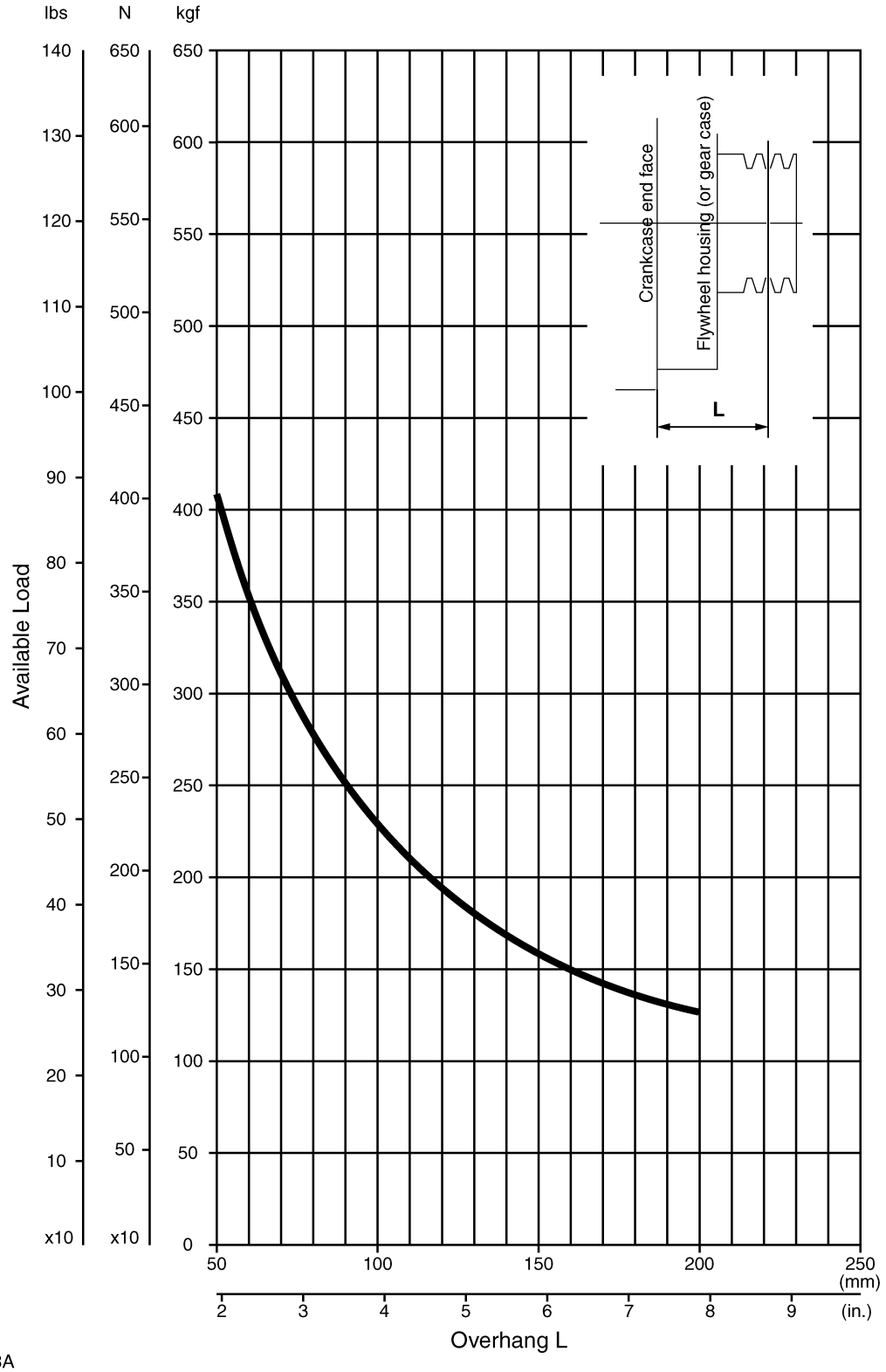
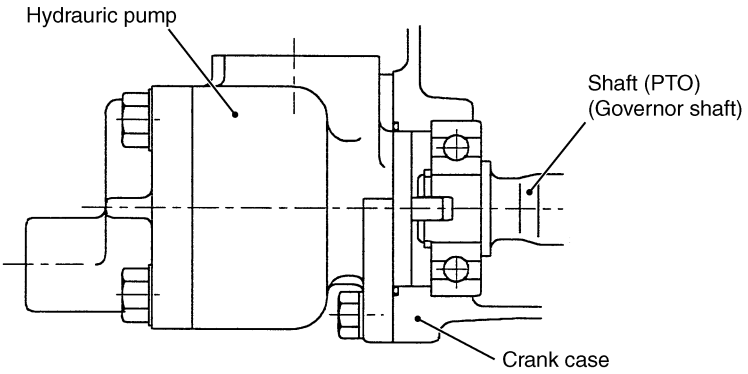


Figure 10-8

5. SHAFT (PTO) (GOVERNOR SHAFT)



WG1605_106A

Figure 10-9

MOUNTING SYSTEM

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1. GENERAL

When setting an engine on a machine, major importance should be given to assembling with precision the parts connected to flywheels, and crank shafts which rotate at high speeds.

The following points must be carefully observed.

1. Do not apply excessive force to the engine during assembly. (For prevention of off-centering surface deflection, excessive, clearance and thrust)
2. Minimize bending moment to rotating shaft. (For extended life of shafts and bearings)
3. Avoid resonance around the engine mounting frame. (Use of appropriate supporting method and rigid mounting frame).
4. Avoid torsional vibration between the engine and driven components. (Connection with a rotating body)
5. Take air flow into consideration when enclosed cover is used. (for proper cooling)
6. Provide access for easy maintenance when covering engine or parts. (for easy maintenance)
7. Take maintenance and reliability into consideration for remote control. (for positive operation)

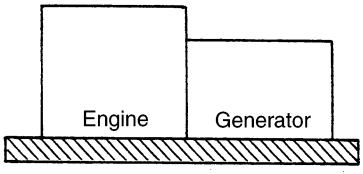
2. SUPPORTING METHOD

Vibrations from a machine mounted with an engine depend on the vibration of the engine itself, rigidity of the mounting frame, weight of engine with equipment connected, vibromotive force and the supporting method between the engine and equipment.

Improper mounting and support will create resonant vibration in the engine system, which will cause noise and can result in major problems. The supporting method must be carefully designed.

[1] TYPICAL CONNECTION AND SUPPORTING METHODS

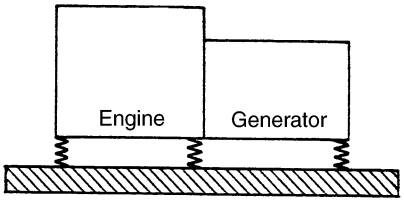
(1) Direct-connection, Stationary



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Figure 11-1

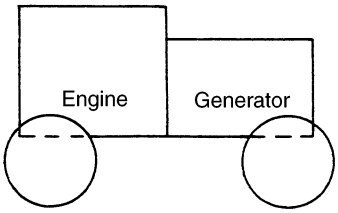
(2) Direct-connection, Anti-vibration Support



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Figure 11-2

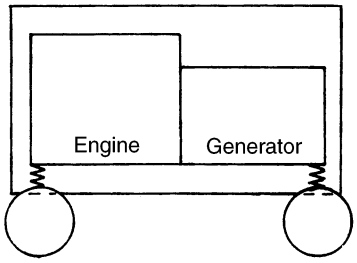
(3) Direct-connection, Movable (Tire)



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Figure 11-3

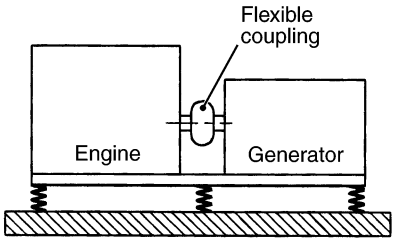
(4) Direct-connection, Anti-vibration Support, Movable



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Figure 11-4

(5) Separate Transmission, Anti-vibration Engine Support



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Figure 11-5

Determine the best supporting method considering the above vibration conditions and the characteristics of the machine on which the engine is to be mounted.

Vibration acceleration and amplitude should be below the allowable levels.

Many types of anti-vibration support are being adopted recently.

[2] THE DETERMINATION METHOD OF ANTI-VIBRATION SUPPORT SPECIFICATIONS

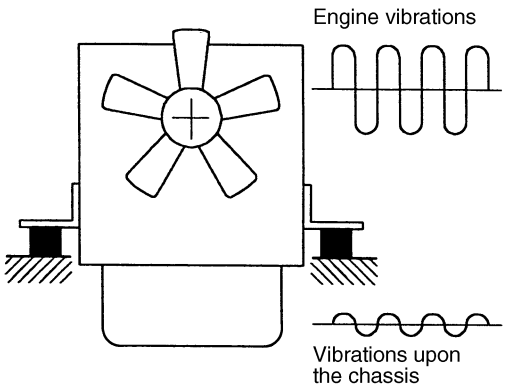
What is the goal for engine mounting ?

a) If machine has an operator and noise / vibration reduction are very important, then maximum vibration isolation is required.
   However, this usually means that the isolators are very "soft" and have larger movement, so any accessory attached to the engine should have their "mass" as closely centralized to the engines / transmissions natural "roll center" as possible or very high displacement, acceleration type vibration can occur.
   e.g. : The further away from engine / transmissions natural "roll" center the end of the muffler gets, the worse the movement.
b) If no operator, (e.g. : water pump) then isolation importance is not as great and "hard" mounts with less movement can be used.
   This will make it much easier to mount the engines accessories to the engine (less "wobble").
   However a high frequency, high acceleration, low displacement vibration can occur.
c) Is machine subjected to heavy bouncing ?
   Either moving by itself or when being carried by another vehicle.
   Mounts that may have to withstand up to 6G (6X) engine transmission weight may be required with strong overload in the vertical +/- and lateral movements.
d) Is mounting base rigid enough ?
   That the base does not have an interfering natural frequency / displacement that coincides with the engine / attachment / transmission isolators and engine rotational frequency.

This is when a vibration reading on the machines chassis is important and may require the use of a strobe to point to the problem area.

[3] REQUIREMENTS IN MOUNTING THE ENGINE

- Keep the chassis isolated from engine vibration as much as possible.
- Support the engine with the operating condition safely.



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Figure 11-6

(1) How To Isolate The Chassis From Engine Vibration

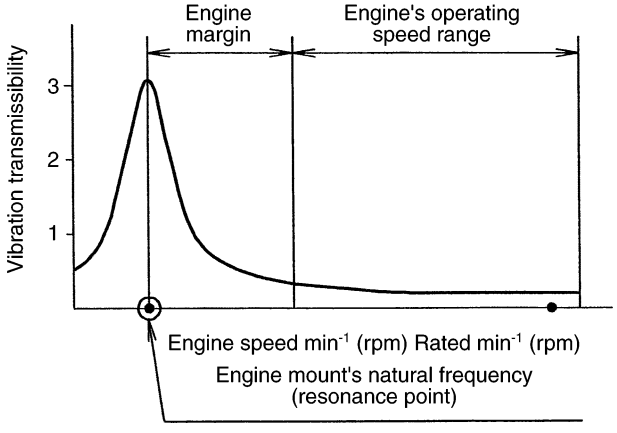
Elastic materials such as vibration-insulating rubber products (VIRP) are used to support an engine mount to isolate the chassis from engine vibration as much as possible.

A flexible supported engine mount has its specific natural frequency.When the engine runs near or at rpm that corresponds to that frequency, resonance occurs, which adversely amplifies the vibratons. To cope with this problem, the following points are important. :

First, support the engine with an elastic material such as VIRP.

Second, keep the engine mount's natural frequency away enough from the engine's operating speed range.

Vibration-insulating rubber products (VIRP), commonly used for engine mounts, are discussed.



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Figure 11-7

(2) Conditions For Safety Supporting With Vibration-insulating Rubber Products (VIRP)

Unlike rigid support with metallic stays, stiffness is a key factor in supporting an engine with VIRP in an elastic way. The VIRP helps reduce the effect of vibration upon the chassis, but the engine tends to shake more.

The softer the rubber is, the smaller the vibration transmissibility becomes, and the lower the resonance point drops. If a strong external force comes from the chassis, however, the engine will move, possibly causing an interference around the radiator or damaging the engine-related equipment. Keep engine mounting base very rigid. If the VIRP, with the rubber's deflection too large, easily gets cracked. For reliable engine mounting, therefore, keep the following point in mind :

Select VIRP that has small deflection with respect to various loads and that is durable enough.

Here are major loads that are exerted on an engine-mounting VIRP.

- Engine's own weight
- Engine's vibromotive force
- External force coming from the chassis

A VIRP to be applied must have a spring constant appropriate to support all these loads.

Now let's discuss some precautions on the loads in mounting an engine.

[A] Engine's Own Weight

An engine's own weight cannot be avoided. Suppose that a load is equally applied on each piece of VIRP. Divide the engine's weight by the number of the VIRP pieces. The result must be below the permissible load of each VIRP piece. When the deflection of the VIRP is high, it is advisable to have a somewhat higher spring constant even within the permissible load. The permissible load P and the deflection H of VIRP are expressed as follow :

Permissible load of VIRP : $P > W/n$

Deflection of VIRP : $H = W / (K \times n)$

Where

W : Engine weight

K : Spring constant of VIRP

n : Number of VIRP pieces

It is clear that the engine weight divided by the VIRP pieces must be smaller than the permissible load and that the deflection H must be kept low.

[B] Engine's Vibromotive Force

The VIRP is exposed to the vibromotive force of an engine while it is running. An appropriately selected spring constant does not give the VIRP much deflection due to the vibromotive force. It should be noted, however, that generally there is a resonance point in the operating speed range of a rubber-mounted engine.

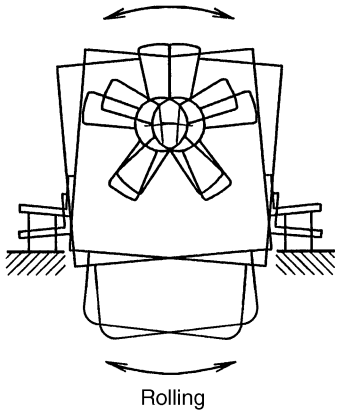
By resonance, the vibromotive force becomes multiplied by several times, which deflects the VIRP greatly. To allow no resonance point in the engine's operating speed range, the natural frequency must be kept out of this range.

Often, the engines low idle speed will have to be increased.

But when the engine STARTS and STOPS, the resonance point is experienced along the way of speeding up and slowing down.

The VIRP must withstand such vibrations that occur during the start and stop the engine.

These vibrations generally roll the engine. To reduce the deflection in such direction, increase the spring constant in the rolling direction or modify the support structure.



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Figure 11-8

[C] External Force Coming From The Chassis

On general purpose engines, an external force coming from the chassis is imposed mostly on the external force varies from machine to machine.

The VIRP must be strong and durable against the external force of the type of machine in question.

But the VIRP is not designed to withstand an impact load or other momentary force.

To deal with such force, it is absolutely necessary to add safety stoppers.

The stoppers can limit the VIRP's maximum deflection that is caused by the external force.

Any external forces beyond the limit are received by the stoppers, which protects the VIRP and ensures safeness.

If by any chance the VIRP breaks down, the stoppers work to hold the engine in place.

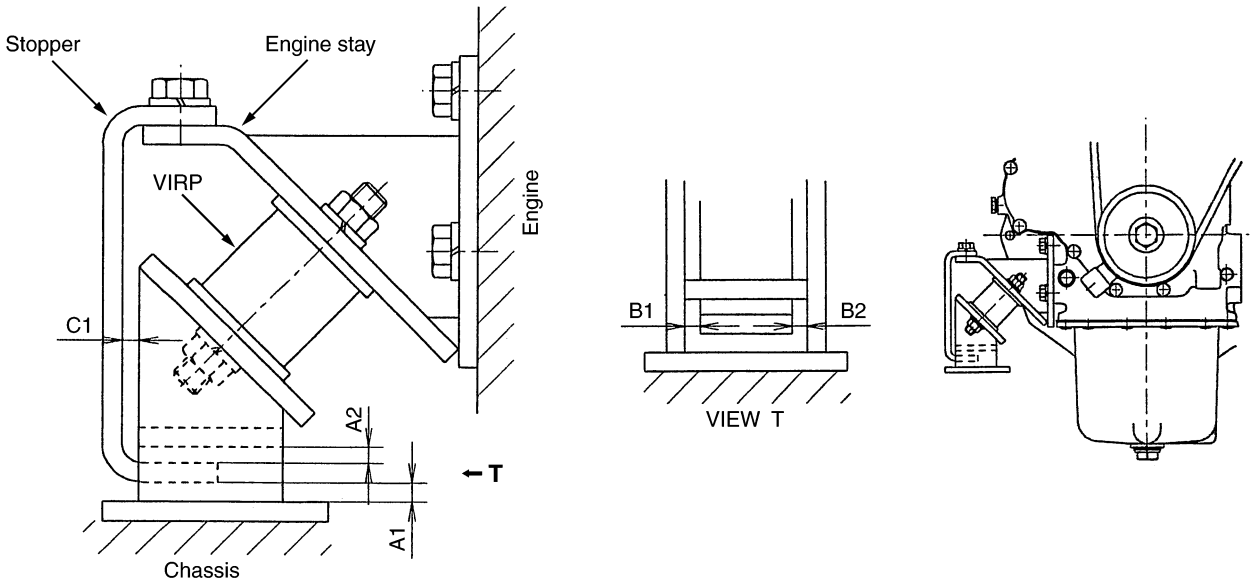
It is preferable to install the stoppers in 3 directions (vertical, crosswise and lengthwise).

Figure 11-9 shows a typical stopper and Table 1 lists external forces that are transmitted from the chassis of various type machines.

Types of machines	External force
Stationary type	1 to 2G
Power unit type	2 to 3G
Offroad, frame and construction machinery	2 to 4G

Impact loads are not included in the above external forces.

Table 1 External forces that are transmitted the chassis of various types of machines



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Figure 11-9

VIRP's vertical maximum deflection is limited by the clearance A1 and A2.

VIRP's lengthwise maximum deflection is limited by the clearance B1 and B2.

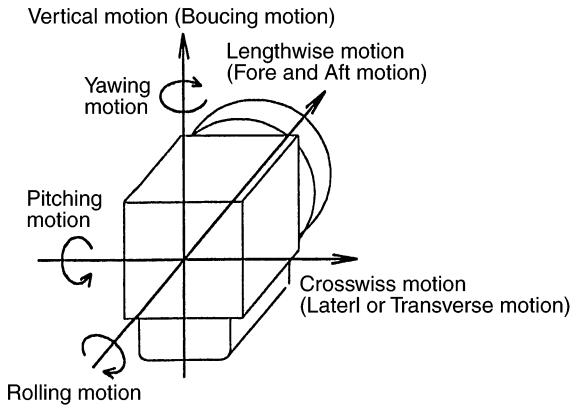
VIRP's crosswise maximum deflection is limited by the clearance C1 and C2.

(Clearance C2 is opposite clearance C1 with respect to the crankshaft center.)

[4] ENGINE'S VIBRATION CHARACTERISTICS

Reciprocating engine structurally have their source of vibration inside (reciprocating movements of the piston and connecting rod, torque variations, etc.) Their frequency characteristics depend on the number of cylinders, cylinder arrangement and other factors. An engine's motion can be divided into 6 types : 3 translational motions (vertical, crosswise and lengthwise) and 3 rotary motions (rolling, yawing and pitching.)

Below discussed are the relations between these 6 types of vibrating motions and the vibration characteristics of 4-cycle in-line 3 cylinders as well 4 cylinders engines.

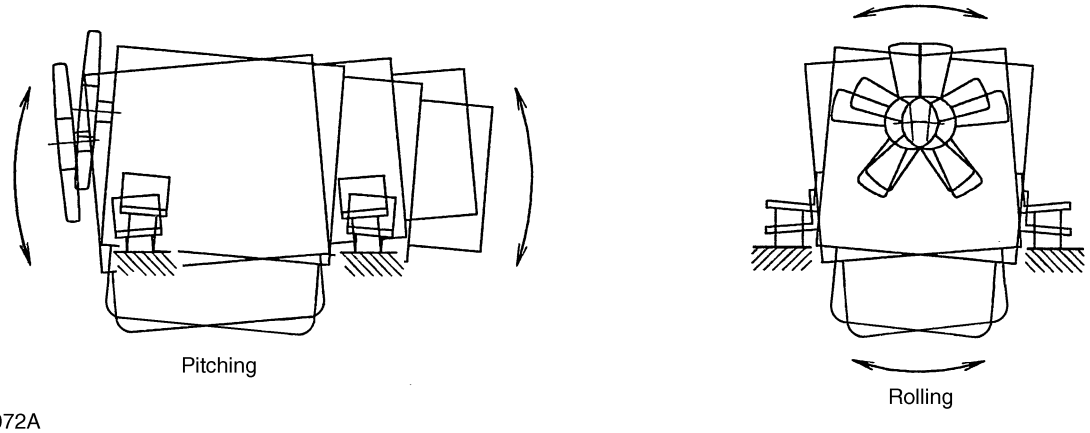


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Figure 11-10

(1) Three-cylinder Engine's Vibration Characteristics

Engine's motion	Pitching and yawing
Rotational degree	1st order
Remarks	Caused by inertial couple of force. Aggravated with increasing rpm.
Engine's motion	Rolling
Rotational degree	One and a half order
Remarks	Caused by torque variations.

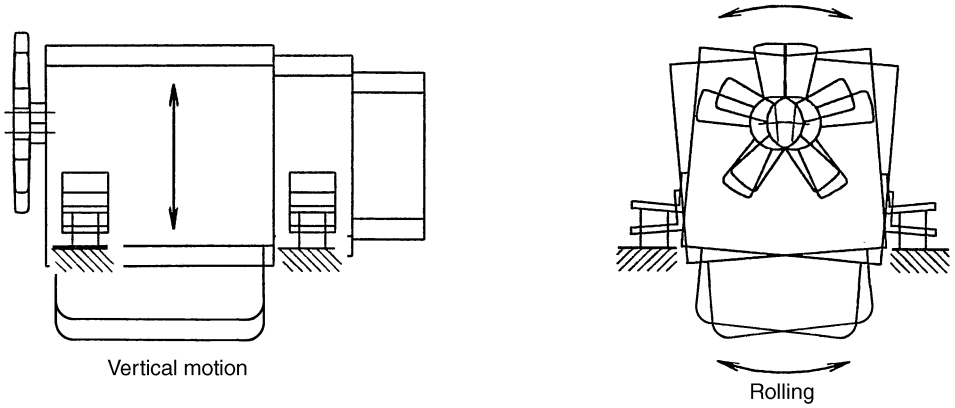


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Figure 11-11

(2) Four-cylinder Engine's Vibration Characteristics

Engine's motion	Vertical
Rotational degree	2nd order
Remarks	Caused by reciprocating secondary inertial force. Aggravated with increasing rpm.
Engine's motion	Rolling
Rotational degree	2nd order
Remarks	Caused by torque variations.



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Figure 11-12

A particular type of vibration to be noted is the one that occurs near the resonance point at low engine rpm. The natural frequency of a rubber engine moment is somewhere between 5 and 25 Hz. At too low an idling engine rpm, for example, the rolling vibration of an idling engine may be (amplified) by resonance.

It is therefore important to make sure that the vibromotive force of an engine idling at low speed does not resonate.

[5] DECIDING THE ENGINE MOUNT SPECIFICATIONS

Fig. 11-13 shows the procedural flow of determining the engine mount specifications.

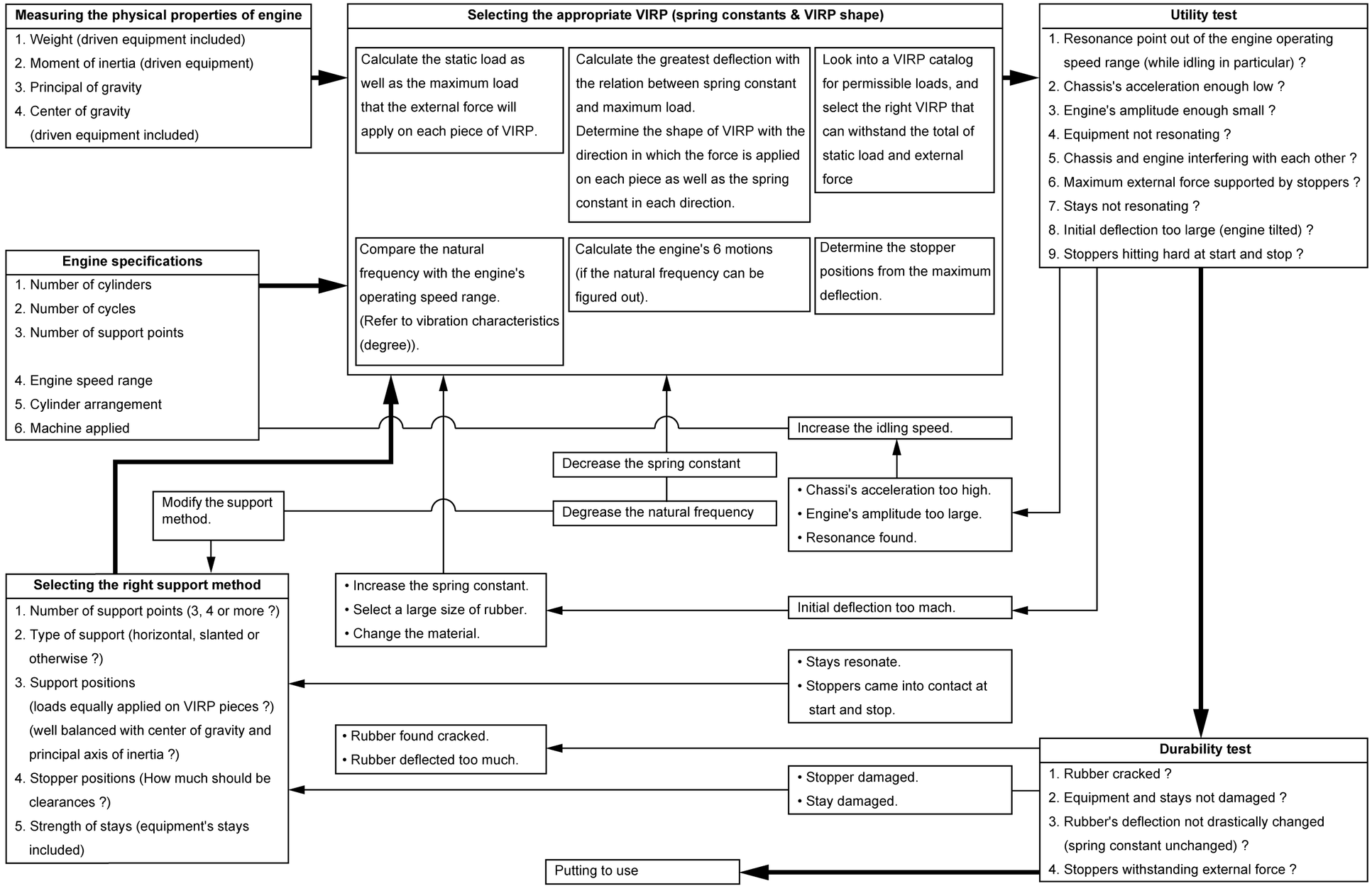
First of all, measure an engine's and attachments physical properties.

Considering the engine mounting position and space and other factors, determine the number of support points, support positions, and support method. Then with the engine's physical properties, support method and specifications in mind, select the right type of VIRP.

At this stage, mount the engine on the machine with the VIRP and carry out the utility test and durability test.

Make sure, there is no problem and introduce this type of VIRP.

The next page chapters cover engine support methods, selection of VIRP, possible problems and other related matters.



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Figure 11-13

[6] VIBRATION INSULATING RUBBER PRODUCTS (VIRP)

(1) Selecting VIRP

Please consult KUBOTA Engineering or VIRP manufacturer for proper selection of VIRP.

(2) VIRP Characteristics

VIRP have the following main features.

- Damping force available
- Spring constants presettable in three axes
- VIRP shaped in a relatively flexible way

For use of VIRP, the following points must be kept in mind.

- Creep phenomenon
- Temperature characteristic
- Oil resitance

[A] Creep Phenomenon

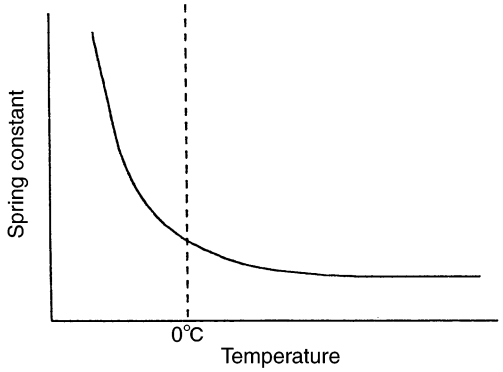
Since the VIRP has been applied, it gradually suffers from permanent deformation.
Initial deflection comes after the first 2 weeks, and slight, gradual deformation continues thereafter.
This problem must be considered in advance.

[B] Temperature Characteristics

The VIRP is greatly affected by temperature fluctuations.
The higher the temperature, the smaller the spring constant, and vice versa.
The temperature characteristics depend on the types of rubber, but their spring constants suddenly get higher.
This means that temperature changes must be understood well. It is also important to adjust test-run temperatures to the practical application.

[C] Oil Resistance

Some VIRP materials are not resistant to oil and grease.
Pick up the appropriate VIRP material that sufficiently withstands oil and grease for engine-supporting applications.



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Figure 11-14

[7] SUPPORTING PROCEDURE

(1) Suporting Points

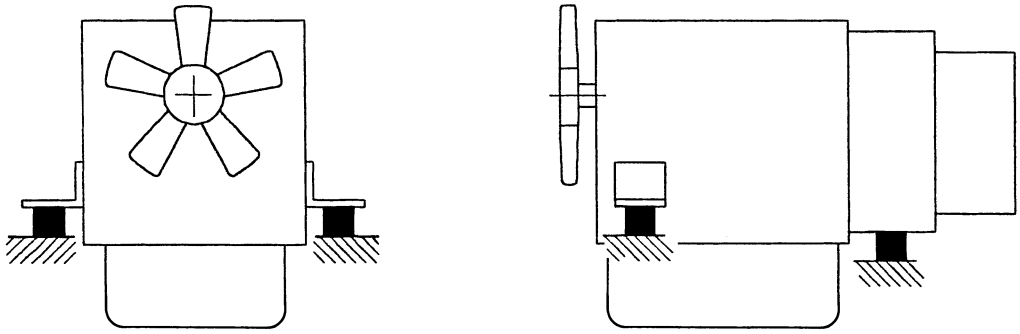
In most cases, engines are supported at 3 or 4 points. Whether in a 3-point or 4-point support design, all the VIRP points must be arranged to be equally loaded. If any of the VIRP pieces is under unequally heavy load, not just its durability is affected, but also unusual vibrations may occur. The load upon each of the VIRP pieces is determined by its center of gravity and supporting position. If the support positions cannot be changed and the load cannot be equally distributed, preferably modify the spring constant of each VIRP piece and allow the same level of deflection to all the pieces.

This helps keep the engine at a level.

[A] Three-point Support Positions

A typical 3-point support is shown in Figure 11-15.

In this design, both sides of the crankcase toward the fan as well as the bottom of the flywheel housing are supported.



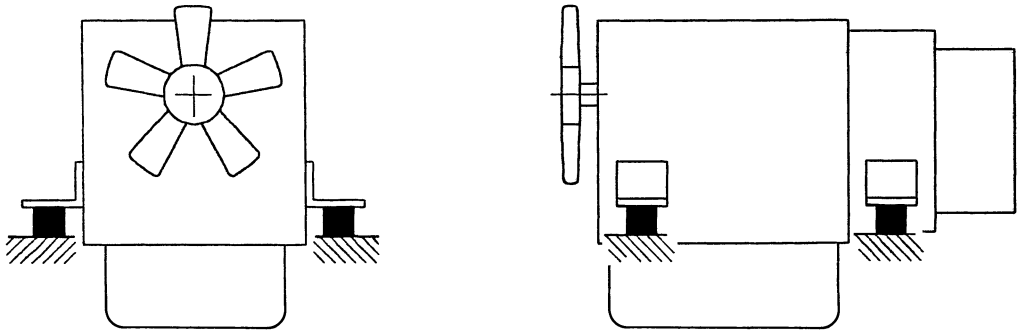
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Figure 11-15

[B] Four-point Support Positions

A typical 4-point support is shown in Figure 11-16.

In this design, both sides of the crankcase toward the fan as well as both sides of the flywheel housing are supported.



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Figure 11-16

(2) Support Stay Configurations

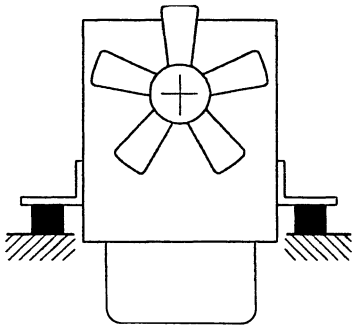
Most general-purpose engines are supported at 4 points. There are two common ways to support them : horizontal stays and slanted stays.

[A] Horizontal Stays

The horizontal stays are shown in Figure 11-17.

This is the simplest method in a compact way.

To keep the natural frequency low in this arrangement, have the stays as close to the center of gravity of the engine as possible. Because the vibrations occur vertically or horizontally depending on the support positions, it is equally important to find the best support positions.



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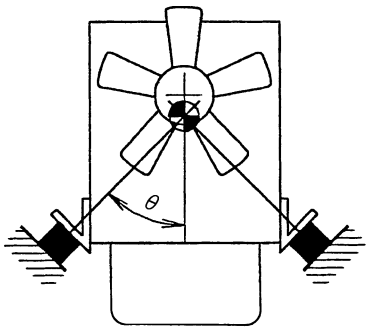
Figure 11-17

[B] Slanted (Angled) Stays

The slanted stays are shown in Figure 11-18. This method is commonly used when the rolling vibration's natural frequency needs to be lower. Such natural frequency is kept smaller by aligning the shearing direction (softest portion) of VIRP with the rolling direction. The tilt angle θ is determined by the following factors among others.

- Principal axis of inertia
- Direction of external force
- Durability of VIRP

The above factors are discussed one by one next.

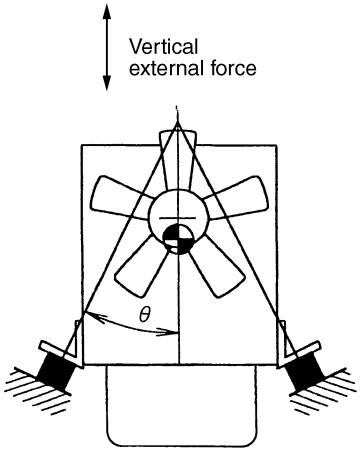


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Figure 11-18

a) Principal axis of inertia
With the support positions fixed, the natural frequency can be lowered by setting the tilt angle θ along the principal axis of inertia (see Figure 11-19). Tilt angles of 30 to 60 ° are commonly adopted.

b) Direction of external force
The slanted support system is weak against the vertical external force coming from the chassis.
The tilt angle therefore must be determined by the type of machine. If the vertical external force is applied, narrow the tilt angle θ or raise the spring constant. It should also be noted that the slanted support has a smaller spring constant in the rolling direction and that the vibrations become noticeable at start and stop of the engine.



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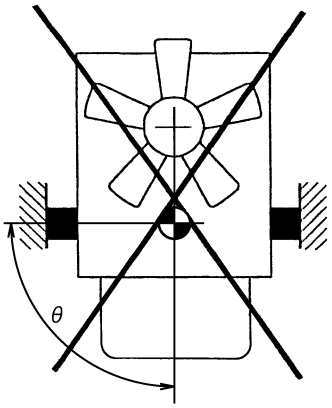
Figure 11-19

c) Durability of VIRP

The slanted stays support the engine in the shearing direction, in which the VIRP is most affected, and help reduce the natural frequency.

An extreme tilt angle of θ = 90 ° must be avoided.

The permissible load of VIRP is generally small in the shearing direction, which may affect its durability. The tilt angle θ must therefore be determined to keep the shearing load low.



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Figure 11-20

[C] Support Stays

The support stays should be designed with a sufficient strength margin. The support stays must also be free from resonance with the engine's vibrations because the stays themselves have their own natural frequency.

The thickness of the stays vary from machine to machine. To cope with a great external force as construction machinery, the stays must be designed to be stiff. It is a advisable to have the stays relatively short and place them near the engine.

[8] ATTACHING EQUIPMENT ON THE ENGINE

Generally speaking, it is better to place a silencer, air cleaner and other equipment separate from the engine. In many cases, stays for air cleaner, silencer, fuel filter and others are affected much by vibrations, and such equipment is set up easy to resonate. Resonance may damage the equipment and their stays much earlier than expected.

Preferably place those equipment on the chassis and connect them with the engine using flexible pipes or the like. When placed directly on the engine, proper measures must be taken against vibrations. And carry out a durability test with the equipment on the engine to make sure there is no problem. It is important to check related water, fuel and other pipes that are vulnerable to vibrations.

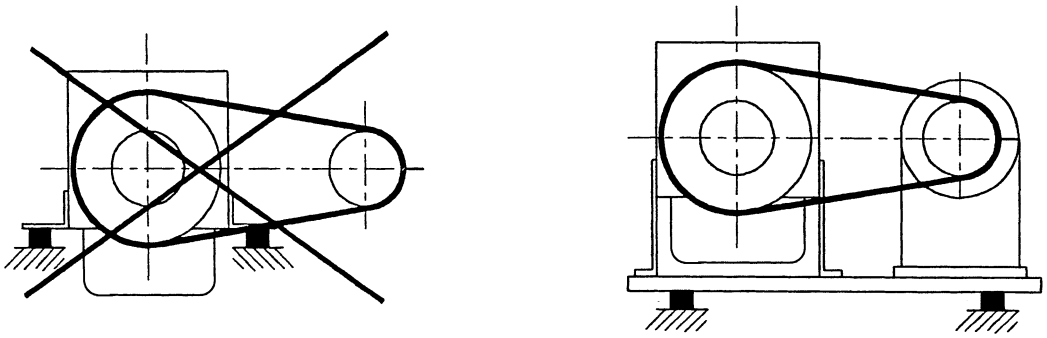
[9] INSTALLING DRIVEN EQUIPMENT

Suppose that a hydraulic pump, for example, is to be connected overhanging on the flywheel side of the engine. In this layout, keep in mind the pump's weight and length.

Too heavy a pump changes the center of gravity of the engine mount too much, which gets the flywheel side VIRP overloaded. Also when an external force is transmitted, the engine may move unusually. Too long a pump, increases the amplitude of the pump's end vibration. With this in mind, it is advisable to employ a pump as short as possible.

If a driven unit is too big, preferably adopt a 4-point support method : 2 points for the engine and 2 points for the driven unit. If a driven unit is not just big but also heavy, a 5 or 6-point support way could be better : 4 points for the engine and 1 or 2 points for the driven unit.

Figure 11-21 shows a typical side-by-side layout of an engine and a driven unit. As shown in here, place the VIRP under the entire system including the engine



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Figure 11-21

[10] NATURAL FREQUENCY VERSUS RESONANCE

When an engine is mounted, there surely is a natural frequency. The natural frequency depends on the following factors :

Weight, moment of inertia, center of gravity, support positions, spring constant of VIRP, and principal axis inertia.

In using rubber for the engine mount, the natural frequency must be strictly considered. If the engine runs around the natural-frequency rpm, resonance occurs and the vibromotive force gets amplified up to several times. This may damage the equipment, stays or VIRP pieces, or invite an innterference with the chassis.

The natural frequency can be calculated. In a practical test, however, run the engine in its entire speed range and find an rpm at which the vibration reaches a peak (resonance point) : the natural frequency stands at this rpm. If the natural frequency is within the engine's operating speed range, it is necessary to keep the natural frequency below the operating speed range or the lowest operating speed above the natural frequency.

The following measures could be taken in order to reduce the natural frequency.

- Lowering the spring constant of VIRP
- Increasing the moment of inertia (for rotary motion)
- Decreasing the distance from the center of gravity to the support positions (for translational motion)
- Increasing the weight (for translational motion)
- Reducing the number of supporting points (VIRP pieces)

The above ways help reduce the natural frequency and keep the resonance point away from the engine's operating speed range. But the entire amplitude and acceleration may remain the same.

When the spring constant of VIRP is made smaller, for example, the natural frequency becomes lower too. The smaller the spring constant, however, the less the VIRP can with stand the vibromotive force.

This means that the VIRP may be affected much more by the same level of vibromotive force.

The durability is also degraded accordingly.

The same is true with a smaller number of VIRP pieces. Just lowering the natural frequency is not sufficient.

Other points that would be adversely affected must be kept. In mind, too.

The engine mount may also resonate by an external force. This is called engine shake.

If the resonance point lies at low frequencies of 5 to 20 Hz, the external force from the chassis gets the engine resonating. In such case, VIRP with great damping force must be used.

[11] PRECAUTIONS IN SWITCHING TO DIFFERENT-TYPE ENGINE

Suppose the VIRP is used for an engine of different type from the previous one.

It is essential to consider a quite different design of engine mount.

This is because a different-type engine requires a different set of VIRP factors. Here are the points to remember in selecting the appropriate VIRP.

- Physical properties of the engine (weight, moment of inertia, center of gravity, etc.)
- Specifications of the engine (number of cylinders, speed range, etc.)
- Supporting method of the engine (support positions, number of supporting points, etc.)

According to these data, the following factors will be different, also, causing a different mode of vibration.

- Natural frequency
- Vibration characteristics of the engine

Take an example of an engine that has nearly the same specifications, except the weight, as those of the previously mounted engine.

The smaller the weight, the greater the natural frequency. This causes the resonance-point rpm to go higher and adversely affects the vibration in the low rpm range. There may be cases in which the engine mount must be redesigned or the idling speed must be changed.

Now we have another example of an engine.

The engine is almost identical in physical properties, supporting positions and piston displacement, but has three cylinders instead of four.

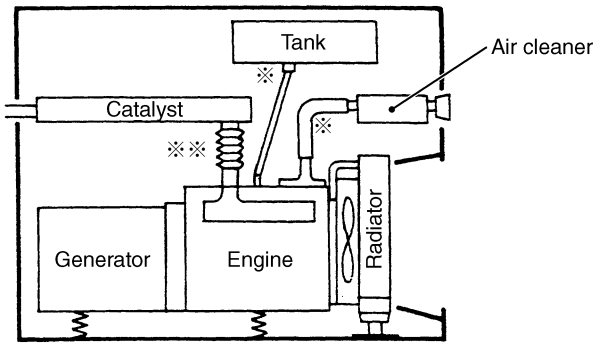
In this case, the vibration characteristics will be different. With the same engine mount design, the three-cylinder engine produces generally proper vibration characteristics in the low speed range. On a four- cylinder engine, the idling vibration happens at the 2nd order engine vibration ; on a three-cylinder engine, it occurs at the one-and-a half order. Let's say, a four cylinder engine resonates at 600 min^{-1} (rpm).

Resonance occurs at 800 min^{-1} (rpm) on a three-cylinder engine. In such cases too, the engine mount must be redesigned or the idling speed must be changed.

In orther words, even through the chassis remains the same and the engine is almost identical to the previous one, the engine mount design may have to be redesigned in order to keep the vibrations low.

[12] PRECAUTIONS IN PIPING WHEN USE RUBBER MOUNT

If engine and related equipment are supported on different frames, flexible piping ※ must be used.



WG1605_082A

※※Refer the exhaust system of installation instructions

Figure 11-22

3. POWER TRANSMISSION DEVICE

[1] FLEXIBLE COUPLING

Torsional vibration and impact of the drive shaft can be absorbed by a flexible coupling which prevents them from being transmitted to the driven shaft. Installation of such a coupling between the engine and driven shaft is limited by available space. A flexible coupling also prevents torsional vibrations and impacts generated at driven shaft from being transmitted to the engine. There are many types available, such as rubber types, resin types, chain types, tire types and fluid types.

Select according to specific load and use condition.

[2] POWER CUTOFF DEVICE (Clutches / Disconnects)

Power cutoff devices (clutches) allow engines to be warmed-up at no load. It is a general practice to install clutches on such as products vehicles, tractors, pump sets ; etc. which can encounter sudden loads.

The following kinds of clutches are available.

Mechanical type	Dry type	• Engagement • Friction plate loaded type (spring)....*1 • Centrifugal clutch
	Wet type	• Friction plate loaded type (spring)....*2
Electric type		• Electromagnetic clutch....*3

■ **NOTE**

- **The spring loaded type clutches (*1, 2) are always "IN" and a clutch pedal or lever is used to cut off power against spring force. For this reason, thrust force is applied to the crankshaft and care must be given to prevent use at a load exceeding the allowable limit.**
- **The electromagnetic clutch (*3), must be grounded to prevent an electric current from flowing to the crankshaft. Otherwise, bearing metals will be electrically corroded, resulting in possible bearing and crankshaft failure.**
  Detailed consultations should be held with the engine maker to determine the most appropriate clutch for a particular engine and purpose.

[3] TORSIONAL VIBRATION

When an output shaft is directly connected to the crankshaft, it is necessary to examine stresses caused by torsional vibration of the shaft system depending on rigidity and inertia force of connecting shaft system. When connecting the engine directly to generator, compressor, pump, air blower, etc., contact KUBOTA.

4. SPEED CHANGE DEVICES

The following kinds of speed change devices are available.

1. Mechanical type : Gear speed change devices
2. Fluid type : Torque converter
3. Fluid type : Hydrostatic transmission (HST)

Efficiency is a common factor of an engine regarding load characteristics against engine characteristics and adaptability to using conditions and its frequency.

Fluid types allow stepless variation of torque and speed. Efficiency is lower than a mechanical type and varies greatly depending on speed range, so that matching should be done carefully.

Fluid types also require special maintenance since oil is used as the transmission a medium.

Various factors, including oil temperature, heat dispersion, rising of starting temperature limit due to resistance increase at cold starting must be considered, along with oil viscosity for use in cold weather.

Oil viscosity, and increased viscosities due to low ambients are important considerations.

5. OPERATING MECHANISM

If an engine is covered ; starting, speed changing, and stopping must be controlled remotely via a mechanical (rod or wire) or an electrical system.

In this case, consider clearances of link mechanism, wear and aging factors carefully. Improper installation will adversely affect engine performance.

Provide special attention to frequency of use and force applied to levers.

6. OTHER PRECAUTIONS

1. When both the engine and transmission machine are directly connected and fixed, rigidity and strength of the mounting base must be considered carefully.
   i.e. Material, plate thickness, flatness, roughness, etc.
2. Engine mounting stands and fixing bolts must have sufficient rigidity and strength.

INSTALLATION INSTRUCTION

INSTALLATION INSTRUCTION

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1. IMPORTANT NOTICE

[1] EMISSION-RELATED INSTALLATION INSTRUCTIONS

These instructions are provided to the Final Engine Assemblers (FEA) who must ensure the engine, exhaust system (catalyst), fuel system etc, are installed correctly in the engine's certified configuration.

The emission related parts which FEA prepare (for example the exhaust pipe between the exhaust manifold and the catalyst) must be designed to function throughout the useful life without any failure.

Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105 (b)), subject to fines or other penalties as described in the Clean Air Act.

2. OBJECTIVE ITEMS

[1] EXHAUST SYSTEM

Kubota supplies a certified catalyst. FEA must use a Kubota certified catalyst and assemble the exhaust system parts according to the instructions.

No other catalyst is certified for use with WG1605 Engine. No Other Catalyst can be used.

FEA may only install the exhaust system parts confirmed at application review.

[2] INTAKE SYSTEM

To prevent decreases of engine output performance, intake resistance must be kept below a certain point.

[3] CRANKCASE VENTILATION CONNECTIONS

Crankcase emissions may not be discharged directly into the ambient atmosphere throughout its useful life.
(40 CFR 1048.115(a))

[4] GASOLINE FUEL SYSTEM

If your equipment uses a volatile liquid fuel (such as gasoline), they must meet the evaporative emission standards of 40 CFR 1048.

[5] GASEOUS FUEL SYSTEM

FEA must use only the vaporizer and the lock-off valve Kubota offers and assemble the LPG fuel system parts according to the instructions.

[6] ENGINE CONTROL UNIT (ECU)

Installation must utilize all 4 of the vibration mounts.

ECU header pins must be horizontal or point downward.

[7] VEHICLE INTERFACE CONNECTORS

Vehicle interface connectors shall be connected with your wire harness.

[8] MALFUNCTION INDICATOR LIGHT (MIL)

When the MIL goes on, it must display "Check Engine," "Service Engine Soon," or a similar message that EPA approve.
(40 CFR 1048.110 (b))

[9] TRACING INFORMATION

You (FEA) may demonstrate compliance with the requirements of 40 CFR 1068.261 by maintaining a database showing how you (FEA) pair aftertreatment components with the appropriate engines such that the final product is in its certified configuration.

(40CFR 1068.261 (b))

Tracing information of Engine, ECU and Catalyst must be reported.

[10] CERTIFICATION LABELS

Kubota installs the certification label on the cylinder head cover.

If you (FEA) install the engine in a way that makes the engine's emission control information label hard to read during normal engine maintenance, you (FEA) must place a duplicate label on the equipment, as described in 40 CFR 1068.105.

(40 CFR 1054.130(b) (7))

[11] END OF LINE (EOL) TEST DATA

FEA must report a record of End Of Line (EOL) test data.

3. EXHAUST SYSTEM

[1] EXHAUST SYSTEM

Exhaust system means the layout of all parts from the exhaust manifold to the exhaust exit.
An example of exhaust system is shown in the below.

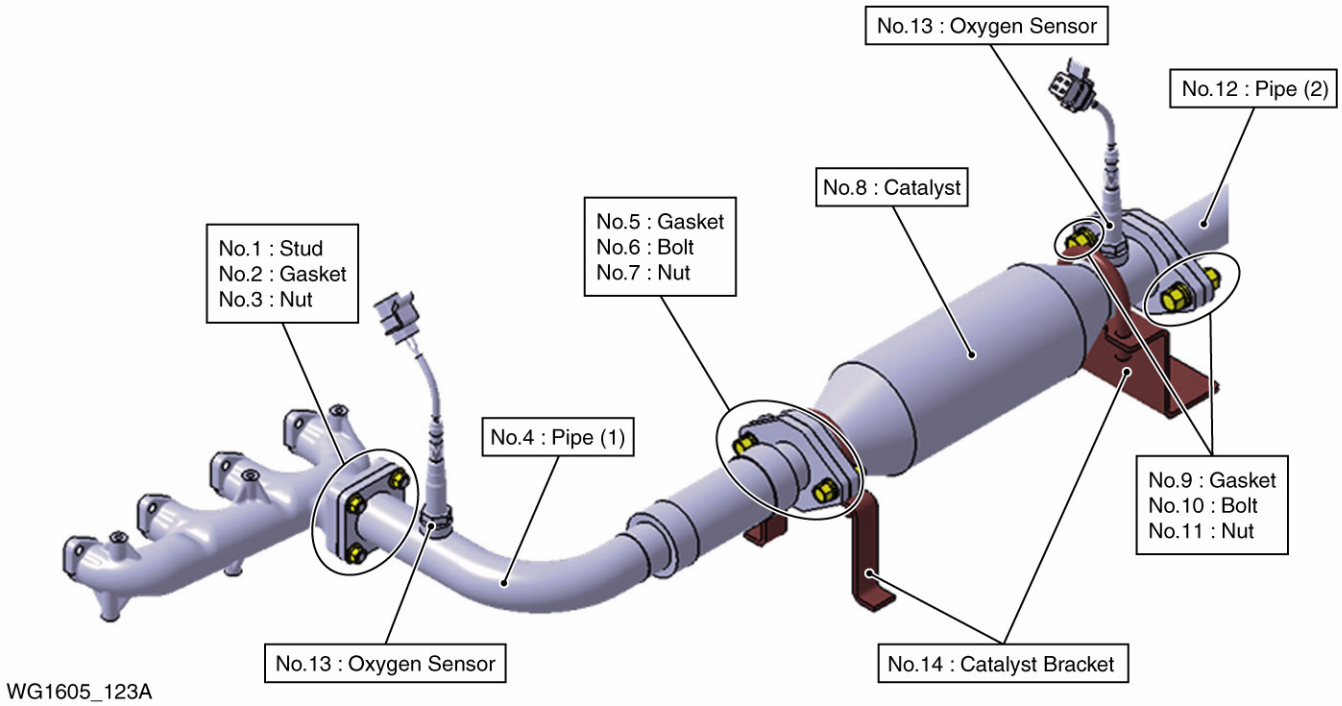


Figure 1-1

Kubota supplies the exhaust system parts as shown in the next page, these parts must be used in the exhaust system.

FEA supplied parts must meet the installation instruction requirements.

No.	Part Name	FEA	Kubota supplied	KBT Part No.	Q'ty	Remarks
1	Stud		❍	1J530-9150Δ	4	M8, length : 20mm (0.79 in.)
2	Gasket		❍	EG523-1223Δ	1	
3	Nut		❍	02756-50080	4	M8
4	Pipe (1)	❍		–	–	material : stainless steel (ISO : X5CrNi18-10 or equivalent) internal diameter : ϕ36 to 38 mm (1.42 to 1.49 in.) length : typically 300 to 910 mm (11.82 to 35.82 in.) (refer to page 1-5) with a thread boss for a pre catalyst oxygen sensor (refer to page 1-8 to 1-9) vibration isolation between the exhaust manifold and the catalyst
5	Gasket		❍	EG523-1237Δ	1	use only what Kubota offers
6	Bolt	❍		–	2	M10 Strength Classification : ISO 8.8
7	Nut	❍		–	2	M10 Strength Classification : ISO 8
8	Catalyst		❍	EG523-1212Δ	1	use only what Kubota offers
9	Gasket		❍	EG523-1238Δ	1	use only what Kubota offers
10	Bolt	❍		–	2	M12 strength classification : ISO 8.8
11	Nut	❍		–	2	M12 strength classification : ISO 8
12	Pipe (2)	❍		–	–	length : minimum 216 mm (8.50 in.) (in case a muffler is not installed)
13	Oxygen Sensor		❍	EG523-1224Δ	2	use only what Kubota offers
14	Catalyst Bracket	❍		–	–	

[2] CATALYST LAYOUT

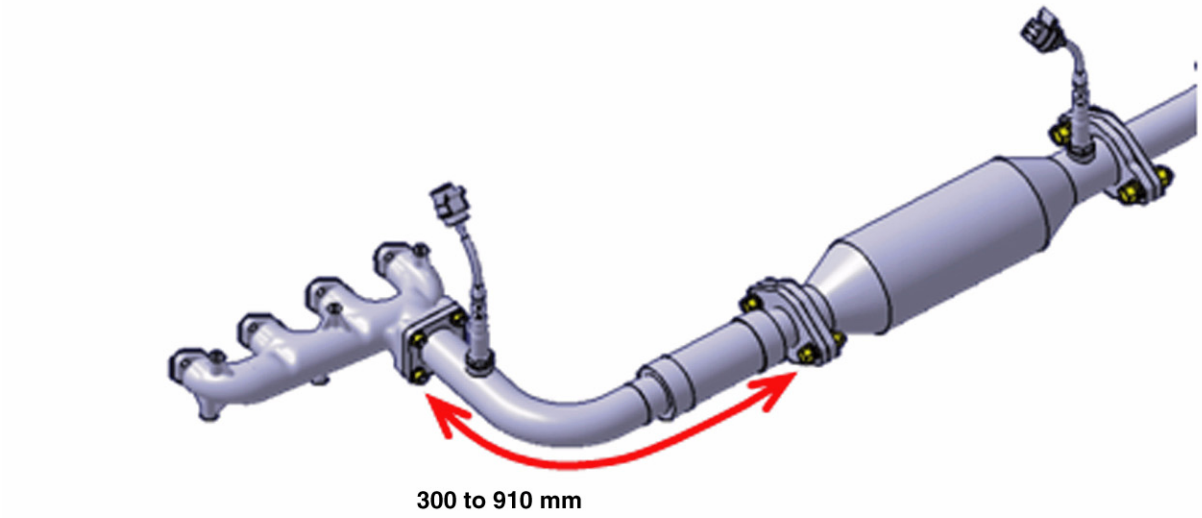
Incorrect catalyst layout will cause emission non-compliance or damage to the catalyst.
Catalyst layout must comply with the following.

1.To maintain emissions compliance

Exhaust gas temperature entering the catalyst must be over 315 °C even at low idle condition.
If the distance from the exhaust manifold to the catalyst is too far, exhaust temperature may be insufficient for proper catalytic reaction.
The distance from the exhaust manifold to the catalyst must be less than 910 mm (35.82 in.).

2.To prevent catalyst break down

Exhaust gas temperature entering the catalyst must be kept under 850 °C at any condition.
If the distance from the exhaust manifold to the catalyst is too short, the catalyst will be damaged due to high exhaust temperature.
The distance from the exhaust manifold to the catalyst must be over 300 mm (11.82 in.).

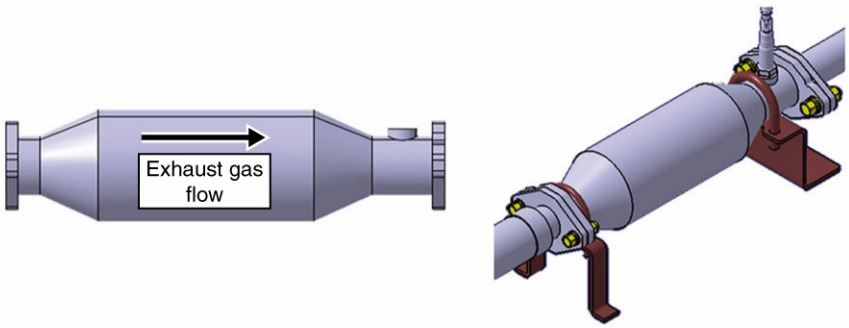


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Figure 1-2

[3] CATALYST INSTALLATION

1. Vibration acceleration must not exceed 5 G at any condition.
   Exhaust pipe should utilize a vibration isolator in the exhaust pipe to isolate vibrations transported to the catalyst.
   – Vibration isolation between the exhaust manifold and the catalyst shall be provided by FEA.
     A piece of flexible tube is recommended.
   – Vibration isolation between the chassis and the catalyst shall be provided by FEA. Vibration damping washers are recommended.
2. The catalyst must be mounted within +/-10˚ of horizontal.
3. The catalyst shall not support mounting loads from adjacent components (pipe).
4. The catalyst must be supported at two places.
   Do not support at substrate portion or taper portion.
   Be careful not to crush or damage the pipe when the catalyst is supported and fastened.
5. Pay attention to the installation direction of the catalyst.
6. Do not use any dropped catalysts.



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Figure 1-3

[4] EXHAUST GAS LEAK (CONNECTION)

Exhaust system parts must be installed according to the following to avoid exhaust gas leaks.

(1) Outlet Of The Exhaust Manifold

The exhaust manifold and the pipe (1) must be jointed using the studs, gasket and the nuts supplied by Kubota with instructed tightening torque.

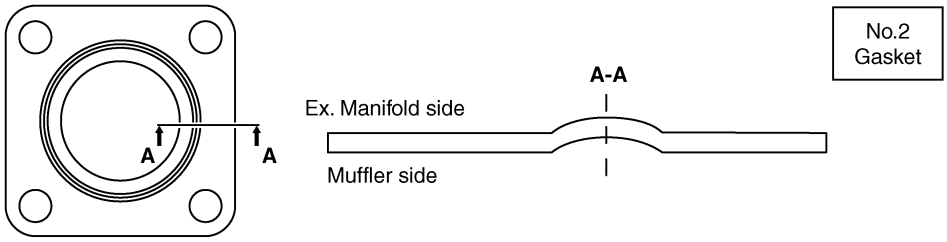
Tightening torque is 29.4 to 34.3 N·m.

FEA must prepare the pipe (1).
The flange jointed to the exhaust manifold;
Flange thickness is 10 to 11 mm (0.40 to 0.43 in.).
Flatness of the flange face is maximum 0.1 mm (0.0039 in.). Roughness of the flange face is 3.2 Ra.

Pay attention to the gasket face direction. Please see Figure 1-4.

(2) Between The Exhaust Manifold And The Catalyst

If the pipe (1) consists of more than 2 parts, the following parts must be used.
Kubota supplied gasket : EG523-1223Δ (ϕ9 mm (0.35 in.) - 4 holes)
FEA supplied bolts and nuts:
flange bolts: M8, strength classification is ISO 8.8
flange nuts: M8, strength classification is ISO 8
tightening torque; 23.5 to 27.5 N·m
Flange thickness is 11 mm (0.43 in.) or more.
Flatness of the flange face is maximum 0.1 mm (0.0039 in.). Roughness of the flange face is 3.2 Ra.

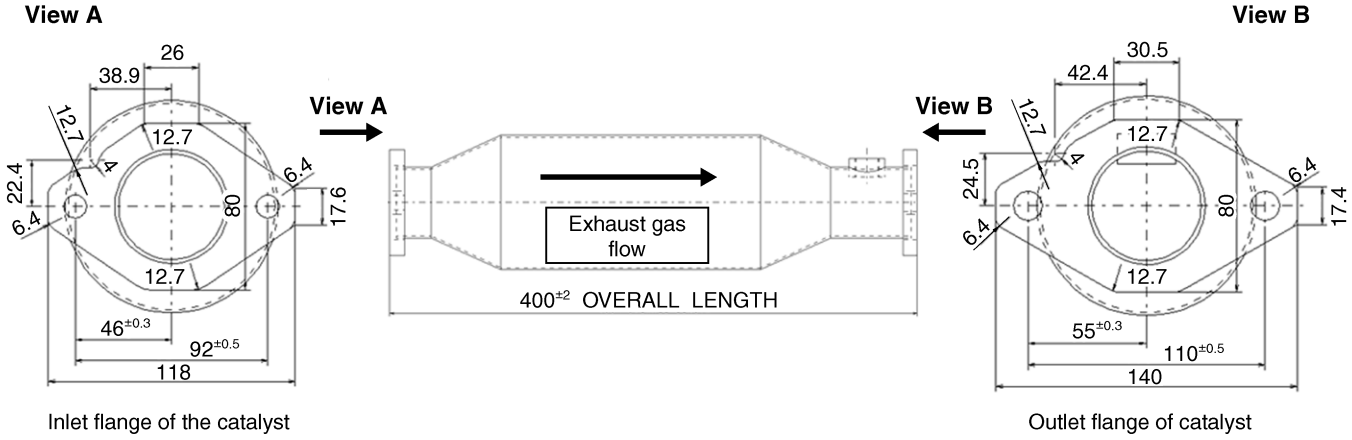


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Figure 1-4

(3) Inlet And Outlet Of The Catalyst

Gaskets supplied by Kubota (inlet of the catalyst; EG523-1237Δ, outlet of the catalyst; EG523-1238Δ) must be used.
FEA supplied bolts and nuts:
flange bolts: strength classification is ISO 8.8
flange nuts: strength classification is ISO 8
inlet of the catalyst: M10, tightening torque is 48.1 to 55.9 N·m.
outlet of the catalyst: M12, tightening torque is 77.5 to 90.2 N·m.
The flange connected to the catalyst;
Flange thickness is 11 mm (0.43 in.) or more.
Flatness of the flange face is maximum 0.1 mm (0.0039 in.). Roughness of the flange face is 3.2 Ra.



Inlet flange of the catalyst

Outlet flange of catalyst

WG1605_127A

Figure 1-5

[5] OXYGEN SENSOR

Do not use any dropped oxygen sensors.

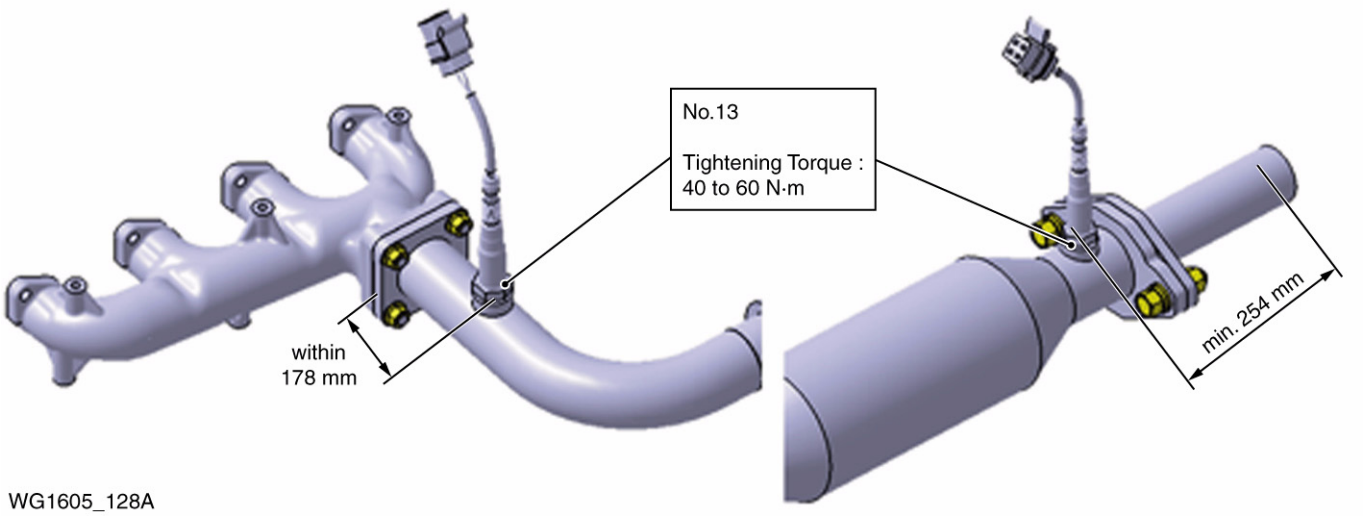


Figure 1-6

The pre catalyst oxygen sensor must be mounted in the pipe which is installed between the exhaust manifold and the catalyst. The sensor must be mounted within 178 mm (7.01 in.) from the exhaust manifold outlet flange.

The post catalyst oxygen sensor must be mounted in the catalyst boss. In case a muffler is not installed, a minimum 254 mm (10.0 in.) of the pipe length after the sensor is required.

Oxygen Sensor Location Guideline

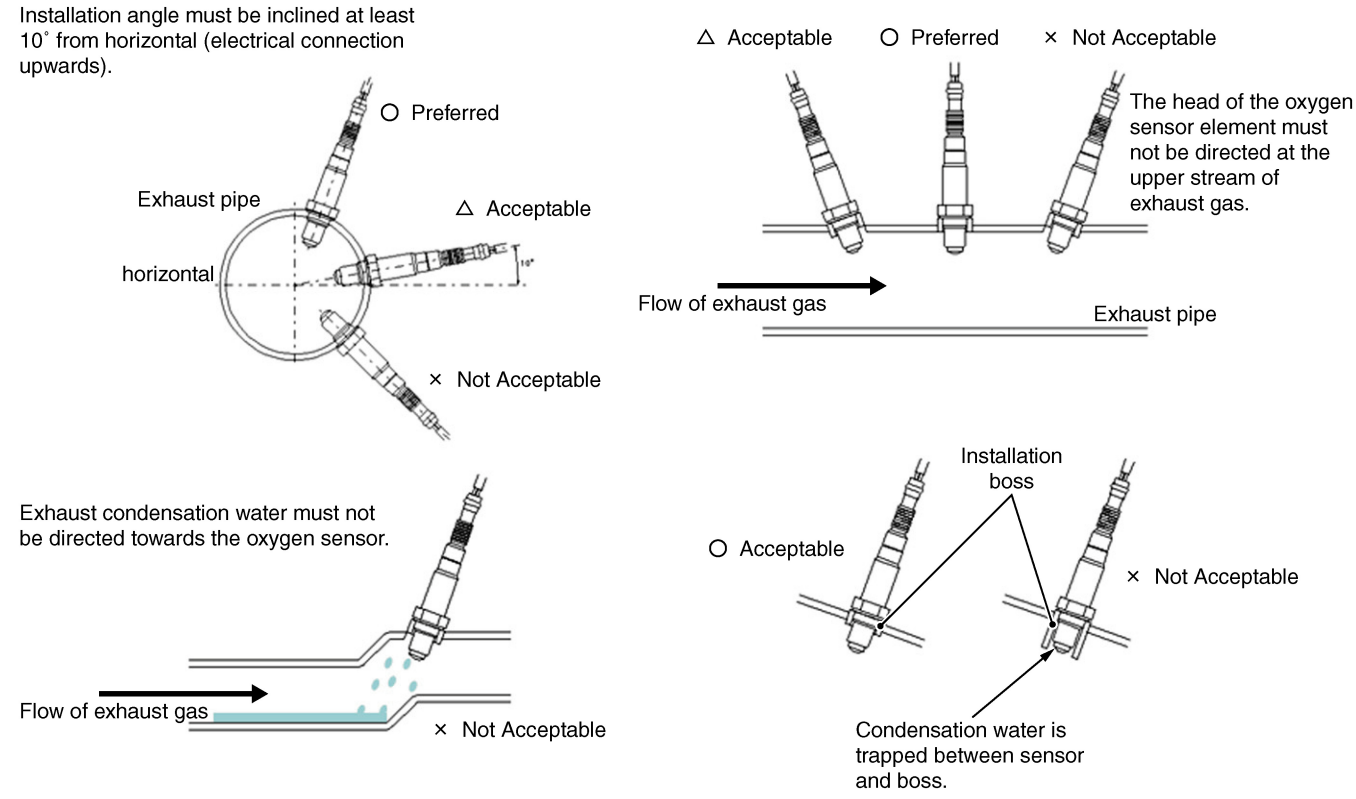


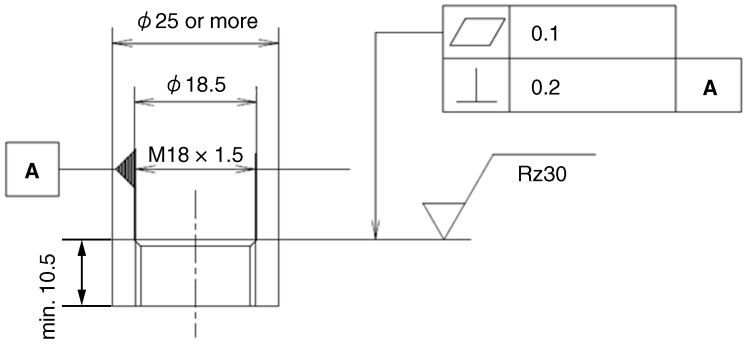
Figure 1-7

Oxygen Sensor Thread Boss

Recommended material : Temperature resistant stainless steel (ISO : X5CrNi18-10 or equivalent)
Thread boss dimensions should be as sketched below.

■ **NOTE**

- **The sensor thread must be completely covered.**

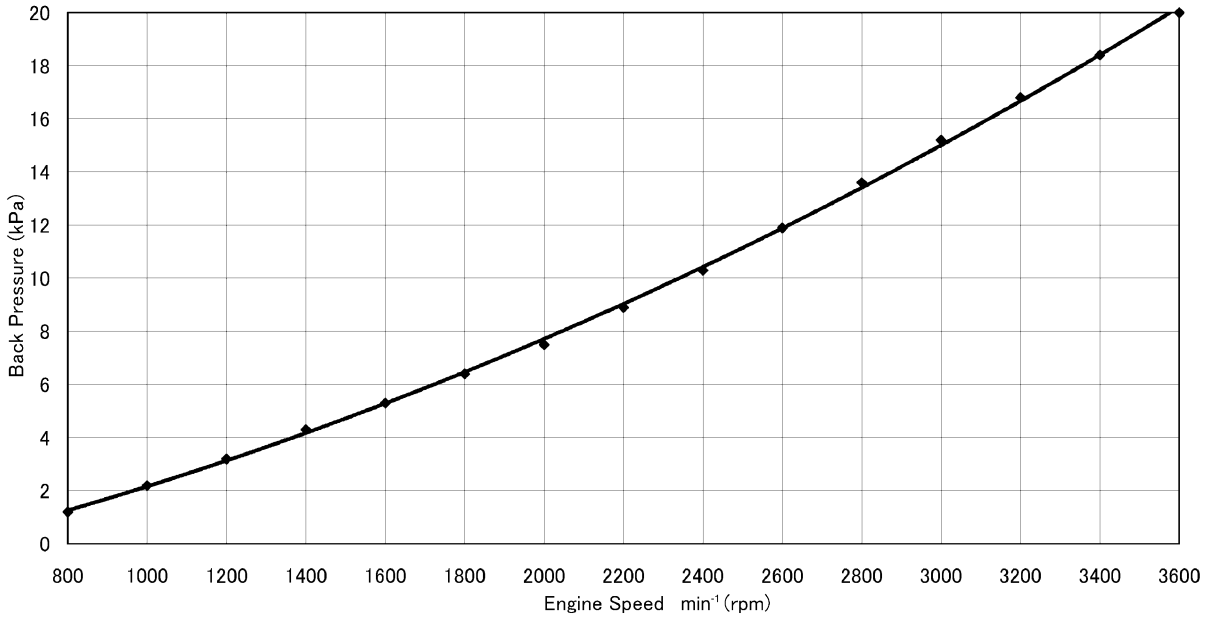


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Figure 1-8

[6] BACK PRESSURE

Back Pressure of exhaust system must be held within the following data at full load condition.
Measurement point of back pressure of exhaust system is between the exhaust manifold and the catalyst.



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Figure 1-9

Engine Speed min^{-1} (rpm)	Back Pressure (kPa)
800	1.2
1000	2.2
1200	3.2
1400	4.3
1600	5.3
1800	6.4
2000	7.5
2200	8.9
2400	10.3
2600	11.9
2800	13.6
3000	15.2
3200	16.8
3400	18.4
3600	20.0

[7] OTHER NOTICE

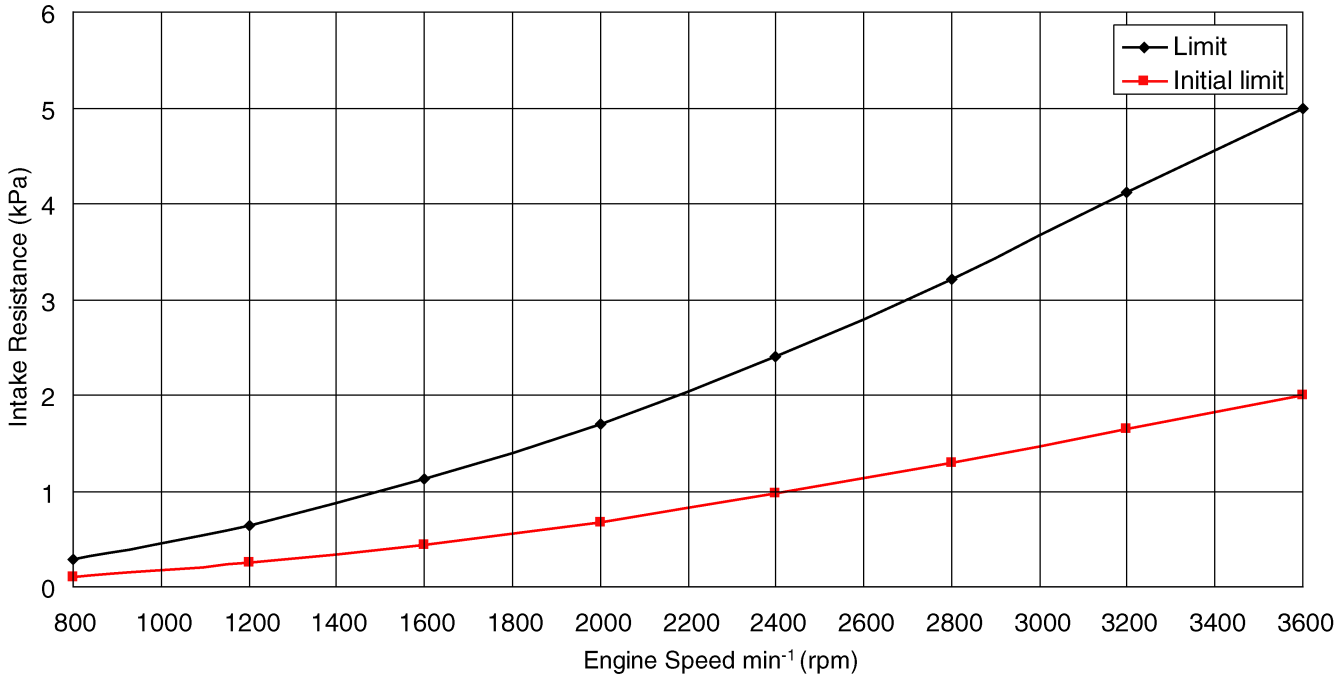
1. The exhaust system will be very hot, so to protect electrical parts such as starter, alternator, oil switch and fuel system parts around the exhaust system and for the safety of operators, FEA should install heat shields or blanket as necessary.
   Heat shield must not be welded to the catalyst.
   FEA must confirm the temperature of the components during the application review.
   Maximum temperature
   - starter : ≤ 80 °C
   - alternator : ≤ 90 °C
   - oil switch : ≤ 110 °C
2. Confirm that water does not enter the exhaust system from the tail pipe outlet. If water entry is possible, install a rain cover or similar device.
3. In case exhaust emissions are sampled after the engine is installed in equipment and placed in service, a 20-centimeter extension must be installed after the tail pipe. (40 CFR 1048.205 (v))

4. INTAKE SYSTEM

Intake Resistance

To prevent decreases of engine output performance, intake resistance must be held within the following data at full load condition.

Measurement point of intake resistance is between the air cleaner and the inlet of the throttle body (–G) or the mixer (–L, –GL).



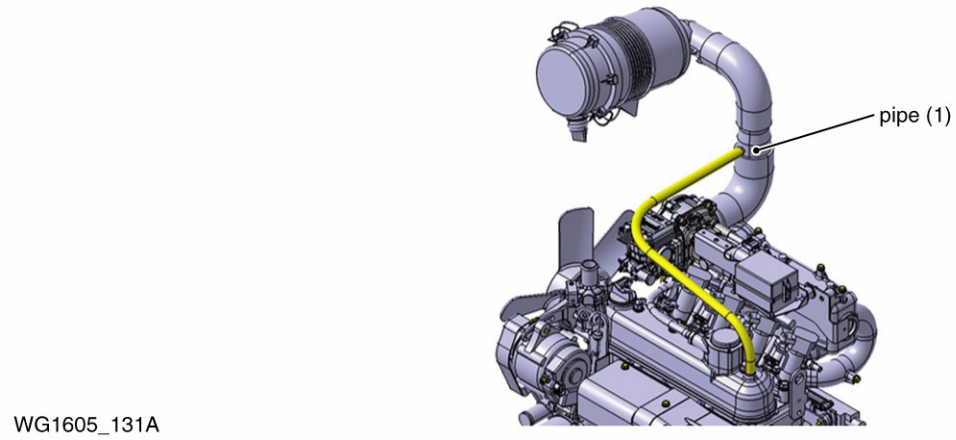
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Figure 1-10

Engine Speed min^{-1} (rpm)	Intake Resistance	
	Limit w/dirty filter (kPa)	Initial limit w/clean filter (kPa)
700	0.22	0.08
800	0.28	0.10
1200	0.64	0.25
1600	1.12	0.44
2000	1.17	0.67
2400	2.40	0.97
2800	3.21	1.29
3200	4.11	1.65
3600	5.00	2.00

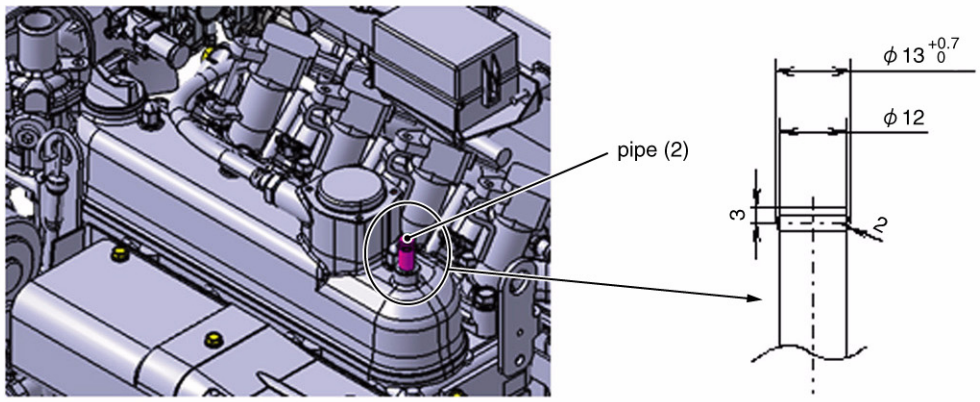
5. CRANKCASE VENTILATION CONNECTIONS

1. Crankcase emissions may not be discharged directly into the ambient atmosphere throughout its useful life. (40 CFR 1048.115 (a))
2. Connect the pipe (1) (between the air cleaner and the throttle body) and the pipe (2) (of head cover) with appropriate hose or tubing.
3. Connections must be verified at application review.
4. Only piping parts which have been verified at application review must be used.
5. External diameter of the pipe which is set on the head cover is as shown in Figure 1-12. Hose or tubing should be smaller diameter to provide an interference fit.



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Figure 1-11



WG1605_132A

Figure 1-12

6. GASOLINE FUEL SYSTEM

[1] FUEL LINE

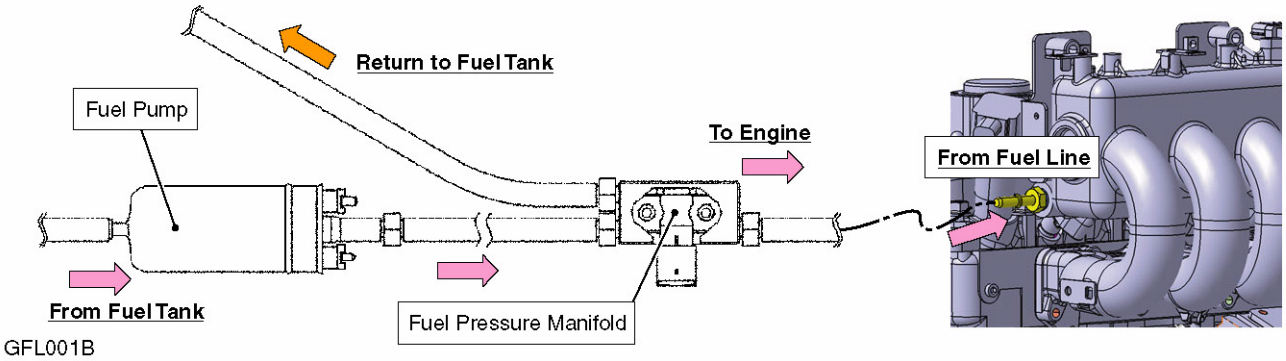


Figure 1-13

[2] FUEL PUMP

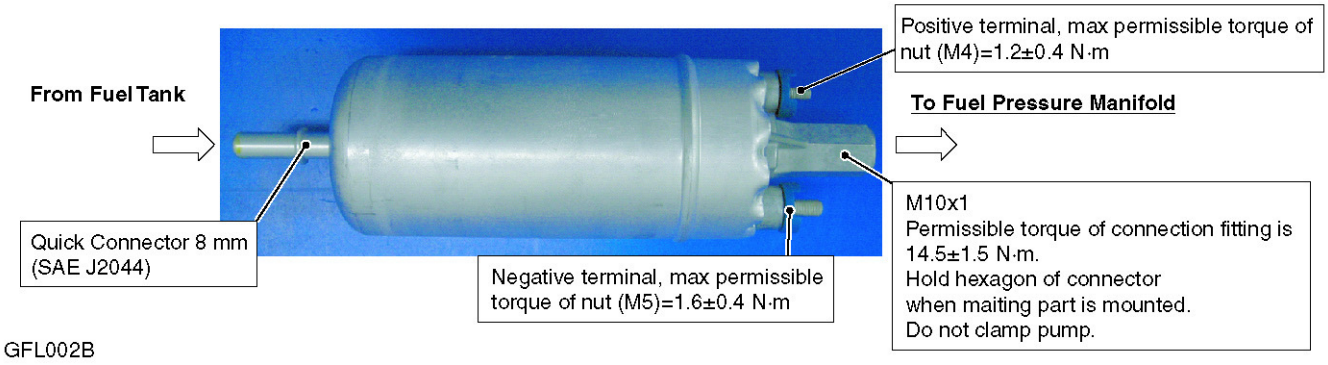


Figure 1-14

Installation Requirements

1. Maximum vibration levels not to exceed 3 G.
2. Maximum allowable suction pressure to be ≤ 10 kPa. (Below atmospheric pressure)
3. Pump body not to be secured by excessive clamping force causing any deformation of pump housing.
4. Teflon tape not to be utilized during fitting assembly.
5. Pump should not be mounted in high temperature environments to prevent cavitation vapor lock conditions.

[3] FUEL PRESSURE MANIFOLD

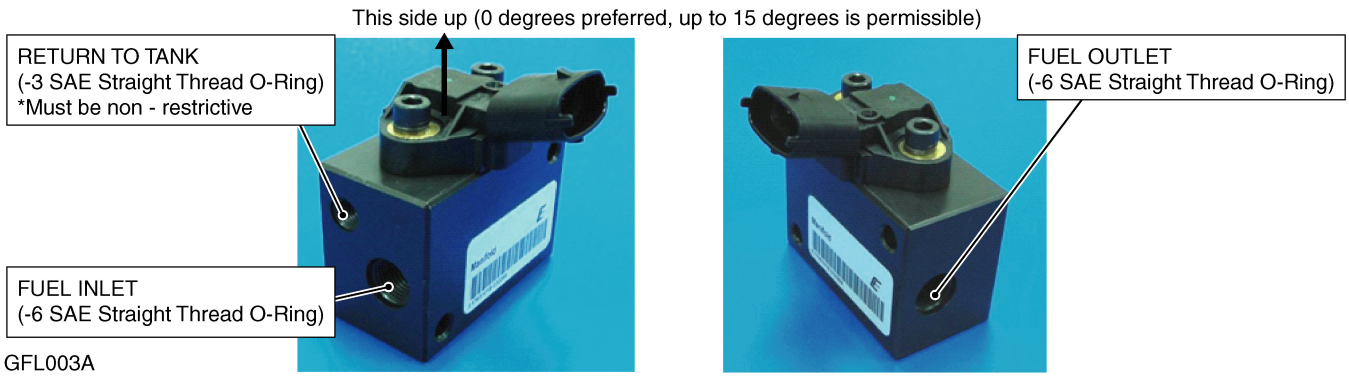


Figure 1-15

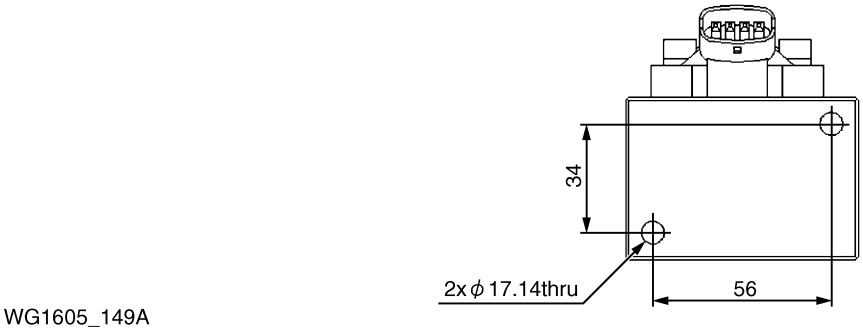


Figure 1-16

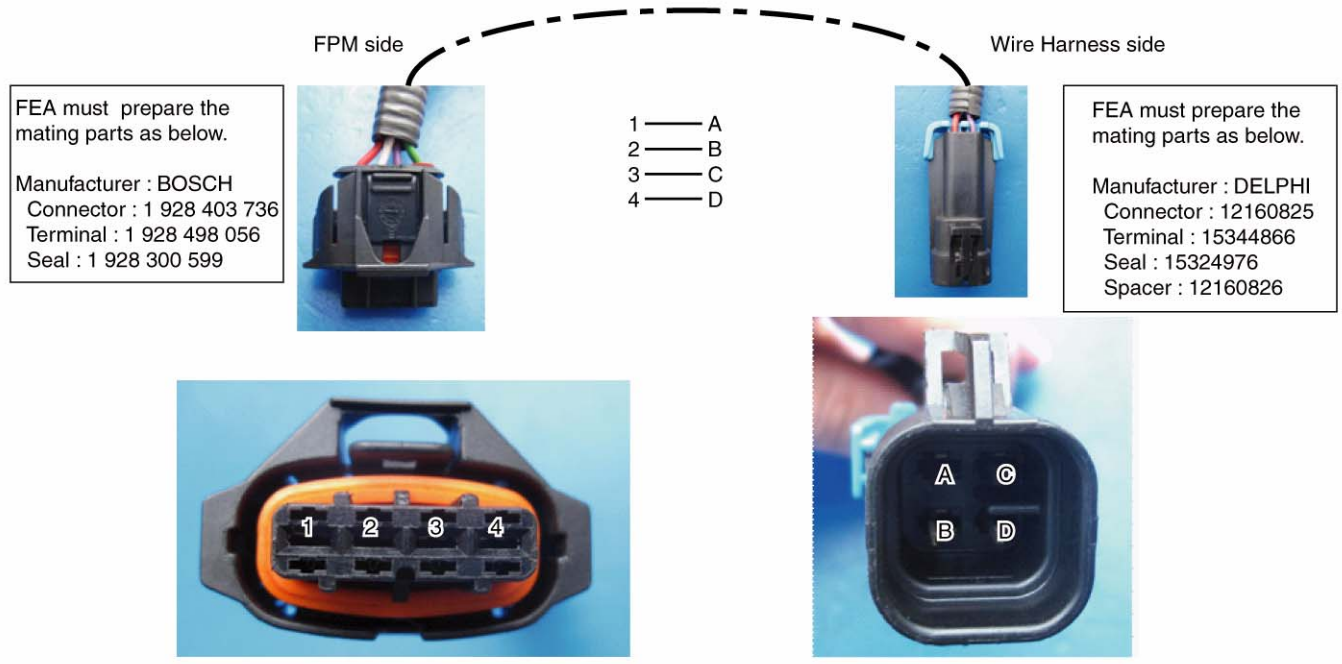
Fuel Pressure Manifold enables gasoline fuel system to meet the EPA evaporative emissions requirements implemented for industrial mobile LSI engines in 2007. The ECU equipped to provide Pulse Width Modulation control of the fuel pump. This control feature and fuel pressure manifold combination prevent the build-up of excess heat in the gasoline tank which in turn reduces the evaporative emissions.

Installation Requirements

1. 0 degrees preferred, up to 15 degrees is permissible, over 15 degrees is not permissible.
2. Device must be mounted direct (no rubber isolation) to frame rail in relatively cool area (not to exceed 85 °C)
3. The volume of fuel between the fuel pump and this device must be a minimum of 25 cm^3, yet can not exceed 75 cm^3 without approval.

[4] WIRING FOR FUEL PRESSURE MANIFOLD

FEA must prepare the relay wire harness between the wire harness and the fuel pressure manifold (FPM).
Wire kind : SAE-J1128-TXL or equivalent
Wire size : AWG18 or equivalent
Heat resistant convoluted tube (> 120 °C) shall be convolved.

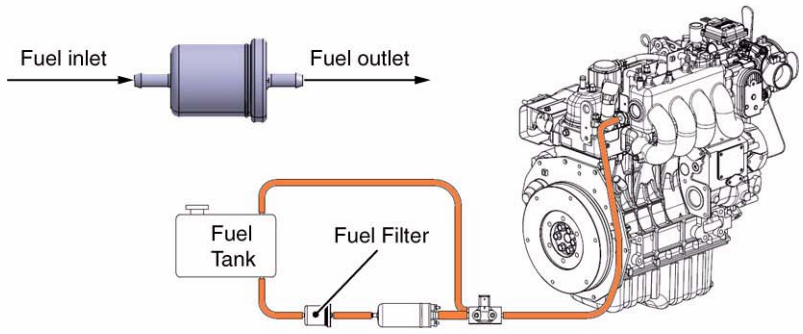


GFL004B

Figure 1-17

[5] FUEL FILTER

Kubota supplies fuel filter (12581-4301Δ).
Fuel filter shall be installed between fuel tank and fuel pump.



WG1605_133A

Figure 1-18

[6] EVAPORATIVE EMISSION

(1) General

If your equipment uses a volatile liquid fuel (such as gasoline), it must meet the evaporative emission standards of 40 CFR 1048.

The Kubota engine is designed to comply with evaporative emissions utilizing a design based certification.

These instructions describe the gasoline fuel system which meets evaporative emission regulations.

FEA must apply the fuel system according to the instructions described in following pages.

(2) Evaporative Emission Controls of KUBOTA Gasoline Fuel System

The Kubota engine is designed to comply with evaporative emissions utilizing a design based certification.

This is accomplished by not adding any additional heat above ambient temperature to the fuel tank.

The fuel system is a return-less rail system, where the pressure is accurately controlled via closed loop control of the fuel pump's speed.

Being a return-less system, the fuel does not have any chance of being heated in the engine's injector fuel rail and then returned to the tank ; consequently it cannot increase the bulk tank temperature resulting in higher vapor pressures.

Accurate pressure control is achieved by the ECU from constantly monitoring the fuel delivery pressure and adjusting fuel pump speed as necessary.

As a verification of compliance, the fuel temperature is also constantly monitored to ensure that it is maintained below the fuel boiling point.

Should the fuel temperature exceed the set point, a diagnostic code is set.

Kubota supplies the fuel pump and fuel pressure manifold with the WG1605 gasoline engine.

FEA must prepare fuel tanks, fuel hoses, and gasoline fuel caps.

These parts must be selected according to Instructions described in the following pages.

And FEA must report these part numbers and / or the official certification numbers such as EO numbers to Kubota.

(3) Evaporative Emissions Guidelines

1. Fuel pressure manifold must be mounted away from engine compartment heat.
   Must be in cool location, preferably close to the machine fuel tank.
2. FEA supplied non-metallic fuel line must conform to permeation Category 1 of SAE J2260. (40 CFR 1048.105 (a))
3. The gasoline fuel tank must have a self-tethered fuel cap sealed up to a positive pressure of 24.5 kPa (3.5 psig). (40 CFR 1048.245 (e) (1) (i))
   Cap must comply with CARB and EPA regulations.
4. Liquid fuel in the fuel tank may not reach boiling during continuous engine operation in the final installation at an ambient temperature of 30 °C. (40 CFR 1048.105 (d))
5. Note that gasoline with a Reid vapor pressure of 62 kPa (9 psi) begins to boil at about 53 °C at atmospheric pressure, and at about 60 °C for fuel tanks that hold pressure as described in § 1048.245 (e) (1) (i). (40 CFR 1048.105 (d))
   FEA must confirm that bulk gasoline in fuel tank will not boil under continuous normal engine operating condition when tested at 30 °C ambient at application review.
6. Nonmetal fuel tanks must also use one of the qualifying designs for controlling permeation emissions specified in 40 CFR 1060.240. (40 CFR 1048.245 (e) (1) (i))
7. FEA must consult Kubota when changes are made to the fuel system after application review.

(4) Fuel Diagram

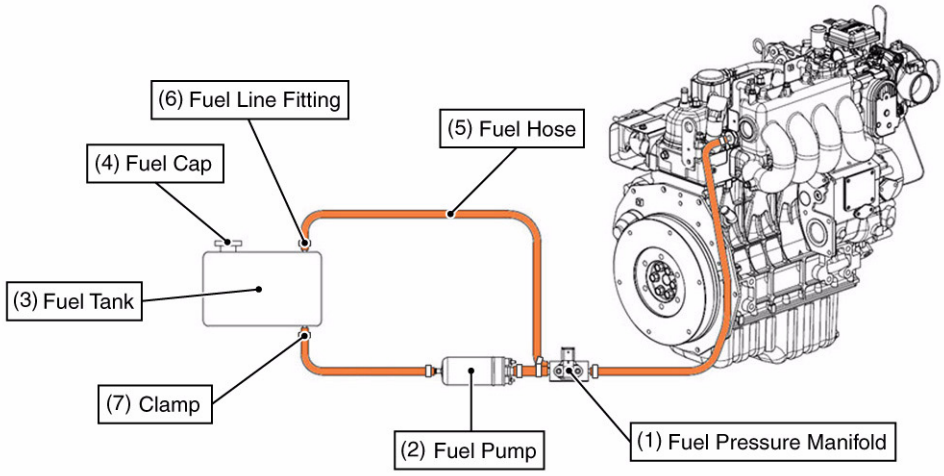


Figure 1-19

FEA must construct your fuel system as shown in Figure 1-19.
Kubota supplies the fuel pump and the fuel pressure manifold that should be used.
FEA must consult Kubota, to use alternative parts (fuel pump, fuel pressure manifold) if desired.
FEA must prepare the other parts according to the instructions described in following pages.

No.	Part Name	FEA	Kubota supplies	KBT Part No.
1	Fuel Pressure Manifold		❍	EG522-5207 Δ
2	Fuel Pump		❍	EG522-5202 Δ
3	Fuel Tank	❍		–
4	Fuel Cap	❍		–
5	Fuel Hose	❍		–
6	Fuel Line Fitting	❍		–
7	Clamp	❍		–

(5) Fuel Tank Approved To Meet Evaporative Emission Requirements

Fuel tank must meet the following requirements.

1. Large SI fuel tanks must meet diurnal emission standards as specified in § 1060.105, which includes measurement of permeation emissions. No separate permeation standard applies.
   (40 CFR 1060.103 (a) (2))
2. Large SI fuel tanks must meet the requirements related to diurnal emissions specified in 40 CFR 1048.105.
   (40 CFR 1060.105 (a) (2))
3. Evaporative hydrocarbon emissions may not exceed 0.2 grams per gallon of fuel tank capacity when measured using the test procedures specified in § 1048.501.
   Diurnal emission controls must continue to function during engine operation.
   (40 CFR 1048.105 (c))

FEA may use a fuel tank listed in the table on the following CARB web site.
http://www.arb.ca.gov/msprog/offroad/sore/sorecomponent/sorecomponent.htm

FEA must report the part number and/or the official certification number such as EO number of the fuel tank to Kubota.

(6) Fuel Cap Approved To Meet Evaporative Emission Requirements

Fuel cap must meet the following requirements.

1. Use a tethered or self-closing gas cap on a fuel tank that stays sealed up to a positive pressure of 24.5 kPa (3.5 psig) ; however, they may contain air inlets that open when there is a vacuum pressure inside the tank. Nonmetal fuel tanks must also use one of the qualifying designs for controlling permeation emissions specified in 40 CFR 1060.240. (40 CFR 1048.245 (e) (1) (i))
2. All equipment must have a tethered fuel cap. Fuel caps must also include a visual, audible, or other physical indication that they have been properly sealed. (40 CFR 1060.101 (f) (1) (i))

   FEA must report the part number and/or the official certification number of the fuel cap to Kubota.

(7) Fuel Hose Approved To Meet Evaporative Emission Requirements

Fuel hose must meet the following requirements.

1. Fuel line permeation. For nonmetallic fuel lines, you (FEA) must specify and use products that meet the Category 1 specifications for permeation in SAE J2260 (incorporated by reference in § 1048.810). (40 CFR 1048.105. (a))
2. Do not use low-pressure rubber hose for any part of the gasoline fuel system. (Nominal fuel pressure of this engine is 300 kPa (43.5 psi).)

   FEA may use a fuel hose listed in the table on the following CARB web site.
   http://www.arb.ca.gov/msprog/offroad/sore/sorecomponent/sorecomponent.htm

FEA must report the part number and/or the official certification number such as EO number of the fuel hose to Kubota.

(8) Fuel Fittings Approved To Meet Evaporative Emission Requirements

Use good engineering judgment to ensure that all fuel-line fittings will remain securely connected to prevent fuel leakage throughout the useful life of the equipment. (40 CFR 1060.101 (f) (2) (i))

(9) Fuel Clamp Approved To Meet Evaporative Emission Requirements

FEA must use fuel hose clamps which will properly secure the fuel line.

7. GASEOUS FUEL SYSTEM

[1] VAPORIZER

1. No artificial pressurization of any ports (other than fuel inlet).
2. Vaporizer requires a normally-closed electrically controlled fuel lock-off solenoid valve that is close coupled to the vaporizer and off when ignition switch is off or when the engine is not running normally (supplied from Kubota). In operation without a lock-off upstream the vaporizer will flow fuel with the engine off. The vaporizer is not a fuel shut-off safety device.
3. Installation Requirements
   (1) Maintain a minimum of 20 mm (0.79 in.) of clearance around vaporizer when mounted.
   (2) Vertical mounting is preferred (mounting bolt surface horizontal).
   Horizontal mounting is not allowed (mounting bolt surface vertical).
   (3) 0 degrees preferred, up to 15 degrees tilt allowed from vertical in any direction.
   (4) Installation must not place regulator at the highest point in the engine coolant flow path.
   (5) Care is to be taken with coolant hose routing to ensure air is not trapped in the coolant portion of regulator heat exchanger.
4. Mounting (refer to page 1-22, Figure 1-23)
   (1) Must utilize both M6 × depth10 mm (0.39 in.) (pitch 41.15 mm (1.62 in.)) mounting points.
   (2) Associated mounting bracket must allow for a minimum of 8 mm (0.31 in.) of clearance to the secondary vent port.
   This may require a “cut out” in the bracket surface.
   (3) Associated mounting bracket must not direct liquids (such as high pressure cleaning fluids) towards either the primary or the secondary vent ports.
   (4) Vibration levels of vaporizer must not exceed 5 G at any frequency.

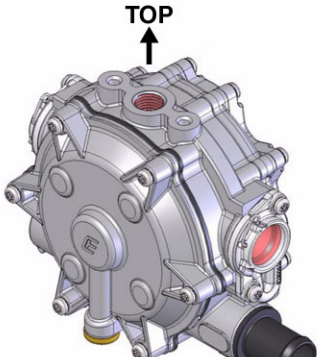


Figure 1-20

5. Location (refer to page 1-24, Figure 1-26)
   Fuel outlet centerline must not be more than 25 mm (0.98 in.) below mixer inlet centerline.
6. Fuel outlet fitting and hose requirements
   (1) Fuel outlet fittings : Fuel outlet ϕ19 mm (0.75 in.) hose straight fitting.
   (2) Fuel outlet hose (vapor hose) :
   • ϕ19.05 fuel hose between vaporizer and EPR, formed or molded hose should have swept bends to eliminate the possibility of sharp bends or kinks.
   • Eliminate drooping and low points that may collect oils or heavy ends in the hose which may affect system performance.
   • Vapor hose length must not exceed 700 mm (27.56 in.), shorter is generally considered better.
   Care should be taken with hose routing and length to minimize the affect on vaporizer vibration isolation.
   The metal reinforced hose should not be used.
7. Fuel inlet fitting requirements
   (1) Use Loctite 565, Loctite 567, Loctite 592, Permatex 565 xx, Permatex 806 xx, thread sealant or approved equivalent when installing. Do not use tape or particle based sealant.
   Care should be taken to not introduce sealant into flow path.
   (2) Tightening torque : 19.6 to 39.2 N·m
   (3) It is recommended to attach the lock-off wire harness to vaporizer in such a way that the harness connector and vaporizer vibrate together or attach the harness to a fixed point which provides 250 to 400 mm (9.85 to 15.74 in.) of free harness length from the lock-off connector.

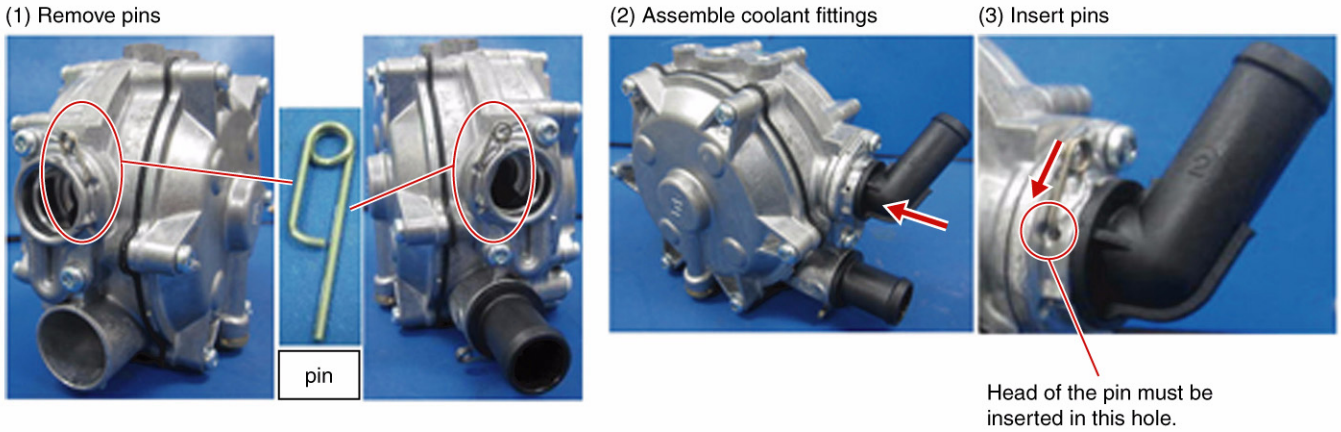
8. Minimum inlet fuel temperature
   –40 °C. Permanent vaporizer damage will occur if fuel inlet temperatures are below –40 °C.
   Fuel leakage and unintended fuel flow may occur if vaporizer fuel inlet temperature drops below –40 °C.
9. Coolant inlet/outlet fittings requirements
   Kubota supplies coolant fittings (EG525-4693△, 16 mm (0.63 in.) hose × 70 deg) as shown in Figure 1-21.
   The coolant fittings must be installed by using the pins which are set on the vaporizer.
   (1) Remove two pins from the vaporizer.
   (2) Assemble two coolant fittings to the vaporizer all the way seated.
   (3) Insert two pins to the original location from above.



Coolant fitting
(EG525-4693△)

WG1605_135A

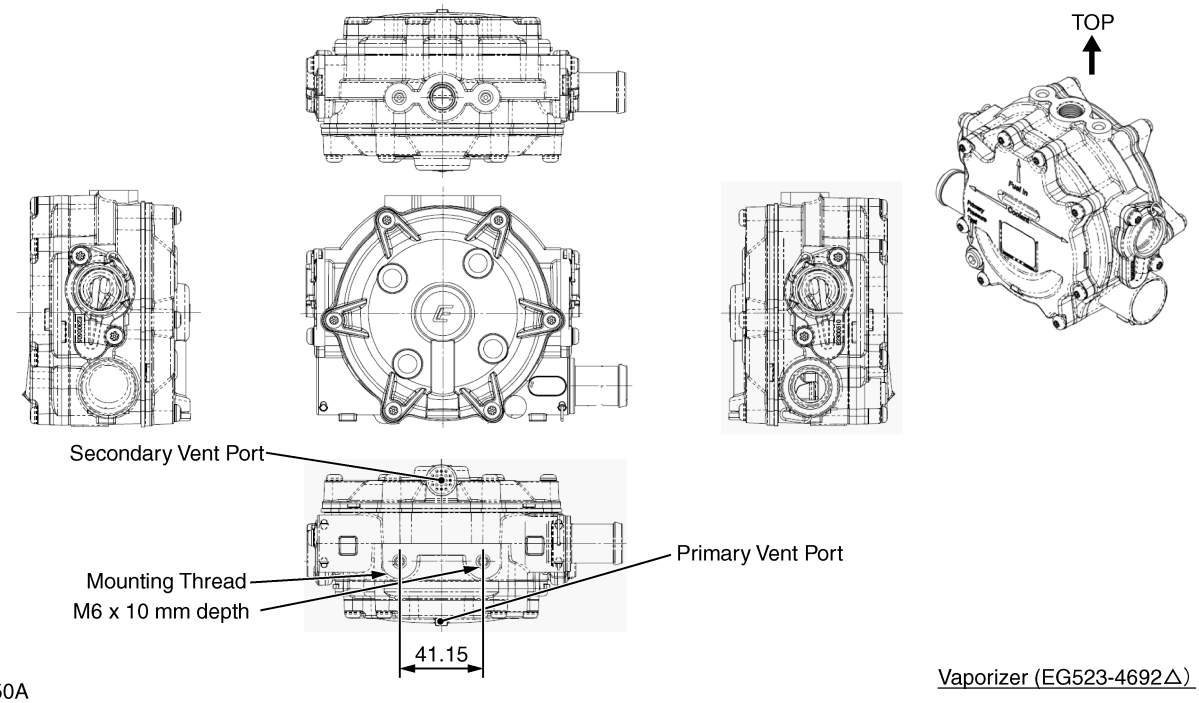
Figure 1-21



WG1605_136A

Figure 1-22

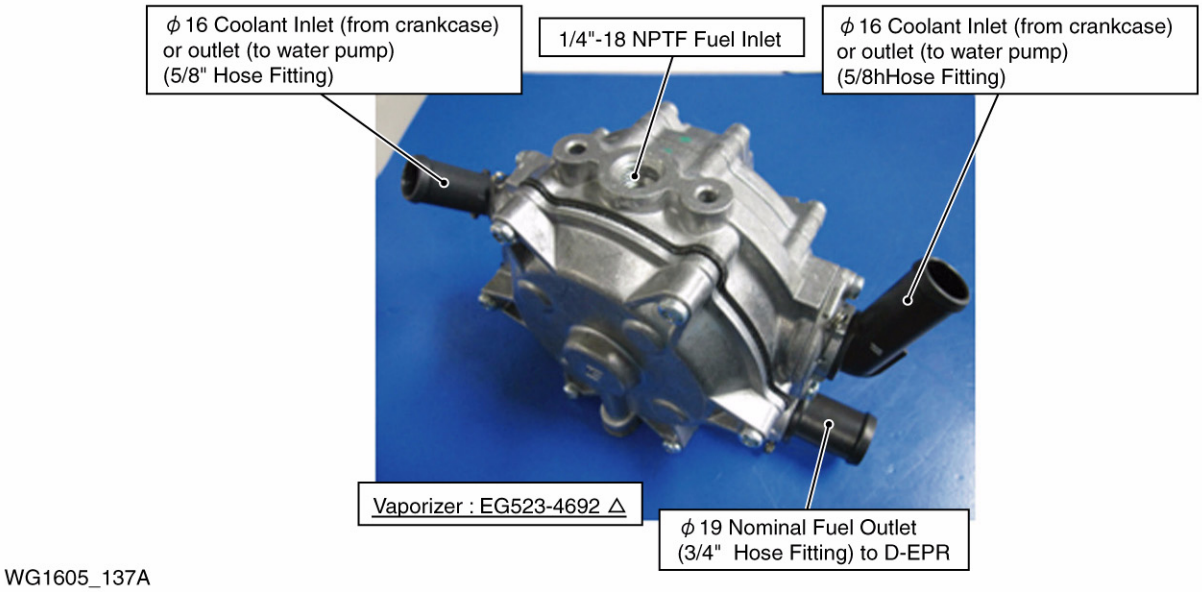
10. Fuel hoses shall be approved for LPG use.
11. All fuel hose and water hose connections need to be clamped.



WG1605_150A

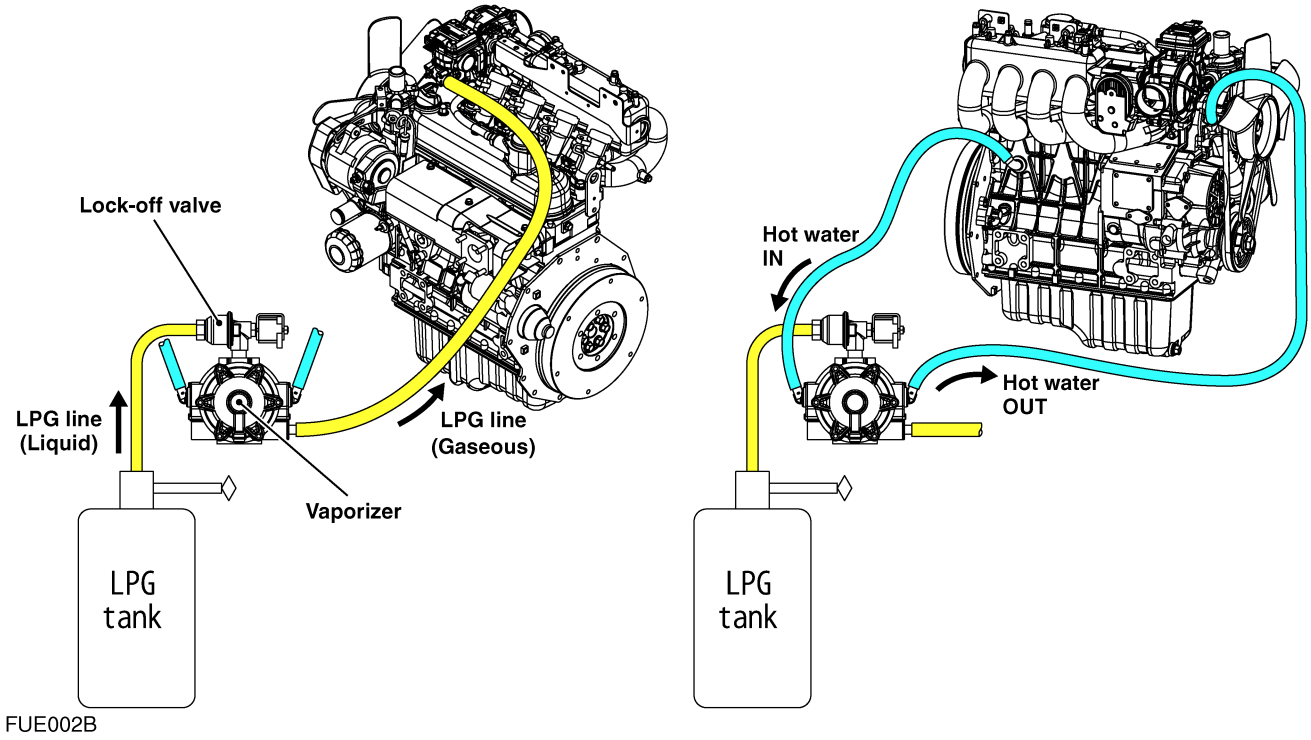
Vaporizer (EG523-4692△)

Figure 1-23



WG1605_137A

Figure 1-24



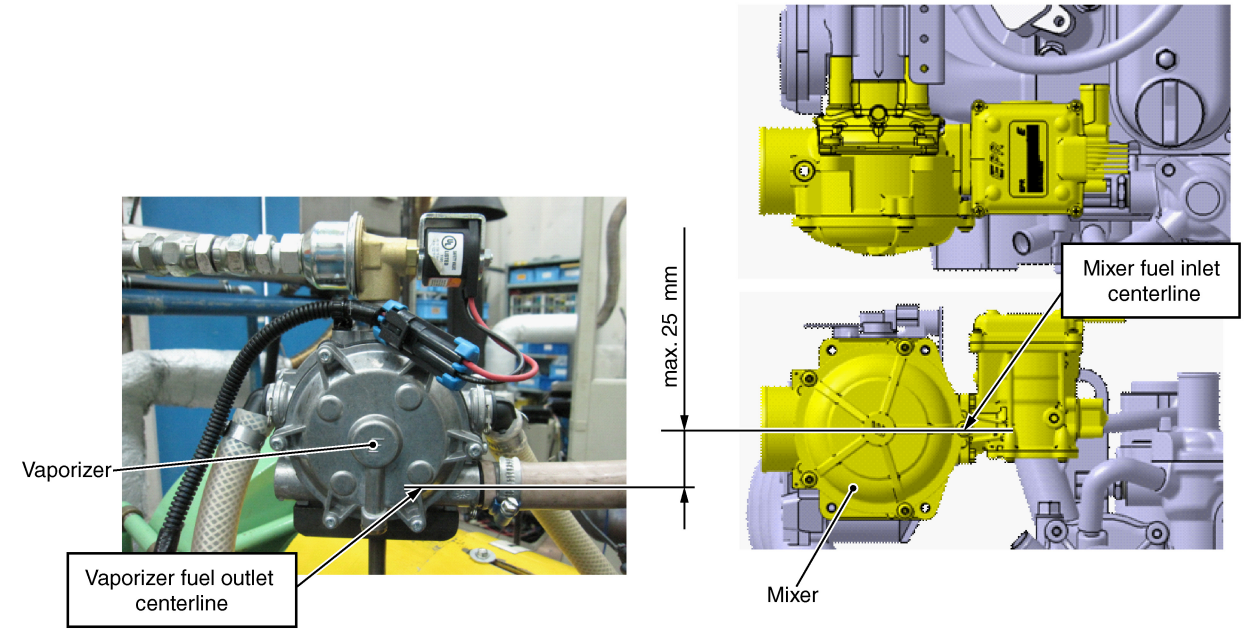
FUE002B

Figure 1-25

Fuel Line between Vaporizer and D-EPR

Vaporizer fuel outlet centerline must not be more than 25 mm (0.98 in.) below mixer inlet centerline.

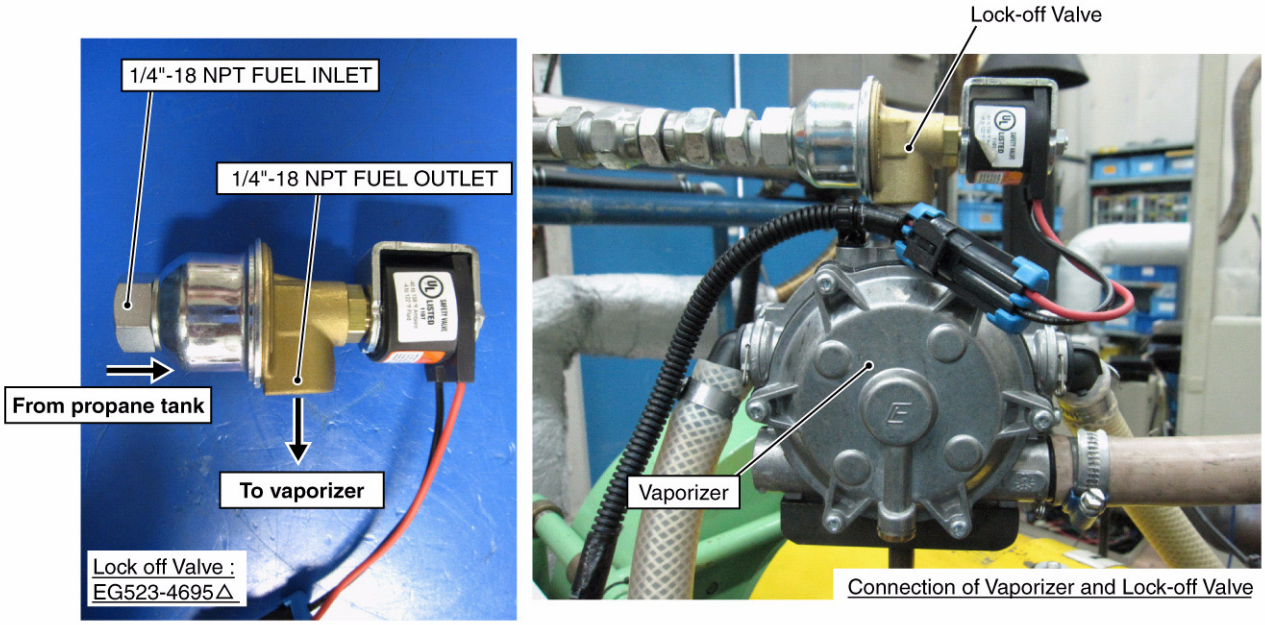
The hose length between the vaporizer and the D-EPR (Electronic Pressure Regulator) must not exceed 700 mm (27.56 in.).



VLV005A

Figure 1-26

[2] LOCK-OFF VALVE

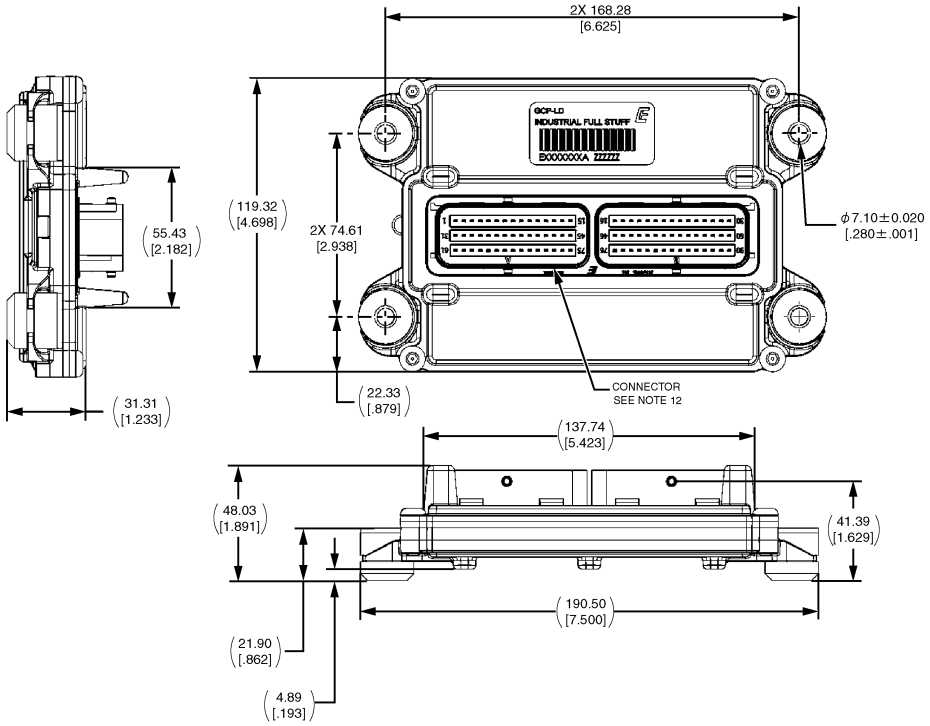


VLV006B

Figure 1-27

8. ENGINE CONTROL UNIT (ECU)

1. Dimensions
   Length = 190.5 mm [7.50 in.]
   Width = 19.3 mm [4.70 in.]
   Height = 48.0 mm [1.89 in.] – includes header
   Height = 31.3 mm [1.23 in.] – without header
   Pitch : 74.61 mm [2.938 in.] long × 168.28 mm [6.625 in.] wide
2. Operational specifications
   (1) Operating voltage : 6 to 18 VDC.
   (2) Max. Vibration : 5 G
   (3) Normal operating temperature : –40 to 105 °C
3. Installation notes
   (1) Installation must utilize all 4 of the vibration mounts.
   (2) ECU header pins must be horizontal or point downward.
   In no case can the header connector be orientated in a way that allows fluids to be trapped in the connector assembly.

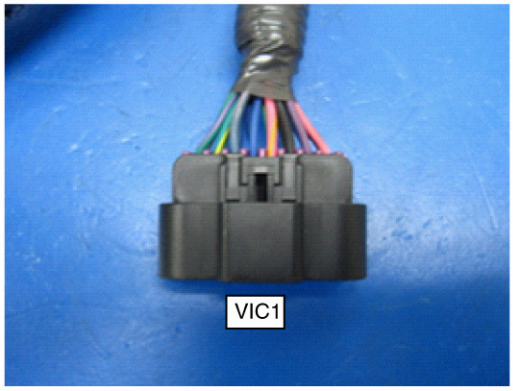


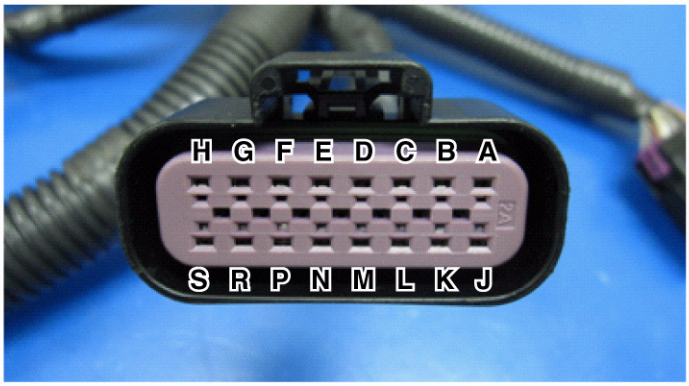
ECM001A

Figure 1-28

9. VEHICLE INTERFACE CONNECTORS

[1] VEHICLE INTERFACE CONNECTORS 1 (VIC1)





"A" - ignition input
"B" - charge indication
"C" - fuel pump -
"D" - fuel pump +
"E" - AUX PWM2
"F" - start command
"G" - MIL
"H" - fuel select input

"J" - FPP2
"K" - FPP1
"L" - 5V RTN
"M" - 5V EXT
"N" - CAN1 +
"P" - CAN1 -
"R" - 5V RTN2
"S" - 5V EXT2

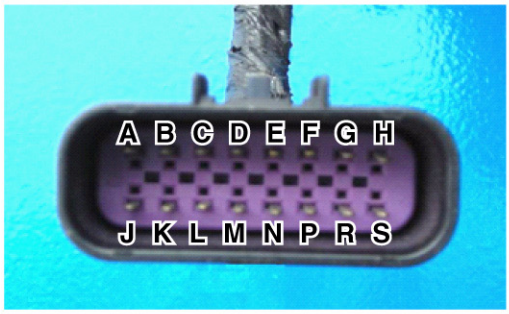
FEA needs to prepare the mating parts as below.
Manufacturer : DELPHI
Connector : 15326868
Terminal : 15326269
Seal : 15366060
Lock : 15358785

VIC001B

Figure 1-29

[2] VEHICLE INTERFACE CONNECTORS 2 (VIC2)





("A" - not used)
("B" - AUX PWM5 RECIRC)
("C" - AUX PWM5)
"D" - TACH
2 pulse / rev
("E" - GROUND)
("F" - AUX PWM1)
("G" - AUX ANA PU3)
("H" - AUX ANA PU1)

"J" - GOV SELECT 2
"K" - GOV SELECT 1
("L" - AUX DIG2)
("M"- AUX DIG3)
("N" - VS+)
("P" - VS-)
("R" - AUX ANA PD1)
("S" - 12V RELAYED POWER)

In case FEA uses VIC2, FEA needs to prepare the mating parts as below.
Manufacturer : DELPHI
Connector : 15326863
Terminal : 12191819
Seal : 15366060
Lock : 15358785

VIC002B

Figure 1-30

[3] INSTLLATION FOR VIC1

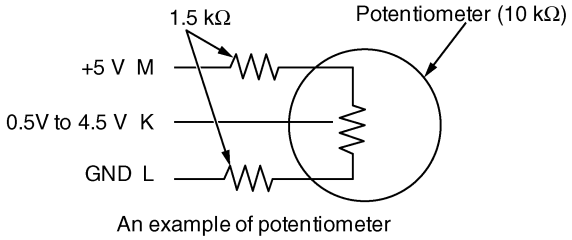
"A" - ignition input (+12VDC from positive terminal of battery)
"B" - charge indication (from alternator L terminal)
"C" - gasoline fuel pump ground (to negative terminal of fuel pump)
"D" - gasoline fuel pump power (to positive terminal of fuel pump)
"E" - Warning Lamp (Provides ground to bulb to illuminate)
"F" - starter (from start terminal of key switch)
"G" - malfunction indicator lamp ground
(MIL- provides ground to bulb to illuminate)
"H" - fuel select input
Tri Fuel (Gasoline, LPG, Natural Gas) ..... "OPEN" - Gasoline "GROUND" - LPG "12V" - Natural Gas
Dual Fuel (gasoline, LPG)..... "OPEN" - Gasoline "GROUND" - LPG
Dual Fuel (LPG, Natural Gas)..... "OPEN" or "GROUND" - LPG "+12V" - Natural Gas
Single Fuel....."OPEN"



VIC003B

Figure 1-31

[4] INSTLLATION FOR ACCELERATOR SIGNAL INPUT



WG1605_152A

	GOV 1	GOV 2
Idle Speed	OFF	OFF
2nd Speed	ON	OFF
3rd Speed	OFF	ON
4th Speed	ON	ON

Figure 1-32

(1) Analog Input

FPP1

VIC 1 “K” - signal to ECM (FPP1) (output voltage of potentiometer 0.5 V to 4.5 V)
VIC 1 “L” - signal ground to potentiometer
VIC 1 “M” - + 5 V to potentiometer (input voltage of potentiometer 5 V)
*Potentiometer connections (use 5k OHM potentiometer minimum)

FPP2

VIC 1 “J” - signal to ECM (FPP2) (output voltage of potentiometer 0.5 V to 2.0 V)
VIC 1 “R” - signal ground to potentiometer
VIC 1 “S” - + 5 V to potentiometer (input voltage of potentiometer 5 V)

(2) Switch Input

Switch (Ground or +12 V can be selected for input signal)

VIC 2 “K” - GOV SELECT 1
VIC 2 “J” - GOV SELECT2

(3) Tap up/dpwn

Tap (Ground or +12 V can be selected for input signal)

Tap Up - - - - - VIC 2 “K” - GOV SELECT 1
Tap Down - - - VIC 2 “J” - GOV SELECT 2

10. MALFUNCTION INDICATOR LIGHT (MIL)

Please see the 40 CFR 1048.110 (b)

1. Use a malfunction-indicator light (MIL).
2. The MIL must be readily visible to the operator; it may be any color except red.
3. When the MIL goes on, it must display "Check Engine," "Service Engine soon," or a similar message that EPA approves.
4. You (FEA) may use sound in addition to the light signal.
5. The MIL requirements and function must be verified during the application review.

11. TRACING INFORMATION

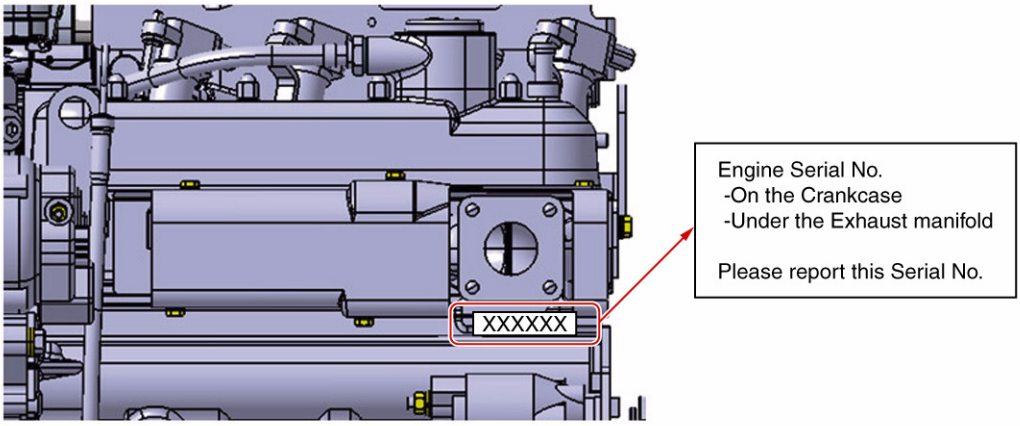
"You (FEA) may demonstrate compliance with the requirements of 40 CFR 1068.261 by maintaining a database showing how you (FEA) pair aftertreatment components with the appropriate engines such that the final product is in its certified configuration."

(40 CFR 1068.261 (b))

FEA must report tracing information of Engine, ECU and Catalyst.

FEA can find these numbers shown in below.

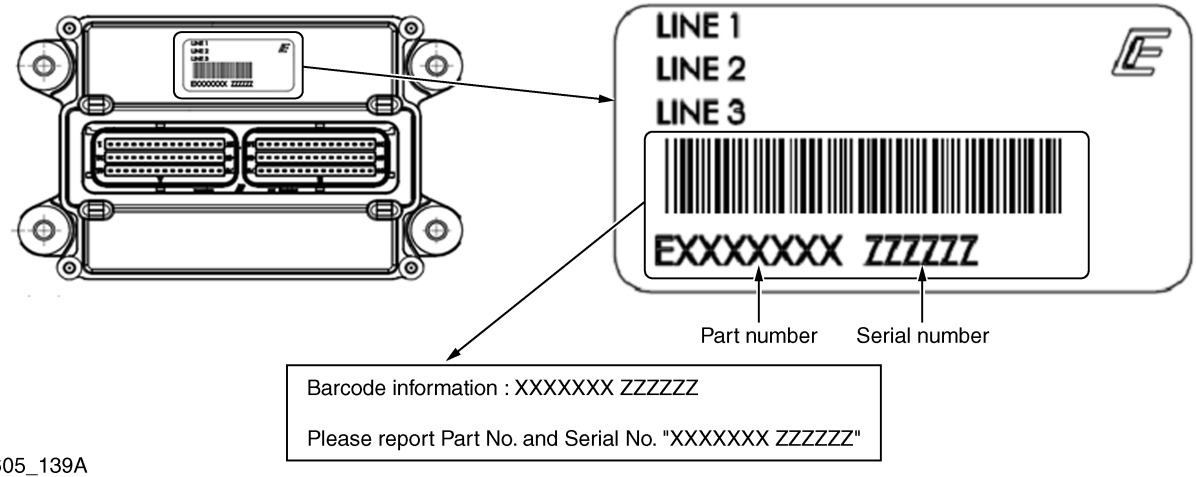
Engine



WG1605_138A

Figure 1-33

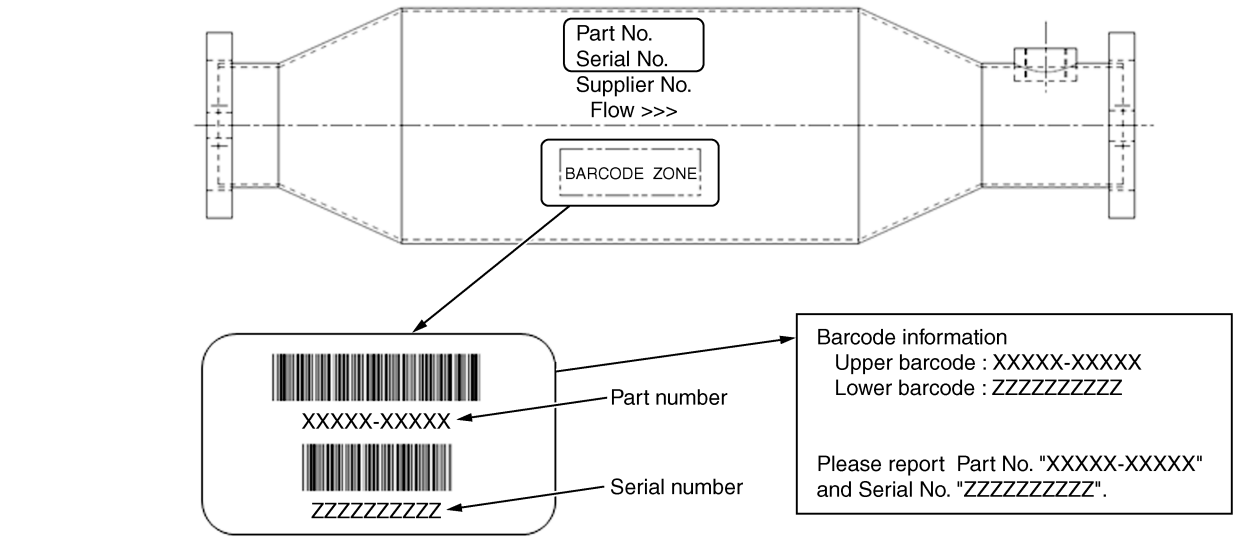
ECU



WG1605_139A

Figure 1-34

Catalyst



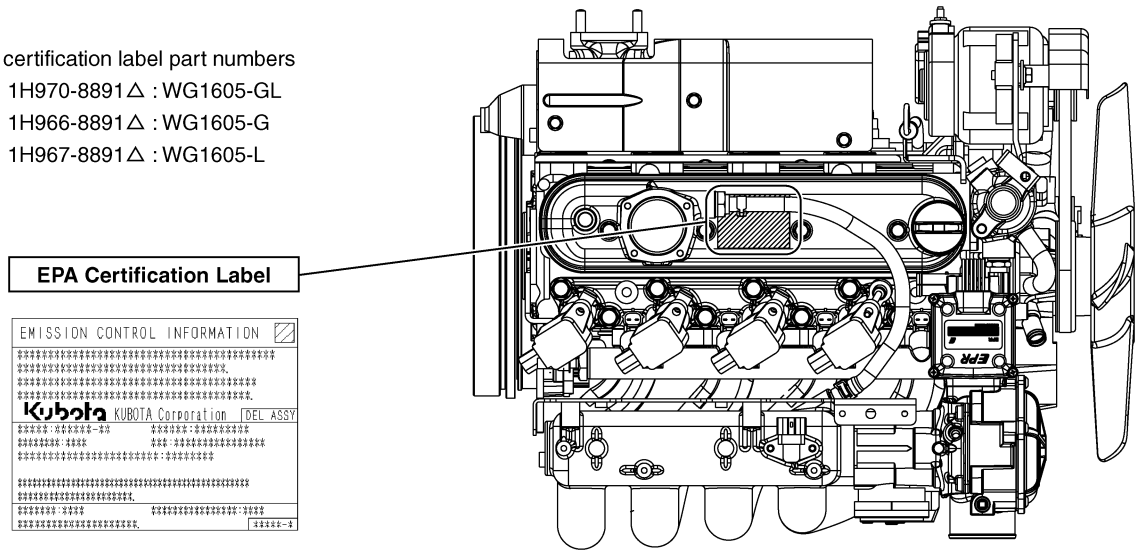
WG1605_140A

Figure 1-35

12. CERTIFICATION LABELS

1. Kubota installs the certification label on the cylinder head cover.
   This label must be visible.
2. If you (FEA) install the engine in a way that makes the engine's emission control information label hard to read during normal engine maintenance, you (FEA) must place a duplicate label on the equipment, as described in 40 CFR 1068.105.
   (40 CFR 1054.130 (b) (7))

EPA certification label part numbers
1H970-8891△ : WG1605-GL
1H966-8891△ : WG1605-G
1H967-8891△ : WG1605-L



LAB001B

Figure 1-36

13. END OF LINE (EOL) TEST DATA

EOL Test Data

FEA must report a record of End Of Line (EOL) test data shown in below.

	Measurement item	
At low-idle condition	Rotation speed	min^{-1} (rpm)
	Water temperature	°C
	Fuel correction factor CL_BM+A_BM	%
At loaded or hi-idle condition	Rotation speed	min^{-1} (rpm)
	Water temperature	°C
	Fuel correction factor CL_BM+A_BM	%
Oxygen sensor test	Pre Oxygen Sensor check	Pass or Fault
	Post Oxygen Sensor check	Pass or Fault

TECHNICAL INFORMATION

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1. BRAKE HORSE POWER

SAE J1349

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))				
				2000	2400	2800	3200	3600
WG1605-G -E3	Gasoline	Net intermittent	kW	23.2	27.9	31.7	35.5	38.5
			HP	31.1	37.4	42.5	47.6	51.6
			PS	31.5	37.9	43.0	48.2	52.3
		Net continuous	kW	18.5	22.3	25.3	28.4	30.8
			HP	24.9	29.9	34.0	38.1	41.3
			PS	25.2	30.3	34.4	38.6	41.8

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))				
				2000	2400	2800	3200	3600
WG1605-L -E3	LPG	Net intermittent	kW	22.8	27.2	30.9	34.2	37.1
			HP	30.6	36.4	41.5	45.9	49.8
			PS	31.0	36.9	42.0	46.6	50.4
		Net continuous	kW	18.3	21.7	24.7	27.4	29.7
			HP	24.5	29.1	33.2	36.7	39.8
			PS	24.8	29.5	33.6	37.2	40.4

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))				
				2000	2400	2800	3200	3600
WG1605-GL-E3	Gasoline	Net intermittent	kW	23.2	27.9	31.7	35.5	38.5
			HP	31.1	37.4	42.5	47.6	51.6
			PS	31.5	37.9	43.0	48.2	52.3
		Net continuous	kW	18.5	22.3	25.3	28.4	30.8
			HP	24.9	29.9	34.0	38.1	41.3
			PS	25.2	30.3	34.4	38.6	41.8
	LPG	Net intermittent	kW	22.8	27.2	30.9	34.2	37.1
			HP	30.6	36.4	41.5	45.9	49.8
			PS	31.0	36.9	42.0	46.6	50.4
		Net continuous	kW	18.3	21.7	24.7	27.4	29.7
			HP	24.5	29.1	33.2	36.7	39.8
			PS	24.8	29.5	33.6	37.2	40.4

■ **NOTE**

- **Conversion rates**
  - **1 kW=1.35962 PS=1.34048 HP**
  - **1 PS=0.7355 kW=0.985925 HP**
  - **1 HP=0.7457 kW=1.01428 PS**
- *** Fuel detail**
  Japanese standard gas
  - **lower heating value : 9699 kcal/m^3 (1090 BTU/ft^3)**
  - **supply pressure : 0.98 − 2.45 kPa (2.27 − 5.68 oz/$inch^2$)**

2. FUEL CONSUMPTION

Specific at net intermittent (SAE J1349)

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -G-E3	Gasoline	Brake horse power	kW	8.3	13.8	19	24.5	30.2	34.9	39.3	42.5
			HP	11.1	18.5	25.5	32.8	40.4	46.8	52.7	57
			PS	11.3	18.8	25.9	33.3	41	47.5	53.4	57.8
		Fuel consumption	g/kWh	287.7	266.1	258.1	254.3	256.6	257.1	258.4	265.9
			g/HPh	214.6	198.5	192.5	189.7	191.4	191.8	192.8	198.4
			g/PSh	211.6	195.7	189.8	187	188.7	189.1	190.1	195.6
			lb/HPh	0.473	0.438	0.424	0.418	0.422	0.423	0.425	0.437

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -L-E3	LPG	Brake horse power	kW	8.8	14	18.8	24.1	29.4	34.1	37.9	41
			HP	11.8	18.7	25.2	32.3	39.4	45.7	50.8	55
			PS	11.9	19	25.6	32.8	40	46.4	51.5	55.7
		Fuel consumption	g/kWh	257.2	231.6	232.8	226.6	223.3	227.1	235.1	242.8
			g/HPh	191.9	172.8	173.7	169	166.6	169.4	175.4	181.1
			g/PSh	189.2	170.3	171.2	166.7	164.2	167	172.9	178.6
			lb/HPh	0.423	0.381	0.383	0.373	0.367	0.373	0.387	0.399

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -GL -E3	Gasoline	Brake horse power	kW	8.3	13.8	19	24.5	30.2	34.9	39.3	42.5
			HP	11.1	18.5	25.5	32.8	40.4	46.8	52.7	57
			PS	11.3	18.8	25.9	33.3	41	47.5	53.4	57.8
		Fuel consumption	g/kWh	287.7	266.1	258.1	254.3	256.6	257.1	258.4	265.9
			g/HPh	214.6	198.5	192.5	189.7	191.4	191.8	192.8	198.4
			g/PSh	211.6	195.7	189.8	187	188.7	189.1	190.1	195.6
			lb/HPh	0.473	0.438	0.424	0.418	0.422	0.423	0.425	0.437
	LPG	Brake horse power	kW	8.8	14	18.8	24.1	29.4	34.1	37.9	41
			HP	11.8	18.7	25.2	32.3	39.4	45.7	50.8	55
			PS	11.9	19	25.6	32.8	40	46.4	51.5	55.7
		Fuel consumption	g/kWh	257.2	231.6	232.8	226.6	223.3	227.1	235.1	242.8
			g/HPh	191.9	172.8	173.7	169	166.6	169.4	175.4	181.1
			g/PSh	189.2	170.3	171.2	166.7	164.2	167	172.9	178.6
			lb/HPh	0.423	0.381	0.383	0.373	0.367	0.373	0.387	0.399

■ **NOTE**

- **Conversion rates**
  - **1 kW=1.35962 PS=1.34048 HP**
  - **1 PS=0.7355 kW=0.985925 HP**
  - **1 HP=0.7457 kW=1.01428 PS**
  - **1 kg=2.20462 lb (1 g=0.00220462 lb)**
  - **1 lb=0.45359 kg**

3. SOUND PRESSURE LEVEL

unit dB(A)

	min^{-1} (rpm)	Load ratio	Fuel	Sound pressure at 1 m (3.3 ft)
WG1605-G-E3 WG1605-GL-E3	3600	0/4	Gasoline	91.5
	3600	4/4		93.5
	3000	0/4		87.5
	3000	4/4		89.4
	750	0/4		68.7

	min^{-1} (rpm)	Load ratio	Fuel	Sound pressure at 1 m (3.3 ft)
WG1605-L-E3 WG1605-GL-E3	3600	0/4	LPG	91.0
	3600	4/4		92.3
	3000	0/4		87.6
	3000	4/4		88.8
	750	0/4		68.8

	min^{-1} (rpm)	Load ratio	Fuel	Sound pressure at 1 m (3.3 ft)
WG1605-GL-E3	3600	0/4	Gasoline	91.5
	3600	4/4		93.5
	3000	0/4		87.5
	3000	4/4		89.4
	750	0/4		68.7
	3600	0/4	LPG	91.0
	3600	4/4		92.3
	3000	0/4		87.6
	3000	4/4		88.8
	750	0/4		68.8

■ **NOTE**

- **Measurement conditions: With radiator, cooling fan, air cleaner and muffler.**

4. AIR REQUIREMENTS

[1] COMBUSTION AIR REQUIREMENTS (At 25 deg.C and 1000 hPa)

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -G-E3	Gasoline	Combustion air requirements	L/sec	8.4	12.3	16.7	20.9	25.0	29.3	33.1	36.2
			m^3/h	30.3	44.1	60.1	75.1	90.0	105.3	119.1	130.2
			in^3/sec	513	748	1019	1273	1526	1785	2019	2207
			ft^3/min	17.8	26.0	35.4	44.2	53.0	62.0	70.1	76.6

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -L-E3	LPG	Combustion air requirements	L/sec	8.4	12.3	16.7	20.9	25.0	29.3	33.1	36.2
			m^3/h	30.3	44.1	60.1	75.1	90.0	105.3	119.1	130.2
			in^3/sec	513	748	1019	1273	1526	1785	2019	2207
			ft^3/min	17.8	26.0	35.4	44.2	53.0	62.0	70.1	76.6

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -GL -E3	Gasoline	Combustion air requirements	L/sec	8.4	12.3	16.7	20.9	25.0	29.3	33.1	36.2
			m^3/h	30.3	44.1	60.1	75.1	90.0	105.3	119.1	130.2
			in^3/sec	513	748	1019	1273	1526	1785	2019	2207
			ft^3/min	17.8	26.0	35.4	44.2	53.0	62.0	70.1	76.6
	LPG	Combustion air requirements	L/sec	8.4	12.3	16.7	20.9	25.0	29.3	33.1	36.2
			m^3/h	30.3	44.1	60.1	75.1	90.0	105.3	119.1	130.2
			in^3/sec	513	748	1019	1273	1526	1785	2019	2207
			ft^3/min	17.8	26.0	35.4	44.2	53.0	62.0	70.1	76.6

■ **NOTE**

- **Combustion air requirements calculating formula**
- **$Q1=Vh \cdot N \cdot C \cdot \eta \cdot 10^{-3}$**
  - **Q1 : Amount of intake air (m^3/min)**
  - **Vh : Total displacement (L)**
  - **N : Engine speed (min^{-1} (rpm))**
  - **C : Coefficient=0.5**
  - **η : Intake efficiency**
    Gasoline : 0.85
    LPG : 0.81

[2] COOLING AIR REQUIREMENTS (At 25 deg.C and 1000 hPa)

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -G-E3	Gasoline	Cooling air requirements	L/sec	192.6	296.2	395.5	617.7	740.9	841.1	913.1	984.8
			m^3/h	693	1066	1424	2224	2667	3028	3287	3545
			in^3/sec	11753	18074	24137	37694	45210	51324	55720	60098
			ft^3/min	408.1	627.6	838.1	1308.8	1569.8	1782.1	1934.7	2086.7

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -L-E3	LPG	Cooling air requirements	L/sec	182.6	261.5	353.0	684.2	820.7	931.7	1011.5	1090.9
			m^3/h	657	941	1271	2463	2954	3354	3641	3927
			in^3/sec	11140	15959	21541	41755	50080	56853	61723	66572
			ft^3/min	386.8	554.1	748.0	1449.8	1738.9	1974.1	2143.2	2311.5

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -GL -E3	Gasoline	Cooling air requirements	L/sec	192.6	296.2	395.5	617.7	740.9	841.1	913.1	984.8
			m^3/h	693	1066	1424	2224	2667	3028	3287	3545
			in^3/sec	11753	18074	24137	37694	45210	51324	55720	60098
			ft^3/min	408.1	627.6	838.1	1308.8	1569.8	1782.1	1934.7	2086.7
	LPG	Cooling air requirements	L/sec	182.6	261.5	353.0	684.2	820.7	931.7	1011.5	1090.9
			m^3/h	657	941	1271	2463	2954	3354	3641	3927
			in^3/sec	11140	15959	21541	41755	50080	56853	61723	66572
			ft^3/min	386.8	554.1	748.0	1449.8	1738.9	1974.1	2143.2	2311.5

■ **NOTE**

- **Above data is decided by following conditions.**
  - **Using the standard radiator.**
  - **Engine is run as open unit.**

[3] COMBUSTION AND COOLING AIR REQUIREMENTS (At 25 deg.C and 1000 hPa)

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -G-E3	Gasoline	Combustion and cooling air requirements	L/sec	201	308	412	639	766	870	946	1021
			m^3/h	724	1110	1484	2299	2757	3133	3406	3676
			in^3/sec	12266	18822	25156	38967	46736	53109	57739	62304
			ft^3/min	426	654	873	1353	1623	1844	2005	2163

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				2000	2400	2800	3200	3600	2800	3200	3600
WG1605-L-E3	LPG	Combustion and cooling air requirements	L/sec	191	274	370	705	846	961	1045	1127
			m^3/h	687	986	1331	2538	3044	3459	3760	4057
			in^3/sec	11653	16707	22561	43028	51606	58638	63742	68779
			ft^3/min	405	580	783	1494	1792	2036	2213	2388

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -GL -E3	Gasoline	Combustion and cooling air requirements	L/sec	201	308	412	639	766	870	946	1021
			m^3/h	724	1110	1484	2299	2757	3133	3406	3676
			in^3/sec	12266	18822	25156	38967	46736	53109	57739	62304
			ft^3/min	426	654	873	1353	1623	1844	2005	2163
	LPG	Combustion and cooling air requirements	L/sec	191	274	370	705	846	961	1045	1127
			m^3/h	687	986	1331	2538	3044	3459	3760	4057
			in^3/sec	11653	16707	22561	43028	51606	58638	63742	68779
			ft^3/min	405	580	783	1494	1792	2036	2213	2388

■ **NOTE**

- **Cooling fan and fan pulley specifications (Cooling fan Part No. 15442-7411∆)**

Item	
Fan diameter	350 mm (13.78 in)
No. of blade and type of shape	5, S type
Diameter of fan driving pulley	105 mm (4.13 in)
Diameter of fan pulley	96 mm (3.78 in)

- **Conversion rates**
  1 L=61.0237 in^3=0.035315 ft^3
  1 ft^3=28.3168 L
  1 L/sec=3.6 m^3/h=2.1189 ft^3/min

5. EXHAUST GAS VOLUME

At 25 deg.C and 1000 hPa

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))				
				2000	2400	2800	3200	3600
WG1605-G-E3	Gasoline	Gas volume	L/sec	68.4	81.0	93.2	102.8	109.0
			m^3/h	246.3	291.5	335.4	370.2	392.5
			in^3/sec	4174	4941	5685	6275	6653
			ft^3/min	144.9	171.6	197.4	217.9	231.0

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))				
				2000	2400	2800	3200	3600
WG1605-L-E3	LPG	Gas volume	L/sec	65.2	77.2	88.8	98.0	103.9
			m^3/h	234.7	277.8	319.6	352.8	374.0
			in^3/sec	3978	4709	5417	5980	6340
			ft^3/min	138.1	163.5	188.1	207.6	220.1

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))				
				2000	2400	2800	3200	3600
WG1605-GL-E3	Gasoline	Gas volume	L/sec	68.4	81.0	93.2	102.8	109.0
			m^3/h	246.3	291.5	335.4	370.2	392.5
			in^3/sec	4174	4941	5685	6275	6653
			ft^3/min	144.9	171.6	197.4	217.9	231.0
	LPG	Gas volume	L/sec	65.2	77.2	88.8	98.0	103.9
			m^3/h	234.7	277.8	319.6	352.8	374.0
			in^3/sec	3978	4709	5417	5980	6340
			ft^3/min	138.1	163.5	188.1	207.6	220.1

■ **NOTE**

- **Conversion rates**
  1 L=61.0237 in^3=0.035315 ft^3
  1 ft^3=28.3168 L
  1 L/sec=3.6 m^3/h=127.133 ft^3/min

6. HEAT REJECTION TO COOLANT

Specific at net intermittent (SAE J1349)

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -G-E3	Gasoline	Brake horse power	kW	8.3	13.8	19	24.5	30.2	34.9	39.3	42.5
			HP	11.1	18.5	25.5	32.8	40.4	46.8	52.7	57
			PS	11.3	18.8	25.9	33.3	41	47.5	53.4	57.8
		Fuel consumption	g/kWh	287.7	266.1	258.1	254.3	256.6	257.1	258.4	265.9
			g/HPh	214.6	198.5	192.5	189.7	191.4	191.8	192.8	198.4
			g/PSh	211.6	195.7	189.8	187	188.7	189.1	190.1	195.6
			lb/HPh	0.473	0.438	0.424	0.418	0.422	0.423	0.425	0.437
		Heat rejection to cooling water	MJ/h	20.39	31.36	41.88	65.40	78.44	89.05	96.68	104.28
			kcal/h	4872	7492	10005	15624	18739	21274	23096	24910
			BTU/h	19330	29727	39698	61996	74357	84414	91644	98843

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -L-E3	LPG	Brake horse power	kW	8.8	14	18.8	24.1	29.4	34.1	37.9	41
			HP	11.8	18.7	25.2	32.3	39.4	45.7	50.8	55
			PS	11.9	19	25.6	32.8	40	46.4	51.5	55.7
		Fuel consumption	g/kWh	257.2	231.6	232.8	226.6	223.3	227.1	235.1	242.8
			g/HPh	191.9	172.8	173.7	169	166.6	169.4	175.4	181.1
			g/PSh	189.2	170.3	171.2	166.7	164.2	167	172.9	178.6
			lb/HPh	0.423	0.381	0.383	0.373	0.367	0.373	0.387	0.399
		Heat rejection to cooling water	MJ/h	19.33	27.69	37.38	72.45	86.89	98.65	107.10	115.51
			kcal/h	4618	6615	8929	17307	20758	23565	25584	27594
			BTU/h	18322	26248	35430	68674	82368	93507	101517	109492

Specific at net intermittent (SAE J1349)

Model	Fuel	Output		Engine Speed (min^{-1} (rpm))							
				800	1200	1600	2000	2400	2800	3200	3600
WG 1605 -GL -E3	Gasoline	Brake horse power	kW	8.3	13.8	19	24.5	30.2	34.9	39.3	42.5
			HP	11.1	18.5	25.5	32.8	40.4	46.8	52.7	57
			PS	11.3	18.8	25.9	33.3	41	47.5	53.4	57.8
		Fuel consumption	g/kWh	287.7	266.1	258.1	254.3	256.6	257.1	258.4	265.9
			g/HPh	214.6	198.5	192.5	189.7	191.4	191.8	192.8	198.4
			g/PSh	211.6	195.7	189.8	187	188.7	189.1	190.1	195.6
			lb/HPh	0.473	0.438	0.424	0.418	0.422	0.423	0.425	0.437
		Heat rejection to cooling water	MJ/h	20.39	31.36	41.88	65.40	78.44	89.05	96.68	104.28
			kcal/h	4872	7492	10005	15624	18739	21274	23096	24910
			BTU/h	19330	29727	39698	61996	74357	84414	91644	98843
	LPG	Brake horse power	kW	8.8	14	18.8	24.1	29.4	34.1	37.9	41
			HP	11.8	18.7	25.2	32.3	39.4	45.7	50.8	55
			PS	11.9	19	25.6	32.8	40	46.4	51.5	55.7
		Fuel consumption	g/kWh	257.2	231.6	232.8	226.6	223.3	227.1	235.1	242.8
			g/HPh	191.9	172.8	173.7	169	166.6	169.4	175.4	181.1
			g/PSh	189.2	170.3	171.2	166.7	164.2	167	172.9	178.6
			lb/HPh	0.423	0.381	0.383	0.373	0.367	0.373	0.387	0.399
		Heat rejection to cooling water	MJ/h	19.33	27.69	37.38	72.45	86.89	98.65	107.10	115.51
			kcal/h	4618	6615	8929	17307	20758	23565	25584	27594
			BTU/h	18322	26248	35430	68674	82368	93507	101517	109492

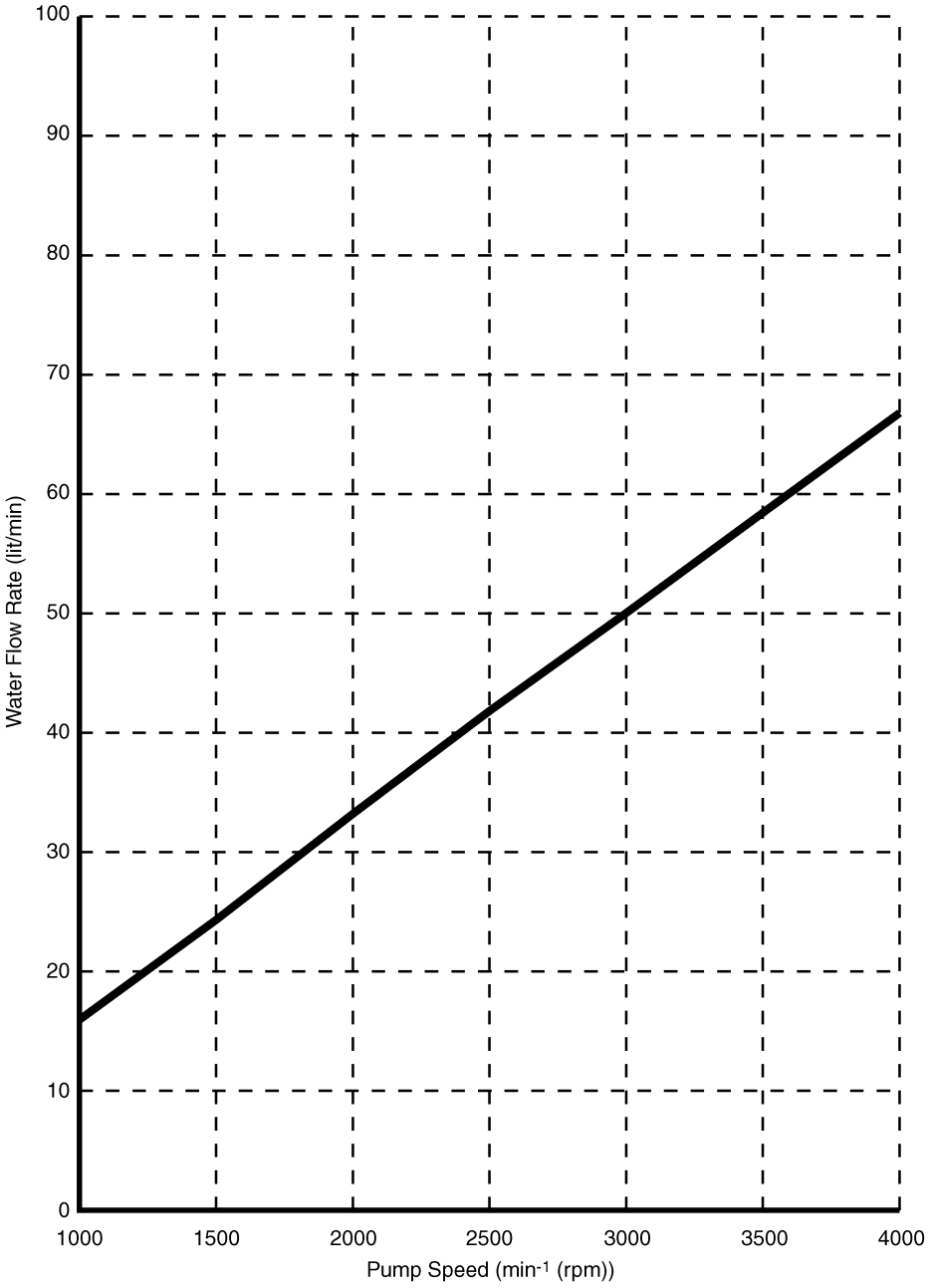
■ **NOTE**

- **Heat rejection to cooling water calculating formula**
- **Ho=Hu·Ne·be·i**

  Ho : Heat rejection to cooling water
  Hu : Fuel lower heating value
  Gasoline : 42.7 MJ/kg, 10201 kcal/kg, 18361 BTU/lb
  LPG : 47.3 MJ/kg, 11300 kcal/kg, 20339 BTU/lb
  Ne : Brake horse power
  be : Specific fuel consumption ratio
  i : Dispersion ratio to cooling water

7. WATER FLOW RATE

Water Pump	16251-7303Δ, EG523-7303Δ
Fan Pulley Dia.	98 mm (3.86 in.)
Fan Drive Pulley Dia.	105 mm (413 in.)
Thermostat	19434-7301Δ



TEC001A

Figure 1-1

■ **NOTE**
- **The flow is with std. radiator.**
- **Including engine block, radiator and piping resistance.**

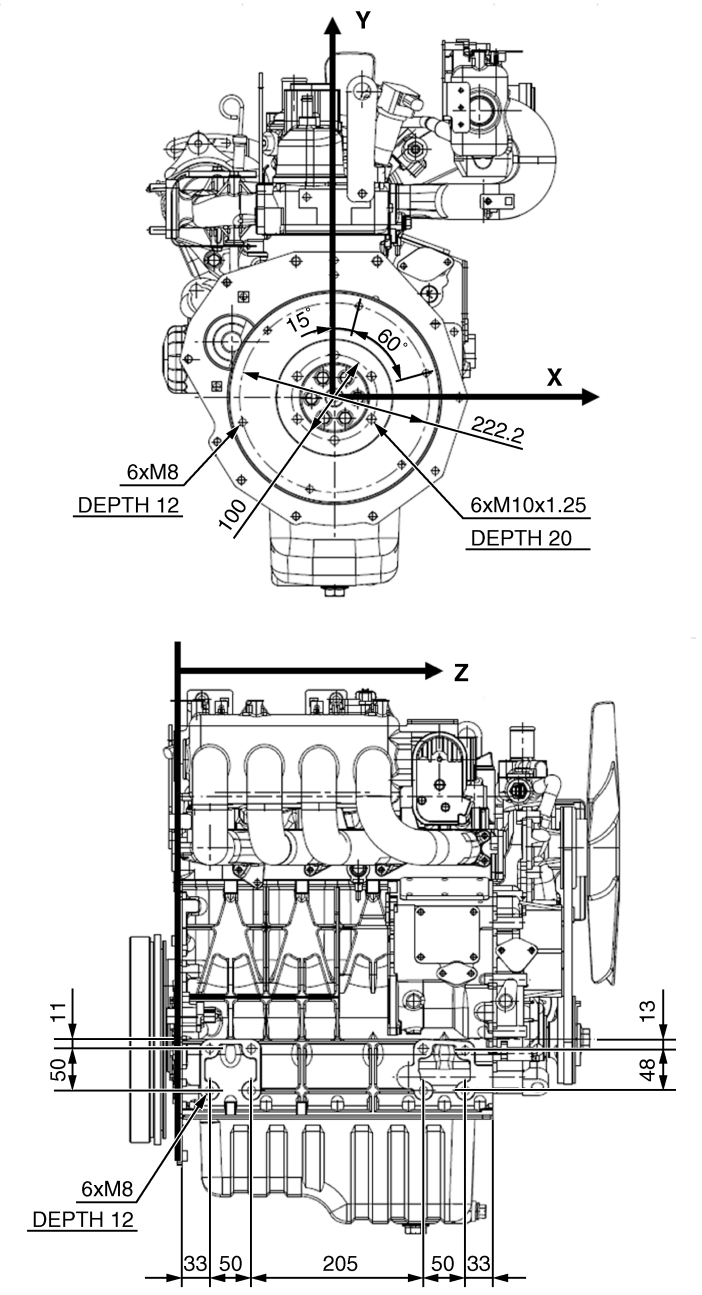
8. CENTER OF GRAVITY

1. With standard flywheel and rear-end plate

Model	Dry weight kg (lb)	Center of gravity		
		X mm (in)	Y mm (in)	Z mm (in)
WG1605-GL-E3-KEA-1	122 (269)	-1 (-0.039)	95 (3.74)	182 (7.17)

■ **NOTE**

- **Cooling water and lubricating oil weight is not included in above engine weight.**

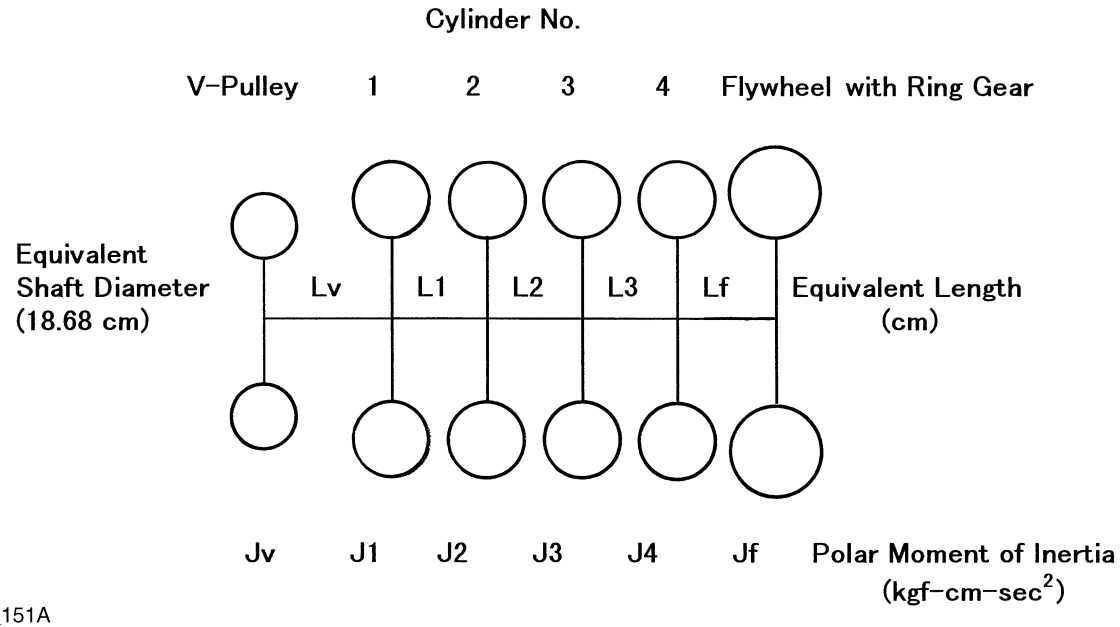


TEC003A

Figure 1-2

9. MASS ELASTIC SYSTEM

[1] EQUIVALENT TORSIONAL VIBRATION DATA



WG1605_151A

Figure 1-3

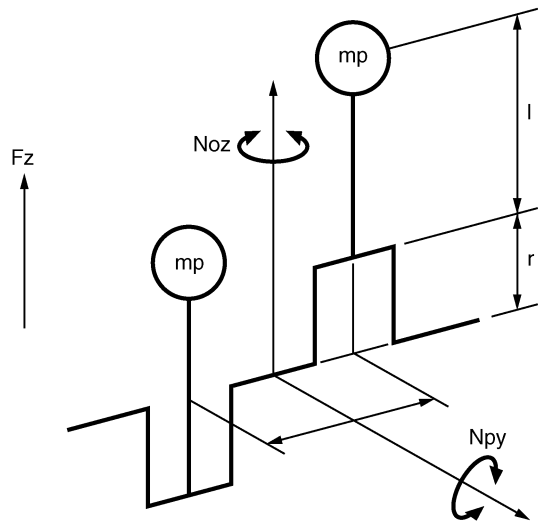
MODEL	EQUIVALENT LENGTH (cm)					POLAR MOMENT OF INERTIA (kgfcm-sec^2)					
	LV	L1	L2	L3	Lf	JV	J1	J2	J3	J4	Jf
WG1605-G-E3	20200	2520	2520	2520	1863	0.013	0.040	0.040	0.040	0.040	0.997
WG1605-L-E3	20200	2520	2520	2520	1863	0.013	0.040	0.040	0.040	0.040	0.997
WG1605-GL-E3	20200	2520	2520	2520	1863	0.013	0.040	0.040	0.040	0.040	0.997

■ **NOTE**

- **Flywheel EG523-2511Δ, V-Pulley 16249-7428Δ**

10. UNBALANCED FORCES

[1] BASE DATA



TEC005A

FZ : Unbalanced inertia force
Npy, Noz : Unbalanced inertia couple
mp : Reciprocating mass
r : Crank radius
l : Center distance of connecting rod
L : Cylinder distance
ω : Angular velocity
$2\pi n/60$
n : Engine speed min^{-1} (rpm)

Figure 1-4

Model	l (m)	r (m)	L (m)	Wp (kgf)	Bore (mm)	Stroke (mm)
WG1605-G-E3	0.116	0.0392	0.085	0.69	79.0	78.4
WG1605-L-E3	0.116	0.0392	0.085	0.69	79.0	78.4
WG1605-GL-E3	0.116	0.0392	0.085	0.69	79.0	78.4

[2] UNBALANCED INERTIA FORCE AND COUPLE

($x\omega^2$)

Model	No. of Cylinder	Cylinder Bore (mm)	Order	Fz	Npy	Noz
WG1605-G-E3	4	79.0	1	0	0	0
			2	0.002575	0	0
WG1605-L-E3	4	79.0	1	0	0	0
			2	0.002575	0	0
WG1605-GL-E3	4	79.0	1	0	0	0
			2	0.002575	0	0

[3] AN EXAMPLE OF CALCULATION

Calculation condition		ω^2	Fz, Npy, Noz		
				Order	Caluculation
Engine model :	WG1605-G-E3 WG1605-L-E3 WG1605-GL-E3	$(2 \times \pi \times 3600/60)^2 = 142122$	Fz (kgf)	1	0
				2	0.002575 × 142122 = 366 kg
			Npy (kgf-m)	1	0
				2	0
Engine speed :	3600 min^{-1} (rpm)		Noz (kgf-m)	1	0
				2	0

8 ACCESSORY HYDRAULIC COMPONENTS

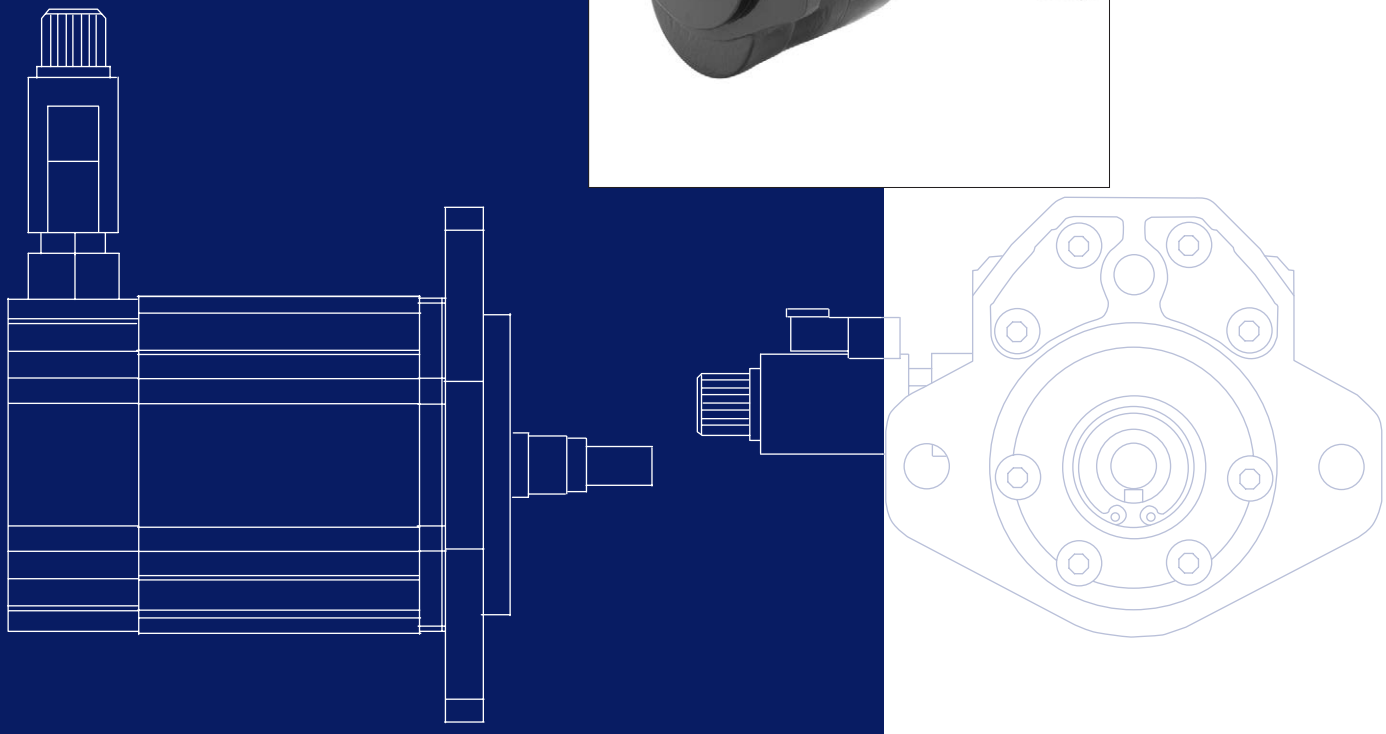
D Series
Gear Motors

Turolla OpenCircuitGear
MEMBER OF THE SAUER-DANFOSS GROUP

Service Manual







History of Revisions

Table of Revisions

Date	Page	Changed	Rev.
November 2010	all	Turolla colors	BB
March 2010	19	Added shaft seal kit number	AC
February 2010	last	Fix Osaka address	AB
April 2009	-	First edition	AA

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D Series Gear Motors
Service Manual
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Turolla OpenCircuitGear
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D Series Gear Motors
Service Manual
Introduction

Overview

This manual includes instructions for the installation, maintenance, and minor repair of D Series Motors. It includes a description of the units and their individual components, troubleshooting information, and minor repair procedures.

A worldwide Authorized Service Center network is available for major repairs. Sauer-Danfoss Authorized Service Centers are trained by the factory and certified on a regular basis. You can locate your nearest Authorized Service Center using the distributor locator at www.sauer-danfoss.com.

Warranty

Performing installation, maintenance, and minor repairs according to the procedures in this manual does not affect your warranty. Major repairs requiring the removal of a unit's rear cover or front flange voids the warranty. Only a Sauer-Danfoss Authorized Service Center may perform major repairs. Sauer-Danfoss trains ASC and certifies their facilities on a regular basis.

Safety Precautions

Always consider safety precautions before beginning a service procedure. Protect yourself and others from injury. Take the following general precautions whenever servicing a hydraulic system.

Unintended Machine Movement

⚠ Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

Flammable Cleaning Solvents

⚠ Warning

Some cleaning solvents are flammable. To avoid possible fire, do not use cleaning solvents in an area where a source of ignition may be present.

Fluid Under Pressure

⚠ Warning

Escaping hydraulic fluid under pressure can have sufficient force to penetrate your skin causing serious injury and/or infection. This fluid may also be hot enough to cause burns. Use caution when dealing with hydraulic fluid under pressure. Relieve pressure in the system before removing hoses, fittings, gauges, or components. Never use your hand or any other body part to check for leaks in a pressurized line. Seek medical attention immediately if you are cut by hydraulic fluid.

Personal Safety

⚠ Warning

Protect yourself from injury. Use proper safety equipment, including safety glasses, at all times.

Hazardous Material

⚠ Warning

Hydraulic fluid contains hazardous material. Avoid prolonged contact with hydraulic fluid. Always dispose of used hydraulic fluid according to state and federal environmental regulations.

Symbols Used in Sauer-Danfoss literature

- WARNING may result in injury
- CAUTION may result in damage to product or property
- Reusable part
- Non-reusable part, use a new part
- Non-removable item
- Option – either part may exist
- Superseded – parts are not interchangeable
- Measurement required
- Flatness specification
- Parallelism specification
- External hex head
- Internal hex head
- Torx head
- O-ring boss port
- Tip, helpful suggestion
- Lubricate with clean hydraulic fluid
- Apply grease/petroleum jelly
- Apply locking compound
- Inspect for wear or damage
- Clean area or part
- Be careful not to scratch or damage
- Note correct orientation
- Mark orientation for reinstallation
- Torque specification
- Press in – press fit
- Pull out with tool – press fit
- Cover splines with installation sleeve
- Pressure measurement/gauge location or specification

The symbols above appear in the illustrations and text of this manual. They are intended to communicate helpful information at the point where it is most useful to the reader. In most instances, the appearance of the symbol itself denotes its meaning. The legend above defines each symbol and explains its purpose.

General Description

A Sauer-Danfoss electrohydraulic proportional fan drive system consists of a combination of fixed or variable displacement open circuit hydraulic pump and an D gear motor with or without proportional relief valve or standard relief valve and check valve to control fan speed. The engine control module or Sauer-Danfoss control module drives the proportional relief valve using a Pulse-Width Modulated (PWM) signal.

Sauer-Danfoss fan drives work with engines produced by all the major North American and European engine manufacturers.

The System Circuit

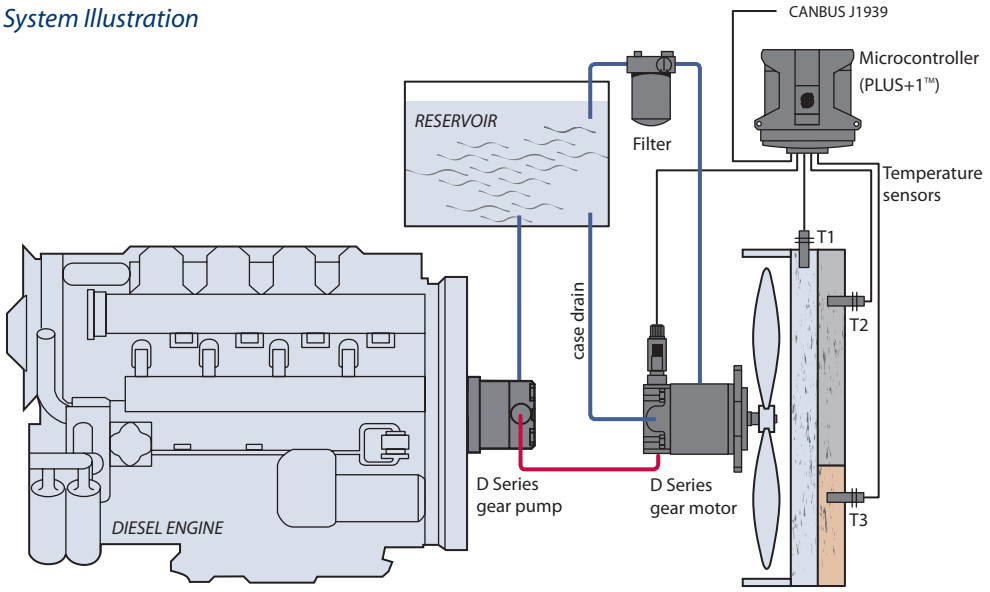
The pump receives fluid directly from the reservoir through the inlet line. The output of the pump is connected to a fixed displacement gear motor, which has an electrohydraulic proportional valve mounted in the motor's rear cover.

The valve setting determines the maximum pressure in the system by passing oil around the motor's gear set directly to the return port of the motor. The proportional valve is normally closed and requires the application of an electrical current to reduce the bypass pressure from a predetermined, customer selected, maximum pressure setting. In a hydraulic fan drive system, the predetermined maximum pressure setting determines the maximum pressure to the motor, and maximum trim speed of the fan.

Applying an electrical current to the valve allows the fan to run at speeds below its maximum trim speed, regardless of the flow supplied to the pump.

Oil exiting the motor is directed back to the reservoir through a filter and a heat exchanger. Oil returning to the reservoir must enter the reservoir well below the fluid level to minimize air entrainment. Baffles in the reservoir diffuse the oil to an acceptable level, mix it with the fluid in the reservoir, and prevent the oil from flowing immediately back to the pump inlet. The return oil remains in the reservoir long enough to allow any entrained air in the fluid to rise to the surface and dissipate.

System Illustration

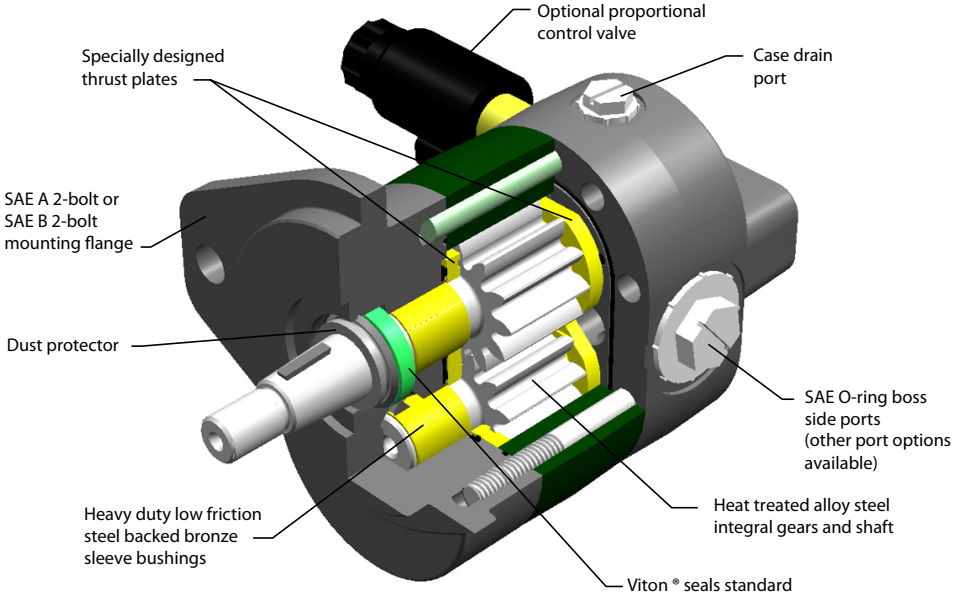


P107 929E

Design

Sauer-Danfoss fixed displacement open circuit gear motors convert hydraulic power into mechanical power. Supply flow determines shaft speed. Load torque results in system pressure between the pump and motor. Bushings at the front and rear of the motor support the shaft. The volume between the gear teeth and the pump body defines the displacement of the motor. A shaft seal and dust protector at the front of the motor prevents leakage where the shaft exits the motor housing.

Cutaway Drawing



P107 920E

Technical Specifications

Technical data for D Motors

Ratings	Units	17	19	21	23	25	29	32	36	38	41	45
Displacement	cm^3/rev	17.0	19.0	20.5	22.5	25.4	29.0	31.8	36.1	38.0	41.0	45.0
	in^3/rev	1.04	1.16	1.25	1.37	1.55	1.77	1.94	2.20	2.32	2.50	2.75
Rated pressure	Bar	276	276	276	276	276	276	276	276	276	241	210
	psi	4000	4000	4000	4000	4000	4000	4000	4000	4000	3495	3045
Peak pressure	Bar	303	303	303	303	303	303	303	303	303	265	231
	psi	4400	4400	4400	4400	4400	4400	4400	4400	4400	3843	3350
Speed at rated pressure	maximum	3400	3400	3400	3400	3400	3400	3400	3400	3400	3000	3000
	minimum*	600	600	600	600	600	600	600	600	600	600	600
Start speed at 1000 PSI	rpm	400	400	400	400	400	400	400	400	400	400	400
Standard Weight	kg	8.53	8.66	8.80	8.94	9.07	9.38	9.53	9.84	9.93	10.16	10.43
	lb	18.8	19.1	19.4	19.7	20.0	20.7	21.0	21.7	21.9	22.4	23.0
Mass moment of inertia	$x10^{-6}$ kg•m²	127	138	146	156	172	191	206	228	239	255	276
	$x10^{-6}$ slug•ft²	94	102	107	115	127	141	152	168	176	188	204
Theoretical torque at rated pressure	N•m	65.7	73.4	79.2	87.0	98.2	112.1	122.9	139.6	146.9	138.4	132.4
	lbf•ft	48.5	54.2	58.4	64.2	72.4	82.7	90.7	102.9	108.3	102.1	97.6
Theoretical power at rated speed	kW	23.4	26.1	28.2	31.0	35.0	39.9	43.8	49.7	46.1	43.5	41.6
	hp	31.2	34.9	37.6	41.3	46.6	53.2	58.4	66.3	61.1	58.0	55.5
Case drain pressure (maximum)	Bar	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	psi	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5

***** minimum speed at maximum pressure

Fluid Specifications

Ratings are based on operation with premium petroleum-based hydraulic fluids containing oxidation, rust, and foam inhibitors.

Parameter	Unit	Minimum	Continuous	Maximum
Viscosity	mm2/sec (cSt) [SUS]	8 [36]	10 - 100 [50 - 212]	1600 [7500]
Temperature	°C [°F]	-40 [-40]	110 [230]	115 [239]
Cleanliness		ISO 4406 Class 22/18/13 or better		
Filtration efficiency	charge filtration	$\beta_{15\text{-}20}=75(\beta_{10}\geq 10)$		

For detailed filtration information, see Sauer-Danfoss publication **520L0463** *Fluids and Filtration*. For information on biodegradable fluids see Sauer-Danfoss publication **520L0465** *Biodegradable Hydraulic Fluids*.

Overview

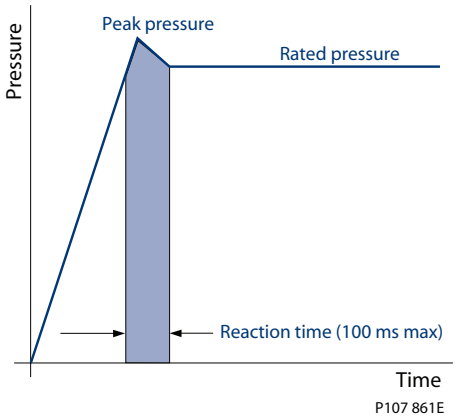
Definitions of the D Series motors operating parameters appear below. Consult Sauer-Danfoss technical support for applications running outside of these parameters.

Pressure

Peak pressure

Peak pressure is the highest intermittent pressure allowed. The relief valve overshoot (reaction time) determines peak pressure. It is assumed to occur for less than 100 ms. The illustration to the right shows peak pressure in relation to rated pressure and reaction time (100 ms maximum).

Pressure vs. time



P107 861E

Rated pressure

Rated pressure is the average, regularly occurring operating inlet pressure that should yield satisfactory product life. The maximum machine load at the motor shaft determines rated pressure.

System pressure

System pressure is the differential between the inlet and outlet ports. It is a dominant operating variable affecting hydraulic unit life. High system pressure, resulting from high load at the motor shaft, reduces expected life. System pressure must remain at, or below, rated pressure during normal operation to achieve expected life.

Back pressure

Back pressure is the average, regularly occurring operating outlet pressure that should yield satisfactory motor life. The hydraulic load demand downstream of the motor determines the back pressure. The Fan Drive Gear Motor can work with back pressure up to 100% of the maximum rated inlet pressure.

Case drain pressure

Case drain pressure is the regularly occurring case drain line pressure that should yield satisfactory motor life. It is recommended to design the case drain piping connecting the case drain direct to the tank in order to keep the case drain pressure as low as possible. Maximum case drain pressure allowed is 5 bar [72.5 psi].

Temperature and Viscosity

Temperature and viscosity requirements must be concurrently satisfied.
Use petroleum/mineral-based fluids.

Temperature

High temperature limits apply at the inlet port of the motor. The motor should run at or below the maximum continuous temperature.

Cold oil, generally, doesn't affect the durability of motor components. It may affect the ability of oil to flow and transmit power. For this reason, keep the temperature at 16°C [60 °F] above the pour point of the hydraulic fluid.

Minimum (cold start) **temperature** relates to the physical properties of component materials.

Continuous temperature is the temperature at or below the temperature which normal motor life can be expected.

Maximum temperature is the highest temperature that is tolerable by the machine for a transient/limited time. (Duty cycle 1% or less)

Viscosity

Minimum viscosity occurs only during brief occasions of maximum fluid temperature and severe duty cycle operation. It's the minimum acceptable viscosity to guarantee the motor life. (Duty cycle 1% or less)

Maximum viscosity occurs only during cold start at very low temperatures. It is the upper limit of viscosity that allows the motor to start.

Continuous viscosity: The viscosity range at which normal motor life can be expected.

Hydraulic Fluid

Ratings and data for gear motors are based on operation with premium hydraulic fluids containing oxidation, rust, and foam inhibitors. These fluids must possess good thermal and hydrolytic stability to prevent wear, erosion, and corrosion of internal components.

Use only clean fluid in the motor and hydraulic circuit.

! Caution
Never mix hydraulic fluids.

For more information on hydraulic fluid selection, see Sauer-Danfoss publications **520L0463** *Hydraulic Fluids and Lubricants, Technical Information*, and **520L465** *Experience with Biodegradable Hydraulic Fluids, Technical Information*.

Required Tools

You can perform the service procedures described in this manual using common mechanic's hand tools. Special tools, if required are shown. When testing system pressures, calibrate pressure gauges frequently to ensure accuracy. Use snubbers to protect gauges.

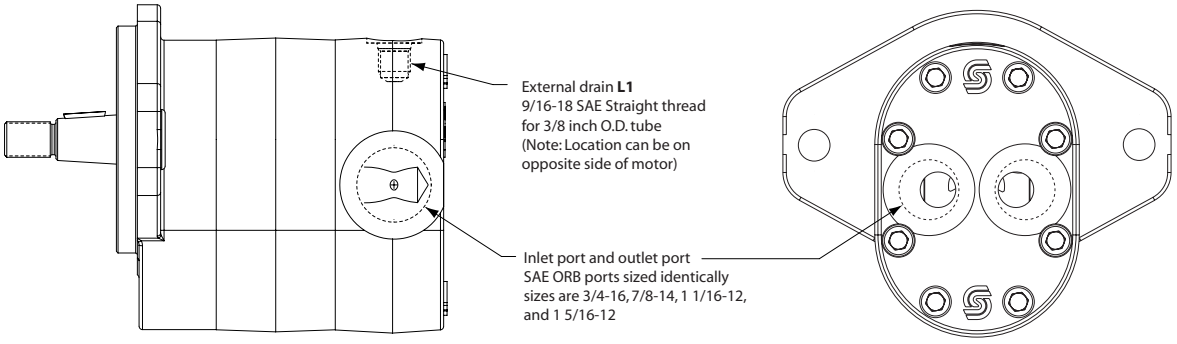
Port locations and Gauge Installation

For economical reasons, the motors do not contain any designated gauge installation ports. Use tee fittings to obtain pressure measurements. The table lists locations and gauge sizes.

D Series Motor

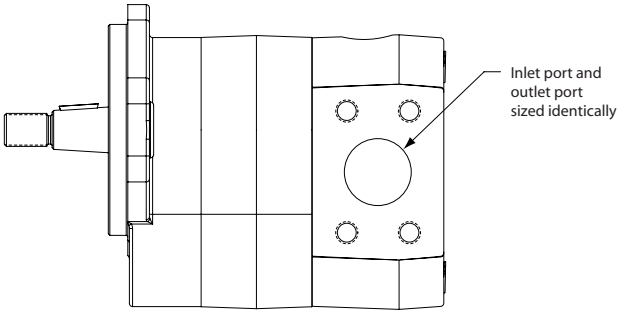
Port information

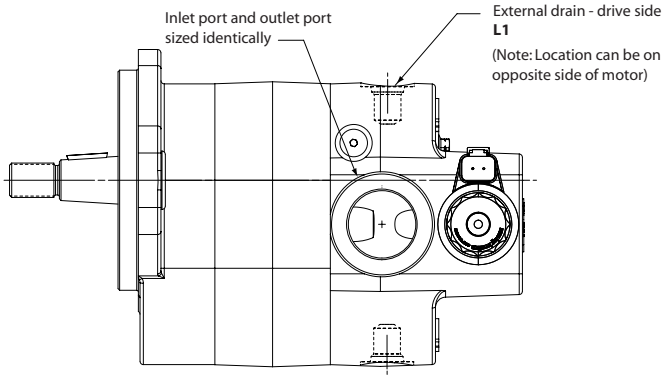
Port identifier	Size	Pressure obtained	Gauge size, bar [psi]
Inlet and outlet ports A and B	3/4-16 SAE J 1926/1 O-ring boss	System and return pressure	600 [10 000]
	7/8-14 SAE J 1926/1 O-ring boss		
	1 1/16-12 SAE J 1926/1 O-ring boss		
	1 5/16-12 SAE J 1926/1 O-ring boss		
	1 inch split flange		
	1 1/4 split flange		
Drain port L1	9/16-18 SAE	Case drain	10 [100]



Radial ports

Axial ports





Split flange ports

Fan drive ports

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D Series Gear Motors
Service Manual
Initial Start-Up Procedures

General

Follow this procedure when starting-up a new motor installation or when restarting an installation in which the motor has been removed.

Prior to installing the motor, inspect for damage incurred during shipping. Make certain all system components (reservoir, hoses, valves, fittings, heat exchanger, etc.) are clean prior to filling with fluid.

Start-Up Procedure

1. Ensure that the machine hydraulic oil and system components (reservoir, hoses, valves, fittings, and heat exchanger) are clean and free of any foreign material.

2. Install new system filter element(s) if necessary.

3. Install the gear motor.

4. Fill the reservoir with hydraulic fluid of the recommended type and viscosity. Use a 10-micron reservoir filler filter.

After start-up the oil level in the reservoir may drop due to filling of the system components. Check the oil level in the reservoir to maintain the full level throughout the start-up.

Caution

If reservoir is low, damage to hydraulic components may occur. Maintain sufficient oil in the reservoir at all times.

5. Use a common method to disable the engine to prevent the engine from starting. Crank the engine starter for several seconds. Do not to exceed the engine manufacturer's recommendation. Wait 30 seconds and then crank the engine a second time as stated above. This operation helps remove unwanted air from the pump outlet line and lubricates the gear motor prior to engine start up. Refill the reservoir to recommended full oil level.

6. Enable engine to start. Start the engine. Let the engine run for a minimum of 30 seconds at low idle to allow the air to work itself out of the system. Check for leaks at all line connections and listen for cavitation.

Caution

Cavitation damages hydraulic components. Take steps to avoid air entrainment in the system.

7. After initial air removal and ensuring the hydraulic reservoir oil level is correct, raise the engine speed enough to increase fan speed to a moderate level but not enough to open the bypass relief valve.

8. With the engine at high rpm disconnect the PWM wire or a sensor to ensure the motor is going to full speed.

9. Check that the reservoir is full. The motor is now ready for operation.

Recommendations

Gear motors are manufactured using a process known as cut-in, during which the gears, motor body, and bearing blocks are allowed to establish a unique relationship to each other. Opening a motor and replacing components is not recommended. Removal or replacement of some internal components will modify their critical dimensions. Because motors are cut-in at a specific pressure to ensure maximum efficiency, removal or replacement of internal components may be detrimental to motor efficiency. Motor conversions are not allowed.

To ensure optimum life, perform regular maintenance of the fluid and filter. Contaminated fluid is the main cause of unit failure. Take care to maintain fluid cleanliness when servicing.

Check the reservoir daily for proper fluid level, the presence of water, and rancid fluid odor. Fluid contaminated by water may appear cloudy or milky or free water may settle in the bottom of the reservoir. Rancid odor indicates the fluid has been exposed to excessive heat. Change the fluid immediately if these conditions occur. Correct the problem immediately.

Inspect vehicle for leaks daily.

Change the fluid and filter per the vehicle/machine manufacturer's recommendations or at these intervals:

Fluid and filter change interval

Reservoir type	Recommended oil change interval
Sealed	2000 hours
Breather	500 hours

Change the fluid more frequently if it becomes contaminated with foreign matter (dirt, water, grease, etc.), or if the fluid is subjected to temperature levels greater than the recommended maximum.

Dispose of used hydraulic fluid properly. Never reuse hydraulic fluid.

Change filters whenever the fluid is changed or when the filter indicator shows that it is necessary to change the filter. Replace all fluid lost during filter change.

Fan Speed Locked High at High Engine Speed (cold conditions)

To determine minimum fan speed at high engine rpm, connect coil to battery voltage to lock coil in open position. Follow steps 1 - 3. If fan is still not operating properly, follow steps 4 - 5.

Item	Description	Action
1. Wire disconnected or shorted	Any wire on the controller, switches, or temperature sensors that is disconnected, cut, or shorted will lock the fan to full speed.	Re-connect wires or re-wire the wiring harness.
2. Faulty electronics	The control module is not sending a current signal to the solenoid. No feel of magnetics on proportional relief valve coil.	Replace the control module. Consult engine repair manual; verify 12 or 24 VDC is going to the coil.
3. Faulty input signal to control module (sensors, switches, PWM signal)	Sensors either not functioning properly or not properly engaged in mounting. Improper or No PWM signal from engine.	Replace or re-mount sensor. Determine why engine is sending faulty signal and fix. Verify 12 or 24VDC going to controller. Check for 5VDC across sensors.
4. Faulty valve	Valve is stuck in closed position.	Replace valve or complete motor assembly.
5. Faulty solenoid coil.	Coil is either shorted or open. No feel of magnetics on coil	Replace coil. Torque coil nut to 4 to 6 N•m [3 to 4.5 lbf•ft].

High Stand-by Fan Speed (cold conditions)

Item	Description	Action
Blockage in main valve flow passages	Blockage in valve flow passages will increase fan speed and system pressure.	Replace valve. Torque to 45 N•m [33 lbf•ft]. Torque coil nut to 4 N•m to 6 N•m [3 to 4.5 lbf•ft].
Faulty electronics, sensor bad or disconnected, PWM signal missing.	Controller is not sending full current signal to the solenoid. Sensor bad or disconnected, PWM signal missing	Replace bad sensor or connect wire. Determine reason for missing PWM signal. Replace the controller.
Faulty solenoid coil.	Coil is either shorted or open. No feel of magnetics on coil	Replace coil. Torque coil nut to 4 to 6 N•m [3 to 4.5 lbf•ft].

Fan Speed Not Controlled by Current to Coil

Item	Description	Action
Fan speed proportional to engine speed at all times	Blocked or stuck valve causes fan speed to be proportional to engine speed at all times.	Replace valve. Torque to 45 N•m [33 lbf•ft]. Torque coil nut to 4 N•m to 6 N•m [3 to 4.5 lbf•ft]

Fan Does Not Turn

Item	Description	Action
Not enough flow through motor.	If engine is left at idle at start-up of machine, there is not enough flow or pressure to turn fan motor.	Rev engine a couple times to get flow through motor. If the fan begins to turn, and continues to turn when the engine returns to idle, the pump and motor are OK.
Delta pressure across proportional valve too low	Delta pressure across motor ports should measure approximately 50 psi minimum at engine idle.	Measure delta pressure across motor ports. If it is greater than 150 psi and the motor does not turn, replace motor. If the delta pressure is between 50 psi and 150 psi and the motor does not turn, rev the engine a couple of times to get flow through the motor and check current to the solenoid. If current is greater than recommended maximum, adjust controller parameters to reduce the current. If increasing the engine rpm makes the fan turn, adjust controller parameters to reduce the current. Consult Sauer-Danfoss controller documentation. Consult engine service manual.
	Check motor case drain flow	Is motor case drain flow greater than 1.2 l/min [US 0.3 gal/min] **YES** - Replace motor. **NO** - Check proportional relief valve
	Check proportional relief valve	Is there 12 or 24 VDC to coil. **NO** - Find out why and repair. **YES** - Disconnect coil.
	Check fan speed	Did fan speed increase? **NO** - Replace proportional relief valve. **YES** - Check controller
	Replace proportional relief valve	After replacing proportional relief valve, is there adequate fan speed?
	Check pump	**YES** - System is OK. **NO** - With solenoid disconnected, measure and record system pressure and fan speed at increasing engine speed (i.e.700, 1200, 1500, 1800, full throttle).
	Check fan speed and system pressure	Is the fan speed and system pressure increasing with engine speed? **NO** - Replace pump.
Inadequate fan system flow coming from pump	If pump or motor lose efficiency, there may not be enough flow to move the motor	Disconnect a sensor wire or battery wire to controller, if the fan does not turn, check motor bearing flow out of motor case drain line (maximum 1.2 l/min [US 0.3 g/min]) and / or with the solenoid disconnected verify system pressures and fan speed while increasing engine speed. If the fan does not turn replace the pump, if it does turn, Repeat troubleshooting chart from the top of this chart. Check engine idle.
	System with Priority Flow Divider (PFD) for steering may be sending too much flow to steering	Check flow to steering unit. Replace pump.
Fan system flow coming from pump is bypassing the motor	Proportional relief valve in motor is stuck in open position	Disconnect solenoid coil. Fan should go to full speed. If fan does not go to full speed, replace relief valve.

Fan Too Slow at High Engine rpm

Disconnect coil to send fan to maximum speed at high engine rpm. If problem remains, follow steps 1 thru 8 below. If fan attains maximum speed, follow step 9 .

Item	Description	Action
1. Low oil level in reservoir	Not enough oil to maintain full system flow.	Fill reservoir to recommended level. Consult operator's manual.
2. PRV set to wrong crack pressure	PRV may be holding pressure below specifications. The PRV controls the maximum speed of the motor.	Replace PRV with one set to appropriate crack pressure. Pressure setting is not externally adjustable.
3. Faulty PRV	Fan runs at low engine speed at all times	Replace valve. Torque to 45 N•m [33 lbf•ft] Torque coil nut to 4 N•m to 6 N•m [3 to 4.5 lbf•ft]
4. Hydraulic oil temperature too high	High oil temperature decreases viscosity and affects efficiency.	Maintain hydraulic oil at normal operating temperatures (110°C [230°F] max). Ensure cooler is operating properly. High oil temperature can also be caused by aeration (see below).
5. Aeration of oil	Air in system decreases efficiency of units and controls. Noise, foaming, and hot oil are signs of aeration.	Find location where air is entering into the system and fix. Check inlet line to pump and repair any leaks. Fill reservoir to recommended level. Consult operator's manual.
6. Damaged motor, low system pressure	Proportional relief valve spool sticking open may prevent full flow from going through motor. Not enough flow from pump.	Measure system pressure between pump and motor. Vary engine speed low to high. Does system pressure change? Check motor case drain flow. Should be maximum 1.2 l/min [US 0.3 gal/min]. If case drain flow exceeds limits, replace motor.
7. Inadequate fan system flow coming from pump.	If pump loses efficiency, it may not produce enough flow to turn the motor. A damaged pump may provide flow when oil is cold and viscous but may not when oil warms up. Systems equipped with steering PFD may be sending too much flow to steering. May be sending too much flow to steering.	Compare performance when oil is hot and cold. Measure flow entering motor. Measure steering flow. Replace pump if flow is insufficient.
8. Inadequate flow coming from the reservoir due to restrictions	Restriction in inlet of the pump, Strainer or filter in the reservoir plugged.	Clean strainer or replace filter in reservoir. Check inlet vacuum at pump inlet. Maximum Inlet vacuum 0.7 bar absolute [10 inches Mercury vacuum]
9. Faulty electronic control module.	The control module is sending too high of a current signal to the solenoid.	Readjust or replace the control module. Verify control module is working properly. Troubleshoot control module according to manufacturers instructions. Replace control module if necessary.

Improper Modulation of Control Module

Item	Description	Action
Faulty input signal to control module (sensors, switches, PWM signal)	Sensors either not functioning properly or not engaged into mounting properly. Improper PWM signal from engine.	Replace or re-mount sensor. Determine why engine is sending faulty PWM signal and fix.
Faulty electronic control module	Control module sending improper current to solenoid.	Consult engine service manual. Replace the control module.
Faulty proportional relief valve	Valve not shifting properly with current signal from control module. Verify proper current signal to valve.	Replace valve assembly. Torque to 45 N•m [33 lbf•ft]. Torque coil nut to 4 N•m to 6 N•m [3 to 4.5 lbf•ft].

System Noise

Item	Description	Action
Aeration of the oil	Low oil in reservoir Air in system decreases efficiency of units and controls. Air in system is indicated by excessive noise in pump, foaming in oil, and hot oil.	Find location where air is entering into the system and fix. Problem is often found in inlet line to pump. Fill reservoir
Cold oil	Low oil temperature increases viscosity and can cause cavitation, resulting in system noise.	Allow the oil to warm up to its normal operating temperature with engine at idle speed.
Fan hitting shroud.	Check fan shroud and hydraulic motor mountings.	Consult owner's manual for proper fastener torques.

Hydraulic System Operating Hot

Item	Description	Action
Low oil level in reservoir and low supply to pump.	Insufficient amount of hydraulic fluid will not meet the cooling demands of the system.	Fill the reservoir to the proper level.
Faulty or blocked heat exchanger (if equipped).	If the heat exchanger fails, or becomes obstructed, it may not meet the cooling demands of the system.	Ensure that heat exchanger is receiving adequate air flow and that the heat exchanger is in good operating condition. Repair or replace as necessary.
Faulty PRV	If a system relief valve becomes unseated for an extended period of time or fails for any other reason, the system could become overheated.	Replace malfunctioning relief valves and verify that the loads on the machine are not excessive. Torque to 45 N•m [33] Torque coil nut to 4 N•m to 6 N•m [3 to 4.5 lbf•ft]
Fan system flow coming from pump is bypassing the motor	Proportional relief valve in motor is stuck in open position	Disconnect solenoid coil. Fan should go to full speed. If fan does not go to full speed, replace relief valve.
	Proportional valve installed into end cover supply port.	Install valve into endcover port on return side of motor

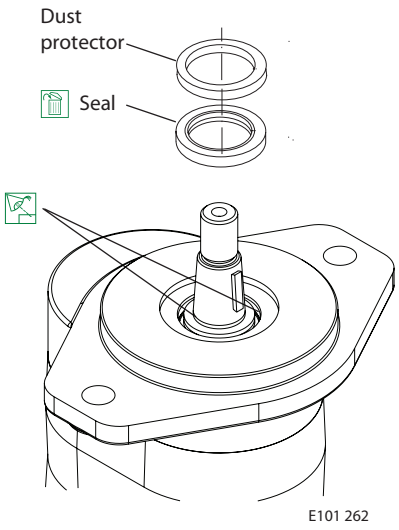
Leaking Motor Shaft Seal

Item	Description	Action
Excessive pressure in case drain line.	Case drain line (from rear of motor) restricted. No other return lines are tied into motor case drain.	Verify case drain line is routed directly to reservoir with no restrictions. Maximum case pressure limit is 5 bar [72 psi]. Replace motor.

Shaft Seal Replacement

Tools needed; snap ring pliers, hammer, awl, (2) sheet metal screws, (2) wire cutting pliers, installation sleeve (PVC tube approximately 0.5 mm [0.02 in] smaller than flange hole diameter), wide cellophane packaging tape, and grease.

Replacing the shaft seal



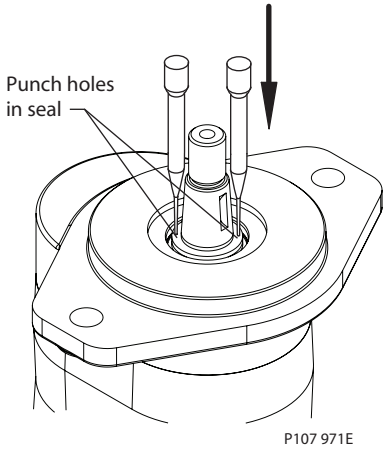
Remove the shaft seal

1. Remove key from shaft.
2. Clean shaft area of all rust, dirt and grime.
3. Use a needle nose pliers or sharp screwdriver to remove the dust protector.

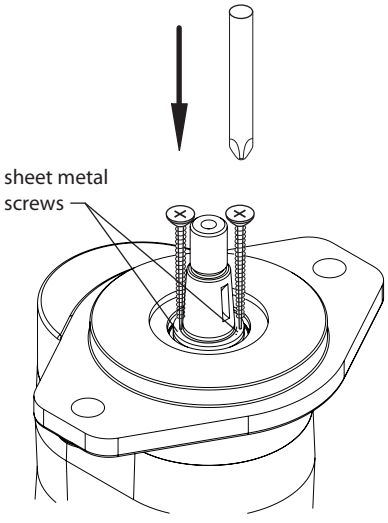
Use the following instructions to carefully pry out the shaft seal.

4. Using a sharp punch or awl, punch two holes in the shaft seal.

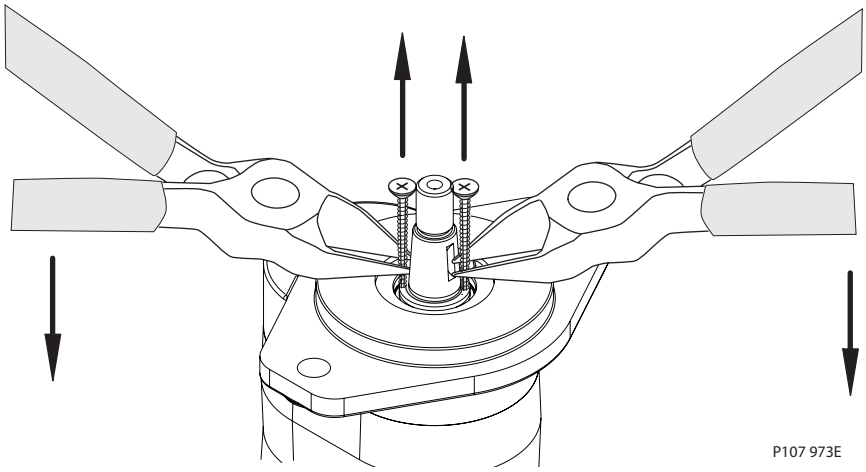
Do not drill holes. Drilling holes produces contamination.



5. Turn two sheet metal screws, one or two turns, into the seal.



Shaft Seal Replacement (continued)



6. Using side cutting wire pliers, remove the seal by prying it out as shown. Take care not to damage the shaft.

7. Discard the seal.

Inspect the components

Inspect the new seal, the motor housing seal bore, and the sealing area on the shaft for rust, wear, and contamination. Polish the shaft and clean the housing if necessary, being careful not to allow contamination to fall into the motor.

Install the new shaft seal

Seal Kit

Kit P/N	11078459

1. Cover the shaft keyway and exposed threads with a shaft cover or packaging tape to protect the shaft and seal during installation.

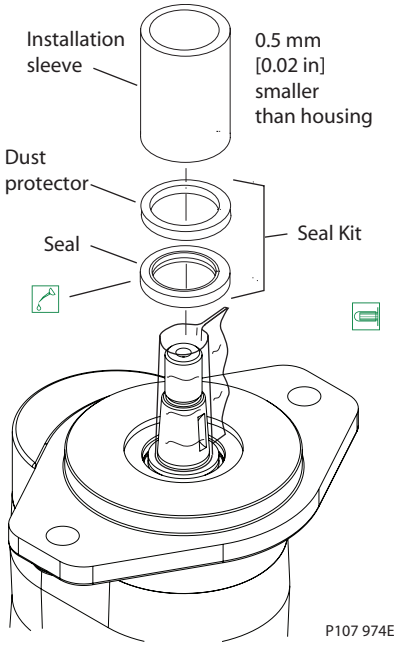
2. Lubricate the inside of the seal.

3. Start the shaft seal into the housing with the cupped side of the seal facing the motor.

4. Use an installation sleeve to press the seal slowly in place.

5. Stop when the seal is seated..

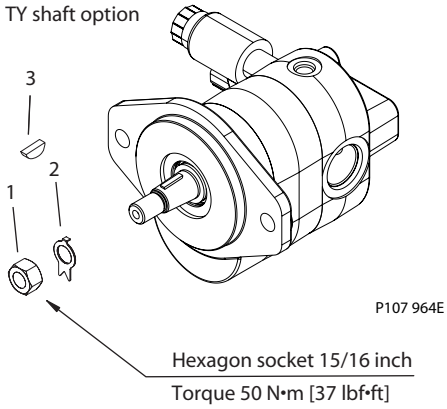
6. Using the installation sleeve, install the dust protector until it is flush with the motor.



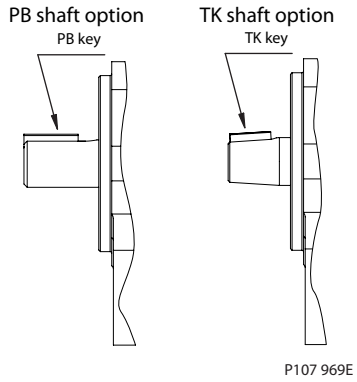
7. Re-install the key into the shaft. Ensure the top of the key does not interfere with the bottom of the keyway in the fan hub when the fan is installed.

8. Thoroughly inspect the operation of the motor after it is installed to ensure no leakage occurs.

Shaft Repair Parts



Item	Description	Part number
1	Shaft nut (5/8-18 UNF)	163M2013
2	Locking washer	163M2428
3	Key	29620-17



Description	Part number
PB Key	163M4001
TK Key	163M4007

Coil Replacement

Refer to the valve drawings on the following pages for wrench sizes and torque specifications.

Remove the coil

1. Disconnect the electrical connection from the coil.
2. Remove the plastic nut holding the coil to the valve.
3. Remove the O-ring and coil.

Install the coil

1. Install new coil.
2. Install O-ring on the valve stem.
3. Install the plastic nut. Torque coil nut to 4 N•m to 6 N•m (3 to 4.5 lbf•ft)

⚠ Warning

Do not overtorque plastic nut. Overtoruque will damage valve.

4. Install the wire connector to the coil.

Valve Replacement

Remove the valve

Remove the valve from the motor.

Install the valve

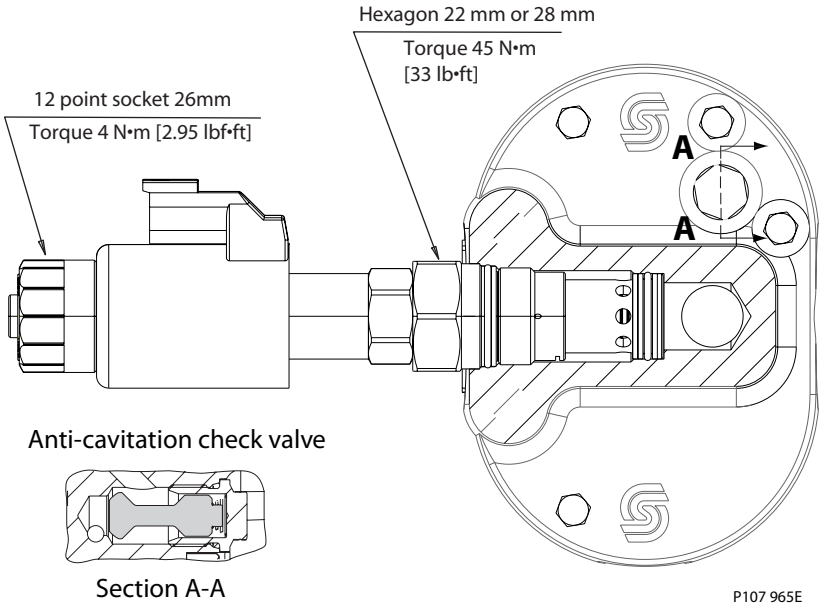
Install new valve into motor. Torque to 45 N•m [33 lbf•ft].

⚠ Warning

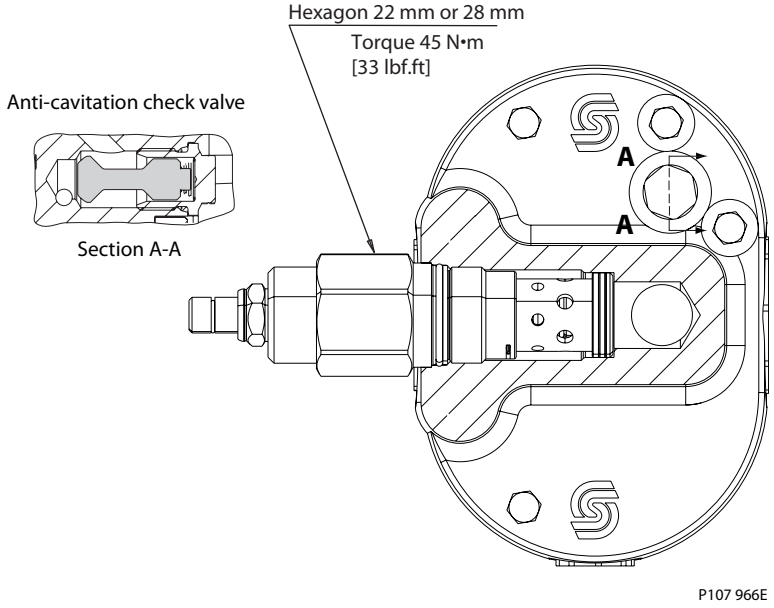
Do not overtorque valve. Overtoruque will damage valve.

Valves

Proportional Relief Valve

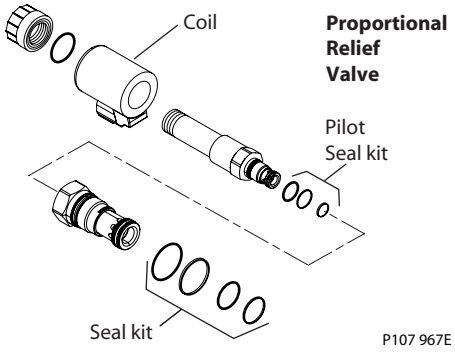


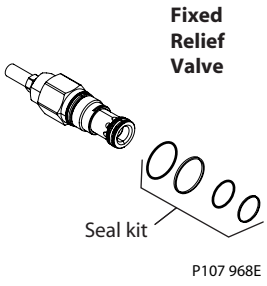
Fixed Relief Valve



Valves (continued)

Valve Repair Parts





Description	Part number
Coil 12 VDC, **P1**, **P2**	11057054
Coil 24 VDC, **P3**, **P4**	11057053
Seal Kit, **P2**, **P4**	11057060
Seal Kit, **P1**, **P3**	11057061
Pilot seal kit	11057166

Description	Part number
Seal Kit, **F**	11057062
Seal Kit, **G**	11057063

Model Code example:

Fan drive motor:

A, **B**, **C**, **D**, **E** *12 VDC proportional relief valve, 25 GPM or less at 172 Bar curve,* **F**.

A	B1	B2	C	D1	D2	E1	E2	F	G	J	K
□□□□	□□□□		□□	□□□□		P1□□		□□□□	□□□□	□□	□□□

Above example shows a 12 volt proportional relief valve (P1) in the E1 position of the model code.

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Fax: +1 515 239 6618

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L1022962 • Rev BB • November 2010

SEQ	ITEMID	QTY_PER	DESCRIPTION
00	163S8143	0	SERVICE KIT D-DUAL 104 & UP (D-MOD)
00	SP494-51	0	TEST SPEC D PUMPS W / FLOW DIVIDER
0010	163D0023	2	PLATE, WEAR, D SERIES
0020	163D0024	2	PLATE, WEAR, D SERIES
0040	163D0069	1	COUPLING-SPLINED D, 1.75"
0050	163D2221	1	BODY, SAE "B", RH SPECIAL
0070	163D3208	2	GEAR PLATE, 125D
0080	163D4266	1	COVER, CODE 09, RH PFD
0090	163D5029	2	IDLER SHAFT 125D SERIES (7/8 BRGS)
0100	163D5042	1	IDLER SHAFT 125D SERIES (7/8 BRG,MULT)
0120	163D5184	1	DRIVE SHAFT CODE H 125D PUMP (MULTI)
0130	163D6214	1	PLATE, CODE 26, COMMON INLET
0140	163M1149	2	SCREW-SOC HD CAP 3/8-6 X 6 3/4
0150	163M3005	4	RING, SEALING
0160	550233889	1	NAMEPLATE, ALUMINUM SELF ADHESIVE
0170	163M3400	2	SEAL, PRELOAD
0180	163M3401	2	SEAL, LOAD
0190	163M3500	1	OIL SEAL
0200	163M7043	4	DOWEL PIN D.3746 / .3742 X 1.385
0230	90052009200	1	PLUG ASSY-PLASTIC ORB 1 5/16-12
0240	90052009000	1	PLUG ASSY-PLASTIC ORB 1 1/16-12
0280	163M1114	6	SCREW-SOC HD CAP 3/8 - 16 X 5 1/2
0320	90052007500	1	PLUG ASSY-PLASTIC ORB 3/4-16
0330	90052008700	1	PLUG ASSY-PLASTIC ORB 7/8-14
0340	163D0079	1	VALVE, D FLOW DIVIDER
0350	49160-3	1	DISC-ORIFICE YC
0360	163D0067	1	SPRING (7 BAR), DN#663X1087
0370	633B1457	2	O-RING ID.600 X .095 THK
0380	163D0054	1	PLUG, SPOOL END DN#631X2046
0390	163D0078	1	PLUG, SPRING END, FLOW DIVIDER
0400	163M5044	2	PLUG, TAMPER PROOF
0430	23413	1	CAP-VALVE-6 SPINDLE
0440	41930	1	SEAT-RELIEF VALVE
0450	24829	1	GASKET
0460	23575-1	1	SPRING
0470	29543-5	1	SCREW-SOC HD SET OVAL PT
0480	32436	1	VALVE

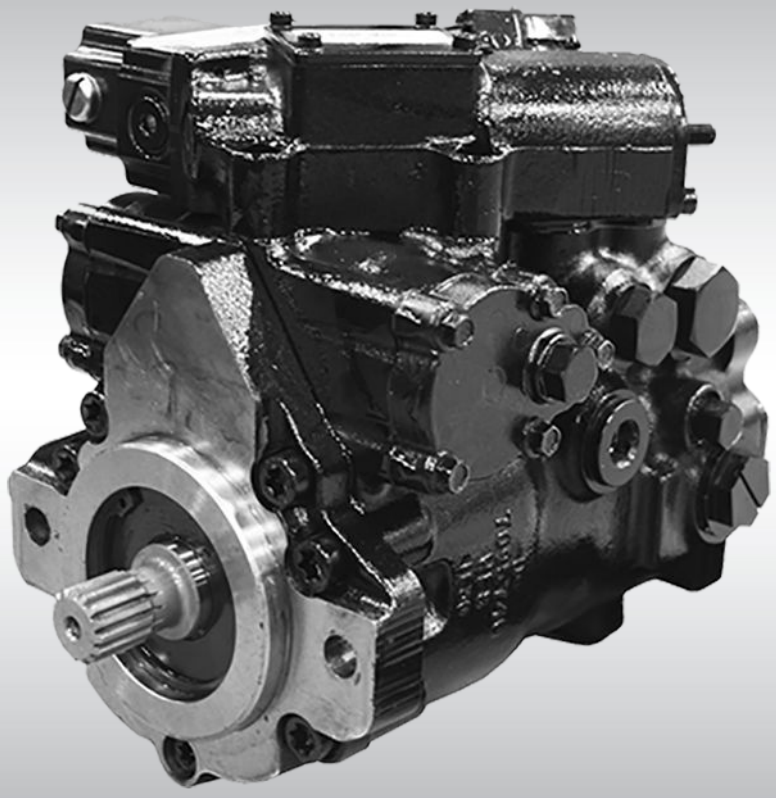
BACK

9 HYDROSTATIC DRIVE COMPONENTS

MAKING MODERN LIVING POSSIBLE

Service Manual

Series 40 M46
Variable Pumps



Revision history

Table of revisions

Date	Changed	Rev
June 2014	Danfoss layout - add HC EDC Control	BA
October 2010	corrections to port location illustration	AE
March 2010	Fix Osaka address	AD
March 2009	added spool alignment illustration	AC
May 2008	Fixed the illustrations	AB
October 2007	First edition	AA

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Introduction

Overview

This manual includes information for the installation, maintenance, and minor repair of the Series 40 M46 pump. It includes a description of the unit and its individual components, troubleshooting information, and minor repair procedures.

Performing minor repairs requires the unit to be removed from the vehicle/machine. Thoroughly clean the unit before beginning maintenance, or repair activities. Since dirt and contamination are the greatest enemies of any type of hydraulic equipment, follow cleanliness requirements strictly. This is especially important when changing the system filter and when removing hoses or plumbing.

A worldwide network of Danfoss Global Service Partners is available for major repairs. Danfoss trains Global Service Partners and certifies their facilities on a regular basis. You can locate your nearest Global Service Partner using the distributor locator at www.powersolutions.danfoss.com.

Warranty

Performing installation, maintenance, and minor repairs according to the procedures in this manual will not affect your warranty. Major repairs requiring the removal of a unit's front flange voids the warranty unless done by a Danfoss Global Service Partner.

General instructions

Follow these general procedures when repairing Series 40 M46 variable displacement closed circuit pumps.

Remove the unit



Prior to performing repairs, remove the unit from the vehicle/machine. Chock the wheels on the vehicle or lock the mechanism to inhibit movement. Be aware that hydraulic fluid may be under high pressure and/or hot. Inspect the outside of the pump and fittings for damage. Cap hoses and plug ports after removal to prevent contamination.

Keep it clean



Cleanliness is a primary means of assuring satisfactory pump life, on either new or repaired units. Clean the outside of the pump thoroughly before disassembly. Take care to avoid contamination of the system ports. Cleaning parts using a clean solvent wash and air drying is usually adequate.

As with any precision equipment, keep all parts free of foreign materials and chemicals. Protect all exposed sealing surfaces and open cavities from damage and foreign material. If left unattended, cover the pump with a protective layer of plastic.

Replace all O-rings and gaskets



Danfoss reccommends you replace all O-rings, seals, and gaskets during repair. Lightly lubricate all O-rings with clean petroleum jelly prior to assembly.

Introduction

Safety precautions

Always consider safety precautions before beginning a service procedure. Protect yourself and others from injury. Take the following general precautions whenever servicing a hydraulic system.

Unintended machine movement

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

Flammable cleaning solvents

Warning

Some cleaning solvents are flammable. To avoid possible fire, do not use cleaning solvents in an area where a source of ignition may be present.

Fluid under pressure

Warning

Escaping hydraulic fluid under pressure can have sufficient force to penetrate your skin causing serious injury and/or infection. This fluid may also be hot enough to cause burns. Use caution when dealing with hydraulic fluid under pressure. Relieve pressure in the system before removing hoses, fittings, gauges, or components. Never use your hand or any other body part to check for leaks in a pressurized line. Seek medical attention immediately if you are cut by hydraulic fluid.

Personal safety

Warning

Protect yourself from injury. Use proper safety equipment, including safety glasses, at all times.

Hazardous material

Warning

Hydraulic fluid contains hazardous material. Avoid prolonged contact with hydraulic fluid. Always dispose of used hydraulic fluid according to state, and federal environmental regulations.

Introduction

Symbols used in Danfoss literature


WARNING may result in injury


CAUTION may result in damage to product or property


Reusable part


Non-reusable part, use a new part


Non-removable item


Option - either part may exist


Superseded - parts are not interchangeable


Measurement required


Flatness specification


Parallelism specification


External hex head


Internal hex head


Torx head


O-ring boss port


Tip, helpful suggestion


Lubricate with hydraulic fluid


Apply grease / petroleum jelly


Apply locking compound


Inspect for wear or damage


Clean area or part


Be careful not to scratch or damage


Note correct orientation


Mark orientation for reinstallation


Torque specification


Press in - press fit


Pull out with tool – press fit


Cover splines with installation sleeve


Pressure measurement/gauge location or specification

The symbols above appear in the illustrations and text of this manual. They are intended to communicate helpful information at the point where it is most useful to the reader. In most instances, the appearance of the symbol itself denotes its meaning. The legend above defines each symbol and explains its purpose.

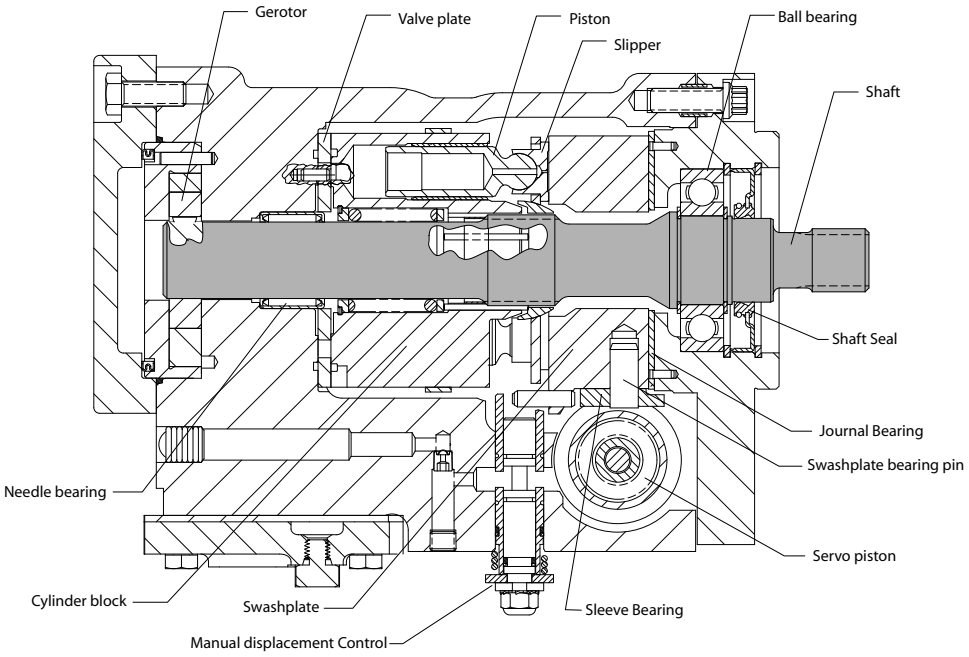
Design

Danfoss Series 40 M46 closed-circuit axial-piston pumps convert input torque into hydraulic power. The input shaft transmits rotational force to the cylinder block. Bearings at the front and rear of the pump support the input shaft. Splines connect the cylinder block to the input shaft. A lip-seal at the front end of the pump prevents leakage where the shaft exits the pump housing. The spinning cylinder block contains seven reciprocating pistons. A ball joint connects a brass slipper to each piston. A spring washer and the force of charge pressure holds the slippers to the swashplate. The reciprocating movement of the pistons occurs as the slippers slide against the inclined swashplate during rotation. Via the valve plate, one half of the cylinder block connects to low pressure and the other half to high pressure. As each piston cycles in and out of its bore, fluid displaces from inlet to outlet imparting hydraulic power into the system. A small amount of fluid flows from the cylinder block/valve plate and slipper/swashplate interfaces for lubrication and cooling. The pump also uses excess flow from the charge pressure relief valve for cooling. Case drain ports return this fluid to the reservoir. A gerotor-style charge pump provides this flow and maintains a minimum pressure in the system loop.

Introduction

The angle of the swashplate controls the volume of fluid displaced into the system. The servo piston sets swashplate angle. The pump control modulates servo piston position by varying differential pressure across the piston.

Cross section view



The system circuit

The basic closed circuit

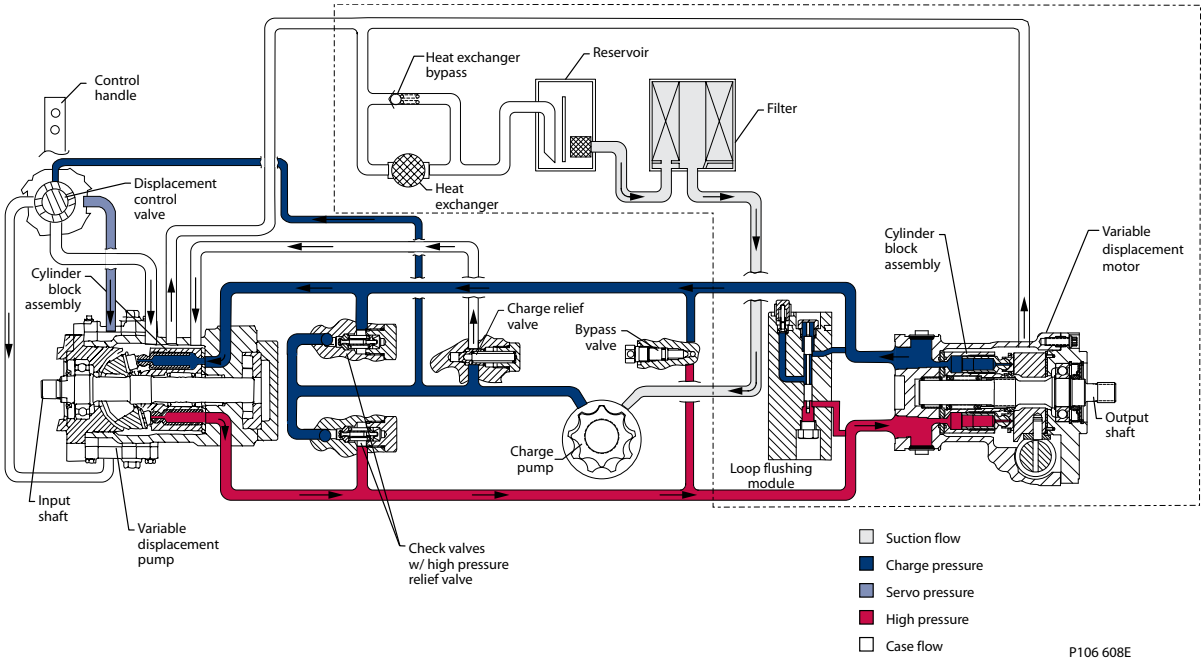
Hydraulic lines connect the main ports of the pump to the main ports of the motor. Fluid flows in either direction from the pump to the motor and back in this closed circuit. Either of the hydraulic lines can be under high pressure. In pumping mode the angle of the pump swashplate determines which line is high pressure as well as the direction of fluid flow.

Case drain and heat exchanger

The pump and motor require case drain lines to remove hot fluid from the system. The pump and motor should be drained from their top most drain port to ensure the case remains full of fluid. Flow from the motor case drain may route to the lower drain port on the pump housing and out the top most port, or feed directly to the heat exchanger. The system requires a heat exchanger with a bypass valve to cool the case drain fluid before it returns to the reservoir.

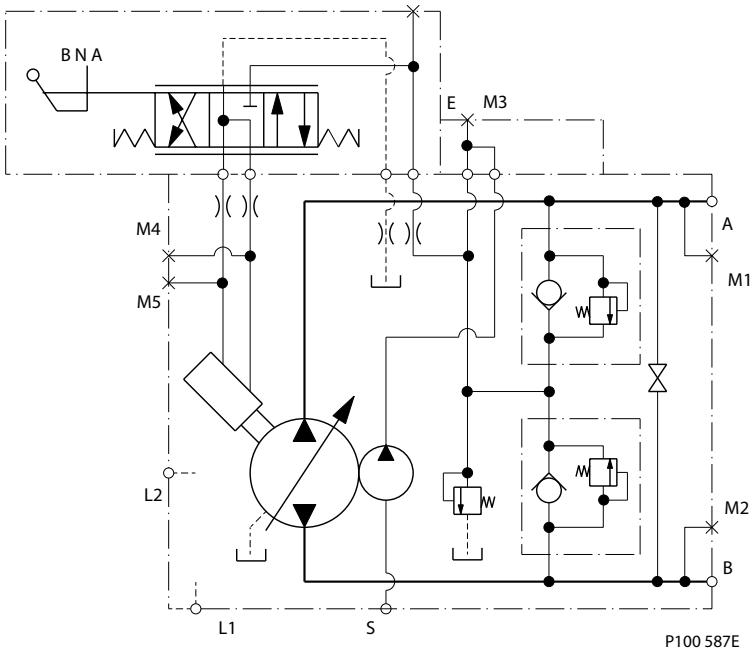
Introduction

System circuit diagram



Pump schematic

Pump schematic



Above schematic shows the function of a Series 40 M46 axial piston variable displacement pump.

Fluid and filter maintenance

Fluid and filter recommendations

To ensure optimum life, perform regular maintenance of the fluid and filter. Contaminated fluid is the main cause of unit failure. Take care to maintain fluid cleanliness when servicing.

Check the reservoir daily for proper fluid level, the presence of water, and rancid fluid odor. Fluid contaminated by water may appear cloudy or milky, or free water may settle in the bottom of the reservoir. Rancid odor indicates the fluid was exposed to excessive heat. Change the fluid immediately if these conditions occur. Correct the problem immediately. Inspect vehicle for leaks daily.

Change the fluid and filter per the vehicle/machine manufacturer's recommendations or at these intervals:

We recommend first fluid change at 500 hours.

Caution

High temperatures and pressures accelerate fluid aging. More frequent fluid changes may be required.

Change the fluid more frequently if it becomes contaminated with foreign matter (dirt, water, grease, etc.) or if the fluid is subjected to temperature levels greater than the recommended maximum.

Dispose of used hydraulic fluid properly. Never reuse hydraulic fluid.

Change filters whenever you change the fluid or when the filter indicator shows that it is necessary to change the filter. Replace all fluid lost during filter change.

Fluid and filter change interval

Reservoir type	Max oil change interval
Sealed	2000 hours
Breather	500 hours

Hazardous material

Warning

Hydraulic fluid contains hazardous material. Avoid contact with hydraulic fluid. Always dispose of used hydraulic fluid according to state, and federal environmental regulations.

Initial startup procedures

General

Follow this procedure when starting-up a new pump installation or when restarting an installation in which the pump was removed. Ensure pump is thoroughly tested on a test stand before installing.

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

Prior to installing the pump, inspect for shipping damage.

Start-up procedure

1. Ensure the machine hydraulic oil and system components (reservoir, hoses, valves, fittings, and heat exchanger) are clean and free of any foreign material.
2. Install new system filter element(s) if necessary. Check that inlet line fittings are properly tightened and there are no air leaks.
3. Install the pump. Install a 50 bar [1000 psi] gauge in the charge pressure gauge port M
4. Fill the housing by adding filtered oil in the upper case drain port. Replace plug.
5. Fill the reservoir with hydraulic fluid of the recommended type and viscosity. Use a 10-micron reservoir filler filter. Ensure inlet line from reservoir to pump is filled.
6. Disconnect the pump from all control input signals.

   After start-up the oil level in the reservoir may drop due to filling of the system components. Check the level in the reservoir to maintain a full oil level throughout start-up.

   Warning

   Damage to hydraulic components may occur if you fail to maintain the oil supply.
7. Use a common method to disable the engine to prevent it from starting. Crank the starter for several seconds. Do not to exceed the engine manufacturer's recommendation. Wait 30 seconds and then crank the engine a second time as stated above. This operation helps remove air from the system lines. Refill the reservoir to recommended full oil level.
8. Check the pressure gauge at M3. When charge pressure begins to build, enable and start engine. Let the engine run for a minimum of 30 seconds at low idle to allow the air to work itself out of the system. Check for leaks at all line connections and listen for cavitation. Check for proper fluid level in reservoir.

   Caution

   Air entrapment in oil under high pressure may damage hydraulic components. Do not run at maximum pressure until system is free of air and fluid has been thoroughly filtered.
9. When the pump estabishes adequate charge pressure (as shown in model code), increase engine speed to normal operating rpm to further purge residual air from the system.
10. Shut off engine. Connect pump control signal. Start engine, checking to be certain pump remains in neutral. Run engine at normal operating speed and carefully check for forward and reverse control operation.
11. Continue to cycle between forward and reverse for at least five minutes to bleed all air and flush system contaminants out of loop.

    Normal charge pressure fluctuation may occur during forward and reverse operation.
12. Check that the reservoir is full. Remove charge pressure gauge. Re-intall charge pressure plug. The pump is now ready for operation.

Required tools and pressure measurements

Required tools

The service procedures described in this manual can be performed using common mechanic's hand tools. Special tools, if required, are shown. When testing system pressures, calibrate pressure gauges frequently to ensure accuracy. Use snubbers to protect gauges.

Port locations and gauge installation

The following tables and drawing show the port locations and gauge sizes needed.

Port information

Port identifier	Port size	Wrench size	Pressure obtained	Gauge size, bar [psi]
L1, L2	1-1/16 12 SAE	9/16 internal hex	Case drain	10 [150]
MA, MB	9/16 18 SAE	11/16 hex	System pressure	600 [9,000]
M3	9/16 18 UNF	11/16 hex	Charge pressure	50 [750]
M4, M5	9/16 18 SAE	11/16 hex	Servo pressure	50 [750]

System valves

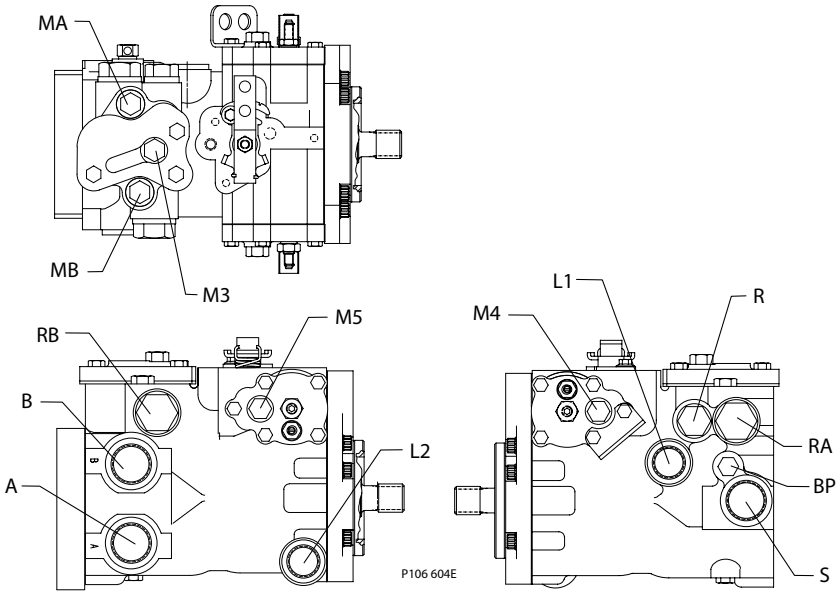
Port identifier	Relief	Port size	Wrench size
RA	A port pressure relief valve	1-5/16 12 UNF	1-1/4 hex
RB	B port pressure relief valve	1-5/16 12 UNF	1-1/4 hex
R	Charge pressure relief valve	3/4 16 UNF	7/8 hex
BP	Bypass valve	5/8 18 UNF	1 inch hex

System ports

Port identifier	Port size
A system pressure port	1-5/16 12 SAE
B system pressure port	1-5/16 12 SAE
S (charge pressure inlet)	1-5/16 12 SAE

Required tools and pressure measurements

Port locations



Troubleshooting

Overview

This section provides general steps to follow if undesirable system conditions occur. Follow these steps until you solve the problem. Some of the items are system specific. For areas this manual covers, we reference the section. Always observe the safety precautions in *Introduction* on page 5 and those related to your specific equipment.

Safety precautions

Caution

High inlet vacuum causes cavitation which can damage internal pump components. Ensure charge pump supply plumbing is adequate. Locating pump below the level of the reservoir, when possible, improves inlet conditions.

Caution

Contamination can damage internal components and void the manufacturer's warranty. Take precautions to ensure system cleanliness when removing and reinstalling system lines

System noise or vibration

Item	Description	Action
Reservoir oil level	Low oil level leads to cavitation.	Fill reservoir.
Aeration of the oil/pump inlet vacuum	Air in system decreases efficiency of units and controls. Excessive noise, foaming oil, and heat may indicate air in system.	Find location where air is entering into the system and repair leak. Check that inlet line is not restricted and is the proper size.
Cold oil	Cold oil may be too viscous for proper function: pump cavitates.	Allow the oil to warm up to it's normal operating temperature with engine at idle speed.
Pump inlet vacuum	High inlet vacuum causes noise/cavitation.	Check that inlet line is not restricted and is the proper size. Check filter and bypass valve.
Shaft couplings	A loose shaft coupling causes excessive noise.	Replace loose shaft coupling. Replace pump shaft.
Shaft alignment	Misaligned shafts creates noise.	Align shafts.
Charge/system relief valves	Unusual noise may indicate sticking valves, possible contamination.	Clean/replace valves and test pump. May be a normal condition.

System operating hot

Item	Description	Action
Oil level in reservoir	Insufficient hydraulic fluid will not meet the cooling demands of system.	Fill the reservoir to the proper level with clean hydraulic oil.
Heat exchanger (if equipped)	The heat exchanger is not sufficiently cooling the system.	Check the air flow and input air temperature for the heat exchanger. Clean, repair, or replace the heat exchanger as necessary.
Heat exchanger bypass valve	A partially activated heat exchanger bypass valve may result in heat generation within the system.	Verify that the bypass valve is fully closed and that the valve is seating properly. Repair or replace as necessary.

Troubleshooting

Item	Description	Action
SCR (System Check / Relief) Valves	A partially activated SCR valve or SCR valves with relief settings too low may generate heat within the system.	Verify that the SCR valve is seating properly and is at the correct relief setting. Repair or replace it as necessary.
Oil filters	Clogged oil filters may result in an insufficient supply of cool oil to the system.	Inspect the oil filters and verify that they are still operable. Replace them if necessary.
Machine load	Excessive loads or extreme duty cycles can result in the pump and/or motor operating at speeds and pressures beyond system design limitations.	Verify that the machine is operating within the parameters for which it was designed. If necessary, reduce the load on the machine.

System will not operate in one direction

Item	Description	Action
Input control signal (linkage, current, or pressure)	A faulty control signal is being received at the pump. (MDC - binding or broken linkage, EDC - faulty or inadequate electrical signal, HDC - blocked or incorrectly orificed control lines).	Verify that the input signal being received is correct and identical in both directions. Adjust, clean, repair, or replace the control module as necessary.
Displacement limiters (if equipped)	The displacement limiters may be improperly adjusted such that the servo piston is prevented from moving in one direction.	Verify that the displacement limiters are adjusted properly.
SCR (system check / relief) valves	The SCR valves are malfunctioning or improperly set.	Verify that the SCR valves are operating properly. Repair or replace them as necessary.
Pump control	A damaged or biased pump control may be sending a signal commanding the pump to stroke only in one direction.	Verify that the pump's control is functioning properly. Repair or replace it as necessary.
Servo pressure	The drain or supply path to one side of the servo piston may be blocked.	Verify that the servo supply and drain paths are unobstructed and that each orifice is of the correct size and free of debris. Clean or repair them as necessary.

System will not operate in either direction

Item	Description	Action
Oil level in reservoir	There is insufficient hydraulic fluid to supply the system loop.	Fill the reservoir to the proper level with clean hydraulic oil.
Displacement limiters	Displacement limiters may be improperly adjusted such that the servo piston is locked in place.	Verify that the displacement limiters are adjusted to the proper setting.
Input control signal (linkage, current, or pressure)	A faulty control signal being received at the pump. (MDC - binding or broken linkage, EDC - faulty or inadequate electrical signal, HDC - blocked or incorrectly orificed control lines)	Verify that the input signal being received is correct and identical in both directions. Adjust, clean, repair, or replace the input device as necessary.
Oil filters	Clogged oil filters may result in an insufficient supply of oil to the system.	Inspect the oil filters and verify that they are still serviceable. Replace them as necessary.
Bypass valve	A partially activated bypass valve (one or both) may result in a cross port leakage.	Verify that the bypass valves are closed and that the valves are seating properly. Clean, repair, or replace them as necessary.
Charge pressure (in neutral)	Charge pressure may be insufficient to recharge the system loop.	Inspect the charge pump for damage and verify that the charge pressure relief valve is at the proper setting. Repair or replace it as necessary.
Charge pressure (in stroke)	There is low charge pressure resulting from internal leakage within the system.	Repair or replace the component or components within the system causing the internal leakage.

Troubleshooting

Item	Description	Action
Servo pressure	There is an insufficient pressure differential across the servo piston.	Check servo pressures to verify sufficient pressure delta. Verify that the servo supply and drain paths are unobstructed and that each orifice is of the correct size and free of debris. Clean, repair, or replace them as necessary.
Charge pump	The charge pump is damaged or has been installed with the incorrect rotational orientation.	Verify that the charge pump is in good working order and that it is correctly installed. Repair or replace it as necessary.
SCR (system check / relief) valves	The SCR valves are malfunctioning or improperly set.	Verify that the SCR valves are operating and properly set. Repair or replace them as necessary.

Neutral difficult or impossible to find

Item	Description	Action
Input control signal (linkage, current, or pressure)	A faulty control signal is being received at the pump. (MDC - binding or broken linkage, EDC - faulty or inadequate electrical signal, HDC - blocked or incorrectly orificed control lines)	Verify that the input signal being received is correct and identical in both directions. Adjust, clean, repair, or replace control module as necessary.
System pressure	With no input signal to the control, a pressure delta may exist between the two sides of the working loop.	Readjust pump neutral setting. Refer to *Swashplate neutral adjustment* on page 22.
Servo pressure	With no input signal to the control, a pressure delta may exist across the servo piston.	Readjust the control neutral setting. Refer to *Manual Displacement Control Neutral-Return Bracket Adjustment* on page 23 and *Electric Displacement Control/Hydraulic Displacement Control Neutral Adjustment* on page 24
PCP pressure (EDCs only)	With no input signal to the control, a pressure difference may exist across the control spool.	Replace the EDC.

System response is sluggish

Item	Description	Action
Reservoir oil level	There is an insufficient amount of hydraulic fluid, resulting in an inadequate supply for the system loop.	Fill the reservoir to the proper level with clean hydraulic fluid.
Input control signal (linkage, current, or pressure)	A faulty control signal is being received at the pump. (MDC - binding or broken linkage; EDC - faulty or inadequate electrical signal; HDC - blocked or incorrectly orificed control lines)	Verify that the input signal being received is correct and identical in both directions.
Pump control	A damaged pump control or control spool will not correctly transmit the control input signal to the pump.	Verify that the pump's control is operating properly and that the control spool is not damaged or worn and moves freely within its bore. Clean, repair, or replace it as necessary.
Bypass valve	A partially activated bypass valve causes cross port leakage.	Verify that the bypass valve is closed and that the valve is seating properly. Clean, repair, or replace it as necessary.
SCR (system check / relief) valves	One or both of the SCR valves may be binding within their bores.	Verify that the SCR valves operate freely. Repair or replace them as necessary.
Charge pressure (in neutral)	There is low charge pressure resulting from a damaged charge pump or low charge pressure relief valve setting.	Inspect the charge pump for damage and verify the charge pressure relief valve setting. Repair or replace as necessary.

Troubleshooting

Item	Description	Action
Charge pressure (in stroke)	There is low charge pressure resulting from internal leakage within the system.	Repair or replace the component or components within the system causing the internal leakage.
Servo pressure	There is insufficient pressure differential across the servo piston.	Check servo pressures at port M4 and M5 to verify sufficient pressure delta. Verify that the servo supply and drain paths are unobstructed and that each orifice is of the correct size and free of debris. Clean, repair, or replace as necessary.
Charge pump	The charge pump has been damaged or installed with the incorrect rotational orientation.	Verify that the charge pump is in good working order and that it is correctly installed. Repair or replace it as necessary.

Electrical troubleshooting

Item	Description	Action
Control operates pump in one direction only	Control coil had failed (EDC).	Measure resistance at coil pins. Resistance should be 14.20 ohms (24V) or 3.66 ohms (12V) at 20°C [70°F]. Replace coil.
No pump function	No power to controller.	Restore power to controller.
Erratic pump function	Electrical connection to pump is bad.	Disconnect connection, check wires, reconnect wires.
Filter bypass indicator switch	Filter switch may be bad.	Check/replace filter switch. Add gauge to filter bypass port to verify proper fluid flow and verify switch operation by measuring resistance. open resistance=>510 ohms, closed resistance<=122 ohms.

Adjustments

Standard procedures, inspections, and adjustments

Before working on the pump, clean all dirt and grime from the outside of the pump and surrounding area.

Caution

Contamination can damage internal components and void the manufacturer's warranty. Take precautions to ensure system cleanliness when removing and reinstalling system lines.

1. If removing the pump, tag each hydraulic line. If you disconnect hydraulic lines, plug each open port to ensure that dirt and contamination do not get into the pump.
2. Inpect the hydraulic fluid for signs of system contamination, oil discoloration, foam in the oil, sludge, or small metal particles.
3. If there are signs of contamination in the hydraulic fluid, replace all filters and drain and clean the hydraulic system. Fill with the correct hydraulic fluid.
4. Flush the lines before replacing the hydraulic fluid.
5. Before re-installing the pump, test for leaks.

Warranty

Performing installation, maintenance, and minor repairs according to the procedures in this manual will not affect your warranty. Major repairs requiring the removal of a unit's front flange voids the warranty unless done by a Danfoss Global Service Partner.

Pump adjustment

This section offers instruction on adjustment of pump components. Read through the entire topic before beginning a service activity. Refer to *Port locations and gauge installation* on page 12, for location of gauge ports and suggested gauge size.

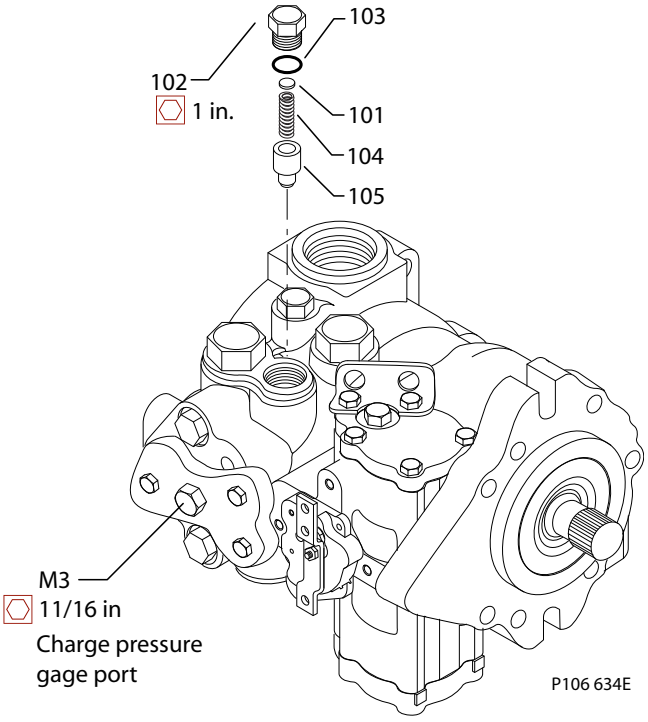
Charge pressure relief valve

This procedure explains how to check and adjust the charge pressure relief valve.

1. Install a 50 bar [1000 psi] pressure gauge in charge pressure gauge port M3. Install a 10 bar [100 psi] gauge in one of the case pressure ports L1 or L2. Operate the system with the pump in neutral (zero displacement) when measuring charge pressure.
2. To adjust charge pressure, shut down system.
3. Using a 1 inch hex wrench, remove charge pressure relief plug (102). Add or remove shims (101) in relief valve. Adding shims increases charge pressure, while removing shims decreases charge pressure.
4. Lubricate and install new O-ring (103).
5. Using a 1 inch hex wrench, reinstall plug. Torque to 108 N•m [80 lbf•ft].
6. Operate pump in neutral to verify proper charge setting. Charge pressure is referenced to case pressure. Subtract case pressure (L1/L2) from charge pressure (M3) to compute actual setting. Repeat steps 1-5 if necessary.
7. Remove gages and replace plugs (M3, L1/L2). Using an 11/16 in. hex wrench, torque plug (M3) to 37 N•m [27 lbf•ft]. Using a 9/16 in. internal hex wrench, torque plug (L1/L2) to 115 N•m [85 lbf•ft].

Adjustments

Charge pressure adjustment



Engaging the bypass function

Test the bypass function with the pump installed on the machine. The bypass function is engaged by unscrewing the bypass valve. Do not open the bypass valve when the machine is operating.

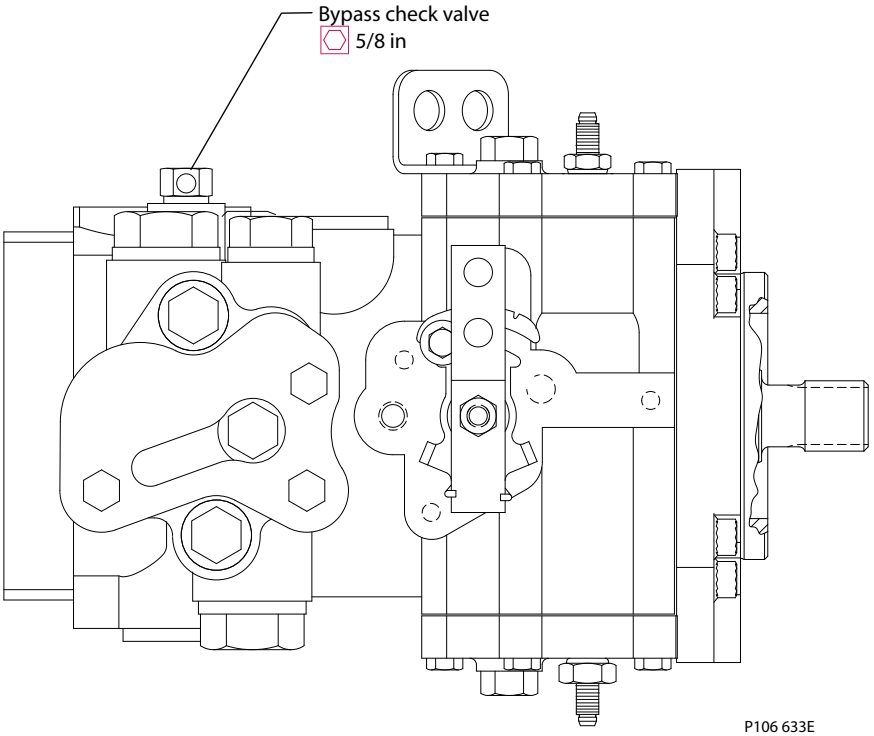
1. To engage the bypass function, use a 5/8 in. hex wrench to unthread the bypass valve.Rotate the bypass valve approximately three turns counterclockwise. Do not rotate more than 3 revolutions: additional rotation permits external leakage.
2. To close the bypass valve, rotate the bypass valve clockwise until seated. Torque to 20 N•m [15 lbf•ft].
3. Vehicle/machine should move with bypass valve open. Close valve for normal operation.

Caution

Bypass valve is not a tow-valve. Damage to pump and motor is possible when operating without charge pressure. Limit speed of movement to 20% of the vehicle/machine's maximum for no longer than 3 minutes.

Adjustments

Using the bypass function



System check/relief (SCR) valves

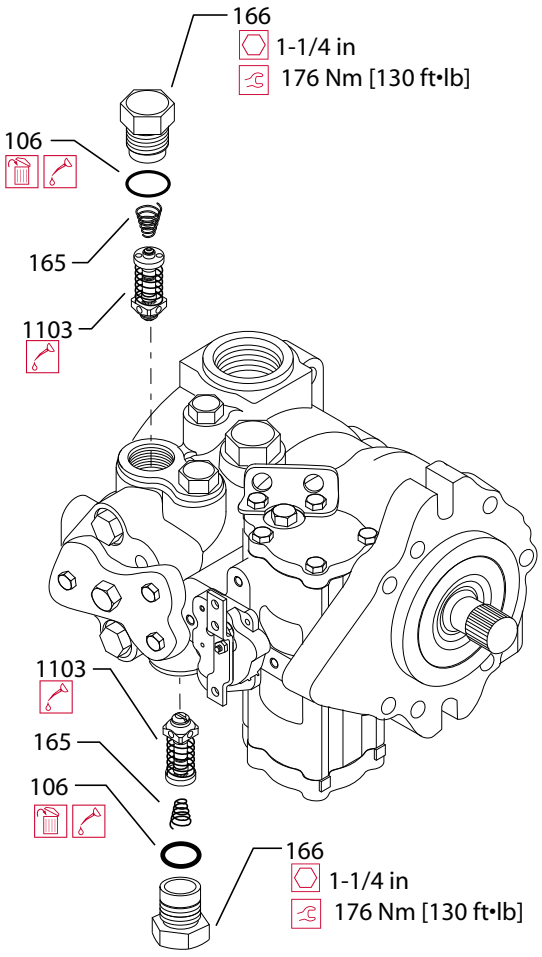
The SCR valve is a high pressure relief valve and a system check valve in combination. Whenever an SCR valve is replaced or opened, opperate the pump in its full range of functions to ensure proper machine operation. The SCR valves are pre-set at the factory, no adjustment is possible. Pressure code is marked on the valve. Refer to the model code for pressure designation. If you suspect SCR malfunction, replace valve and test operation of pump.

This procedure explains how to replace the SCR valves.

1. Shut down the system.
2. Using a 1-1/4 in. hex wrench, remove relief valve plug (166).
3. Remove spring (165) and relief valve (1103) from pump housing.
4. Insert new relief valve and spring into pump housing.
5. Lubricate and install new O-ring (106).
6. Using a 1-1/4 in. hex wrench, install relief valve plug. Torque to 176 N•m [130 lbf•ft].

Adjustments

Installing the SCRs



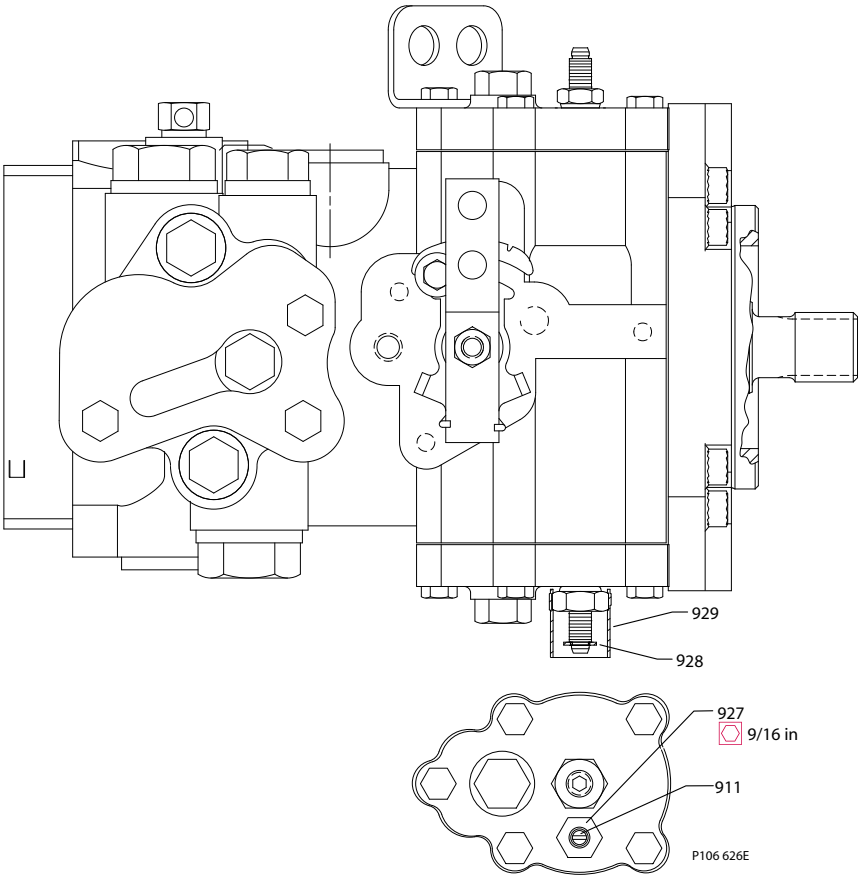
Displacement limiter adjustment

Pump may have a displacement limiter on each side of the servo. Each limiter may be adjusted to a different setting.

1. Remove snap ring (928) and sleeve (929).
2. Using a flat screw driver to hold the displacement limiter, loosen the locking nut (927) with a 9/16 hex wrench.
3. Rotate the displacement limiter (911) to adjust maximum displacement. Rotating the adjusting screw clockwise decreases the maximum displacement of the pump while rotating the adjusting screw counterclockwise increases the maximum displacement. The displacement changes approximately 4 cm^3 per revolution.
4. After establishing the desired maximum displacement setting, hold displacement limiter in place using a flat screw driver and tighten the locking nut with a 9/16 in. hex wrench. Torque to 12 N•m [9 lbf•ft]. Repeat if necessary to adjust maximum displacement in other direction.
5. After adjustment, verify proper maximum vehicle/machine speed. Readjust if necessary.

Adjustments

Displacement limiter adjustment



Swashplate neutral adjustment

With the pump properly plumbed, primed, and mounted on a vehicle or test stand, use this procedure to adjust mechanical neutral. If pump is on a vehicle, securely block the wheels to prevent movement.

Measured data

- System pressure at MA
- System pressure at MB
- Pressure differential between MA and MB (optional)

Pump Setup

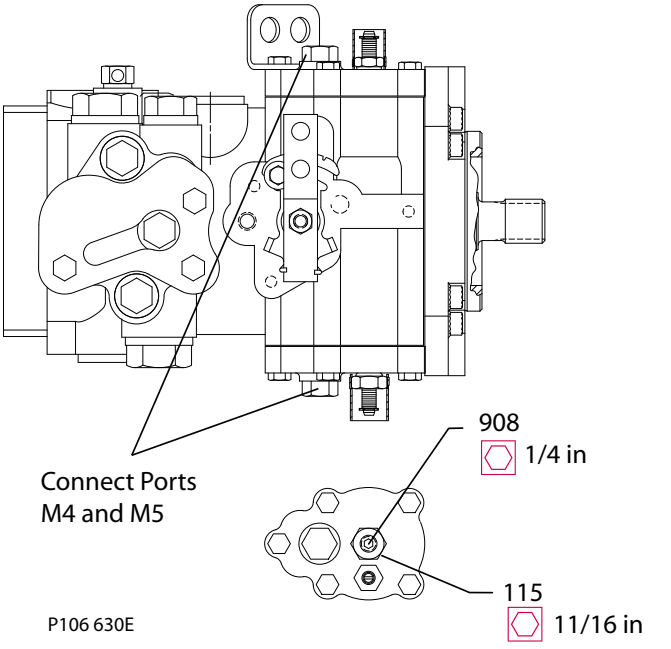
1. Attach 600 bar [10,000 psi] gauge to system pressure gage ports MA and MB.
2. Using a hydraulic line and fittings, shunt the servo piston by connecting servo pressure ports (M4 and M5).

   Connecting servo ports M4 and M5 defeats the affect of any control pressure on the servo piston.
3. Run prime mover at normal operating speed.
4. Use a 1/4 hex wrench to hold adjusting screw (908) in place and a 9/16 hex wrench to loosen servo lock nut (115).
5. Turn neutral adjustment screw (908) until one system pressure gage begins to show an increase in pressure. Note position of screw. Turn the neutral adjustment screw (908) in the opposite direction until the other system pressure gage begins to show an increase in pressure. Note position of screw. Turn the neutral adjustment screw half way between the two postitions.

Adjustments

6. Use a 1/4 hex wrench to hold the servo adjustment screw in place, and a 9/16 hex wrench to tighten servo lock nut (115). Torque to 37 N•m [27 lbf•ft].
7. Shut down prime mover and remove previously installed gauges and fittings. Plug ports MA, MB, M4, and M5.

Servo neutral adjustment



Manual Displacement Control Neutral-Return Bracket Adjustment

With the pump properly plumbed, primed, and mounted on a vehicle or test stand, use the following procedure to adjust the pump displacement control to neutral position. If pump is on a vehicle, securely block the wheels to prevent movement. Check swashplate mechanical neutral adjustment before adjusting control bracket. Refer to previous topic *Swashplate neutral adjustment* on page 22 for instructions. If swashplate neutral is properly adjusted and system is not in neutral, adjust MDC bracket as described below.

Measured data

- Servo pressure at M4
- Servo pressure at M5
- Pressure differential between M4 and M5 (optional)

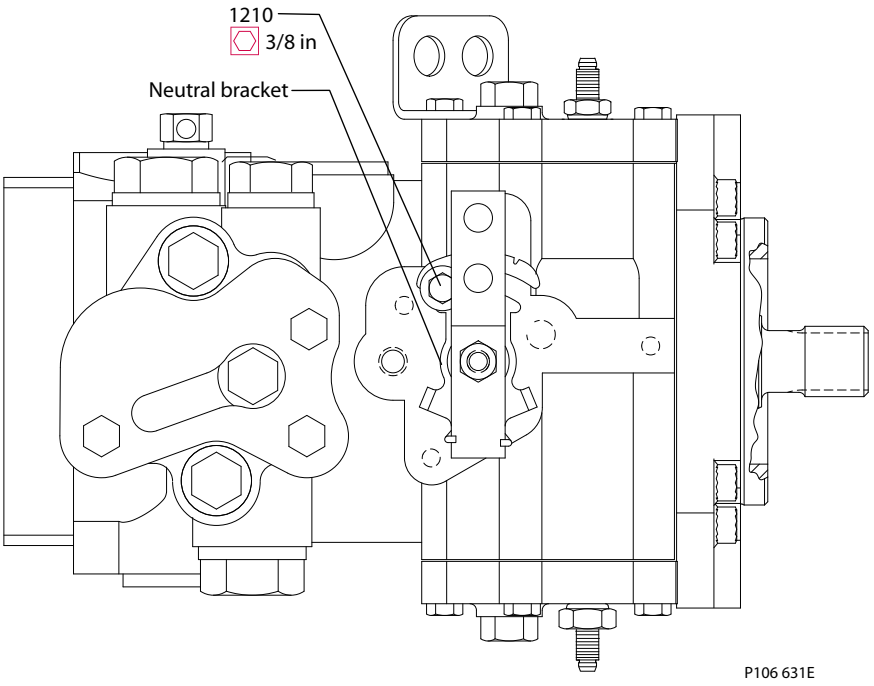
Procedure

1. Attach 20 bar [300 psi] gauge to each servo gage port M4 and M5. Run prime mover at normal operating speed.
2. Using a 3/8 in. hex wrench, loosen screw (1210) allowing the neutral bracket to move, but not freely.
3. Start prime mover and slowly accelerate to normal operating rpm.
4. Using your hand, press neutral bracket towards the pump housing, and rotate it until one of the servo pressure gages indicates an increase in pressure. Note position of bracket. Rotate neutral bracket in opposite direction until the other servo pressure gage indicates an increase in pressure. Note position of bracket. Rotate neutral bracket half way between the two positions.
5. Holding the neutral adjustment bracket in place, use a 3/8 in. hex wrench to tighten screw (1210). Torque to 14 N•m [10 lbf•ft].

Adjustments

6. Shut down prime mover and remove previously installed gauges. Plug ports M4, M5. Torque to 37 N•m [27 lbf•ft]

Manual displacement control bracket adjustment



Electric Displacement Control/Hydraulic Displacement Control Neutral Adjustment

With the pump properly plumbed, primed, and mounted on a vehicle or test stand, use this procedure to adjust the pump displacement control to neutral position. If pump is on a vehicle, block the wheels to prevent movement.

Measured data

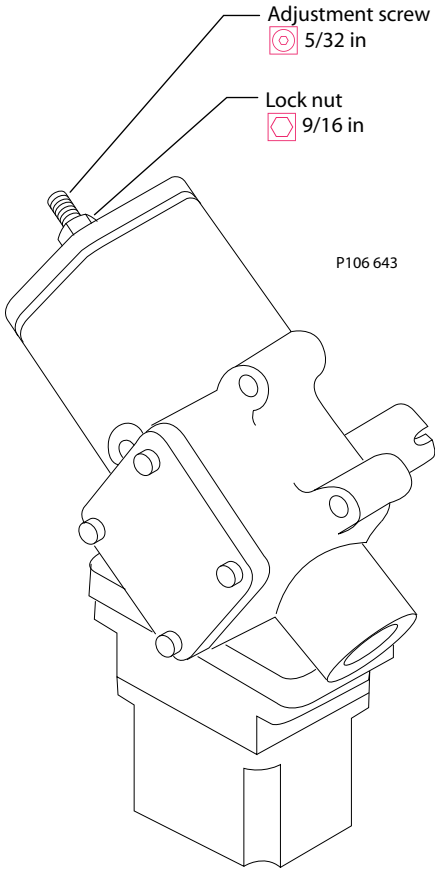
- Servo pressure at M4
- Servo pressure at M5
- Pressure differential between M4 and M5 (optional)

Procedure

1. Attach 20 bar [300 psi] gauge to each servo gage port.
2. Use a 5/32in. internal hex wrench to hold the adjusting screw in place and a 1/2 hex wrench, loosen locknut.
3. Start prime mover and slowly accelerate to normal opperating rpm.
4. Rotate adjustment screw until one of the servo pressure gages indicates an increase in pressure. Note position of screw. Rotate adjustment screw in opposite direction until the other servo pressure gage indicates an increase in pressure. Note position of screw. Rotate adjustment screw halfway between the two positions.
5. While holding the neutral adjustment screw in place, tighten locknut. Torque to 3 N•m [27 lbf•in].
6. Stop prime mover and remove previously installed gauges. Plug ports M4, M5. Torque to 37 N•m [27 lbf•ft]

Adjustments

EDC / HDC control adjustment



HC EDC Control

Control Neutral Adjustment

All functions of the Electric Displacement Control (EDC), are preset at the factory. If necessary, adjust the pump to neutral with the pump running on a test stand or on the vehicle/machine with the prime mover operating. If adjustment fails to give satisfactory results, you may need to replace the control or coils. See Minor repair for details.

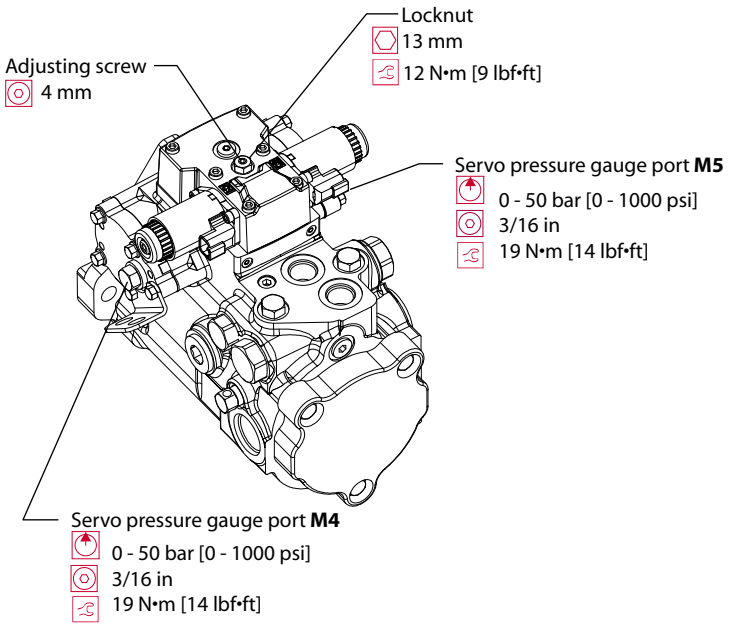
Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

1. Install a 50 bar [1000 psi] gauge in each of the two servo gauge ports (M4 and M5). Disconnect the external control input (electrical connections) from the control. Start the prime mover and operate at normal speed.
2. Use a 4mm internal hex wrench to hold the neutral adjusting screw (D015) stationary while loosening the locknut (D060) with a 13mm wrench.
3. Observe pressure gauges. If necessary, turn adjusting screw (D015) to reduce pressure differential.

   EDC adjustment is very sensitive. Be sure to hold the hex wrench steady while loosening the locknut. Total adjustment is less than 120 degrees.

Adjustments



4. Rotate the neutral adjusting screw (D015) clockwise until the pressure increases on the gauge. Note the angular position of the wrench. Then rotate the neutral adjusting screw counterclockwise until the pressure increases by an equal amount on the other gauge. Again note the angular position of the wrench.
5. Rotate the neutral adjusting screw clockwise half the distance between the wrench positions noted above. The gauges should read the same pressure, indicating that the control is in its neutral position.
6. Hold the neutral adjusting screw stationary and tighten the locknut (D060). Torque to 12 N•m [9 lbf•ft]. Do not over torque the nut.
7. When the neutral position is set, stop the prime mover, remove the gauges, and install the gauge port plugs. Reconnect the external control input.

A small pressure differential of 1.5 bar [22 psi] or less is acceptable. Zero differential is usually not possible.

Adjustments

Neutral Adjustment (EDC) (bottom view)

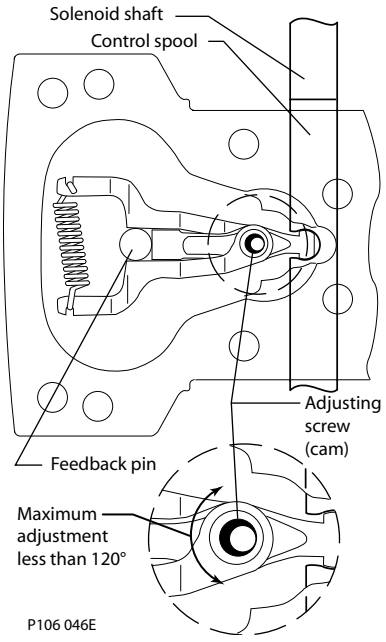


Illustration shows how cam on adjusting pin rotates to adjust for neutral position after pump is re-installed.

Minor repair

Standard procedures, removing the pump

Before working on the pump, clean all dirt and grime from the outside.

If the pump has an auxiliary pump attached, remove both pumps as a single unit.Tag all hydraulic lines as they are disconnected and plug all open ports to ensure that dirt and contamination do not get into the pump.

Caution

Contamination can damage internal components and void the manufacturer's warranty. Take precautions to ensure system cleanliness when removing and reinstalling system lines.

Removal

1. With the prime mover off, thoroughly clean all dirt and grime from the outside of the pump.
2. Tag and disconnect each hydraulic line connected to the pump. As hydraulic lines are disconnected, plug each open port, to ensure that dirt and contamination do not get into the pump.
3. Remove the pump and its auxiliary pump (if applicable) as a single unit.

Caution

Be careful not to damage solenoids and electrical connections when using straps or chains to remove pump from machine.

Inspection

1. Ensure the work surface and surrounding area are clean and free of contaminants such as dirt and grime.
2. Inspect the hydraulic fluid for signs of system contamination, oil discoloration, foam in the oil, sludge, or small metal particles.

Reassembly

1. Before replacing the pump on the machine, replace all filters and drain the hydraulic system. Fill the system with the correct, filtered, hydraulic fluid.
2. Flush the lines before replacing the hydraulic fluid.

   For repair part information, see *Danfoss publication Series 40 M46 Variable Pump Parts Manual* **BLN-2-41701** for your model.

Displacement limiter

Removal

Only remove displacement limiter (911) if replacement is necessary. Mark the location of displacement adjustment and neutral adjustment screws before disassembly. This saves time during re-assembly.

1. Remove snap ring (928) and sleeve (929). Use a 1/4 in. hex wrench to hold neutral adjustment screw in place. Use a 9/16 in. hex wrench to remove hex nut (115).
2. Use a flat screw driver to hold displacement limiter (911) in place. Use a 9/16 in. hex wrench to remove lock nut (927).
3. Using a 3/8 in. hex wrench, remove five bolts (921) from servo cover (902).
4. Unscrew servo cover (902) to remove it from neutral adjustment screw. Remove and discard gasket (936).
5. Turn displacement limiter (911) out of servo cover (902).

Minor repair

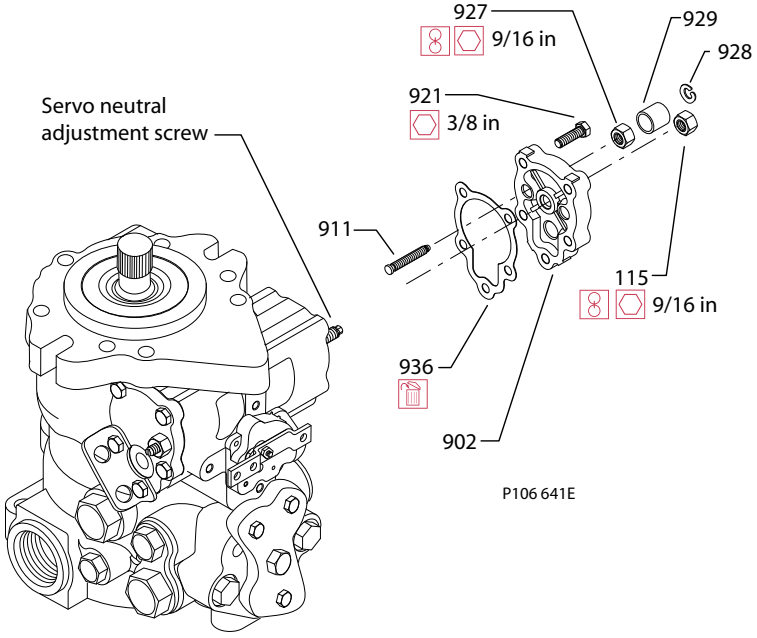
Inspection

Inspect all parts for damage. Inspect the mating surfaces of the servo cover (902) and pump housing for scratches, grooves, and other damage. Inspect threads of screws and nuts for damage. Replace any damaged parts.

Reassembly

1. Turn displacement limiter (911) into servo cover (902). Install new gasket (936) and turn servo cover (902) onto neutral adjustment screw.
2. Using a 3/8 in. hex wrench, install five bolts (921). Torque to 15 N•m [11 lbf•ft].
3. Adjust displacement limiter to position originally noted during disassembly. Use a flat screw driver to hold displacement limiter. Use a 9/16 in. hex wrench to install seal nut (927) onto displacement limiter (911). Torque to 12 N•m [9 lbf•ft].
4. Set neutral adjustment screw at the position noted during disassembly. Use a 1/4 in. hex wrench to hold neutral adjustment screw and a 9/16 in. hex wrench to install hex nut (115). Torque to 37 N•m [27 lbf•ft]. Install sleeve (929) and snap ring (928).

Displacement limiter removal/installation



Pressure filtration adapter

Removal

1. Using an 11/16 in. hex wrench, remove plug (810). Remove and discard O-ring (810A).
2. Using a 1/2 in. hex wrench, remove screws (806).
3. Remove pressure filtration cover (801). Remove and discard seal adapter (805).

Inspection

Inspect the machined surface on the control. If any nicks or scratches are found, replace the damaged component.

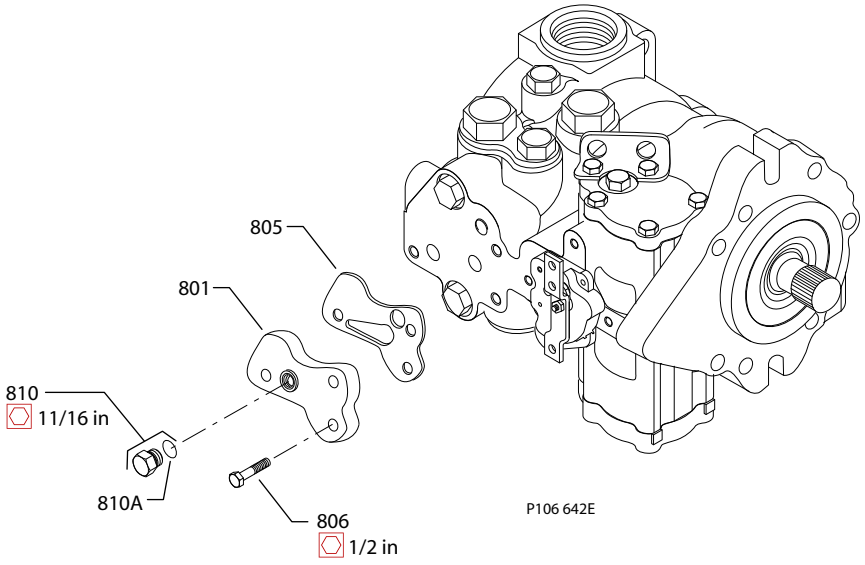
Reassembly

1. Install new seal adapter (805) and filtration cover (801).

Minor repair

2. Using a 1/2 hex wrench, install three screws (806). Torque to 30 N•m [22 lbf•ft].
3. Lubricate and install O-ring (810A) onto plug (810). Using an 11/16 in. hex wrench, install plug (810). Torque to 37 N•m [27 lbf•ft].

Pressure filtration adapter removal/installation



Charge pump

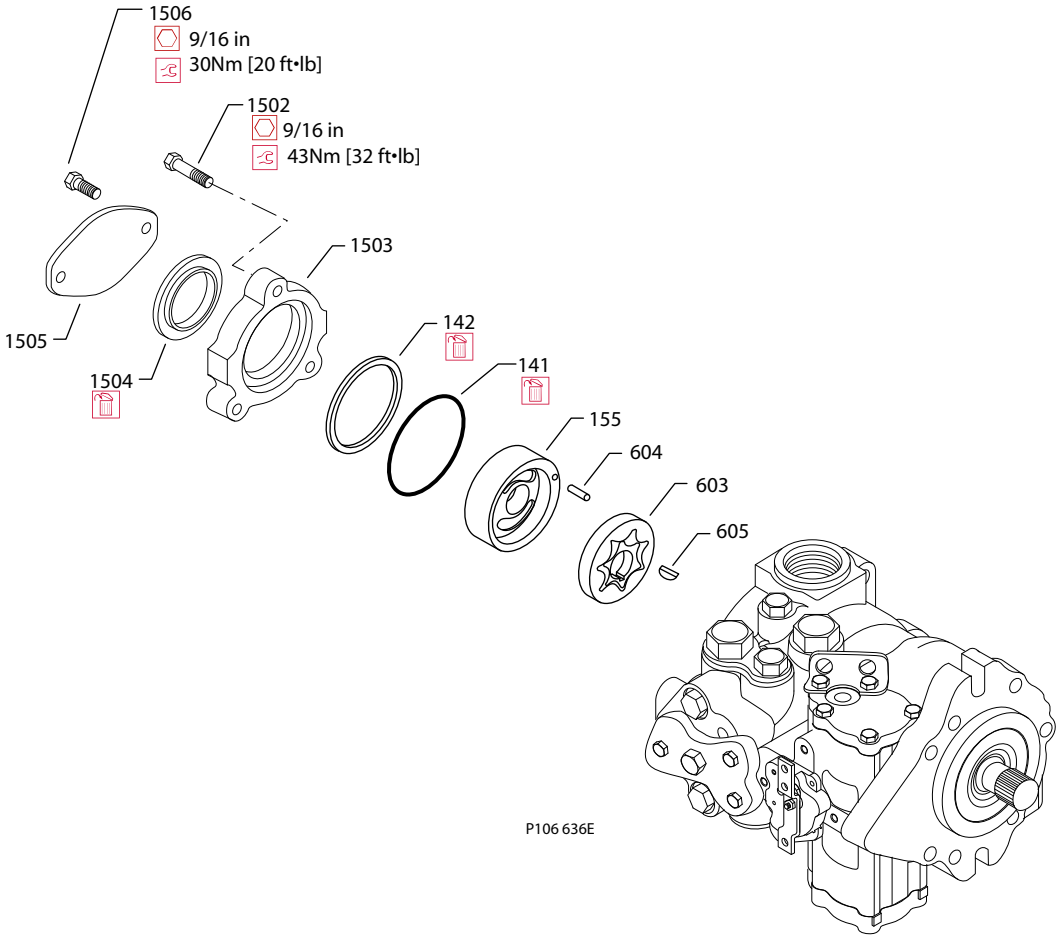
Removal

If a gear pump is attached to the auxiliary pad, remove the gear pump and O-ring or gasket.

1. Using a 9/16 in. hex wrench, remove screws (1506) and cover plate (1505). Remove and discard seal (1504).
2. Using a 9/16 in. hex wrench, remove screws (1502). Remove auxiliary pad (1503).
3. Remove and discard O-ring (141) and load ring (142).
4. Remove gerotor cover (155) and gerotor (603).
5. Remove pin (604) and key (605).

Minor repair

Charge pump removal/installation



Inspection

Inspect the gerotor (603) and gerotor cover (155) for wear, scratches or pitting. If any component shows signs of wear, scratching, or pitting, relpace all components. Inspect pin (604) and key (605) for damage, and replace parts if necessary. Replace O-ring (141), load ring (142), and seal (1504) whenever charge pump is disassembled.

Reassembly

Charge pump parts are available as a complete set

1. Install key (605). Lubricate and install gerotor assembly (603).
2. Install pin (604) and gerotor cover (155).
3. Lubricate and install new O-ring (141) and load ring (142). Install auxiliary pad (1503).
4. Using a 9/16 in. hex wrench, install screws (1502). Torque to 43 N•m [32 lb•ft].
5. Lubricate and press seal (1504) onto auxiliary pad (1503).

   If a gear pump is a ttached to the auxiliary pad, install a new O-ring or gasket and gear pump
6. Install cover plate (1505). Using a 9/16 in. hex wrench, install capscrews (1506). Torque to 30 N•m [22 lbf•ft].

   If a gear pump is attached, seal (1504), cover (1505), and bolts (1506) are not used. Replace O-ring or gasket between gear pump and M46 pump.

Minor repair

Shaft seal, roller bearing and shaft replacement

The shaft assembly is serviceable without removing the front cover of the pump, but the charge pump must be removed first. Orient the pump on the work surface so the shaft is pointing up with the charge pump (603) and key (605) removed from shaft. See *Charge pump* on page 30

Removal

1. Using a snap-ring pliers, remove snap-ring (132) from pump cover. Remove and discard seal (301). Remove second snap-ring (132).
2. Remove shaft assembly from pump cover.

Caution

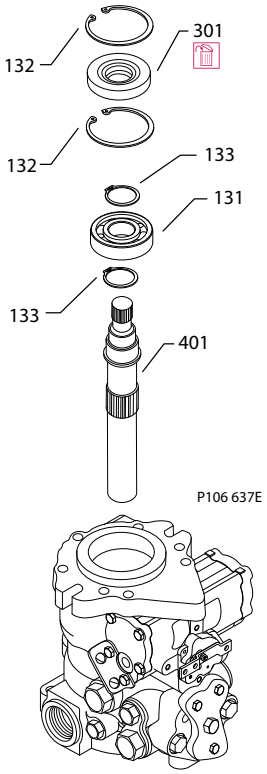
Do not damage the housing bore, shaft, or bearing when removing the shaft and shaft seal.

3. Using a snap ring pliers, remove both snap-rings (133). Press bearing (131) off of shaft.

Caution

Do not rotate or move pump after removing shaft. Internal components may be dislodged making shaft replacement impossible without complete disassembly.

Shaft assembly



Inspection

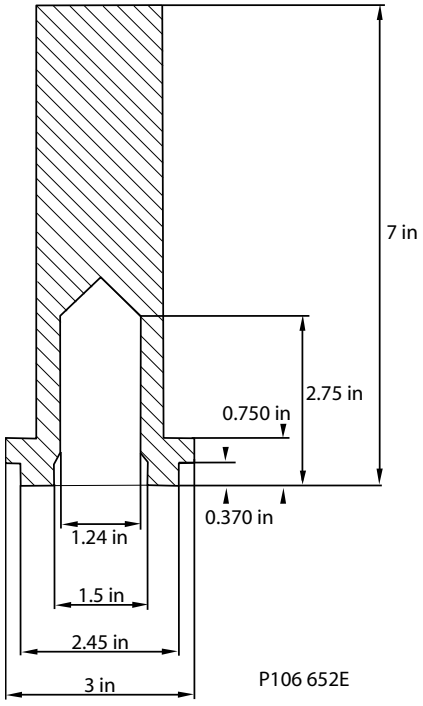
Inspect the shaft and bearing for wear, scratching and pits. If wear, scratching or pitting is found, replace the shaft and bearing. Rotate bearing while feeling for roughness. Replace bearing if it doesn't spin freely.

Minor repair

Reassembly

1. Using a snap ring pliers, install snap-ring (133). Lubricate and press bearing (131) onto shaft. Install second snap-ring (133).
2. Install shaft and bearing assembly into front cover. Rotate shaft to align with block-splines. Ensure bearing is installed deep enough to clear snapring groove.
3. Using a snap ring pliers, install snapring (132).
4. Cover shaft splines with an installation sleeve to protect lipseal during installation. Lubricate and press new seal (301) into pump cover.
5. Install second snap-ring (132). Remove installation sleeve.

Shaft seal installation tool



SCR valves

The SCR valves are factory set and are not field adjustable.

Removal

1. Using a 1-1/4 in. hex wrench, remove relief valve plug (166). Remove and discard Oring (106).
2. Remove spring (165) and relief valve (1103) from pump housing.

Inspection

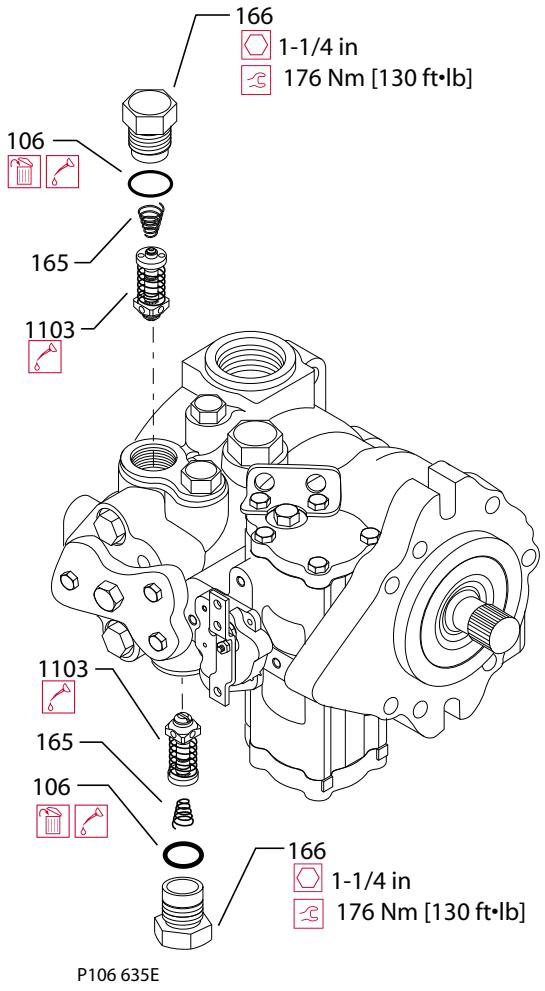
Inspect the sealing surfaces of the pump for nicks or scratches. Inspect the relief valve (1103) sealing surface for nicks or scratches. If the relief valve (1103) is damaged, replace it.

Reassembly

1. Lubricate and insert relief valve (1103) and spring (165) into pump housing.
2. Lubricate and install new O-ring (106) onto plug (166). Using a 1-1/4 in. hex wrench install relief valve plug (166). Torque to 176 N•m [130 lbf•ft].

Minor repair

SCR valves



P106 635E

Charge pressure relief valve

Replace the charge pressure relief valve components if they are damaged or if you suspect failure. See *Charge pressure relief valve* on page 18, for adjustment instructions.

Removal

1. Using a 1 inch hex wrench, remove charge pressure relief plug (102). Remove and discard O-ring (103).
2. Remove shims (101), spring (104), and charge pressure relief valve (105).

Inspection

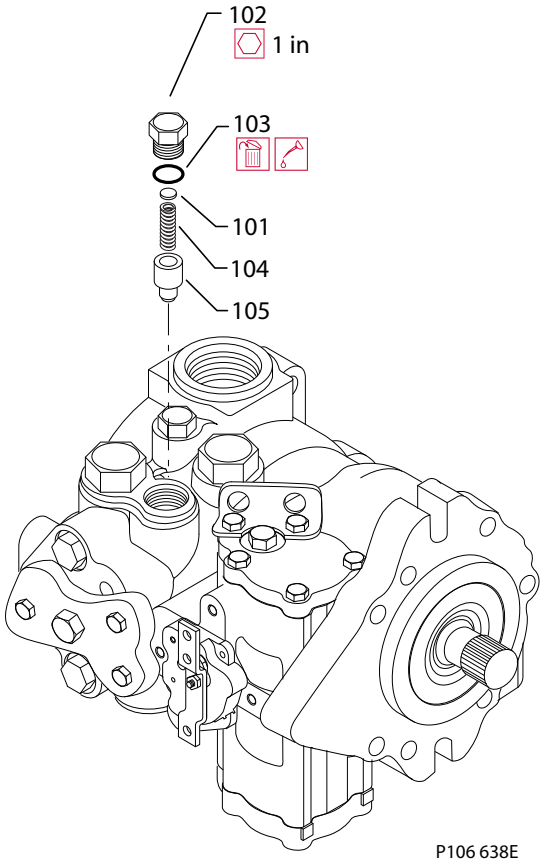
Inspect the sealing surfaces of the pump for nicks or scratches. Inspect the relief valve (105) sealing surface for nicks or scratches. If the relief valve (105) is damaged, replace it.

Reassembly

1. Install charge pressure relief valve, spring, and shims.
2. Lubricate and install O-ring onto plug. Using a 1 in. hex wrench, install plug. Torque to 108 N•m [80 lbf•ft].
3. Operate pump at full range of controls to ensure proper machine operation.

Minor repair

Charge pressure relief valve



Bypass valve

Removal

1. Using a 5/8 in. hex wrench, remove bypass valve (1001).
2. Remove and discard O-ring (1003) and backup ring (1002).

Inspection

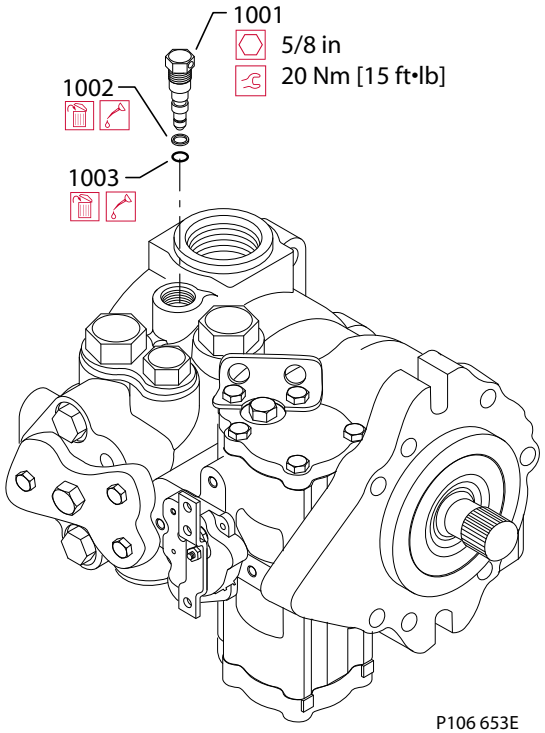
Inspect the sealing surfaces of the pump for nicks or scratches. Inspect the bypass valve (1001) sealing surface for nicks or scratches. Replace any damaged parts.

Reassembly

1. Lubricate and install new O-ring (1003) and backup ring (1002) onto bypass valve (1001).
2. Using a 5/8 in. hex wrench, install bypass valve (1001). Torque to 20 N•m [15 lbf•ft].
3. Operate pump at full range of controls to ensure proper machine operation.

Minor repair

Bypass valve



Manual displacement control

Removal

1. Using a 3/8 in. hex wrench, remove screw (1210). Remove manual control spool assembly from pump housing.
2. Using a 1/2 in. hex wrench, remove lock nut (1213). Remove lock washer (1235), handle (1215), neutral return bracket (1216), and spring (1214) from spool (1207).

   Mark the location of neutral return bracket (1216) before disassembly.
3. Remove and discard backup ring (1209) and O-ring (303) from spool.
4. Remove sleeve (1402). Remove and discard backup ring (1208) and O-ring (302).

Inspection

Inspect all parts of control assembly. Replace any damaged parts. Inspect spool and sleeve for grooves, scratches, and other damage. If spools are damaged, replace them. Inspect sleeve bore in housing for damage.

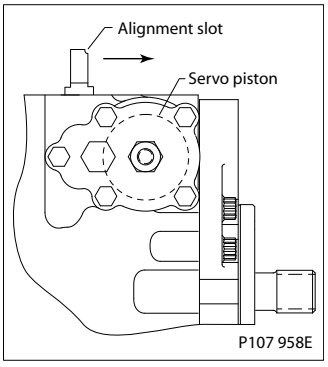
Reassembly

1. Lubricate and install O-ring (302) and backup ring (1208) onto sleeve (1402). Lubricate and install sleeve (1402) into motor housing.

   When installing sleeve (1402), ensure that sleeve groove engages spring pin on swashplate.
2. Lubricate and install O-ring (303) and backup ring (1209) onto spool (1207).

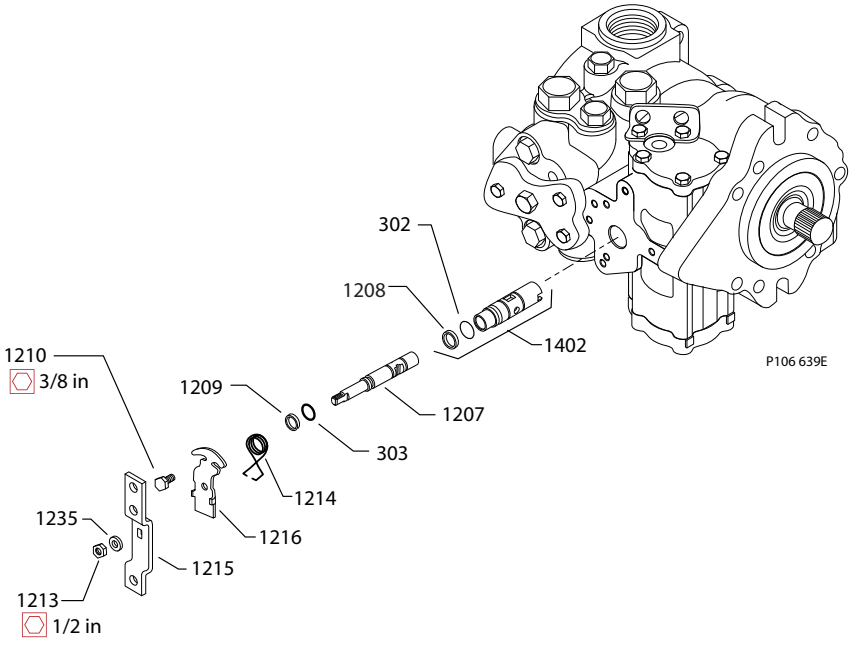
   Install control spool (1207) with alignment slot facing servo piston.

Minor repair



3. Install neutral return spring (1214), neutral return bracket (1216), handle (1215), and washer (1235) onto spool (1207).
4. Using a 1/2 in. hex wrench, install lock nut (1213). Torque to 15 N•m [11 lbf•ft].
5. Lubricate and install spool (1207) into sleeve (1402).
6. Using a 3/8 in. hex wrench, install screw (1210). Torque to 14 N•m [10 lbf•ft]. See *Manual Displacement Control Neutral-Return Bracket Adjustment* on page 23, for adjustment procedure.

Manual displacement control



Electronic displacement control/hydraulic displacement control

Removal

If you suspect control of failure, replace control and test pump for proper operation. When installing control, ensure that sleeve groove engages spring pin on swashplate.

1. Using a 3/16 in. internal hex wrench, remove screws (1203 and 1204) or (1224). If you have a three position controll, remove screws (1226) using a 4 mm internal hex wrench.
2. Remove control housing (1201) or manifold (1225). Remove and discard O-rings (1220 and 304) or (1227, 1228, and 1223A).

Minor repair

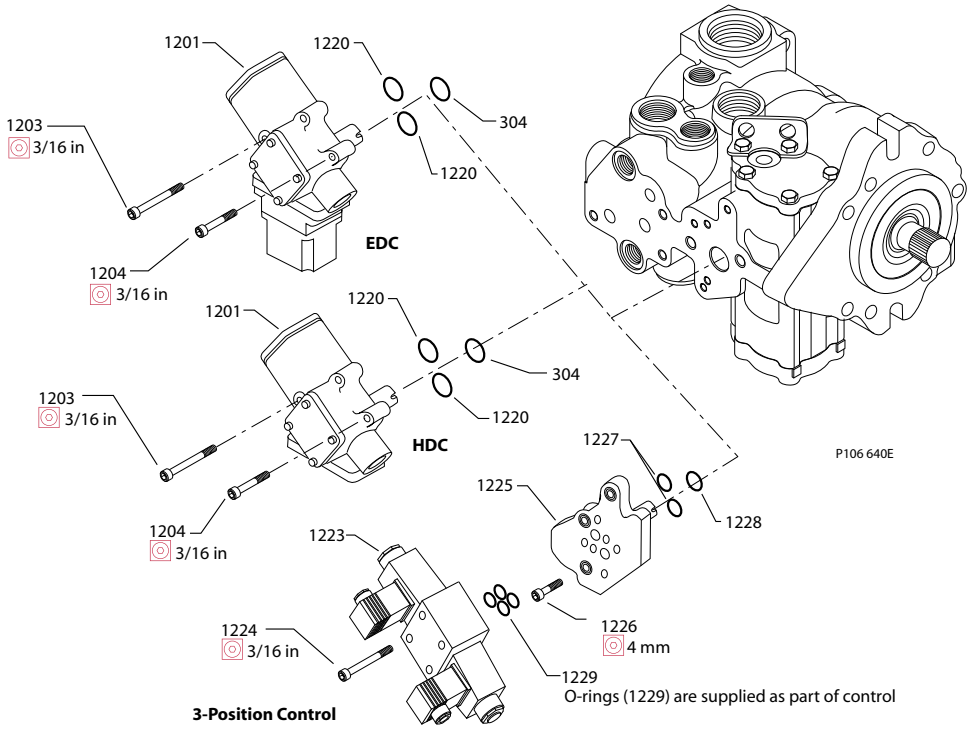
Inspection

Inspect control spool for scratches, grooves, and other damage. If spool is damaged, or you suspect control malfunction, replace entire control unit. Inspect sleeve bore in housing for damage.

Reassembly

1. Lubricate and install O-rings (1220 and 304) onto control housing (1201) or for a three position control, lubricate and install O-rings(1227 and 1228) onto manifold (1225) and O-rings (1229) onto control housing (1223). Install control housing (1201) or manifold (1225) onto pump housing, align sleeve groove with spring pin on swashplate.
2. If you have a three position control, use a 4 mm internal hex wrench to install screws (1226). Torque screws to 14 N•m [10 lbf•ft]. Install three posion control housing (1223). Using a 3/16 in. internal hex wrench, install screws (1203 and 1204) or (1224). Torque to 14 N•m [10 lbf•ft].

EDC / HDC repair



MDC orifice repair

Removal

1. Using a 3/16 in. internal hex wrench, remove pipe plug (1219).
2. Using a 1/8 in. internal hex wrench, remove filter or orifice plug (1401).

Inspection

Clean orifice. Replace if necessary.

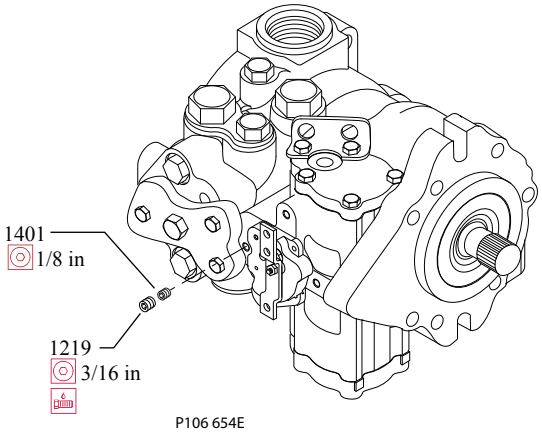
Reassembly

1. Using a 1/8 in. internal hex wrench, install filter or orifice plug (1401). Torque to 3 N•m [2 lbf•ft].
2. Using a 3/16 in. internal hex wrench, install pipe plug (1219). Torque to 22 N•m [16 lbf•ft].

Minor repair

Install Pipe plug (1219) with thread lock. Apply a few drops before installation.

MDC orifice repair



EDC/HDC orifice repair

Removal

1. Remove servo covers. See *Displacement limiter* on page 28, for servo cover removal and installation instructions.
2. Using a 7/32 in. internal hex wrench, remove orifice plugs (1403 and 1404).

Inspection

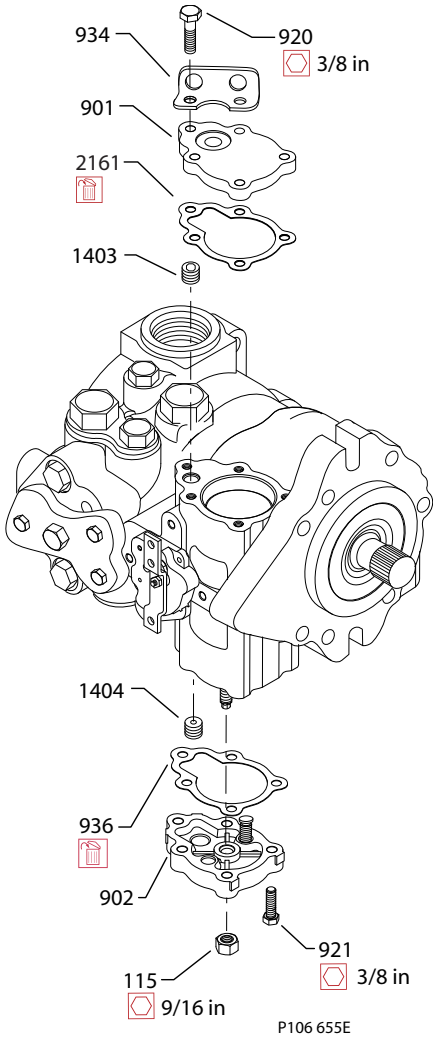
Clean orifice. Replace if necessary.

Reassembly

1. Using a 7/32 in. internal hex wrench, install orifice plugs (1403 and 1404). Torque to 3 N•m [2 lbf•ft].
2. Install servo covers. See *Displacement limiter* on page 28, for servo cover removal and installation instructions.

Minor repair

EDC/HDC orifice repair



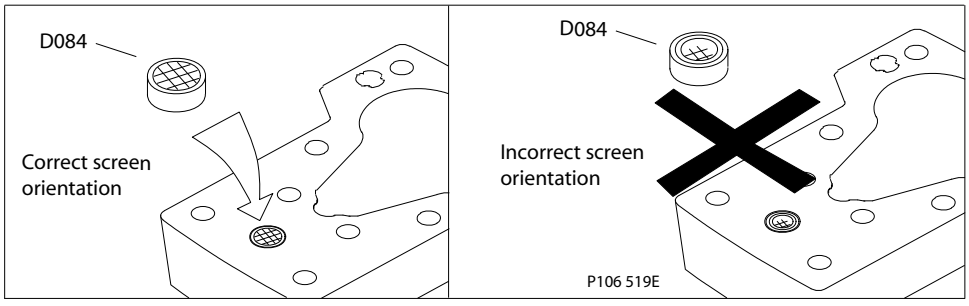
HC EDC Control Repair

1. Using a 5 mm internal hex wrench, remove the six cap screws (D250).
2. Remove the control module and gasket (D150). Discard the gasket.
3. Inspect the machined surfaces on the control and top of the pump. If you find any nicks or scratches, replace the component.
4. Install a new gasket (D150).

   Ensure that you install the dowel pins (D300) in the housing before installing the control.
5. If you removed screen (D084), install a new one. Install with the mesh facing outward (see drawing).

Minor repair

Proper screen orientation

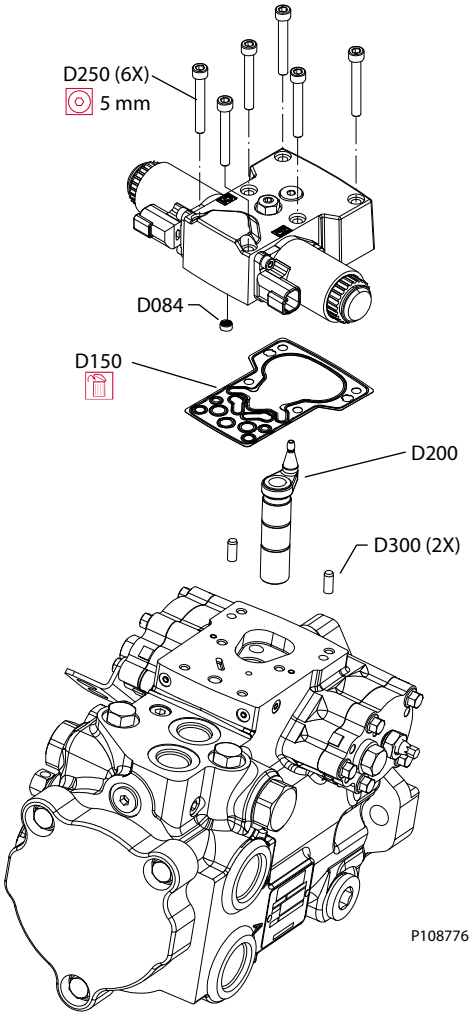


6. Install the control module and six cap screws (D250).

   Remove plug on top of control to ensure the swashplate feedback pin is properly positioned in the center of the control module when installing control.

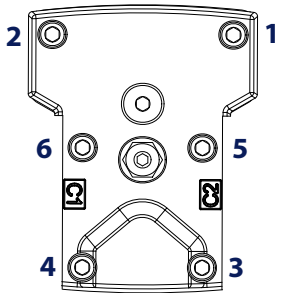
7. Using a 5 mm internal hex wrench, torque the cap screws (D250) to 13.5 N•m [10 lbf•ft].

HC ECD Control



Minor repair

Torque sequence



Torque chart

Fastener size and torque chart

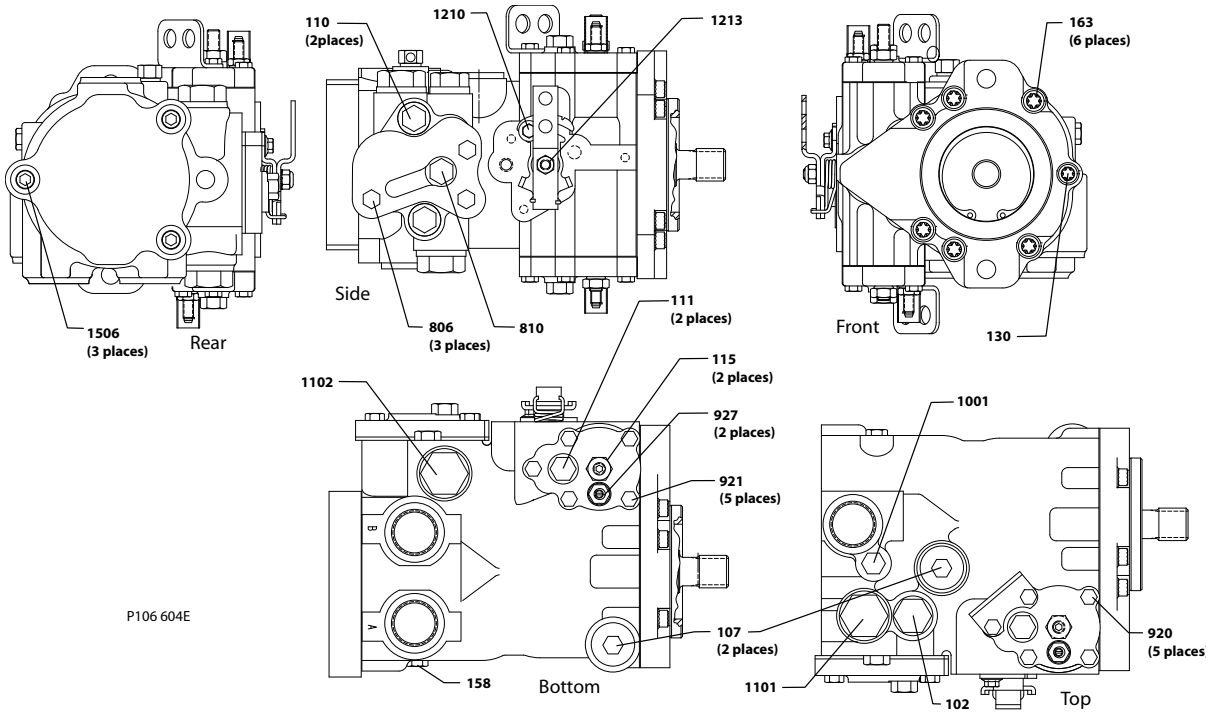
Item	Fastener	Wrench size	Torque
920	Servo piston cover screws	3/8 hex	15 N•m [11 lbf•ft]
921	Servo piston cover screws	3/8 hex	15 N•m [11 lbf•ft]
130	Front cover screw	T50 Torx	58 N•m [43 lbf•ft]
163	Front cover screws	T55 Torx	91 N•m [67 lbf•ft]
1506	Rear cover screws	9/16 hex	77 N•m [57 lbf•ft]
806	Filtration cover screw	1/2 hex	30 N•m [22 lbf•ft]
115	Lock/seal nut	11/16 hex	37 N•m [27 lbf•ft]
927	Displacement limiter lock/seal nut	9/16 hex	12 N•m [9 lbf•ft]
1213	Control handle nut	1/2 hex	15 N•m [11 lbf•ft]
1210	Screw	3/8	14 N•m [10 lbf•ft]

Plug size and torque chart

Item	O-ring plug	Wrench size	Torque
102	3/4 16 UNF	1 inch hex	108 N•m [80 lbf•ft]
107	1-1/16 12 UNF	9/16 internal hex	115 N•m [85 lbf•ft
110	9/16 18 UNF	11/16 hex	37 N•m [27 lbf•ft]
111	9/16 18 UNF	11/16 hex	37 N•m [27 lbf•ft]
158	7/16 20 UNF	9/16 hex	20 N•m [15 lbf•ft]
810	9/16 18 UNF	11/16 hex	37 N•m [27 lbf•ft]
1001	5/8 18 UNF	5/8 hex	20 N•m [15 lbf•ft]
1101	1-5/16 12 UNF	1-1/4 hex	176 N•m [130 lbf•ft]
1102	1-5/16 12 UNF	1-1/4 hex	176 N•m [130 lbf•ft]

Torque chart

Hardware locations



Products we offer:

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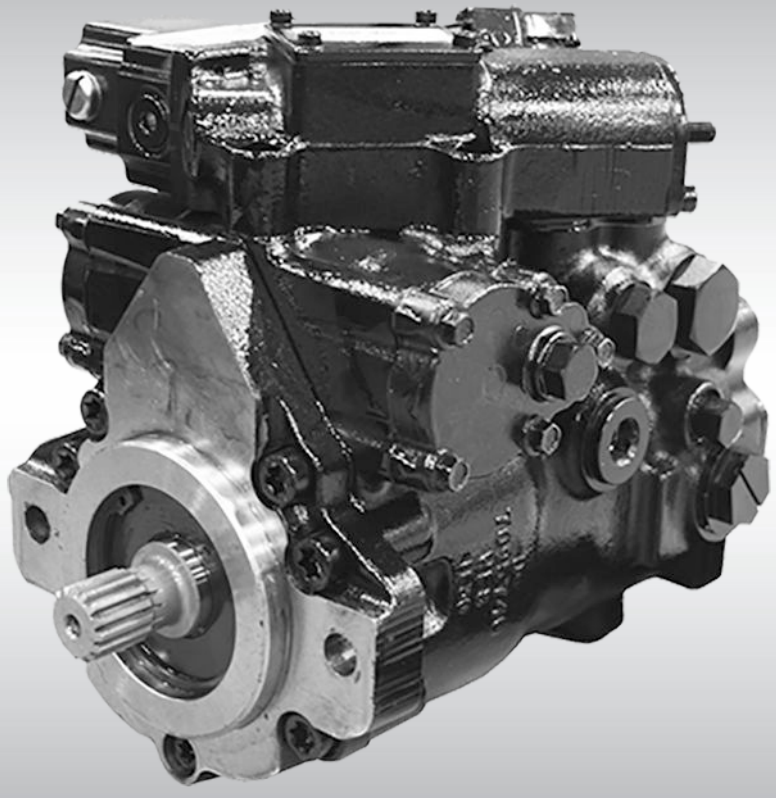
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MAKING MODERN LIVING POSSIBLE

Technical Information

Axial Piston Pumps
Series 40 M46



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Revision history

Table of revisions

Date	Changed	Rev
May 2015	more corrections to tandem pumps model code	BG
March 2015	correction to tandem pumps model code	BF
January 2015	minor edits	BE
January 2015	added port callouts - HC EDC drawings	BD
November 2014	corrections to shaft options	BC
July 2014	Edits to HC EDC Schematic	BB
April 2014	Danfoss layout	BA

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Specifications

Design Specifications

Product line	Series 40 Pumps
Pump type	In-line, axial piston, variable, positive displacement pumps
Direction rotation	Clockwise (CW) or counterclockwise (CCW) available
Installation position	Discretionary, the housing must be filled with hydraulic fluid
Filtration configuration	Suction or charge pressure filtration
Other system requirements	Independent braking system, suitable reservoir and heat exchanger

Technical Specifications

Model		Unit	M46 Single Pump	M46 Tandem Pump
Displacement		cm^3/rev [in^3/rev]	45.9 [2.80]	45.9 x 2 [2.80 x 2]
Shaft Speed	**Minimum**	min-1 (rpm)		
	Rated	min-1 (rpm)	4000	
	Maximum	min-1 (rpm)	4100	
System Pressure	**Maximum working***	bar [psi]	345 [5000]	
	Maximum		385 [5585]	
	Minimum low loop		10 [145]	
Weight (MDC without aux pad)		kg [lb]	33 [73]	59 [131]
Mass moment of inertia of the rotating components		kg ·m^2 [slug·ft^2]	0.0050 [0.0037]	0.0100 [0.0073]
Charge Pressure	**Minimum**	bar [psi]	6 [87]	
	Maximum		31 [450]	
Control Pressure	Minimum @ corner power	bar [psi]	21.5 [312]	
Case Pressure	**Continuous**	bar [psi]	1.7 [25]	
	Maximum (cold start)		5.2 [75]	
Inlet Pressure	**Rated**	bar absolute [inches of Mercury vacuum]	0.8 [6]	
	Minimum		6 [9.2 Maximum]	

* Operation above maximum working pressure is permissible with Danfoss application approval.

Operating Parameters

Fluid Viscosity	Minimum	mm2/s (cSt) [SUS]	7 [49]
	Continuous		12-16 [70-278]
	Maximum (cold start)		1600 [7500]
	Intermittent [1]		6 [46]

Specifications

Fluid Temperature	Minimum (intermittent cold start)	degrees C [degrees F]	- 40° C [- 40° F]
	Continuous		82.2° C [180° F]
	Maximum Intermittent [1]		104.4° C [220° F]

(1) Intermittent equals a short period of time at less than one minute per incident and not exceeding two percent of duty cycle based on load life.

Options

		Single	Tandem
Mounting Flange	SAE - B	X	X
Input Shaft	**Ø 25.4 mm [1.000 in] straight keyed**	X	X
	Ø 25.4 mm [1.000 in] 1:8 taper (SAE J501)	X	X
	13-tooth, 16/32 pitch (ANSI B92.1 1970 - Class 5)	X	-
	15-tooth, 16/32 pitch (ANSI B92.1 1970 - Class 5)	X	X
	19-tooth, 16/32 pitch (ANSI B92.1 1970 - Class 5)	-	X
Auxillary Mounting Flange	**9-tooth internal spline, 16/32 pitch (SAE A)**	X	X
	11-tooth internal spline, 16/32 pitch (SAE A)	X	X
	13-tooth internal spline, 16/32 pitch (SAE B)	X	X
	15 - tooth internal spline, 16/32 pitch (SAE BB)	-	X
Main Port Configuration	1-5/16 - 12 SAE A straight thread O-ring Ports (SAE J514)	X	X

Fluid specifications

Ratings and data are based on operation with premium petroleum-based hydraulic fluids containing oxidation, rust, and foam inhibitors.

Parameter		**Unit**	**Minimum**	**Continuous**	**Maximum**
Viscosity		mm /sec (cSt) [SUS]	7 [47]	12-60 [70-278]	1600 [7500]
Temperature		°C [°F]	-40 [-40]	82 [180]	104 [220]
Cleanliness			ISO 4406 Class 18/13 or better		
Filtration efficiency	suction filtration		$\beta_{35-44}=75$ ($\beta_{10}\geq 1.5$)		
	charge filtration		$\beta_{15-20}=75$ ($\beta_{10}\geq 10$)		

General Information

M46 Pumps

M46 pumps are designed for medium power applications with maximum loads of 345 bar [5000 psi]. These pumps can be combined with other products in a system to transfer and control hydraulic power.

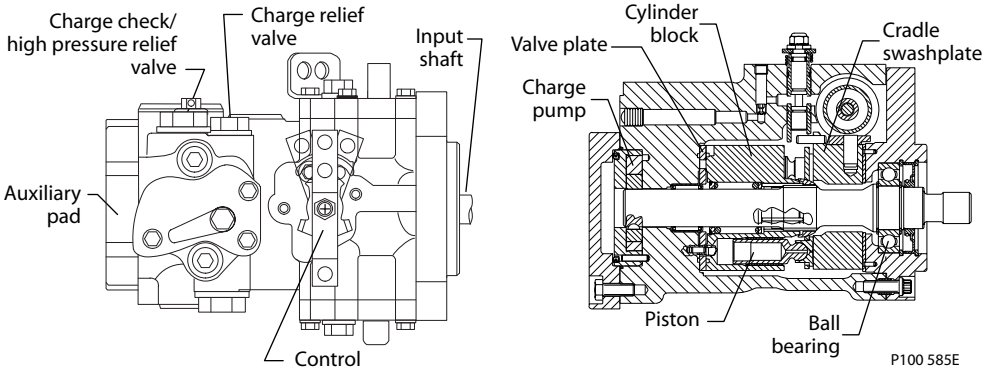
M46 pumps provide an infinitely variable speed range between zero and maximum in both forward and reverse modes of operation.

M46 pumps are compact, high power density units. All models use the parallel axial piston / slipper concept in conjunction with a tiltable swashplate to vary the pump's displacement. Reversing the angle of the swashplate reverses the flow of fluid from the pump, reversing the direction of rotation of the motor output.

M46 pumps may include an integral charge pump to provide system replenishing and cooling fluid flow, as well as servo control fluid flow. M46 pumps feature a range of auxiliary mounting pads to accept auxiliary hydraulic pumps for use in complementary hydraulic systems.

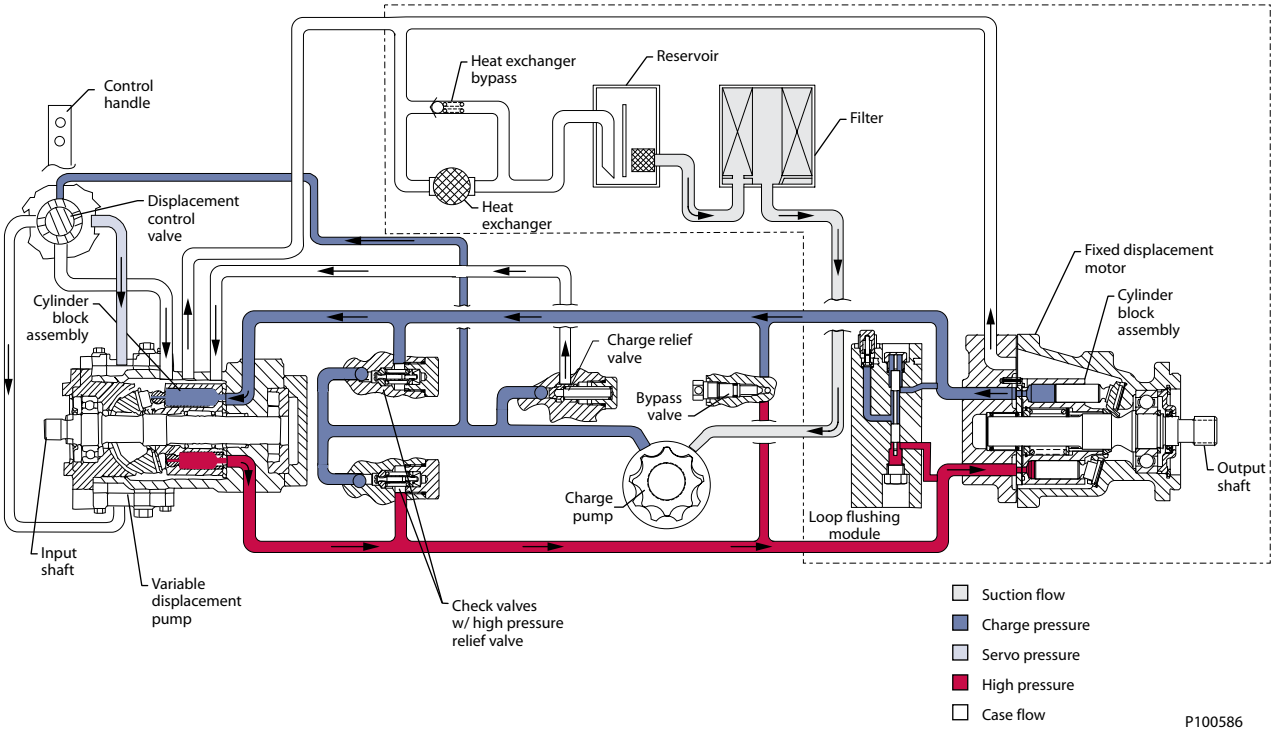
M46 pumps offer proportional controls with either manual, hydraulic, or electronic actuation. An electric three-position control is also available.

M46 Variable Pumps

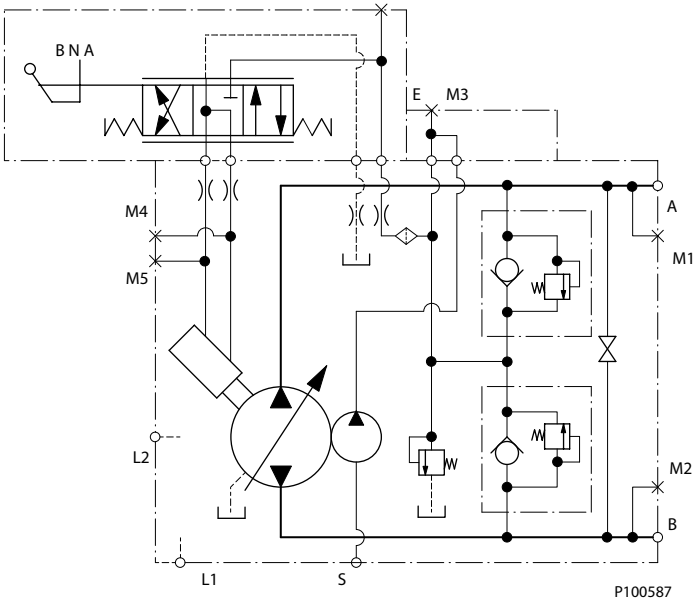


General Information

System Circuit Diagram



Schematic Diagram



Features and Options

Features

- Efficient Axial Piston Design
- Compact, Lightweight Pumps
- Worldwide Support
- Low Noise
- Single and Tandem Integrated Tandem Configurations
- Manual, Hydraulic or Electric Control

Options

High Pressure Relief Valve (HPRV) - A high pressure relief valve limits the system pressure to protect the system from over-pressure.

Charge Relief Valve - The charge pressure relief valve regulates charge pressure.

Displacement Limiters - Optional displacement limiters allow maximum displacement adjustment to allow for fine tuning of the propel system.

Auxiliary Mounting Pads - Several auxiliary mounting pad options allow for adding a second pump.

Control Options - Control options include manual displacement control (MDC), hydraulic displacement control (HDC), electric displacement control (EDC), and threeposition electric displacement control (FNR).

Input Shafts - Straight keyed, tapered keyed, and several splined shaft options are available.

Operating Parameters

Fluids

Ratings and performance data are based on operating with premium hydraulic fluids containing oxidation, rust, and foam inhibitors. These include premium turbine oils, API CD engine oils per SAE J183, M2C33F or G automatic transmission fluids (ATF), Dexron II (ATF) meeting Allison C-3 or Caterpillar T0-2 requirements, and certain specialty agricultural tractor fluids. For more information on hydraulic fluid selection, see Danfoss publications: *Hydraulic Fluids and Lubricants, Technical Information*, **520L0463** and, *Experience with Biodegradable Hydraulic Fluids, Technical Information*,**520L465**.

Viscosity

For maximum efficiency and bearing life, ensure the fluid viscosity remains in the recommended range.

The minimum viscosity should be encountered only during brief occasions.

Maximum temperature is based on material properties. Measure maximum temperature at the hottest point in the system. This is usually the case drain. The maximum viscosity should be encountered only at cold start, and is merely a reflection of a viscosity condition supporting an engine start, at idle. Normal vehicle operation and performance should not occur until the fluid viscosity improves with increrased temperature. For more information on viscosity, see Danfoss publication, *Hydraulic Fluids and Lubricants, Technical Information* **520L0463**.

Temperature

Maintain fluid temperature within the limits shown in the table. Minimum temperature relates to the physical properties of the component materials. Cold oil will not affect the durability of the pump components. However, it may affect the ability of the pump to transmit power.

Maximum temperature is based on material properties. Measure maximum temperature at the hottest point in the system. This is usually the case drain.

Ensure fluid temperature and viscosity limits are concurrently satisfied.

Charge Pressure

An internal charge relief valve regulates charge pressure. Charge pressure supplies the control with pressure to operate the swashplate and to maintain a minimum pressure in the low side of the transmission loop.

The charge pressure setting listed in the order code is the set pressure of the charge relief valve with the pump in neutral, operating at 1800 min-1 [rpm], and with a fluid viscosity of 32 mm2/s [150 SUS]. Pumps configured with no charge pump (external charge supply) are set with a charge flow of 19 l/min [5 US gal/min] (single pumps), 38 l/ min [10 US gal/min] (tandem pumps), and a fluid viscosity of 32 mm2/s [150 SUS].

The charge pressure setting is referenced to case pressure. Charge pressure is the differential pressure above case pressure.

Minimum charge pressure is the lowest pressure allowed in order to maintain a safe working condition in the low side of the loop. Minimum **control** pressure requirements are a function of speed, pressure, and swashplate angle, and may be higher than the minimum charge pressure shown in the *Specifications* section.

Maximum charge pressure is the highest charge pressure allowed by the charge relief adjustment, and which provides normal component life. Elevated charge pressure can be used as a secondary means to reduce the swashplate response time.

Operating Parameters

Control Pressure

Control pressure is the pressure in the servo system needed to position and hold the pump on stroke. Servo pressure depends on system pressure and speed.

At **minimum** control pressure, the pump will run at reduced stroke depending on speed and pressure.

Minimum control pressure at corner power holds the pump on full stroke at maximum speed and maximum pressure.

Maximum control pressure is the highest pressure typically given by the charge pressure setting.

Case Pressure

Under normal operating conditions, do not exceed rated case pressure. During cold start, keep case pressure below maximum intermittent case pressure.

Caution

Operating outside of charge and case pressure limits will damage the pump. To minimize this risk, use full size inlet and case drain plumbing, and limit line lengths.

System Pressure

System pressure is the differential pressure between high pressure system ports. It is the dominant operating variable affecting hydraulic unit life. High system pressure, which results from high load, reduces expected life. Hydraulic unit life depends on the speed and normal operating, or weighted average, pressure that can only be determined from a duty cycle analysis.

Application pressure is the high pressure relief or pressure limiter setting normally defined within the order code of the pump. This is the applied system pressure at which the driveline generates the maximum calculated pull or torque in the application.

Maximum Working pressure is the highest recommended application pressure. Maximum working pressure is not intended to be a continuous pressure. Propel systems with application pressures at, or below, this pressure should yield satisfactory unit life given proper component sizing.

Maximum pressure is the highest allowable application pressure under any circumstance. Application pressures above maximum working pressure will only be considered with duty cycle analysis and factory approval.

Minimum low loop pressure must be maintained under all operating conditions to avoid cavitation.

All pressure limits are differential pressures referenced to low loop (charge) pressure. Subtract low loop pressure from gauge readings to compute the differential.

Speed Ratings

Minimum speed is the lowest input speed recommended during engine idle condition. Operating below minimum speed limits the pump's ability to maintain adequate flow for lubrication and power transmission.

Rated speed is the highest input speed recommended at full power condition. Operating at or below this speed should yield satisfactory product life.

Maximum speed is the highest operating speed permitted. Exceeding maximum speed reduces product life and can cause loss of hydrostatic power and braking capacity. Never exceed the maximum speed limit under any operating conditions.

Operating conditions between rated speed and maximum speed should be restricted to less than full power and to limited periods of time. For most drive systems, maximum unit speed occurs during downhill braking or negative power conditions.

Operating Parameters

For more information consult Pressure and Speed Limits BLN-9884, when determining speed limits for a particular application.

During hydraulic braking and downhill conditions, the prime mover must be capable of providing sufficient braking torque in order to avoid pump over speed. This is especially important to consider for turbocharged and Tier 4 engines.

Warning

Unintended vehicle or machine movement hazard.

The loss of hydrostatic drive line power, in any mode of operation (forward, neutral, or reverse) may cause the system to lose hydrostatic braking capacity. You must provide a braking system, redundant to the hydrostatic transmission, sufficient to stop and hold the vehicle or machine in the event of hydrostatic drive power loss.

Inlet Pressure

Achieving acceptable pump life and performance requires proper charge pump inlet design. A **continuous inlet pressure** of not less than 0.8 bar absolute (not more than 6.3 inches Hg vacuum) is recommended. Normal pressure less than the **minimum inlet pressure** of 0.7 bar absolute (greater than 9.2 inches Hg vacuum) indicates inadequate inlet design or a restricted filter. Pressures less than 0.7 bar absolute (greater than 9.2 inches Hg vacuum) during cold start are likely, but should improve quickly as the fluid warms.

System Design Parameters

Sizing Equations

Use these equations to help choose the right pump size and displacement for your application.

	Based on SI units		Based on US units	
Flow	Output flow Q =	$\frac{V_g \cdot n \cdot \eta_v}{1000}$ (l/min)	Output flow Q =	$\frac{V_g \cdot n \cdot \eta_v}{231}$ (US gal/min)
Torque	Input torque M=	$\frac{V_g \cdot \Delta p}{20 \cdot \pi \cdot \eta_m}$ (N•m)	Input torque M=	$\frac{V_g \cdot \Delta p}{2 \cdot \pi \cdot \eta_m}$ (lbf•in)
Power	Input power P =	$\frac{M \cdot n \cdot \pi}{30\,000} = \frac{Q \cdot \Delta p}{600 \cdot \eta_t}$ (kW)	Input power P =	$\frac{M \cdot n \cdot \pi}{198\,000} = \frac{Q \cdot \Delta p}{1714 \cdot \eta_t}$ (hp)

Variables

SI units [US units]

V_g = Displacement per revolution cm^3/rev [in^3/rev]

p_O = Outlet pressure bar [psi]

p_i = Inlet pressure bar [psi]

$\Delta p = p_O - p_i$ (system pressure) bar [psi]

n = Speed min^{-1} (rpm)

η_v = Volumetric efficiency

η_m = Mechanical efficiency

η_t = Overall efficiency ($\eta_v \cdot \eta_m$)

Filtration

Ensure fluid entering pump is free of contaminants to prevent damage (including premature wear) to the system. M46 pumps require system filtration capable of maintaining fluid cleanliness at ISO 4406-1999 class 22/18/13 or better.

Consider these factors when selecting a system filter:

- Cleanliness specifications
- Contaminant ingression rates
- Flow capacity
- Desired maintenance interval

Locate filter either on the inlet (suction filtration) or discharge (charge pressure filtration) side of the charge pump.

Filter efficiency can be measured with a Beta ratio[1] (βX). For simple suction-filtered closed circuit transmissions and open circuit transmissions with return line filtration, a filter with a β-ratio within the range of β35-45 = 75 (β10 ≥ 2) or better has been found to be satisfactory. Systems with multiple cylinders that are feed from a single reservoir require a more efficient filter. This also applies to systems with gears or clutches using a common reservoir.

For high volume systems, use a charge pressure or return filtration system with a filter β-ratio in the range of β15-20 = 75 (β10 ≥ 10) or better.

Because each system is unique, only a thorough testing and evaluation program can fully validate the filtration system. Please see *Design Guidelines for Hydraulic Fluid Cleanliness Technical Information* **520L0467** for more information.

System Design Parameters

Cleanliness level and β_x-ratio			
Filtration (recommended minimum)	Cleanliness per ISO 4406		22/18/13
	Efficiency (charge pressure filtration)	β-ratio	$\beta_{15-20} = 75$ ($\beta_{10} \geq 10$)
	Efficiency (suction and return line filtration)		$\beta_{35-45} = 75$ ($\beta_{10} \geq 2$)
	Recommended inlet screen mesh size	µm	100 – 125

[1] Filter βx-ratio is a measure of filter efficiency defined by ISO 4572. It is defined as the ratio of the number of particles greater than a given diameter ("x" in microns) upstream of the filter to the number of these particles downstream of the filter.

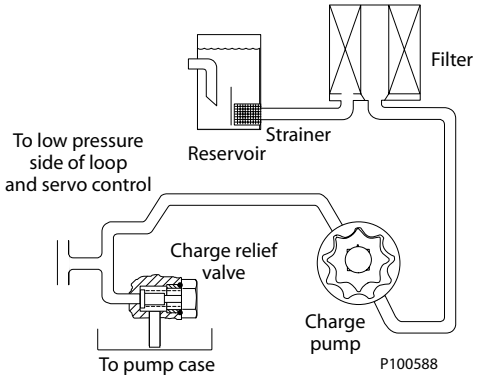
Suction Filtration

The filter is located between the reservoir and the charge pump inlet, as shown in the accompanying illustration.

Caution

Operating outside of charge and case pressure limits will damage the pump. To minimize this risk, use full size inlet and case drain plumbing, and limit line lengths.

Suction filtration



Charge Pressure Filtration

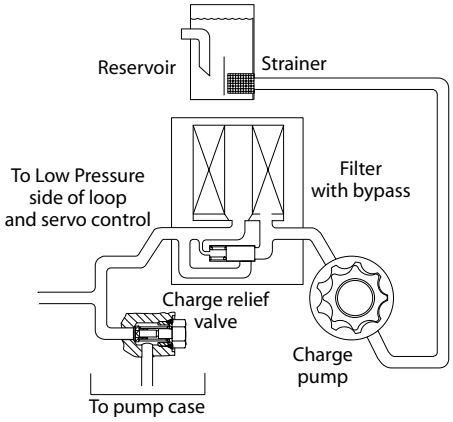
The filter is mounted remotely after the charge pump outlet, as shown in the accompanying illustration.

For charge pressure filtration, use a filter that is rated to at least 34.5 bar [500 psi] pressure. Use a 100 - 125 µm screen in the reservoir or charge inlet line.

A bypass valve is necessary to prevent filter damage and to avoid contaminants from being forced through the filter by high pressure. In the event of high pressure drop associated with a blocked filter or cold start-up conditions, fluid will bypass the filter. Avoid working with an open bypass for an extended period. We recommend a visual or electrical bypass indicator. Proper filter maintenance is mandatory.

System Design Parameters

Charge filtration



Redundant Braking System Requirement

Warning

Unintended vehicle or machine movement hazard

The loss of hydrostatic drive line power, in any mode of operation (forward, neutral, or reverse) may cause the system to lose hydrostatic braking capacity. You must provide a braking system, redundant to the hydrostatic transmission, sufficient to stop and hold the vehicle or machine in the event of hydrostatic drive power loss.

Loop Flushing

Closed circuit systems may require loop flushing to meet temperature and cleanliness requirements. A loop flushing valve removes hot fluid from the low pressure side of the system loop for additional cooling and filtering. Ensure the charge pump provides adequate flow for loop flushing and the loop flushing valve does not cause charge pressure to drop below recommended limits.

Reservoir

The reservoir provides clean fluid, dissipates heat, and removes entrained air from the hydraulic fluid. It allows for fluid volume changes associated with fluid expansion and cylinder differential volumes. Minimum reservoir capacity depends on the volume needed to perform these functions. Typically, a capacity of one half the charge pump flow (per minute) is satisfactory for a closed reservoir. Open circuit systems sharing a common reservoir require greater fluid capacity.

Locate the reservoir outlet (suction line) near the bottom, allowing clearance for settling foreign particles. Use a 100 - 125 µm screen covering the outlet port.

Place the reservoir inlet (return lines) below the lowest expected fluid level, as far away from the outlet as possible.

Use a baffle (or baffles) between the reservoir inlet and outlet ports to promote de-aeration and reduce fluid surging.

System Design Parameters

Case Drain Usage for Tandem Pumps

The tandem housings are connected through the center section via a drilled hole. The charge relief valve discharges oil into the front housing. In order to provide positive flow through both housings, use a case drain in the rear housing. The front housing case drain ports should only be used if the pump is used as a common drain manifold for the vehicle where external drain flow is brought into the rear housing and discharged out the front.

Allowable case pressure limits must be satisfied.

Bearing Life and External Shaft Loading

Bearing life is a function of speed, system pressure, charge pressure, and swashplate angle, plus any external side or thrust loads. Other life factors include oil type and viscosity. The influence of swashplate angle includes displacement as well as direction. External loads are found in applications where the pump is driven with side/thrust load (belt or gear) as well as in installations with misalignment and improper concentricity between the pump and drive coupling.

In vehicle propel drives with no external shaft loads and where the system pressure and swashplate angle are changing direction and magnitude regularly, the normal L20 bearing life (80% survival) will exceed the hydraulic load-life of the unit.

In non propel drives such as vibratory drives, conveyor drives, or fan drives, the operating speed and pressure are often nearly constant and the swashplate angle is predominantly at maximum. These drives have a distinctive duty cycle compared to a propulsion drive. In these types of applications a bearing life review is recommended.

M46 pumps are designed with bearings that can accept some external radial and thrust loads. When external loads are present, the allowable radial shaft loads are a function of the load position relative to the mounting flange, the load orientation relative to the internal loads, and the operating pressures of the hydraulic unit. In applications where external shaft loads can not be avoided, the impact on bearing life can be minimized by proper orientation of the load. Optimum pump orientation is a consideration of the net loading on the shaft from the external load, the pump rotating group, and the charge pump load. A high capacity (cylindrical roller) input shaft bearing is available for applications with high external shaft loads. Contact your Danfoss representative.

- In applications where the pump is operated such that nearly equal amounts of forward vs reverse swashplate operation is experienced; bearing life can be optimized by orientating the external side load to the 0 or 180 deg position (90 deg to rotating group load Fb). See drawing.
- In applications where the pump is operated such that the swashplate is predominantly (>75%) on one side of neutral (e.g. vibratory, conveyor, typical propel); bearing life can be optimized by orientating the external side load generally opposite of the internal rotating group load, Fb. The direction of the internal loading is a function of rotation and system port, which has flow out.
- Avoid axial thrust loads in either direction.

The **maximum allowable radial loads** (Re), based on the **maximum external moment** (Me) and the distance (L) from the mounting flange to the load, may be determined from the tables below and the cross section drawing.

The maximum allowable radial load is calculated as: $\mathbf{R_e = M_e / L}$

Contact your Danfoss representative for an evaluation of unit bearing life if continuously applied external radial loads are 25% or more of the maximum allowable, or if thrust loads are known to exist.

Shaft loading parameters

Re	Maximum external radial load
Me	Me Maximum external moment
L	Distance from mounting flange to point of load

System Design Parameters

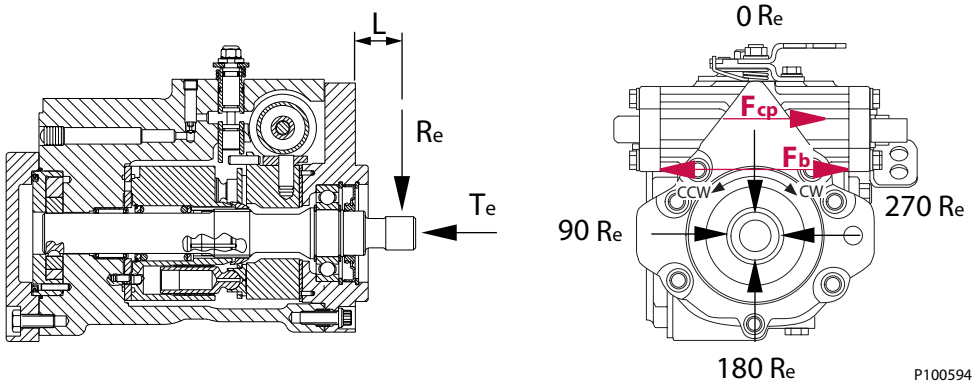
Shaft loading parameters (continued)

Fb	Force of cylinder block
Te	Thrust external load
Fcp	Force of charge pump

Maximum external shaft moments

Standard Bearing	
Me/N•m [in·lbf]	186 [1650]

External radial shaft load



Hydraulic Unit Life

Hydraulic unit life is defined as the fatigue life expectancy of the hydraulic components. It is a function of speed and system pressure; however, system pressure is the dominant variable. High pressure, which results from high load, reduces expected hydraulic unit life.

System component selection is based on determination of the application maximum loads and speeds. Testing is recommended to secure duty cycle data in which to predict hydraulic unit life. Contact your Danfoss representative for assistance in unit life determination. If duty cycle data is not available, normal input power and maximum pump displacement can be used to determine an application pressure in which to predict life.

M46 pumps will meet most application hydraulic unit life expectancies if applied within the parameters specified in this manual and chosen considering the guidelines within Danfoss publication *Selection of Driveline Components* **BLN-9885**. For more detailed information on hydraulic unit life, see Danfoss publication *Pressure and Speed Limits* **BLN-9884**.

Mounting Flange Loads

Shock load moment is the result of an instantaneous jolt to the system. **Continuous load moments** are generated by the typical vibratory movement of the application. Avoid excessive loading of the mounting flange such as adding tandem mounted auxiliary pumps and/or subjecting pumps to high shock loads. Design pump applications to stay within the allowable shock load moment and allowable continuous load moment.

Use the following formulas to estimate overhung load moment for multiple pump mountings:

System Design Parameters

$M_S = G_S (W_1L_1 + W_2L_2 + ... + W_nL_n)$

$M_C = G_C (W_1L_1 + W_2L_2 + ... + W_nL_n)$

Refer to the *Installation Drawings* section to find pump length (L). Refer to the table *Technical Specifications* in the *Specifications* section, to find pump weight (W). An exact measure of W will depend on the pump's features.

The tables below show allowable overhung load moment values. If system parameters exceed these values add additional pump support.

Estimated maximum and continuous acceleration factors for some typical Series 40 applications are shown. Applications which experience extreme resonant vibrations may require additional pump support. Typical continuous (vibratory) values can vary significantly due to changes in engine and pump configuration and mounting methods.

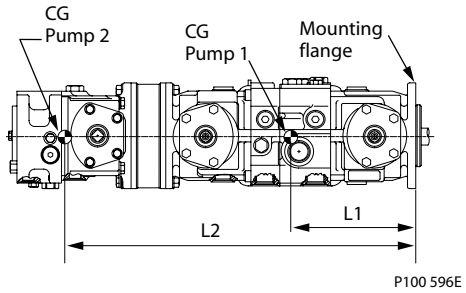
Overhung loading parameters

M_s	Shock load moment
M_c	Continuous load moment
G_s	Maximum shock acceleration (Gs)
G_c	Continuous (vibratory) acceleration (Gs)
W_n	Weight of nth pump
L_n	Distance from mounting flange to center of gravity of nth pump

Allowable overhung parameters

Frame size	**Continuous load moment (M_c) 10^7 cycles N•m [in•lbf]**		**Shock load moment (M_s) 10^3 cycles N•m [in•lbf]**	
M46 PV	517	[4600]	832	[7400]
M46 PT	517	[4600]	754	[6700]

Shaft loading parameters



The illustration shows a tandem plus a single pump.

G-factors for sample applications

Application	**Continuous (vibratory) acceleration (G_c)**	**Maximum (shock) acceleration (G_s)**
Skid steer loader	4	10
Trencher (rubber tires)	3	8
Asphalt paver	2	6
Windrower	2	5
Aerial lift	1.5	4

System Design Parameters

G-factors for sample applications (continued)

Application	Continuous (vibratory) acceleration (G_c)	Maximum (shock) acceleration (G_s)
Turf care vehicle	1.5	4
Vibratory roller	6	10
* Applications which experience extreme resonant vibrations require addition pump support.		

Shaft Torques

Shaft selection

Base shaft selection on a review of the maximum torque required by the application and the maximum torque available from the prime mover. Application duty cycle and continuous torque rating of the prime mover are the main variable to consider when selecting a shaft.

Shaft torque and spline lubrication

The **rated torque** is a measure of tooth wear and is the torque level at which a normal spline life of 1 x 10^7 shaft revolutions can be expected. The rated torque presumes a regularly maintained minimum level of lubrication via a moly-disulfide grease in order to reduce the coefficient of friction and to restrict the presence of oxygen at the spline interface. It is also assumed that the mating spline has a minimum hardness of R_c 55 and full spline depth. The rated torque is proportional to the minimum active spline length.

However, a spline running in oil-flooded environment provides superior oxygen restriction in addition to contaminant flushing. The rated torque of a flooded spline can increase to that of the maximum published rating. A flooded spline would be indicative of a pump driven by a pump drive or plugged into an auxiliary pad of a pump.

Maximum torque ratings are based on torsional fatigue strength considering 1 x 10^5 full load reversing cycles.

Maintaining a spline engagement at least equal to the pitch diameter will also maximize spline life. Spline engagements of less than ¾ pitch diameter are subject to high contact stress and spline fretting.

Shaft torque for tapered shafts

The **rated torque** is based on the contact pressure between the shaft and hub surfaces with poor contact areas. With increased quality of the contact areas, the contact pressure between shaft and hub is increased, allowing higher torque to be transmitted.

A key is intended as an installation aid only. Any torque carried by the key as a result of poor contact area or mis-alignment will limit the torque carrying capability of the shaft significantly.

Maximum torque rating is based on an ideal contact area of 100% and the retaining nut properly torqued. This allows for the highest contact pressure between the shaft and the mating hub.

Model Code - Single Pumps

Single Pumps

Product			Frame	Type	C	D	E			F	G	H	J		K	L	M			N		P	R		S	T			Z		
M	P	V	046	C																											

C Swashplate

Description	Code	Remarks
Standard	B	

D - Seal Group

Description	Code	Remarks
Seal group for MDC	A	Must select an MDC control
Seal group for EDC/HDC/FNR	B	Must select an EDC/HDC/FNR control

E - Input Shaft/Auxiliary Spline

Description	Code	Remarks
13T 16/32 Spline / None	A	Requires S: None aux.. pad
13T 16/32 Spline / 9T 16/32 SplineR	B	Requires S: SAE-A aux.. pad
13T 16/32 Spline / 11T 16/32 Spline	L	Requires S: SAE-A aux.. pad
13T 16/32 Spline / 13T 16/32 Spline	D	Requires S: SAE-B aux.. pad
15T 16/32 Spline / None	G	Requires S: None aux.. pad
15T 16/32 Spline / 9T 16/32 Spline	H	Requires S: SAE-A aux.. pad
15T 16/32 Spline / 11T 16/32 Spline	J	Requires S: SAE-A aux.. pad
15T 16/32 Spline / 13T 16/32 Spline	K	Requires S: SAE-B aux.. pad
Tapered, 1 inch dia., 1.5 in/foot, square key/9T 16/32 Spline	P	Requires S: SAE-A aux.. pad. Includes key and nut
Tapered, 1 inch dia., 1.5 in/foot, square key/ 13T 16/32 Spline	S	Requires S: SAE-B aux.. pad. Includes key. Nut is customer supplied
Straight key, 1 inch diamater / None	V	Requires S: None aux.. pad. Includes key.
Straight key, 1 inch diameter / 9T 16/32 Spline	W	Requires S: SAE-A aux.. pad, includes key.

F - Rotation and valve plate

Description	Code	Remarks
CW, Quiet (Standard)	S	CP15; 3 deg. index. Requires charge pressure > 19.5 bar.
CCW, Quiet (Standard)	T	CP15; 3 deg. index. Requires charge pressure > 19.5 bar.

G - Charge pump

Description	Code	Remarks
None	A	Charge relief set at 19 l/min, external supply
13.9 cc [0.85 in./cu]	B	Charge relief set at 1800 rpm

Model Code - Single Pumps

H - Charge pressure

Description	Code	Remarks
19.5 bar	B	
21.5 bar	J	
25.0 bar	S	EDC/HDC controls calibrated at 20.7 bar charge

J - Filtration

Description	Code	Remarks
Suction, with charge pump	AA	Requires G: with charge pump
Remote pressure, with charge pump	BA	Requires G: with charge pump
Remote (external) pressure , without charge pump	BC	Requires G: no charge pump
Suction, with charge pump (HC EDC housing)	HA	requires G: with charge pump, N: with HC EDC
Remote pressure with charge pump(HC EDC housing)	HB	requires G: with charge pump, N: with HC EDC
Remote (external) pressure, without charge pump (HC EDC housing)	HC	requires G: no charge pump, N: with HC EDC

K - Displacement limiters

Description	Code	Remarks
Full displacement, 46 cc/rev [2.8 cu. in./rev]	A	
46 cc/rev [2.8 cu. in./rev] with adj. limiter, side #2 only, centered side #2	V	

L - Bypass valve

Description	Code
Bypass valve	A

M - System pressure protection, A and B ports

		Port protection	
Plug type	Letter	Port A	Port B
Standard	B	Relief/Check	Relief/Check

Second and Third Letter	
M	140 bar
B	175 bar
C	100 bar
D	210 bar
E	230 bar
F	250 bar
G	280 bar
H	300 bar
R	325 bar
J	345 bar

Contact your Danfoss representative for configurations or pressures not shown.

Model Code - Single Pumps

N - Control type

Description	Code	Remarks
MDC handle with (2) 10 mm diameter holes, standard spring	AB	Recommend AW with metered spool
MDC with (3) 10 mm diameter holes, standard spring	AC	Recommend AK with metered spool
MDC with (3) 10 mm diameter holes, U shaped, standard spring, metered spool	AK	
MDC handle with (2) 10 mm diameter holes, standard spring, metered spool	AW	
MDC heavy duty handle with (4) 10 mm diameter holes, heavy spring, metered spool	GB	P; handle position to be B
HDC 1.3-11.7 bar	BA	19-170 psi
HDC 3.0-13.8 bar	BB	44-200 psi
HDC 4.8-15.2 bar	BC	70-220 psi
EDC dual coil, oil filled, Packard connector, 4-pin, 23-132 mA	CE	
EDC dual coil, oil filled, MS connector, 4-pin, 23-132 mA	CG	
EDC dual coil, oil filled, Deutsch connector, 4-pin, 23-132 mA	CN	
FNR 12 volt, DIN 43650 connector	DA	
FNR 24 volt, DIN 43650 connector	DB	
EDC, high current, 12 volt, Deutsch connector, 2-pin	HA	
EDC, high current, 24 volt, Deutsch connector, 2-pin	HB	

P - Handle position

Description	Code	Remarks
Not applicable (EDC, HDC, FNR)	A	
Both, up and down	B	N: MDC to include heavy duty 4-hole handle. Handle is symmetric over spool
Down (MDC)	D	2, or 3 hole handles only. Handle oriented away from suction port.
Up (MDC)	U	2, or 3 hole handles only. Handle oriented towards from suction port.

R - Control orifice (contact factory for orifice options not shown)

MDC							
		Supply				Drain	(Supply and drain orifice chosen independently)
F	-	None		F	-	None	
A	-	0.031 inch		A	-	0.031 inch	
B	-	0.036 inch		B	-	0.036 inch	
C	-	0.041 inch		D	-	0.041 inch	
D	-	0.046 inch					

EDC/HDC/FNR - Servo A and B							
		Servo A&B					
GG	-	0.055 inch					
HH		0.037 inch					
JJ		None					

Model Code - Single Pumps

HC EDC - Servo A and B							
		Servo A&B					
HA	-	0.046 inch					
HB		0.055 inch					
HC		0.037 inch					
HD		0.024 inch					
HE		None					

S - Auxiliary mounting flange

Description	Code	Remarks
SAE A, side #2 lift bracket location	A	E: Shaft to include 9T or 11T aux.. spline
SAE B, side #2 lift bracket location	B	E: Shaft to include 13T aux.. spline
None, side #2 lift bracket location	C	E: Shaft to include no aux.. pad

T - Special hardrare

Description	Code	Remarks
Black paint, Danfoss tag, Layout A	NNN	
High capacity shaft bearing, black paint, Danfoss tag, Layout A	NNR	

Z - Special features, Non hardware

Description	Code	Remarks
None	***	

Model Code - Tandem Pumps

Tandem Pumps

Product			Frame	Type	E	F	G	H	J	
M	P	T	046	C						

	C	D	K	L	M			N		P	R		
Front Section													

	Q	D	U	X	V			Y	Z	W		S	T			Z		
Rear Section																		

E - Input Shaft

Description	Code	Remarks
15T 16/32 Spline	A	Requires S: None aux.. pad
19T 16/32 Spline	B	Requires S: SAE-B aux.. pad
Tapered, 1 inch dia., 1.5 in/foot, square key without thru hole	H	Includes key and nut.
Straight key, 1 inch diamater	D	Includes key.

F - Rotation and valve plate

Description	Code	Remarks
CW, without charge pump. Quiet (Standard)	S	CP15; 3 deg. index. Requires charge pressure > 19.5 bar.
CCW, without charge pump. Quiet (Standard)	T	CP15; 3 deg. index. Requires charge pressure > 19.5 bar.
CW, with 22.9 cc charge pump. Quiet (Standard)	V	CP15; 3 deg. index. Requires charge pressure > 19.5 bar.
CCW, with 22.9 cc charge pump. Quiet (Standard)	Z	CP15; 3 deg. index. Requires charge pressure > 19.5 bar.

G - Charge pump

Description	Code	Remarks
None	A	Charge relief set at 38 l/min, external supply
22.9 cc [1.4 in./cu]	C	Charge relief set at 1800 rpm. Filtration and rotation must include charge pump

H - Charge pressure

Description	Code	Remarks
19.5 bar	B	
21.5 bar	J	
25.0 bar	S	EDC/HDC controls calibrated at 20.7 bar charge

J - Filtration

Description	Code	Remarks
Suction, with charge pump	AA	Requires a charge pump
Remote pressure, with charge pump	BA	Requires a charge pump
Remote (external) pressure, without charge pump	BC	Requires no charge pump

Model Code - Tandem Pumps

C - Swashplate group, front pump/Q - Swashplate group, rear pump

Description	Code	Remarks
Balanced	B	

D - Seal Group

Description	Code	Remarks
Seal group for MDC - Front pump	A	Must select an MDC control
Seal group for EDC/HDC/FNR - Front pump	B	Must select an EDC/HDC/FNR control
Seal group for MDC - Rear pump	C	Must select an MDC control
Seal group for EDC/HDC/FNR - Rear pump	D	Must select an EDC/HDC/FNR control

K - Displacement limiters, front pump, U- Displacement limiters, rear pump

Description	Code	Remarks
Full displacement, 46 cc/rev [2.8 cu. in./rev]	A	
46 cc/rev [2.8 cu. in./rev] with adj. limiter, side #2 only, centered side #2	V	

L/X - Bypass valve

Description	Code
Bypass valve	A

***M** - System pressure protection, A and B ports **V** - System pressure protection, rear pump, A and B ports*

		Port protection	
Plug type	First Letter	Port A	Port B
Standard	B	Relief/Check	Relief/Check

Second and Third Letter	
M	140 bar
B	175 bar
C	100 bar
D	210 bar
E	230 bar
F	250 bar
G	280 bar
H	300 bar
R	325 bar
J	345 bar

Contact your Danfoss representative for configurations or pressures not shown.

***N** - Control type, front pump /**Y** - Control type, rear pump*

Description	Code	Remarks
MDC handle with (2) 10 mm diameter holes, standard spring	AB	Recommend AW with metered spool
MDC with (3) 10 mm diameter holes, standard spring	AC	Recommend AK with metered spool
MDC with (3) 10 mm diameter holes, U shaped, standard spring, metered spool	AK	

Model Code - Tandem Pumps

N - Control type, front pump /Y - Control type, rear pump (continued)

Description	Code	Remarks
MDC handle with (2) 10 mm diameter holes, standard spring, metered spool	AW	
MDC heavy duty handle with (4) 10 mm diameter holes, heavy spring, metered spool	GB	P; handle position to be B
HDC 1.3-11.7 bar	BA	19-170 psi
HDC 3.0-13.8 bar	BB	44-200 psi
HDC 4.8-15.2 bar	BC	70-220 psi
EDC dual coil, oil filled, Packard connector, 4-pin, 23-132 mA	CE	
EDC dual coil, oil filled, MS connector, 4-pin, 23-132 mA	CG	
EDC dual coil, oil filled, Deutsch connector, 4-pin, 23-132 mA	CN	
FNR 12 volt, DIN 43650 connector	DA	
FNR 24 volt, DIN 43650 connector	DB	

P/Z - Handle position

Description	Code	Remarks
Not applicable (EDC, HDC, FNR)	A	EDC, HDC, FNR only
Both, up and down	B	N: MDC to include heavy duty 4-hole handle. Handle is symmetric over spool
Down (MDC)	D	2, or 3 hole handles only. Handle oriented away from suction port.
Up (MDC)	U	2, or 3 hole handles only. Handle oriented towards from suction port.

R - Control orifice, front pump, W- Control orifice, rear pump

MDC							
		Supply				Drain	(Supply and drain orifice chosen independently)
F	-	None		F	-	None	
A	-	0.031 inch		A	-	0.031 inch	
B	-	0.036 inch		B	-	0.036 inch	
C	-	0.041 inch		D	-	0.041 inch	
D	-	0.046 inch					

EDC/HDC/FNR - Servo A and B							
		Servo A&B					
GG	-	0.055 inch					
HH		0.037 inch					
JJ		None					

S - Auxiliary mounting flange and coupling

Description	Code	Remarks
None	C	
SAE A, 9 tooth 16/32 spline	A	

Model Code - Tandem Pumps

S - Auxiliary mounting flange and coupling (continued)

Description	Code	Remarks
SAE A, 11 tooth 16/32 spline	D	
SAE B, 11 tooth 16/32 spline	B	

T - Special hardrare

Description	Code	Remarks
Black paint, Danfoss tag, Layout A	NNN	
High capacity shaft bearing, black paint, Danfoss tag, Layout A	NNR	

Z - Special features, Non hardware

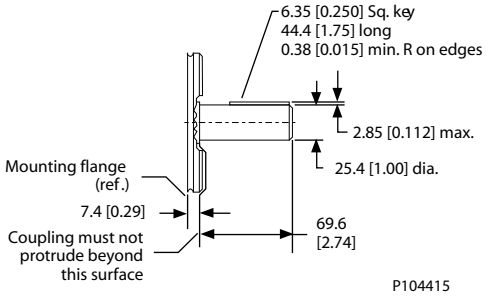
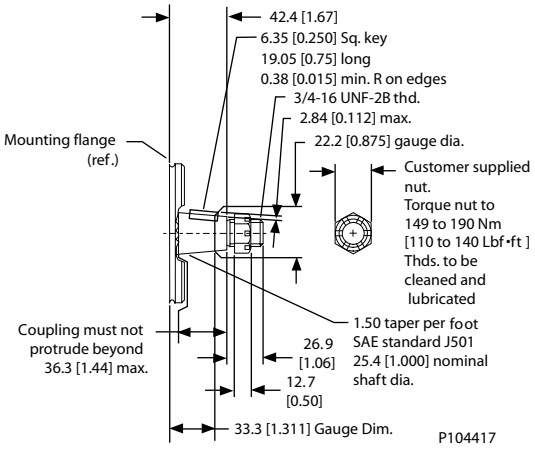
Description	Code	Remarks
None	***	

Options

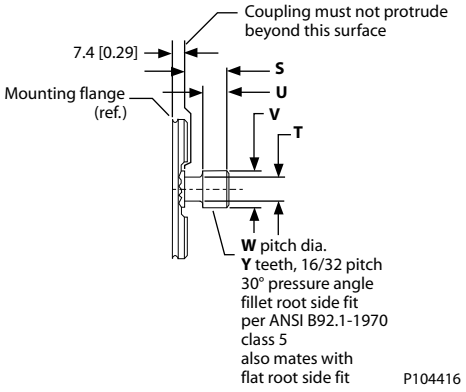
Shaft options

Recommended mating splines for Series 40 splined output shafts should be in accordance with ANSIB 92.1 Class 5. Danfoss external splines are modified Class 5 Fillet Root Side Fit. The external splined Major Diameter and Circular Tooth Thickness dimensions are reduced in order to assure a clearance fit with the mating spline. Other shaft options may exist. Contact your Danfoss representative for availability.

Single pumps

Code	Description	Maximum torque rating Nm [lbf in]	Drawing
V, W	Ø 25.4 mm [1.000 in] Straight keyed - Shipped with key	362 [3200]	
P, S	Ø 25.4 mm [1.000 in] 1:8 taper (SAE J501) - No thru hole - Shipped with key only	497 [4400]	

Options

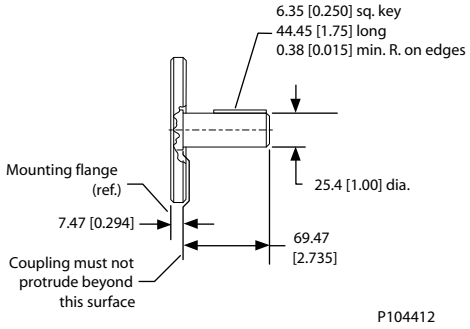
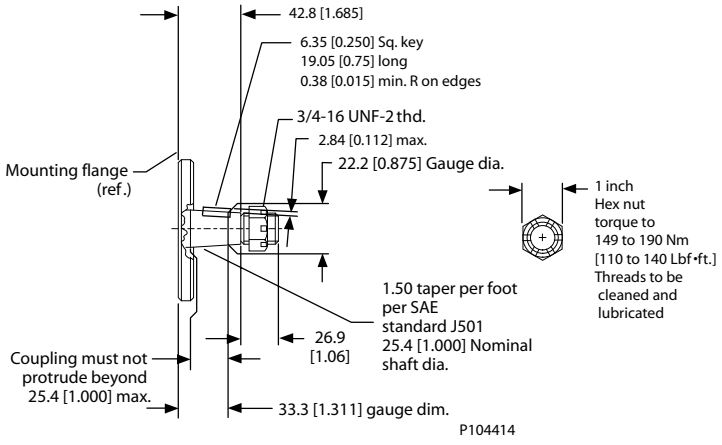
Code	Description	Maximum torque rating Nm [lbf in]	Rated torque Nm [lbf in	Drawing
A, B, L, D	13-tooth 16/32 pitch (ANSI B92.1 1970 - Class 5)	226 [2000]	124 [1100]	
G, H, J, K	15-tooth 16/32 pitch (ANSI B92.1 1970 - Class 5)	362 [3200]	153 [1350]	

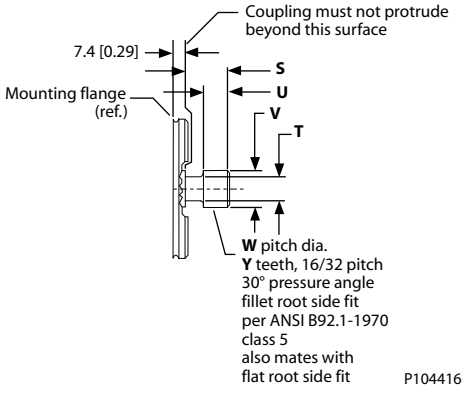
Shaft options	Length	Shaft diameter	Full spline	Major diameter	Pitch diameter	No. teeth
	S	T	U	V	W	Y
A, B, D, L	37.7 [1.485]	22.3 [0.88]	23.4 [0.92]	24.89 [0.9800]	23.81 [0.9375]	13
G, H, J, K	32.9 [1.297]	20.3 [0.80]	16.26 [0.64]	21.72 [0.8550]	20.64 [0.8125]	15

Other shaft options may exist. Contact your Danfoss representative for availability and for specific installation drawings.

Options

Tandem pumps

Code	Description	Maximum torque rating Nm [lbf in]	Drawing
D	Ø 25.4 mm [1.000 in] Straight keyed - Shipped with key	362 [3200]	
H	Ø 25.4 mm [1.000 in] 1:8 taper (SAE J501) - No thru hole - Shipped with key only	497 [4400]	

Code	Description	Maximum torque rating Nm [lbf in]	Rated torque Nm [lbf in	Drawing
A	15-tooth 16/32 pitch (ANSI B92.1 1970 - Class 5)	362 [3200]	153 [1350]	
B	19-tooth 16/32 pitch (ANSI B92.1 1970 - Class 5)	734 [6500]	305 [2700]	

Options

Shaft options	Length	Shaft diameter	Full spline	Major diameter	Pitch diameter	No. teeth
	S	T	U	V	W	Y
A	37.7 [1.485]	22.3 [0.88]	23.4 [0.92]	24.89 [0.9800]	20.638 [0.9375]	15
B	37.7 [1.497]	28.7 [1.13]	24.1 [0.95]	31.24 [1.230]	30.163 [1.1875]	19

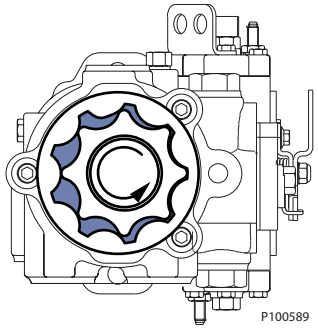
Other shaft options may exist. Contact your Danfoss representative for availability and for specific installation drawings.

Charge Pump

Charge flow is required on all M46 units to make up for internal leakage, maintain positive pressure in the main circuit, provide flow for cooling, replace any leakage losses from external valving or auxiliary systems, and to provide flow and pressure for the control system.

Maintain minimum charge pressure under all conditions of operation to prevent damage to the transmission.

Charge pump



Many factors influence the charge flow requirements and the resulting charge pump size selection. These factors include system pressure, pump speed, pump swashplate angle, type of fluid, temperature, size of heat exchanger, length and size of hydraulic lines, control response characteristics, auxiliary flow requirements, hydraulic motor type, etc. Charge pump displacement should be equal to or greater than 10% of the total displacement of all units in the system.

The total charge flow requirement is the sum of the charge flow requirements of each of the components in the system. Use the information provided on the following pages to make a charge pump selection for a given application.

System features and conditions that may invalidate the 10% of displacement rule include (but are not limited to):

- Operation at low input speeds (below 1500 RPM)
- Shock loading
- Excessively long system lines
- Auxiliary flow requirements
- Use of low speed high torque motors

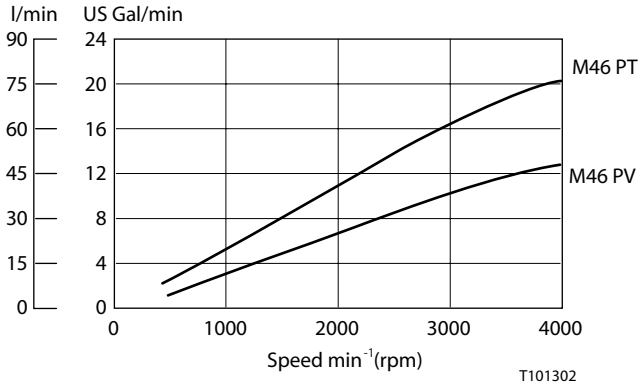
If a charge pump of sufficient displacement to meet the 10% of displacement rule is not available or if any of the above conditions exist which could invalidate the 10% rule, contact your Danfoss representative. A charge pump sizing worksheet is available in *Selection of Driveline Components* **BLN-9885**.

When an integral charge pump is not used, an external charge supply is required to ensure adequate charge pressure and cooling.

Options

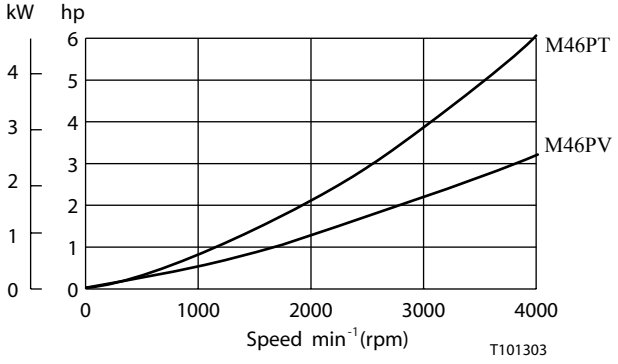
Charge Pump Output Flow

Flow at 19.5 bar charge relief setting, 70°C [160°F] inlet



Charge Pump Power Requirements

Power at 19.5 bar charge relief setting, 70°C [160°F] inlet



Higher charge pressure will influence charge flow and power.

Charge Relief Valve

An integral charge pressure relief valve provides a relief outlet for charge flow. This valve, in effect, sets charge pressure. Flow through the valve is ported to case.

The M46 PV/PT uses a cone-style poppet valve which dumps hydraulic fluid to the front pump.

The nominal charge relief setting is referenced to case pressure. It is factory set at 1800 min-1 (rpm) with the pump in neutral position. A proper charge relief setting takes into account input speeds and control requirements.

The charge pressure setting for pumps without an internal charge pump is set with an externally supplied charge flow of 19 l/min [5 US gal/min] on pumps and 38 l/min [10 US gal/min] on tandem pumps. These units must have adequate charge flow supplied to the charge inlet in order to maintain charge pressure at all times.

Incorrect charge pressure settings may result in the inability to build required system pressure and/or inadequate loop flushing flows. Ensure correct charge pressure under all conditions.

Options

The charge relief valve is factory set. If necessary, it can be field adjusted with shims.

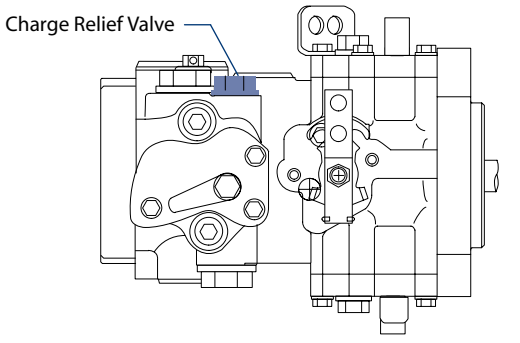
Charge Relief Valve Specs

M46		
Type	Cone poppet valve	
Available Setting	19.5-26.2 bar [285-380 psi]	
Adjustment	Via shims inside of valve cartridge*	
Rise Rate	Adjustment	2.3 bar [33 psi]/mm
	Performance	1.8 bar [26 psi]/10 lpm (Approx.)

*Shimming offers adjustment over a limited range. A spring change may be required to reach a higher setting.

Contact your Danfoss representative for further information regarding charge pressure relief valve options.

Charge relief valve location



M46 PV P100591

High Pressure Relief Valve (HPRV) and Charge Check

All M46 pumps are equipped with a combination high pressure relief and charge check valve. The high-pressure relief function is a dissipative (with heat generation) pressure control valve for the purpose of limiting excessive system pressures. The charge check function acts to replenish the low-pressure side of the working loop with charge oil. Each side of the transmission loop has a dedicated HPRV valve that is non-adjustable with a factory set pressure. When system pressure exceeds the factory setting of the valve, oil is passed from the high pressure loop, into the charge gallery, and into the low pressure loop via the charge check.

High pressure relief valves are a differential pressure valve referencing high system to charge (low system). The numeric model code represents the differential pressure setting, in bar. The model code allows for different pressure settings to be specified at each system port.

HPRV´s are factory set at a low flow condition. Any application or operating condition which leads to elevated HPRV flow will cause a pressure rise with flow above a valve setting. Consult factory for application review. Excessive operation of the HPRV will generate heat in the closed loop and may cause damage to the internal components of the pump.

Caution

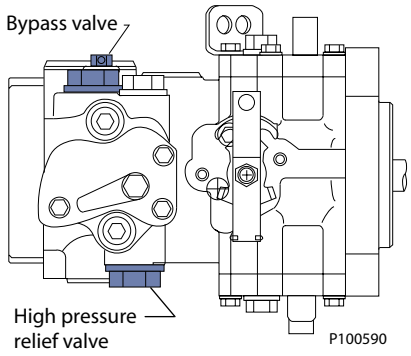
High pressure relief valves are intended for transient overpressure protection and are not intended for continuous pressure control. Flow over relief valves for extended periods of time may result in severe heat build up. High flows over relief valves may result in pressure levels exceeding the nominal valve setting and potential damage to system components.

Options

Check/high pressure relief valve specs

Type	Cartridge-style poppet valve
Setting	140-345 bar (2030-5000 psi)
Option	Check only - no relief valve

High pressure relief valve locations



Bypass Function

All M46 pumps are equipped with a loop bypass valve that connects the A and B sides of the working loop. The bypass function allows a machine to be moved without rotating the pump shaft or prime mover. To open the bypass valve turn it counterclockwise 2 full turns. Do not open past 2 full turns. Use a 5/8 inch hex wrench to open the valve. To return to normal operation, close the valve and torque to 20 Nm [15 ft•lbs]. Do not over torque the valve.

Caution

Do not move the machine faster than 20% of maximum speed or for more than 3 minutes. Towing faster or longer than described may result in damage to the drive motor(s). To return to normal operation, carefully close and torque the bypass valve.

Displacement Limiters

M46 single or tandem units are designed with optional non-adjustable mechanical displacement (stroke) limiters located in the servo piston. You can limit maximum displacement of the pump to a certain percent of its maximum displacement. These displacement limiters are fixed physical stops inside the pump, are not externally adjustable, and limit the pump symmetrically across both sides. Contact your Danfoss representative for a list of available settings.

It is also possible to configure an M46 pump with an externally adjustable displacement limiter screw on side #2 only. The screw is located on the side of the servo piston opposite the neutral adjustment screw.

Warning

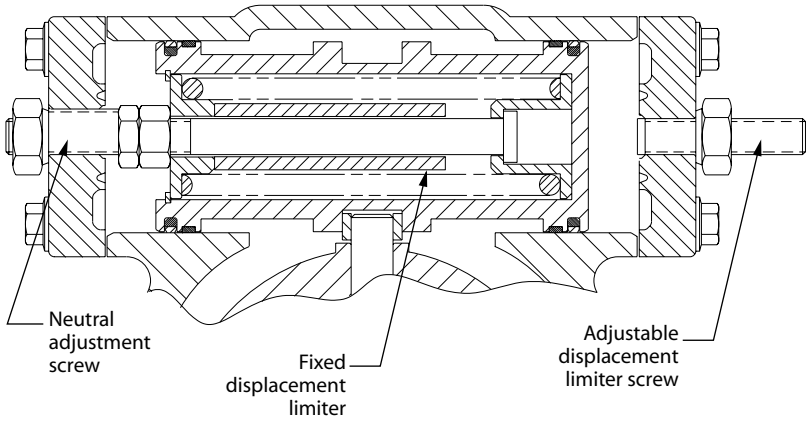
Unintended vehicle or machine movement hazard

Take care in adjusting displacement limiters to avoid an undesirable condition of output flow or speed. Re-torque the sealing lock nut after every adjustment to prevent an unexpected change in output conditions and to prevent external leakage during pump operation.

One full revolution of the adjustment screw produces a change in displacement of approximately 4.4 cm3/rev [0.27 in3/rev]. Full unit displacement is attained with the adjustment screw at its maximum extension from servo cover. All pumps are shipped with the limiter set for maximum pump displacement.

Options

M46 Displacement limiter (side #2)



Auxiliary Mounting Pads and Auxiliary Pumps

Auxiliary mounting pads are available on all pumps. A sealed shipping cover is included as standard equipment on all mounting pads.

An O-ring seals the auxiliary pump mounting flange to the pad. The drive spline is lubricated (flooded) with oil from the main pump case.

Spline specifications and torque ratings are shown in the accompanying table.

- All auxiliary mounting pads meet SAE J744 specifications
- Do not exceed the maximum pump input shaft rating shown in the Shaft availability and torque ratings table in the Shaft Options section
- Applications subject to severe vibratory or high G loading require an additional structural support. This is necessary to prevent leaks and possible mounting flange damage. Refer to Mounting flange loads in the System Design Parameters section, for additional information

Auxiliary mounting pad specs

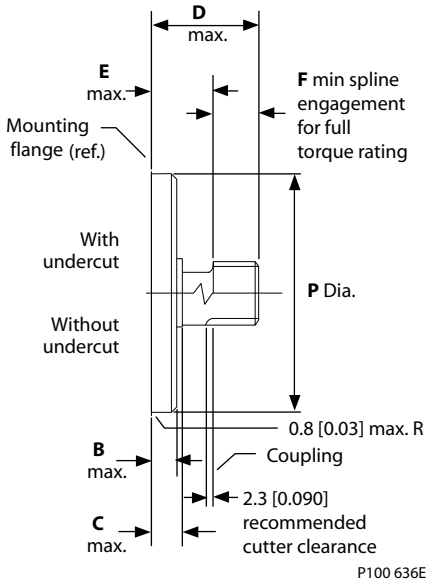
Internal spline size	Pad size	Maximum Torque Rating	
		Nm	[in lbf]
9T 16/32P	SAE A	107	[950]
11T 16/32P	SAE A	147	[1300]
13T 16/32P	SAE B	248	[2200]

The drawing and table below show the dimensions of the auxiliary pump mounting flanges and shafts. Auxiliary pump mounting flanges and shafts with the dimensions noted are compatible with the auxiliary mounting pads on the Series 40 pumps.

Auxiliary pump mating dimensions mm [in.]

Pad size	P	B	C	D	E	F
SAE A	82.55 [32.50]	6.35 [0.250]	12.70 [0.500]	58.2 [2.29]	15.0 [0.59]	13.5 [0.53]
SAE B	101.60 [4.000]	9.65 [0.380]	15.2 [0.60]	53.1 [2.09]	17.5 [0.69]	14.2 [0.56]

Options



Manual Displacement Control (MDC) - Options AB, AC, AK, AW, and GB

The Manual Displacement Control (MDC) converts a mechanical input signal to a hydraulic signal with a spring centered 4-way servo valve, and ports hydraulic pressure to either side of a double acting servo piston. The MDC provides output flow to the servo piston in proportion to the angular position of the control handle. The servo piston tilts the cradle swashplate, thus varying the pump's displacement from full displacement in one direction to full displacement in the opposite direction.

Due to normal operating force changes, the swashplate tends to drift from the position preset by the machine operator. Drift, sensed by the feedback linkage system connecting the swashplate to the control valve, activates the valve and supplies pressure to the servo piston, maintaining the swashplate in its preset position.

A metered control porting spool is available that provides improved controllability. The metered spool has machined notches that feather the porting of oil into and out-of the double acting servo piston when very small changes in control input are commanded. Nevertheless, the metered spool remains a high response control when normal input changes open the porting to a full open position, porting maximum flow to the servo cylinder. In neutral, these notches allow a small amount of pressure into both ends of the servo, elevating the neutral servo pressure slightly above case. This servo piston preloading improves the swashplate control coming out of neutral.

For a list of available control options, refer to the Model Code section.

Features:

- The MDC is a high gain control: with only a small movement of the control handle (input signal) the control valve moves to a full open position porting maximum flow to the servo cylinder. This is a high response control system with low input forces.
- Mechanical feedback senses swashplate reactions to load.
- Precision parts provide repeatable, accurate displacement settings with a given input signal.
- The servo piston is coupled to a spring centering mechanism.

Benefits:

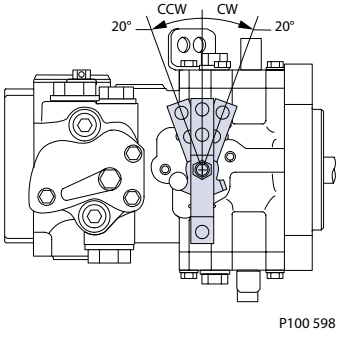
Options

- Simple-low cost design.
- Pump output is maintained regardless of load.
- Pump will return to neutral after prime mover shuts down.
- Pump returns to neutral if external control linkage becomes disconnected from the control handle or if there is a loss of charge pressure.

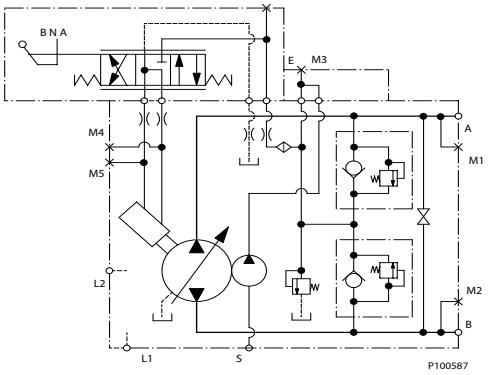
Control Handles and Springs

The standard MDC encompasses a three hole control handle with a standard return spring. This control is available with metered (standard) or non-metered porting spool. Optional two hole or four hole (heavy duty) control handles are available. The two hole handle is available with metered or non-metered spool and only available with a standard return spring. The four hole heavy duty handle is only available with metered spool and heavy return spring.

Three hole handle shown (in up position)



MDC Hydraulic schematic



Pump flow direction with MDC control

		Pump flow direction with MDC control			
		CW		CCW	
Single or Front Tandem	Handle Rotation	CW	CCW	CW	CCW
	Port A Flow	Out	In	In	Out
	Port B Flow	In	Out	Out	In
Rear Tandem	Handle Rotation	CW	CCW	CW	CCW
	Port C Flow	In	Out	Out	In
	Port D Flow	Out	In	In	Out
High Servo Gauge Port		M4	M5	M4	M5
Refer to pump installation drawing for port locations.					

All M46 pumps have a 40 mesh [0.4 mm (0.015 inch)] servicable screen located in the control supply port.

Response Time

The time required for the pump output flow to change from neutral to full flow (acceleration) or full flow to neutral (deceleration) is a function of the size of the supply orifice in the control inlet passage and the size of the drain orifice in the control sleeve.

A range of orifice sizes is available to assist in matching the rate of swashplate response to the acceleration and deceleration requirements of the application. The table at right shows some sample response times under certain conditions. (These figures assume 1775 min-1 (rpm), 140 bar [2000 psi] system pressure, and 20 bar [290 psi] charge pressure.) Vehicle testing is required to determine the proper orifice sizes for the desired response.

Options

MDC Response time

Orifice diameter* mm [in]		Average response time [seconds]	
Supply	Drain	Acceleration	Deceleration
0.9 [0.036]	0.8 [0.031]	2.5	1.9
0.9 [0.036]	1.2 [0.046]	2.0	1.4
1.4 [0.054]	1.2 [0.046]	1.2	0.9
None	None	0.5	0.4
*Contact Danfoss for special orifice combinations.			

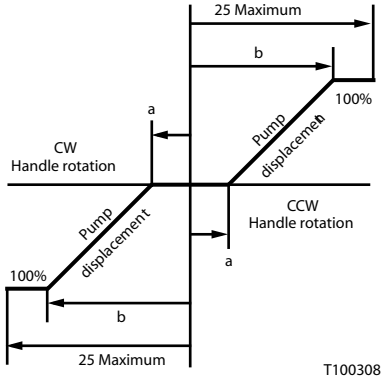
External control handle torque requirements

	Standard spring	Heavy duty spring
Rotation of handle to reach full displacement	20 degrees	20 degrees
Maximum handle rotation	25 degrees	25 degrees
Neutral deadband	± 1.5 degrees	± 0.8 degrees
Torque needed to begin handle rotation (1 degree)	1.2 Nm [11 in•lbf]	2.5 Nm [22 in•lbf]
Torque required to reach full stroke (20 degrees)	1.7 N•m [15 in•lbf]	3.4 N•m [30 in•lbf]
Maximum allowable handle torque	17 N•m [150 in•lbf]	17 N•m [150 in•lbf]

Handle direction

The MDC handle can be configured in either the up or down or both (symmetric) positions. The up position is shown on the previous page. The down position is oriented 180° of the up position.

Pump displacement vs control lever rotation



MDC signal required for swashplate position

	Swashplate position (refer to above chart)	
Handle configuration	Swashplate movement begins (point A) degrees	Full displacement reached (point B) degrees
Metered	0.8°	20°
Non-metered	1.5°	20°

Options

Hydraulic Displacement - Options BA, BB and BC

The Hydraulic Displacement Control (HDC) is a two stage design which uses a hydraulic input signal to operate a spring centered 4-way servo valve, which ports hydraulic pressure to either side of a double acting servo piston. The servo piston tilts the cradle swashplate, thus varying the pump's displacement from full displacement in one direction to full displacement in the opposite direction.

The HDC provides output flow in proportion to a hydraulic command signal. This allows for remote control of the machine with a hydraulic pressure source rather than with mechanical linkage. With no command signal, the control returns to neutral position. The HDC is only available with a non-metered spool.

For a list of available control options, refer to the Model Code section.

Features:

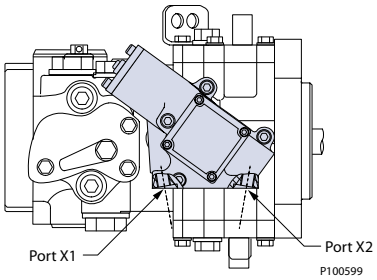
- The hydraulic displacement control is a high gain control: with only a small change in the input signal pressure level, the servo valve moves to a full open position, porting maximum flow to the servo cylinder.
- Internal mechanical stops on the servo valve allow rapid changes in input signal pressure without damaging the control mechanism.
- Precision parts provide repeatable, accurate displacement settings with a given input signal.
- Both ends of the double-acting servo piston are drained to case when input signal pressure is not present. The servo piston is coupled to a spring centering mechanism.

Benefits:

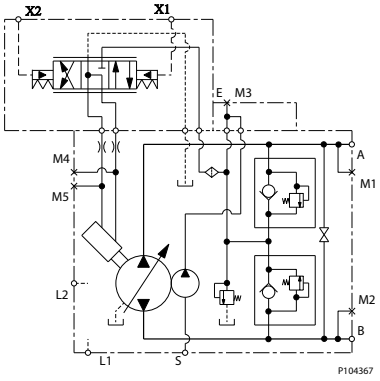
- Simple-low cost design.
- Pump will return to neutral after prime mover shuts down.
- Pump will return to neutral if external hydraulic input signal fails or if there is a loss of charge pressure.

All M46 pumps have a 40 mesh [0.4 mm (0.015 inch)] servicable screen located in the control supply port.

HDC on M46 PV



HDC Hydraulic schematic



Pump flow direction with HDC control

		Input Shaft Rotationump flow direction with MDC control			
		CW		CCW	
Single or Front Tandem	Higher pressure into control port:	X1	X2	X1	X2
	Port A Flow	Out	In	In	Out
	Port B Flow	In	Out	Out	In

Options

Pump flow direction with HDC control (continued)

Rear Tandem	Higher pressure into control port:	X1	X2	X1	X2
	Port C Flow	In	Out	Out	In
	Port D Flow	Out	In	In	Out
High Servo Gauge Port		M4	M5	M4	M5
Refer to pump installation drawing for port locations.					

Response Time

The time required for the pump output flow to change from neutral to full flow (acceleration) or full flow to neutral (deceleration) is a function of the size of the supply orifice in the control inlet passage and the size of the drain orifice in the control sleeve.

A range of orifice sizes is available to assist in matching the rate of swashplate response to the acceleration and deceleration requirements of the application. The table at right shows some sample response times under certain conditions. (These figures assume 1775 min^{-1} (rpm), 140 bar [2000 psi] system pressure, and 20 bar [290 psi] charge pressure.) Vehicle testing is required to determine the proper orifice sizes for the desired response.

Control input signal requirements

The standard command signal range required to stroke the pump between neutral and full stroke is 1.3 to 11.7 bar [19 to 170 psi] differential. The maximum command pressure must not exceed 27.5 bar [400 psi].

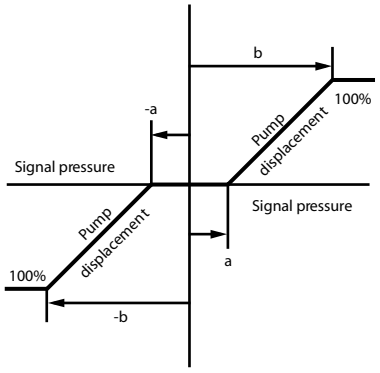
HDC options

The HDC can be tailored to respond to a higher signal pressure. Optional heavy spring packs are available that operate in the 3 to 14 bar [44 to 200 psi] range and the 5 to 15 bar [70 to 220 psi] range.

HDC Response time

Orifice diameter* mm [in]		**Average response time [seconds]**	
		Acceleration	Deceleration
0.9 [0.037]	0.8 [0.031]	1.6	1.3
1.4 [0.055]	1.2 [0.046]	0.9	0.7
None	None	0.4	0.3
*Contact Danfoss for special orifice combinations.			

Pump displacement vs control lever rotation



T101310-

Options

HDC signal required for swashplate position

	Swashplate position (refer to above chart)			
	Swashplate movement begins (point A)		Full displacement reached (point B)	
Configuration	bar	[psid]	bar	[psid]
BA	1.3±0.5	[19±7]	11.7±1.1	[170±16]
BB	3.0±0.7	[44±10]	13.8±1.4	[200±20]
BC	4.8±0.7	[70±10]	15.2±1.4	[220±20]

HDC Input specs

Maximum input pressure bar [psi]	27.5 [400]

Electrical Displacement Control- Options CE, CG, CM, and CN

The Electrical Displacement Control (EDC) is a three stage control similar to the HDC, but it uses an electrohydraulic Pressure Control Pilot (PCP) valve to control the pilot pressure. The PCP valve converts an electrical input signal to a hydraulic signal to operate a spring centered 4-way servo valve, which ports hydraulic pressure to either side of a double acting servo piston. The servo piston tilts the cradle swashplate, thus varying the pump's displacement from full displacement in one direction to full displacement in the opposite direction.

The EDC provides output flow in proportion to a DC electrical command signal (current). This control is suited for applications where remote or automatic control of system function is required, or where closed loop feedback is needed. With no electrical command signal, the control returns to the neutral position. The EDC is only available with a nonmetered spool.

The M46 EDC is a current driven device designed for a DC signal. Use a PWM signal with a 100-200 Hz dither frequency for optimum control operation. Limit the amplitude of the PWM signal to 6 Vdc. For further assistance, contact your Danfoss representative.

Features:

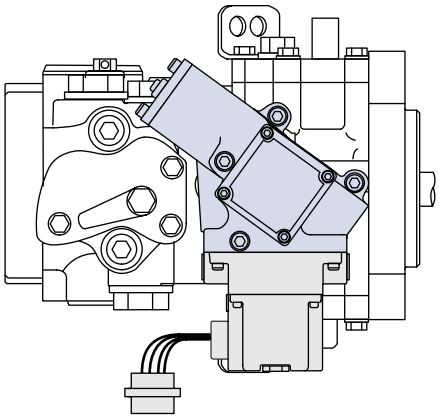
- The EDC is a high gain control: with only a small change in the input current, the servo valve moves to a full open position thus porting maximum flow to the servo cylinder.
- Oil filled PCP valve case lengthens control life by preventing moisture ingression and dampening component vibrations.
- Internal mechanical stops on the servo valve allow rapid changes in input signal voltages without damaging the control mechanism.
- Precision parts provide repeatable accurate displacement settings with a given input signal.
- Both ends of the double acting servo piston are drained to case when input signal current is not present. The servo piston is coupled to a spring centering mechanism.

Benefits:

- Simple, low-cost design.
- Pump will return to neutral after prime mover shuts down.
- Pump will return to neutral if external electrical input signal fails or if there is a loss of charge pressure.

Options

EDC on M46 PV



P100600

Pump flow direction with EDC control

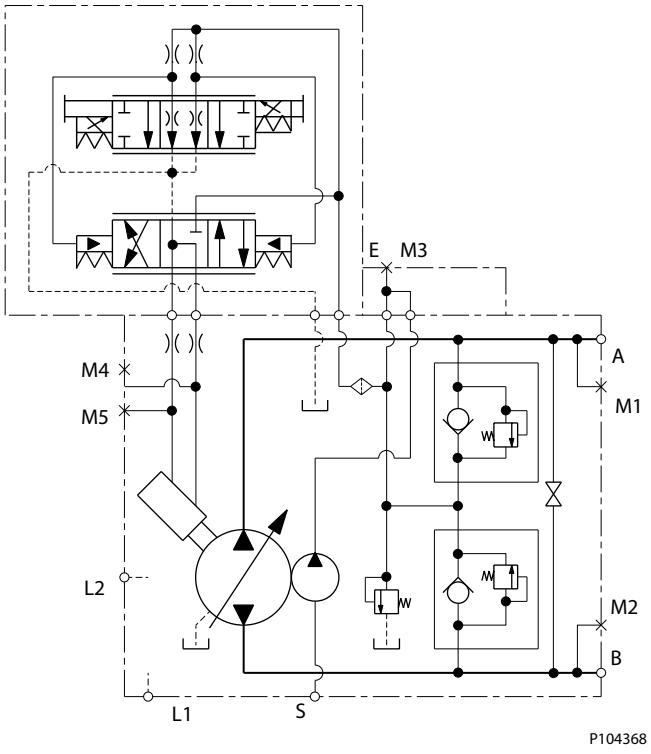
		Input Shaft Rotation			
	Positive signal to pin	CW		CCW	
Single or Front Tandem	Single coil or Dual coil in parallel (A&C common, B&D common)	A or C	B or D	A or C	B or D
	Dual coil in series (B&C common)	A	D	A	D
	Port A Flow	Out	In	In	Out
	Port B Flow	In	Out	Out	In
Rear Tandem	Single coil or Dual coil in parallel (A&C common, B&D common)	A or C	B or D	A or C	B or D
	Dual coil in series (B&C common)	A	D	D	A
	Port C Flow	In	Out	Out	In
	Port D Flow	Out	In	In	Out
High Servo Gauge Port		M4	M5	M4	M5
Refer to pump installation drawing for port locations.					

All M46 pumps have a 40 mesh [0.4 mm (0.015 inch)] servicable screen located in the control supply port.

For a list of available control and connector options, refer to the Model Code section.

Options

EDC Hydraulic Schematic



Response time

The time required for the pump output flow to change from neutral to full flow (acceleration) or full flow to neutral (deceleration) is a function of the size of the orifices in the servo and supply passages.

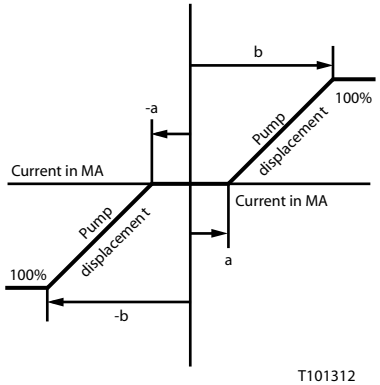
A range of orifice sizes is available to assist in matching the rate of swashplate response to the acceleration and deceleration requirements of the application. The table below shows some sample response times under certain conditions. (These figures assume 1775 min-1 (rpm), 140 bar [2000 psi] system pressure, and 20 bar [290 psi] charge pressure.) Test system response to determine the proper orifice selection for the desired response.

Control Input, Coils and Connectors

The standard EDC is a dual coil device with a silicone oil -filled case. It is available with a Packard Weather-Pak, Deutsch DT or MS connector. It is possible to design a system that uses only one coil or use both coils in series or in parallel. Using both coils allows for the use of two command stations with the resulting command being the algebraic sum of the two signals. The Deutsch DT connector has an IP67 rating. The MS connector is IP66 rated, and the Packard Weather-Pak connector is IP65 rated.

Options

Pump displacement vs electrical control



EDC Input Options

Coil configuration	(Point a) mA	(Point b) mA	Pin Connections
Dual coil, using only one coil	23 ± 6	132 ± 18	A & B or C & D
Dual coil, coils in series	11.5 ± 3	65 ± 9	A & D (C & B common)
Dual coil, coils in parallel	23 ± 6	132 ± 18	AC & BD
* Dual coil EDCs are production tested using two coils in parallel.			

Dual coil EDC input specs

	A-B coil	C-D coil
Coil resistance @24°C [75°F]	20 Ohms	16.5 Ohms
Coil resistance @104°C [220°F]	24.7 Ohms	19.7 Ohms

Contact factory for other control options, such as: Single coil or low current controls and for other connector options.

EDC Response time

Orifice diameter* mm [in]		Average response time [seconds]	
		Acceleration	Deceleration
0.9 [0.037]	0.8 [0.031]	1.6	1.3
1.4 [0.055]	1.2 [0.046]	0.9	0.7
None		0.4	0.3
*Contact Danfoss for special orifice combinations.			

For further information refer to Danfoss publication *Electrical Displacement Control - MDT* **BLN-95-8988**.

Mount M46 pumps with an EDC control so the control is on the top or the side.

High Current Electric Displacement Control - Options HA (12Vdc) and HB (24Vdc)

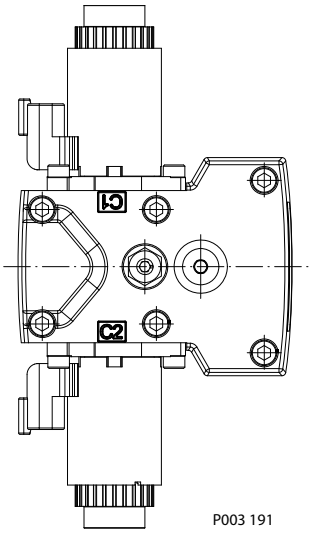
High Current EDC principle

The High Current Electrical Displacement Control (HC EDC) consists of a pair of proportional solenoids on each side of a three-position, four-way porting spool. The proportional solenoid applies a force input to the spool, which ports hydraulic pressure to either side of a double acting servo piston. Differential pressure across the servo piston rotates the swashplate, changing the pump's displacement from full displacement in one direction to full displacement in the opposite direction.

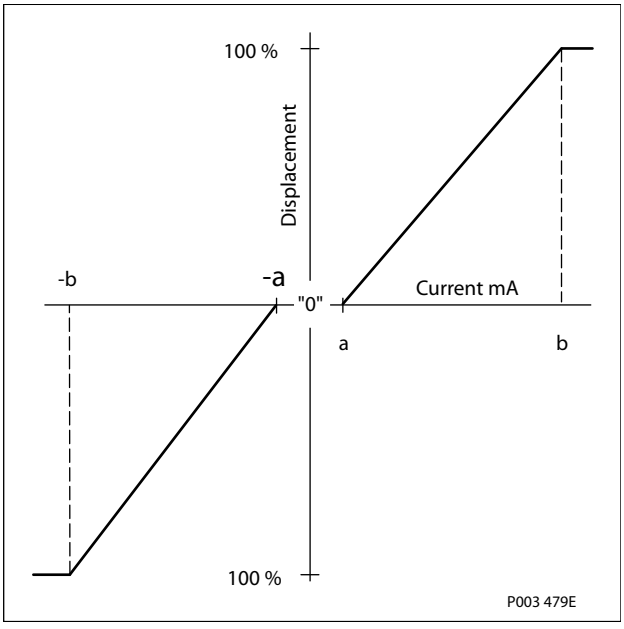
Options

Under some circumstances, such as contamination, the control spool could stick and cause the pump to stay at some displacement.

A serviceable 125 µm screen is located in the supply line immediately before the control porting spool.

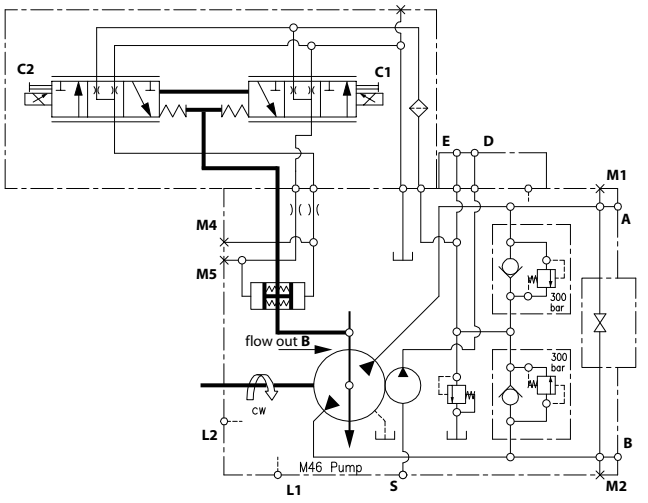


Pump displacement vs. control current



Options

Schematic diagram



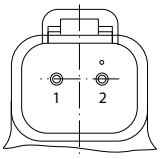
Control signal requirements

Control current

Voltage	a* mA	b mA	Pin connections
12 V	640	1640	any order
24 V	330	820	

* Factory test current, for vehicle movement or application actuation expect higher or lower value.

Connector



Description	Quantity	Ordering number
Mating connector	1	Deutsch® DT06-2S
Wedge lock	1	Deutsch® W2S
Socket contact (16 and 18 AWG)	2	Deutsch® 0462-201-16141
Danfoss mating connector kit	1	K29657

Solenoid data

Voltage	12V	24V
Maximum current	1800 mA	920 mA
Coil resistance @ 20 °C [70 °F]	3.66 Ω	14.20 Ω
Coil resistance @ 80 °C [176 °F]	4.52 Ω	17.52 Ω
PWM Range	70-200 Hz	
PWM Frequency (preferred)**	100 Hz	

Options

Solenoid data (continued)

Voltage	12V	24V
Inductance	33 mH	140 mH
IP Rating (IEC 60 529) + DIN 40 050, part 9	IP 67	
IP Rating (IEC 60 529) + DIN 40 050, part 9 with mating connector	IP 69K	

* PWM signal required for optimum control performance.

Flow table

Shaft rotation	CW		CCW	
Coil energized*	C2	C1	C2	C1
Port A	in	out	out	in
Port B	out	in	in	out
Servo port pressurized	M5	M4	M5	M4

* For coil location see installation drawings.

Response times

A range of servo orifice options are available to assist in matching the rate of swashplate response to the application requirements (e.g. in the event of electrical failure). Software ramp or rate limiting should be used to control vehicle response in normal operation. The time required for the pump output flow to change from zero to full flow (acceleration) or full flow to zero (deceleration) is a net function of spool porting, orifices, and charge pressure. The table below shows some sample response times under certain conditions. These figures assume 1775 min-1 (rpm), 140 bar [2000 psi] system pressure, and 20 bar [290 psi] charge pressure. Testing should be conducted to verify the proper software and orifice selection for the desired response.

Software is envisioned as the means to control the swashplate response in normal operating conditions. Mechanical servo orifices are to be used only for fail-safe return to neutral in the event of an electrical failure.

Contact Danfoss technical representative for additional information regarding orifice options and response times.

Typical response times shown below at the following conditions:

Response times

HC EDC Response time

Orifice diameter* mm [in]	Average response time [seconds]	
	Acceleration	Deceleration
1.2 [0.046]	2.0	1.6
None	0.9	1.0
*Contact Danfoss for special orifice combinations.		

Manual OverRide (MOR)

All high current controls are standard with Manual Over Ride (MOR), used for temporary actuation of the control to aid in diagnostics.

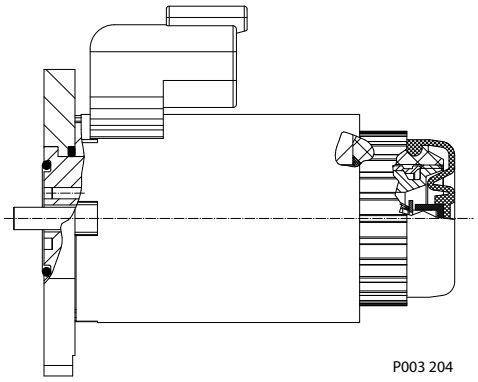
Options

Unintended MOR operation will cause the pump to go into stroke. The vehicle or device must always be in a safe condition (i.e. vehicle lifted off the ground) when using the MOR function. The MOR plunger has a 4 mm diameter and must be manually depressed to be engaged. Depressing the plunger mechanically moves the control spool which allows the pump to go on stroke. The MOR should be engaged anticipating a full stroke response from the pump.

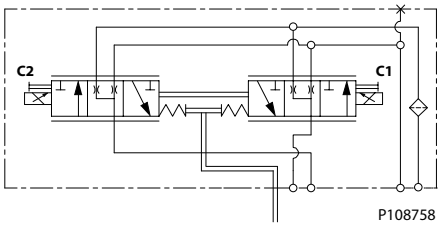
Warning

An O-ring seal is used to seal the MOR plunger where initial actuation of the function will require a force of 45 N to engage the plunger. Additional actuations typically require less force to engage the MOR plunger. Proportional control of the pump using the MOR should not be expected.

Refer to the control flow table for the relationship of solenoid to direction of flow.



MOR Schematic diagram (EDC shown)



Three-position Electrical Control - Options DA and DB

The three-position Forward-Neutral-Reverse (FNR) is a two stage control that uses a solenoid operated 3-position, 4-way valve to move pump displacement from neutral to maximum displacement in either direction.

When a solenoid is energized, charge pressure is directed to one end of the pump servo control cylinder, which results in the pump going to maximum displacement. The direction of pump output flow is determined by which solenoid is energized. (See the accompanying table)

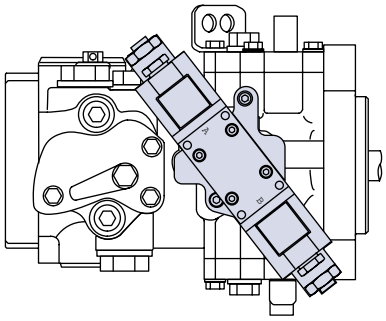
Features and benefits

- Electric control.
- If voltage is lost, the control returns pump to neutral.
- Simple, low-cost design.
- Ideal for non-propel applications that do not require proportional control.
- A manual override (MOR) option is available. It requires a 3 mm tool for engagement.

For a list of available control options, refer to the Model Code section.

Options

FNR Control on M46 PV



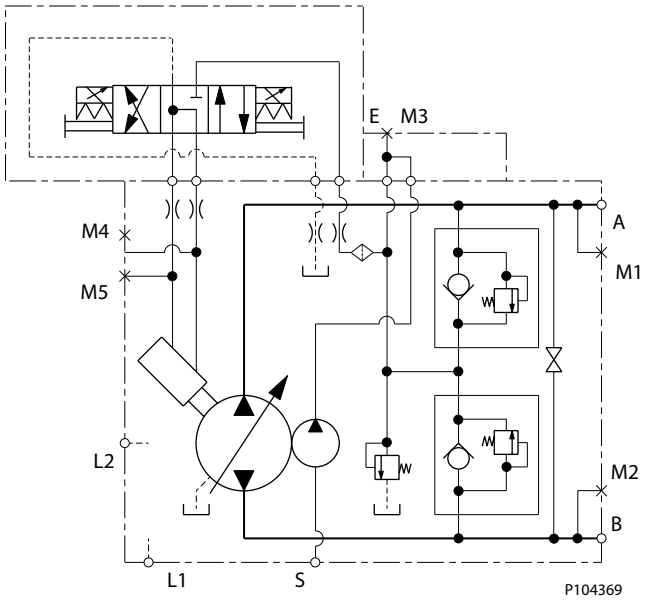
P100601

Pump flow direction with FNR control

		Input Shaft Rotation			
		CW		CCW	
Single or Front Tandem	Solenoid energized:	A	B	A	B
	Port A Flow	Out	In	In	Out
	Port B Flow	In	Out	Out	In
Rear Tandem	Solenoid energized:	A	B	A	B
	Port C Flow	In	Out	Out	In
	Port D Flow	Out	In	In	Out
High Servo Gauge Port		M4	M5	M4	M5
Refer to pump installation drawing for solenoid and port locations.					

All M46 pumps have a 40 mesh [0.4 mm (0.015 inch)] servicable screen located in the control supply port.

FNR Hydraulic schematic



P104369

Options

Response time

The time required for the pump output flow to change from neutral to full flow (acceleration) or full flow to neutral (deceleration) is a function of the size of the orifices in the servo, supply and drain passages.

A range of orifice sizes is available to assist in matching the rate of swashplate response to the acceleration and deceleration requirements of the application. The table below shows some sample response times under certain conditions. (These figures assume 1775 min-1 (rpm), 140 bar [2000 psi] system pressure, and 20 bar [290 psi] charge pressure.) Test system response to determine the proper orifice selection for the desired response.

Control input signal requirements

The solenoids are available in versions for 12 or 24 Vdc. Maximum power consumption is 30 Watts. They are available with terminals for a DIN 43650 connector.

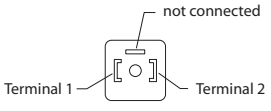
FNR Response time

Orifice diameter* mm [in]		**Average response time [seconds]**	
Acceleration	Deceleration		
0.9 [0.037]	0.8 [0.031]	1.6	1.3
1.4 [0.055]	1.2 [0.046]	0.9	0.7
None	None	0.4	0.3
*Contact Danfoss for special orifice combinations.			

FNR input specifications

Vdc	12 or 24
Max power	30 W
Connectors	DIN 43650

FNR connector

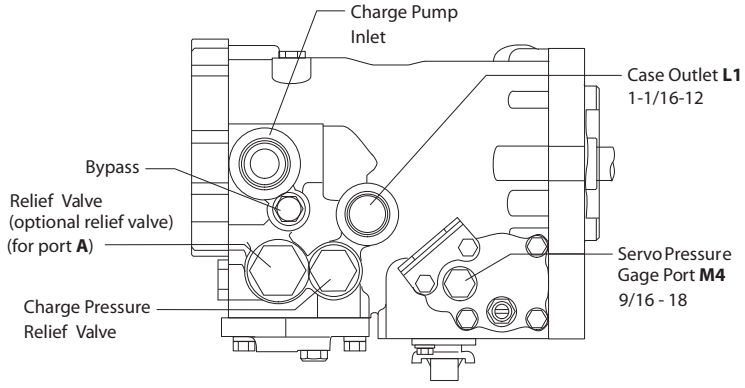


Solenoid Plug Face

P108514

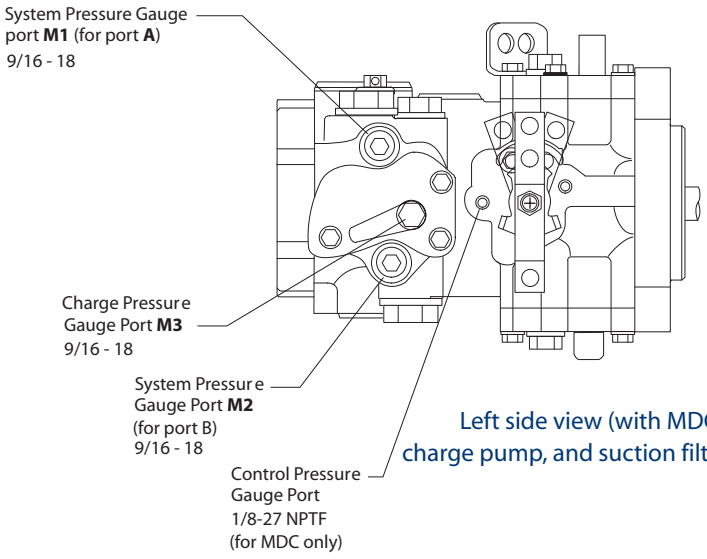
Port Locations

Single Pump

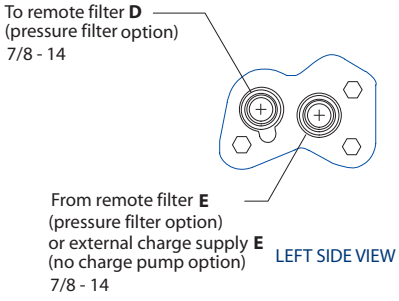


Top view (with MDC, charge pump, and suction filtration)

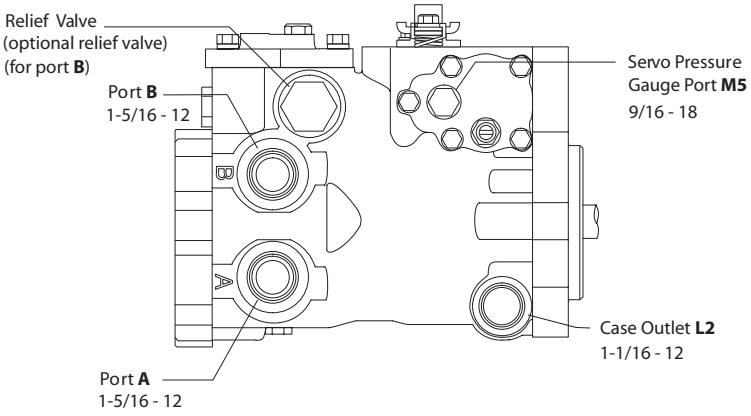
All ports are straight thread O-ring boss per ISO 11926-1 and SAE J1926/1



Left side view (with MDC, charge pump, and suction filtration)



Remote filtration with or without charge pump

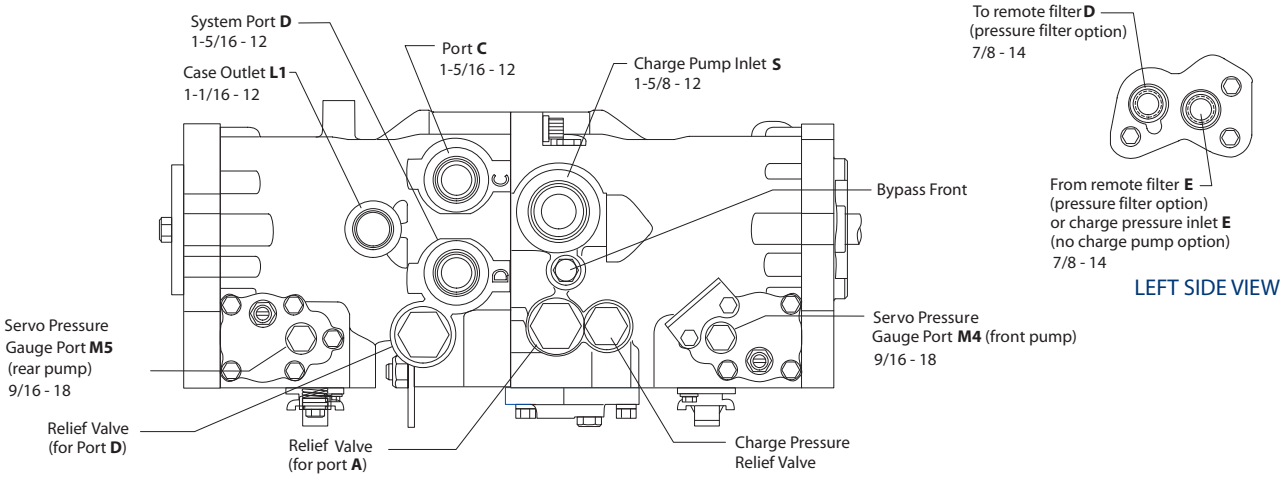


Bottom view (with MDC and suction filtration)

P108401

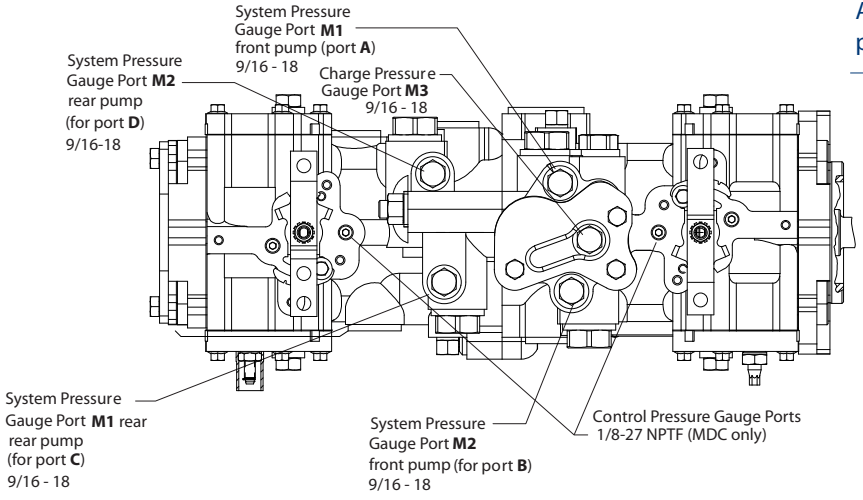
Port Locations

Tandem Pump

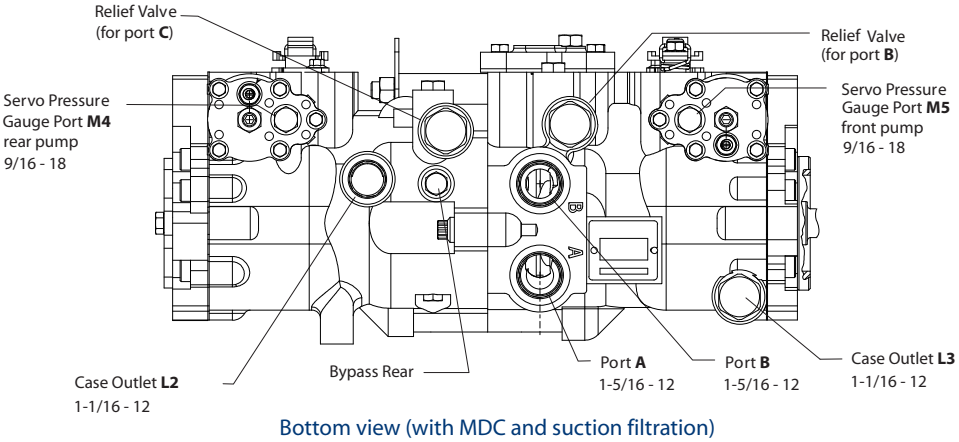


Top view (with MDC, charge pump, and suction filtration)

All ports are straight thread O-ring boss per ISO 11926-1 and SAE J1926/1



Left side view (with MDC, charge pump, and suction filtration)

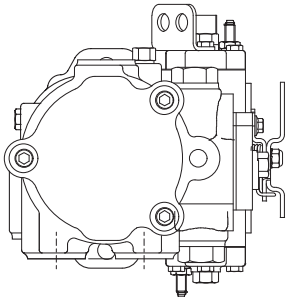


Bottom view (with MDC and suction filtration)

P108402

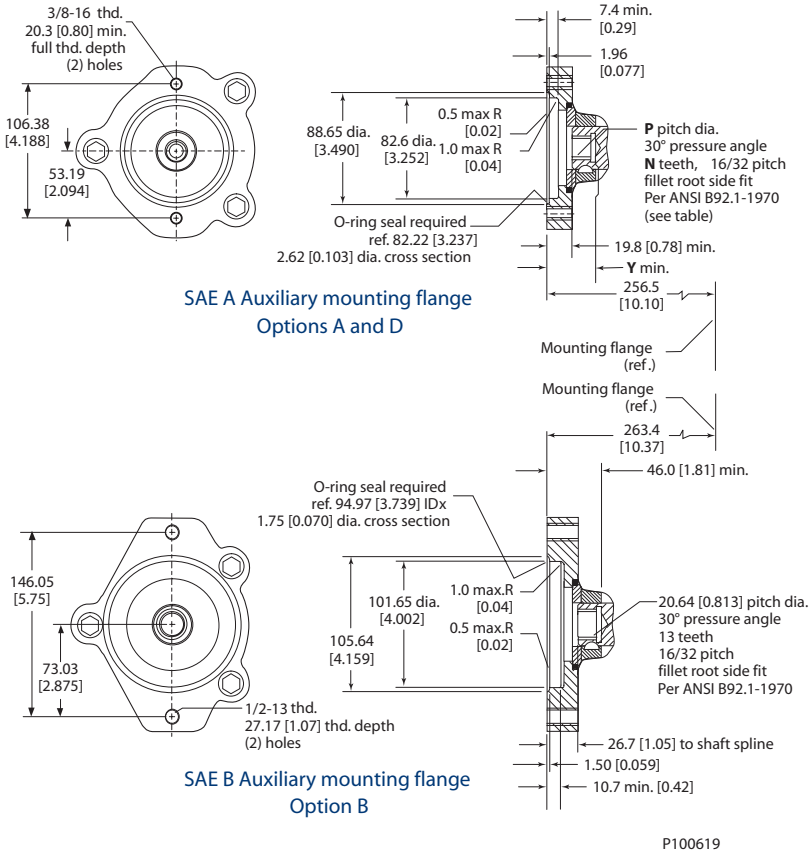
Installation Drawings - Single Pump Dimensions

Auxiliary Mounting Flanges



Rear view (no pads shown)

Contact Danfoss for individual dimension drawings



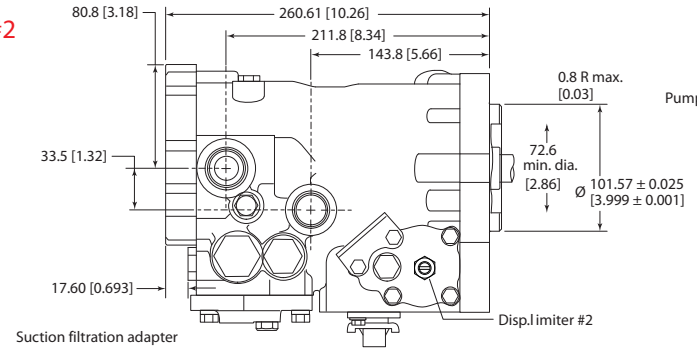
Auxiliary mounting flange and coupling options

Number of teeth N	Auxiliary mounting flange		Spline pitch dia. P	Minimum clearance Y
9	SAE A	Option A	14.29 [0.563]	36.6 [1.44]
11	SAE B	Option B	17.46 [0.688]	42.4 [1.67]

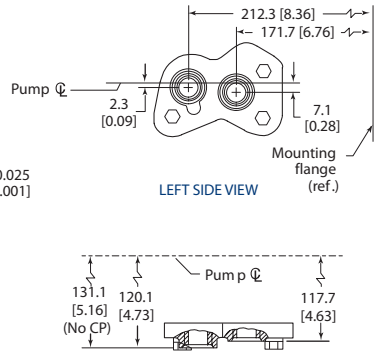
Installation Drawings - Single Pump Dimensions

Pump, filtration/charge pump options, MDC, displacement limiter

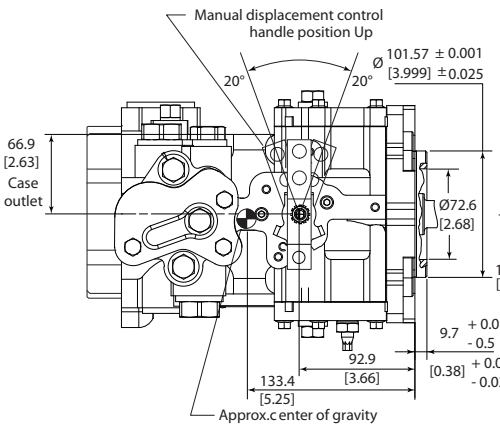
Side #2



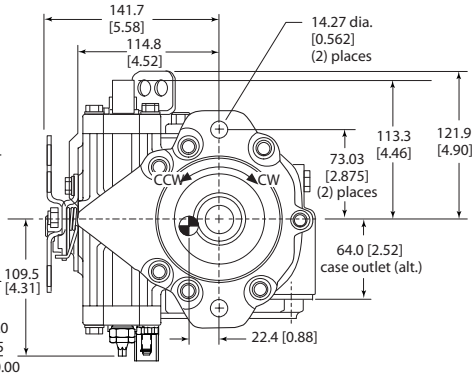
Top view (with MDC, charge pump, and suction filtration)



Remote filtration with or without charge pump



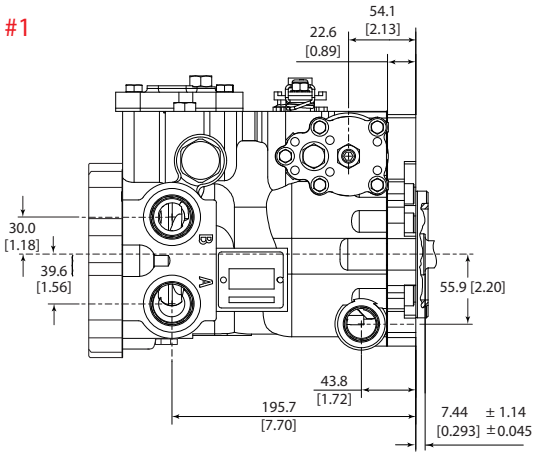
Left side view (with MDC, charge pump, and suction filtration)



Front view (with MDC)

P100618

Side #1



Bottom view (with MDC and suction filtration)

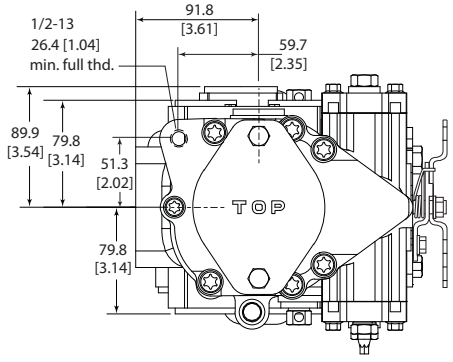
Contact Danfoss for individual dimension drawings.

M46 PV adjustable displacement limiter (option)

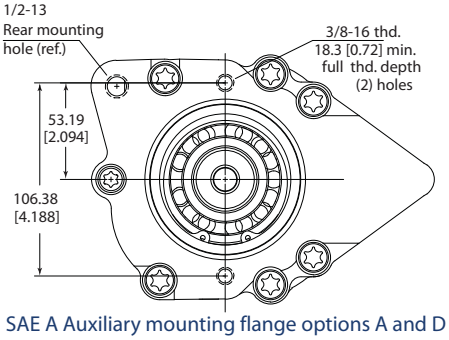
Shaft rotation	CW	CCW
Displacement limiter side	2	2
Limits flow out of port	B	A

Installation Drawings - Tandem Pump Dimensions

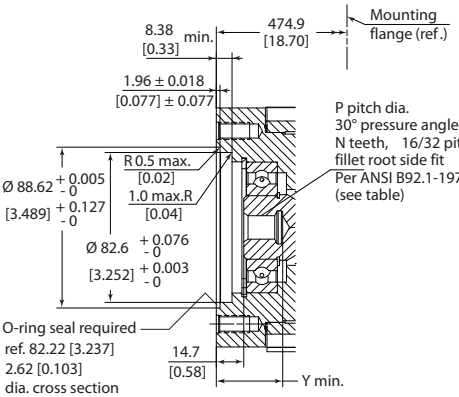
Auxiliary mounting flange

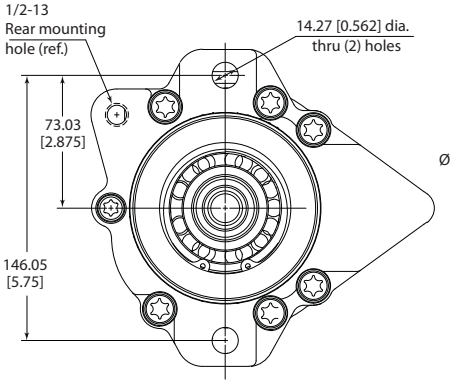


No auxiliary mounting flange

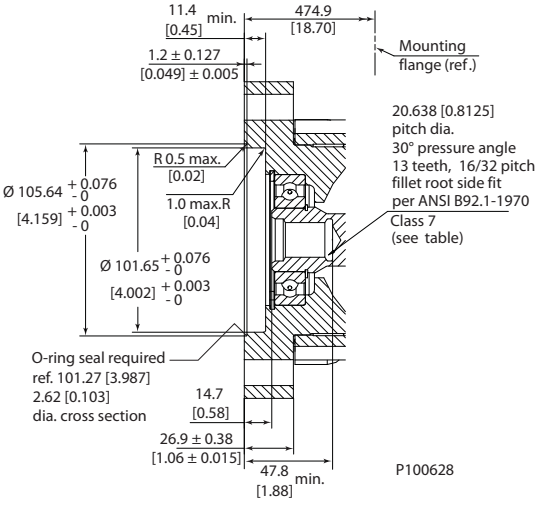


SAE A Auxiliary mounting flange options A and D





SAE B Auxiliary mounting flange Option B

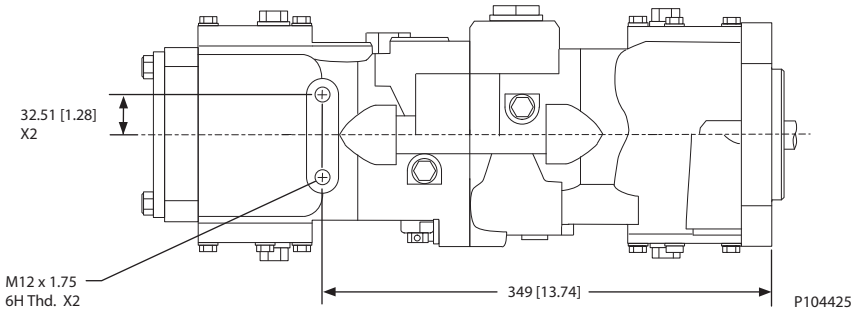


Auxiliary mounting flange and coupling options

Auxiliary mounting flange		Spline pitch dia. P	Number of teeth N	Minimum clearance Y
SAE A	Option A	14.30 [0.563]	9	34.8 [1.37]
SAE B	Option B	17.46 [0.688]	11	37.34 [1.47]

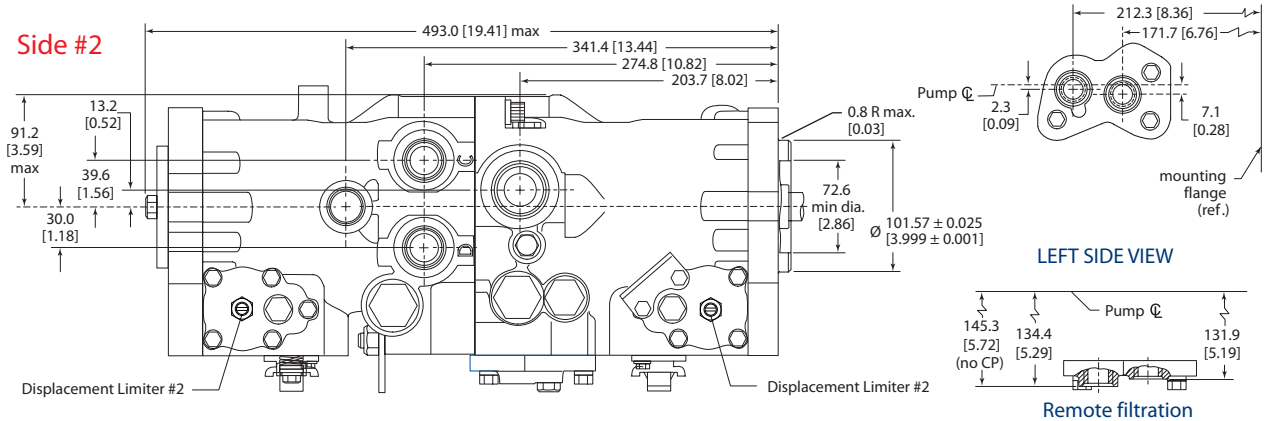
Installation Drawings - Tandem Pump Dimensions

Rear mounting boss

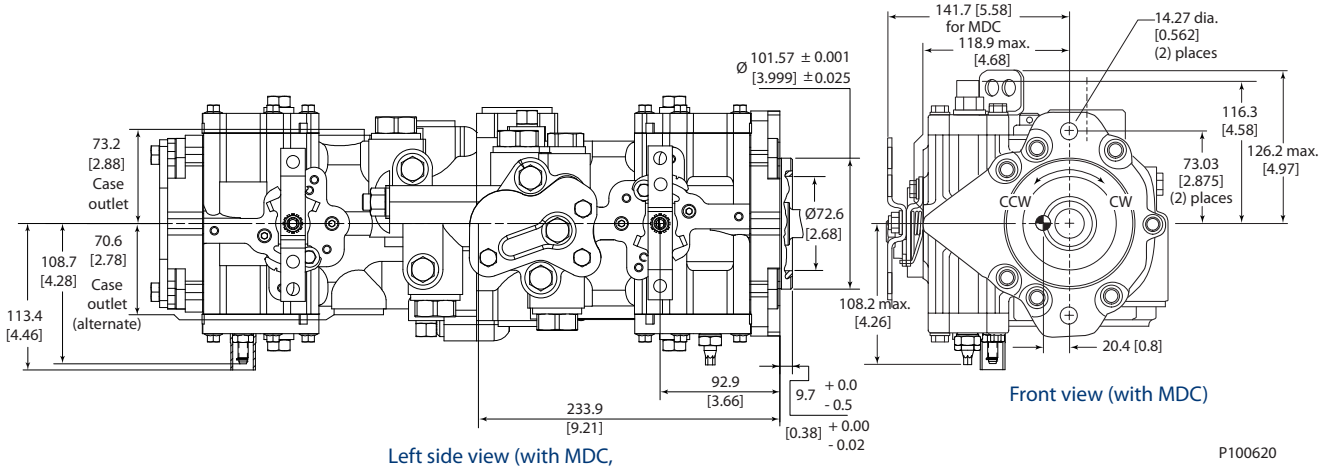


Installation Drawings - Tandem Pump Dimensions

Pumps, filtration/charge pump options, MDC, displacement limiters

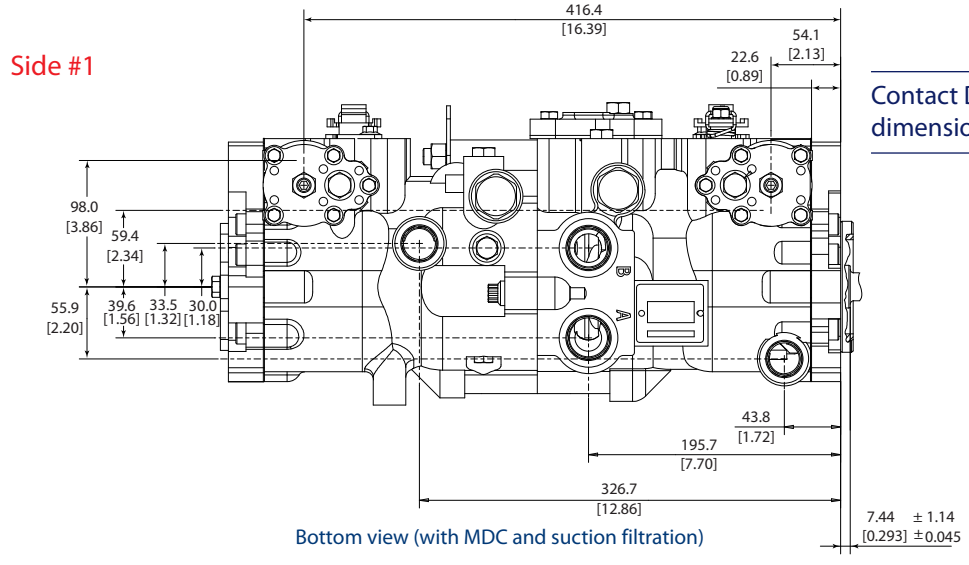


Top view (with MDC, charge pump, and suction filtration)



Left side view (with MDC, charge pump, and suction filtration)

Front view (with MDC)



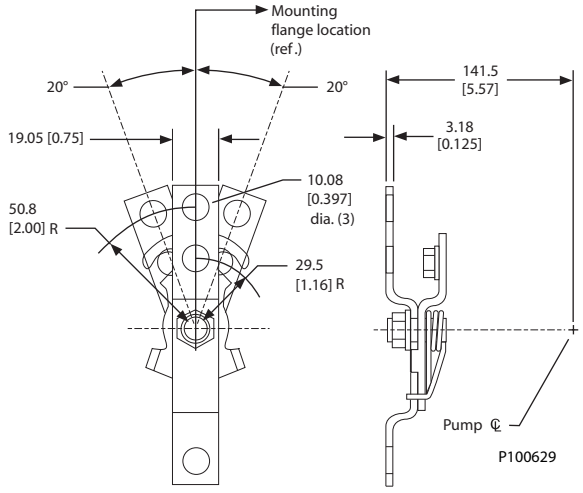
Bottom view (with MDC and suction filtration)

Contact Danfoss for individual dimension drawings.

Control Options - Installation Drawings

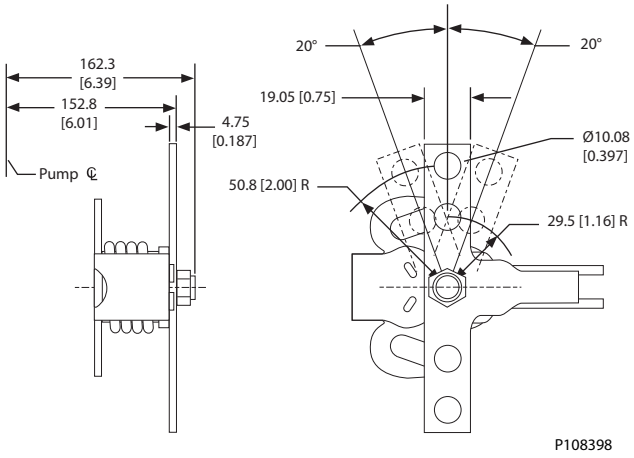
Control options, AC, AK

Three hole control handle with standard spring



Option GB

Control handle with heavy spring and heavy duty four hole handle

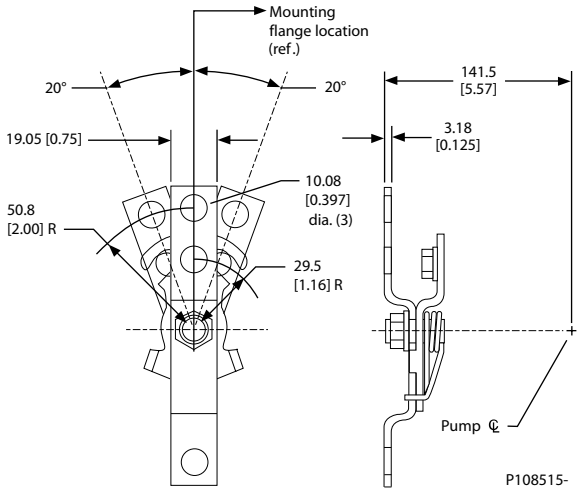


Contact Danfoss for individual dimension drawings.

Control Options - Installation Drawings

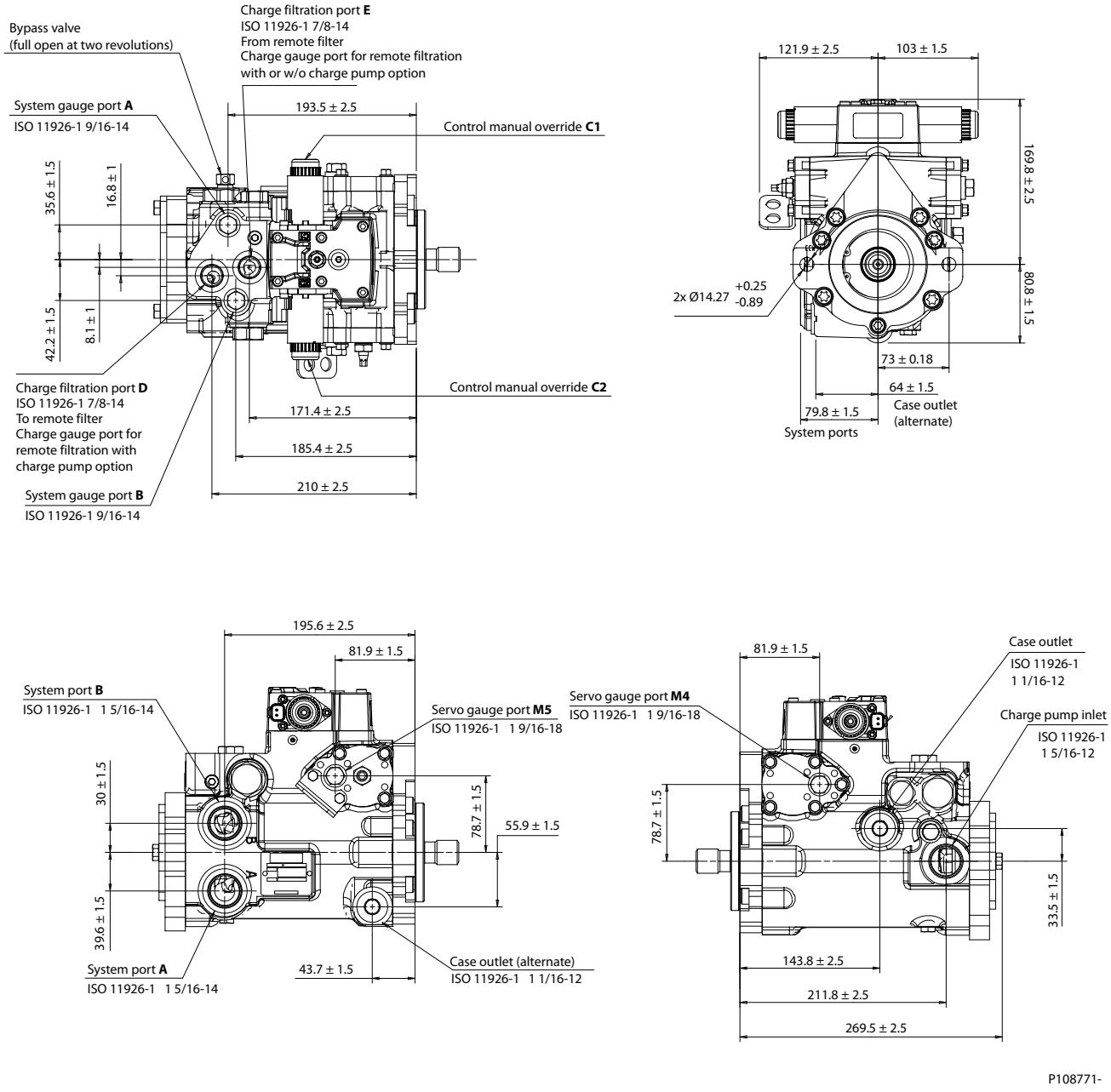
Options AB, AW

Two hole control handle with standard spring



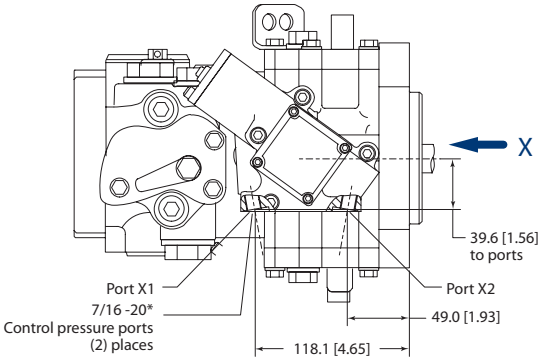
Control Options - Installation Drawings

HC EDC Control

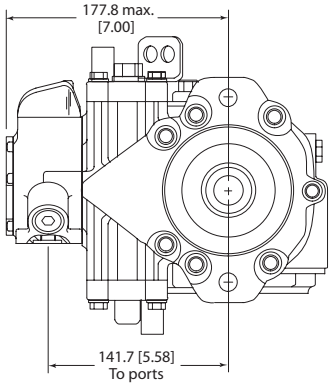


Control Options - Installation Drawings

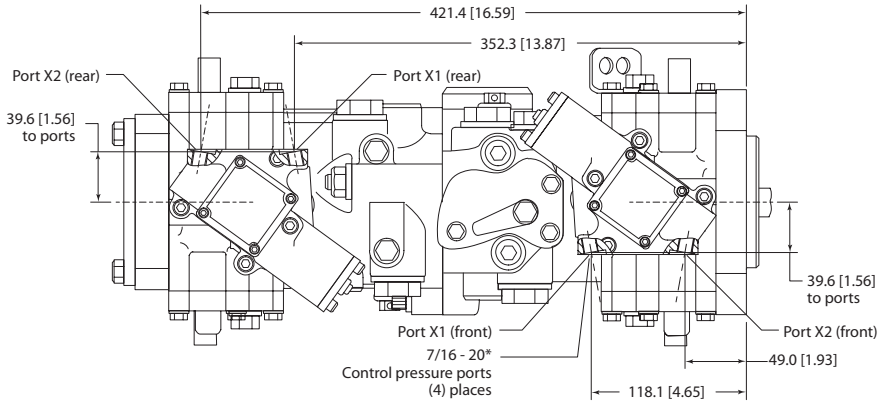
Hydraulic displacement control (HDC)



Side view
Variable pump with HDC



View X
Front view
Variable pump with HDC



Side view
Tandem pump with HDC

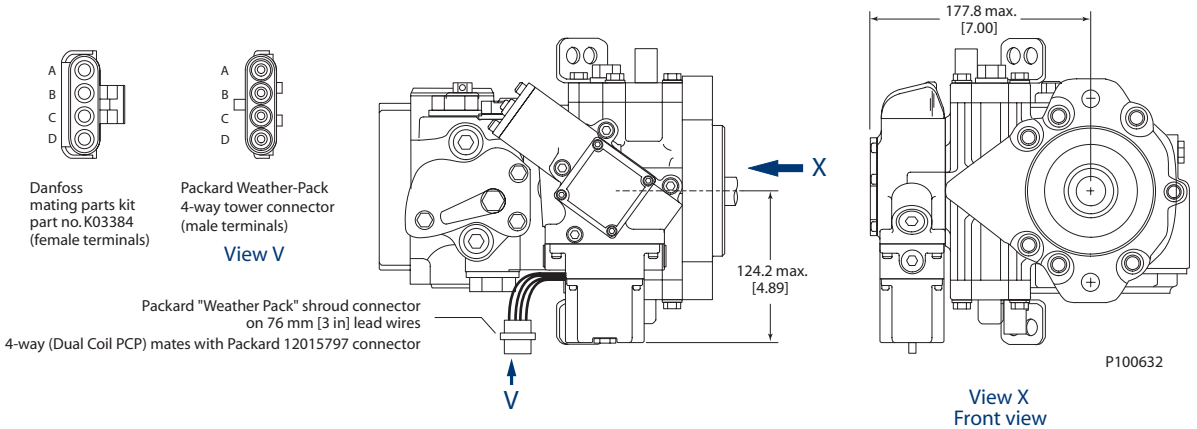
P100631

Contact Danfoss for individual dimension drawings.

Control Options - Installation Drawings

Option CE

Electronic displacement control (EDC)

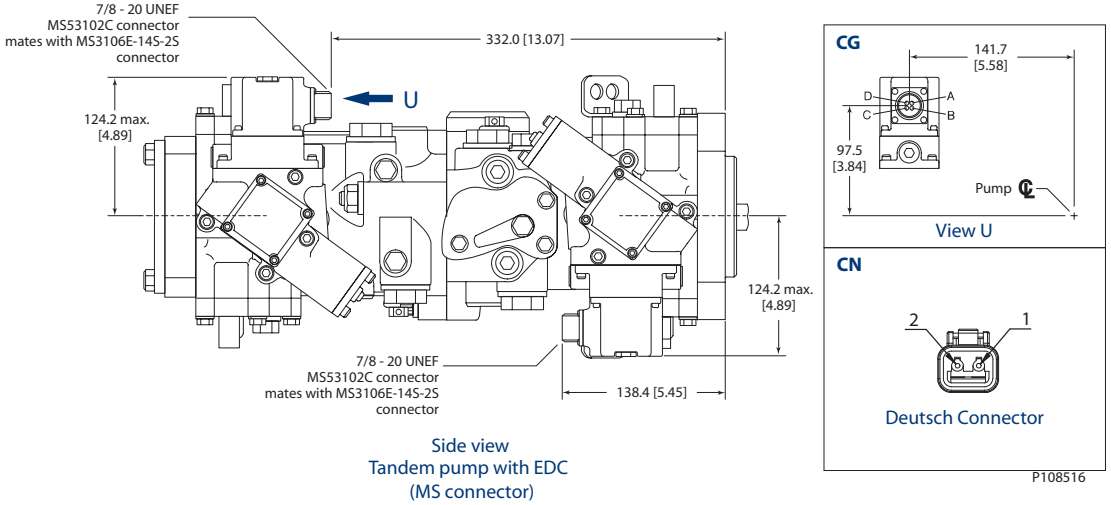


Side view
Variable pump with EDC
(Packard Weather-Pack connector)

View X
Front view
Variable pump with EDC
(Packard Weather-Pack connector)

Options CG, CN

Electronic displacement control (EDC)



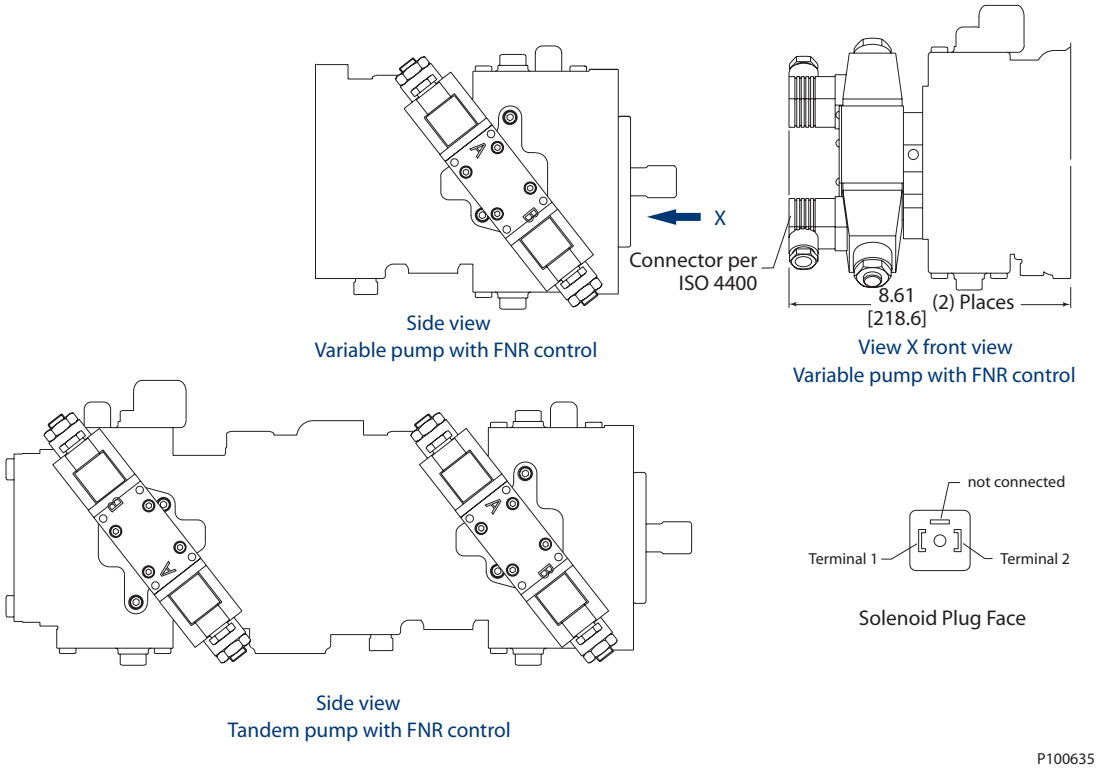
Side view
Tandem pump with EDC
(MS connector)

View U

Control Options - Installation Drawings

Options DA, DB

Three-position electric displacement control (FNR)



Side view
Variable pump with FNR control

View X front view
Variable pump with FNR control

Solenoid Plug Face

Side view
Tandem pump with FNR control

P100635

Reference Literature

Literature

M46 systems may consist of a variety of pump, motor, valve and control combinations. Refer to the literature listed below for product information and specifications for M46 pumps and other Danfoss components.

M46 Pumps literature

- Series 40 M46 Single Pumps Service Manual **11026743**
- Series 40 M46 Tandem Pumps Service Manual **11029852**

Propel Systems related Literature

- Series 40 Motors Technical Information **520L0636**
- L&K Frame Motors Technical Information **520L0627**
- JS 1000, JS 6000 Joystick Grips Technical Information **520L0872**
- PLUS+1 Controller Family Technical Information **520L0719**

Hydraulic Systems Guidelines

- Hydraulic Fluids and Lubricants Technical Information **520L0463**
- Pressure and Speed Limits **BLN-9884**
- Design Guidelines for Hydraulic Fluid Cleanliness **520L0467**
- Experience with Biodegradable Hydraulic Fluids, Technical Information **520L465**
- Pressure and Speed Limits **BLN-9884**
- Selection of Driveline Components **BLN-9885**

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- Proportional Valves
- Sensors
- Steering
- Transit Mixer Drives

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10 WATER PUMP

Models 11860-Series
11870-Series

SELF-PRIMING PUMPS
ELECTRO-MAGNETIC CLUTCH UNIT

FEATURES

Body:	Bronze
Impeller:	Nitrile
Shaft:	Stainless Steel
Seal:	Carbon-Ceramic, Face Type
Ports:	11860-Series, 1" NPT Internal 11870-Series, 1-1/4" NPT Internal
Bearings:	Shielded Ball Bearings
Weight:	11860-Series, 15 lb (6.8 kg) Approx. 11870-Series, 19-1/2 lb (8.9 kg) Approx.

Model	Clutch Volt/Belt	Cam	Impeller	Insert
11860-0005	12 / 2-A	Brass	Nitrile	Brass
11860-0045	12 / 1-B	Brass	Nitrile	Brass
11860-0006	24 / 2-A	Brass	Nitrile	Brass
11860-0046	24 / 1-B	Brass	Nitrile	Brass
11870-0005	12 / 2-A	Brass	Nitrile	Brass
11870-0045	12 / 1-B	Brass	Nitrile	Brass
11870-0006	24 / 2-A	Brass	Nitrile	Brass
11870-0046	24 / 1-B	Brass	Nitrile	Brass
11870-0007	32 / 2-A	Brass	Nitrile	Brass

APPLICATION

MARINE: Pumping bilges, Washdowns, Circulating water in bait tanks, Utility dock-side pump.

INDUSTRIAL: Circulating and transferring, Velocity-mixing, Pumping machine tool coolants, Return spill, Sump drainage, Chemicals, Pharmaceuticals, Soap, Liquors, Ink, Dyes, Alcohol, Various acids, Tanning Liquors, Glycerine, Brine, etc.

FARMING: Pumping water stock, Pumping water from shallow wells and cisterns.

PLUMBING AND HOME EMERGENCY USE: Pumping out flooded basements, Cesspools, Sumps, Water heaters and water closets, Drains and sinks, Draining fishponds and pools.

PUBLIC UTILITIES AND MUNICIPALITIES: Under the hood mounting on service trucks for draining meter boxes, manholes, excavations; For pollution control and watering for dust control.

INSTALLATION

Pump may be mounted in any position. Intake and discharge ports are determined by the direction of shaft rotation (refer to dimensional drawing). Before installing, energize clutch and turn pump shaft in direction of shaft rotation. Drive pump with two “A” size belts or one “B” size belt. Avoid dry-running by using Vacuum Switch Model 4732-0000 for automatic shutoff.



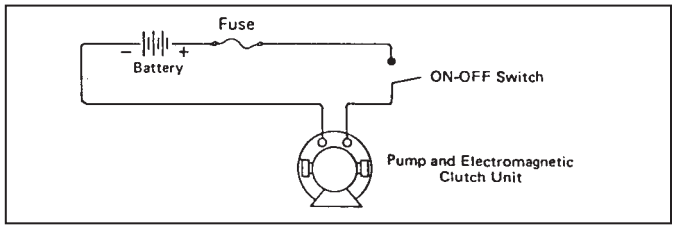
Models 11860, 11870-Series



WIRING

Connect wires as shown for manual on-off operation. Install appropriate size fuse (see Electrical Specification Chart) in positive lead as close to power source as possible. For complete wiring instruction, see diagram on last page.

Connect wires as shown for manual on-off operation.



ELECTRICAL SPECIFICATIONS

Voltage	Amp Draw	Fuse Size
12	4	7
24	2	4
32	1.5	2

OPERATION

Pump will self-prime at low or high speeds. Make sure that all connections are airtight. 12 Volt models are equipped with mechanical clutch engagement screws in case of electrical failure. To mechanically engage clutch, loosen locking nuts, tighten allen head screws and retighten locking nuts. Reverse procedure to disengage clutch. If the mechanical engagement feature is not desired, the screws may be removed. DO NOT RUN PUMP DRY FOR MORE THAN 30 SECONDS. LACK OF WATER FLOW MAY DAMAGE IMPELLER. To drain pump, loosen end cover screws. See Head Capacity Table for head pressures and flow. To avoid costly shutdowns, keep a Jabsco Service. Kit on hand.

SERVICE INSTRUCTIONS

IMPELLER REPLACEMENT: Remove end cover gasket. Pull impeller out by grasping hub with pliers. With rotary motion in the direction the pump will be turning, push the impeller into the impeller bore. A light coating of grease in the impeller bore will protect the impeller during initial dry start up. Install gasket and end cover.

SHAFT SEAL REPLACEMENT, 11870-SERIES: Remove end cover, gasket and impeller, as outlined above. Loosen cam screw several turns. Give cam screw a couple of sharp raps with the handle of the screwdriver to loosen the cam from the impeller bore. Remove the cam screw and cam (clean sealant from cam and impeller bore). Remove wearplate with hooked wire. Remove marcel washer, seal assembly and seal s eat assembly from seal bore with hooked wire, taking care not to scratch shaft or seal seat bore. Clean shaft surfaces behind splines and inspect for scratches or wear. Replace if necessary. Before installing new seal parts, clean any oil or grease from carbon and ceramic seal faces. Dip seal seat and gasket assembly in water and press into seal bore with boot first. Dip carbon seal assembly in water and install over shaft, carbon towards ceramic seal seat, until it bottoms firmly against ceramic seat. Slide marcel spring washer over shaft and against the rubber boot (washer) on carbon seal assembly. Replace wearplate, aligning notch with dowel pin in body. Apply sealant to top surface of cam and cam screw threads and install cam in impeller bore. Snug up but do not tighten cam screw. Replace impeller, gasket and end cover as outlined above. Tighten end cover screws. Tighten cam screw.

SHAFT SEAL REPLACEMENT, 11860-SERIES: Refer to major repair instructions.

FIELD COIL REPLACEMENT: Remove drive belts from pulley. Remove center bolt and washer from pulley (it may be necessary to remove end cover to hold impeller from turning, while removing center pulley bolt). Tap pulley with soft mallet to remove from shaft taper. Remove 3 bolts and washers holding field coil to adaptor (11870) or body (11860). Remove and replace field coil, tightening the 3 bolts securely. With drive key in place in shaft, replace pulley assembly. Secure to shaft, replace pulley assembly. Secure to shaft with center bolt and washer (again, it may be necessary to hold the impeller from turning to tighten center bolt). Replace drive belts. Do not over tighten belts. A deflection of 1/2" midway between pulleys is generally considered normal.

MAJOR REPAIR: Remove pump from installation for major repair. Disassembly: Remove end cover, gasket,impeller, cam and wearplate as outlined in shaft seal replacement, 11870-Series. Remove clutch as outlined in field coil replacement. Model 11870-Series: Use a punch to drive roll pins (key 17) in toward shaft approximately 3/8" (10mm). Remove clutch adaptor from body. Punch roll pin out of adaptor. Model 11860-Series does not have adaptor, clutch is secured directly to body. Remove bearing to body retaining ring. Support bearing end of body on arbor press platten. Press on impeller end of shaft to remove shaft and bearing assembly from body. Use screwdriver to pry inner bearing seal from body. Take care not to scratch or damage body bore.

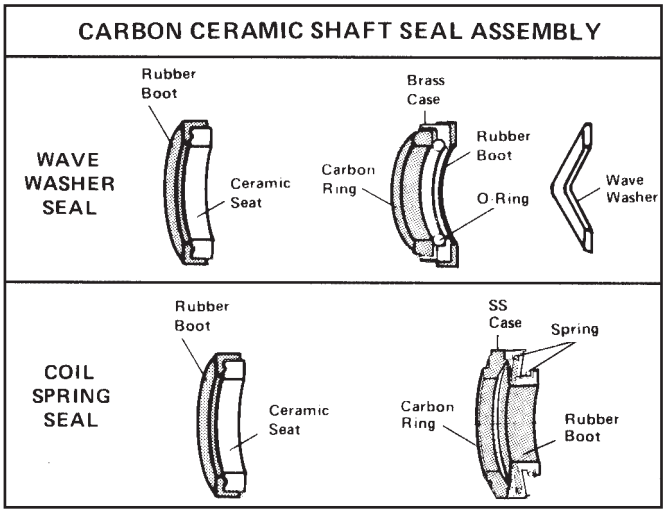
11860-SERIES: Remove seal seat assembly from shaft. Support impeller end of body on arbor press platten and, using suitable tube, press seal out of seal bore towards impeller end.

11870-SERIES: Remove slinger from drain area. Carbon portion of the seal assembly will be freed from shaft when shaft is remove from body. Press seal seat assembly from bearing bore end towards impeller bore.Remove bearing to shaft retaining ring. Support bearing and press on clutch drive end of shaft to remove shaft from bearing.

ASSEMBLY: Support inner race of bearing on arbor press platten. Oil shaft, insert drive end of shaft into bearing and press shaft through bearing until it bottoms firmly against shoulder.Install shaft to bearing until it bottoms firmly against shoulder. Install shaft to bearing retaining ring in groove of shaft. Support impeller bore end of pump on arbor press platten. Lubricate bearing seal with grease and press into bearing seal bore, flush with bearing bore shoulder, with lip facing away from bearing bore. For 11870-Series only: Insert slinger in drain slot, to be picked up by shaft during shaft/bearing assembly. Insert splined end of shaft through bearing seal (and slinger on Model 11870-Series). Press on outer bearing race to assemble shaft/bearing assembly into body, bottoming bearing firmly against bearing bore shoulder.Install body to bearing retaining ring in groove in body with flat side against bearing. For 11870-Series only: Install clutch adaptor in bearing bore. If re-using adaptor previously disassembled from pump, line up dowel pin holes during assembly of adaptor to body. If installing new adaptor (which does not have pre-drilled dowel pin holes), insert into bearing bore until it bottoms and use dowel pin holes in body to pilot drill dowel pin holes through adaptor in two places, 180° apart. Clean any brass chips from bearing area. Press roll pins into body to secure adaptor. Attach field coil to adaptor (11870-Series) or body (11860-Series) with three round head bolts. Turn body over and support on field coil.

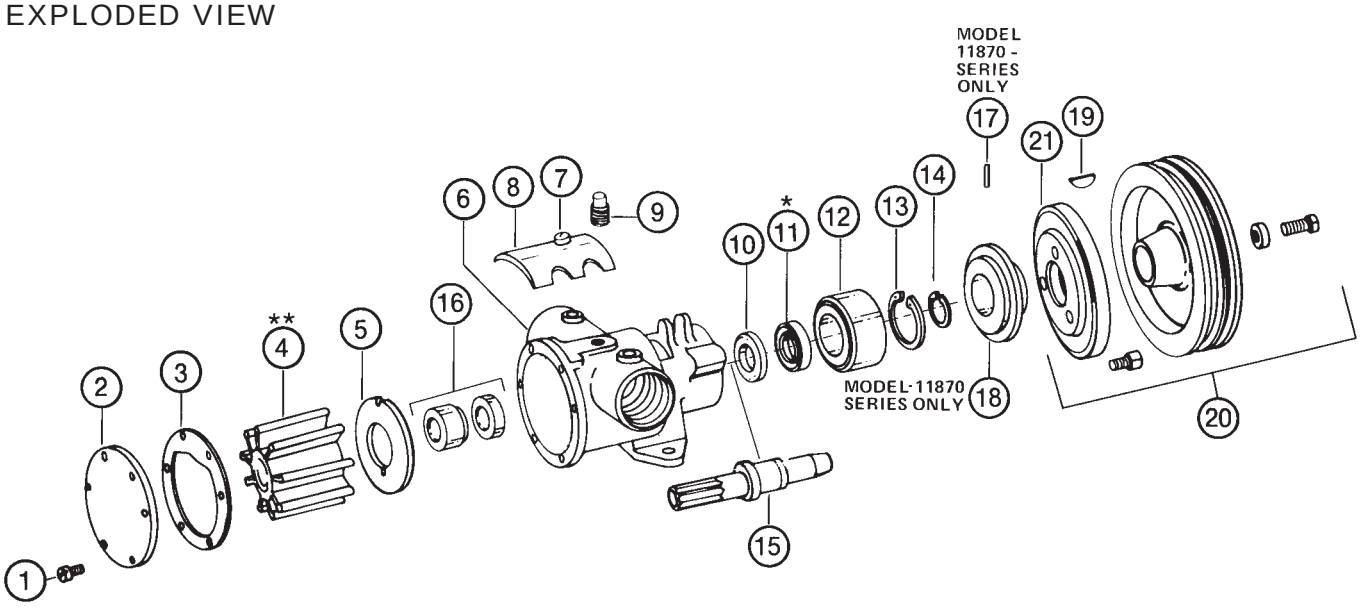
11860-SERIES: Dip seal seat assembly, consisting of ceramic seal seat and rubber washer, in water and push over shaft, with shiny side of ceramic facing impeller bore, until bottoms firmly against shaft shoulder. Press on outside edge of seal case with carbon seal face towards ceramic seat to install seal assembly in seal bore. Press flush with bottom of impeller bore.

11870-SERIES: Assemble rubber boot over ceramic seal seat so that shiny surface of seal seat is outwards. Dip assembly in water and insert into seal bore. Press firmly but carefully on seal seat until it bottoms against shoulder of seal bore. Check to see that the seal seat assembly remains in position and does not “pop” back out. A slight twisting motion while pressing will seat it firmly in position.In this pump, either a wave washer seal or coil spring carbon seal may be used. The wave washer is used only if the carbon portion of the seal does not have a coil spring attached.



Inspect shaft and seal seat bore to be sure sealing surfaces are free of nicks or scratches. Clean shaft surface behind splines to ensure proper O-ring seal on shaft. Apply light film of grease on shaft surface behind spline area. Slide carbon ring assembly, with carbon facing ceramic, over the shaft and firmly up against the ceramic seat. If carbon portion of seal does not have an integral coil type tensioning spring, slide wave washer over the shaft and against the rubber boot on metal case containing O-ring and carbon. Install wearplate in bottom of impeller bore, locating slot in outside edge of wearplate over dowel pin in body. Apply a small amount of sealant to surface of cam and cam screw threads and install cam in impeller bore. Edge of cam should be flush with flange face of body. With a rotary motion in the direction the pump will be turning, push the impeller into the impeller bore until it is firmly bottomed. Turn body over to install clutch pulley assembly. Press key into shaft. Position clutch/pulley assembly on shaft aligning key with slot in pulley hub. Secure with bolt and washer. To tighten bolt securely, it may be necessary to hold the impeller to prevent the shaft from turning. Turn pump assembly over. Dip gasket in water, position on pump flange face, install end cover and secure with end cover screws.

EXPLODED VIEW

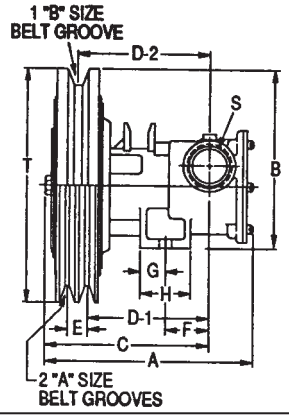


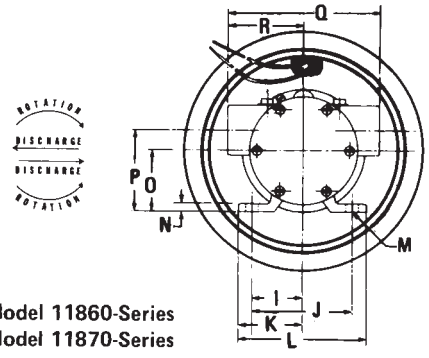
PARTS LIST

Key	Description		Qty. Req.	11860-Series Part No.	11870-Series Part No.
1	Screw End Cover	(3 Per Kit)	2	91003-0010	–
	Screw End Cover	(3 Per Kit))	2	–	91005-0040
2	End Cover		1	11831-0000	12062-0000
3	Gasket		1	890-0000	816-0000
4	Impeller Nitrile, Brass**		1	920-0003	836-0003
5	Wearplate		1	7868-0000	2574-0000
6	Body		1	11864-0000	18753-0585
7	Screw Cam	(3 Per Kit)	1	91004-0090	91005-0040
8	Cam, Brass		1	934-0000	834-0001
9	Pipe Plug		2	92650-0070	92650-0070
10	Slinger		1	3180-0000	3181-0000
11	Seal (Bearing)*		1	913-0000	817-0000
12	Ball Bearing (Pump)		1	92600-0540	92600-0040
13	Retaining Ring (Brg to Body)		1	18724-0000	18712-0000
14	Retaining Ring (Brg to Shaft)		1	18713-0000	18711-0000
15	Shaft		1	11867-0000	11877-0000
16	Seal (Shaft)		1	96080-0080	6407-0010
17	Roll Pin (Adaptor)		2	–	93100-0160
18	Adaptor		1	–	11876-0000
19	Key (Clutch Drive)		1	91401-0100	91401-0100
20	Clutch Assy. Complete	12 V – 2-A Grooves	1	92300-0030	92300-0030
		12 V – 1-B Groove		18753-0493	18753-0493
		24 V – 2-A Grooves		92300-0061	92300-0061
		24 V – 1-B Groove		18753-0494	18753-0494
		32 V – 2-A Grooves		–	92300-0050
21	Replacement Field Coil	12 V		98022-0500	98022-0500
		24 V		98022-2155	98022-2155
		32 V		98022-0510	98022-0510
	Service Kit Nitrile Impeller			90118-0003	90062-0003

* Use on pre 2002 models. Date code 01H or earlier.
**Special application model 11860-7001, use Impeller 17937-0001, Service Kit 90118-0001

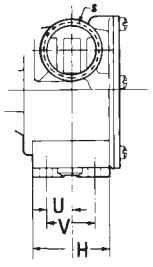
DIMENSIONAL DRAWING





Model 11860-Series
Model 11870-Series

Foot Mounting Details For Model 11870-Series



TABULATION OF DIMENSIONS (Inches and Millimeters)

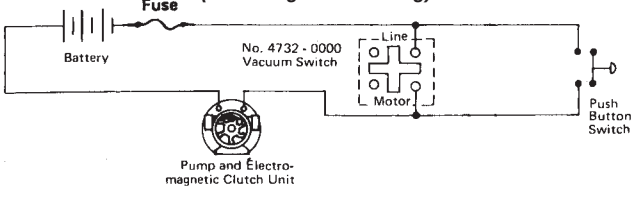
Model	A	B	C	D-1	D-2	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
11860 Series	6-3/16 157	5-3/8 137	4-29/32 125	3-9/16 90	3-7/8 98	5/8 16	1-5/16 33	3/4 19	1-1/2 38	1-9/16 40	3-1/8 79	2 51	4 102	13/32 10	1/4 6	1-7/8 48	2-1/2 64	4-3/4 21	2-3/8 60	1" NPT	7 178	—	—
11870 Series	8-3/16 208	6-1/16 154	7-1/16 179	5-1/4 133	5-9/16 141	5/8 16	—	1-7/32 31	2-5/16 59	2-1/4 57	4-1/2 114	2-3/4 70	5-1/2 140	13/32 10	5/16 8	2-9/16 65	3-13/16 97	5-7/8 149	2-15/16 75	1-1/4" NPT	7 178	3/16 21	1-1/2 38

CAPACITY TABLES

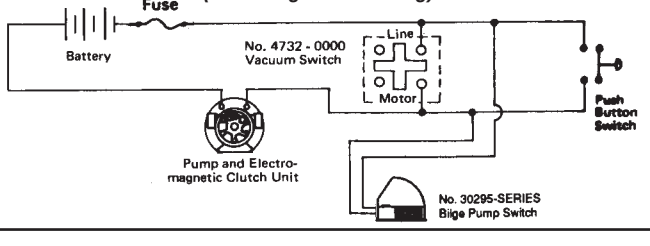
			Total Head		500 RPM			1160 RPM			1750 RPM			2450 RPM			3000 RPM		
	psi	kg per sq cm	feet of water	meters of water	GPM	LPM	HP	GPM	LPM	HP	GPM	LPM	HP	GPM	LPM	HP	GPM	LPM	HP
11860 Series	4.3	0.3	10	3.0	6.0	22.7	1/4	14.8	56.0	1/3	23.3	88.2	3/4	32.5	123.0	1	34.8	131.7	1-1/2
	8.7	0.6	20	6.1	5.5	20.8	1/4	14.1	53.4	1/2	22.3	84.4	3/4	31.8	120.4	1-1/2	34.2	129.5	1-1/2
	17.3	1.2	40	12.2	4.0	15.1	1/4	12.0	45.4	1/2	19.5	73.8	3/4	28.5	107.9	1-1/2	32.5	123.0	2
	26.0	1.8	60	18.3	—	—	—	8.8	33.3	3/4	15.0	56.8	1	23.5	89.0	1-1/2	29.8	112.8	2
	34.6	2.4	80	24.4	—	—	—	—	—	—	—	—	—	17.0	64.4	1-1/2	23.8	90.1	2
11870 Series	4.3	0.3	10	3.0	18.0	68.1	1/2	41.0	155.2	1	62.0	234.7	1-1/2	—	—	—	—	—	—
	8.7	0.6	20	6.1	17.0	64.4	1/2	40.0	151.4	1	60.0	227.1	1-1/2	—	—	—	—	—	—
	17.3	1.2	40	12.2	14.0	53.0	1/2	37.0	140.1	1-1/2	55.0	208.2	2	—	—	—	—	—	—
	26.0	1.8	60	18.3	—	—	—	30.0	113.6	1-1/2	50.0	189.3	2	—	—	—	—	—	—
	34.6	2.4	80	24.4	—	—	—	—	—	—	40.0	151.4	3	—	—	—	—	—	—

WIRING DIAGRAMS

Remote Control Engine Driven Pump
(While engine is running)



Remote Control and Automatic Engine Driven Bilge Pump
(While engine is running)



REMOTE CONTROL: Install a pushbutton switch at one or more locations (multiple switches should be wIred parallel). Depress pushbutton for 2 seconds. If there is water in bilge, pump will operate until dry, at which time vacuum switch will stop pump. If no water is in bilge, pump will stop when pushbutton is released.

AUTOMATIC BILGE PUMP: Install No. 30295-Series Automatic Bilge Pump Switch where it will energize clutch at maximum high water level in bilge. When water raises switch float, pump will start. Vacuum switch will maintain closed circuit until bilge is pumped dry. Pump will automatically stop, preventing impeller damage.

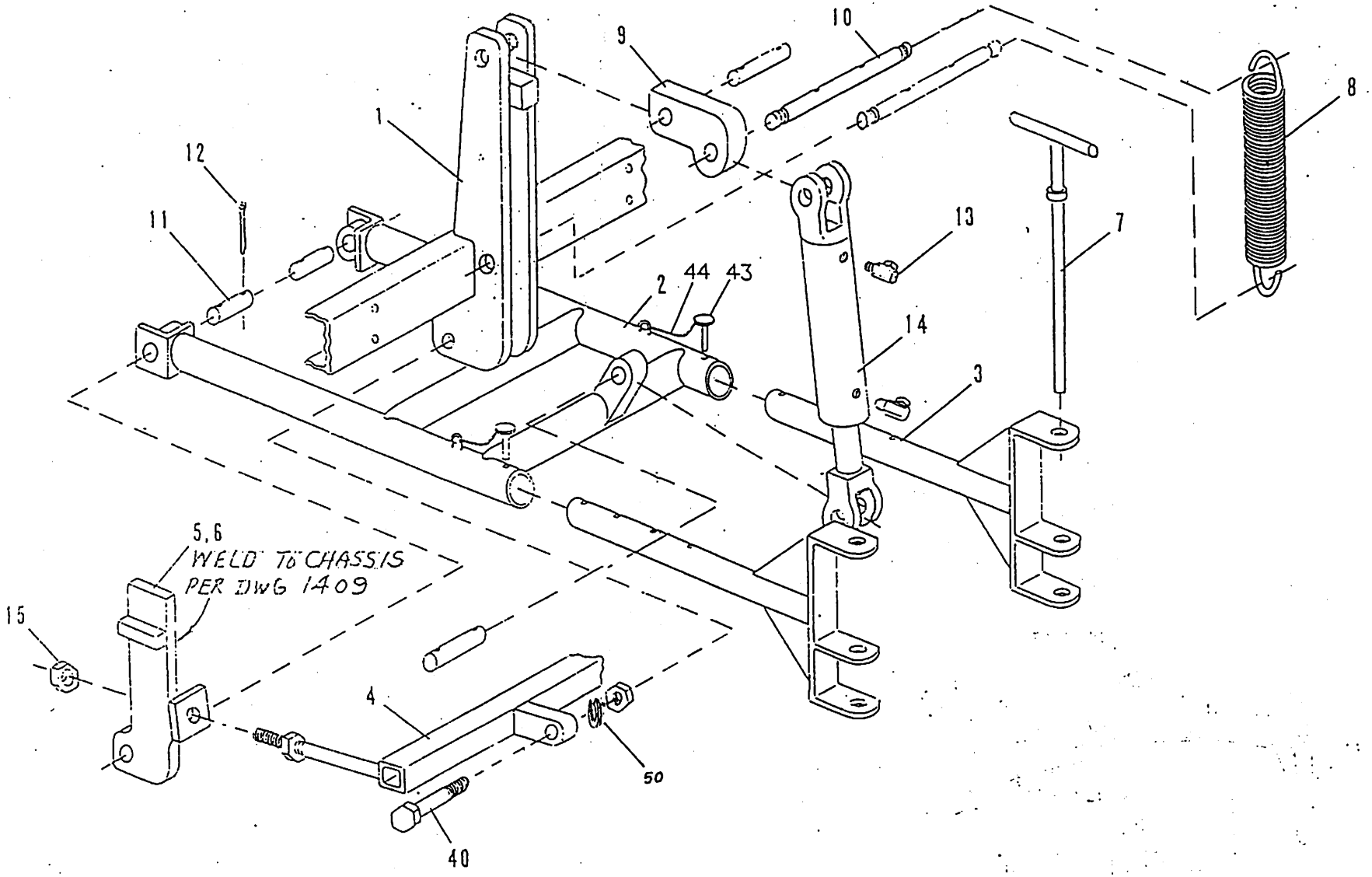
Jabsco

ITT Industries
Engineered for life

THE PRODUCTS DESCRIBED HEREIN ARE SUBJECT TO THE JABSCO ONE YEAR LIMITED WARRANTY, WHICH IS AVAILABLE FOR YOUR INSPECTION UPON REQUEST.

11 OPTIONS

MATL.	FINISH	DESC. KIT MOUNTING HARDWARE PLOWS AND FRONT SQUEEGEE	SHEET 1 OF 3	ITEM NO. 1446



DATE
12/11/86
REV. DATE
8/20/87
11/03/92
11/10/92
9/18/96

DRAWN BY:	SCALE	DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED. TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS F[illegible]OWS: ANGLES: ± 1° FRACTIONS: ± 1/16 .XX ± .010 .XXX ± .0010	FRANK J. ZAMBONI & CO., INC. PARAMOUNT, CALIFORNIA, U.S.

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MATL.	FINISH	DESC. KIT, MOUNTING HARDWARE FOR PLOWS AND FRONT SQUEEGEE	SHEET 2 OF 3	ITEM NO. 1-746

ITEM	PART NO.	DESCRIPTION	QTY
1	1410	BRKT, CYLINDER MTG.	1
2	9051	MOUNT, LIFT, "U" BRKT	1
3	9025	ARM, LIFT	2
4	1406	BRACE, BUMPER	1
5	1405	MOUNT, FRAME RT. SIDE	1
6	1407	MOUNT, FRAME, LT. SIDE	1
7	9020	PIN, CONNECTING	2
8	9022	SPRING	2
9	9037	BAR, CYLINDER PIVOT	1
10	9024	PIN, CYLINDER PIVOT	2
11	9023	PIN, PIVOT	4
12	HA-55716	COTTER PIN, 1/4 x 2	12
13	F2-69060	90 EL, 8MP, 4FS	2
14	9045	CYLINDER, HYD.	1
15	HA-22980	NUT, 3/4 -10	5

ITEM	PART NO.	DESCRIPTION	QTY
16	PM-3104C	HOSE, 3/8 x 26, 6MP, 6MP	1
17	PM-16928	HOSE, 1/4 x 168, 4MP, 6MP	2
18	7656	VALVE, SELECTOR	1
19	FL-81550	TEE, 06FP, 06FP, 06FP	1
20	F2-69080	90 EL, 6MP, 6FS	1
21	F2-64090	ADAPTER, 8MP, 6FS	3
38	HA-08009	SCREW, HX HD, 5/16-18 x 3/4	2
39	HA-08862	LOCKWASHER, 5/16	2
40	HA-22121	SCREW, HX HD, 3/4 -10, 3 1/4	1
43	9056	PIN	2
44	9100	CHAIN, #10 x 8"	2
45	PM-3176B	HOSE, 3/8 x 44, 06MP, 06MP	1
46	PM-1120B	HOSE, 1/4 x 30, 06MP, 06MP ... (1) ALSO USED WITHOUT PLOW	
47	F2-64080	ADATER, 06MP, 06FS	1
49	F2-62020	ADAPTER, 06MP, 06MPA	1

DATE
12/11/86
REV. DATE
8/20/87
8-23-88
11/9 R2 CB

DRAWN BY: CG	DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED. TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS: ANGLES: ± 1° FRACTIONS: ± 1/16 .XX ± .010 .XXX ± .0010	FRANK J. ZAMBONI & CO., INC. PARAMOUNT, CALIFORNIA, U.S.A.
SCALE		

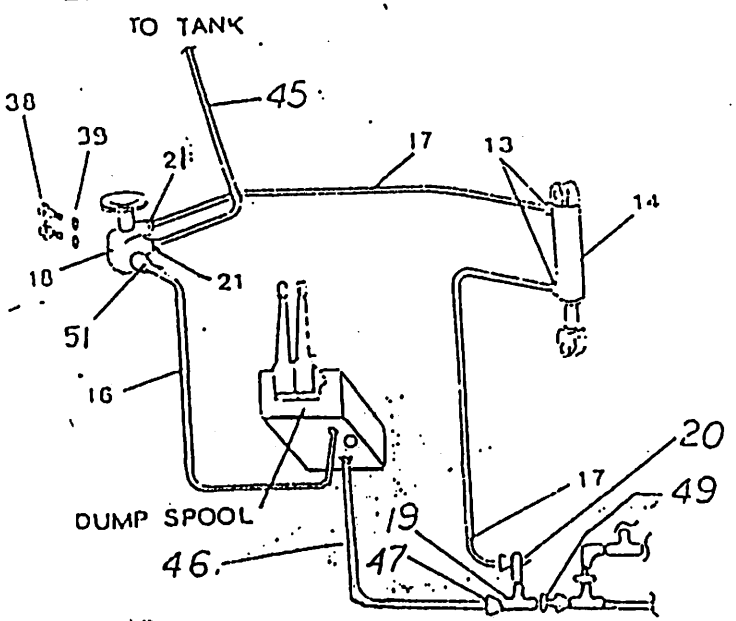
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MATL.	FINISH	DESC. KIT MOUNTING HARDWARE PLOWS AND FRONT SQUEEGEE	SHEET 3 OF 3	ITEM NO. 1446

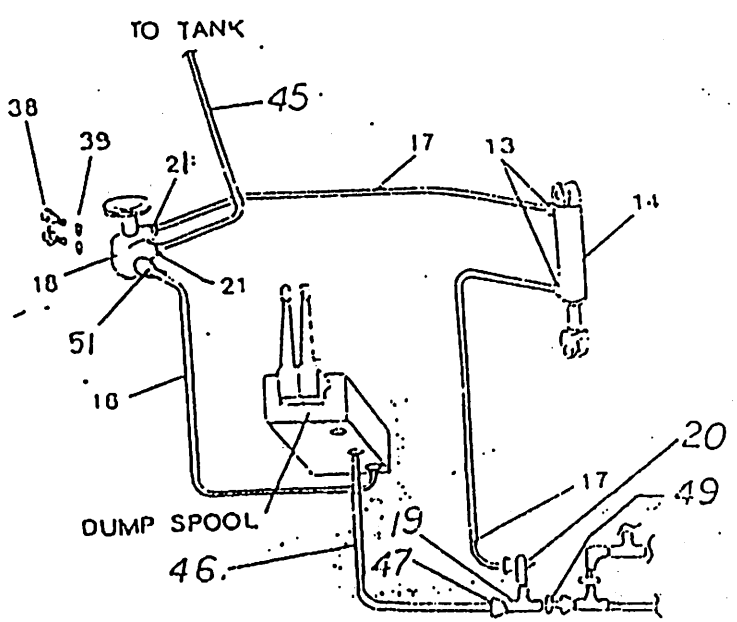
DATE 9/18/16

REV. DATE

WALVOIL VALVE



VICKERS VALVE



DRAWN BY: CG	DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED. TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS: ANGLES: ± 1° FRACTIONS: ± 1/16 .XX ± .010 .XXX ± .0010	FRANK J. ZAMBONI & CO., INC. PARAMOUNT, CALIFORNIA, U.S.A.
SCALE N-T-S		

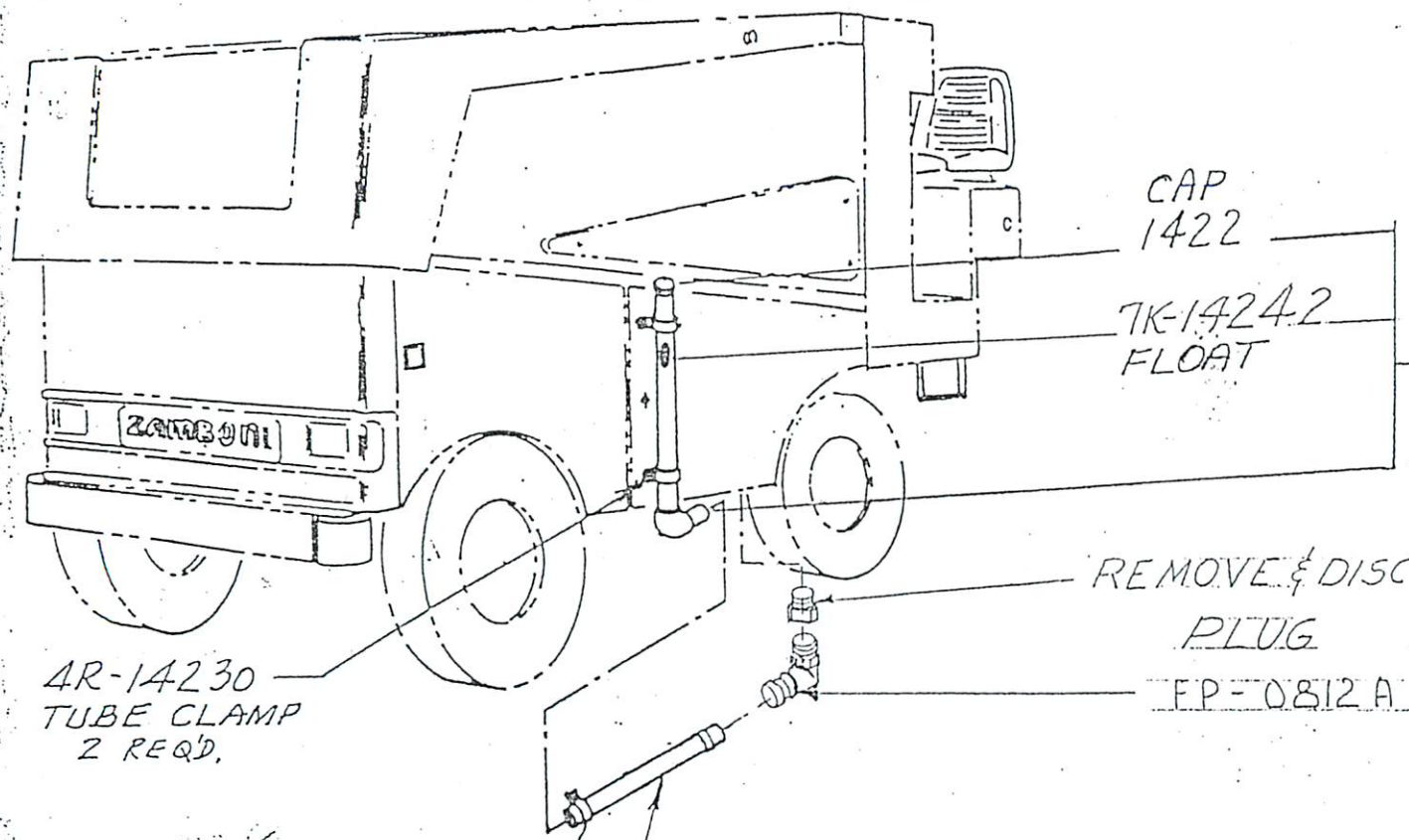
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MATL.	FINISH	DESC. KIT, WATER LEVEL SIGHT GAGE	SHEET 1 OF 1	ITEM NO. KZ-1421A

FOR FIELD KIT INCLUDE DK-1421A INSTRUCTIONS

DATE 7/29/91

REV. DATE



CAP 1422

7K-14242 FLOAT

7K-14240 ASSEMBLY

REMOVE & DISCARD EXISTING PLUG

FP-0812A-90° EL 08MP-12HOSE

4R-14230 TUBE CLAMP 2 REQ'D.

27-2016A HOSE CLAMP 2 REQ'D.

RH-4096A HOSE

DRAWN BY: C.G.

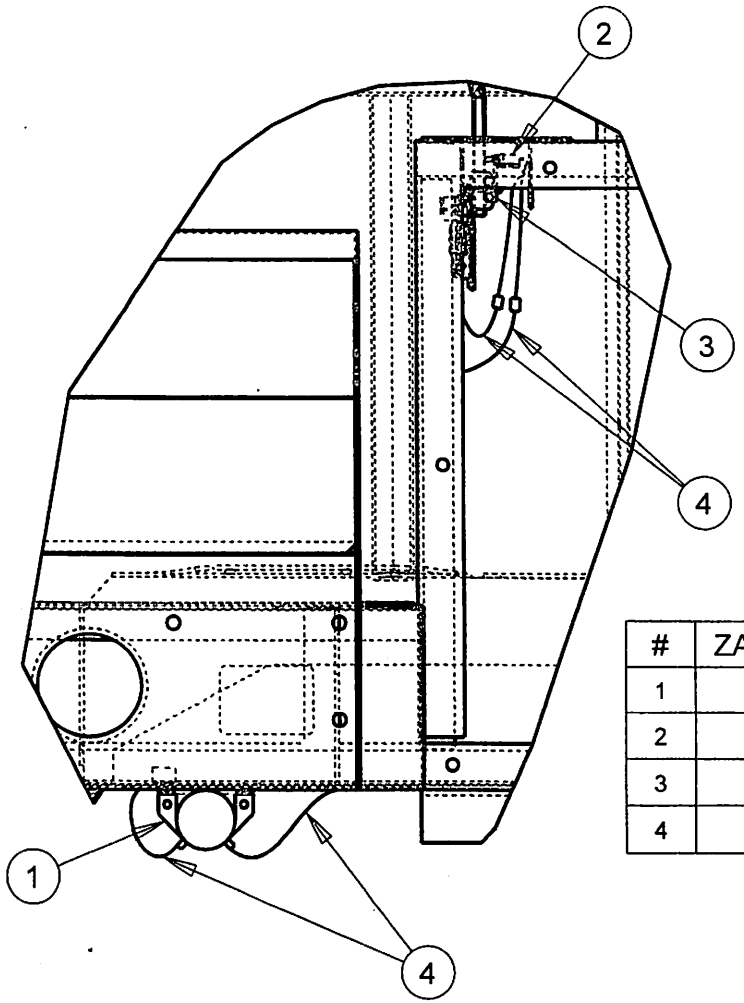
SCALE

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS:
ANGLES: ± 1° FRACTIONS: ± 1/16 .XX ± .010 .XXX ± .0010

FRANK J. ZAMBONI & CO., INC.
PARAMOUNT, CALIFORNIA, U.S.

MATL.	FINISH	DESC.	SHEET	ITEM NO.
		KIT, BACK UP ALARM FACTORY INSTALLATION, 500/540/545/546/700	1 OF 2	KZ-0240A

REV. A
8/31/12
KM



#	ZAMBONI P/N	DESCRIPTION	QTY
1	7X-0501A (A)	BACKUP ALARM	1
2	7P-0410C	SWITCH, BACKUP ALARM	1
3	7P-0520D	BRCKT, BACKUP ALARM	1
4	75-19830	LOOM, BACKUP ALARM	1

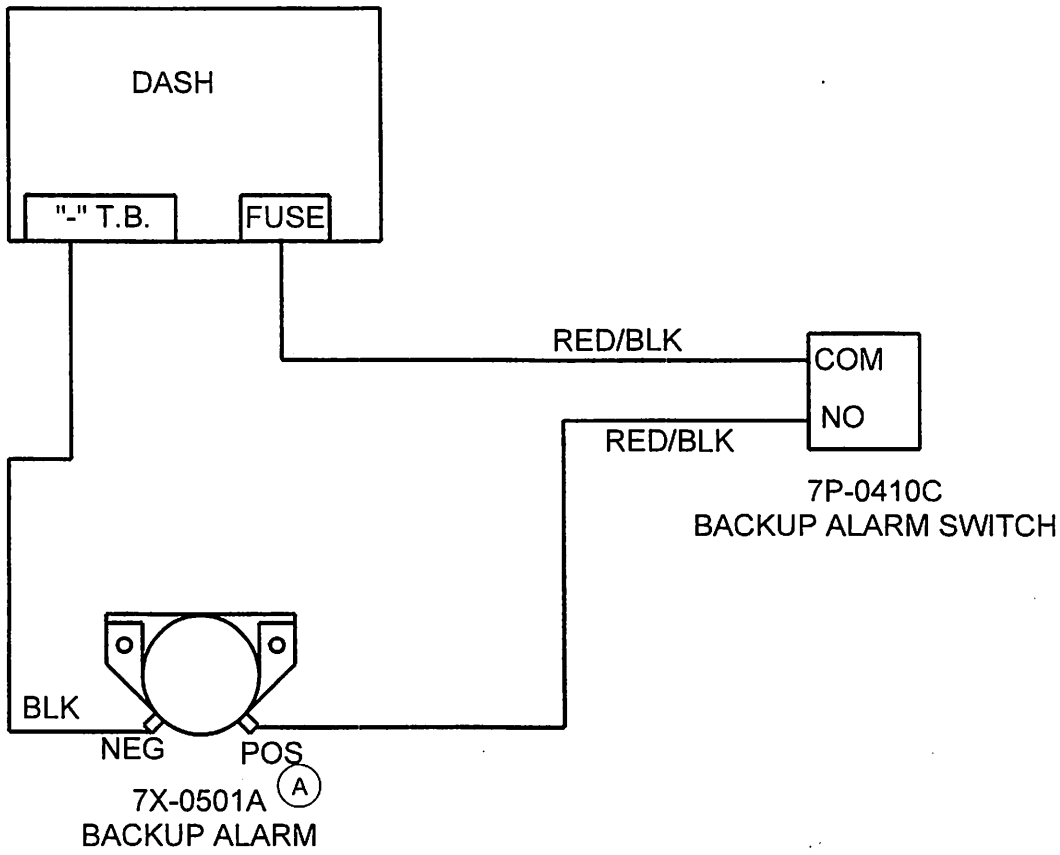
REAR VIEW OF OPERATOR PLATFORM

DRAWN BY K. BITTER	CAD INFO	DIR TURTLE D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE N/A	DATE 3/12/03	.DWG KZ0240A .PRT	ASM KZ0240A	

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
		KIT, BACK UP ALARM ELEC. DIAGRAM 500/540/545/546/700	2 OF 2	KZ-0240A

REV. (A) 8/31/12 KM

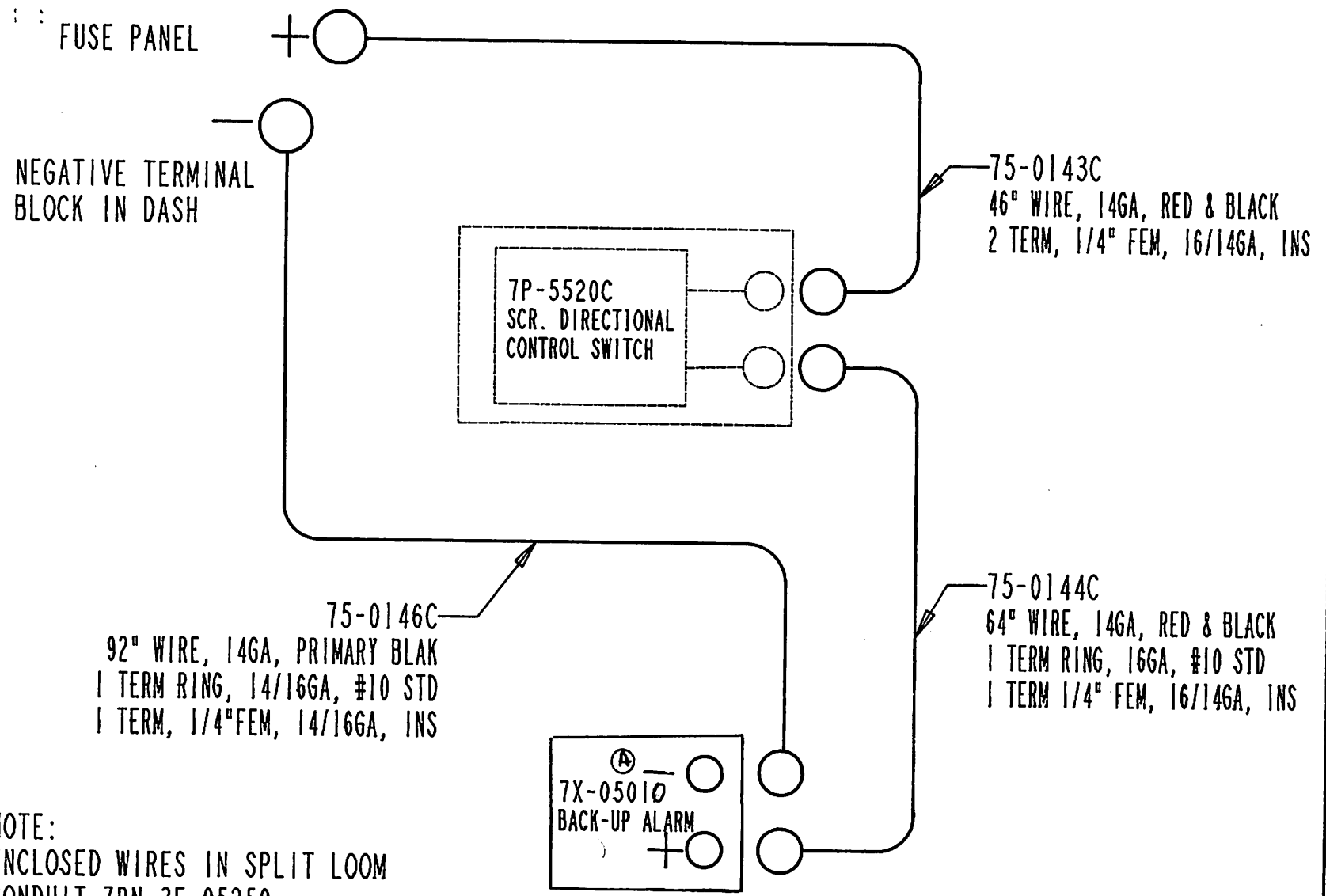


DRAWN BY K. BITTER	CAD INFO	DIR TURTLE_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ± 1°	FRANK J. ZAMBONI & CO. INC.
SCALE N/A DATE 3/12/03	.DWG KZ0240A			THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.
	.PRT	ASM		

MATL.	FINISH	DESC.	SHEET	ITEM NO.
NOTED	-------	BACK-UP ALARM SCHEMATICS	1 OF 1	KZ-0210D

REV. (A) 3/2/95 CB; (B) 4/25/95

(B) NOTE : ALL WIRES ~~ARE PART~~ OF 75-19830



NOTE:
ENCLOSED WIRES IN SPLIT LOOM CONDUIT ZPN 3E-95259.

FRANK J. ZAMBONI & CO. INC.

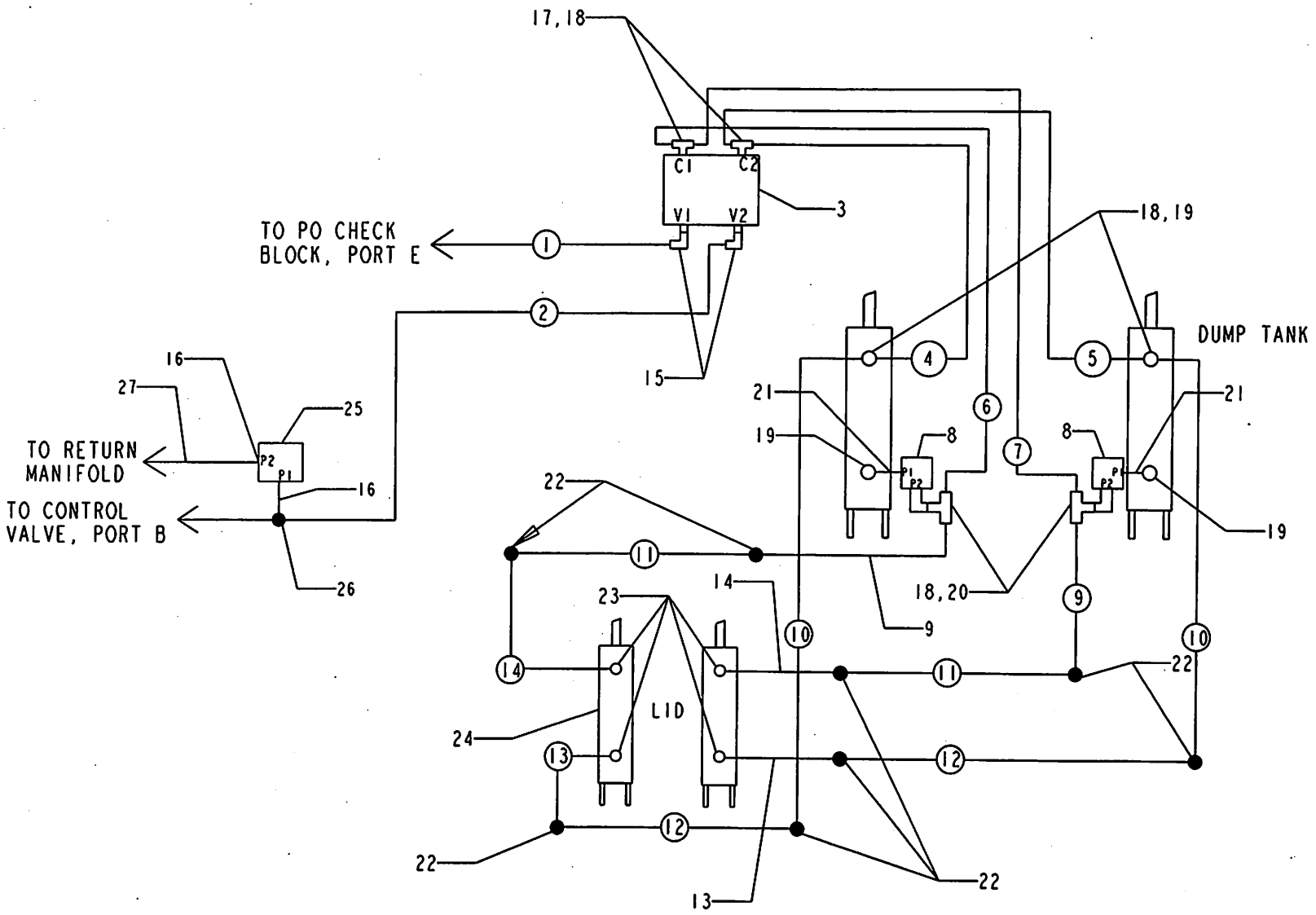
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DIMENSIONS ARE IN INCHES.
TOLERANCES: X±.10, XX±.060, XXX±.030
ANGLES ±1°

DRAWN BY	CB
SCALE	NONE
DATE	6/29/94

MATL.	FINISH	DESC.	SHEET	ITEM NO.
		HYDRAULIC LID ACTUATION, MODELS 545/552	1 OF 2	DM-56240

REV.



DRAWN BY CA		CAD INFO	DIR PROE20PARTS	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE NONE	DATE 1/18/11	.DWG DM56240			THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.
		.PRT	.ASM		

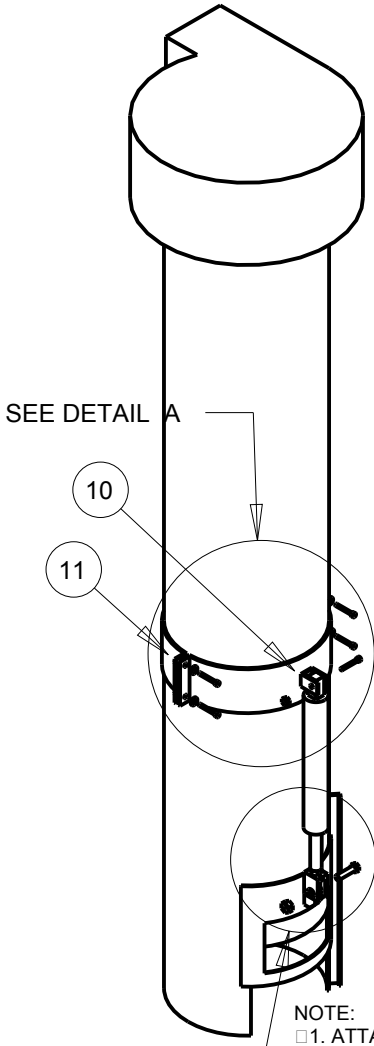
MATL.	FINISH	DESC. HYDRAULIC LID ACTUATION, MODELS 545/552	SHEET 2 OF 2	ITEM NO. DM-56240

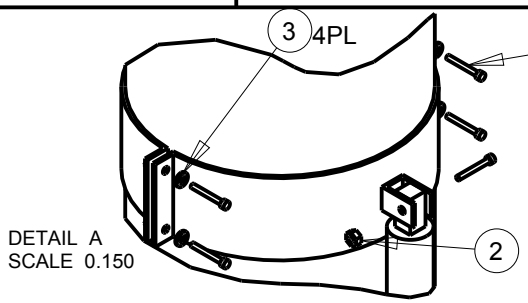
REV.

ITEM #	PART #	DESCRIPTION	QTY
1	PM-1454A	HOSE, 1/4X109.0, 06MP X 06MP	1
2	PM-3528B	HOSE, 3/8X132.0, 06MP X 06MP	1
3	2V-56500	VALVE, LOAD HOLDING	1
4	PN-3178A	HOSE, 3/8X44.5, 06ORS X 06ORS 45°	1
5	PN-3208A	HOSE, 3/8X52, 06ORS X 06ORS 45°	1
6	PN-3144A	HOSE, 3/8X36, 06ORS X 06ORS 45°	1
7	PN-3164A	HOSE, 3/8X41, 06ORS X 06ORS 45°	1
8	2V-56600	VALVE, FLOW DIVERSION	2
9	PN-2144A	HOSE, 1/4X36, 04ORS X 06ORS 90°	2
10	PN-2084A	HOSE, 1/4X21, 04ORS X 06ORS 90°	2
11	4P-55630	TUBE, STEEL, 1/4X87, 04FORS	2
12	4P-55620	TUBE, STEEL, 1/4X85, 04FORS	2
13	PN-2060A	HOSE, 1/4X15, 04ORS X 04ORS 90°	2
14	PN-2104A	HOSE, 1/4X26, 04ORS X 04ORS 90°	2
15	FI-69030	ADAPTER, 06MB,06FS, 90°	2
16	FI-64300	ADAPTER, 06MB, 06FS, STR.	2
17	FS-50600	ADAPTER, 06MB, 06ORS, STR.	2
18	FS-23600	TEE, 06 ORS	6
19	FS-50608	ADAPTER, 08MP, 06ORS, STR.	4
20	FS-04600	ADAPTER, 06MB, 06ORS, 90°	2
21	FS-50601	ADAPTER, 06MB, 06 FORS, STR.	2
22	FS-23400	ADAPTER, BULKHEAD, 04 ORS	8
23	FS-04404	ADAPTER, 04MP, 04 ORS, 90°	4
24	2X-56000	HYDRAULIC CYLINDER, LID	2
25	2V-56700	RELIEF VALVE, SET @ 100PSI	1
26	F2-81135	TEE, 06MP-06MP-06FS	1
27	PM-3128B	HOSE, 3/8X32, 06MP X 06MP	1
N/S	5T-56240	BRACKET, LOAD HOLDING VALVE MOUNT	1
N/S	7A-15560	WELDMENT, SNOW TANK, HYD. LID	1

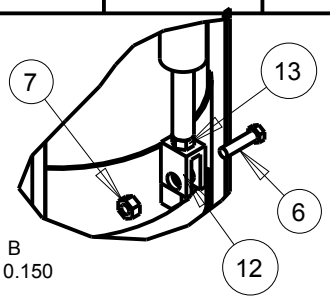
DRAWN BY CA	CAD INFO	DIR PROE20PARTS	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE NONE DATE 1/18/11	.DWG DM56240			THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.
	.PRT	.ASM		

MATL.	FINISH	DESC.	SHEET	ITEM NO.
		AUTOMATIC HYDRAULIC SNOW BREAKER	1 OF 5	DK-65100





DETAIL A
SCALE 0.150



DETAIL B
SCALE 0.150

INDEX	DESCRIPTION	QTY	ZPN
1	1/4-20 UNC 2A X 1 BOLT	5	HA-06014
2	(A) 1/4-20 UNC 2B NUT NYLOCK	1	HA-06860
3	1/4 LOCK WASHER	4	HA-06862
6	3/8-16 UNC 2A X 1.5 BOLT	1	HA-10014
7	3/8-16 UNC 2B NUT NYLOCK	1	HA-10981
8	3/8-16 UNC 2A X 1 BOLT	2	HA-10011
9	5/16 FLAT WASHER	2	HA-08860
10 *	(A) CYLINDER MTG BRACKET	1	5T-65120
11 *	(A) CYLINDER MTG BRKT	1	5T-65110
12 *	(A) CYLINDER CLEVIS	1	36-01570
13	(B) 3/8-24 UNF NUT	1	HA-11980

*NOTE:
FOR ITEM 11 USE:

552	SERIAL#
5T-65110	4493-6318
5T-65115	6583-6894

500	SERIAL#
5T-65110	2804-6288
5T-65115	6484-6864

STARTING AT SERIAL # 7089 FOR 552 AND 6989 FOR 500 MODELS, ITEM #10 IS WELDED ON THE HOUSING.

NOTE:
1. ATTACH SWOW BREAKER TO CYLINDER CLEVIS WITH CYLINDER IN RETRACTED POSITION
2. SLIDE SNOW BREAKER IN TRACKS & ALIGN THE BOTTOM END WITH TOP OF OPENING IN VERTICAL AUGER
3. ATTACH CYLINDER TO MOUNTING BRACKET & CLAMP AROUND AUGER TUBE AS SHOWN
4. ITEMS 8 & 9 NOT USED FOR PRODUCTION KITS
(B) 5. USE LOCKTITE (BLUE) ON CYLINDER CLEVIS & JAM NUT THREADS

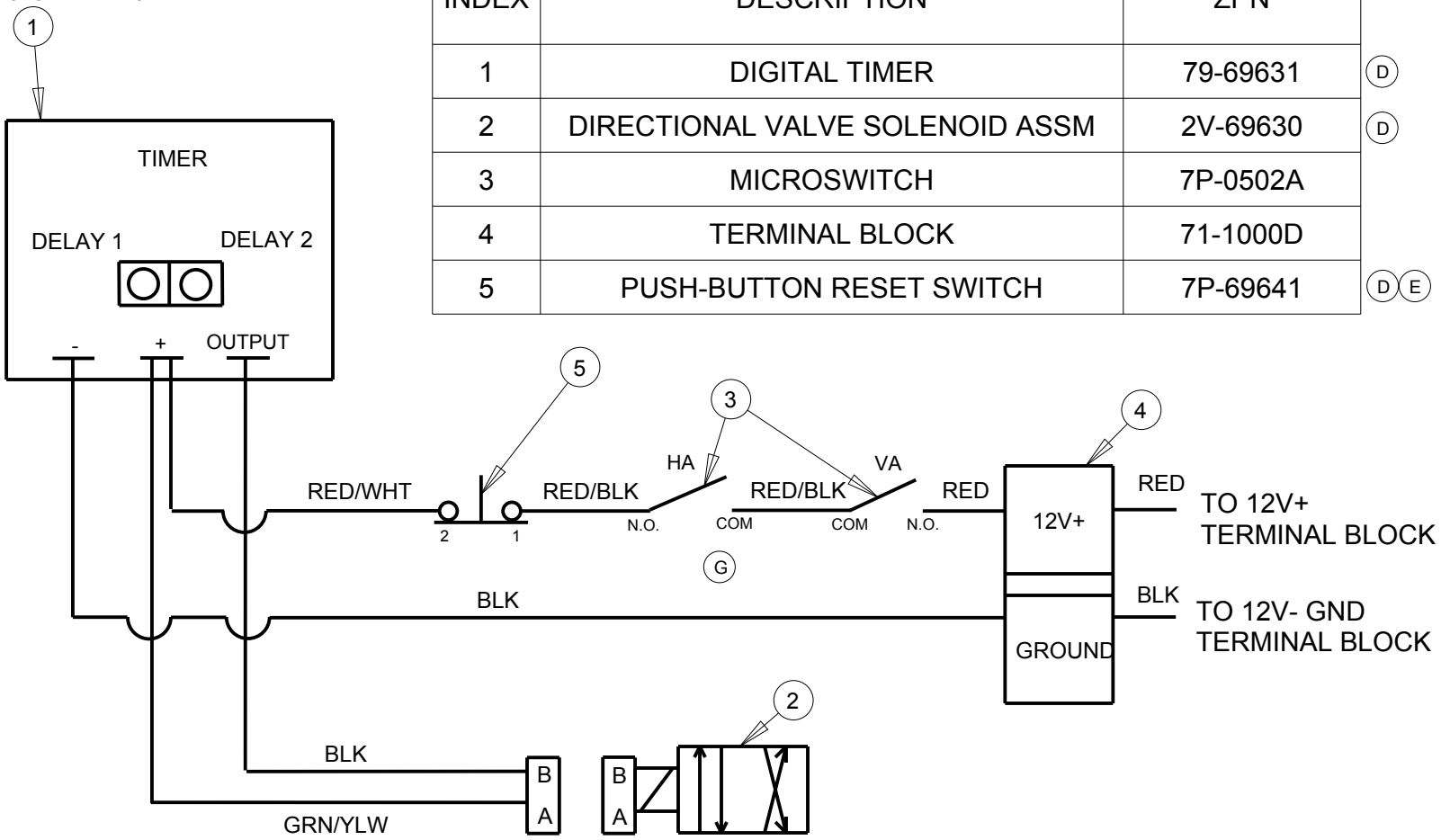
REV.	
(A)	1/27/99 RC
(B)	3/31/99 RC
(C)	2/14/01 CB
(D)	1/11/10 KM
(E)	10/26/11 KM
(F)	4/10/12 KM
(G)	11/15/12 KM
(H)	12/9/13 KM

DRAWN BY	R.CONCEPCION	CAD INFO	DIR RUDY_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE	NONE	DATE 12/13/96	.DWG DK65100		THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.
			.PRT .ASM		

MATL.	FINISH	DESC.	SHEET	ITEM NO.
		AUTOMATIC SNOWBREAKER ELECTRIC SCHEMATIC	2 OF 5	DK-65100

DELAY 1: CYCLE TIME TO EXTEND CYLINDER
DELAY 2: CYCLE RETRACT TIME + DELAY TIME

INDEX	DESCRIPTION	ZPN	
1	DIGITAL TIMER	79-69631	D
2	DIRECTIONAL VALVE SOLENOID ASSM	2V-69630	D
3	MICROSWITCH	7P-0502A	
4	TERMINAL BLOCK	71-1000D	
5	PUSH-BUTTON RESET SWITCH	7P-69641	D E



* NOTE:
1. KIT KZ-65105; USE 2 MICRO SWITCHES (7P-0502A)
2. KIT KZ-65110; USE MICRO SWITCH 7P-65100-VER. AUGER & 7P-0502A-HOR. AUGER
3. WHEN USING KZ-65105 & KZ-65110, USE TWO SWITCH BRKTS 7T-55235 FOR 500 & AN ADDITIONAL ONE FOR 552
4. KIT KZ-65115; USE DASH SWITCH 7P-65110
5. REFER TO WIRE HARNESS 75-65100 FOR ADDITIONAL DIAGRAM NOTES

REV.	
D	1/11/10 KM
E	10/26/11 KM
F	4/10/12 KM
G	11/15/12 KM
H	12/9/13 KM

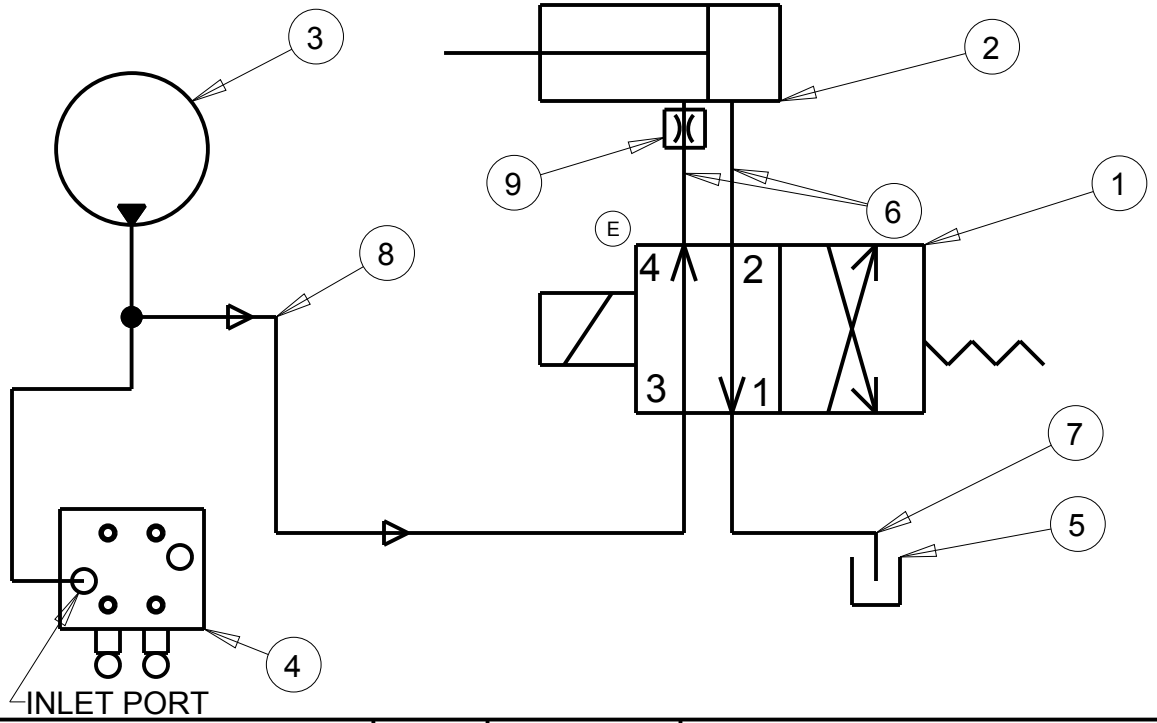
DRAWN BY R.CONCEPCION	CAD INFO .DWG DK65100 .PRT .ASM	DIR RUDY_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°
SCALE NONE	DATE 11/20/96		

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
		AUTOMATIC SNOWBREAKER HYDRAULIC CIRCUIT	3 OF 5	DK-65100

INDEX	DESCRIPTION	ZPN
1	DIRECTIONAL CONTROL VALVE (SNOW BREAKER)	2V-69630 (D)
2	1 1/2" BORE X 7" STROKE CYLINDER	2X-65100
3	HYDRAULIC ACCESSORY PUMP 500/552	--------
4	VERTICAL AUGER HYD. CONTROL VALVE (INLET)	--------
5	HYDRAULIC TANK RETURN MANIFOLD	7A-15870



INDEX	HYDRAULIC HOSE ZPN
6	PM-1124C
7	PM-3124B
8	PM-3196B
9	F2-9304E

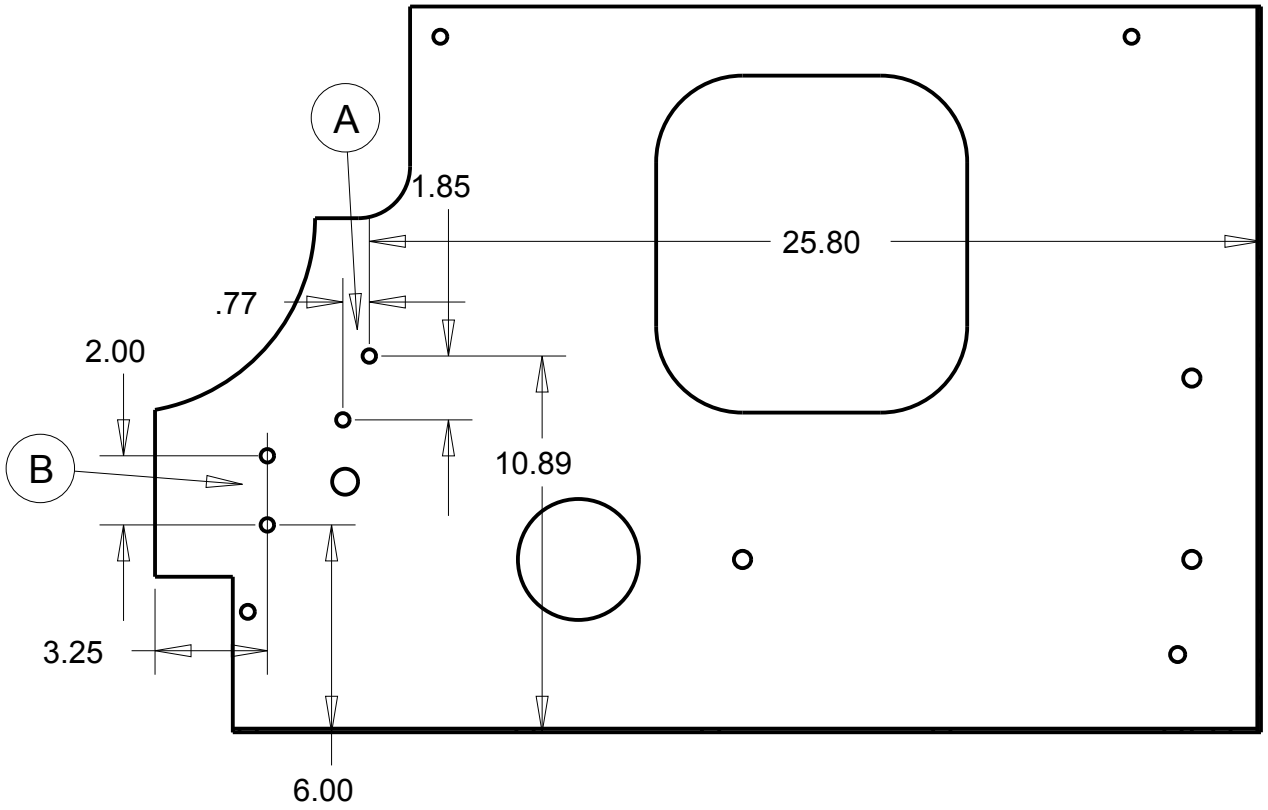
REV.	
(D)	1/11/10 KM
(E)	10/26/11 KM
(F)	4/10/12 KM
(G)	11/15/12 KM
(H)	12/9/13 KM

DRAWN BY R.CONCEPCION	CAD INFO	DIR RUDY_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ± 1°
SCALE NONE / DATE 11/20/96	.DWG DK65100	.PRT / .ASM	

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
		SNOW BREAKER PANEL MNTG HOLE LOCATION	4 OF 5	DK-65100



REV.	
D	1/11/10 KM
E	10/26/11 KM
F	4/10/12 KM
G	11/15/12 KM
H	12/9/13 KM

NOTE:

□A. HOLE LAYOUT FOR VEHICLES WITH MANUAL BOARD BRUSH HYDRAULIC VALVE

□B. HOLE LAYOUT FOR VEHICLES WITH SOLENOID OPERATED BOARD BRUSH

□C. DRILL HOLES @ ∅ 3/8

DRAWN BY R.CONCEPCION	CAD INFO / DIR RUDY_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ± 1°	FRANK J. ZAMBONI & CO. INC.
SCALE NONE / DATE 12/13/96	.DWG DK65100 / .PRT / .ASM		

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MATL.	FINISH	DESC. AUTOMATIC SNOWBREAKER TIMER SETTING INSTRUCTIONS	SHEET 5 OF 5	ITEM NO. DK-65100

REV.	
D	1/11/10 KM
E	10/26/11 KM
F	4/10/12 KM
G	11/15/12 KM
H	12/9/13 KM

INSTRUCTIONS FOR SETTING THE AUTO SNOWBREAKER TIMER INSIDE THE DASH:

1. VIEWED WITH THE TERMINALS ON THE BOTTOM AND THE POTENTIOMETERS ABOVE THEM (REF SHT 2):
LEFT POTENTIOMETER: CYLINDER EXTEND TIME - TIME IT TAKES TO STROKE DOWN
RIGHT POTENTIOMETER: CLYINDER RETRACT + DELAY TIME - TIME IT TAKES TO STROKE UP AND RESTART CYCLE

2. FULL CYCLE TIME SHOULD BE SET TO 10 SEC:
CYCLE: 3 SEC DOWN / 3 SEC UP / 4 SEC HOLD

3. TURN THE MACHINE POWER ON. MAKE SURE THE MACHINE IS IN A SAFE CONDITION,
AS THE VERTICAL AND HORIZONTAL AUGERS WILL NEED TO BE RUN TO SET THE TIMER CORRECTLY.
ON FUEL-POWERED MACHINES, ADJUST THE ENGINE SPEED TO THE STANDARD OPERATING RPM FOR RESURFACING
(2800-3000 RPM).

4. TURN BOTH OF THE AUGERS ON WITH THE VALVE HANDLES.
THIS CLOSES THE MICROSWITCHES THAT DELIVER 12V+ POWER TO THE TIMER.

5. USING A SMALL PHILLIPS OR FLATHEAD SCREWDRIVER, TURN BOTH POTENTIOMETERS COMPLETELY COUNTER CLOCKWISE (CCW).
THE SNOWBREAKER WILL MOVE IN SHORT, INCOMPLETE DOWN/UP MOTIONS.

6. ADJUST DELAY 1 AND DELAY 2 CLOCKWISE (CW) UNTIL THE CYLINDER EXTEND TIME (~3SEC) IS CORRECT.
ADJUSTING DELAY 2 WILL BE REQUIRED TO ALLOW THE CYLINDER TO FULLY EXTEND.
THE OVERRIDE BUTTON CAN BE USED TO RESTART THE CYCLE TO SPEED UP THIS PROCESS.

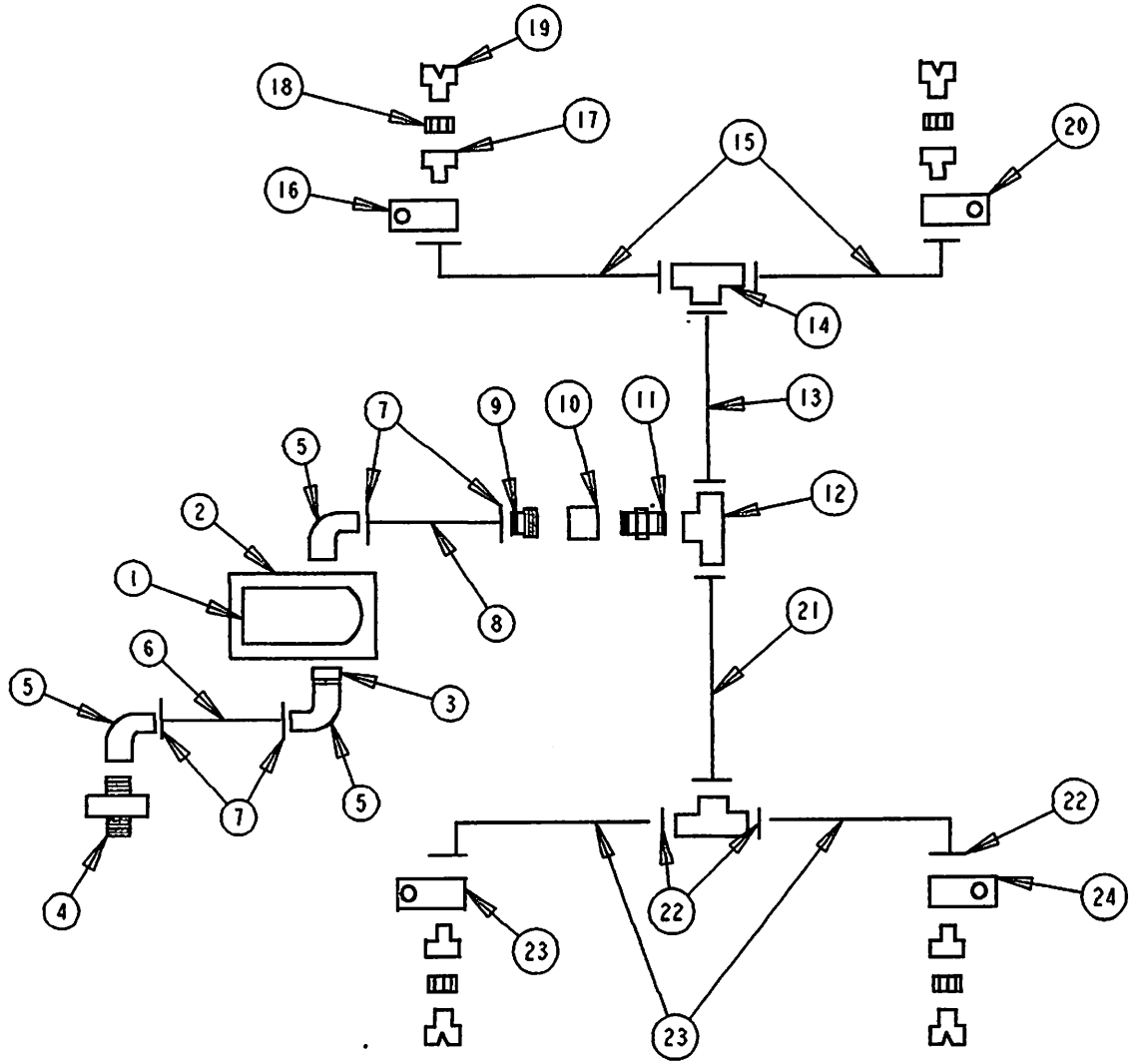
7. ONCE THE CYLINDER EXTEND TIME IS CORRECT, ADJUST DELAY 2 SO THAT THE COMPLETE CYCLE TIME IS CORRECT:
10 SEC (6 CYCLES/MIN).

DRAWN BY R.CONCEPCION	CAD INFO	DIR RUDY_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE NONE DATE 11/20/96	.DWG DK65100			
	.PRT	.ASM		

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
NOTED	------	TIRE WASH SYSTEM, 500, 552	1 OF 3	DK-SL500

REV.	
A	3/16/99 CB
B	6/1/99 CB



NOTE;
SEE NEXT SHEET FOR PN'S, DESCRIPTION, AND QTY'S.

DRAWN BY	CB	CAD INFO	DIR
SCALE	NONE	DATE	1/26/96
		.DWG	
		.PRT	.ASM

DIMENSIONS ARE IN INCHES.
TOLERANCES: X±.10, XX±.060, XXX±.030
ANGLES ±1°

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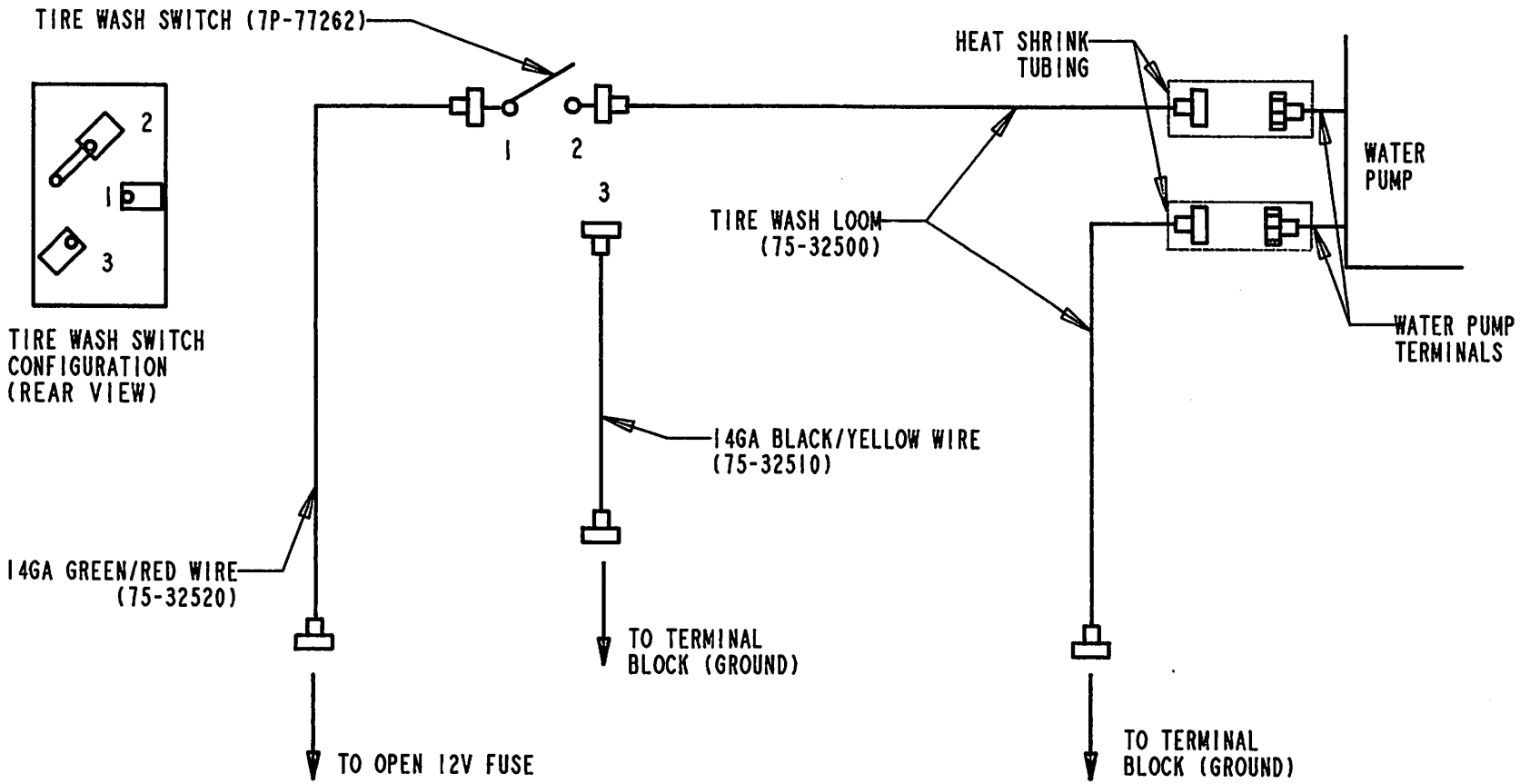
DK-32500 - INSTRUCTIONS, TIRE WASH SYSTEM

IND.NO.	PN	DESCRIPTION	QTY	NOTES
1	2P-3200	WATER PUMP	1	
2	5T-00008	BRACKET, WATER PUMP	1	
N/S	HA-04113	SCREW, SKT HD, 10-32 X 1-1/4	4	
NS/	HA-04981	LOCKNUT, HEX, 10-32	4	
3	3R-32000	STRAINER, WATER PUMP	1	
4	FP-0808B	STR ADAPTER	1	IF EQUIPPED W/SIGHT GAUGE, SUBSTITUTE WITH A TEE
5	FP-1200A	FITTING, SWIVEL WINGNUT	3	
6	RH-4000A	HOSE, 3/4", 23"LONG	23"	
7	27-2012A	CLAMP, 1-1/4	4	
8	RH-4000A	HOSE, 3/4", 10" LONG	10"	
9	FP-0812C	ADAPTER	1	
10	FV-33530	COUPLING	1	
11	2V-32510	CHECK VALVE	1	
12	FP-0808C	TEE	1	
13	RH-2000A	HOSE, 1/2", 44" LONG	44"	
14	FP-0808A	TEE	2	
15	RH-2000A	HOSE, 1/2, 30" LONG	30" X 4	
16	5T-32017	LH FRONT NOZZLE BRACKET	1	USED FOR 552 MACHINES
N/S	HA-10980	NUT, HX, 3/8-16	1	
N/S	HA-10862	LOCKWASHER, 3/8	1	
16	5T-32080	LH FRONT NOZZLE BRACKET	1	UED FOR 500 MACHINES
N/S	HA-06009	SCREW, HX HD, 1/4-20X3/4	2	
N/S	HA-06981	LOCKNUT, 1/4-20	2	
17	FP-0811A	ELBOW	4	
18	FP-1100A	NUT, SWIVEL, SPRAY NOZZLE	4	
19	FA-32000	SPRAY TIP	4	
20	5T-32016	RH FRONT NOZZLE BRACKET	1	USED ON 552 MACHINES
N/S	HA-10980	NUT, HX, 3/8-16	1	
N/S	HA-10862	LOCKWASHER, 3/8	1	
20	5T-32070	RH FRONT NOZZLE BRACKET	1	USED ON 500 MACHINES
N/S	HA-08009	SCREW, HEX HD, 5/16-18X3/4	1	
N/S	HA-08860	FLAT WASHER, 5/16	1	
N/S	HA-08981	LOCKNUT, 5/16-18	1	
21	RH-2000A	HOSE, 1/2", 50" LONG	50"	
22	27-2006B	CLAMP, 7/16	12	
23	5T-32030	LH REAR NOZZLE BRACKET	1	
24	5T-32040	RH REAR NOZZLE BRACKET	1	
N/S	HA-08011	SCREW, HEX HD, 5/16-18X1	2	
N/S	HA-08860	FLAT WASHER, 5/16	4	
N/S	HA-08981	LOCKNUT, 5/16-18	2	

MAT'L.	FINISH	DESC.	SHEET	ITEM NO.
NOTED		TIRE WASH SYSTEM	3 OF 3	DK-32500

REV.

ELECTRICAL SCHEMATIC



75-0670C - TERMINAL 1/4 MALE PUSH ON INS.

75-0670D - TERMINAL 1/4 FEM 16/14GA INS

NOTE:
PULL TWO HEAT SHRINK TUBES OVER THE CONNECTOR TERMINALS INSTALLED ON THE WATER PUMP AND USE A HEAT GUN TO SHRINK THEM.

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DIMENSIONS ARE IN INCHES.
TOLERANCES: X±.10, XX±.060, XXX±.030
ANGLES ±1°

DRAWN BY	C.B.
SCALE	NONE
DATE	1/25/95

KZ-19710

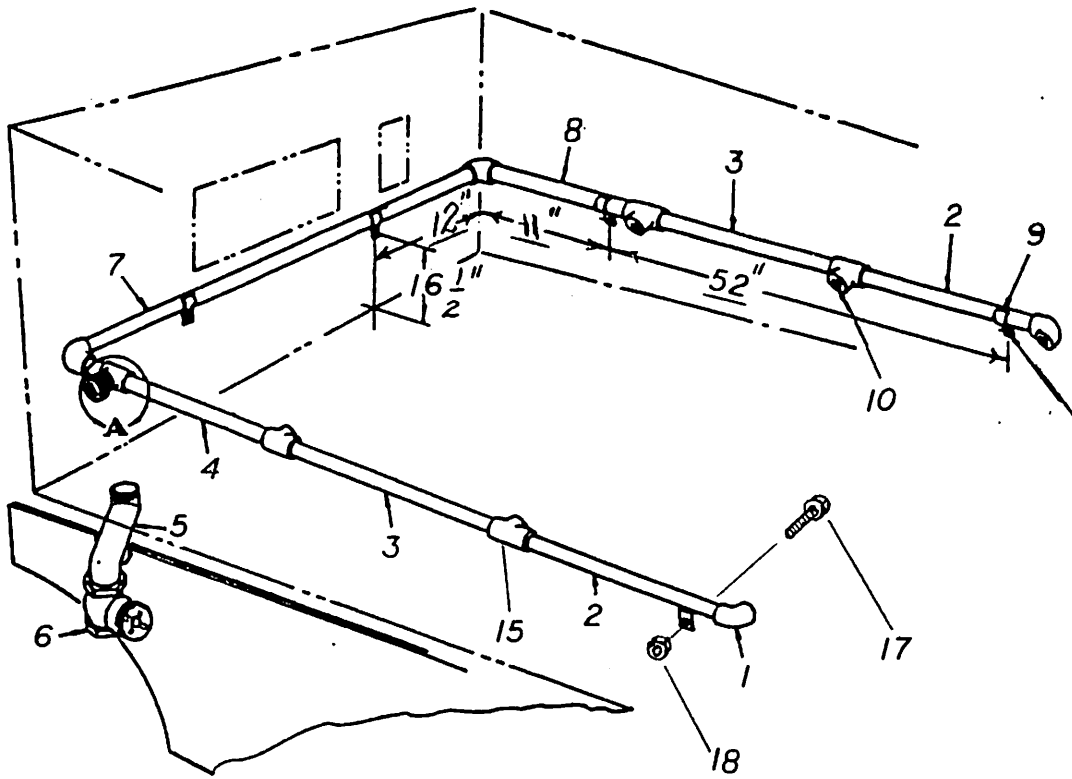
SNOW MELTING INSTALLATION

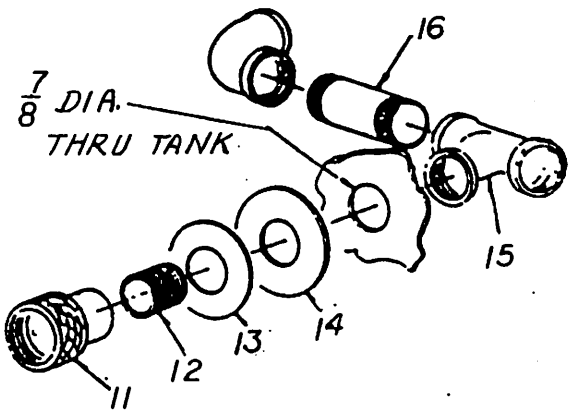
1. Cut 2 7/8" diameter hole in bottom of snow tank.
2. Weld flange in tank part # FH-28420.
3. Assemble pipes set in tank 16 1/2" from floor.
4. Lay out hole for hose connector using pipe assembly as fixture. Drill 7/8" hole.
5. Drill 5 9/32" hole for clamps and install pipe assembly.
6. Replace right rear side panel.
7. Install manifold and 2" gate valve.

MATL.	FINISH	DESC. KIT, SPRINKLER, SNOW MELTING	SHEET 2 OF 4	ITEM NO. DK-19710

DATE 12/12/86

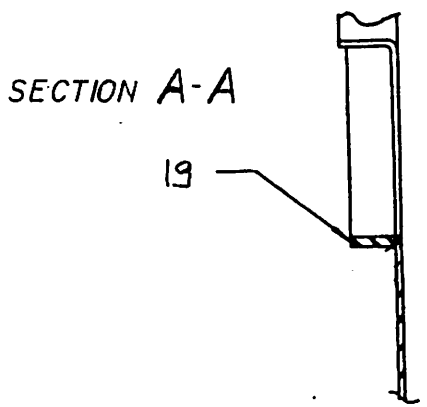
REV. DATE



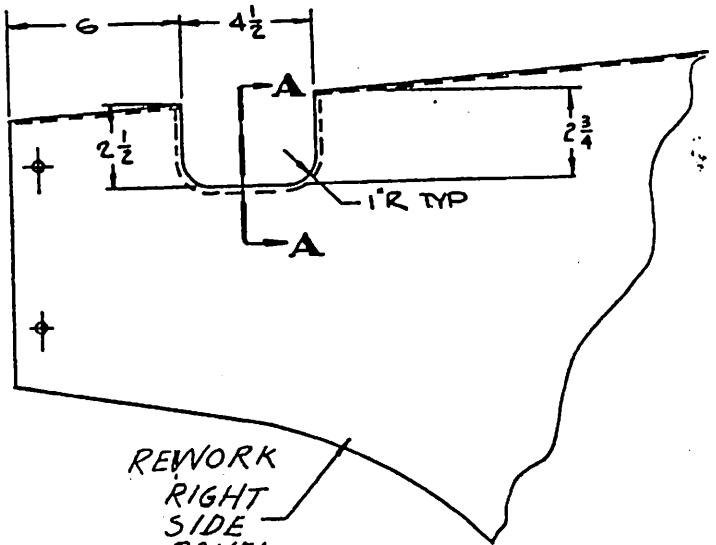


9/32 HOLE 5 PLCS

EXPLODED VIEW AT A



SECTION A-A



DRAWN BY: CG (COPIED)	DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED. TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS: ANGLES. ± 1° FRACTIONS: ± 1/16 .XX ± .010 .XXX ± .0010	FRANK J. ZAMBONI & CO., INC. PARAMOUNT, CALIFORNIA, U.S.A.
SCALE NONE		

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MATL.	FINISH	DESC. KIT, SPRINKLER, SNOW MELTING	SHEET 3 OF 4	ITEM NO. DK-19710

DATE 12/12/86
REV. DATE 10/27/92 CB
(A) 6/18/02 DHK

ITEM	PART No.	DESCRIPTION	QTY
1	FF-02160	90 EL, GALV., ½ NPT	4
2	FF-0118E	NIPPLE, ½ x 18, GALV.	2
3	FF-0119M	NIPPLE, ½ x 30, GALV	2
4	FF-01177	NIPPLE, ½ x 15 5/8, GALV	1
5	23-19700	MANIFOLD	1
6	2V-33240	VALVE, 2" GATE	1
7	FF-0179A	NIPPLE, ½ x 52 1/2 (A) GALV	1
8	FF-0118M	NIPPLE, ½ x 20, GALV	1
9	4R-1423A	CLAMP, ½" CONDUIT	5
10	FA-1000A	NOZZLE	6
11	FW-0500A	ADAPTER, LAWN HOSE UNION x ½ NPT	1
12	FF-0116A	NIPPLE, ½ x CLOSE, GALV	1
13	HA-26861	WASHER, SAE, 7/8	1
14	2D-0500A	GASKET, RUBBER	1
15	FF-08160	TEE, ½ NPT, GALV	5
16	FF-0116M	NIPPLE, ½ x 3, GALV.	1
17	HA-06009	SCREW, H x HD, ¼-20 x 3/4	5
18	HA-06981	LOCKNUT, ¼-20	5
19	2H-0500A	TRIM STRIP, BLACK	10'

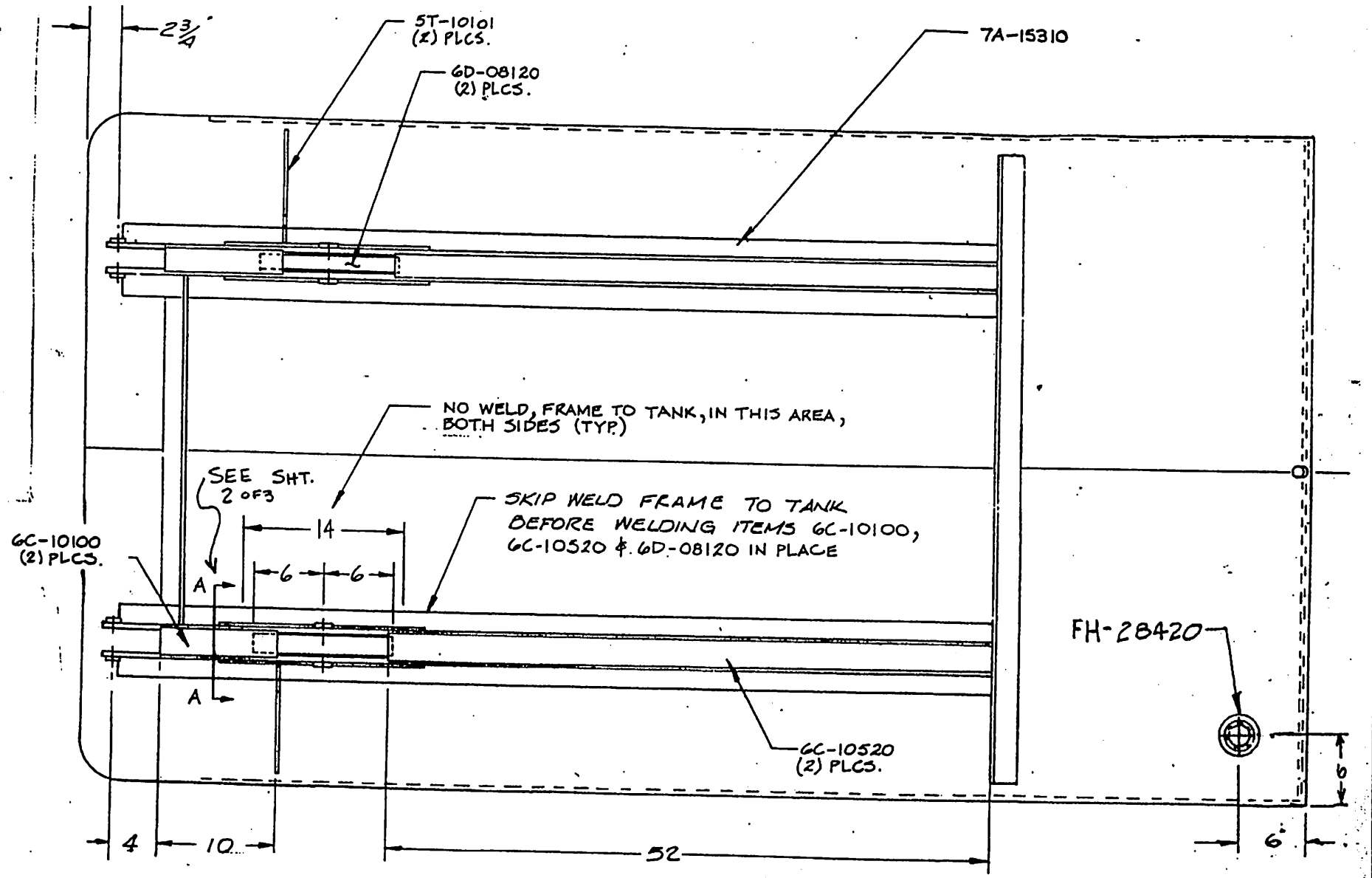
DRAWN BY: G
SCALE

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS:
ANGLES: ± 1° FRACTIONS: ± 1/16 .XX ± .010 .XXX ± .0010

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PARAMOUNT, CALIFORNIA, U.S.A.

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
NOTED	—	WELDMENT, SNOW TANK ASSEMBLY	4 OF 4	DK-19710



DATE 11/17/83

REV. DATE

DRAWN BY: —

SCALE —

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS:
ANGLES: ± 1° FRACTIONS: ± 1/16 .XX ± .010 .XXX ± .0010

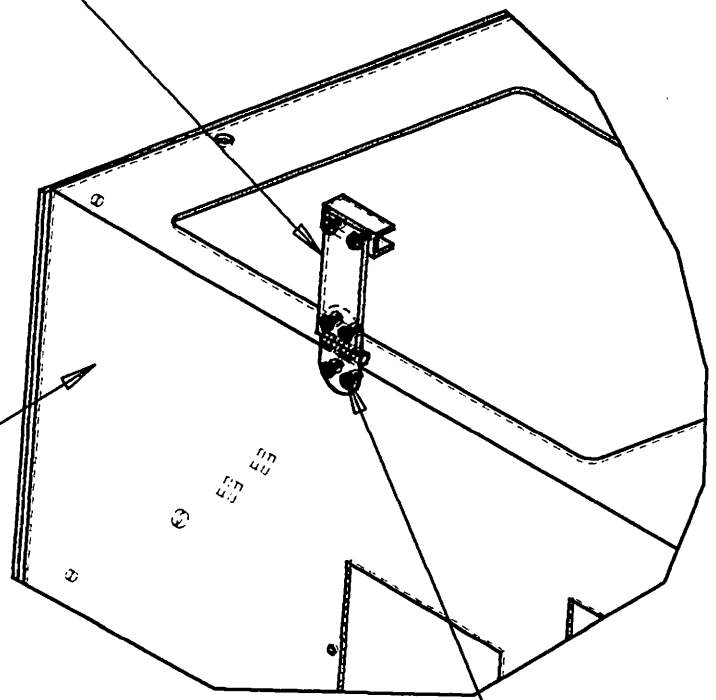
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THE BLUEPRINT PLACE FOR A

MATL.	FINISH	DESC.	SHEET	ITEM NO.
NOTED	--------	SNOW TANK WINDOW PROP ASSEMBLY DETAIL	1 OF 2	DK-15516

REV.

KZ-15516
SNOW TANK WINDOW PROP ASSY



7A-15500
SNOW TANK ASSY

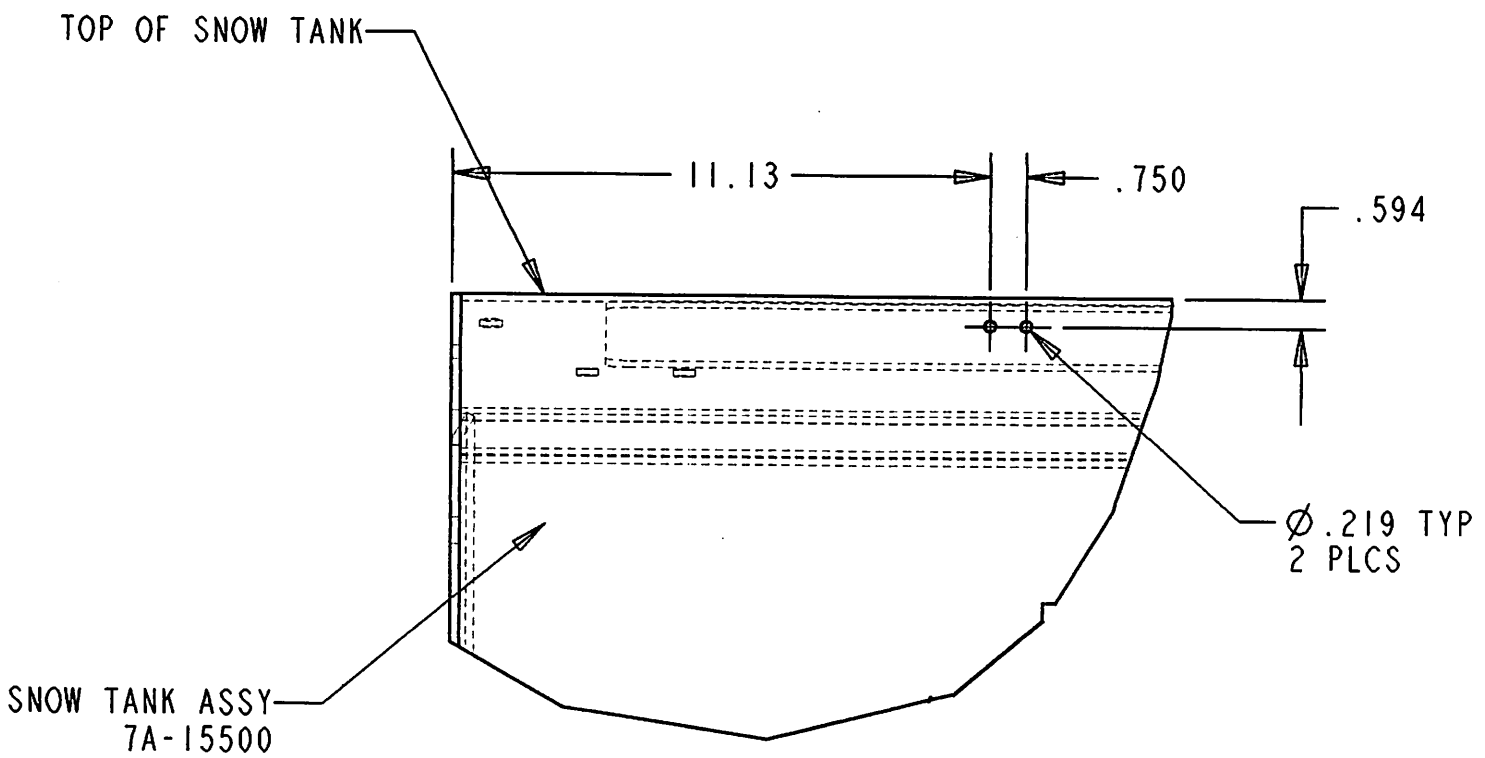
SEE SHEET 2 OF 2
FOR MOUNTING HOLE LOCATIONS

NOTE:
ATTACH SNOW TANK WINDOW PROP TO SNOW TANK WITH 2 BOLTS(HA-04750) & NUTS(HA-04988)
PLACE FOAM RUBBER BETWEEN PROP HINGE AND SNOW TANK

DRAWN BY K. BITTER	CAD INFO DIR TURTLE_D3P	DIMENSIONS ARE IN INCHES.	FRANK J. ZAMBONI & CO. INC.
SCALE 0.188 DATE 1/21/02	.DWG DK15516 .PRT .ASM DK15516	TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.

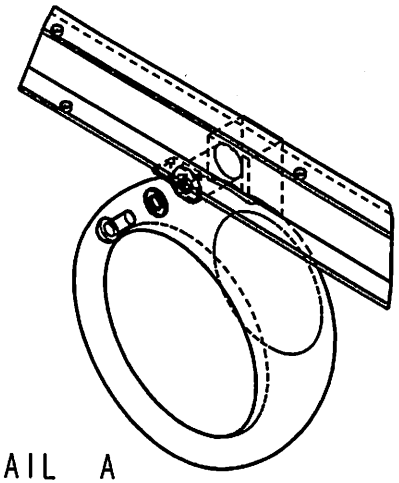
MATL.	FINISH	DESC.	SHEET	ITEM NO.
NOTED	--------	SNOW TANK WINDOW PROP SNOW TANK HOLE LOCATIONS	2 OF 2	DK-15516

REV.

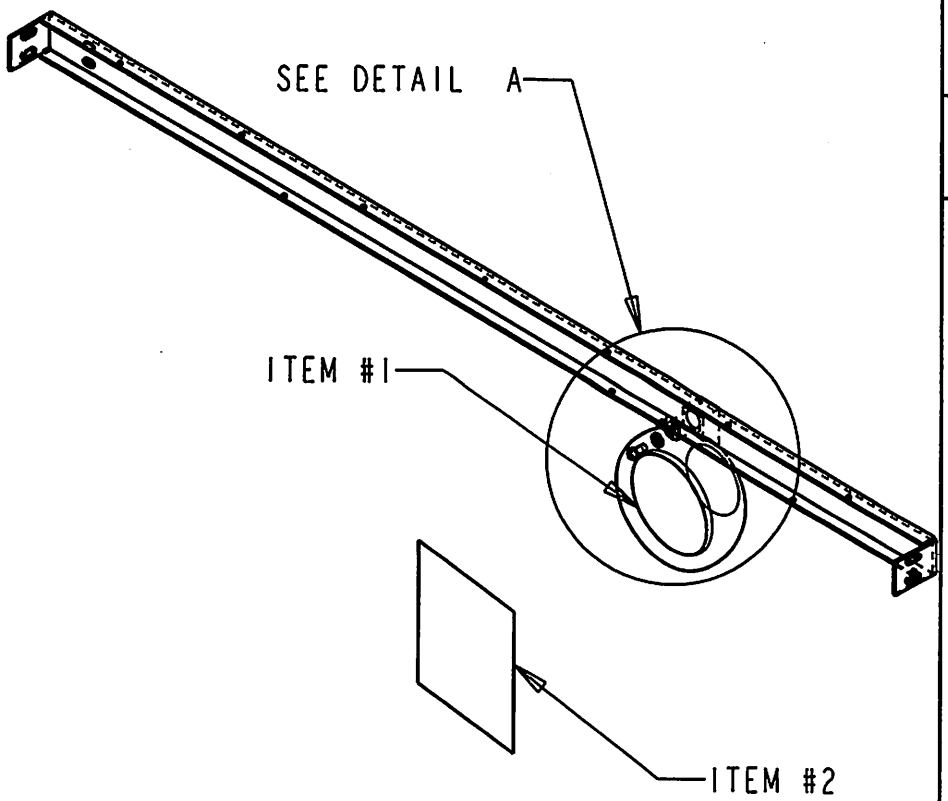


DRAWN BY K. BITTER	CAD INFO DIR TURTLE_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE 0.25 DATE 1/22/01	.DWG DK15516 .PRT DK15516_5 .ASM		THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.

MATL.	FINISH	DESC.	SHEET	ITEM NO.
		SNOW TANK LIGHT	1 OF 3	DK-15100



DETAIL A
SCALE 0.200



REV.	
A	11/3/00 CB
B	8/19/05 KM

NOTE:
1. INSTALL ITEM #2 (GLASS) TO REAR OF SNOW TANK
   WITH SILICONE ADHESIVE
2. ASSEMBLE ITEM #1 (LIGHT) TO WASH WATER TANK BRACKET
3. RUN WIRE LOOM (SEE SHEET 3 OF 3) AND SECURE TO INSIDE OF WASH WATER PLATFORM
   WITH ADHESIVE BACKED CLAMPS

DRAWN BY R.CONCEPCION		CAD INFO	DIR ASIMOV//PROE20PARTS	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°
SCALE NONE	DATE 6/4/98	.DWG DK15100		
		.PRT	.ASM	

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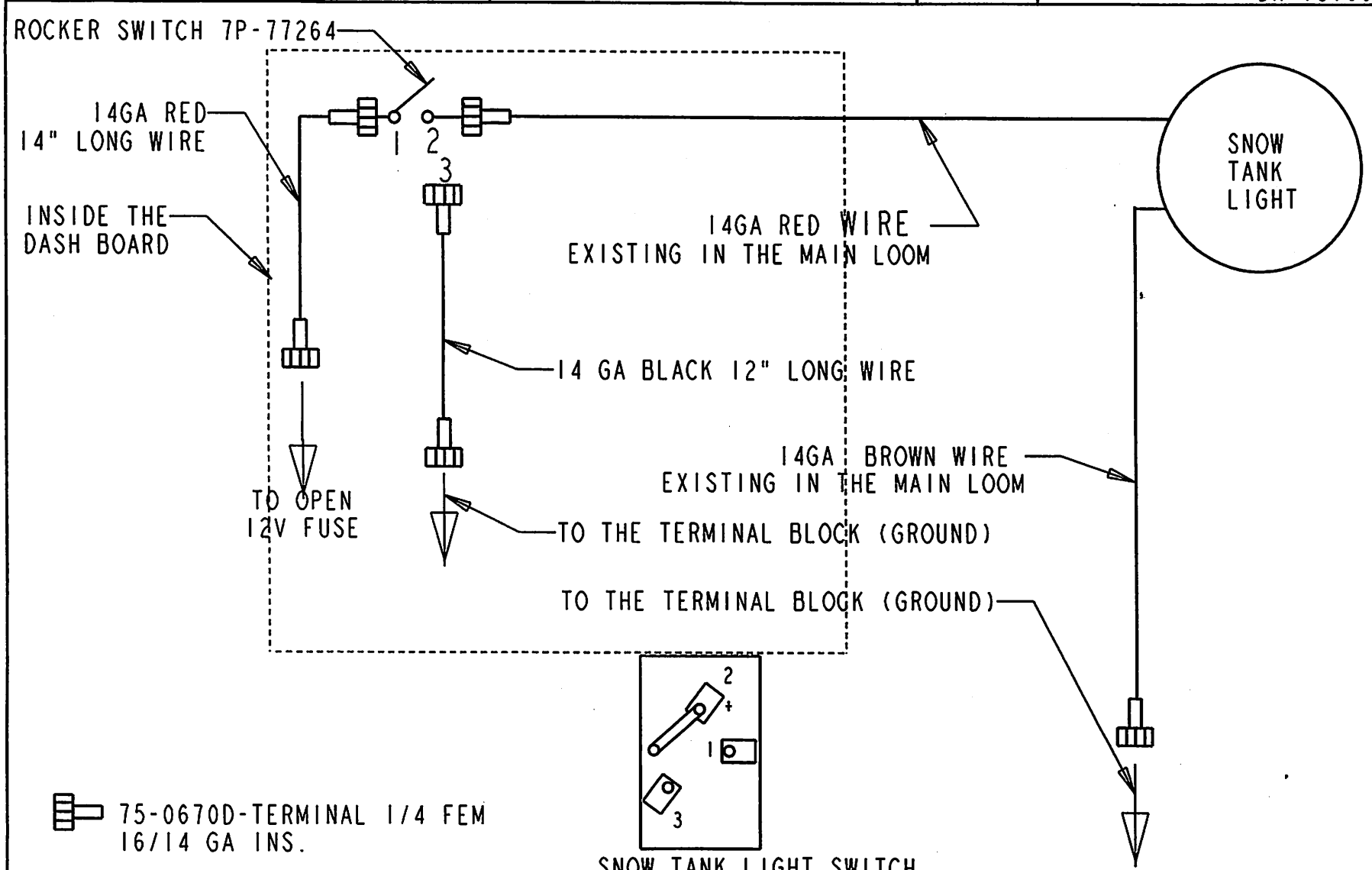
MATL.	FINISH	DESC.	SHEET	ITEM NO.
		SNOW TANK LIGHT	2 OF 3	DK-15100

REV.
(A) 11/3/00 CB
(B) 8/19/05 KM

ITEM	ZPN	DESCRIPTION	QTY
1	75-15100	SNOW TANK LIGHT & LOOM	1
2	7A-15504	REAR SNOW TANK GLASS	1
3 NS	27-55210	CLAMP, ADH BACKED, 3/16	2
4 NS	27-55220	CLAMP, ADH BACKED 3/8	4
5 NS	3E-0262D (B)	DIODE, ALT FEEDBK SUPPRESOR	1
6 NS	7A-15505	BRACKET, NON-PLASTIC WASH WATER TANKS	1
7 NS	7P-77262 (B)	SWITCH	1
8 NS	81-15100	NAMEPLATE	1
9 NS	9M-15100	SILICONE, AUTOGLASS ADHESIVE	1

DRAWN BY R.CONCEPCION	CAD INFO DIR ASINOV//PROE20PARTS	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE NONE DATE 6/4/98	.DWG DK15100 .PRT .ASM		THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.

MATL.	FINISH	DESC.	SHEET	ITEM NO.
		SNOW TANK LIGHT	3 OF 3	DK-15100



REV.	
A	11/3/00 CB
B	8/19/05 KM

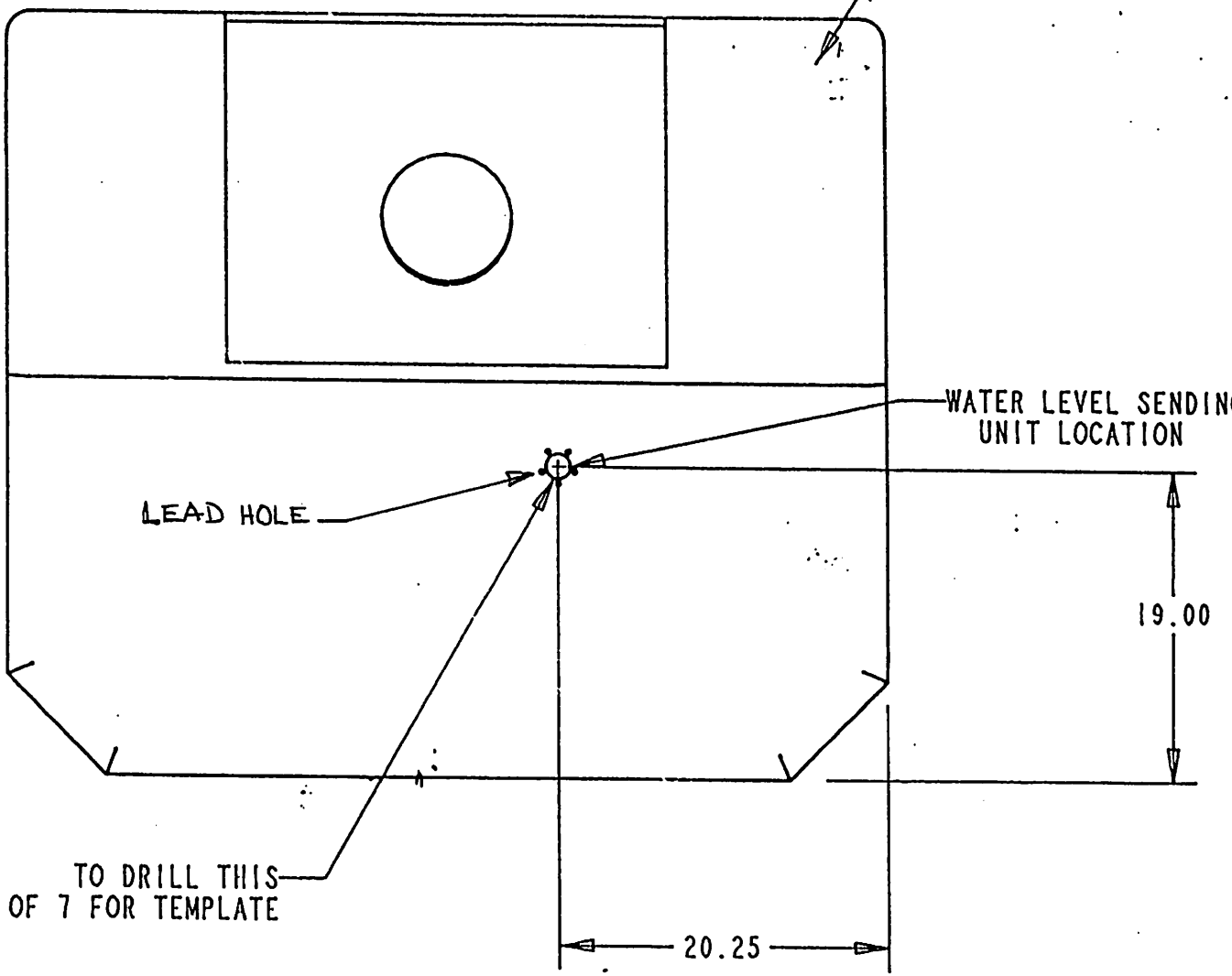
DRAWN BY CB	CAD INFO	DIR AS1MOV//PROE2.0PARTS	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°
SCALE NONE / DATE 11/3/00	.DWG DK15100	.PRT / .ASM	

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MATL.	FINISH	DESC. WATER LEVEL GAUGE-ELECTRIC INSTRUCTIONS	SHEET 1 OF 7	ITEM NO. DK-14211

REV. (A) 7/14/98 RC



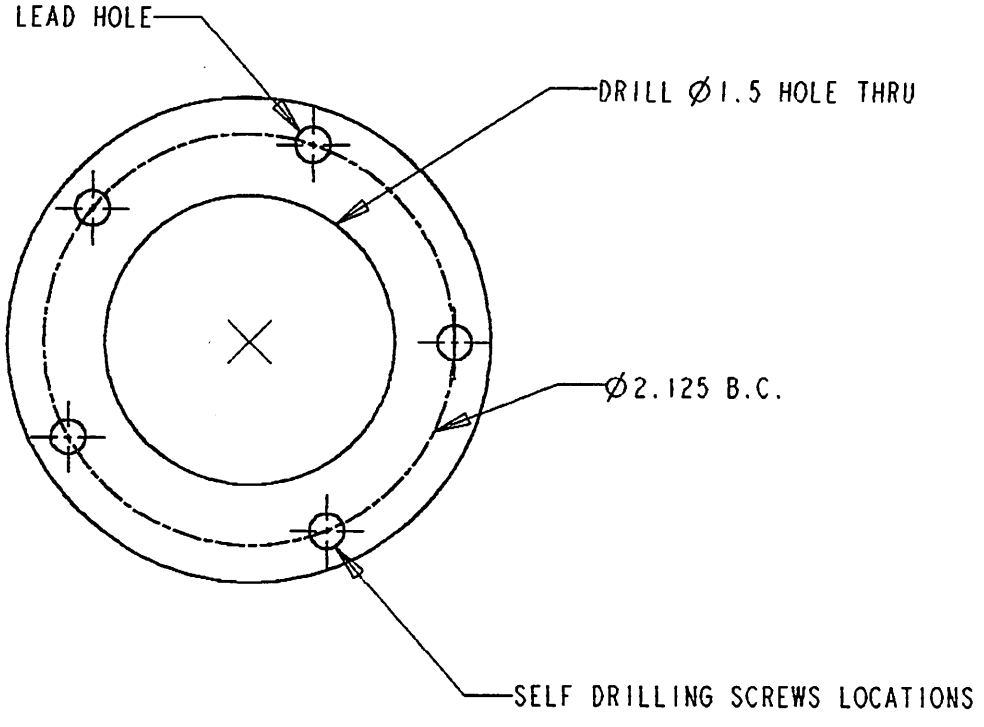
TO DRILL THIS HOLE SEE SHEET 2 OF 7 FOR TEMPLATE

FRANK J. ZAMBONI & CO. INC.	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	DRAWN BY TRAIAN ZAIONCIUC
		SCALE NONE DATE 06/06/94

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MATL.	FINISH	DESC. WATER LEVEL GE-ELECTRIC INSTRUCTIONS	SHEET 2 OF 7	ITEM NO. DK-14211

REV. (A) 7/14/98 RC

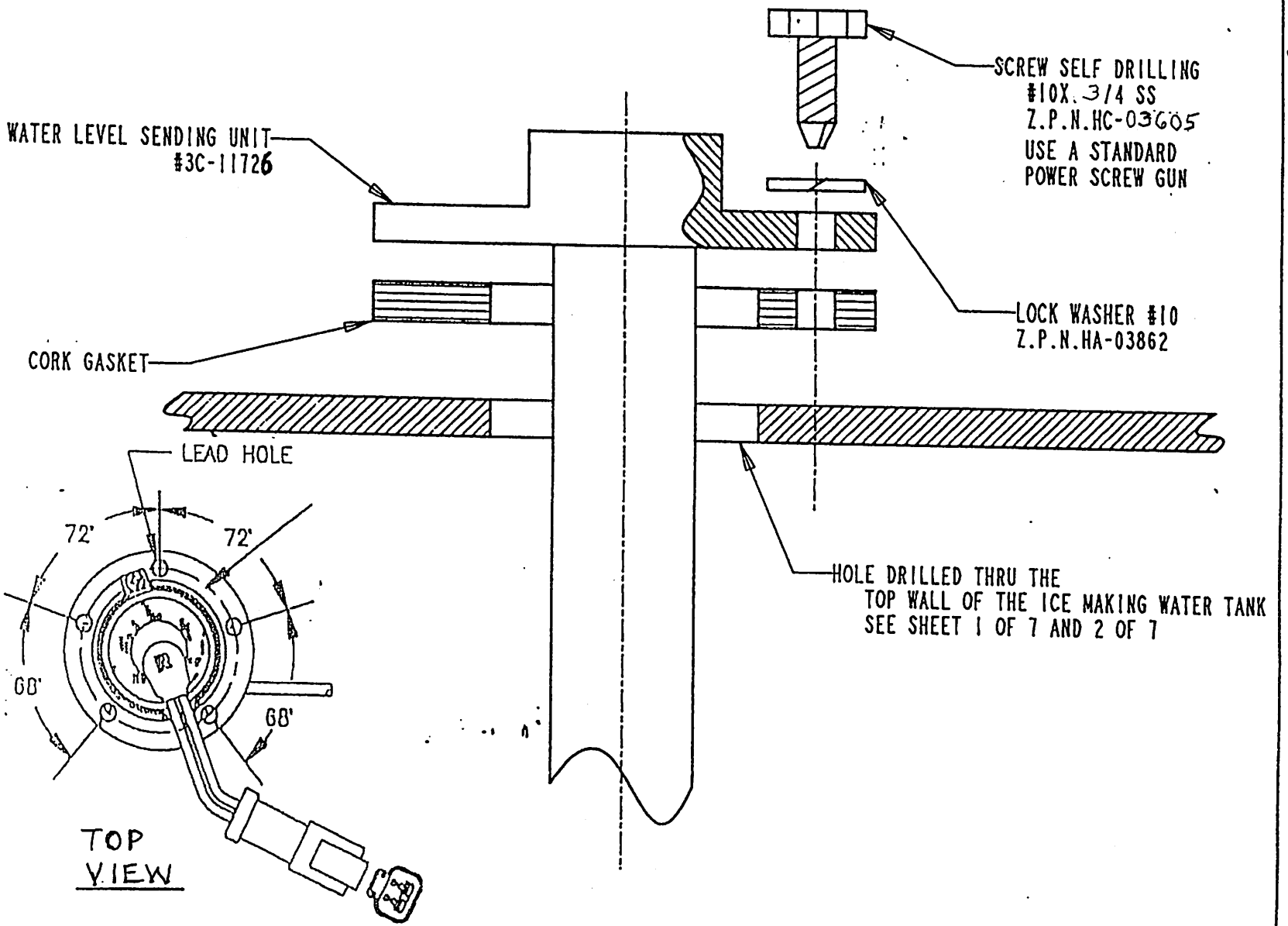


TEMPLATE TO DRILL THE HOLE
FOR THE ELECTRIC WATER LEVEL
SENDING UNIT #3C-11726
SEE SHEET 1 OF 7 FOR LOCATION

DRAWN BY R.CONCEPCION	CAD INFO	DIR	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE NONE DATE 7/14/98	.DWG			THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.
	.PRT	.ASM		

MATL.	FINISH	DESC. WATER LEVEL GAUGE-ELECTRIC INSTRUCTIONS	SHEET 3 OF 7	ITEM NO. DK-14211

REV. (A) 7/14/98



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DIMENSIONS ARE IN INCHES.
TOLERANCES: X±.10, XX±.060, XXX±.030
ANGLES ±1°

DRAWN BY TRAIAN ZAIONCIUC

SCALE NONE

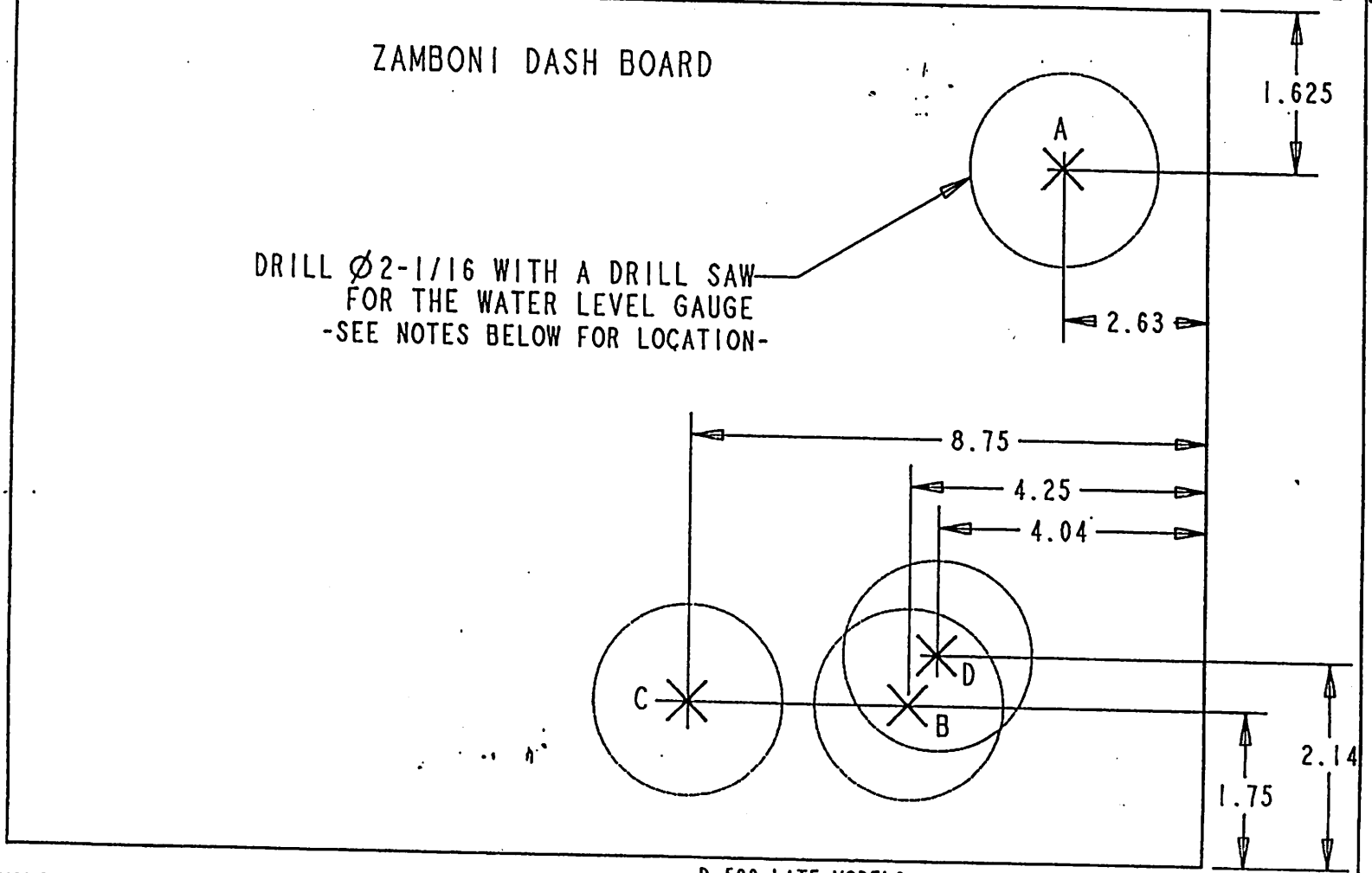
DATE 06/06/94

MAIL.	FINISH	DESC. WATER LEVEL GAUGE-ELECTRIC INSTRUCTIONS	SHEET 4 OF 7	ITEM NO. DK-14211

SUGESTED LOCATIONS FOR THE WATER LEVEL GAUGE ON ZAMBONI DASH BOARD

CAUTION! DO NOT OVERLAP THE APPLIQUE LETTERING BY INSTALLING THE NEW GAUGE

REV. (A) 7/14/98 RC



A-552 LATE MODELS (NEW DESIGNED APPLIQUE-S/N 4983-)
B-552 OLD MODELS WITH DIGITAL DISPLAY ON TOP (S/N 4493-4945)
C-552 LATE MODELS WITH THE DIGITAL DISPLAY ON THE LOWER RIGHT HAND LOCATION OF THE DASH BOARD (S/N 4981-)

D-500 LATE MODELS
-500 OLD MODELS PLACE THE GAUGE ANY WHERE THE OPERATION INSTRUCTIONS (LETTERING ONLY) WILL BE NOT COVERED BY THE GAUGE
-500 WITH LPG SYSTEM WATER LEVEL GAUGE WILL REPLACE THE PLUG IN THE GAS GAUGE HOLE

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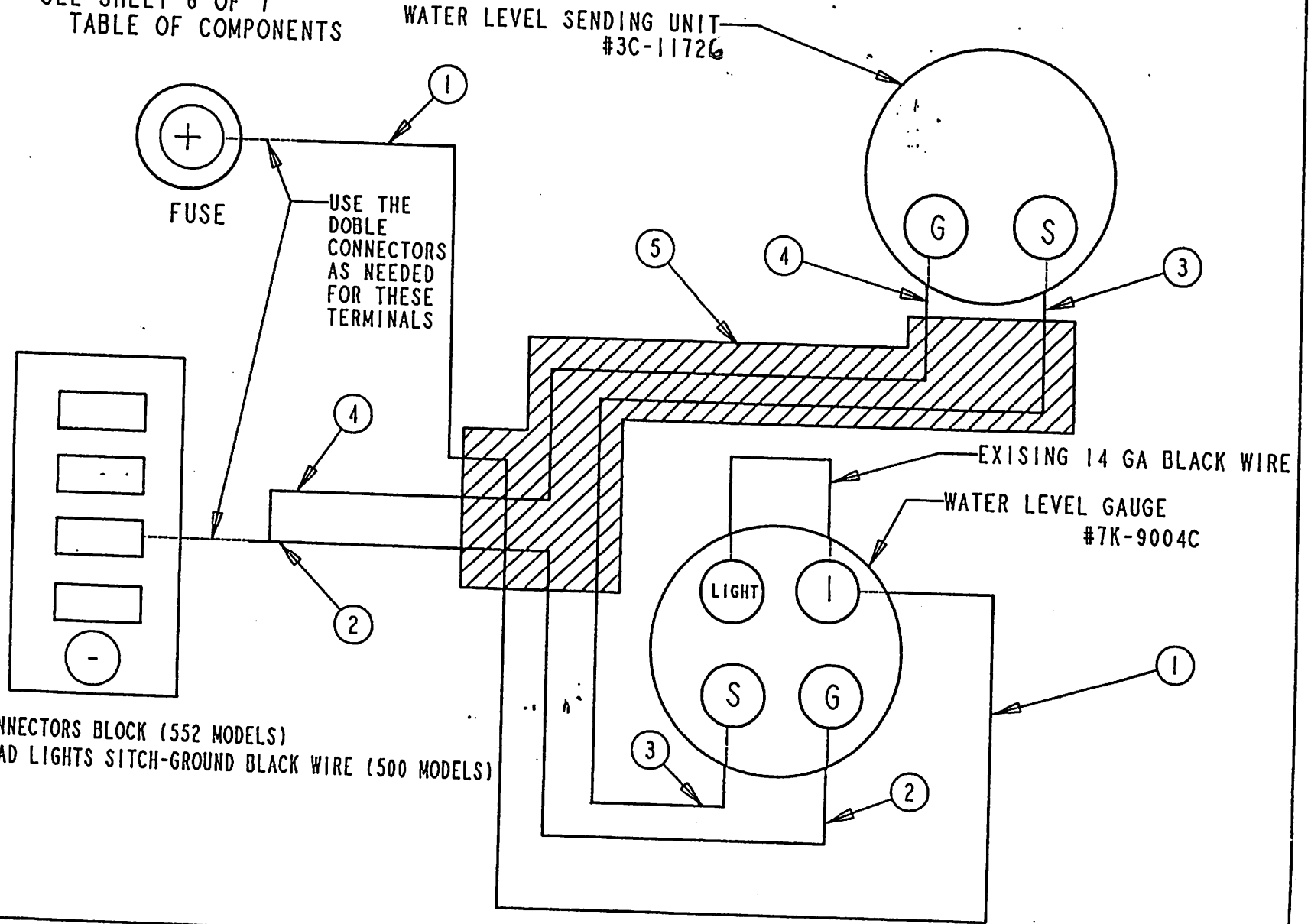
DIMENSIONS ARE IN INCHES.
TOLERANCES: X±.10, XX±.060, XXX±.030
ANGLES ±1°

DRAWN BY	TRAIAN ZAIONCIUC
SCALE NONE	DATE 6/7/94

MAYL.	FINISH	DESC.	SHEET	ITEM NO.
		WATER LEVEL GAUGE-ELECTRIC INSRUCTIONS	5 OF 7	DK-14211

REV. Ⓐ 7/14/98 RC

SEE SHEET 6 OF 7
TABLE OF COMPONENTS



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DIMENSIONS ARE IN INCHES.
TOLERANCES: X±.10, XX±.060, XXX±.030
ANGLES ±1°

DRAWN BY	TRAIAN ZAIONCIUC
SCALE	NONE
DATE	6/7/94

MATL.	FINISH	DESC. WATER LEVEL GAGE-ELECTRIC INSTRUCTIONS	SHEET 6 OF 7	ITEM NO. DK-14211

REV. (A) 7/14/98 RC

#75-19811 - MAIN LOOM WATER LEVEL GAUGE

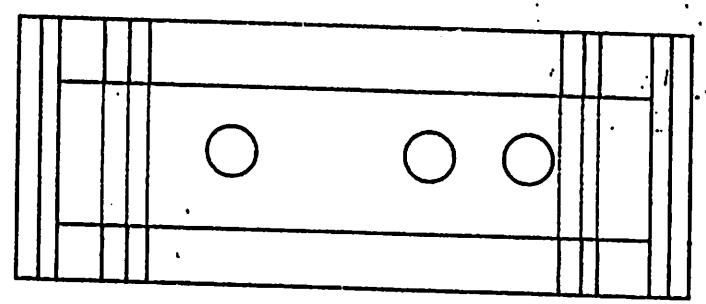
INDEX	TERMINAL 1	TERMINAL 2	DESCRIPTION
1	1/4 SLIDE FEM. #75-0670D -FUSE-	#10 RING #75-0574B -GAUGE POS. "I"-	WIRE ORANGE 16 GA, 24" LONG
2	1/4 SLIDE FEM. #75-0670D -GROUND-	#10 RING #75-0574B -GAUGE POS. "G"-	WIRE BLACK 16 GA, 24" LONG
3	DEUTSCH 2 PIN DT06-2S -SENDING UNIT PLUG-	#10 RING #75-0574B -GAUGE POS. "S"-	WIRE GRN/YLO 16 GA, 122" LONG
4	DEUTSCH 2 PIN DT06-2S -SENDING UNIT PLUG-	1/4 SLIDE FEM. #75-0670D -GROUND-	WIRE BLACK 16 GA, 132" LONG
5	-	-	FLEX GUARD .25 X 10' LONG

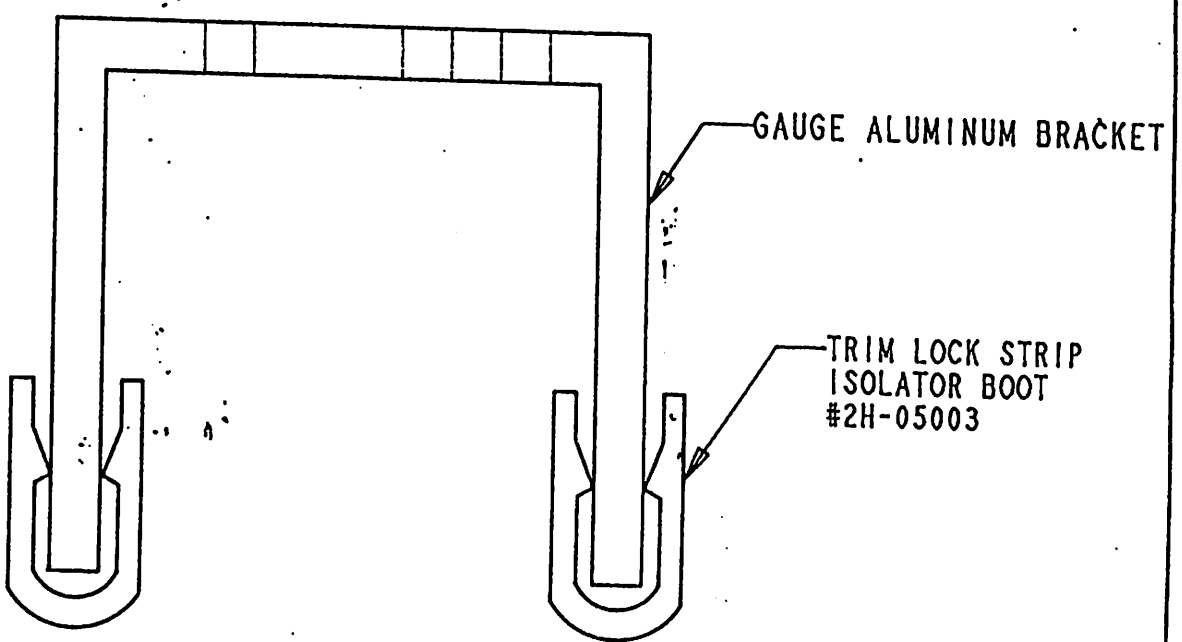
DRAWN BY R.CONCEPCION	CAD INFO	DIR	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE NONE DATE 7/14/98	.DWG			THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.
	.PRT	.ASM		

MATL.	FINISH	DESC. WATER LEVEL GAUGE-ELECTRIC -INSTRUCTIONS-	SHEET 7 OF 7	ITEM NO. DK-14211

REQUIRED TO INSTALL THE WATER LEVEL GAUGE #7K-9004C
FOR 552 MODELS ONLY

REV. (A) 7/14/98 RC





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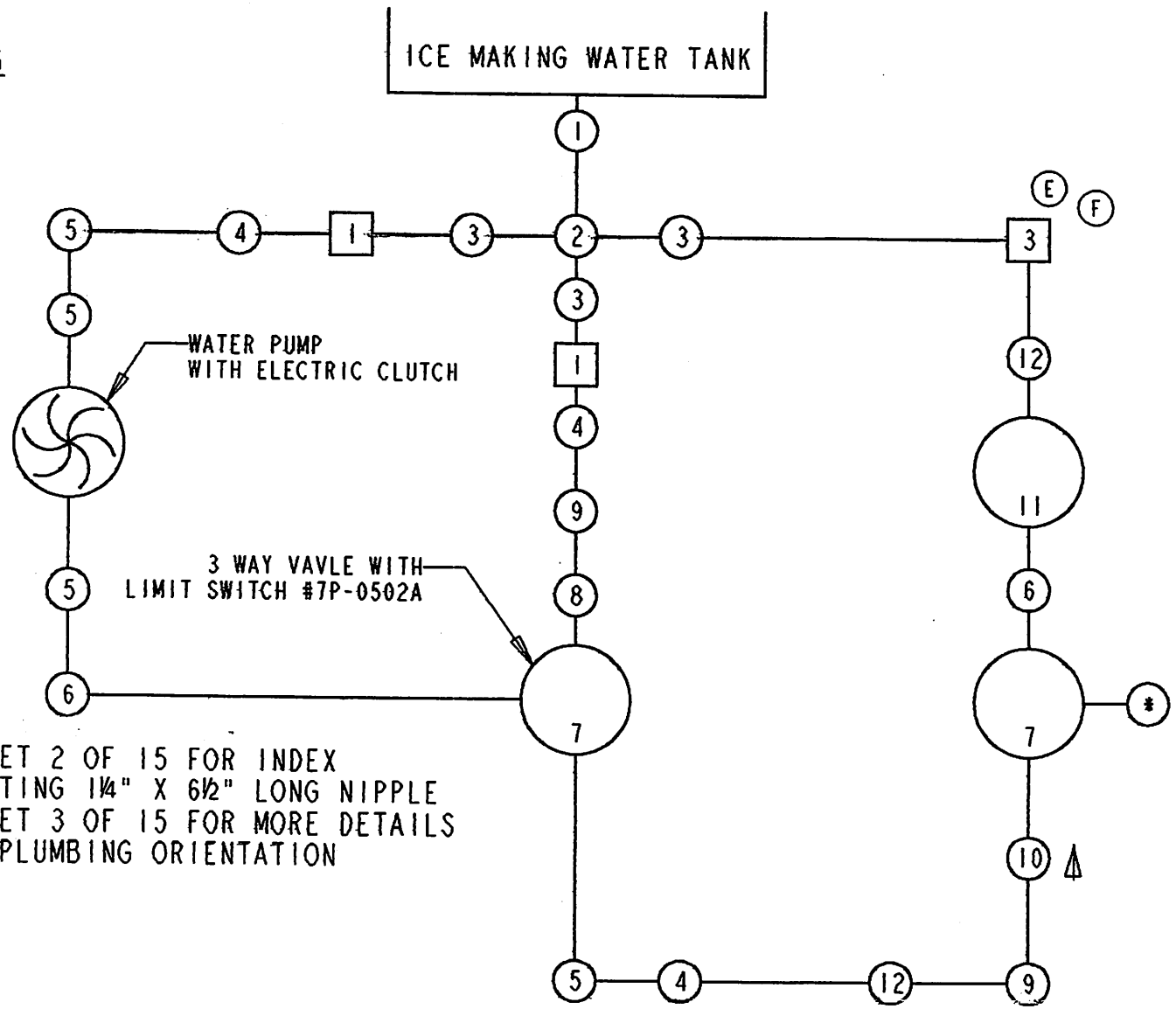
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DIMENSIONS ARE IN INCHES.
TOLERANCES: X±.10, XX±.060, XXX±.030
ANGLES ±1°

DRAWN BY TRAIAN ZAIONCIUC
SCALE NONE
DATE 6/7/94

MATL.	FINISH	DESC.	SHEET	ITEM NO.
		ADVANCED WATER SYSTEM	1 OF 14	DK-07100

PLUMBING



NOTE:
- SEE SHEET 2 OF 15 FOR INDEX
- "*" EXISTING 1¼" X 6½" LONG NIPPLE
- SEE SHEET 3 OF 15 FOR MORE DETAILS AND PLUMBING ORIENTATION

○ = FITTING

□ = HOSE

REV.	
C	10/25/95 CB
D	5/29/98 CB
E	2/3/99 RC
F	6/8/99 CB
G	12/5/01 KB

DRAWN BY T. ZAIONCIUC	CAD INFO DIR TURTLE_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE N/A DATE 6/30/94	.DWG DK07100 .PRT .ASN		THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.

MATL.	FINISH	DESC.	SHEET	ITEM NO.
		ADVANCED WATER SYSTEM	2 OF 14	DK-07100

REV.
(E) 2/3/99 RC
(F) 6/8/99 CB
(G) 12/5/01 KB

PLUMBING INDEX

INDEX ○	Z.P.N.	DESCRIPTION	QTY.
1	FF-0136E	1½ NPT X 2 " LONG GALV. NIPPLE	1
2	FF-08320	1½ NPT SIDE OUTLET TEE GALV.	1
3	FP-2426B	1½ NPT 1½ BARB PVC	3
4	FF-0131K	1¼ NPT TOE X 2½ LONG	2
5	FF-04310	1¼ NPT EL. STREET	4
6	FF-0131A	1¼ NPT CLOSE NIPPLE	2
7	2V-79702	1¼ NPT 3 WAY VALVE	2
8	FF-0131M	1¼ NPT X 3" LONG NIPPLE	1
9	FF-02310	1¼ NPT ELBOW	2
10	FF-0132F	1¼ NPT 8½ LONG NIPPLE	1
11	2V-47100	1¼ NPT CHK. VALVE	1
12	FW-43652	1¼ NPT TOE X 3½ LONG.	2
4A	FW-43652	1¼ NPT TOE X 3½ LONG	1

INDEX □	Z.P.N.	DESCRIPTION	QTY.
1	RC-5017A	1-5/8 HOSE X 4½" LONG	2
2	RC-5250A	1-5/8 HOSE X 64½" LONG	1
3	RC-5216A	1-5/8 HOSE X 56" LONG	1

DRAWN BY T. ZAIONCIUC	CAD INFO	DIR TURTLE_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°
SCALE N/A DATE 6/27/94	.DWG DK07100		
	.PRT	.ASM	

FRANK J. ZAMBONI & CO. INC.

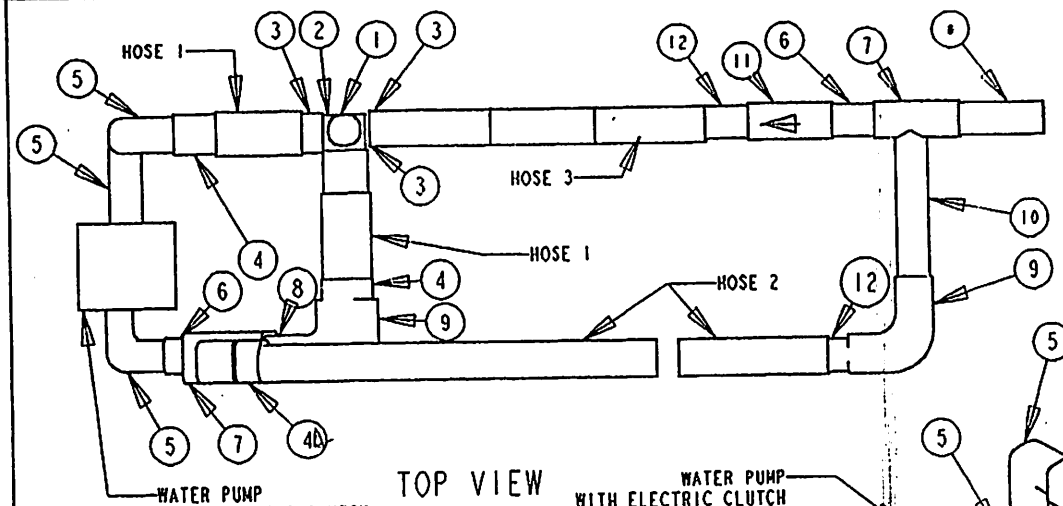
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MATL.	FINISH	DESC.	SHEET	PART NO.
		ADVANCED WATER SYSTEM	3 OF 14	DK-07100

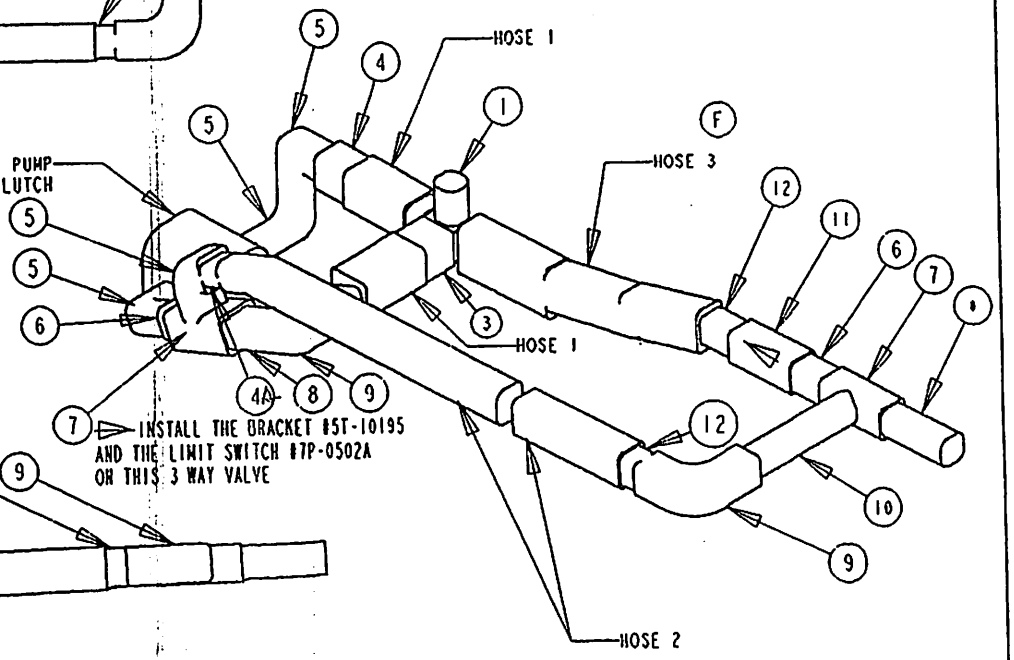
REV. F 6/8/99 CB

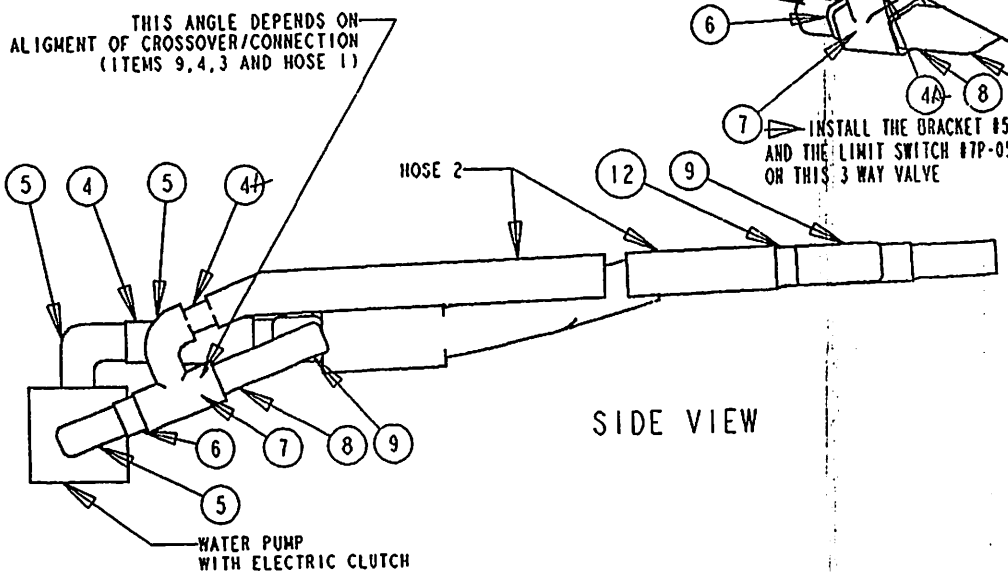
G 12/5/01 KB

PLUMBING DETAILS -ORIENTATION-



TOP VIEW





SIDE VIEW

TO FRONT OF VEHICLE

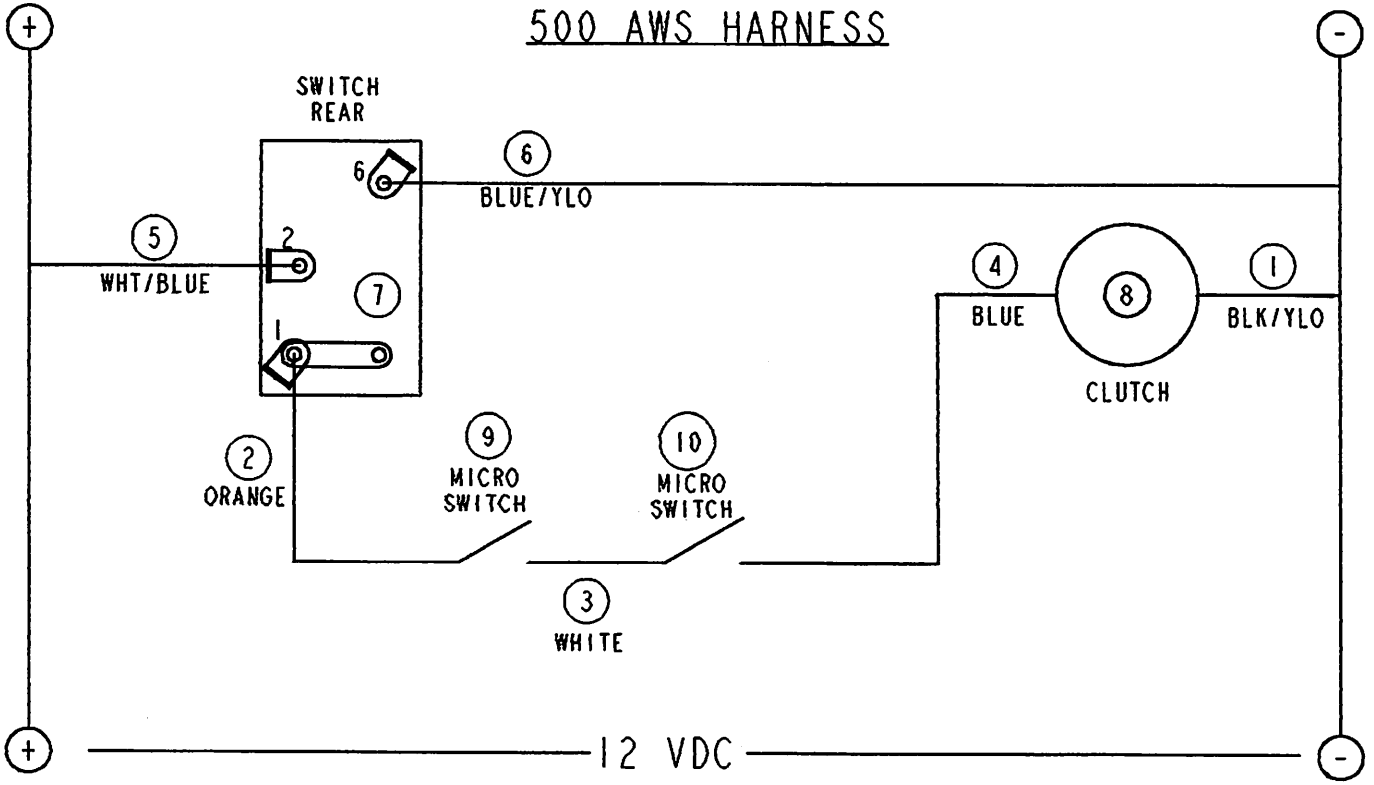
FRANK J. ZAMBONI & CO. INC.	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	DRAWN BY TRAIAN ZAIONCIUC
		SCALE NONE / DATE 07/01/94

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
		ADVANCED WATERING SYSTEM	4 OF 14	DK-07100

REV. G 12/5/01 KB

500 AWS HARNESS



DRAWN BY R. CONCEPCION	CAD INFO	DIR TURTLE_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°
SCALE NONE	DATE 2/3/99	.DWG DK07100	
		.PRT .ASM	

FRANK J. ZAMBONI & CO. INC.

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
		ADVANCED WATE..NG SYSTEM	5 OF 14	DK-07100

REV.
B 7/3/95 RC
E 2/3/99 RC
G 12/5/01 KB

500 AWS HARNESS

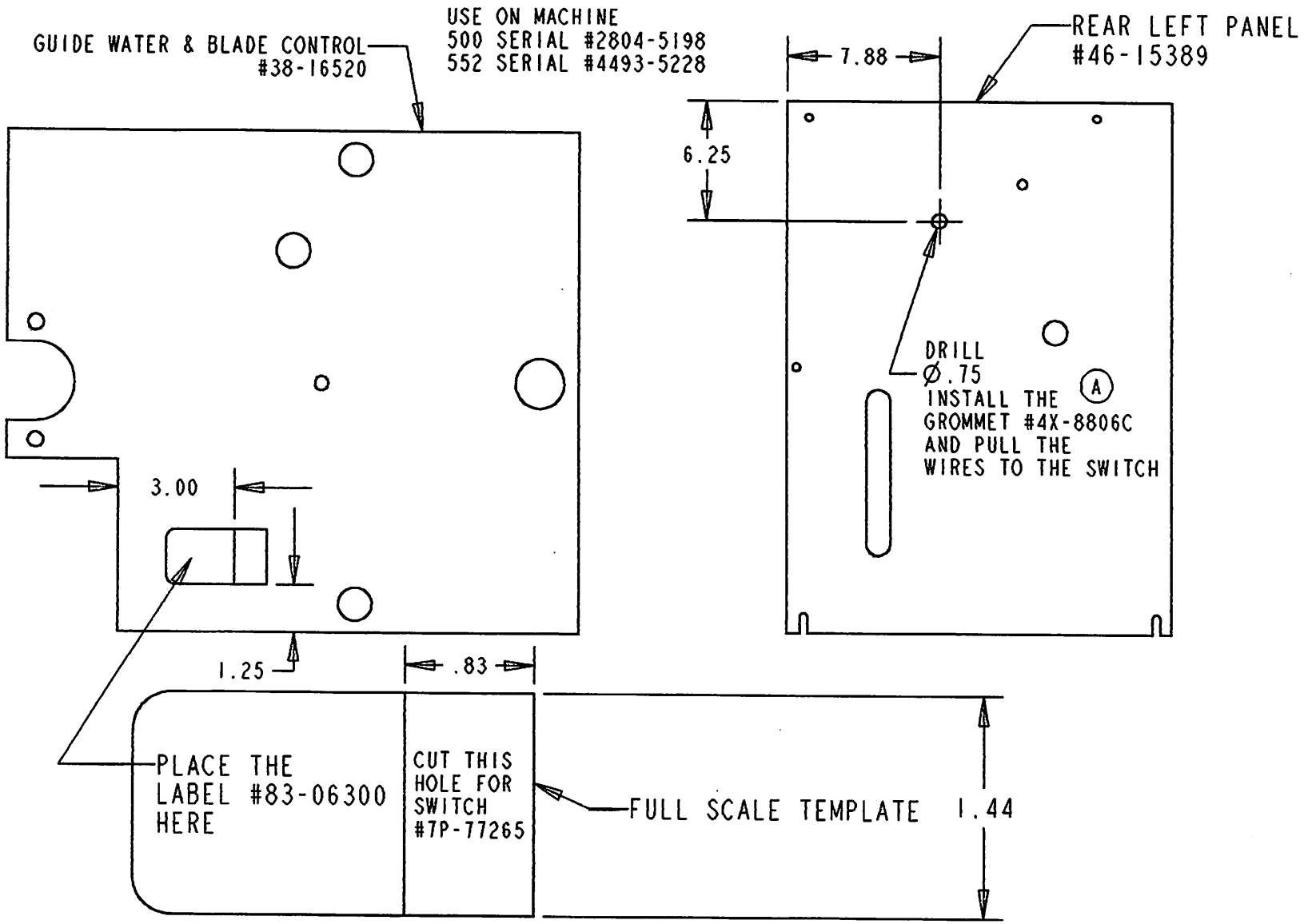
INDEX	Z..P.N.	WIRE	DESCRIPTION	NOTES
1	-	A1-A2	16 AWG BLK/YLO 115" LONG	TB "NEGATIVE" - ELEC. CLUTCH(PUMP)
2	-	B1-B2	16 AWG ORANGE 68" LONG	SWITCH "3" - LIMIT SWITCH DIR. CONTROL "NC"
3	-	C1-C2	16 AWG WHITE 88" LONG	LIMIT SWITCH DIR. CONTROL"COMM" - LIMIT SWITCH BALL VALVE"NO"
4	-	D1-D2	16 AWG BLUE 9" LONG	LIMIT SWITCH BALL VALVE"COM" - ELECTRIC CLUTCH (PUMP)
5	-	E1-E2	16 AWG WHT/BLU 26" LONG	SWITCH "1" - FUSE
6	-	F1-F2	16 AWG BLU/YLO 26" LONG	SWITCH "2" - TB NEGATIVE
7	7P-77262	-	ROCKER SWITCH	ROCKER SWITCH
8	2P-38748	-	WATER PUMP W/TERM, PROPORTIONAL	ELECTRIC CLUTCH WATER PUMP
9	79-0502A	-	MICRO SWITCH SPDT 15A 250V	MICRO SWITCH
10	7P-0502A	-	MICRO SWITCH SPDT 15A 250V	MICRO SWITCH

NOTE:
1. REFER TO #75-19816 HARNESS

DRAWN BY R. CONCEPCION	CAD INFO DIR TURTLE_D3P	DIMENSIONS ARE IN INCHES.	FRANK J. ZAMBONI & CO. INC.
SCALE NONE DATE 2/3/99	.DWG DK07100	TOLERANCES: X±.10, XX±.060, XXX±.030	THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.
	.PRT .ASM	ANGLES ±1°	

MATL.	FINISH	DESC.	SHEET	ITEM NO.
		ADVANCED WATERING SYSTEM	6 OF 14	DK-07100

REV.	
A	9/15/94 TZ
B	7/3/95 RC
G	12/5/01 KB



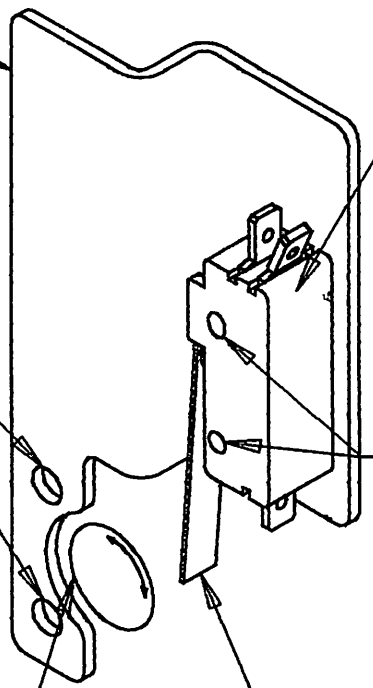
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SCALE NONE	DATE 7/6/94	.DWG DK07100	
		.PRT	.ASM

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
		ADVANCED WATERING SYSTEM	7 OF 14	DK-07100

REV. G 12/5/01 KB



BRACKET #5T-10185

LIMIT SWITCH #7P-77265

INSERT ¼-20 X ½ BOLTS #HA-06862 TO INSTALL THE BRACKET #5T-10185 ON THE 3 WAY VALVE (USE REMOVABLE LOCTITE)

INSERT SCREWS #6-32 X 1-1/8 LONG #HA-01981, TO ASSEMBLE THE LIMIT SWITCH USE LOCKNUTS #6-32 #HA-01981

LOCATION FOR THE 3 WAY VALVE LEVER (90° ROTATION)

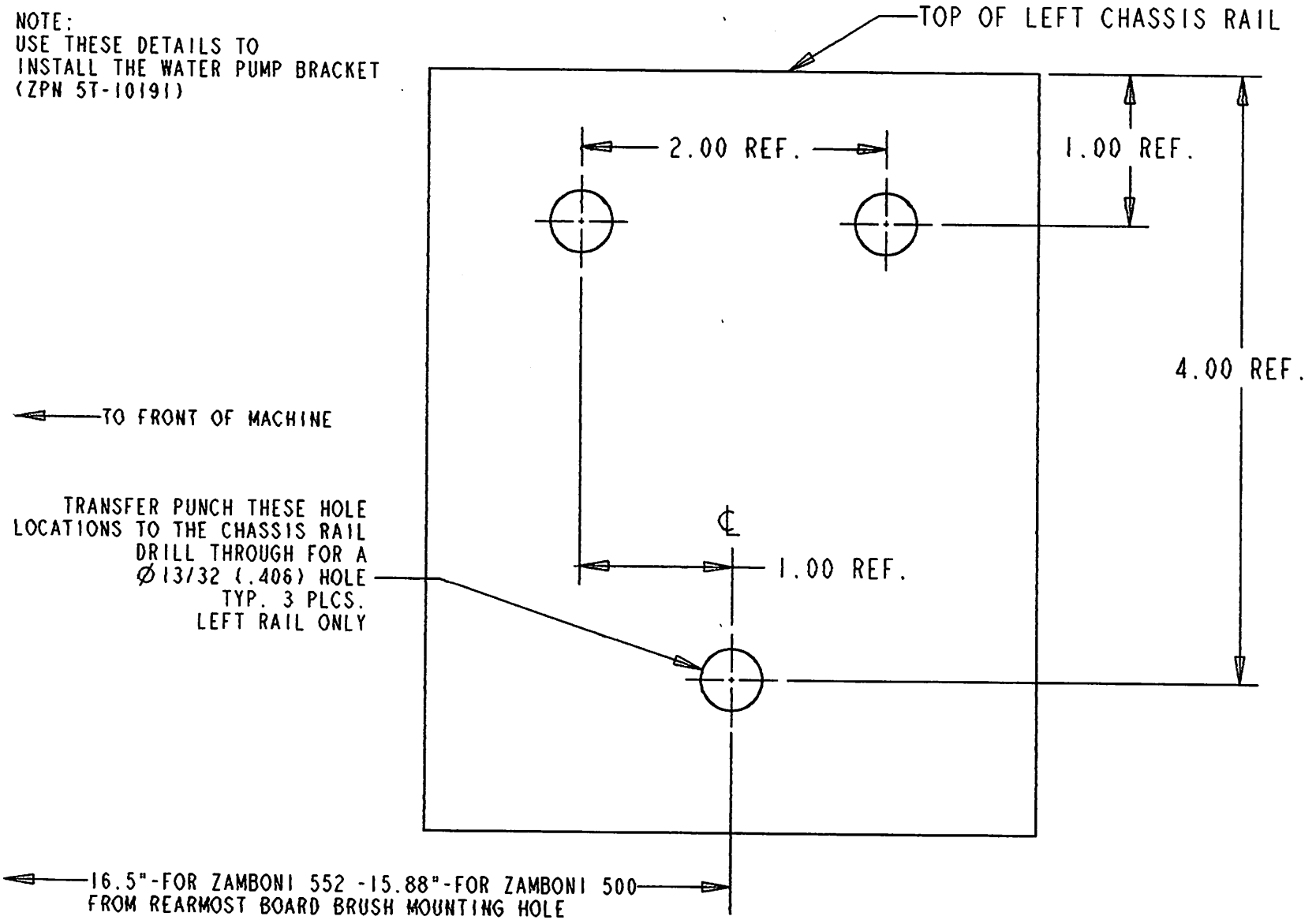
BEND THE LIMIT SWITCH LEVER AS MUCH AS REQUIRED TO ACTIVATE THE SWITCH "ON" OR "OFF" PROPERLY

DRAWN BY T. ZAIONCIUC	CAD INFO DIR TURTLE_D3P	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
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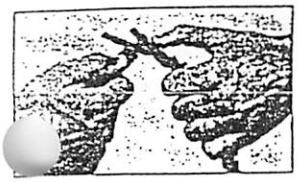
MATL.	FINISH	DESC.	SHEET	ITEM NO.
		ADVANCED WATERING SYSTEM	8 OF 14	DK-07100

REV. G 12/5/01 KB

NOTE:
USE THESE DETAILS TO
INSTALL THE WATER PUMP BRACKET
(ZPN 5T-10191)

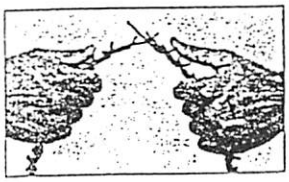


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SCALE 1.00 DATE 6/28/94	.DWG DK07100 .PRT .ASM		THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.

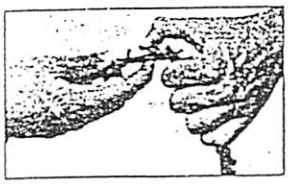


III. ASSEMBLY

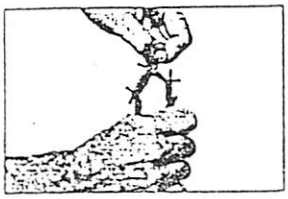
Hold belt with tabs pointing outward.



Place end tab through two links at once.

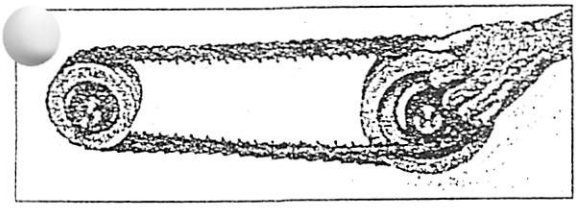


Flex belt further and insert second tab through end link by twisting tab with thumb.



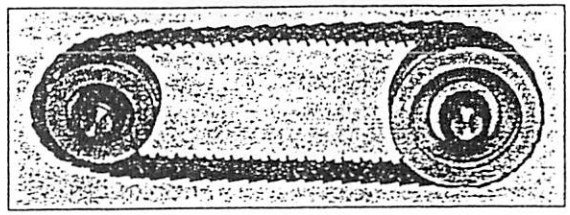
Ensure tab returns to position across belt. Reverse belt so tabs run inside.

IMPORTANT–Turn Belt INSIDE OUT (As shown) To Ensure Easy Assembly and Disassembly



IV. INSTALLATION

1. Turn belt with tabs to the inside before installing.
2. Determine direction of drive rotation.
3. Align belt directional arrow (←) with drive rotation.
4. Fit belt in nearest groove of smaller sheave.
5. Roll belt onto larger sheave, turning the drive slowly. Belt may seem very tight; this is okay; DO NOT JOG MOTOR.
6. Check to see all tabs are still in their correct position and are not twisted out of alignment.
7. For multiple belt drives, work belt from groove to groove. On particularly wide drives, it may be easier to install half the belts from the inboard side and half from the outboard. Note: With drive ratios around 1:1, it may be necessary to *add back* one link to allow belts to be rolled on. This does *not* apply if using Alternative Installation Method.



V. ALTERNATIVE INSTALLATION METHOD

1. Set motor to mid position of adjustment range and mark base clearly.
2. Determine required belt length as in I.
3. Push motor forward to minimum center distance.
4. Install belts as in IV.
5. Pull motor back to previously marked mid position.

VI. RETENSIONING

Like all high performance V-belts, PowerTwist Plus V-Belts require the maintenance of correct drive tension to operate efficiently. Experience indicates that drive tension should be checked after 24 hours running at full load. A retension may be necessary depending on the severity of the drive. Any initial belt stretch is then taken up. Subsequently, belt tension should be checked periodically and adjusted when necessary.

42-07110 - Belt, AWS Power Twist (OPTIONAL)

42-07100 - Belt, "A" AWS, 552

42-07150 - Belt, "A" AWS, 500

NOTE:
RUBBER BELTS STARTED AT:
552-6608 / 500-6544

DK-00710 Pg 9 of 14 Rev G

Operating Instructions - Advanced Watering System
KZ-07100

The Advanced Watering System (AWS) allows the operator to supply water to the ice surface in two different ways; "proportional flow" and "gravity flow."

Proportional flow supplies water relative to the Zamboni ground speed. The faster the machine is driven, the more water is supplied. When the machine is driven slowly, as in turns or in the corners, the water flow decreases.

Gravity flow supplies water at a constant rate regardless of the vehicle's speed.

Both types of flow may be regulated by the operator using the ice making water valve control rod.

To use "Proportional Flow."

1) The handle of the AWS 3 way diverter valve is located on the left side of the vehicle, behind the board brush. It must be in line with the piping (see sheet 12 of 14.), when using the advanced watering system.
2) With water in the fresh water tank, turn on the switch located on the dash. You may hear a "click" as the water pump clutch engages. Open the ice making water control valve.
3) Resurface normally. You will notice that the water flow is proportional to how fast you are driving. You can further regulate the flow by opening or closing the ice making water valve.
4) At the end of the resurfacing, turn off the switch and close the ice making water valve.

To use "Gravity Flow:"

1) Turn the lever of the AWS diverter valve 90° clockwise (handle down). You should hear a microswitch click when you do this
2) Resurface normally by using the fresh water control rod to supply water to the ice.

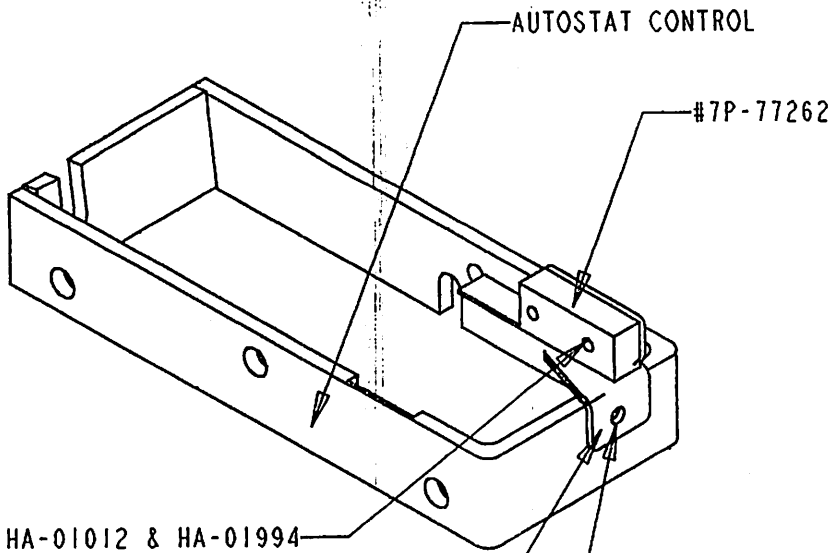
NOTE: You do not have to turn on the AWS switch for gravity feed. If the switch is activated, the light in the switch will go on but the pump will not be operational.

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
		ADVANCED WATER[illegible] SYSTEM	11 OF 14	DK-07100

REV. G 12/5/01 KB

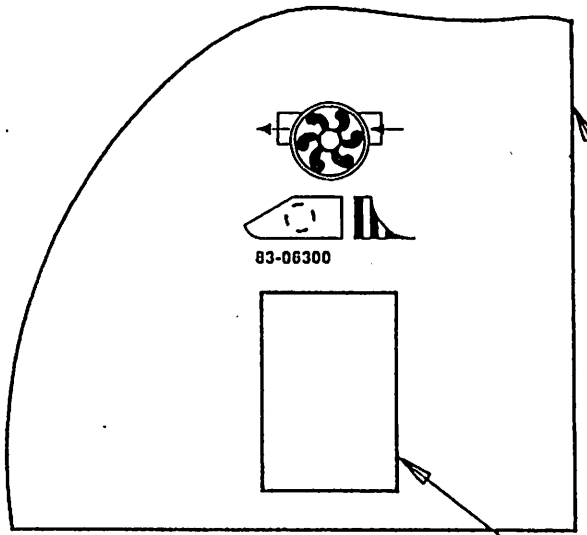
REVERSE LIMIT SWITCH
500-520 MODEL

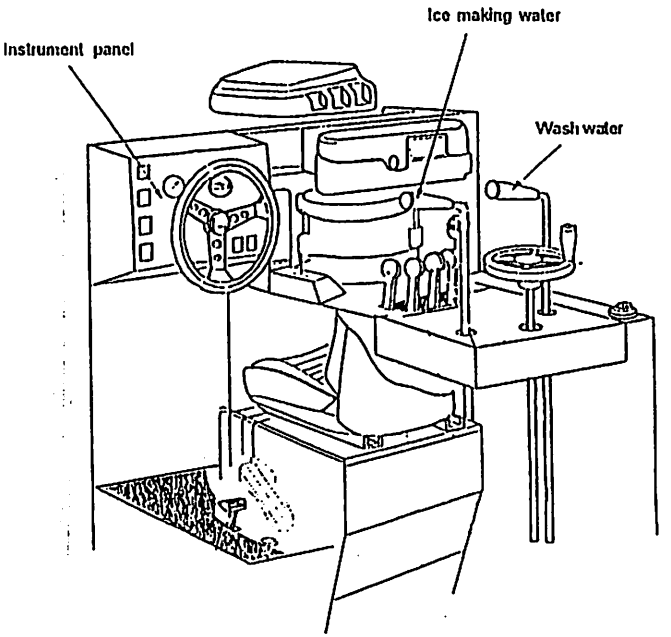


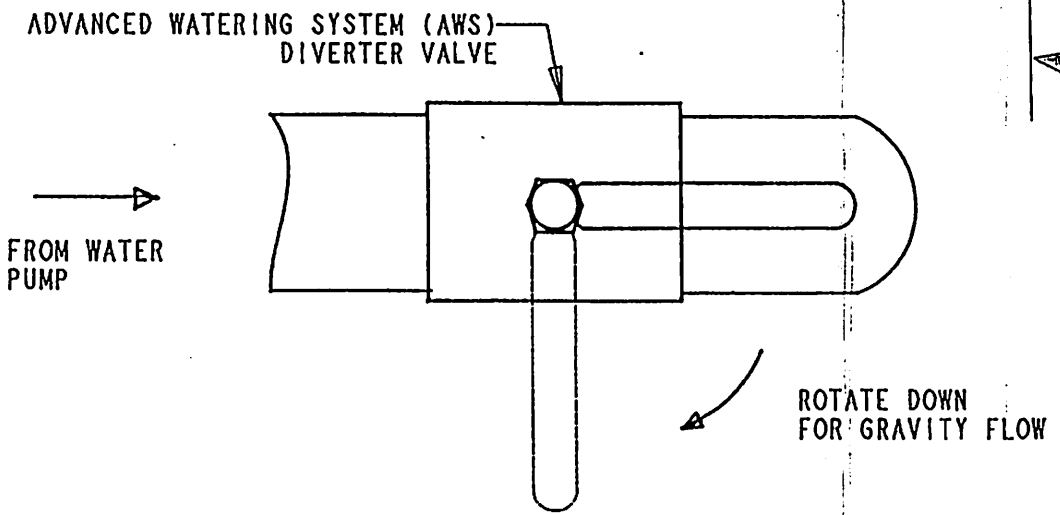
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SCALE NONE	DATE 2/3/99	.DWG			THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.
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MAT'L	FINISH	DESC.	SHEET	ITEM NO.
		ADVANCED WATERING SYSTEM	12 OF 14	DK-07100

REV. G 12/5/01 KB







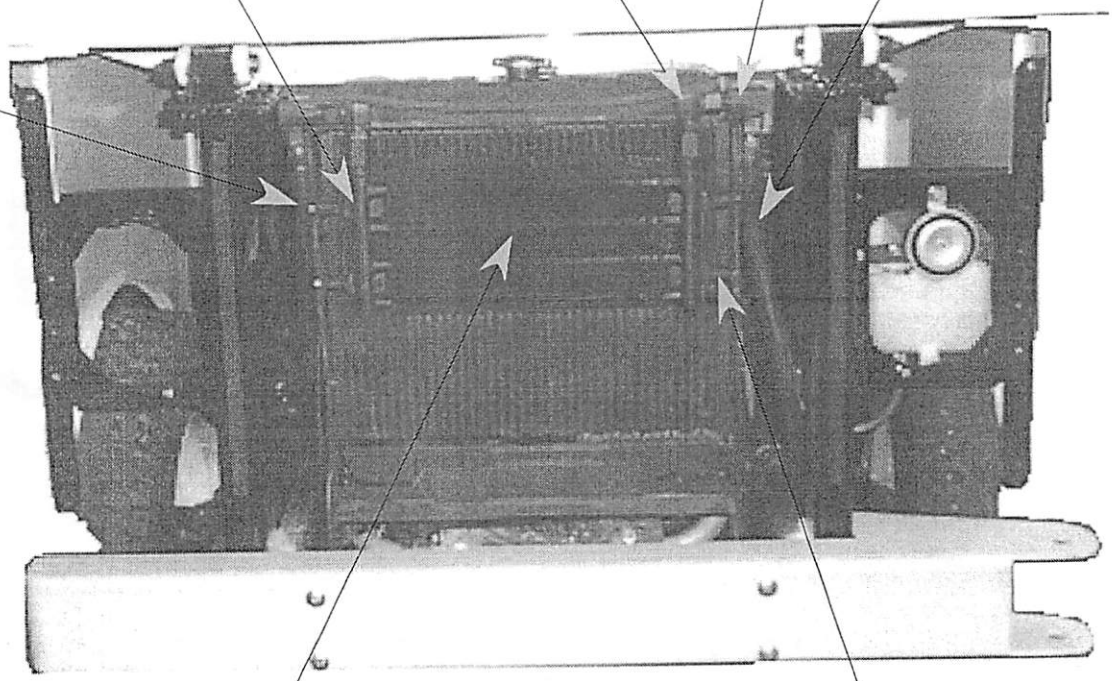
F:\USERS\CARMEN.OPE

FRANK J. ZAMBONI & CO. INC.	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	DRAWN BY C.B.
		SCALE NONE / DATE 8/5/96

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DK-0515A
HYDRAULIC OIL COOLER KIT
MODEL 540

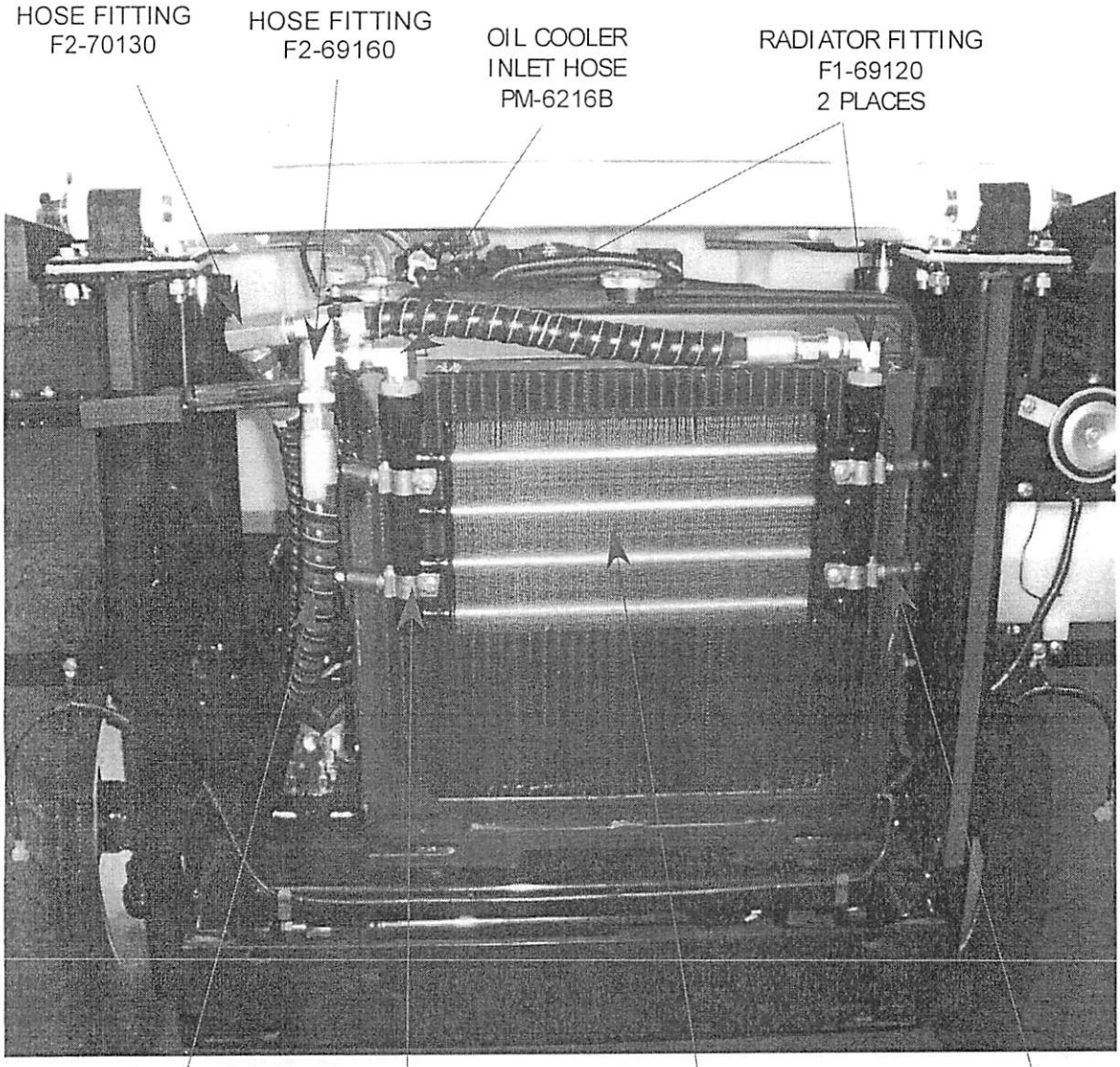
REV. B
10.8.12 KM



PARTS NOT SHOWN

DESCRIPTION	ZAMBONI P/N	QTY
HEX HD SCREW ¼-20x1¼	HF-06013	4
FLAT WASHER, ¼	HF-06860	20
HEX LOCKNUT, ¼-20	HA-06981	8
CABLE TIE 7.5x.19	27-40200	4
90° ELBOW HYDRAULIC FITTING	F2-70130	2

DK-0515A
HYDRAULIC OIL COOLER KIT
MODEL 545



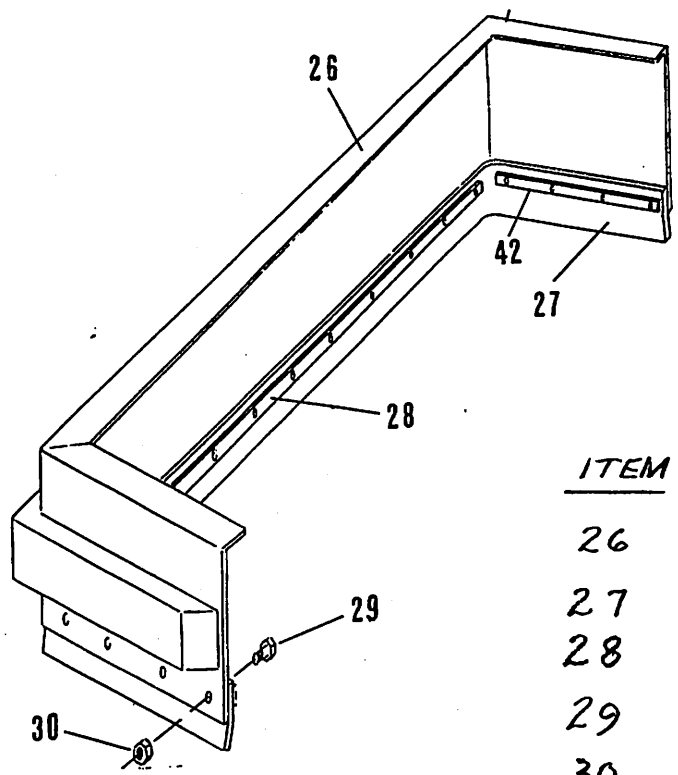
PARTS NOT SHOWN

DESCRIPTION	ZAMBONI P/N	QTY
HEX HD SCREW ¼-20x1¼	HF-06013	4
FLAT WASHER, ¼	HF-06860	20
HEX LOCKNUT, ¼-20	HA-06981	8
CABLE TIE 7.5x.19	27-40200	4

MATL.	FINISH	DESC. KIT, FRONT SQUEEGEE	SHEET 1 OF 2	ITEM NO. 1448

DATE 12/11/86

REV. DATE



ITEM	PART No.	DESCRIPTION	QTY
26	4185	WELDMENT, SQUEEGEE MOUNT	1
27	4279	SQUEEGEE	1
28	4280	STRAP, SQUEEGEE RETAINING, 70 INCH	1
29	HA-10013	SCREW, 3/8-16 x 1-1/4	20
30	HA-10981	LOCKNUT, 3/8-16	20
42	4340	STRAP, SQUEEGEE RETAINING, 23 INCH	2

DRAWN BY: CJ

SCALE

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS:
ANGLES: ± 1° FRACTIONS: ± 1/16 .XX ± .010 .XXX ± .0010

FRANK J. ZAMBONI & CO., INC.
PARAMOUNT, CALIFORNIA, U.S.A

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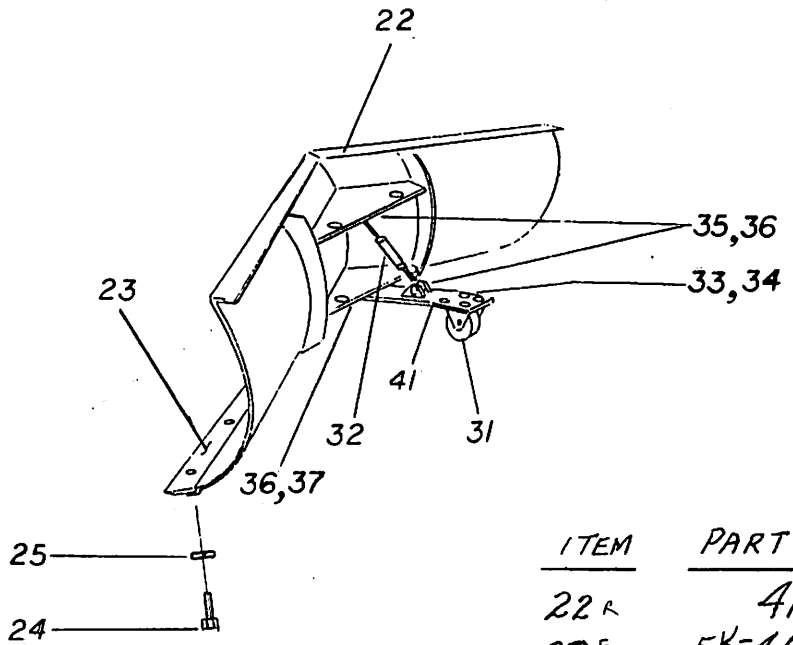
MATL.	FINISH	DESC. KIT, V-PLOW	SHEET 1 OF 2	ITEM NO. 1447

DATE 12/11/86

REV. DATE 9.27.91 SA

SEE KIT 1446 FOR MOUNTING TO VEHICLE

SEE KIT 1445 FOR V-PLOW & SQUEEGE KITS COMBINED

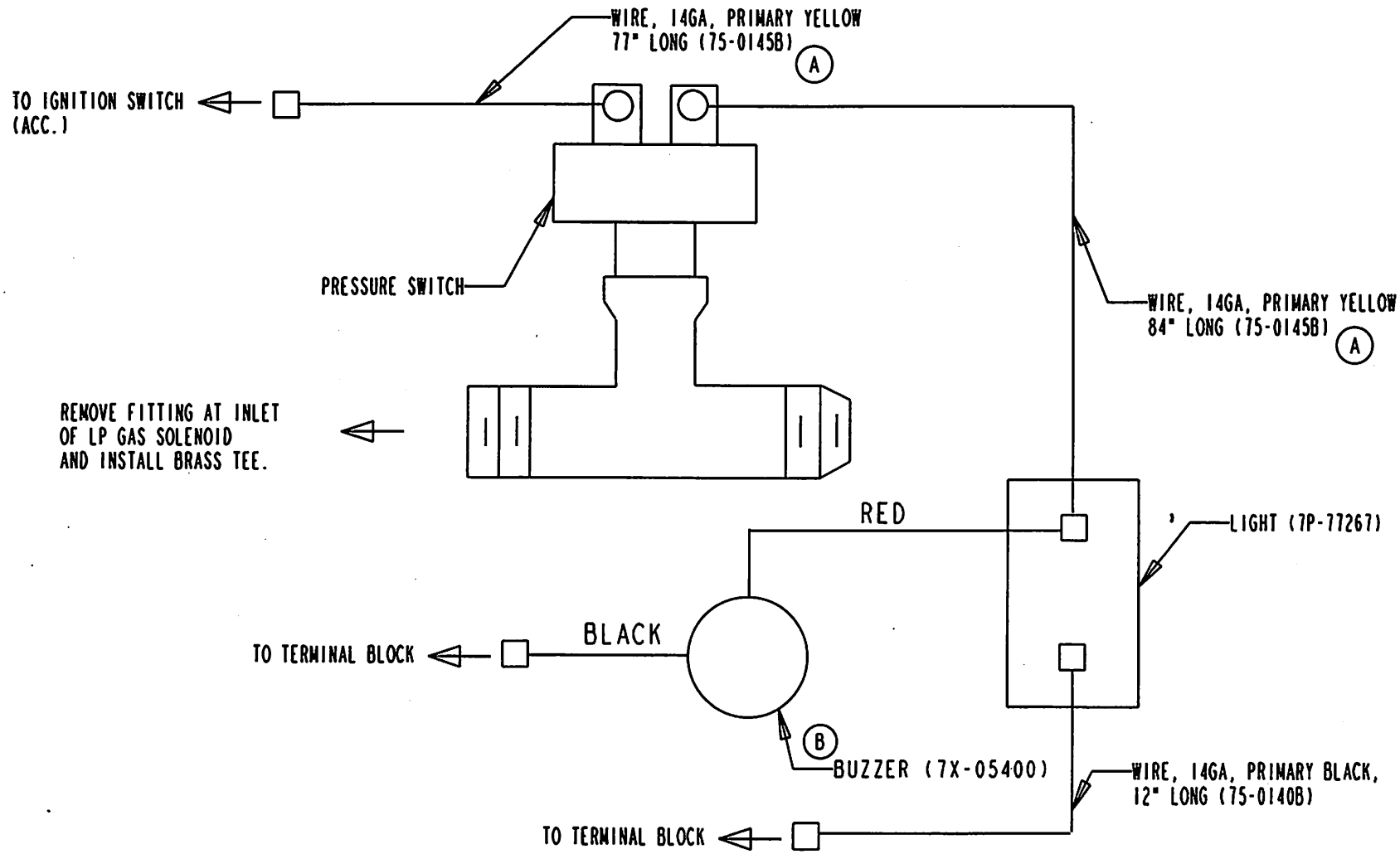


ITEM	PART NO.	DESCRIPTION	QTY
22R	4186	V-PLOW WELDMENT	1
23F	5K-4499	SET, LT. & RT. BLADE	1
24	HA-14011	SCREW, 1/2-13 x 1	10
25	HA-14862	LOCKWASHER, 1/2	10
31A	9054	CASTER	1
32R	9059	TURNBUCKLE ASSY	1
33	HA-10010	SCREW, 3/8-16 x 7/8	4
34	HA-10981	LOCKNUT, 3/8-16	4
35R	9057	PIN, 5/8 x 2-3/4	2
36I	HA-52711	COTTER PIN, 1/8 x 1	6
37R	9058	PIN, 5/8 x 6 3/4	1
41F	4504	RUNNER, V-PLOW WHEEL	1

DRAWN BY: CJ	DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED. TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS: ANGLES: ± 1° FRACTIONS: ± 1/16 .XX ± .010 .XXX ± .0010	FRANK J. ZAMBONI & CO., INC. PARAMOUNT, CALIFORNIA, U.S.A
SCALE		

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MATL.	FINISH	DESC.	SHEET	ITEM NO.
NOTED	------	INSTRUCTIONS, RECTANGUALR LOW FUEL LIGHT KIT	1 OF 1	DK-0045C



□ TERM, 1/4 FEM, 16/14GA, INS (75-0670D)
○ TERM RING, 16/14GA, #10 STUD (75-0574B)

N:\Engineering CAD Library\Clark\PROE20PARTS\proe_d3p

REV.	
A	6/26/06 DHR
B	12/10/07 CA

DRAWN BY C. B.	CAD INFO / DIR	DIMENSIONS ARE IN INCHES. TOLERANCES: X±.10, XX±.060, XXX±.030 ANGLES ±1°	FRANK J. ZAMBONI & CO. INC.
SCALE NONE / DATE 6/24/96	.DWG DK0045C / .PRT / .ASM		THIS DOCUMENT AND THE INFORMATION THEREON ARE THE PROPERTY OF THE FRANK J. ZAMBONI & CO. INC. AND ARE NOT TO BE USED WITHOUT PERMISSION.

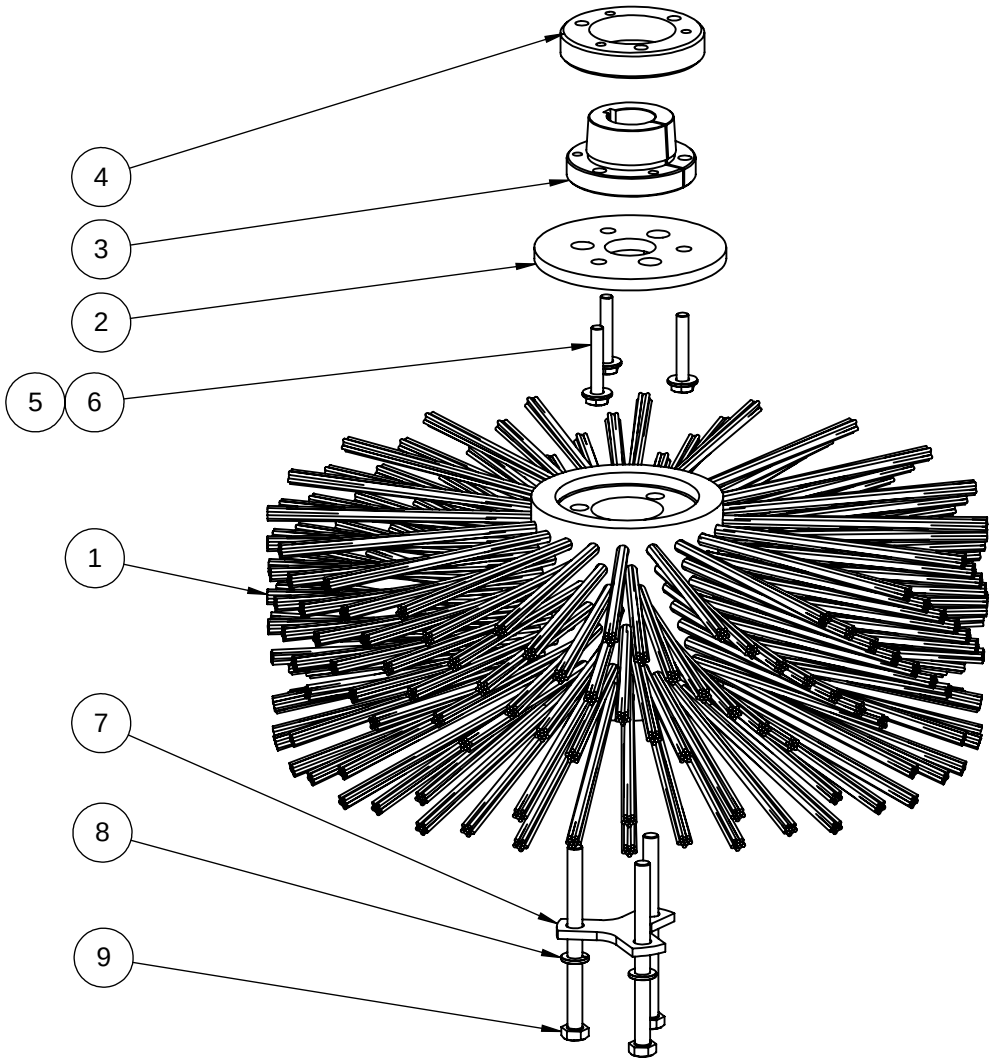
MATERIAL	FINISH	DESC	SHEET	DWG. NO.	REV
N/A -	- -	**KIT, CYLINDER STYLE BOARD BRUSH, 500 SERIES**	1 OF 1	**KZ-18575**	**A**

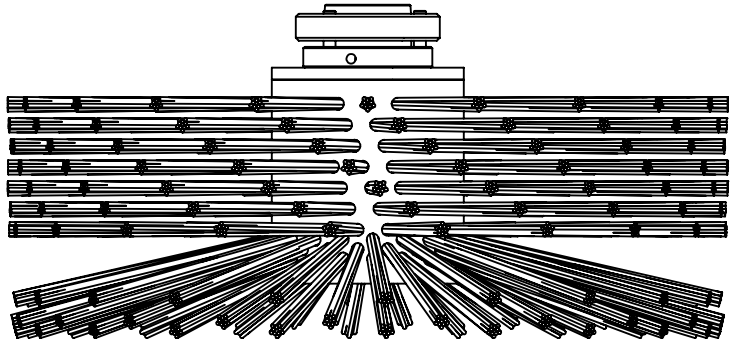
REV	REVISION DESCRIPTION	REV DATE	BY
A	5V-60030 WAS 5V-60020.	16/06/09	DLJ

1. **ASSEMBLE ITEMS 2, 3 AND 4 ONTO BOARD BRUSH MOTOR SHAFT. USE SUPPLIED BOLTS AND WASHERS (ITEMS 5 AND 6).**

2. **ASSEMBLE BRUSH ELEMENT (ITEM 1) TO MOUNTING PLATE (ITEM 2) USING THE SUPPLIED HARDWARE AS SHOWN. TIGHTEN THE 5/16 x 4 INCH BOLTS EQUALLY.**

3. **NOTE THAT THE ANGLED BRISTLES ARE ON THE BOTTOM OF THE BRUSH.**





ITEM	PART NO.	DESCRIPTION	QTY.
1	5V-60030	BOARD BRUSH, CYLINDER STYLE,	1
2	4F-65060	MOUNT, BRUSH ELEMENT, BB, 650	1
3	43-73380	BSHNG,QD,SIZE SH,1 IN BORE	1
4	5V-0500B	BB ADAPTR,QD,1/4-20,2.25BC	1
5	HA-06860	WASHER, FLAT (1/4)	3
6	HA-06014	BOLT, HEX HD (1/4-20 x 1.5)	3
7	4F-65070	RETAINER, BOARD BRUSH, 650	1
8	HA-08862	WASHER, LOCK (5/16)	3
9	HA-08024	BOLT, HEX HD (5/16-18 x 4)	3

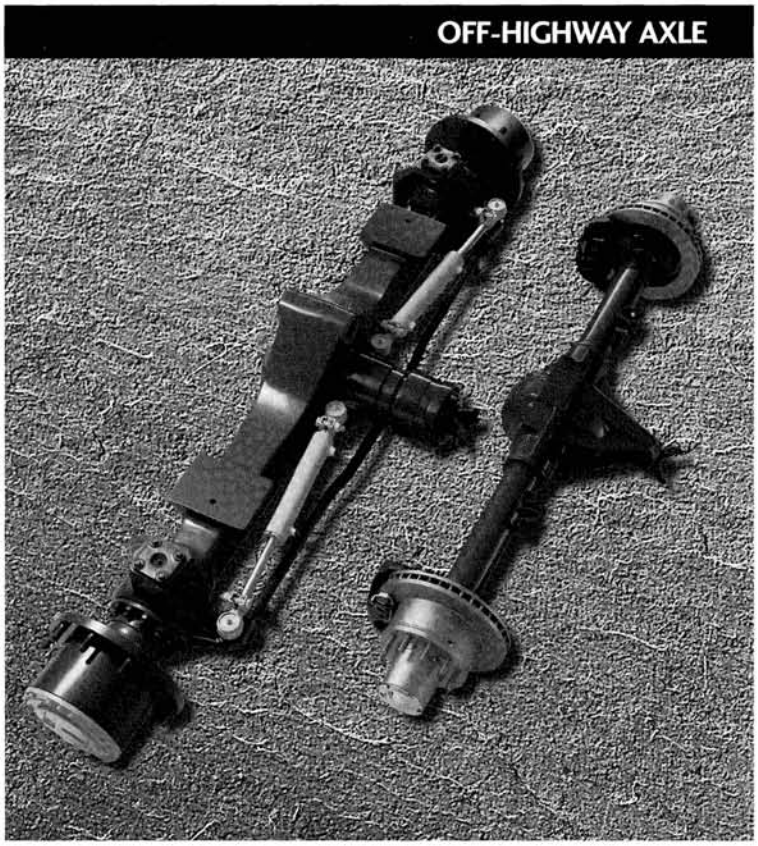
DRAWN	DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: MACHINED ± 0.5˚ BEND ± 1˚ TWO PLACE DECIMAL ± 0.03 THREE PLACE DECIMAL ± 0.015	**ZAMBONI È COMPANY LTD.**
DOUG JOHNSON		
DATE 15/10/02		THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF ZAMBONI È COMPANY LTD. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF ZAMBONI È COMPANY LTD. IS PROHIBITED.

12 MEMOS AND UPDATES

MODEL 44
MAINTENANCE MANUAL

SPICER®

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SPICER



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IMPORTANT SAFETY NOTICE

Should an axle assembly require component parts replacement, it is recommended that "Original Equipment" replacement parts be used. They may be obtained through your local service dealer or other original equipment manufacturer parts supplier. CAUTION: THE USE OF NON-ORIGINAL EQUIPMENT REPLACEMENT PARTS IS NOT RECOMMENDED AS THEIR USE MAY CAUSE UNIT FAILURE AND/OR AFFECT VEHICLE SAFETY.

Proper service and repair is important to the safe, reliable operation of all motor vehicles or driving axles whether they be front or rear. The service procedures recommended and described in this service manual are effective methods for performing service operations. Some of these service operations require the use of tools specially designed for the purpose. The special tool should be used when and as recommended.

It is impossible to know, evaluate and advise the service trade of all conceivable ways in which service might be done or of the possible hazardous consequences of each way.

Accordingly, anyone who uses a service procedure or tool which is not recommended must first satisfy himself thoroughly that neither his safety or vehicle safety will be jeopardized by the service methods he selects.

NOTE

Throughout this manual, reference is made to certain tool numbers whenever special tools are required. These numbers are numbers of the Miller Special Tools, 32615 Park Lane, Garden City, Michigan 48135. They are used herein for customer convenience only. Dana Corporation makes no warranty or representation with respect to these tools.

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Litho in U.S.A.

LUBRICATION

It is not our intent to recommend any particular brand or make of lubricant for Spicer axles. However, a S.A.E. 90 weight multipurpose gear lubricant meeting Mil. Spec. L-2105-B, or 80 W 90 multipurpose gear lubricant meeting Mil. Spec. L-2105-C, and suitable for A.P.I. Service Classificiation GL-5 is suggested as a minimum requirement.

IMPORTANT

As special equipment limited slip differentials are provided in many vehicles, the freedom from "chatter" is a function of the lubricant used and cannot be covered in the above specifications. In some applications, a special limited slip differential lubricant may be required. If required, these special lubricants are normally available through the original equipment manufacturer.

WHEEL BEARING LUBRICATION

Wheel bearings are lubricated by either grease packing the wheel bearing itself, or it can be lubricated from the hypoid gear lube in the housing.

For grease packing it is recommended that a number 2 consistency, lithium base 12 hydroxy stearate grease containing an E.P. additive be used. Such a lubricant would pass a load-carrying test at 40 pounds minimum with base oil pour point at —10° F. maximum.

Wheel bearings which depend on lubrication from the hypoid gear lube in the axle housing, it is recommended that a S.A.E. 90 multipurpose gear lube meeting Mil. Spec. L-2105-B be used.

CLOSED WHEEL END STEERING KNUCKLE LUBRICATION

The closed steering knuckle requires lubrication from a source other than the gear carrier assembly. Inboard tube seals contain the hypoid gear lube in the housing to provide an adequate lubricant level for the gears, bearings, etc. This then requires an additional lubricant level to be maintained outboard, in each steering knuckle, which can be observed by removing fill plugs on each knuckle. Adequate level would be to the bottom of the fill plug hole, when vehicle is observed to be in a normal horizontal position.

Recommended lubricant is a S.A.E. 140 grade, multipurpose gear lubricant meeting the Mil-L-2105-B specification.

COLD WEATHER OPERATION

If the vehicle is operated below 0 °F (−18 °C), it is advisable to use S.A.E. 80 multipurpose gear lubricant meeting Mil. Spec. L-2105-B and suitable for A.P.I. Service Classification GL-5.

SUBMERSION OR DEEP WATER FORDING

If the vehicle is exposed to water deep enough to cover the hubs of either the front or rear axles, it is recommended that the wheel ends be dissassembled and inspected for water damage, and/or contamination daily.

Clean, examine and replace damaged parts if necessary, prior to relubricating and assembling the wheel end components. Pay particular attention to the bearings and the closed steering knuckle on the front driving axle.

In the event the gear carrier housing should become submerged in water, particularly if over the breathers, it is recommended that the hypoid gear lubricant be drained daily and internal parts be inspected for water damage and/or contamination.

Clean, examine and replace damaged parts if necessary, prior to assembling the cover housing and refilling with the specified hypoid lubricant.

NOTE

It is recommended that whenever bearings are removed they are to be replaced with new ones, regardless of mileage.

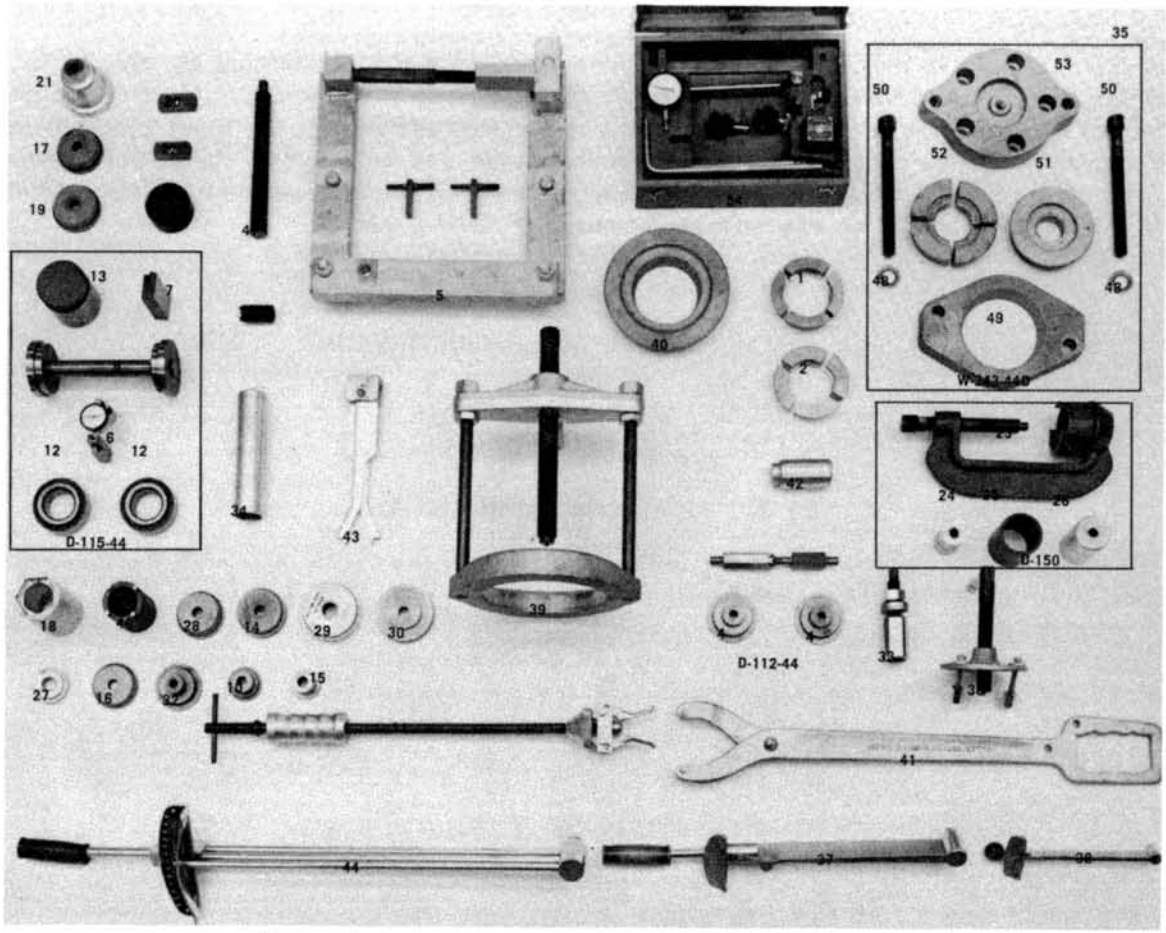


Figure 2 1009-2

The following is a detailed list of all Special Service Tools required to service the Model 44 Front and Rear Axles.

Item No.	Tool No.	Description
1	C-293-18	Adapter Set—Differential Bearing Cones
2	C-293-39	Adapter Set—Rear Pinion Bearing Cone
**** 3	D-112	Screw
**** 4	D-112-1	Installer—Front Axle—Differential Inner Oil Seal
5	D-113	Spreader
* 6	D-115	Scooter Gauge
* 7	D-115-1	Pinion Height Block
* 8	D-115-3	Arbor
* 9	D-115-4	Arbor Discs
10	D-112	Installer—Front Spindle Needle Bearing
11	D-131	Puller—Slide Hammer
*12	D-135	Master Bearing Differential
*13	D-139	Master Pinion Block
14	D-140	Installer—Front Brake Hub Cup (outer)
15	D-141	Installer—Front Spindle Bushing
16	D-142	Installer—King Pin Bearing Cup (Heavy Duty)
17	D-144	Installer—Front Pinion Bearing Cup
18	W-144A	Wrench—Wheel Bearing Adjusting (Nut Type)
19	D-145	Installer—Rear Pinion Bearing Cup
20	D-147	Remover—Front Pinion Bearing Cup
21	W-147-D	Installer—Pinion Oil Seal
22	D-148	Remover—Rear Pinion Bearing Cup
***23	D-150-1	Remover & Installer—Front Axle Ball Joint
***24	D-150-2	Adjuster—Ball Joint Removing
***25	D-150-3	Sleeve—Ball Joint Removing
***26	D-150-4	Sleeve—Ball Joint Installing
27	D-151	Installer—King Pin Bearing Cup

Item No.	Tool No.	Description
28	D-153	Installer—Front Brake Hub Inner Bearing Cup (Regular)
29	D-154	Installer—Front Brake Hub Inner Bearing Cup (Heavy Duty)
30	D-155	Installer—Front Brake Hub Grease Seal (Reg. & Heavy Duty)
31	D-156	Installer—Differential Side Bearings
32	D-157	Installer—Axle Shaft Outer Oil Seal
33	W-162	Installer—Flange or Yoke
34	W-262	Installer—Rear Pinion Bearing Cone
**35	W-343-44D	Remover & Installer—Axle Shaft Bearings
36	C-452	Remover—Flange or Yoke
37	C-524-A	Torque Wrench (100 ft. lb.)
38	C-685-A	Torque Wrench (300 inch lb.)
39	DD-914-P	Press
40	DD-914-9	Adapter Ring
41	C-3281	Holder—Flange or Yoke
42	C-293-3	Adapter Plug—Differential Hub
43	C-4049	Remover—Bearing Cups
44	C-4053	Torque Wrench (300 ft. lb.)
45	C-4169	Wrench—Upper Ball Joint Removing, Installing & Torquing
46	C-4170	Wrench—Wheel Bearing Adjusting (Lug Type)
47	C-4171	Handle—Universal
**48	SP-3020	Washers
**49	SP-5017	Adapter Ring
**50	SP-5026	Bolts
**51	SP-5439	Adapter Plate—Installer
**52	SP-5442-D	Adapter Set—Removing
**53	SP-5443-A	Flange Plate
54	D-128	Dial Indicator Set

*Pinion Setting Gauge and Master Differential Bearing Kit D-115-44

**Axle Shaft Bearing Removing and Installing Kit W-343-44D

***40 Degree Steer Front Ball Joint Removing and Installing Kit D-150

****Inner Axle Shaft Seal Installing Kit D-112-44

Note: Torque wrenches C-524A, C-685-A, and C-4053 are optional and can be purchased separately. These Torque wrenches are not included in the DW-44 Axle Tool Kit.

AXLE IDENTIFICATION

All Spicer axles are identified with a manufacturing date and the complete part number stamped in the right hand tube. Also each axle contains a gear ratio tag; and if the axle is equipped with a limited slip differential, it will contain a tag requesting the use of limited slip lubricant.

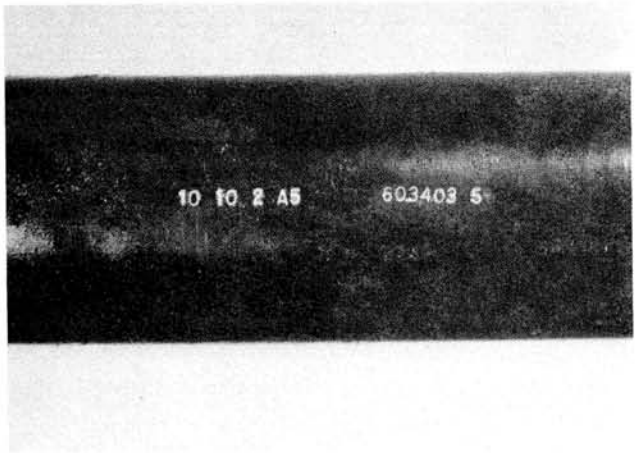


Figure 3 1009-3

In the figure the axle is identified with 1/8" high numbers stamped in the tube. For example, the numbers 10-10-2 A5 is the manufacturing or build date of the axle and is interpreted as follows. The first number is the month, the second number is the day of the month, the third number is the year, the letter is the shift and the last number is the line that built the axle. For example: October 10, 1972, first shift, line 5.

NOTE

In the event there are two build dates, the latter will be the date in which the brake components were assembled.

It is recommended that when referring to the axle, obtain the complete part number and build date. To do this, it may be necessary to wipe or scrape off the dirt, etc., from the tube.

NOTE

On front driving axles, the above numbers can be either on the long or short tube.

AXLE IDENTIFICATION

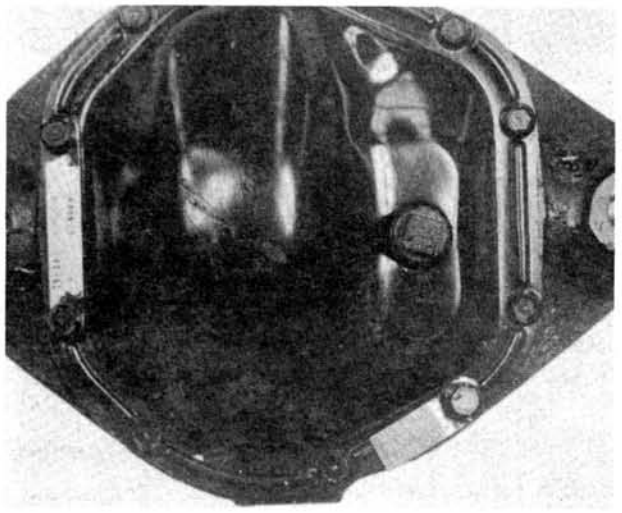


Figure 4 1009-4

The gear ratio tag is located on the left side of the cover plate and is held in place with two cover plate screws. This tag gives the tooth combination of the ring and pinion, the total gear ratio, and also the customer part number.

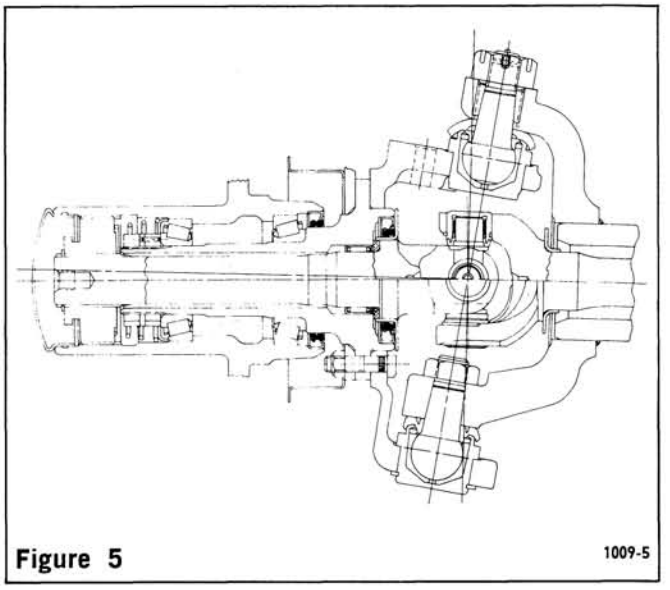


Figure 5 1009-5

40 DEGREE STEER WITH INTERNAL HUBS

FRONT AXLE

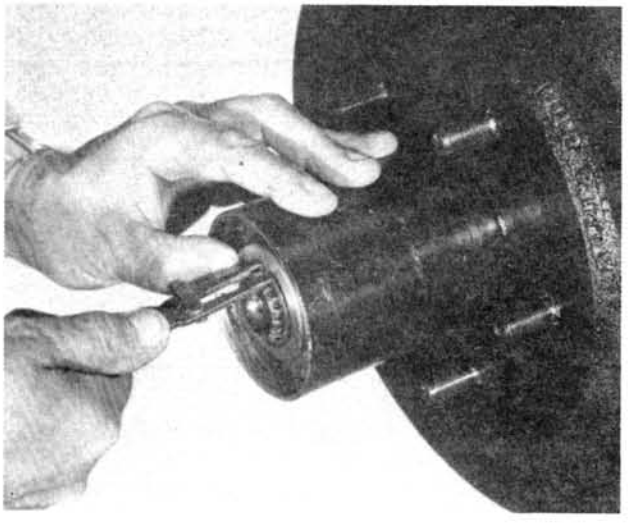


Figure 6 1009-6

Remove hub cap and snap ring.

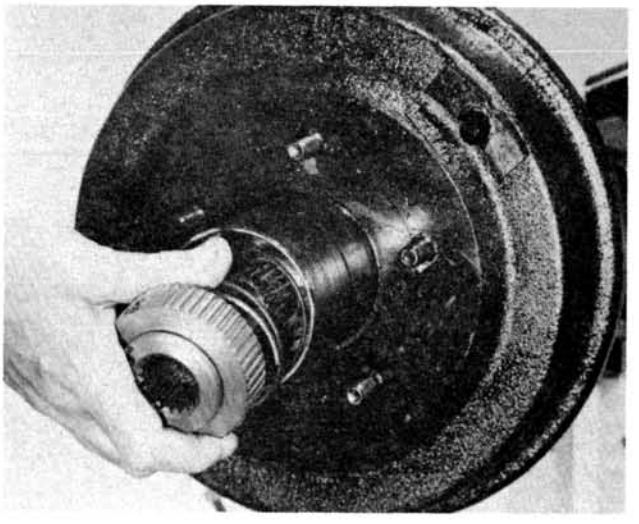


Figure 7 1009-7

Remove drive gear and pressure spring. If drive gear is stuck to the shaft, use a screw driver to pry out gear.

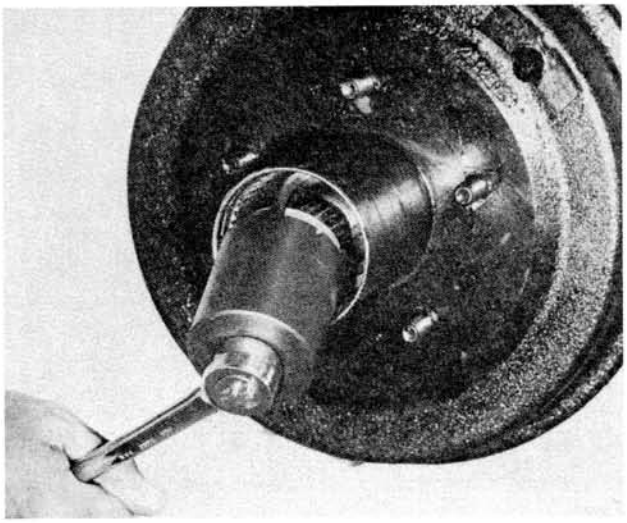


Figure 8 1009-8

Remove wheel bearing lock nut, lock ring and the wheel bearing adjusting nut.

Tool—#C-4170 Wheel bearing wrench.

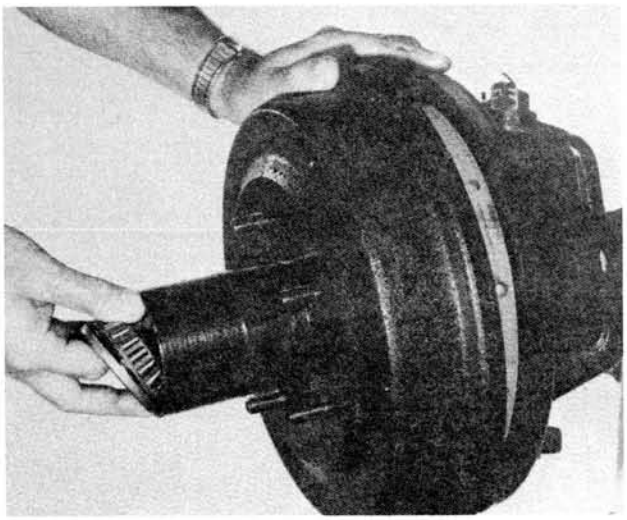


Figure 9 1009-9

Remove hub and drum assembly. Spring retainer and outer wheel bearing will slide out as drum is removed.

NOTE

If it is necessary to replace brake components such as drum, shoes, backing plate, etc., refer to vehicle service manual.



Figure 10 1009-10

Remove hub grease seal and inner wheel bearing cone.

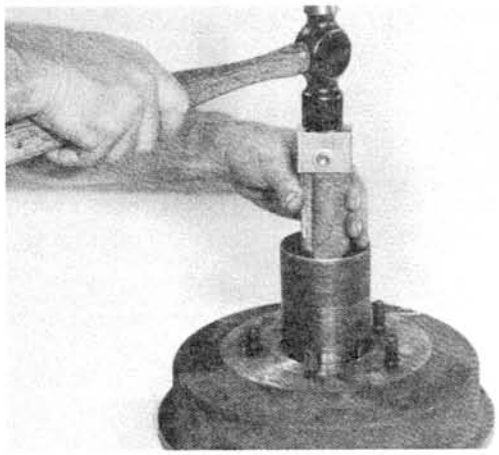


Figure 11 1009-11

Remove inner wheel bearing cup.

Tool—#C-4049 Wheel bearing cup remover.

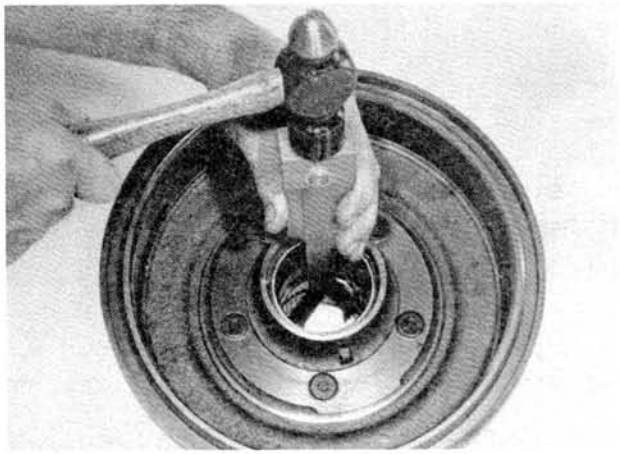


Figure 12 1009-12

Remove outer wheel bearing cup.

Tool—#C-4049 Wheel bearing cup remover.

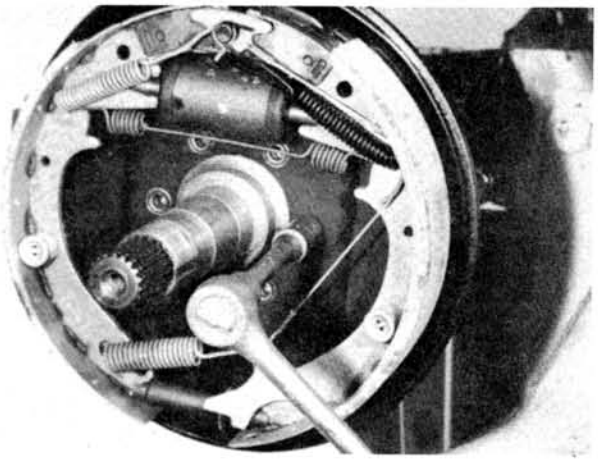


Figure 13 1009-13

Remove backing plate screws and remove backing plate.

> **NOTE**
> The brake backing plate assembly can be retained with screws or nuts. If the nuts are of the torque prevailing design, they are to be replaced with new ones.

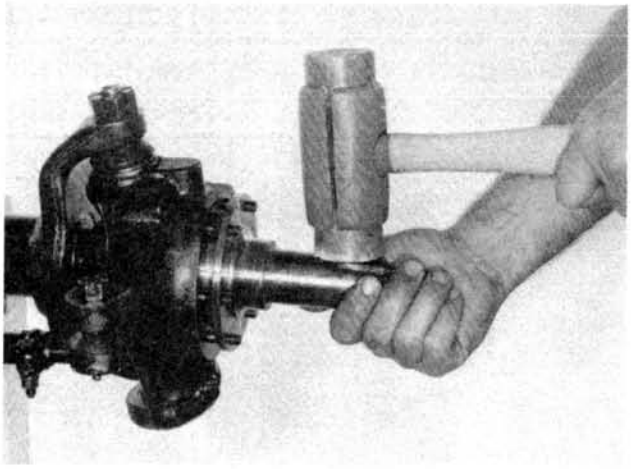


Figure 14 1009-14

Remove spindle. If necessary tap lightly with a rawhide hammer to free it from the knuckle. Check brone spacer located between shaft joint assembly and bearing. If wear is evident, replace with a new one.

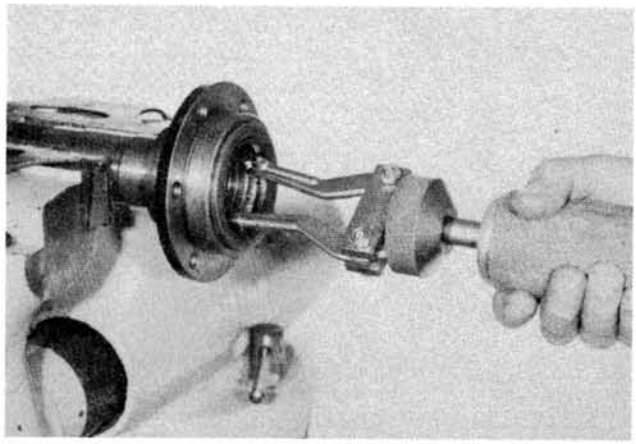


Figure 15 1009-15

Place spindle in vise. **Do not locate on bearing diameters.**

Remove grease seal. **Discard seal.**

Tool—#D-131 Slide hammer.

> **NOTE**
> Be sure that vise jaws are equipped with brass protectors or similar type to protect the machined surfaces of any parts that are to be placed in the vise.

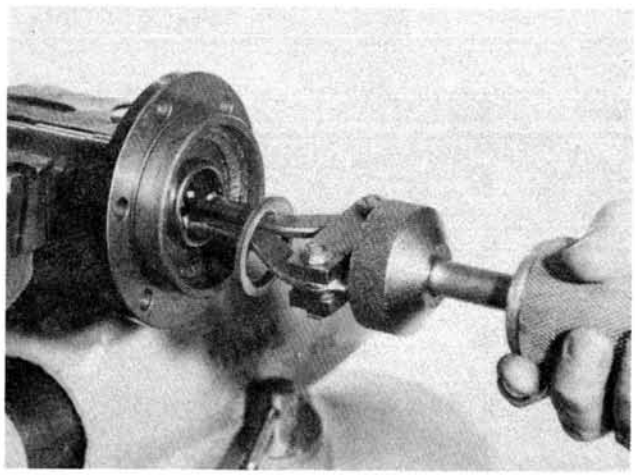


Figure 16 1009-16

Remove needle bearing. Bronze bushing may stick to the bearing as the spindle was removed, but can be removed when removing the needle bearing as shown.

Tool—#D-131 Slide hammer.

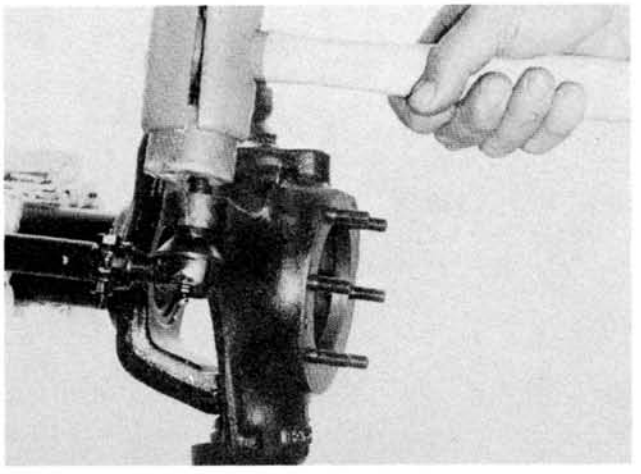


Figure 17 1009-17

Remove cotter key from tie rod nut. Remove nut. Tap on tie rod stud to free it from the steering arm.

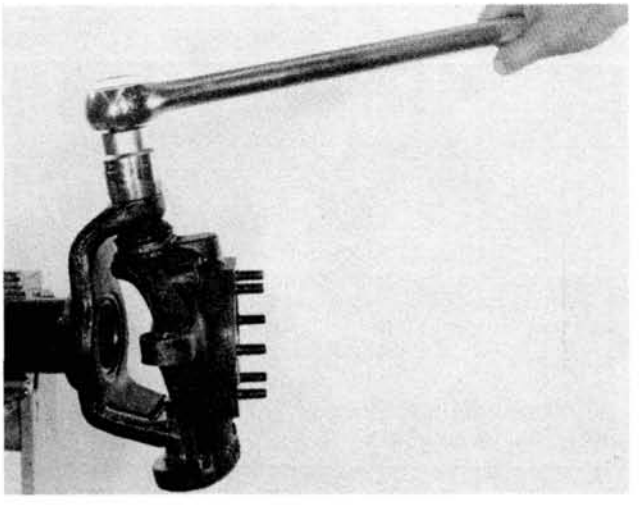


Figure 18 1009-18

Remove cotter key from top socket. Loosen both the top and bottom nuts.

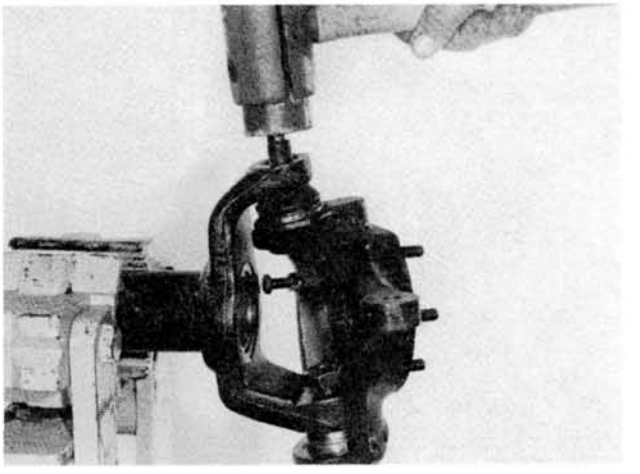


Figure 19 1009-19

Using a rawhide hammer, hit sharply on the top stud to free the knuckle from the tube yoke. After knuckle is free from the yoke, remove both the top and bottom nuts. **Discard bottom nut.** The nut on the bottom socket is of the torque prevailing design and is not to be reused.

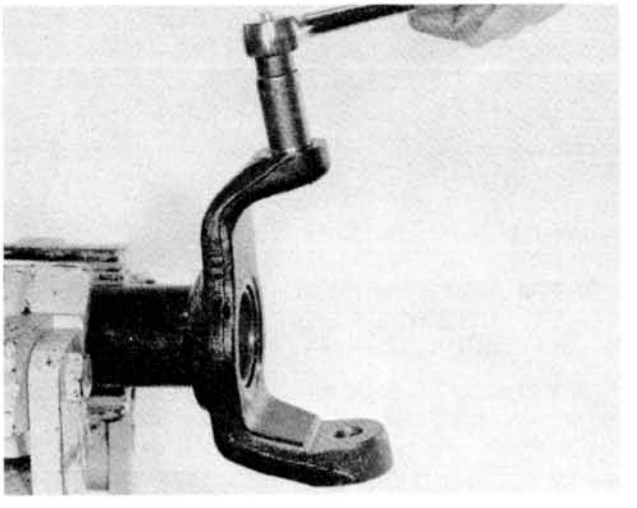


Figure 20 1009-20

Remove threaded sleeve from yokes with Tool #C-4169 socket wrench.

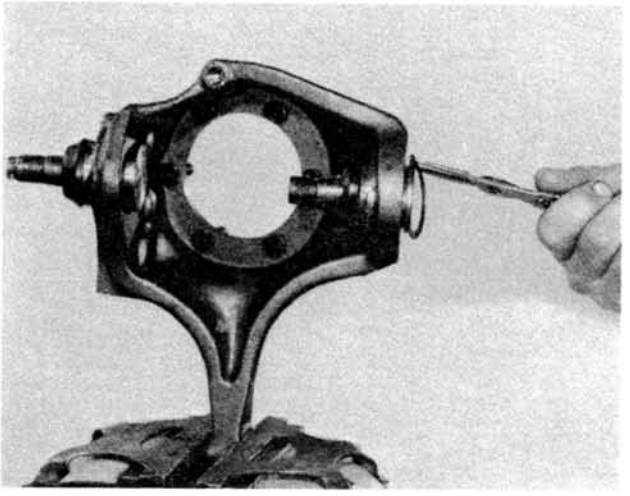


Figure 21 1009-21

Place knuckle in vise as shown. If bottom ball socket is equipped with a snap ring, remove as shown.

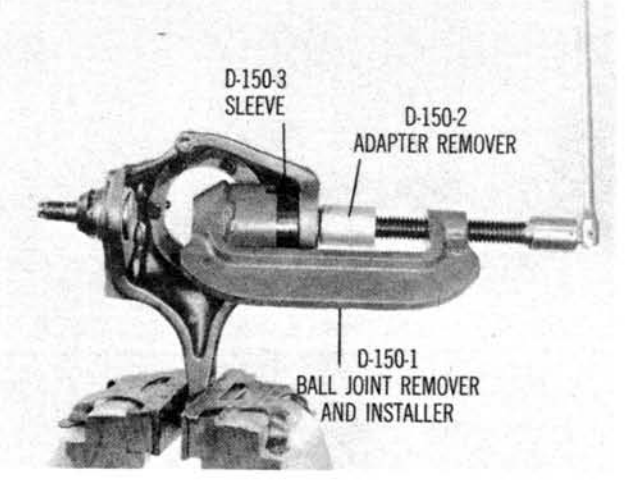


Figure 22 1009-22

NOTE: BOTTOM BALL SOCKET MUST BE REMOVED BEFORE THE TOP BALL SOCKET CAN BE REMOVED.

Assemble ball socket tools as shown. Turn forcing screw and push out bottom socket.

DISCARD BALL SOCKET

Tools—#D-150-1 Ball Joint Remover & Installer, #D-150-2 Adapter Remover, and #D-150-3 Sleeve.

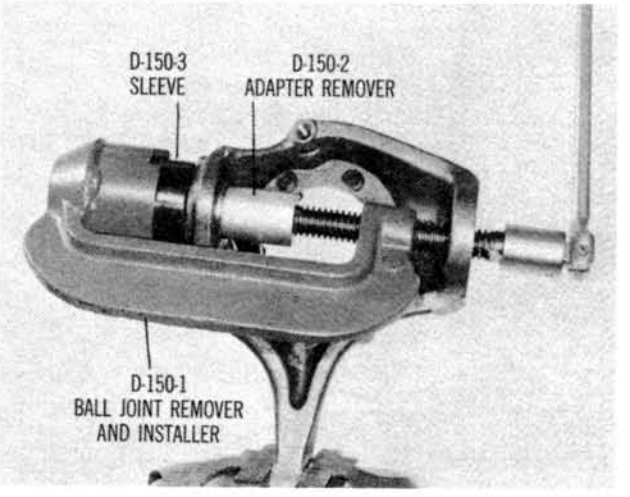


Figure 23 1009-23

Assemble ball socket tools as shown. Turn forcing screw and push out top socket.

Discard Ball Socket

Tools—#D-150-1 Ball Joint Remover & Installer, #D-150-2 Adapter Remover, and #D-150-3 Sleeve.

ASSEMBLY

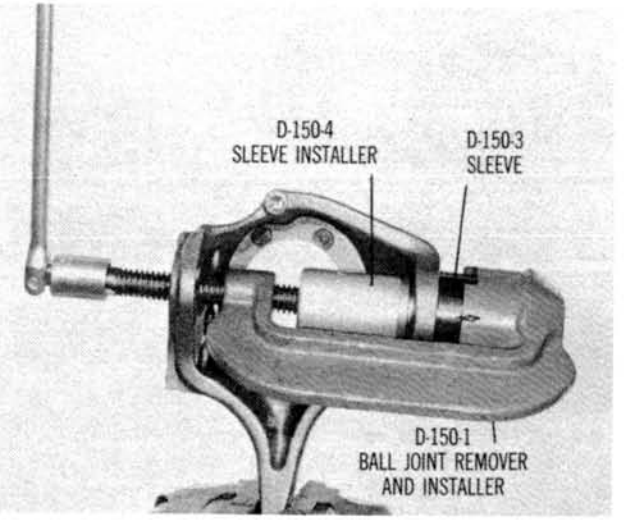


Figure 24 1009-24

(Lower ball socket does not have a cotter key hole in the stud end.)

Assemble bottom socket into the knuckle. Make sure socket is straight.

Assemble tools as shown. Turn forcing screw and push socket into knuckle as far as it will go.

Tools—#D-150-1 Ball Joint Remover & Installer, #D-150-3 Sleeve, & #D-150-4 Sleeve Installer.

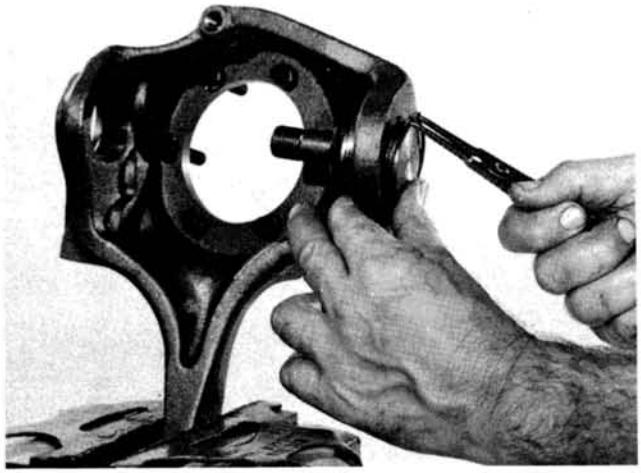


Figure 25 1009-25

If required, assemble snap ring on bottom socket.

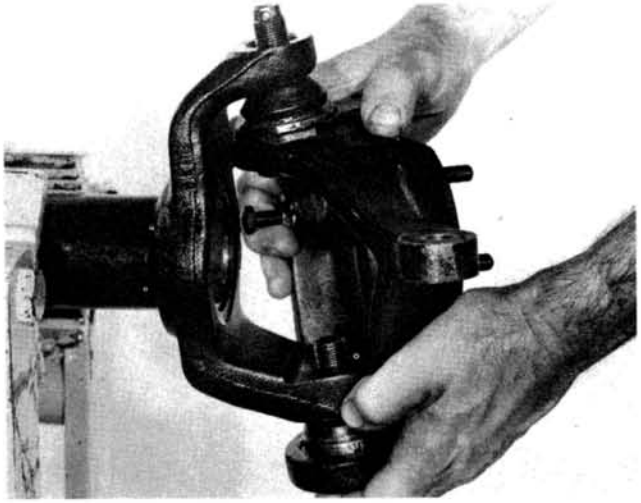


Figure 27 1009-27

Assemble knuckle and socket assembly to yoke as shown.

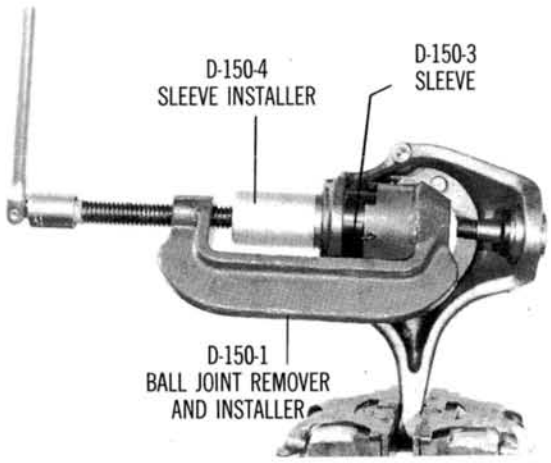


Figure 26 1009-26

Upper ball socket has a cotter key hole in the stud end. Assemble socket into knuckle. Make sure socket is straight.

Assemble tools as shown. Turn forcing screw and push socket into knuckle as far as it will go.

Tools—#D-150-1 Ball Joint Installer & Remover, #D-150-3 Sleeve, & #D-150-4 Sleeve Installer.

Remove tools. Make sure this area is free from dirt, etc.

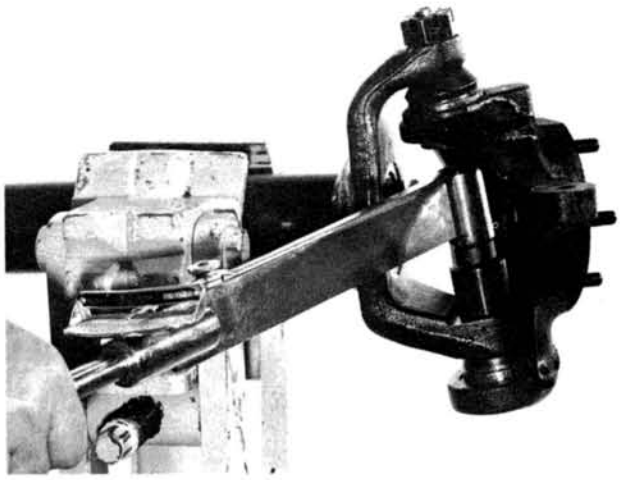


Figure 28 1009-28

Assemble new torque prevailing nut on bottom socket finger tight.

Assemble top nut on top socket. **Do not assemble at this time.**

Torque top nut until it is tight. This will pull the studs of the bottom socket into the tapered hole of the yoke.

Torque bottom nut to 80 lbs. ft.

Tool—#C-524-A Torque wrench.

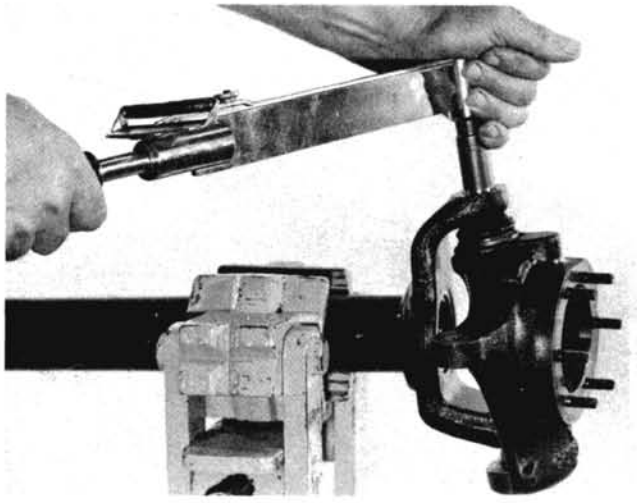


Figure 29 1009-29

Assemble new threaded sleeve into top of yoke. Using tool as shown torque sleeve to 50 lbs. ft.

Tools — #C-4169 Sleeve socket, #C-524-A Torque wrench.

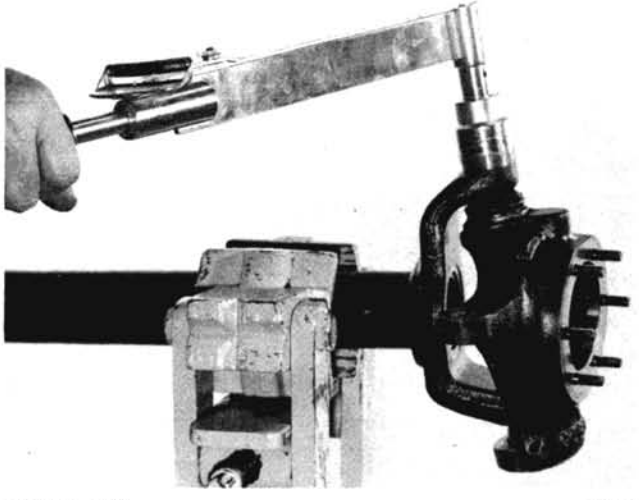


Figure 30 1009-30

Assemble top socket nut. Torque nut to 100 lbs. ft. After nut has been torqued, tighten nut to line up the cotter key hole of the stud with the next castellation or slot of the nut. **Do not loosen nut.**

Tool—#C-524-A Torque wrench.

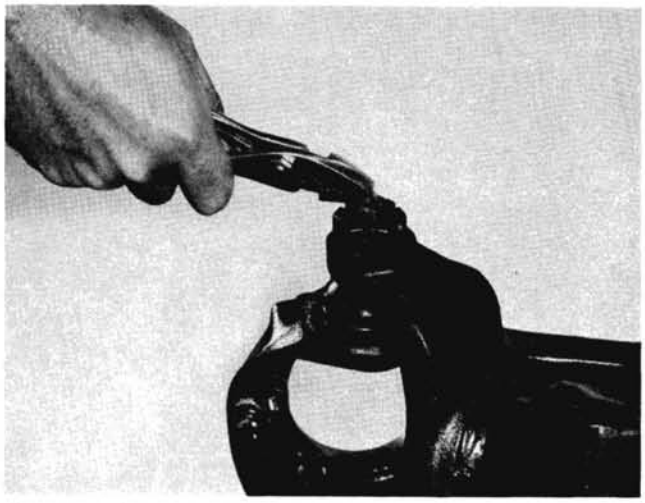


Figure 31 1009-31

Assemble cotter key.

NOTE

In the event that knuckles are received with the sockets and snap ring assembled to the knuckle, along with new top and bottom nuts, split sleeve and cotter key. Follow procedures as illustrated through Figues 27 through 31 for assembly.

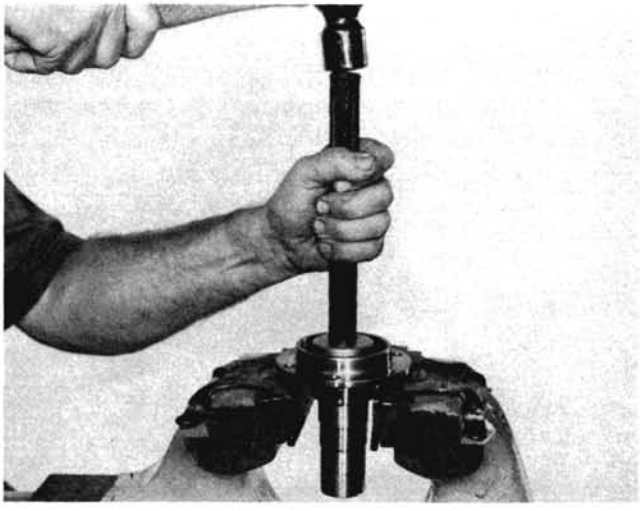


Figure 32 1009-32

Assemble new needle bearing into spindle.

Tools—#D-122 Installer, #C-4171 Handle.

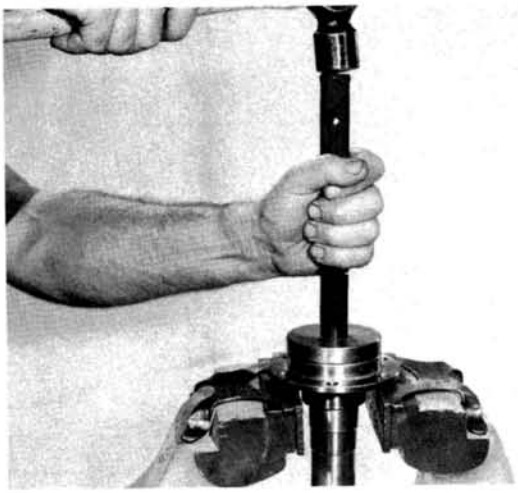


Figure 33 1009-33

Assemble new grease seal into spindle.
Tools—#D-155 Installer, #C-4171 Handle.

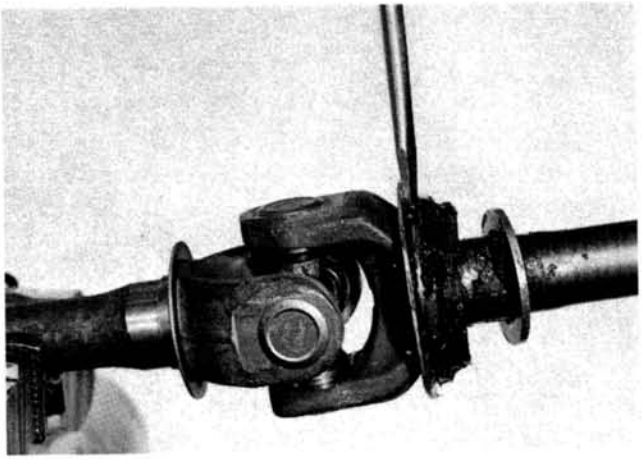


Figure 34 1009-34

Some front axles are equipped with a "V" seal which is assembled to the axle shaft stone shield as shown. If seal is worn, remove and replace with a new one.



Figure 35 1009-35

Assemble new seal as shown. Lip of the seal is to be directed towards the spindle.

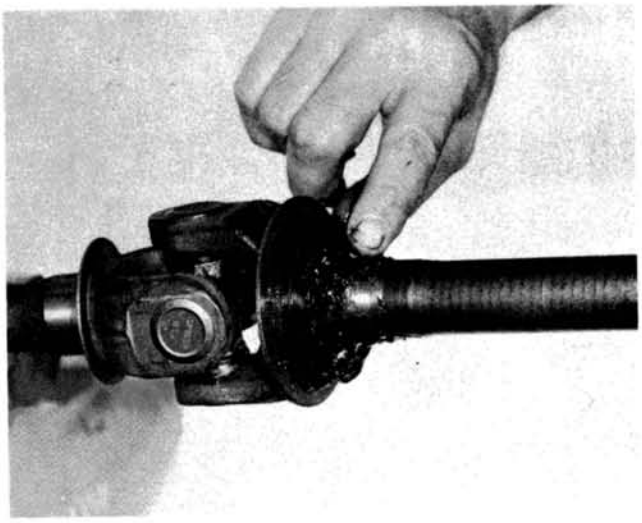


Figure 36 1009-36

Pack the area around the thrust face area of the shaft and seal full of grease. Also, fill the seal area of the spindle with grease.

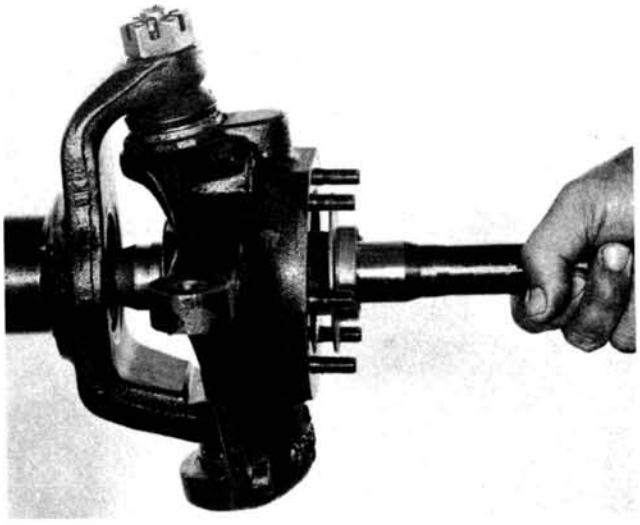


Figure 37 1009-37

Assemble axle shaft joint assembly into tube.

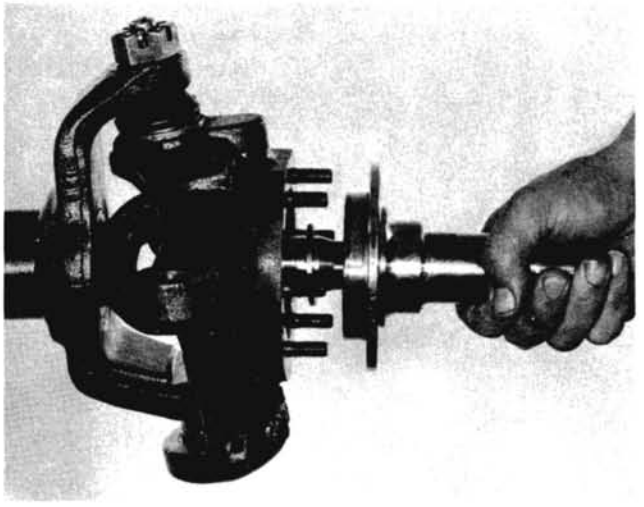


Figure 38 1009-38

Assemble new bronze spacer and spindle.

> **NOTE**
>
> Be sure chamfer end of spacer is directed toward the seal slinger of the axle shaft joint.

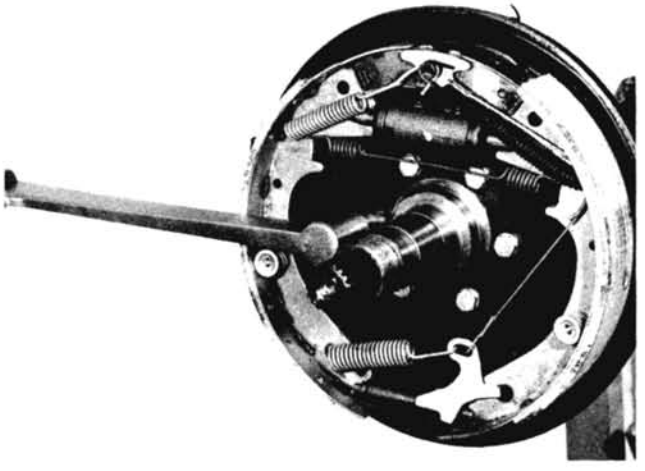


Figure 39 1009-39

Assemble brake backing plate assembly. Assemble new nuts. Torque nuts to 25-30 lbs. ft.

Tool—#C-524-A Torque wrench.



Figure 40 1009-40

Assemble new outer wheel bearing cup.
Tools—#D-140 Installer, #C-4171 Handle.



Figure 41 1009-41

Assemble new inner wheel bearing cup.
Tools—#D-153 Installer, #C-4171 Handle.

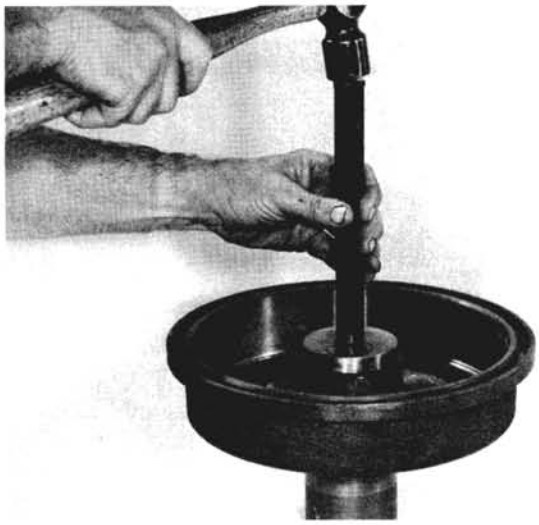


Figure 42 1009-42

Assemble new wheel bearing grease seal.
Tools—#D-155 Installer, #C-4171 Handle.



Figure 43 1009-43

Assemble brake drum and outer wheel bearing cone to spindle. Assemble inner wheel bearing adjusting nut. Torque nut to 50 lbs. ft. Rotate hub, then back off nut 90° maximum. Assemble lockwasher, line tap up with keyway of spindle, turn nut to nearest hole of the lockwasher. Assemble outer locknut. Torque nut to 50 lbs. ft. minimum.

Tool—#C-4170 Wheel bearing wrench.

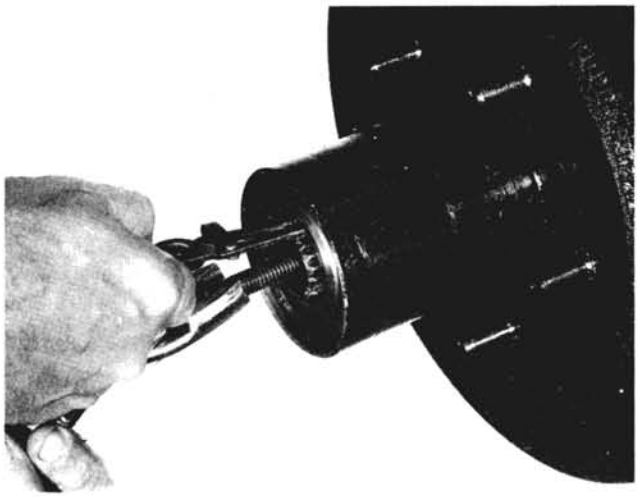


Figure 44 1009-44

Assemble drive gear and snap ring. Assemble bolt into shaft. Pull on bolt, push on gear to allow clearance of the snap ring groove. Be sure snap ring is seated in snap ring groove.

40 DEGREE STEER— INTERNAL HUBS WITH DISC BRAKES DISASSEMBLY

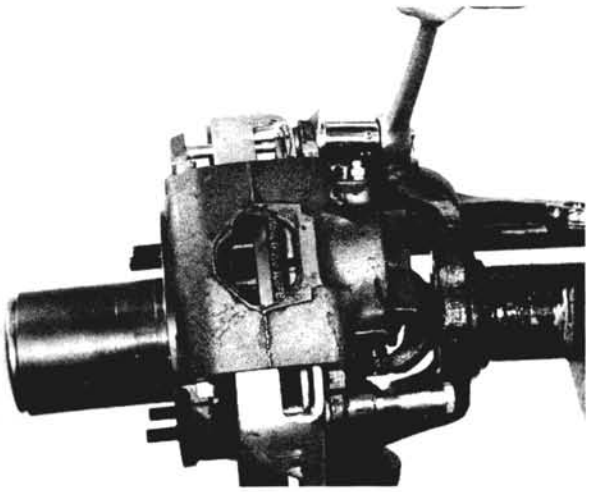


Figure 45 1009-45

Remove both brake caliper assembly bolts.

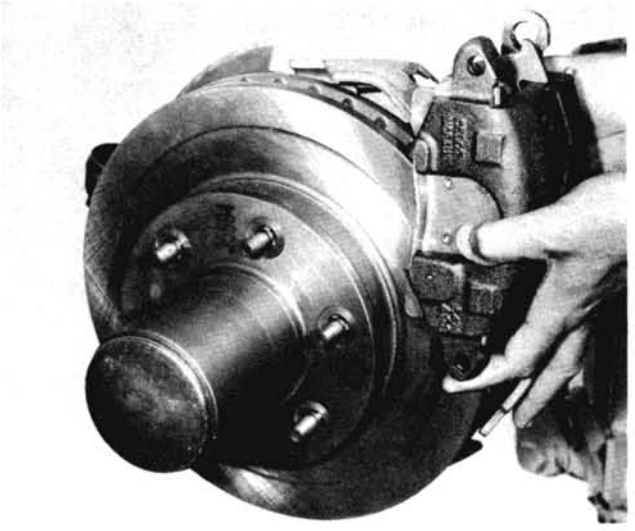


Figure 46 1009-46

Remove brake caliper assembly.

To remove the hub and brake disc assembly follow the same procedures as illustrated in Figures 7 thru 9.

To remove wheel bearings and seal from the hub follow the same procedures as illustrated in Figures 1009-10 thru 1009-12.

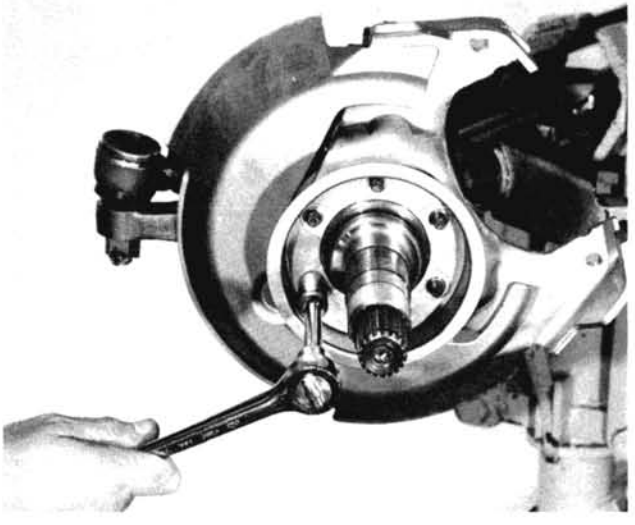


Figure 47 1009-47

Remove six (6) torque prevailing nuts from brake disc shield.

NOTE

These nuts are of the torque prevailing design and should be discarded and replaced with new ones during assembly.

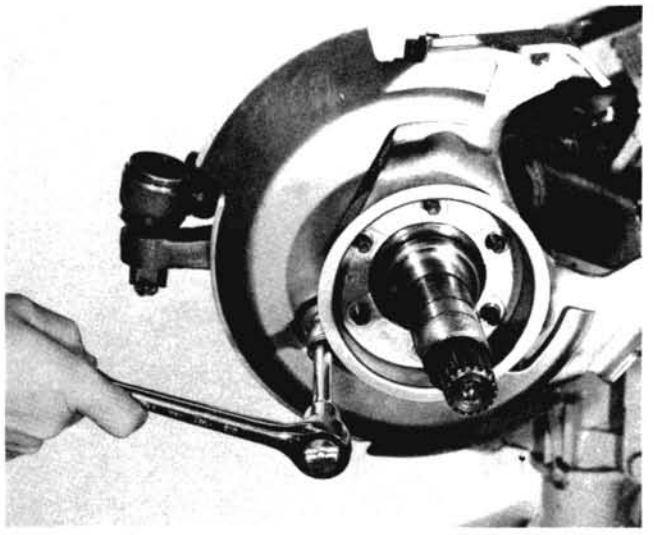


Figure 48 1009-48

Remove shield bolt which is retained in the knuckle.

Remove shield and bracket assembly from spindle.

To remove spindle, spindle seals, spindle bearings and axle shaft joint assembly, follow the same procedures as illustrated in Figures 1009-14 thru 1009-16.

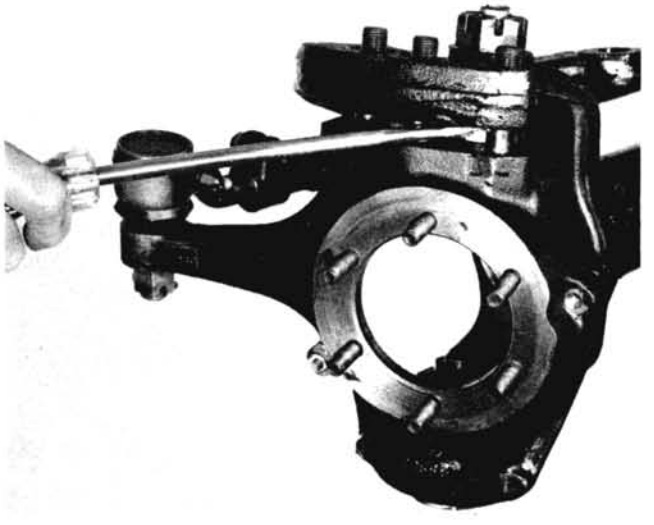


Figure 49 1009-49

Remove three steering arm nuts and cone washers and remove steering arm. Use a rawhide hammer and tap lightly on arm to free it from knuckle. Also a screw driver as shown to remove arm.

Remove cotter key, tie rod nut and remove tie rod.

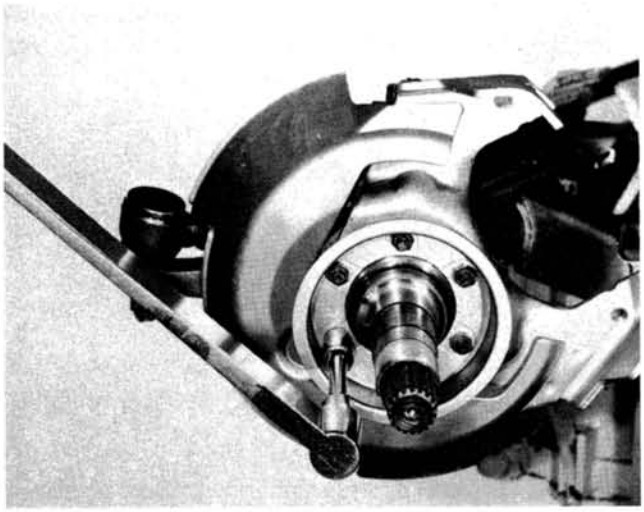


Figure 50 1009-50

Assemble brake shield bracket assembly to spindle using new torque prevailing nuts.

Torque nuts to 30-40 lbs. ft.

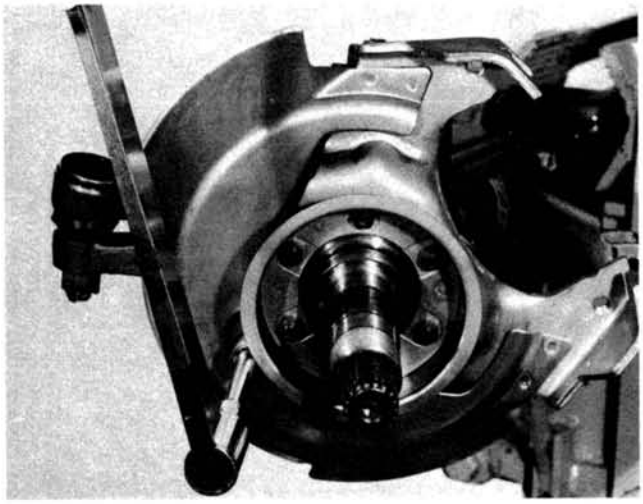


Figure 51 1009-51

Assemble shield bolt to knuckle. Torque bolt to 5-10 lbs. ft.

To assemble new wheel bearings and new seal to hub and brake disc assembly, follow the same procedure as illustrated in Figures 1009-40 thru 1009-42.

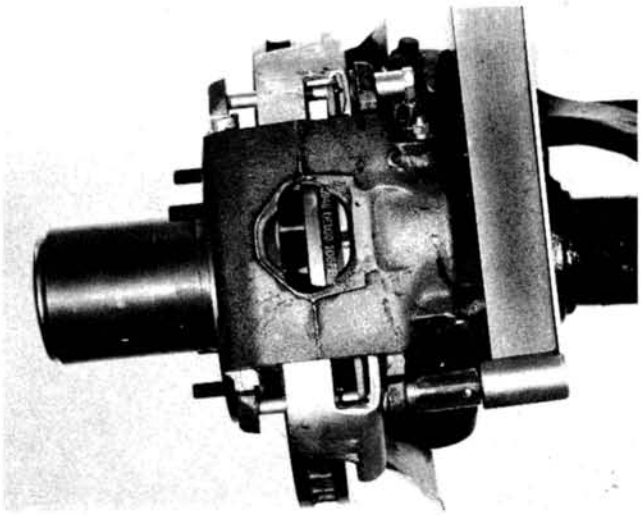


Figure 52 1009-52

Assemble brake caliper bolts. Torque bolts to 30-40 lbs. ft.

40 DEGREE STEER WITH EXTERNAL HUBS DISASSEMBLY

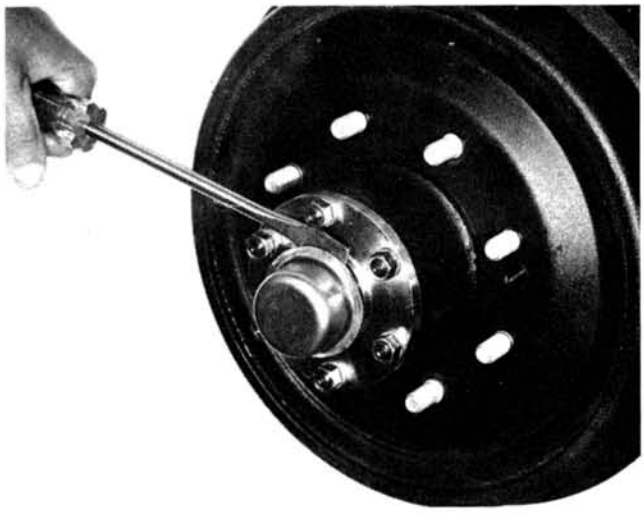


Figure 53 1009-53

Remove hub cap.

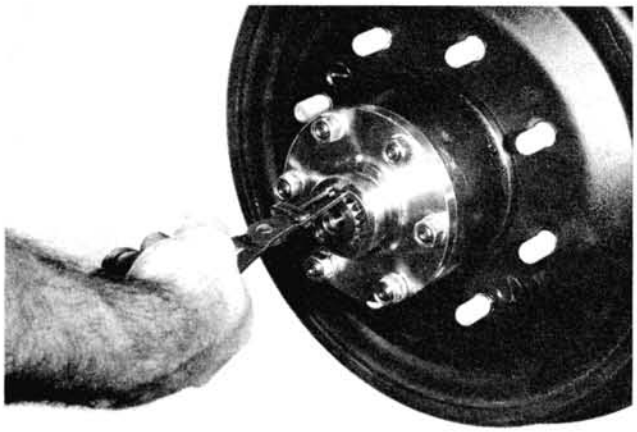


Figure 54 1009-54

Remove snap ring.

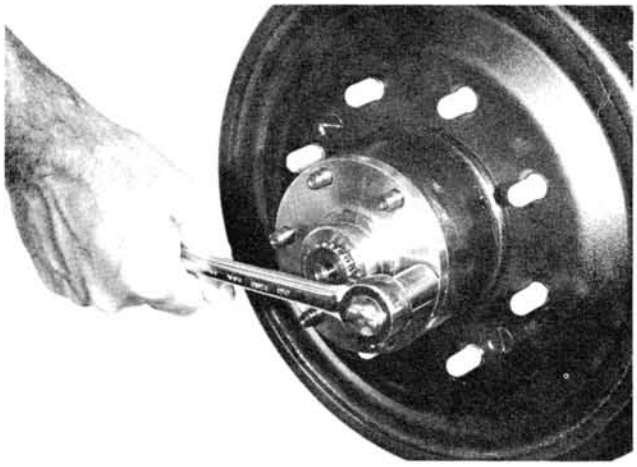


Figure 55 1009-55

Remove six flange nuts and lockwashers.

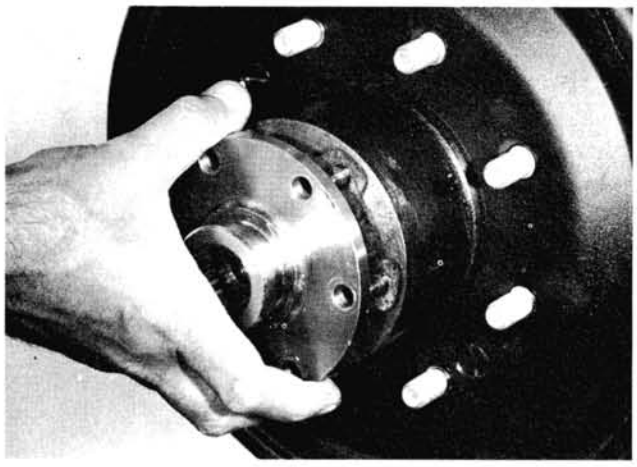


Figure 56 1009-56

Remove drive flange and gasket. **Discard gasket.** To free flange from hub, tap lightly with a rawhide hammer. Replace new gasket at time of assembly.

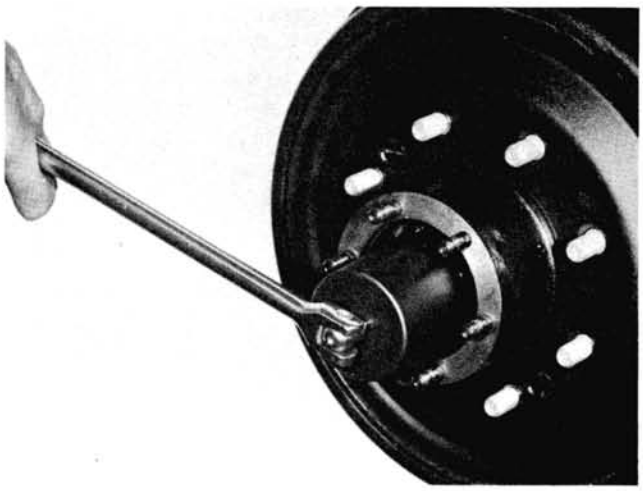


Figure 57 1009-57

Remove outer lock nut, lock ring, and wheel bearing adjusting nut.



Figure 58 1009-58

Remove drum assembly. Outer wheel bearing will slide out as drum is removed.

NOTE

If it is necessary to replace brake components such as drum, shoes, backing plate, etc., refer to Vehicle Service Manual.



Figure 59 1009-59

Remove wheel bearing grease seal and inner bearing cone.



Figure 60 1009-60

Remove outer wheel bearing cup. Locate tool on cup and drive out.
Tool—#C-4049.



Figure 61 1009-61

Remove inner wheel bearing cup. Locate tool on cup and drive out.
Tool—#C-4049.

ASSEMBLY



Figure 62 1009-62

Assemble new outer wheel bearing cup.
Tools—#C-4171 Handle, #D-140 Installer.



Figure 63 1009-63

Assemble new inner wheel bearing cup.
Tools—#C-4171 Handle, #D-154 Installer.



Figure 64 1009-64

Assemble new wheel bearing grease seal.
Tools—#C-4171 Handle, #D-155 Installer.

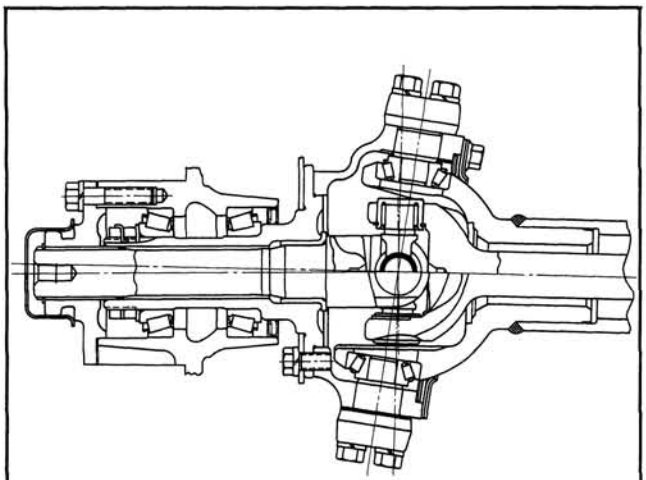


Figure 65 1009-65

LD-65.

KNUCKLE OIL SEAL CONVERSION

NOTE

Some Spicer front driving axles of the closed knuckle design are available with a unitized (one piece) spherical ball knuckle oil seal.

For field conversion from the four piece seal construction (retainer plates (2), felt, and sealing ring), follow the steps as shown in Figures 1009-66 thru 1009-61. Remove retaining screws from the knuckle retaining plates.

Discard screws and both retainer plates.

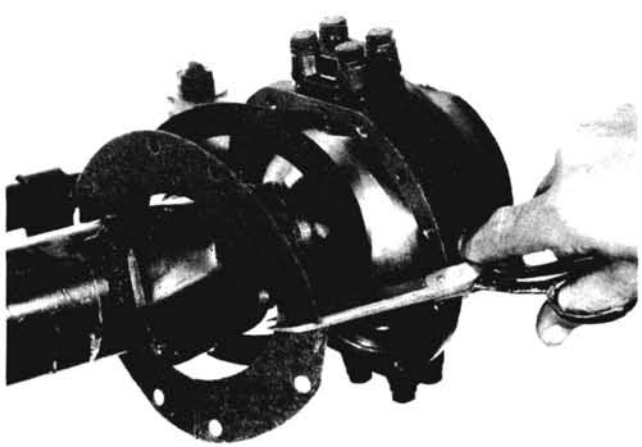


Figure 66 1009-66

Cut felt seal in half as shown and discard. Spread split of old sealing ring over tube and discard.

ASSEMBLY



Figure 67 1009-67

Assemble new unitized seal by spreading split over tube as shown, with rubber portion towards knuckle. Be sure split of seal is at the top side of knuckle. Do not spread seal further than necessary.

Assemble new tensil lock screws. Torque screws evenly to 15-20 lbs. ft.

NOTE

It is recommended that when the seal is disassembled from the knuckle for any reason, the seal is to be replaced along with new screws.

CLOSED TYPE KNUCKLE STANDARD VERSION DISASSEMBLY

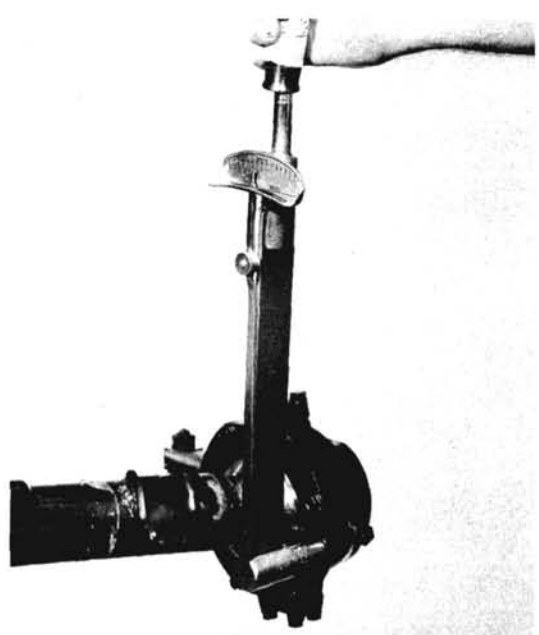


Figure 68 1009-68

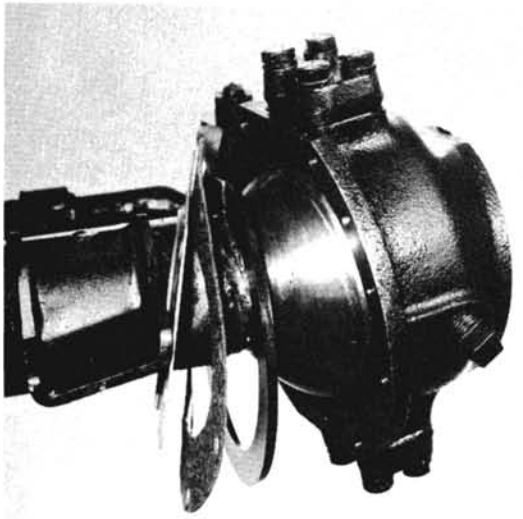


Figure 69 1009-69

Remove eight cap screws from knuckle. Remove two retainer plates, felt and seal. Discard plates, felt and seal. They are to be replaced with new parts.

Cut felt in half to remove over tube. Spread seal far enough to slip over tube.

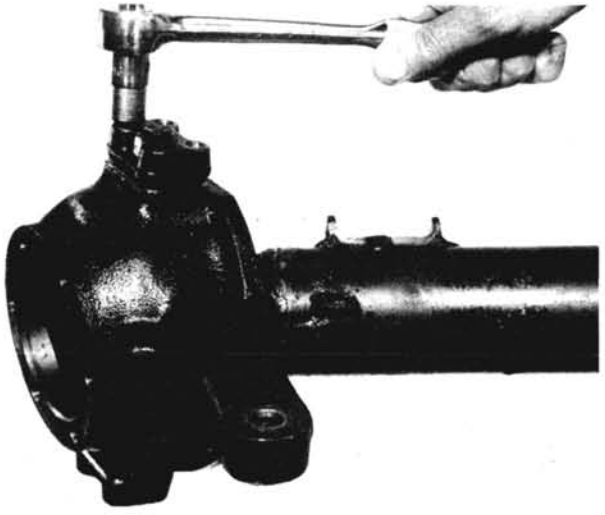


Figure 70 1009-70

Remove cap screws from the top and bottom bearing caps and nuts from steering arm if so equipped. Shims are located on the top bearing cap between the knuckle and cap. These shims control the king pin bearing preload. Save these shims since they will be required at time of assembly.

NOTE

Some front axles are designed with a bronze bushing in the top king pin instead of a roller bearing. Bushing can be either the spline or key design.

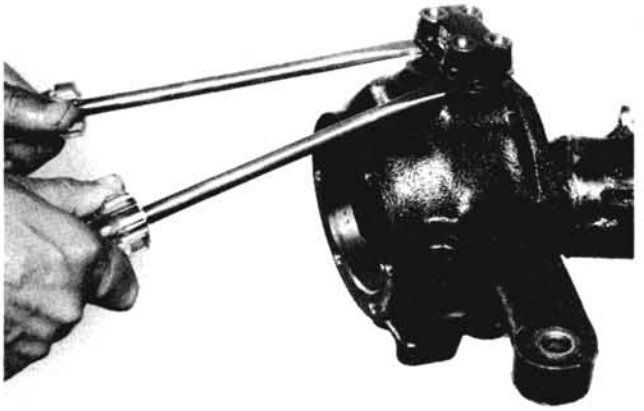


Figure 71 1009-71

Pry bearing caps loose with screwdrivers if necessary. When removing knuckle, the bottom bearing may fall out. To prevent damage, catch the bearing by hand.

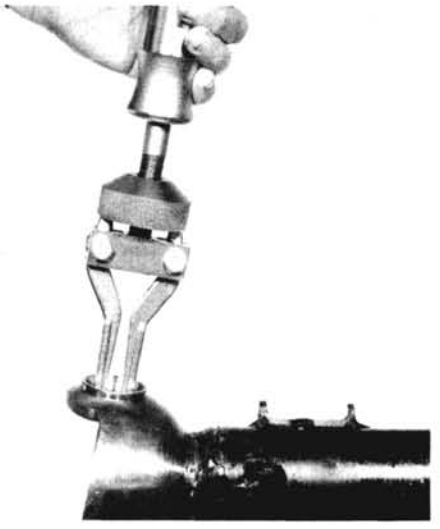


Figure 72 1009-72

Remove bearing cups from ball yoke, using puller as shown.

Tool—#D-131 Slide hammer.

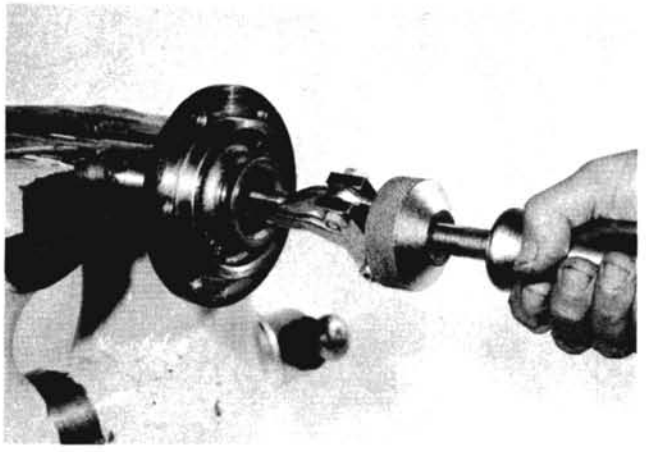


Figure 73 1009-73

Place spindle in vise. Do not clamp on bearing diameters. Remove bronze bushing using puller.

Tool—#D-131 Slide hammer.



Figure 74 1009-74

Assemble new bronze bushing.

Tools—#C-4171 Handle, #D-141 Installer.

If needle bearing is used, use tool as shown in Figure 1009-32.

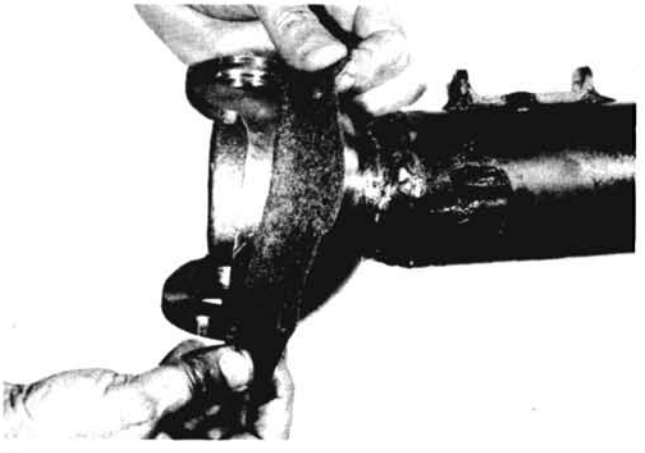


Figure 75 1009-75

Assemble new felt seal over ball yoke. Apply a thin coat of oil over ball to allow felt to slide and prevent it from tearing.

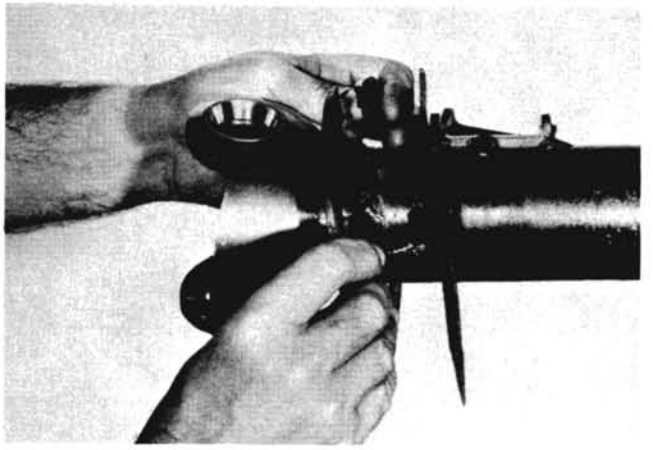


Figure 76 1009-76

Assemble new seal over tube. Spread seal just enough to clear tube; otherwise, it may become distorted. Metal portion of seal is to be towards the knuckle.

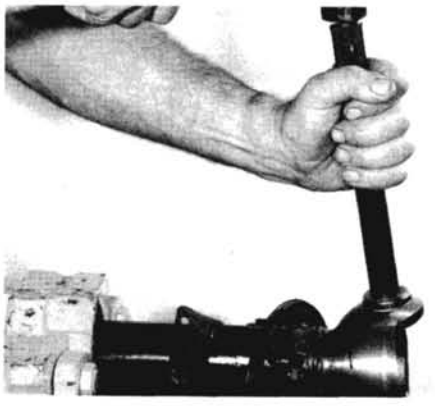


Figure 77 1009-77

Assemble new king pin bearing (top and bottom) into ball yoke.

Tools—#C-4171 Handle, #D-151 Installer.



Figure 78 1009-78

Grease top and bottom bearing cones with the specified grease.

Assemble bottom bearing cap and bearing to knuckle. Assemble top bearing into bearing cup and assemble knuckle over ball yoke.

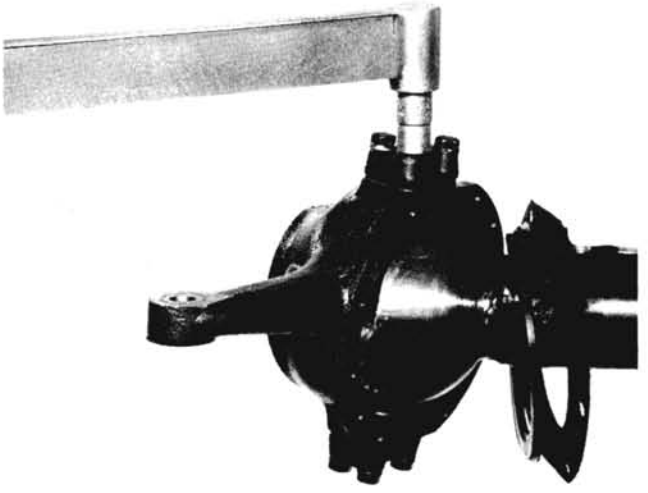


Figure 79 1009-79

Assemble preload shims top bearing cap on king pin. Assemble cap screws.

Torque screws to 30-40 lbs. ft. (top and bottom).

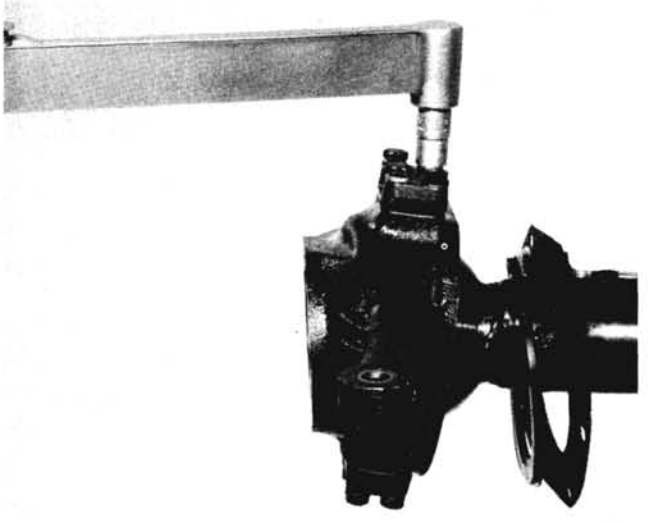


Figure 80 1009-80

Locate torque wrench on one screw to check for proper preload. Torque specification to rotate knuckle is 5-10 lbs. ft. If equipped with bronze bushing, torque specification is 10-20 lbs. ft. starting torque.

To increase torque reading, remove shims; to decrease torque reading, add shims.

NOTE

When checking king pin bearing preload, make sure the tie rod is disconnected, and also the knuckle oil seals, etc., are still disassembled.

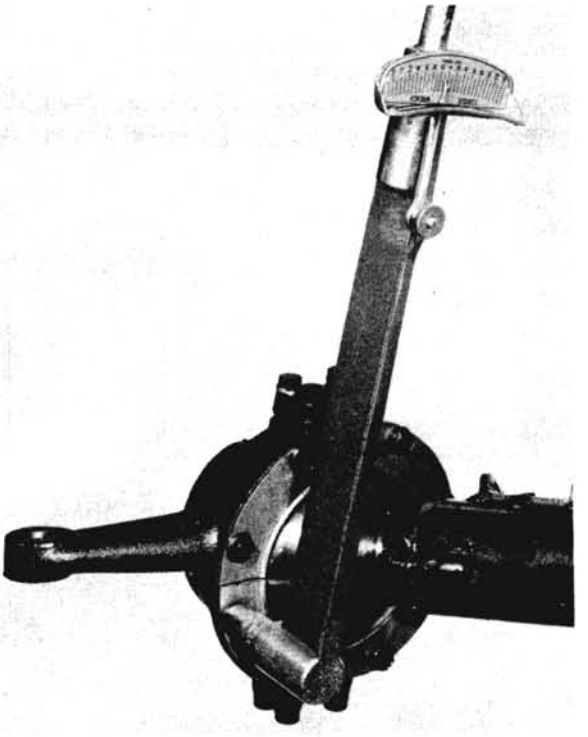


Figure 81 1009-81

Assemble new seal into knuckle, new felt seal, new retainer plates, and new screws. Torque screws to 10-25 lbs. ft.

Assemble axle shaft joint assembly, spindle wheel ends, etc.

Refer to Vehicle Service Manual for proper torque specification, etc.

Also, refer to Vehicle Service Manual for proper setting of toe in.

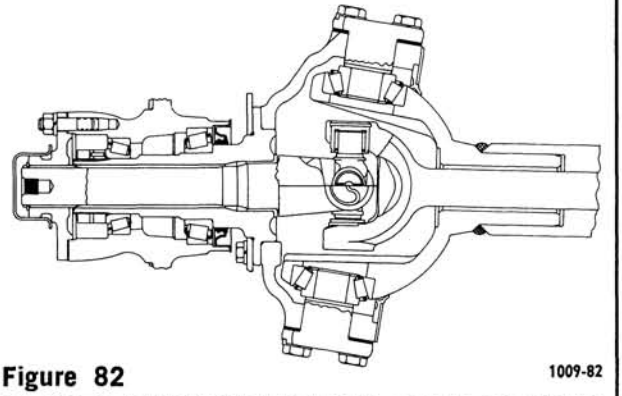


Figure 82 1009-82

CLOSED KNUCKLE-HEAVY DUTY DESIGN

Remove twelve (12) cap screws which retain the oil seal to the knuckle.

DISASSEMBLY

Remove four (4) cap screws from bottom bearing cap. Use a screwdriver to pry cap loose from knuckle.

The king pin bearing preload shims are located between the bottom bearing cap and knuckle as shown. Keep shims intact as they will be used later during assembly.

These shims are available in thicknesses of .003, .005, .010, and .030.

CAUTION

When removing the knuckle the bottom bearing cone will fall out of the cup. Catch it with your hand to prevent it from becoming damaged.



Figure 83 1009-83

Remove axle shaft joint assembly.

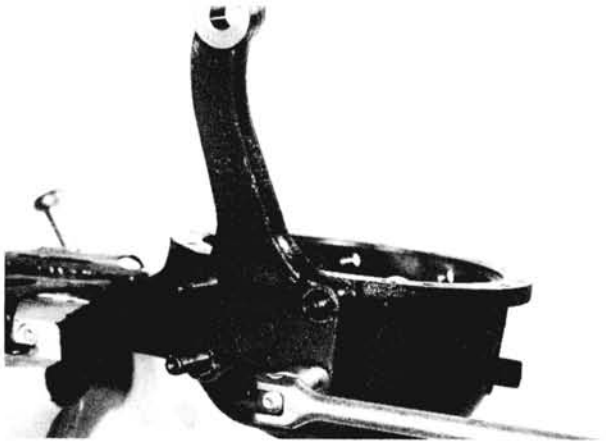


Figure 84 1009-84

Place knuckle in vise as shown. Remove the top bearing cap nuts.



Figure 85 1009-85

Remove steering arm. Tap lightly wtih a rawhide hammer to free it from the knuckle.

NOTE

There is a constant shim pack between the steering arm and knuckle. This pack is to be saved and reused during assembly.

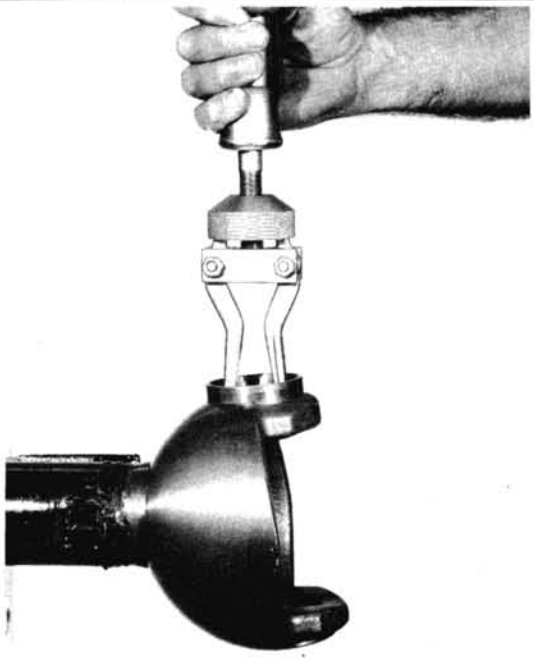


Figure 86 1009-86

Remove king pin bearing cups from spherical ball. Use puller as shown.

Tool—#D-131.

NOTE

Some axles are equipped with a bronze bushing on the top bearing cap, instead of a roller bearing. Remove bushing by using two (2) large screwdrivers until it is free of the king pin. If woodruff key is used, discard and replace with a new one during assembly.

ASSEMBLY



Figure 87 1009-87

Assemble new grease seal with rubber portion towards knuckle. Do not spread seal any further than necessary, this will prevent distortion of the seal.



Figure 88 1009-88

Assemble new bearing cup to ball yoke.
Tools—#C-4171 Handle, #D-142 Installer.

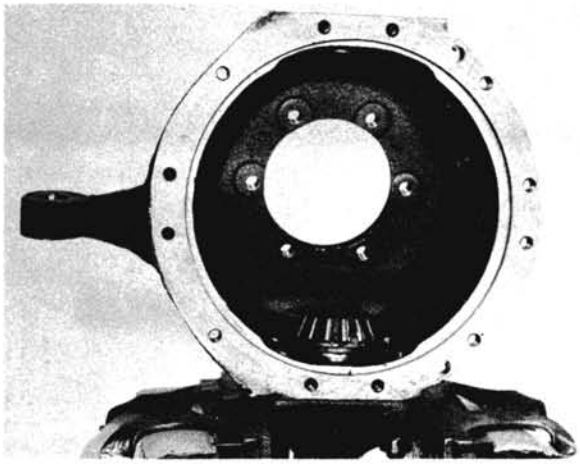


Figure 89 1009-89

Assemble steering arm king pin assembly to knuckle. Assemble new bearing cone to king pin. Grease bearing with the specified grease.

If bronze bushing is used, line up key-way of the bushing with the key-way of the pin and use new key. If bushing is of the spline design, line up the splines with those of the pin. Use a brass hammer to seat bushings.

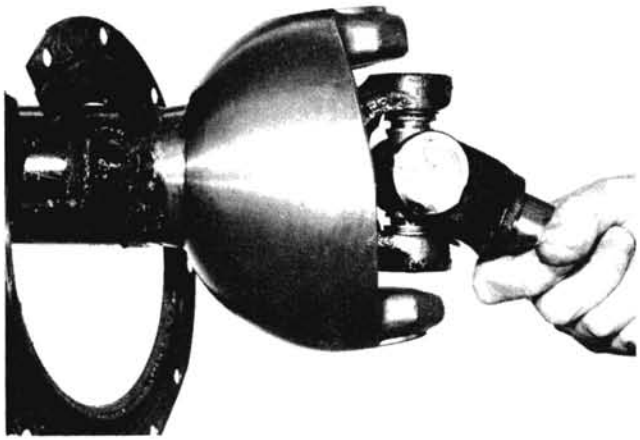


Figure 90 1009-90

Assemble axle shaft joint assembly to axle.

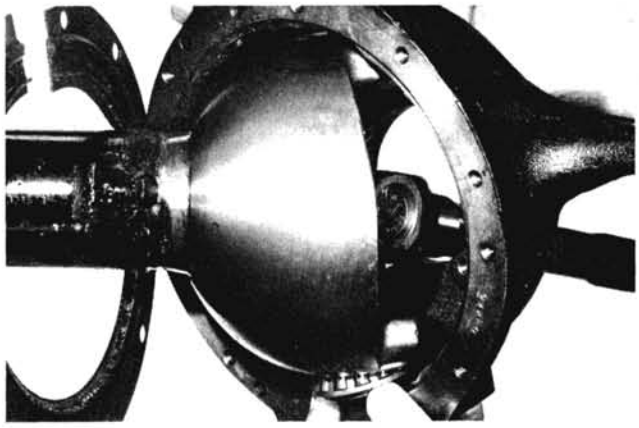


Figure 91 1009-91

Assemble knuckle to ball yoke. Hold bottom bearing as shown to prevent it from falling out.

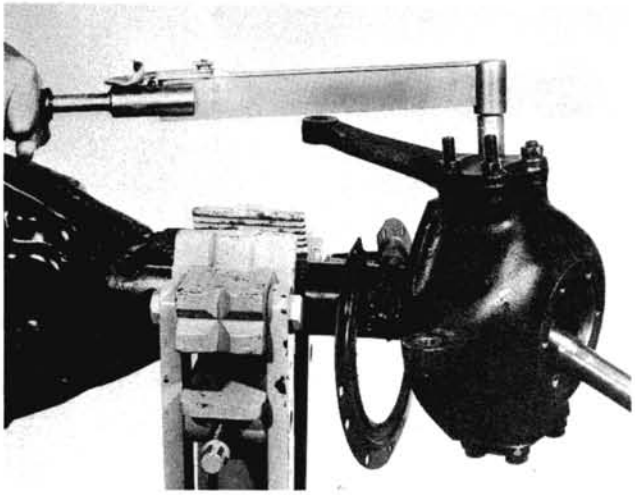


Figure 92 1009-92

Assemble bottom bearing cap with preload shims. Torque screws to 80-90 lbs. ft.

Torque top four (4) nuts on top bearing cap to 80-90 lbs. ft.

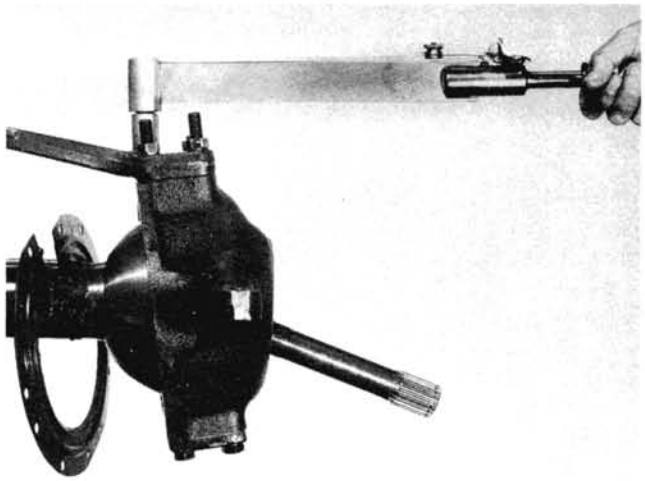


Figure 93 1009-93

Apply a torque wrench on one screw as shown. Torque to actuate knuckle with roller bearings is 10-15 lbs. ft. With bronze bushing 15-35 lbs. ft.

When checking torque rotation of knuckle, make sure tie rod and seals are not assembled to the knuckle.

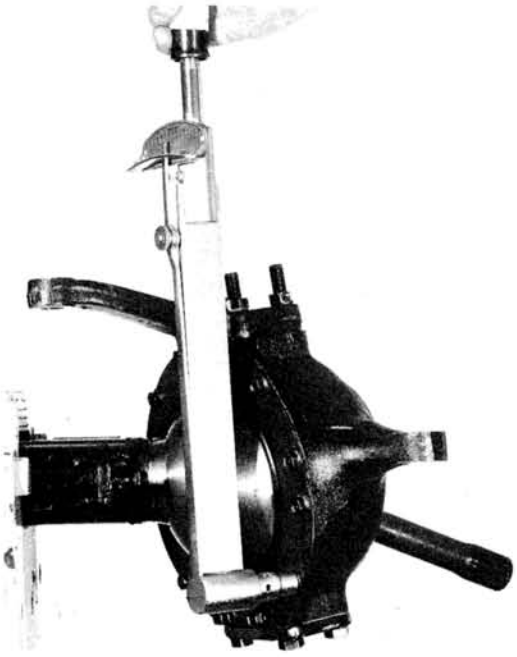


Figure 94 1009-94

Assemble grease seal to knuckle. Be sure split of seal is located at the top of the axle.
Torque screws to 10-15 lbs. ft.

UNIT WHEEL BEARING DESIGN LUBRICATED WITH HYPOID LUBRICANT

NOTE

Unit wheel bearings that are dependent on lubrication from the hypoid gear lube in the axle housing, rather than grease, are not equipped with an inner axle shaft oil seal as shown in Figue 1009-105.

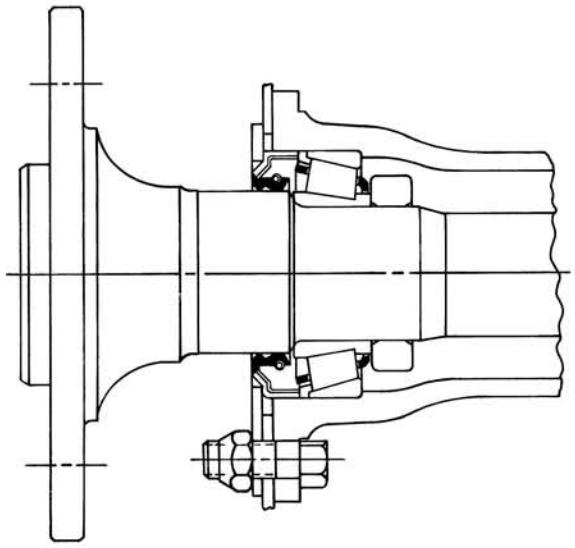


Figure 95 1009-95

Unit wheel bearing L/D without grease seal.

DISASSEMBLY



Figure 96 1009-96

After wheel is removed, remove brake drum.

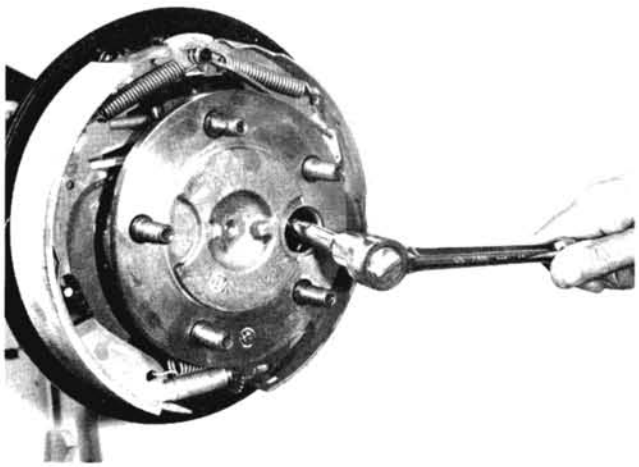


Figure 97 1009-97

Remove backing plate nuts which hold the brake backing plate to the axle housing. **Discard nuts, replace with new ones at time of assembly.** Nuts are of torque prevailing design and are not to be reused.

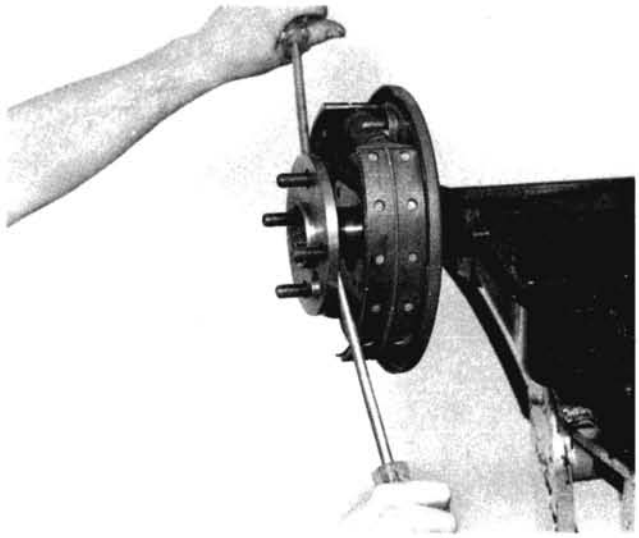


Figure 98 1009-98

Remove the axle shaft by pulling on the axle. It may be necessary to free the axle by prying it loose with two screwdrivers or pry bars as shown.

NOTE

Backing plate can normally be wired to the frame, without loosening the hydraulic brake line connection at the wheel cylinder, if desired. Use caution to avoid damage to brake line.

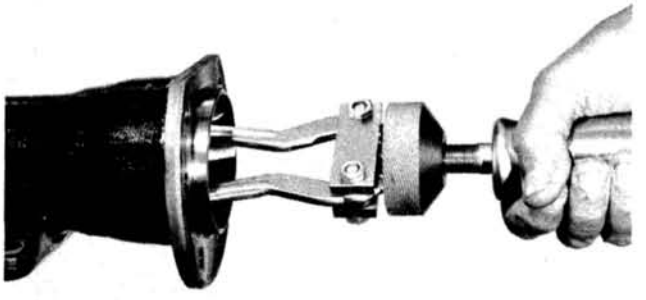


Figure 99 1009-99

The bearing cup will normally stay in place in the housing. To remove bearing cup, use puller as shown.

Tool—#D-131 Slide Hammer.

CLEANING, INSPECTING AND RELUBRICATING WHEEL UNIT BEARING

Clean bearing cup with any of the standard metal cleaning solvents. Inspect cup for any possible wear, nicks, etc.

The cone assembly can be cleaned in place on the axle shaft. Use any standard metal cleaning solvent and a stiff bristle brush to remove any dirt or any other contamination that might be present, then use compressed air. Air should be directed at the cone assembly so that it goes through the bearing from one end of the rollers to the other. It is important not to "spin dry" the bearing with compressed air. Spinning the dry bearing may score the raceways and rollers due to lack of lubricant.

Use a standard metal cleaning solvent to clean out the bearing bore in the housing. Wipe this area clean making sure it is free from dirt or any other contamination that might be present.

After the bearing has been inspected and approved for continued service, it must be lubricated prior to installation. The bearing must be lubricated by applying a small amount of the specified lube around the rollers of the bearing cone.

ASSEMBLY

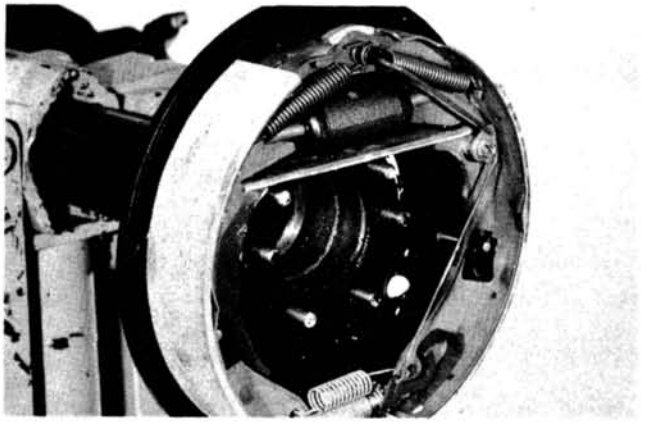


Figure 100 1009-100

Assemble backing plate bolts and backing plate assembly.

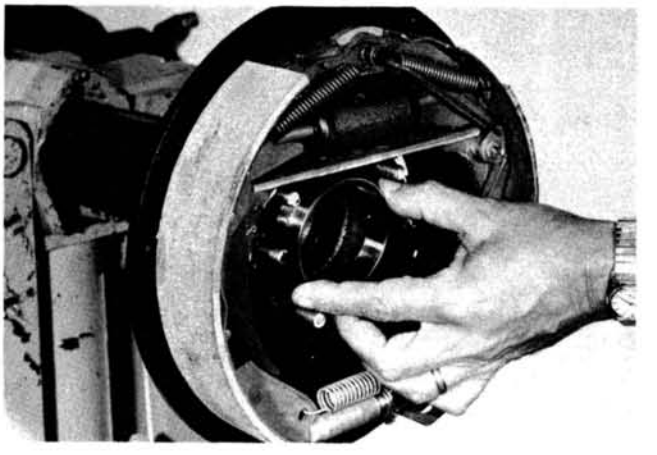


Figure 101 1009-101

Assemble bearing cup into bearing bore of the tube. Make sure the cup backface is against the bearing seat of the tube.

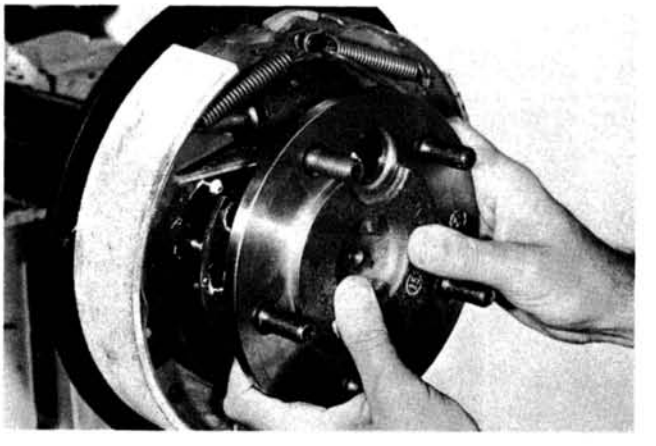


Figure 102 1009-102

Assemble axle shaft into housing. Care should be taken not to damage the bearing rollers.

Line up the holes of the retainer plate with the bolts, push axle shaft into the housing as far as possible.

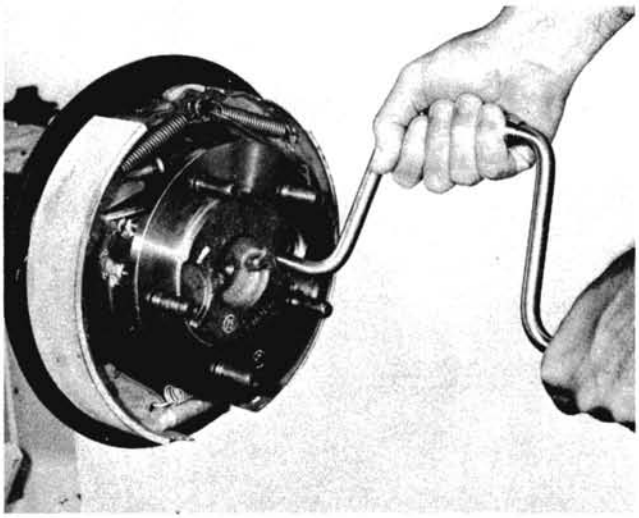


Figure 103 1009-103

Start nuts on backing plate bolts by hand. Use a speed wrench as shown and tighten to approximately 15 lbs. ft.

The nuts should be tightened in a manner that assures that the seal and cup rib ring are drawn evenly against the cup in the housing.

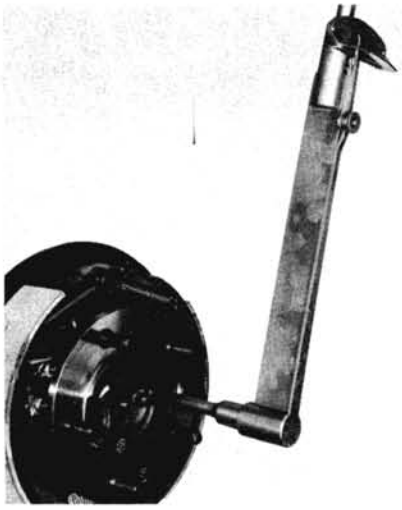


Figure 104 1009-104

Using a torque wrench as shown, torque nuts to 25-35 lbs. ft. Assembly brake drums, retainer nuts, wheels, etc.

Tool—#C-524-A Torque wrench.

UNIT WHEEL BEARING DESIGN LUBRICATED WITH GREASE

NOTE

Unit wheel bearings that are dependent on grease for lubrication, rather than hypoid gear lube from the axle housing, are equipped with an inner axle shaft oil seal as shown in Figure 1009-105.

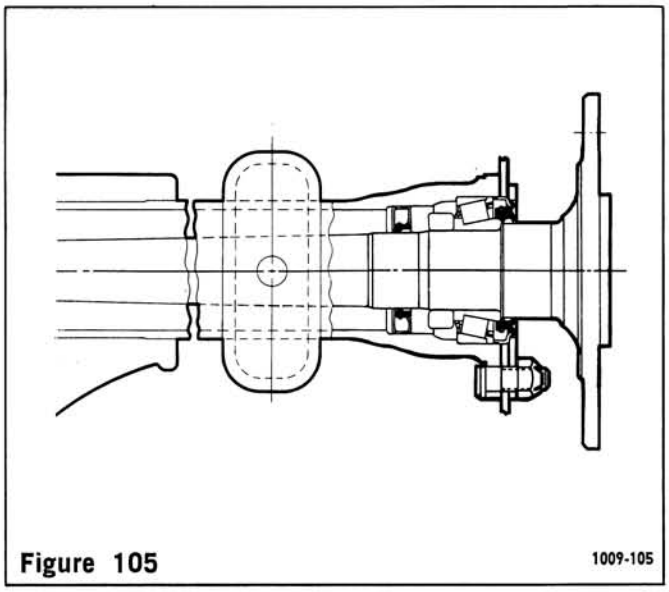


Figure 105 1009-105

Unit wheel bearing L/D with grease seal.

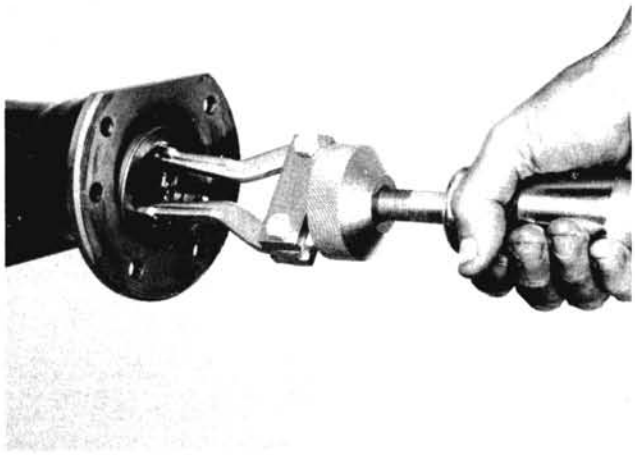


Figure 106 1009-106

Remove inner axle shaft seal using puller as shown.

Tool—#D-131 Slide hammer.

Discard seal and replace with new one at time of assembly.

NOTE

Avoid contacting seals with cleaning solvent in cleaning operation.

CLEANING, INSPECTING AND RELUBRICATING UNIT BEARINGS

Clean bearing cup with any of the standard metal cleaning solvents. Inspect cup for any possible wear, nicks, etc.

The cone assembly can be cleaned in place on the shaft. Use a standard metal cleaning solvent and a stiff bristle brush to loosen the old grease. To insure removal of the old grease and any contamination that might be present, use compressed air. Air should be directed at the cone assembly so that it goes through the bearing from one end of the rollers to the other. It is important not to "spin dry" the bearing with compressed air. Spinning the dry bearing may score the raceways and rollers due to the lack of lubricant.

Use a standard metal cleaning solvent to clean out the bearing and oil seal bore in the housing. Wipe this area clean making sure it is free from any old grease or other contamination that might be present.

After the bearing has been inspected and approved for continued service, it must be lubricated prior to installation.

The grease should be a good quality number 2 E.P. (extreme pressure), lithium soap, wheel bearing grease.

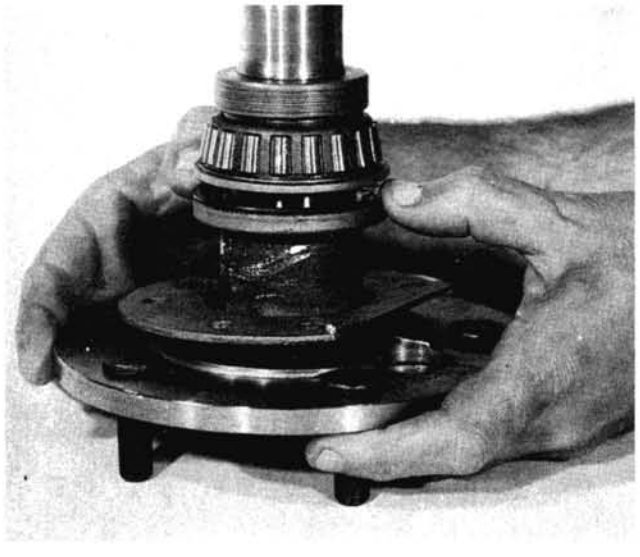


Figure 107 1009-107

Push seal and retainer away from the bearing to allow a cavity between the seal and bearing.

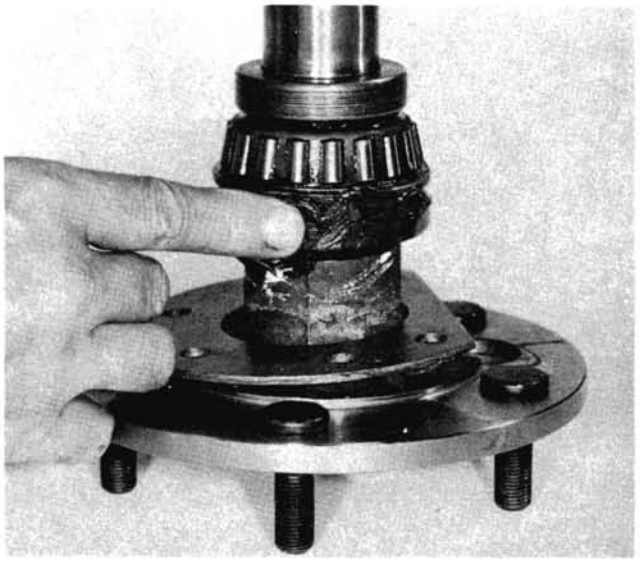


Figure 108 1009-108

Fill the area or cavity between the seal and bearing with the recommended grease.

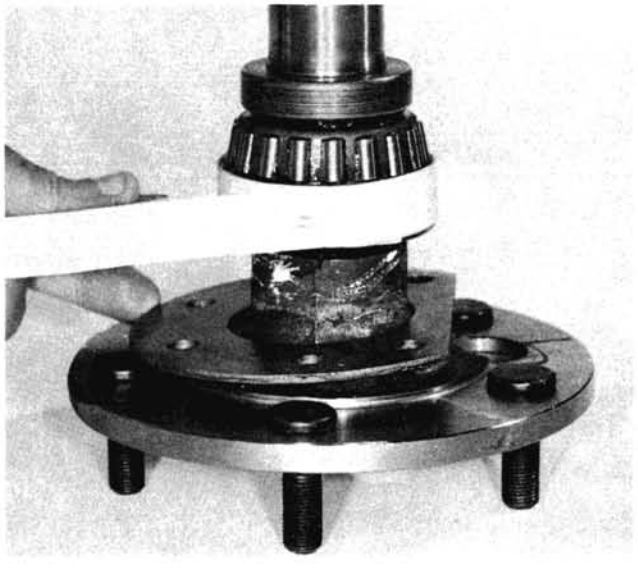


Figure 109 1009-109

After the cavity is full of grease, wrap tape compeltely around the rib ring and seal as shown to enclose the cavity.

ASSEMBLY



Figure 110 1009-110

With tape still wrapped around the ring, push seal up until it contacts the rib ring. This will force the grease up through the rollers.

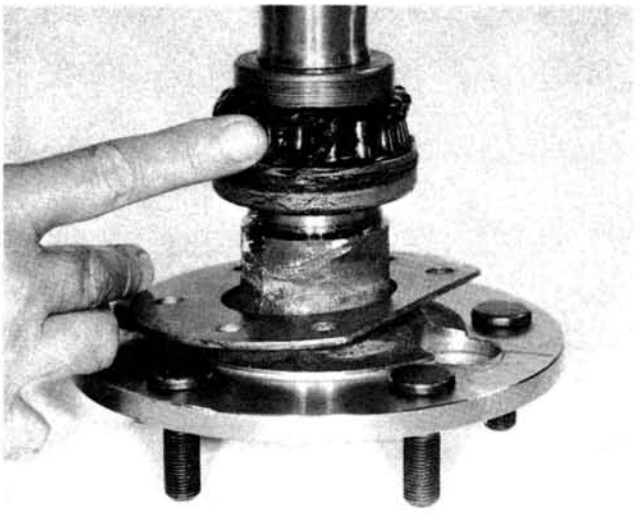


Figure 111 1009-111

> **NOTE**
>
> If grease is not apparent on small end of rollers, repeat these same steps until grease appears.

Remove tape and wipe excess grease on roller bodies.



Figure 112 1009-112

Assemble new grease seal into housing.

Tools—#D-157 Seal Installer, #C-4171 Handle.

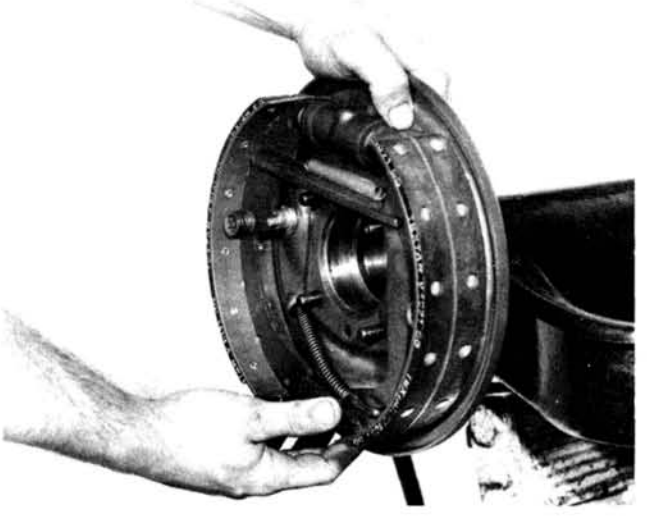


Figure 113 1009-113

After seal has been assembled, grease lip of seal.

Assemble backing plate bolts and backing plate assembly.

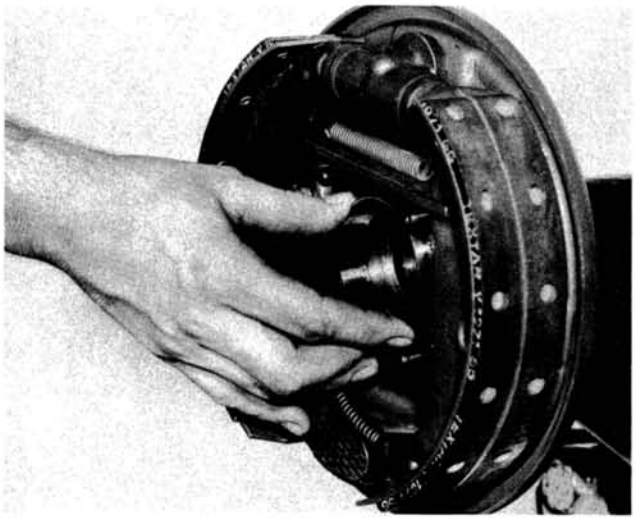


Figure 114 1009-114

Assemble bearing cup into bearing bore of the tube. Make sure the cup backface is against the bearing seat of the tube.

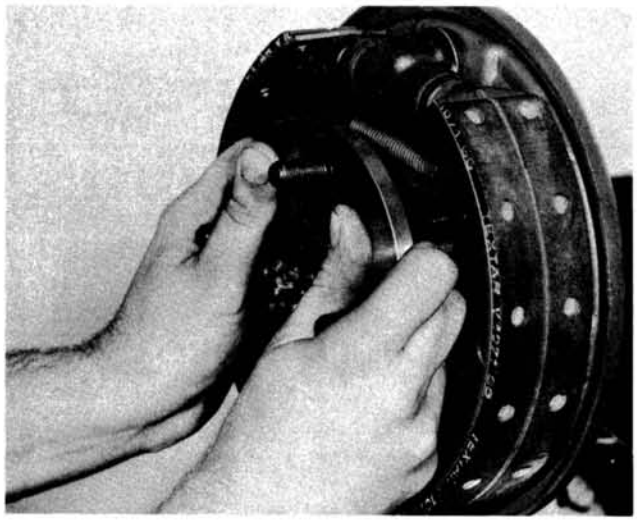


Figure 115 1009-115

Assemble axle shaft into housing. Care should be taken not to damage the seal lip and bearing rollers.

Line up the holes of the retainer plate with the bolts; push axle shaft into the housing as far as possible.

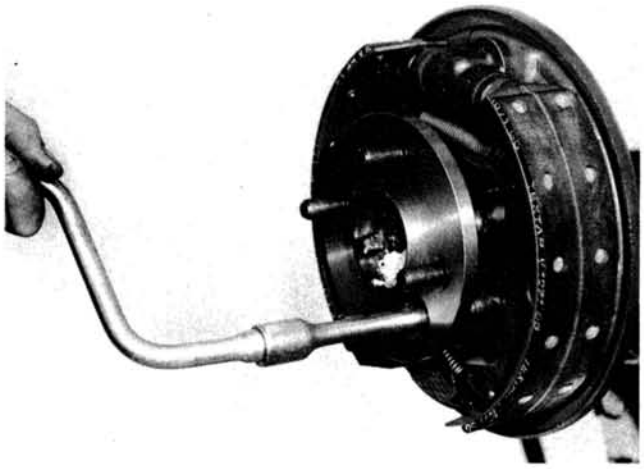


Figure 116 1009-116

Start nuts on backing plate by hand. Use a speed wrench as illustrated and tighten to approximately 15 lbs. ft.

The nuts should be tightened in a manner that assures the seal and cup rib ring are drawn evenly against the cup in the housing.

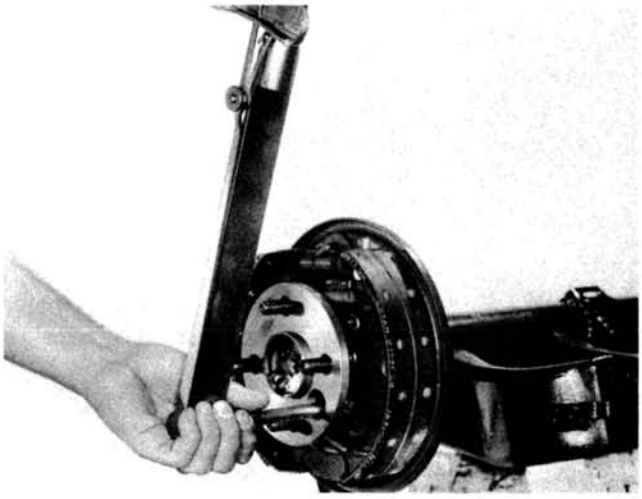


Figure 117 1009-117

Use a torque wrench and torque nuts to 25-35 lbs. ft.

REMOVAL OF UNIT BEARING FROM AXLE SHAFT

NOTE

To disassemble axle shaft from housing, follow the procedures illustrated in Figures 1109-95 thru 1009-99.

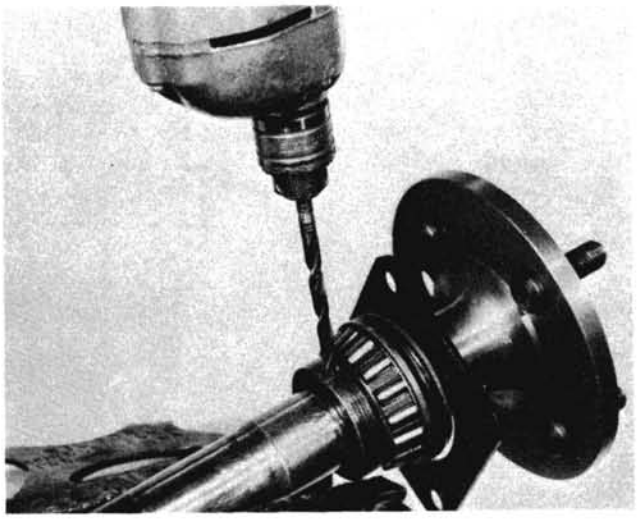


Figure 118 1009-118

Place axle shaft in a vise. Drill a ¼" hole in the outside of the retainer ring to a depth approximately ¾ the thickness of the ring. Do not drill all the way through the ring; the drill could damage the axle shaft.

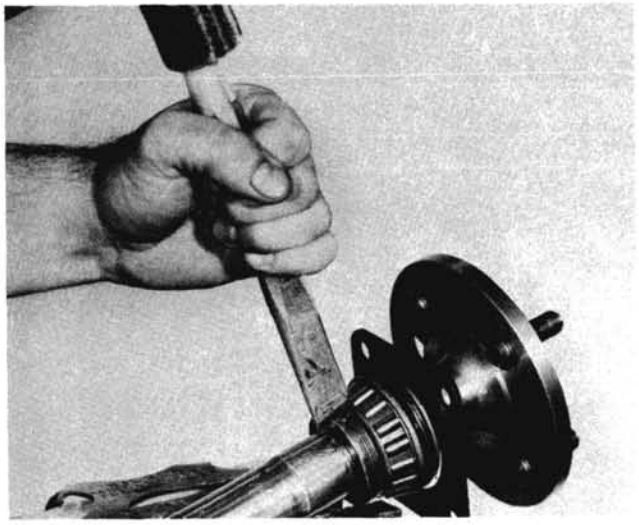


Figure 119 1009-119

After drilling the ring, use a chisel positioned across the hole and strike sharply to break the ring. Discard and replace with a new one at time of assembly.

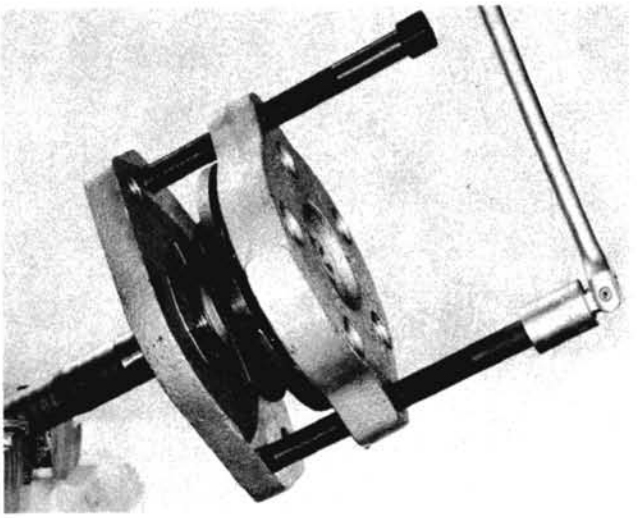


Figure 120 1009-120

Push retainer plate and seal towards flange of axle shaft. Install the flange plate to the flange of the axle shaft. Install bolts into flange plate. Slide forcing plate over the axle shaft. Install the adapters so they seat under the cup rib ring.

Gradually tighten the bolts until they locate in the dimples on the backside of the forcing plate.
Tools—#SP-5443-A Flange plate, #SP-5017 Adapter ring, #SP-5442-D Adapters, #SP-5026 Bolts.

Tighten bolts of tool alternately until bearing cone is removed from axle shaft. Be careful not to mar the machined surfaces of the axle shaft.

CAUTION

Do not heat or cut the bearing cone assembly with a torch to remove. Damage to the axle shaft will result.
Remove seal and retainer plate. Discard seal. Replace with new one at time of assembly.
Inspect retainer plate for possible distortion. If any portion of the retainer plate is damaged, it should be replaced.
Inspect machined surfaces of the axle shaft, such as the seal and bearing diameters. Clean axle shaft, remove all nicks or burrs.

INSTALLATION OF NEW UNIT BEARING

NOTE

The retainer ring area of the axle shaft is 1.3790 minimum in diameter, and the retainer ring inside diameter is 1.374 maximum. Therefore, it should require some 6,000 lbs. minimum press to seat the ring against the unit bearing.

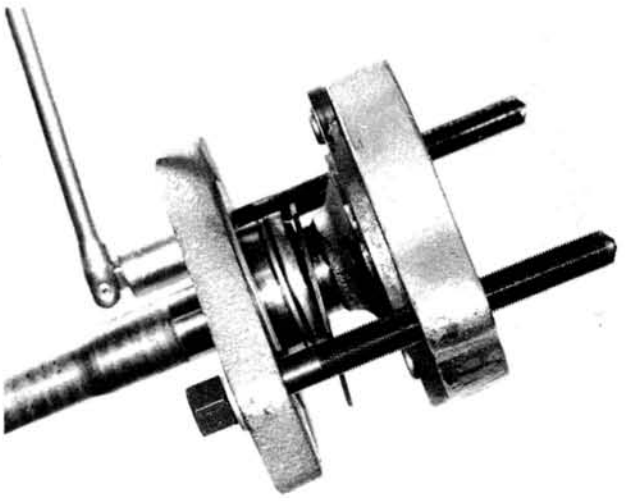


Figure 121 1009-121

Flange plate should still be assembled to the flange of the axle shaft. Remove bolts from flange plate.

Assemble new retainer plate and oil seal. The rubber portion of the oil seal, which extends beyond the casing has numbers bonded in the rubber. These numbers are to face toward the flange of the axle shaft.

Assemble new unit wheel bearing on axle shaft.

Slide installing ring on axle shaft. Be sure to locate unit wheel bearing on the inside of the installing ring. Slide forcing plate on axle shaft and locate on installing ring. Install bolts and washers through the holes in the forcing plate and into the flange plate.

Tools—#SP-5443-A Flange plate, #SP-5017 Adapter ring, #SP-5439 Adapter plate installer, #SP-5026 Bolts, #SP-3020 Washers.

Tighten bolts alternately and evenly making sure bearing is not cocked on axle shaft. Continue until unit wheel bearing is seated. To make sure bearing is seated, use a .0015″ feeler gage between bearing seat and bearing. If gage enters, force bearing further on the axle shaft, until gage does not enter.

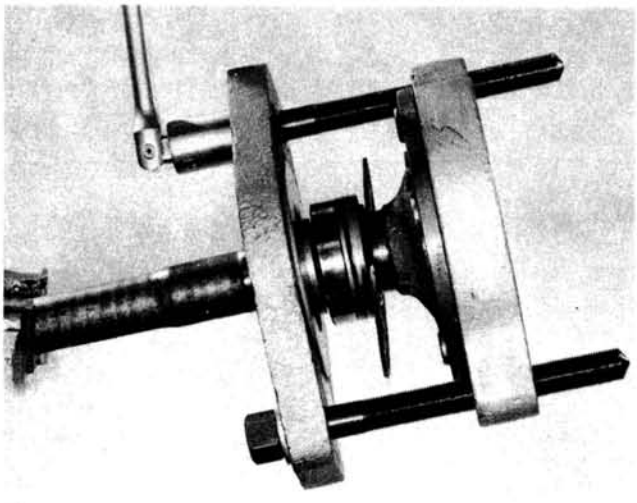


Figure 122 1009-122

Install retainer ring on axle shaft. Follow the same procedures as illustrated in Figure 1009-121 to assemble the retainer ring.

Use a .0015″ feeler gage between the bearing and retainer ring to be sure that the retainer ring is seated. At least one point should exist, where the gage will not enter between the retainer ring and bearing. If gage enters completely around the diameter, retainer ring must be forced further onto the axle shaft.

To assemble axle shaft assembly into housing, follow steps as illustrated in Figures 1009-115 thru 1009-117.

LUBRICATING NEW UNIT BEARING WITH GREASE

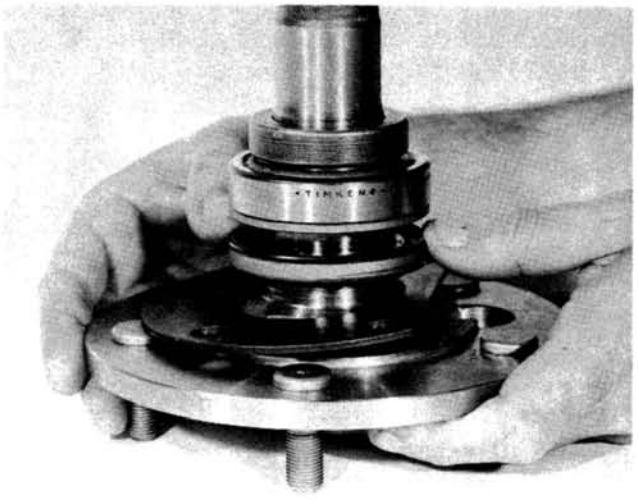


Figure 123 1009-123

Push seal and retainer away from bearing to allow a cavity between the seal and bearing.

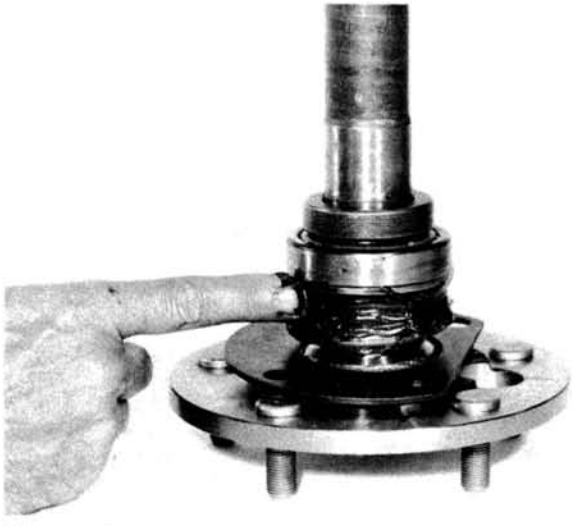


Figure 124 1009-124

Fill cavity with a good quality #2 E.P. (extreme pressure), lithium soap, wheel bearing grease.

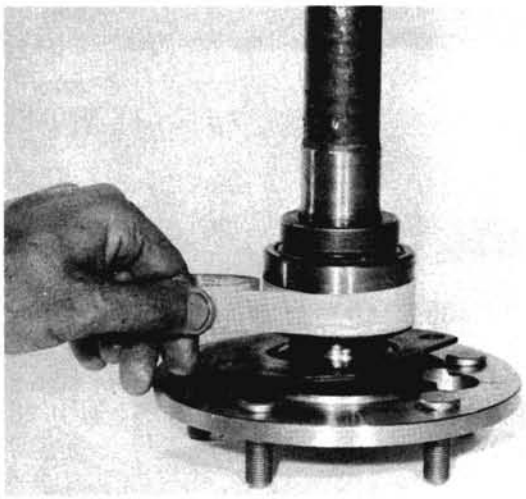


Figure 125 1009-125

After cavity is full of grease, wrap tape completely around rib ring, and seal to enclose the cavity.

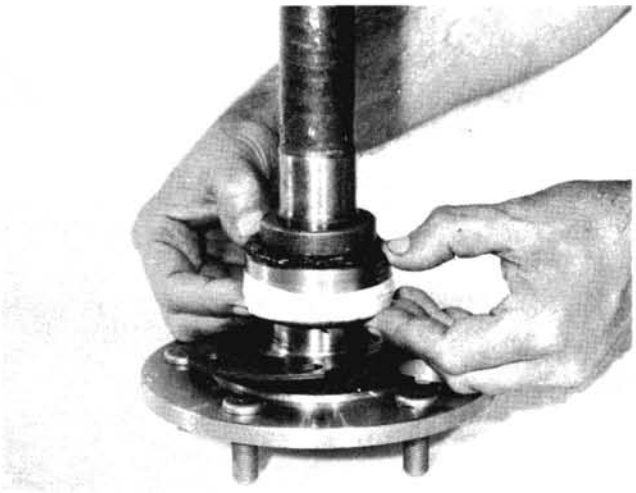


Figure 126 1009-126

Push seal towards the bearing until it contacts the rib ring. This will force the grease between the rollers and cup.

> **NOTE**
> If grease is not apparent on the small ends of the rollers, repeat the same steps until grease is evident between the small end of the roller and cup. **Remove tape.**

CARRIER SECTION

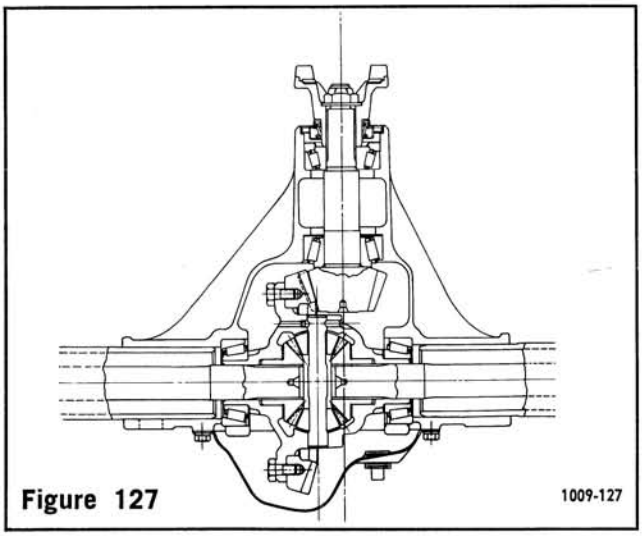


Figure 127 1009-127

L/D Carrier.

DISASSEMBLY

> **NOTE**
> If it becomes necessary to disassemble any parts inside the carrier, it is suggested that the entire axle be removed from the vehicle and held tight in a stand or rack.

Remove drain plug and drain lubricant. If there is no drain plug in the carrier, the lube will drain out as the cover plate is removed.

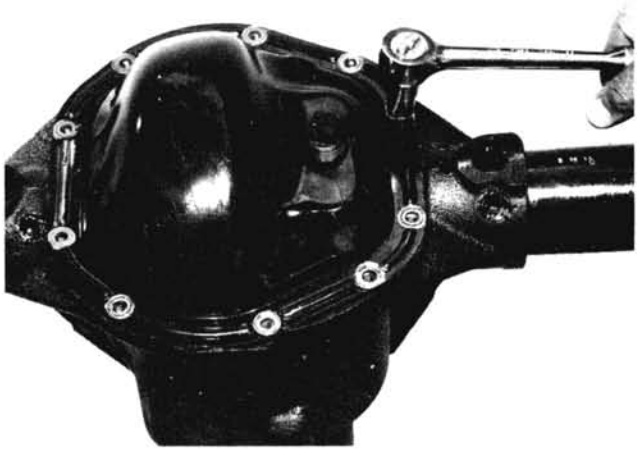


Figure 128 1009-128

Remove cover plate screws, cover plate, and cover plate gasket. **Discard old gasket.** Tip carrier to allow lube to drain completely.

Also, during this time clean the cover face of the carrier, making sure it is free from any nicks and any particles left by the old gasket.

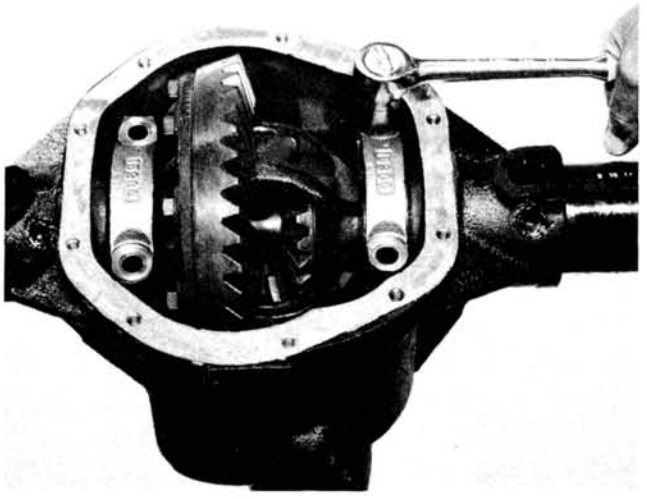


Figure 129 1009-129

Remove bearing caps. Note mating letters stamped on caps and carrier. This is important at time of assembly as they are to be assembled exactly as removed. Letters or numbers are in horizontal and vertical position.

CAUTION

Before removing differential case and ring gear, make sure the axle shafts are pulled out far enough for clearance to remove differential.

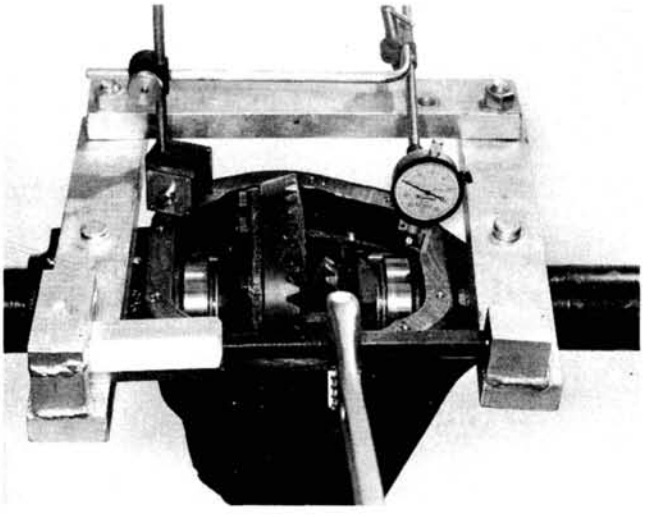


Figure 130 1009-130

Mount spreader to housing. **Do not spread carrier over .020″.** Use dial indicator as shown. **Note:** This spreader can also be used on the Spicer Model 44 axle.

Tools — #D-113 Spreader, #D-128 Indicator set.

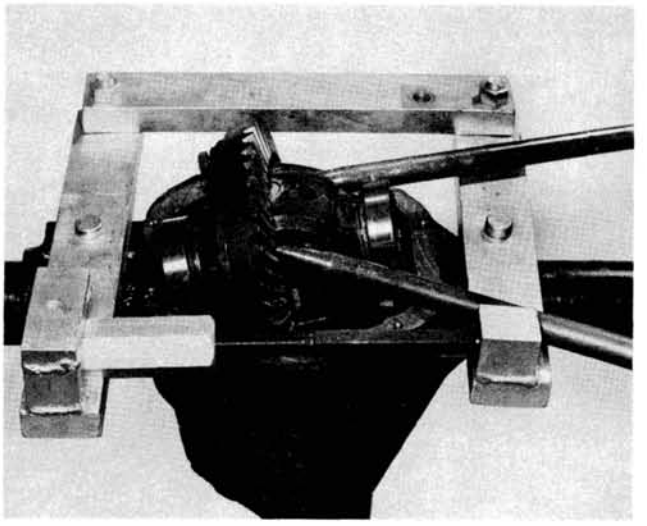


Figure 131 1009-131

Pry differential case from carrier with two pry bars as shown. **After differential case has been removed, remove spreader.** Use caution to avoid damage to ring and pinion. Mark on tag bearing cups indicating from which side they were removed.

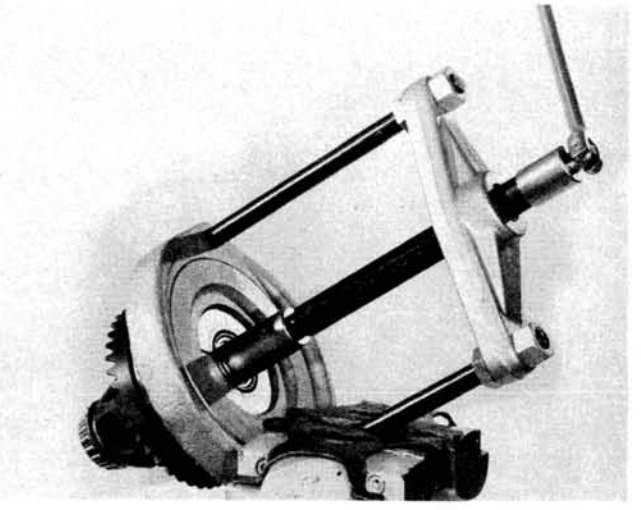


Figure 132 1009-132

Remove differential bearings with a puller as shown. Wire shims, bearing cup and bearing cone together. Identify from which side they were removed (ring gear side or opposite side). If shims are mutilated, replace with new shims at the time of assembly. Shims are available in thicknesses of .003″, .005″, .010″, and .030″. Reposition case in puller and remove other bearing cone as described above.

Tools—#DD-914-9P Press and Adapter Ring, #C-293-3 Adapter Plug, #C-293-18 Adapter Set.

NOTE

It is recommended that whenever bearings are removed, they are (regardless of mileage) to be replaced with new ones.

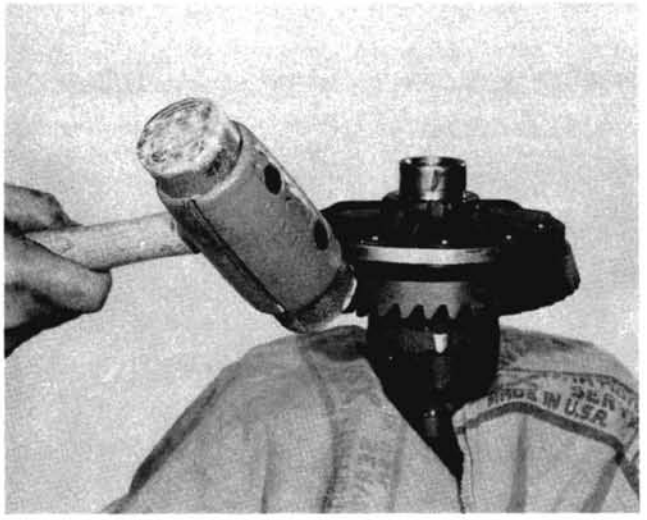


Figure 133 1009-133

Place a few shop towels over the vise to prevent the ring gear teeth from being nicked after it is free from the case.

Place case in vise. Remove ring gear screws. Tap ring gear with a rawhide hammer to free it from the case. Remove case and ring gear from vise.

> **NOTE**
> It is recommended that whenever the ring gear screws are removed, they are to be replaced with new ones.



Figure 134 1009-134

Replace case in vise and drive out lock pin which secures the pinion mate shaft. Use a small drift as shown.

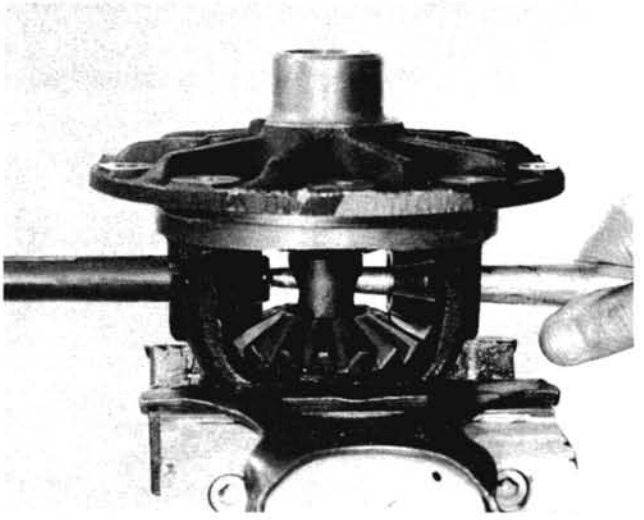


Figure 135 1009-135

Remove pinion mate shaft with drift as shown.

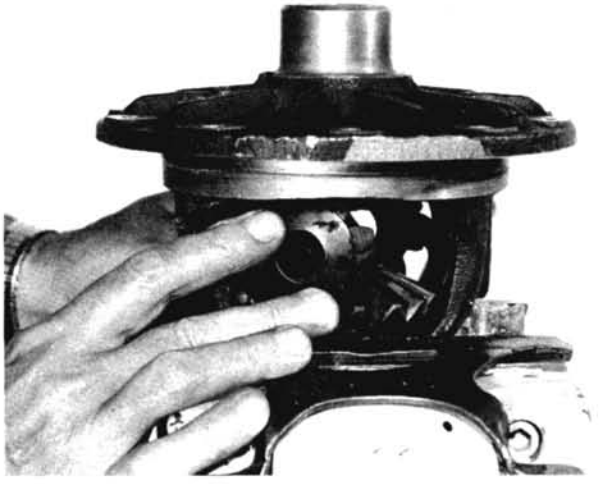


Figure 136 1009-136

To remove side gears and pinion mate gears, rotate the side gears. This will allow the pinion mate gears to turn to the opening of the case. Remove pinion mate gears and also the spherical washers behind the gears. Lift out gears and thrust washers. Inspect all parts, including the machined surfaces of the case itself. Where necessary replace all worn parts. If excessive wear is visible on all parts, it is suggested that the complete differential assembly be replaced. If any one of the gears are to be replaced, **they are to be replaced as a set.**

> **NOTE**
> Axle shafts which require end play adjustment have a spacer block in the differential case. The spacer block controls the end thrust of the axle shaft. If the ends of the spacer block are worn, it is to be replaced during assembly. Spacer block must not be used with ball or unit wheel bearings.

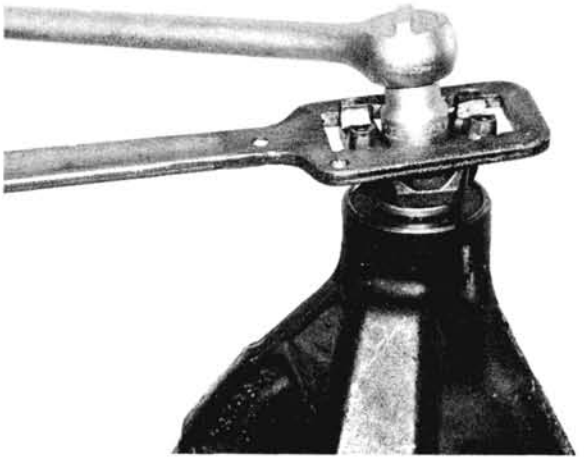


Figure 137 1009-137

Turn nose of carrier in a horizontal position to remove pinion nut. Hold end yoke or flange with tool similar to the one shown, and remove pinion nut and washer.

Tool—#C-3281 Holding wrench.

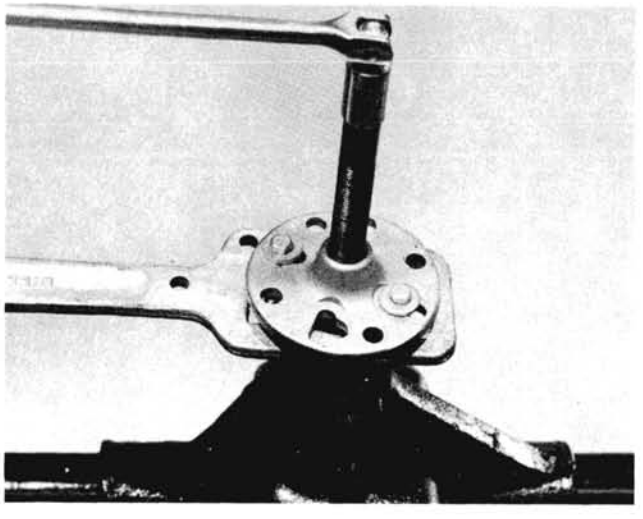


Figure 138 1009-138

Remove end yoke or flange with tools as shown. If yoke or flange shows wear in the area of the seal contact, it should be replaced.

Tool—#C-452.



Figure 139 1009-139

Remove pinion by tapping with a rawhide hammer. Catch the pinion with your hand to prevent it from falling to the ground and being damaged.

NOTE

On the spline end of the pinion, there are bearing preload shims. These shims may stick to the bearing — pinion — or even fall out. The shims are to be collected and kept together since they will be used later in assembly. Try not to mutilate shims. If shims are mutilated, replace with new ones; shims are available in thicknesses of .003″, .005″, .010″, and .030″.



Figure 140 1009-140

Pull out pinion seal with puller as shown. **Discard seal.** Replace with new seal at time of assembly. Remove bearing cone and outer pinion oil slinger.

Tool—#D-131 Slide hammer.

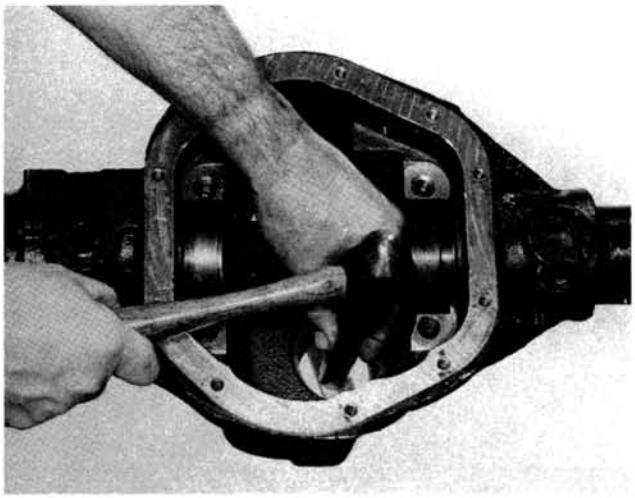


Figure 141 1009-141

Turn nose of carrier down. Remove outer pinion bearing cup as shown. Locate driver on back edge of cup; drive cup out of carrier. **Caution: Do not nick carrier bore.**

Tools—#D-147 Remover, #C-4171 Handle.



Figure 142 1009-142

NOTE

The front and rear axle carrier section may vary in pinion bore depth due to the possibility of the need for either a baffle or slinger or both.

The baffle serves the same purpose of assisting the lube to flow up through the oil channels to lubricate the pinion bearings. If used, they are part of the pinion setting adjustment. In Figure 1009-142 we show the four different options.



Figure 143 1009-143

Remove the inner bearing cup with tools as shown.

Tools—#D-148 Removed, #C-4171 Handle.

NOTE

Shims are located between the bearing cup and carrier bore, and, as illustrated in Figure 142, may also include an oil baffle. If shims and baffle are bent or nicked, they should be replaced at time of assembly. Wire the stacks together and measure each. If stack has to be replaced, replace with the same thickness.

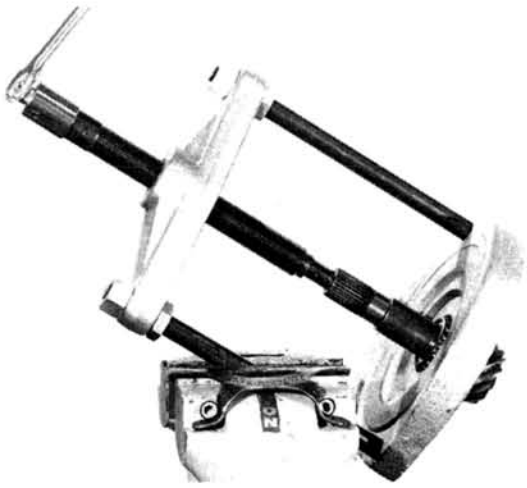


Figure 144 1009-144

Remove inner pinion bearing cone with tools as shown.

Tools—#DD-914-P Press, #DD-914-9 Adapter Ring, #C-293-39 Adapter Set.

NOTE

Both baffle and slinger are part of the pinion adjustment shims and are to be kept intact for assembly.

ASSEMBLY

On all front axles there are axle shaft oil seals which are pressed into the tube ends of the carrier. There are two different designs.

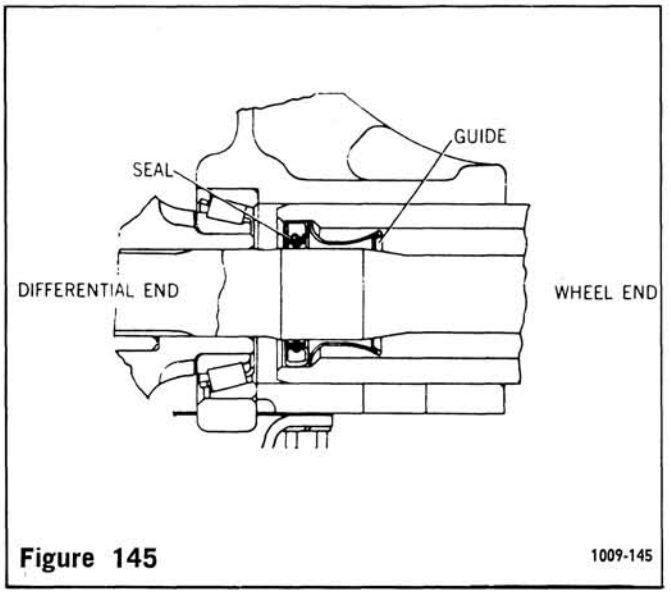


Figure 145 1009-145

As shown in Figure 1009-145, this design consists of an axle shaft guide and seal. (One guide and one seal for each side.)

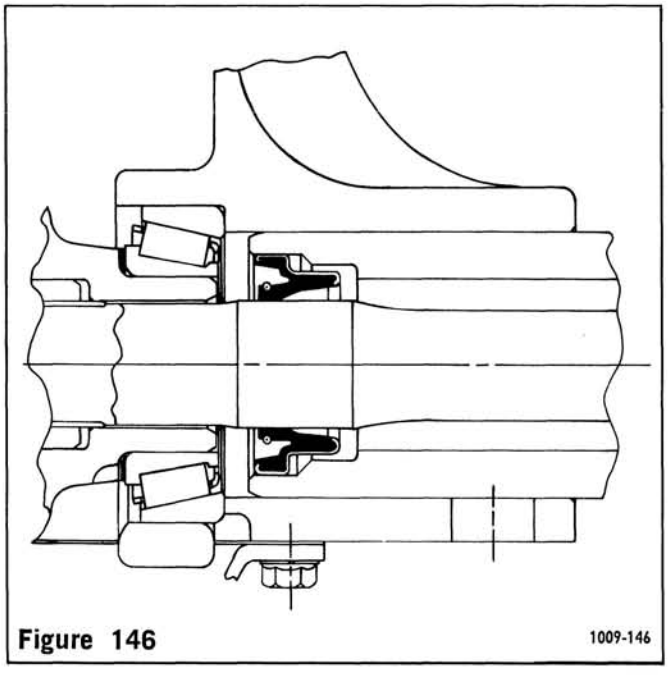


Figure 146 1009-146

As shown in Figure 1009-146, this design consists of the integral seal (unit) whereby the seal and guide are combined. (One seal for each side.)

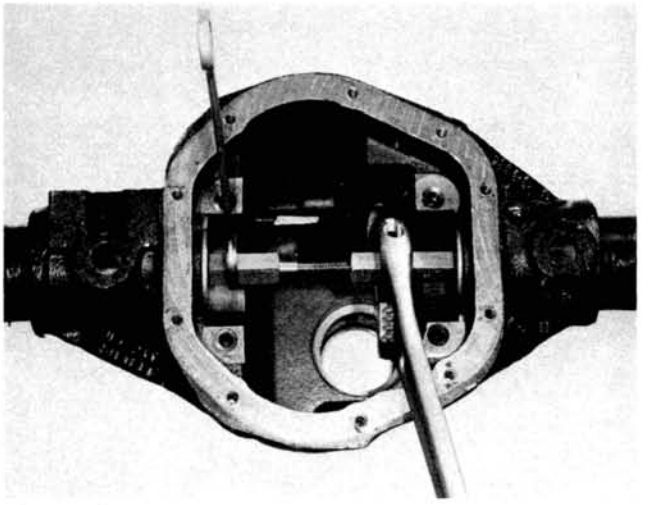


Figure 147 1009-147

Assemble inner axle shaft seals and guides. To assemble axle shaft guides and seals, use tools as described.

Tools—#D-112 Screw, #D-112-1 Adapter.

When assembling the seals make sure they are positioned straight and do not get cocked.

Turn forcing screw until it stops; seal will then be seated.

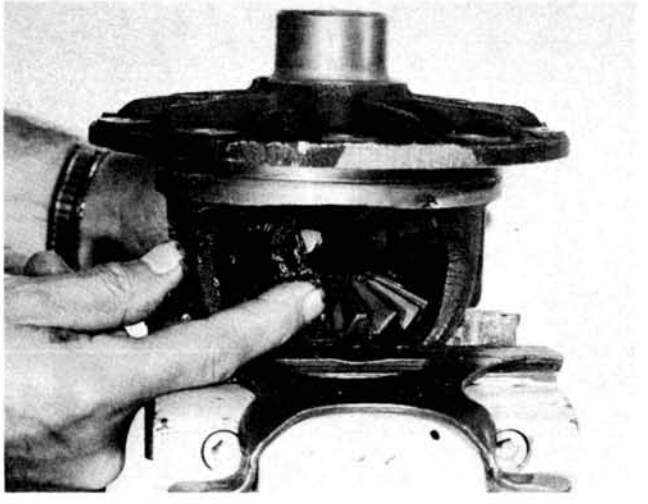


Figure 148 1009-148

Place differential case in vise as shown. Apply grease to new side gear thrust washers and hubs of side gear. Assemble both side gears. Apply grease to new pinion mate spherical washers and the pinion mate gears. Assemble pinion mate gears. An easy way to assemble the side gears and pinion mate gears is to have all parts lubricated before assembly. Assemble both side gears and thrust washers, hold them in place with hand, then assemble the pinion gears to hold the side gears in place.

Rotate the side gears until the holes of the washers and pinion gears line up with the holes of the case. If the gears cannot be rotated by hand, install one of the axle shafts into the side gear spline and use a pipe wrench to turn the shafts.

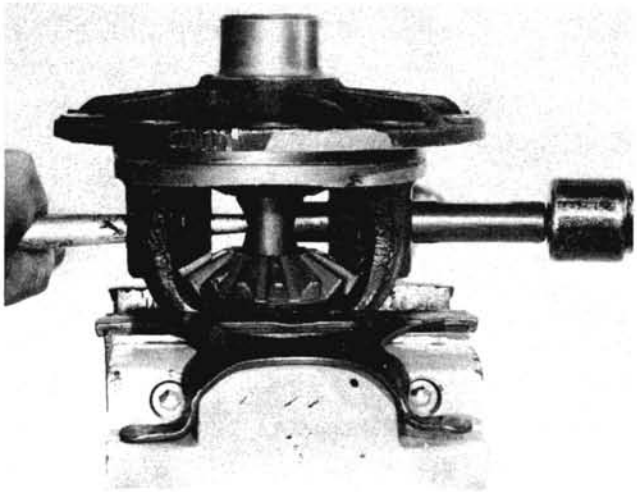


Figure 149 1009-149

If spacer block is used, assemble as shown. Use a drift to line holes of the gears up with the case. Assemble shaft, drive on shaft to remove drift. Be sure vertical lock pin hole is lined up with that of the case, and that the pinion mate spherical washers are in place and lined up with gear and case.

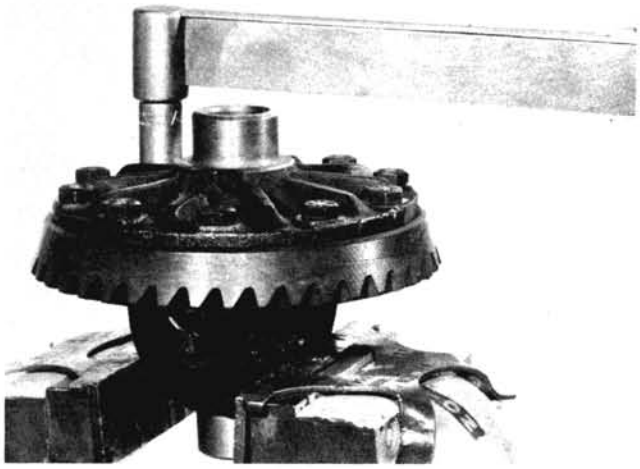


Figure 151 1009-151

Be sure flange face of the case is free of nicks or burrs. Assemble ring gear to case **using new ring gear screws.** Line up holes of gear and case. Draw up screws alternately and evenly.

Torque screws to 45-60 lbs. ft.

Tool—#C-524-A Torque wrench.



Figure 150 1009-150

Assemble lock pin. Peen metal of case over pin to lock in place.

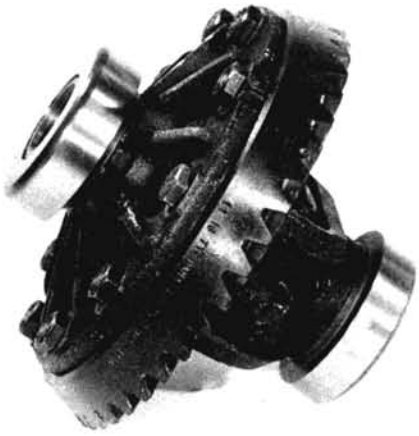


Figure 152 1009-152

Install master differential bearing onto case. Remove all nicks, burrs, dirt, etc., from hubs to allow master bearings to rotate freely.

Tool—#D-135 Master bearings.

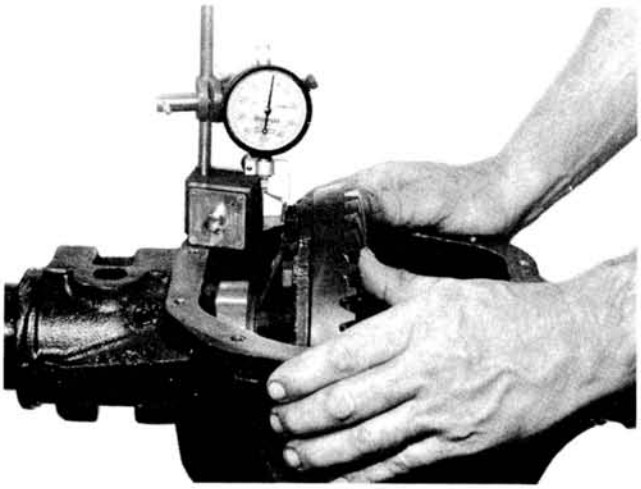


Figure 153 1009-153

Assemble differential case into carrier (less pinion). Mount dial indicator with a magnetic base as shown. Locate tip of indicator on flat surface of one of the gear screws. Mark screw with a piece of chalk. Force the differential assembly as far as possible in the direction towards the indicator. With force still applied, set indicator at zero (0).

Tool—#D-128 Indicator.

> **NOTE**
> Indicator should have a minimum of .200" travel.

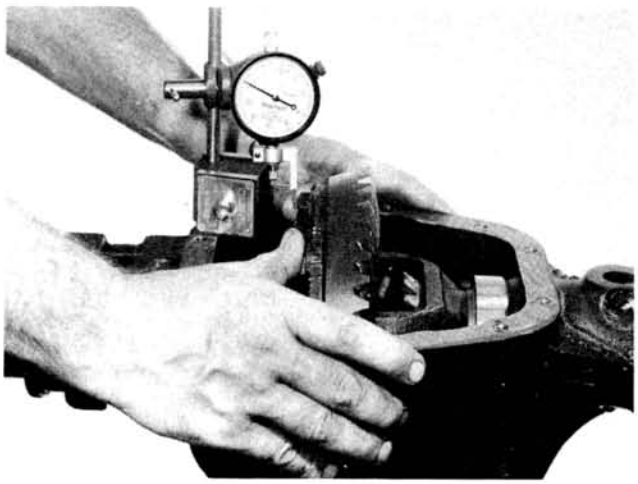


Figure 154 1009-154

Force the differential assembly as far as it will go in the opposite direction. Repeat these steps until the same reading is obtained.

Record the reading of the indicator.

This will be the total amount of shims required (less preload) and will be calculated later during assembly.

After making sure the readings are correct, remove indicator and differential assembly from housing. **Do not remove master bearings from differential case at this time.**

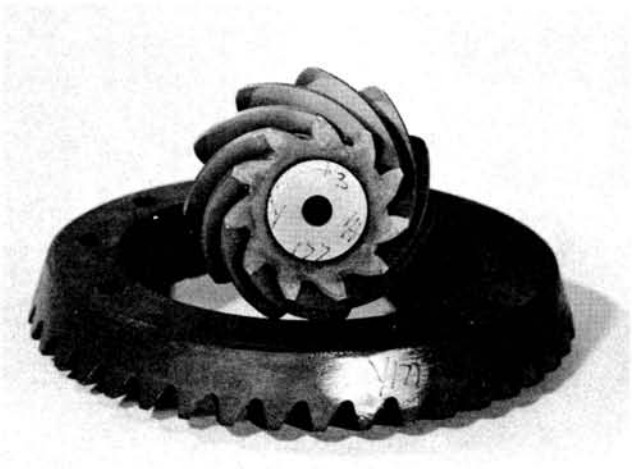


Figure 155 1009-155

View of ring and pinion set.

Ring gears and pinions are supplied in matched sets only. Matching numbers on both the pinion and ring gear are etched for verification. If a new gear set is being used, verify the numbers of each pinion and ring before proceeding with assembly.

The distance from the centerline of the ring gear to the button end of the pinion for the Model 44 (Front and Rear) axle is 2.625 inches.

On the button end of each pinion there is etched a plus (+) number, a minus (—) number, or a zero (0) number, which indicates the best running position for each particular gear set. This dimension is controlled by the shimming behind the inner bearing cup.

For example — if a pinion is etched +3, this pinion would require .003" less shims than a pinion etched "0". This means by removing shims, the mounting distance of the pinion is increased to 2.268" which is just what a +3 indicates. Our if a pinion is etched —3, we would want to add .003" more shims than would be required if the pinion were etched "0". By adding .003" shims the mounting distance of the pinion was decreased to 2.622" which is just what a —3 etching indicated.

If the old ring and pinion set is to be reused, measure the old shim pack and build a new shim pack to this same dimension. If a baffle is in the axle assembly, it is considered as part of the shim pack.

To change the pinion adjustment, shims are available in thicknesses of .003", .005", and .010".

> **NOTE**
> If baffle or slinger is bent or mutilated, it should be replaced.

Measure each shim separately with a micrometer and add together to get total shim pack thickness from original build up.

If a new gear set is being used, notice the (+) or (—) etching on both the old and new pinion and

adjust the thickness of the new shim pack to compensate for the difference of these two figures.

For example: If the old pinion reads (+) 2 and the new pinion is (—) 2, add .004″ shims to the original shim pack.

The above procedures also apply to pinion adjustment on the front axle which includes the oil slinger between the inner bearing cone and pinion, and baffle between the inner bearing cup and carrier.

CARRIER SECTION

Old Pinion Marking	New Pinion Marking								
	−4	−3	−2	−1	0	+1	+2	+3	+4
+4	+0.008	+0.007	+0.006	+0.005	+0.004	+0.003	+0.002	+0.001	0
+3	+0.007	+0.006	+0.005	+0.004	+0.003	+0.002	+0.001	0	−0.001
+2	+0.006	+0.005	+0.004	+0.003	+0.002	+0.001	0	−0.001	−0.002
+1	+0.005	+0.004	+0.003	+0.002	+0.001	0	−0.001	−0.002	−0.003
0	+0.004	+0.003	+0.002	+0.001	0	−0.001	−0.002	−0.003	−0.004
−1	+0.003	+0.002	+0.001	0	−0.001	−0.002	−0.003	−0.004	−0.005
−2	+0.002	+0.001	0	−0.001	−0.002	−0.003	−0.004	−0.005	−0.006
−3	+0.001	0	−0.001	−0.002	−0.003	−0.004	−0.005	−0.006	−0.007
−4	0	−0.001	−0.002	−0.003	−0.004	−0.005	−0.006	−0.007	−0.008

Figure 156 1009-156

Pinion setting chart shown. Use this chart as a guideline to set pinion.

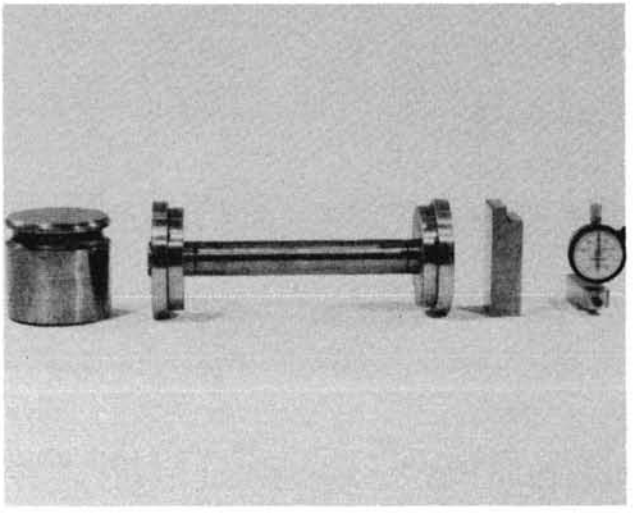


Figure 157 1009-157

View of master pinion block, pinion height block, scooter gage, cross arbor, and master bearing discs.

NOTE

Cross arbor and master bearing discs can be used on both the Model 30 and Model 44 axles. Use large diameter discs for Model 44 axle.

Be sure that all carrier bores are free from all nicks, dirt or any other contamination.

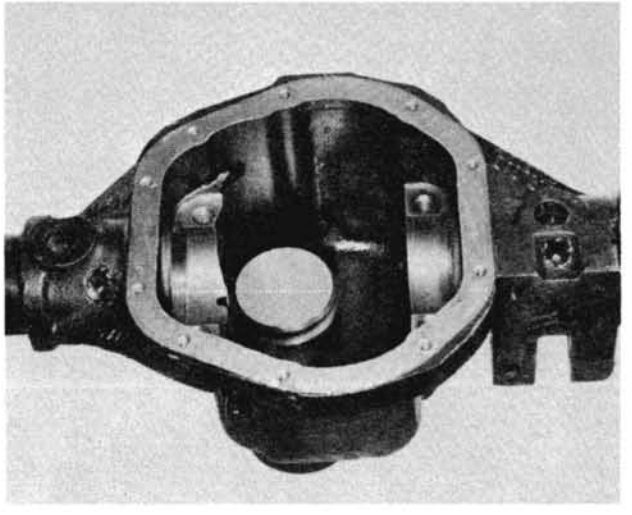


Figure 158 1009-158

Place the master pinion block into the pinion bore of the carrier as shown.

Tool—#D-139 Master pinion block.

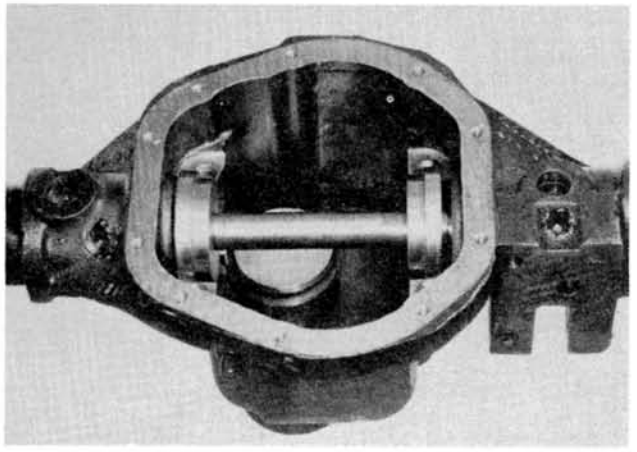


Figure 159 1009-159

Place arbor discs and arbor into cross bores of the carrier as shown.

Tools—#D-115-3 Arbor, #D-115-4 Arbor discs.

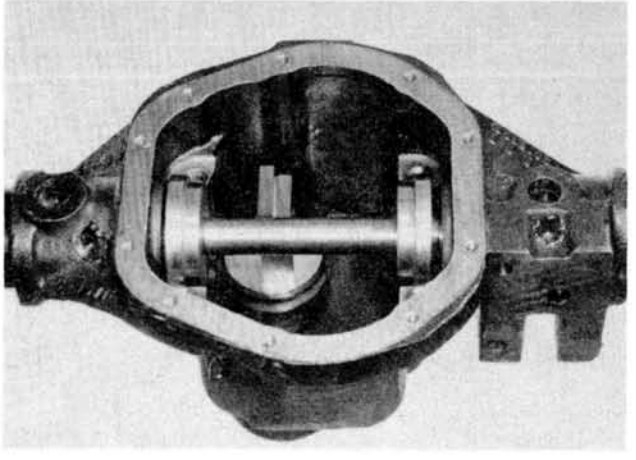


Figure 160 1009-160

Place pinion height block on top of master pinion block, and against arbor as shown.

Tool—#D-115-1 Pinion height block.

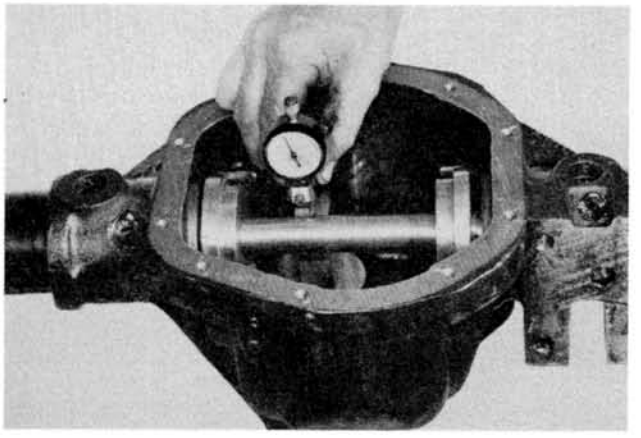


Figure 161 1009-161

Place scooter gage on small step of pinion height block. Apply pressure with fingers making sure the gage is flat on the pinion height block, while pressure is applied, set indicator at zero "0".

Tool—#D-115 Scooter gage.

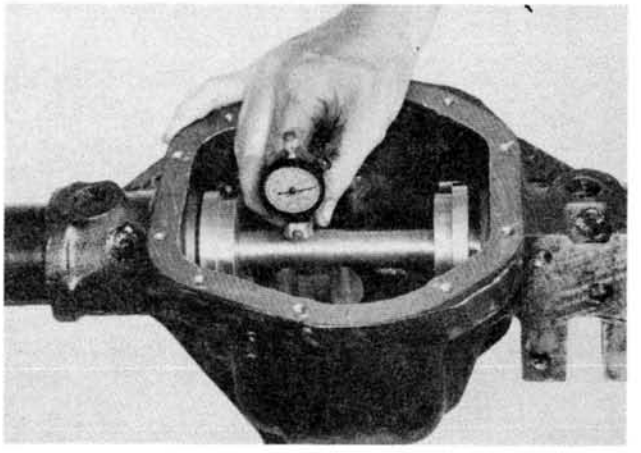


Figure 162 1009-162

Slide scooter gage over arbor. As gage slides over top of arbor, it will travel in a clockwise direction. When indicator is on center of arbor (on top), it will stop traveling in a clockwise direction. If indicator starts to travel in a counterclockwise direction, this means that you have passed the center (top) of the arbor. Record only the reading when the indicator is at the highest point. This reading indicates the amount of shims necessary to obtain the correct shim pack, plus (+) or minus (—) the etching on the bottom end of the pinion. If the etching is zero (0), the shim pack will remain unchanged.

For example: If a pinion is etched +3, this pinion would require .003″ less shims than a pinion etched zero "0".

If a pinion is etched —3, we would want to add .003″ more shims than would be required if the pinion were etched zero "0".

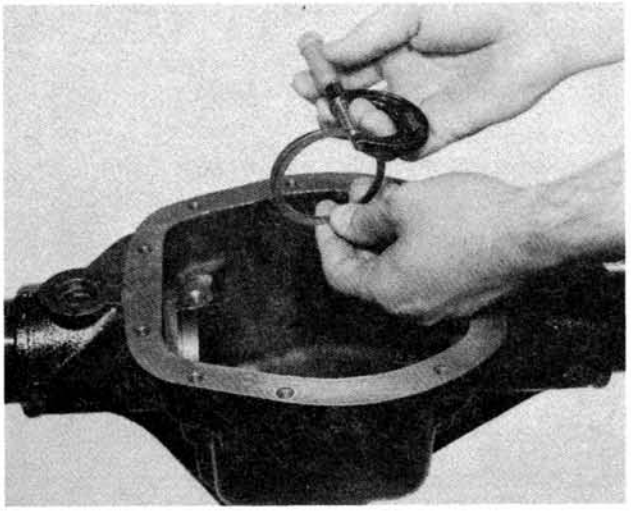


Figure 163 1009-163

Measure each shim separately with a micrometer and add together to get total shim pack thickness. If baffle is required, it is to be included in the shim pack. If slinger is used between the inner bearing cone and thrust face of pinion, the slinger is also to be measured and included as a part of the total shim pack.

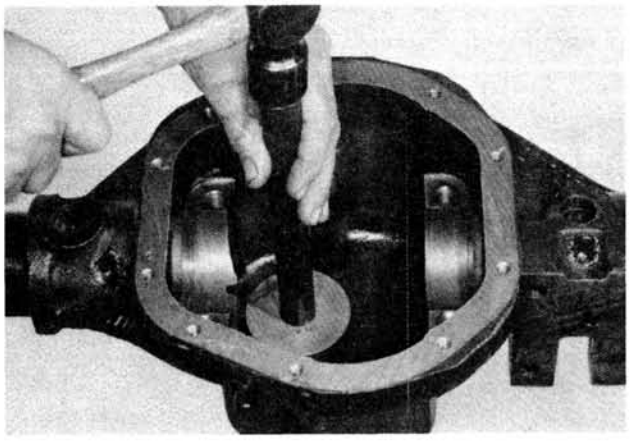


Figure 164 1009-164

Place the required amount of shims (and baffle if used) in the inner bearing bore; drive the inner bearing cup into carrier with tools as shown.

Tools—#D-145 Cup installer, #C-4171 Handle.

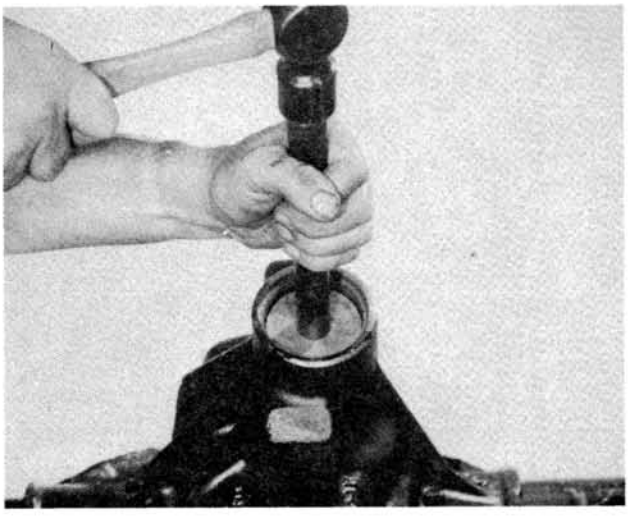


Figure 165 1009-165

Assemble the outer pinion bearing cup into carrier as shown.

Tools—#D-144 Cup installer, #C-4171 Handle.

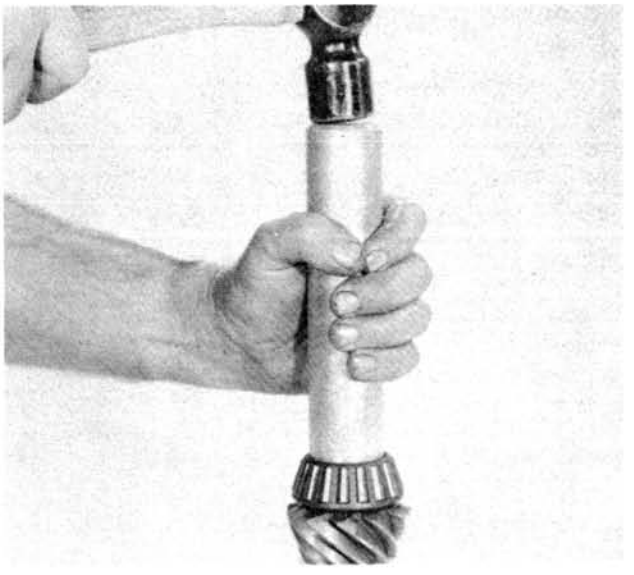


Figure 166 1009-166

Assemble inner bearing cone (and slinger if used) on pinion, place bearing installer over pinion shaft as shown. Drive bearing on shaft until it is completely seated.

Tool—#W-262.

Assemble preload shims (which were removed during disassembly) onto pinion. Assemble bearing cone, slinger.

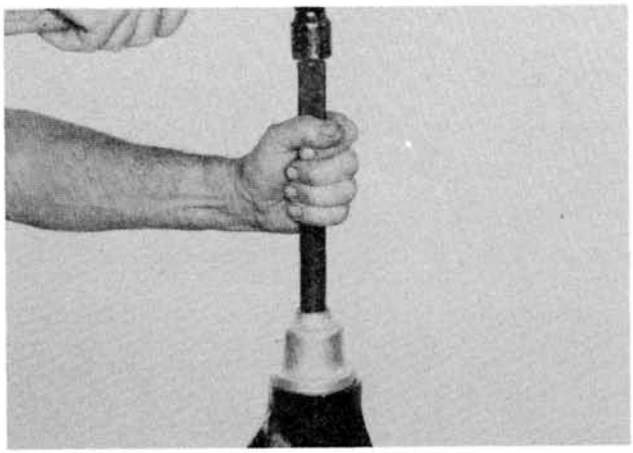


Figure 167 1009-170

Apply a light coat of hypoid lubricant to the lip of the pinion seal and assemble into housing.

Tools—#W-147D Seal installer, #C-4171 Handle.

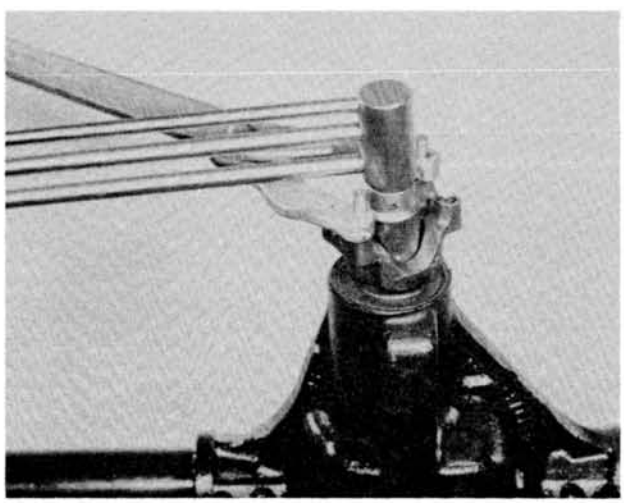


Figure 168 1009-171

Assemble end yoke, washer, and pinion nut. Torque nut to 200-220 lbs. ft.

Tools—#C-4053 Torque wrench, #C-3281 Yoke holder.

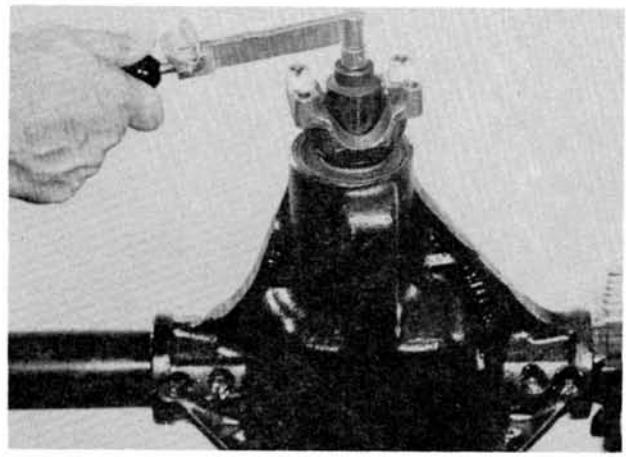


Figure 169 1009-172

Using an inch lb. torque wrench as shown, rotate pinion. Torque of pinion should read between 20-40 lbs. inch.

To increase preload, remove shims; to decrease preload, add shims.

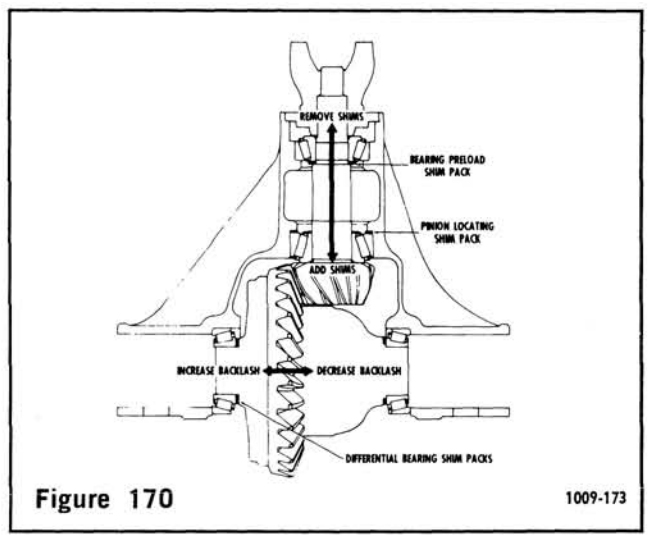


Figure 170 1009-173

L/D Carrier Section.

CARRIER SECTION

The illustration in Figure 1009-170 shows the arrow in the pinion pointing in two directions. The direction of the arrow pointing towards the end yoke indicates that by removing pinion locating shims, the distance from the center line of the axle to pinion button is increased giving a plus reading. The preload shim pack do not affect the pinion depth setting.

Arrows on the ring gear illustrate the method to increase or decrease backlash and differential bearing preload.

ASSEMBLY OF DIFFERENTIAL

Place differential assembly (with pinion assembled) into housing. Differential master bearings should still be installed to differential case.

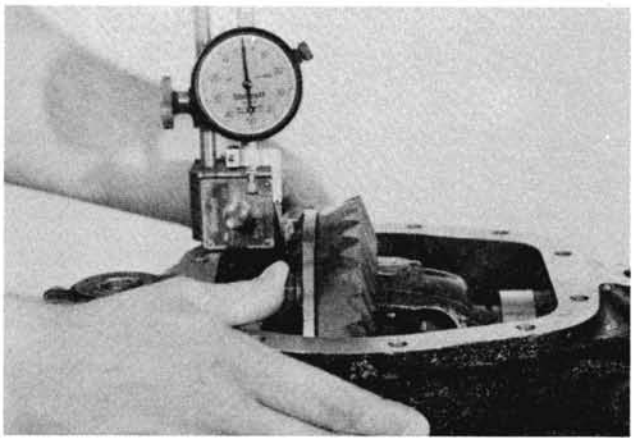


Figure 171 1009-174

Set up dial indicator as shown. Be sure to locate dial indicator on same ring gear screw as shown in Figure 171. Force ring gear to mesh with pinion gear. Rock ring gear to allow the teeth of the gears to mesh. With force still applied to the differential case, set indicator at zero "0".

Tool — #D-128 Indicator.

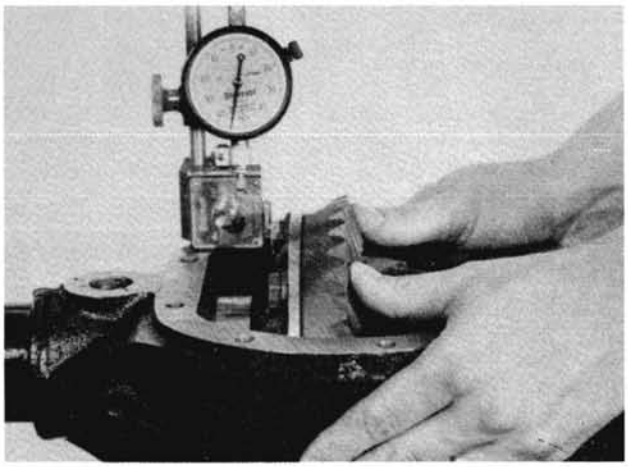


Figure 172 1009-175

Force the differential assembly (ring gear) away from the pinion gear to obtain an indicator reading. Repeat until the same reading is obtained each time. This reading will be the necessary amount of shims between the differential case and differential bearing on the ring gear side. Remove indicator and differential case from the carrier.

Remove master bearings from differential case.

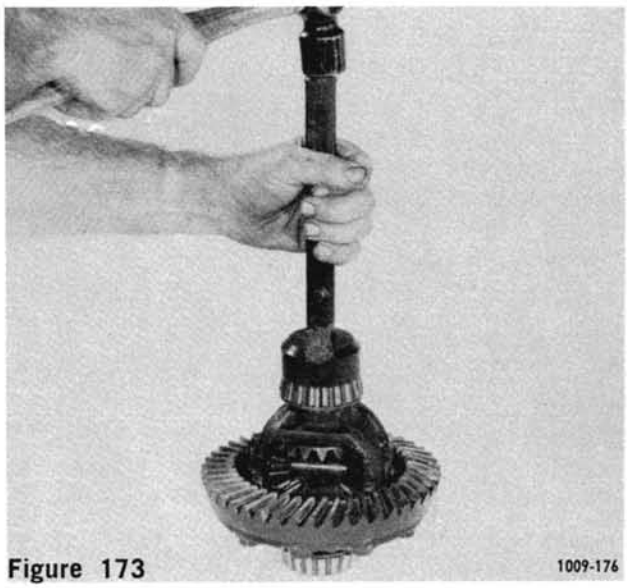


Figure 173 1009-176

Assemble the required amount of shims onto hub (ring gear side) as determined in Figure 172. Place bearing cone on hub of case. Use bearing installer to seat bearing cone as shown.

Tools — #D-156 Installer, #S-4171 Handle.

Assemble the remaining of the total shim pack which was determined in Figure 154 on the opposite side of the differential case. Add an additional .015 of shims on this side to compensate for differential bearing preload. Assemble differential bearing using the same tools as shown in Figure 173.

For example:

In Figure 154 (less pinion) a total of .085 indicator reading was recorded.

In Figure 172 (with pinion) a total of .055 indicator reading was recorded. This leaves a balance .030 of shims for the opposite side and adds up to the .085 which was first recorded.

Add an additional .015 shims on the opposite side for bearing preload and backlash.

Ring gear side — .055
Opposite side — .030
Opposite side preload — .015

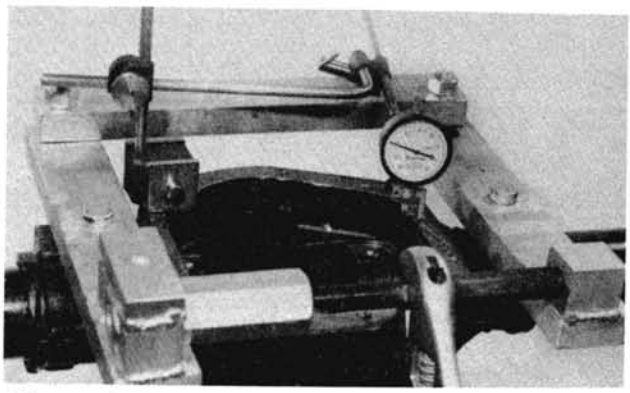


Figure 174 1009-177

Install spreader and indicator to carrier as shown. **Do not spread carrier over .015″.**

Remove indicator.

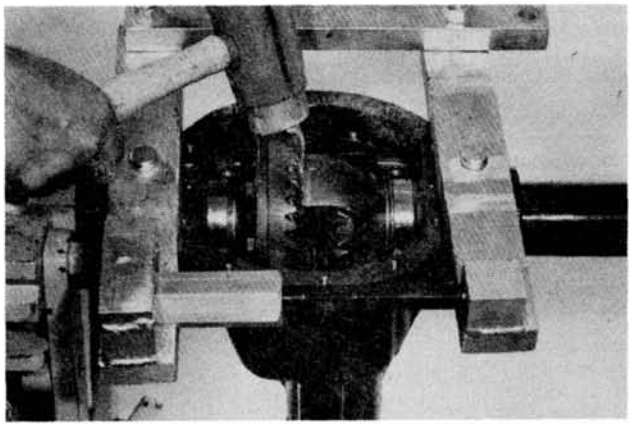


Figure 175 1009-178

Assemble differential bearing cups to differential bearing cones.

Install differential assembly into carrier.

Use a rawhide hammer to seat differential assembly into cross bore of carrier. Care should be taken to avoid nicking the teeth of the ring gear and pinion during assembly.

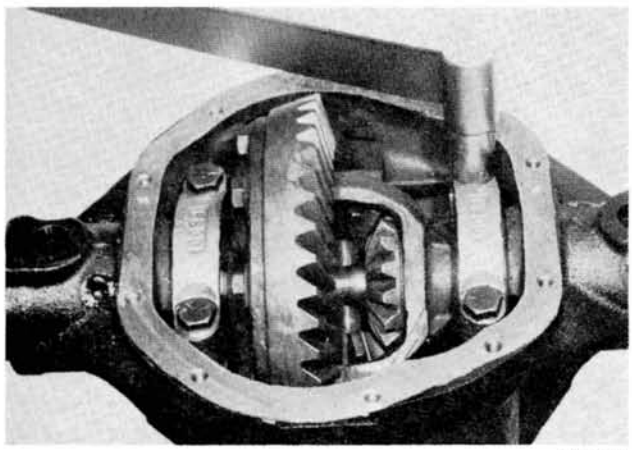


Figure 176 1009-179

Install bearing caps. Make sure the letters stamped on the caps correspond with those on the carrier; torque bearing cap screws to 70-90 lbs. ft.

Tool—#C-524-A Torque wrench.

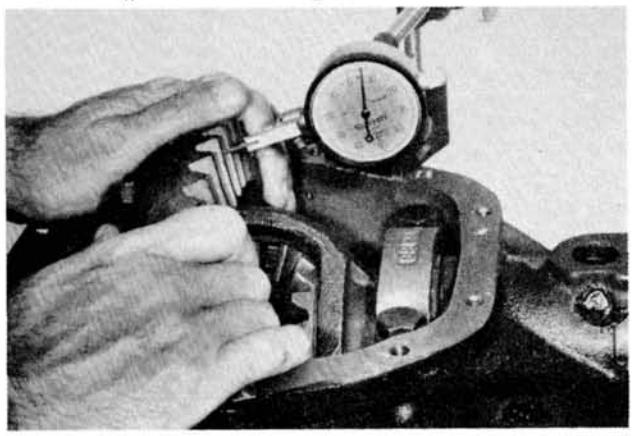


Figure 177 1009-180

Check ring gear and pinion backlash in three equally spaced points with dial indicator as shown.

Backlash tolerance is .005 to .008 and cannot vary more than .002 between points checked.

High backlash is corrected by moving the ring gear closer to the pinion.

Low backlash is corrected by moving the ring gear away from the pinion.

These corrections are made by switching shims from one side of the differential case to the other.

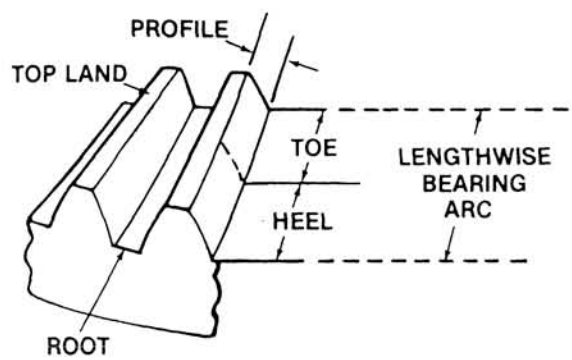
If backlash is to specification, check ring gear and pinion tooth contact pattern as follows and adjust accordingly.

RING GEAR & PINION TOOTH PATTERN INTERPRETATION

When setting the pinion position, many of the previous service manuals required a final pinion position check by using gauges that verified the dimension from the center line of the differential carrier (center line of ring gear) to the face of the pinion (button).

This surface (button) is not used on all new gears for verifying the pinion position. The service tools will be used to establish the proper amount of shims required prior to installing the pinion gear. The final pinion position will be verified by using the GEAR CONTACT PATTERN METHOD, as described below.

RING GEAR AND PINION TOOTH CONTACT PATTERN



RING GEAR TOOTH

The TOE of the gear tooth is the portion of the tooth surface at the end towards the center. The HEEL of the gear tooth is the portion of the tooth surface at the outer end. The TOP LAND of a gear tooth is the surface of the top of the tooth. Every gear has a characteristic pattern. The illustrations show typical patterns only, and explains how patterns shift as gear location is changed. When making pinion position changes, shims should be changed in the range of .002 inch (.05 mm) to .004 inch (.10 mm) until correct pattern has been obtained.

When a change in backlash is required, backlash shims should be changed in the range of 1½ times the amount of backlash required to bring the gears into specification. For example, if the backlash needed to be changed by .004 inch (.10 mm), the shim pack should be changed by .006 inch (.15 mm) as a starting point. The actual amount of backlash change obtained will vary depending upon the ratio and gear size.

High backlash is corrected by moving the ring gear closer to the pinion. Low backlash is corrected by moving the ring gear away from the pinion. These corrections are made by switching shims from one side of the differential case to the other.

NOTE

When making changes, note that two variables are involved. Example: If you have the backlash set correctly to specifications and you change the pinion position shim, you may have to readjust the backlash to the correct specification before checking the pattern. Refer to pattern interpretation.

WARNING: Gear teeth may have sharp edges. When handling gears, use care to avoid personal injury.

STEPS

(1) Paint ring gear teeth with a marking compound to both the drive and coast side.
(2) Rotate ring gear one complete revolution in both directions while load is being applied with a large screwdriver or similar tool between the carrier casting and differential case flange.

PATTERN INTERPRETATION (RING GEAR)

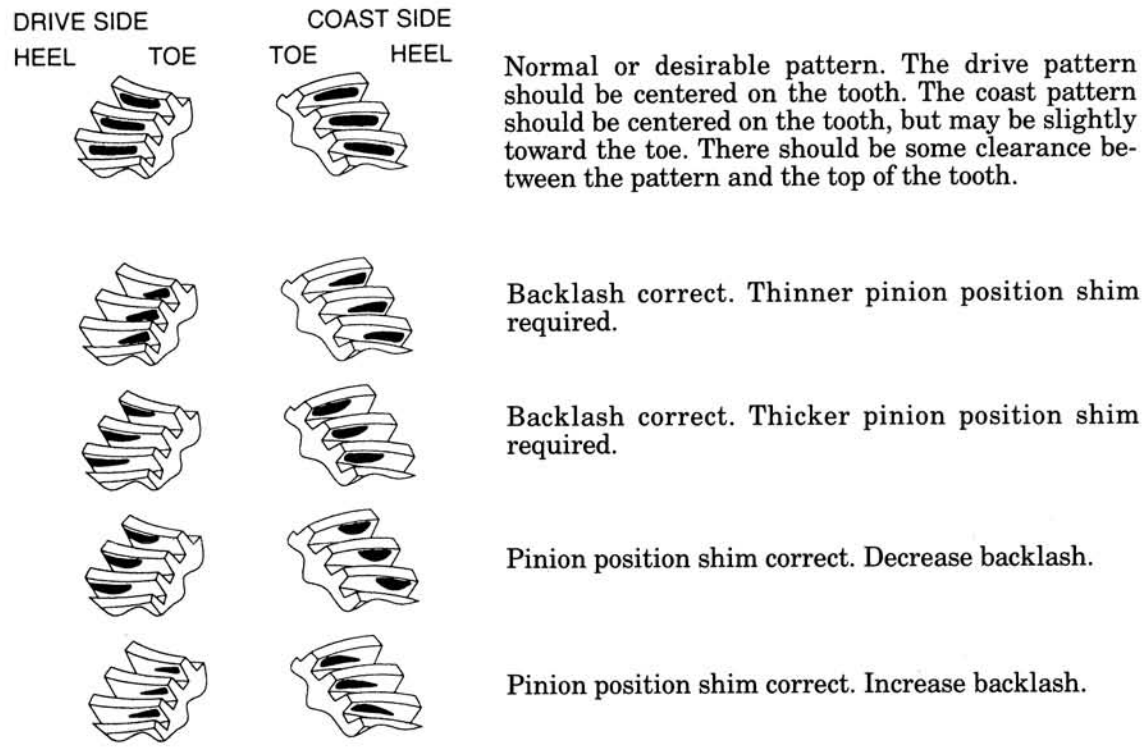


Figure 178

PATTERN MOVEMENTS SUMMARIZED

(1) Decreasing backlash moves the ring gear closer to the pinion.
Drive pattern (convex side of gear) moves slightly lower and toward the toe.
Coast pattern (concave side of gear) moves lower and toward the toe.

(2) Increasing backlash moves the ring gear away from the pinion.
Drive pattern moves slightly higher and toward the heel.
Coast pattern moves higher and towards the heel.

(3) Thicker pinion position shim with the backlash constant moves the pinion closer to the ring gear.
Drive pattern moves deeper on the tooth (flank contact) and slightly toward the toe.
Coast pattern moves deeper on the tooth and toward the heel.

(4) Thinner pinion position shim with the backlash constant moves the pinion further from the ring gear.
Drive pattern moves toward the top of the tooth (face contact) and toward the heel.
Coast pattern moves toward the top of the tooth and slightly toward the toe.

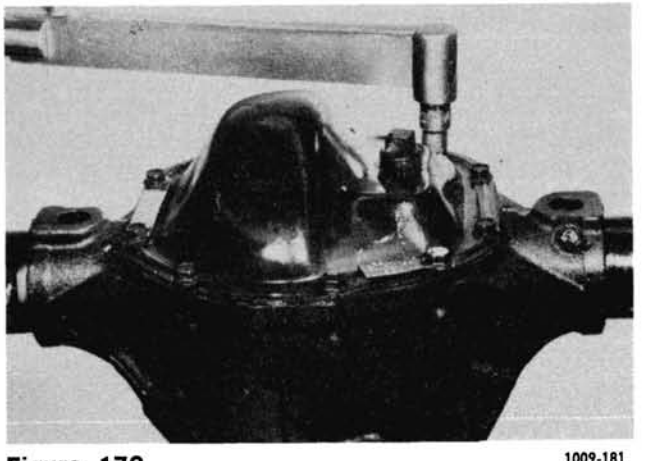


Figure 179 1009-181

Install new cover gasket and install cover plate. Torque screws to 30-40 lbs. ft.
Tool—#C-524-A Torque wrench.

For more information, contact:
DANA CORPORATION
SPICER OFF-HIGHWAY
AXLE DIVISION
P.O. Box 2424
Fort Wayne, IN 46801
Tel: (219) 481-3174
Fax: (219) 481-3165

MM-005-44-2M-12/95
Parrot Press

MODEL 60
MAINTENANCE MANUAL

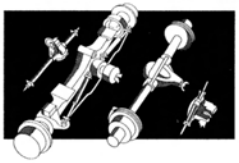
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REAR AXLES — WHEEL ENDS, FULL-FLOAT DESIGN 32

CARRIER SECTION 34

REAR AXLE SEMI-FLOAT SHAFT RIDING BEARING DESIGN 50

IMPORTANT SAFETY NOTICE

Should an axle assembly require component parts replacement, it is recommended that "Original Equipment" replacement parts be used. They may be obtained through your local service dealer or other original equipment manufacturer parts supplier. CAUTION: THE USE OF NON-ORIGINAL EQUIPMENT REPLACEMENT PARTS IS NOT RECOMMENDED AS THEIR USE MAY CAUSE UNIT FAILURE AND/OR AFFECT VEHICLE SAFETY.

Proper service and repair is important to the safe, reliable operation of all motor vehicles or driving axles whether they be front or rear. The service procedures recommended and described in this service manual are effective methods for performing service operations. Some of these service operations require the use of tools specially designed for the purpose. The special tool should be used when and as recommended.

It is impossible to know, evaluate and advise the service trade of all conceivable ways in which service might be done or of the possible hazardous consequences of each way.

Accordingly, anyone who uses a service procedure or tool which is not recommended must first satisfy himself thoroughly that neither his safety or vehicle safety will be jeopardized by the service methods he selects.

NOTE

Throughout this manual, reference is made to certain tool numbers whenever special tools are required. These numbers are numbers of Miller Special Tools, 32615 Park Lane, Garden City, Michigan 48135. They are used herein for customer convenience only. Dana makes no warranty or representation to these tools.

LUBRICATION

It is not our intent to recommend any particular brand or make of lubricant for Spicer axles. However, a S.A.E. 90 weight multipurpose gear lubricant meeting Mil. Spec. L-2105-B, or 80 W 90 multipurpose gear lubricant meeting Mil. Spec. L-2105-C, and suitable for A.P.I. Service Classificiation GL-5 is suggested as a minimum requirement.

WHEEL BEARING LUBRICATION

Wheel bearings are lubricated by one of two different methods. One is to pack the wheel bearing with grease; while the other method is to lubricate the wheel bearing with the hypoid gear lube in the housing.

For grease packing, it is recommended that a number 2 consistency, lithium base 12 hydroxy stearate grease containing an E.P. additive be used. Such a lubricant would pass a load-carrying test at 40 pounds (18.5 Kg.) minimum with base oil pour point at -10 °F (-23 °C) maximum.

NOTE

We suggest that wheel bearing lubricants selected for use with Disc Brake applications, in addition to the E.P. properities expressed in this manual, should be compatible with elevated temperatures, i.e., high temperature lubricant. For specified wheel bearing lubricant, refer to Vehicle Service Manual.

CLOSED WHEEL END STEERING KNUCKLE LUBRICATION

The closed steering knuckle requires lubrication from a source other than the gear carrier assembly. Inboard tube seals contain the hypoid gear lube in the housing to provide adequate lubricant level for the gears, bearings, etc. This then requires an additional lubricant level to be maintained outboard, in each steering knuckle, which can be observed by removing fill plugs on each knuckle. Adequate level would be to the bottom of the fill plug hole, when vehicle is observed to be in a normal horizontal position.

Recommended lubricant is an S.A.E. 140 grade, multi-purpose gear lubricant meeting the MIL-L-2105C specification.

COLD WEATHER OPERATION

If the vehicle is operated below 0 °F (−18 °C), it is advisable to use S.A.E. 80 multipurpose gear lubricant meeting Mil. Spec. L-2105-B and suitable for A.P.I. Service Classification GL-5.

IMPORTANT

As special equipment, limited slip differentials are provided in many vehicles, the freedom from "chatter" is a function of the lubricant used and cannot be covered in the above specification. In some applications, a special limited slip differential lubricant may be required. If required, these special lubricants are normally available through the original equipment manufacturer.

SUBMERSION OR DEEP WATER FORDING

If the vehicle is exposed to water deep enough to cover the hubs or wheel bearing retainer plate and oil seal of either the front or rear axles, it is recommended that the wheel ends be disassembled and inspected for water damage and/or contamination daily.

In the event the gear carrier housing should become submerged in water, particularly if over the breathers, it is recommended that the hypoid gear lubricant be drained daily and internal parts be inspected for water damage and/or contamination.

Clean, examine and replace damaged parts, if necessary, prior to assembling the cover housing and refilling with the specified hypoid lubricant.

NOTE

It is recommended that whenever bearings are removed they are to be replaced with new ones, regardless of mileage.

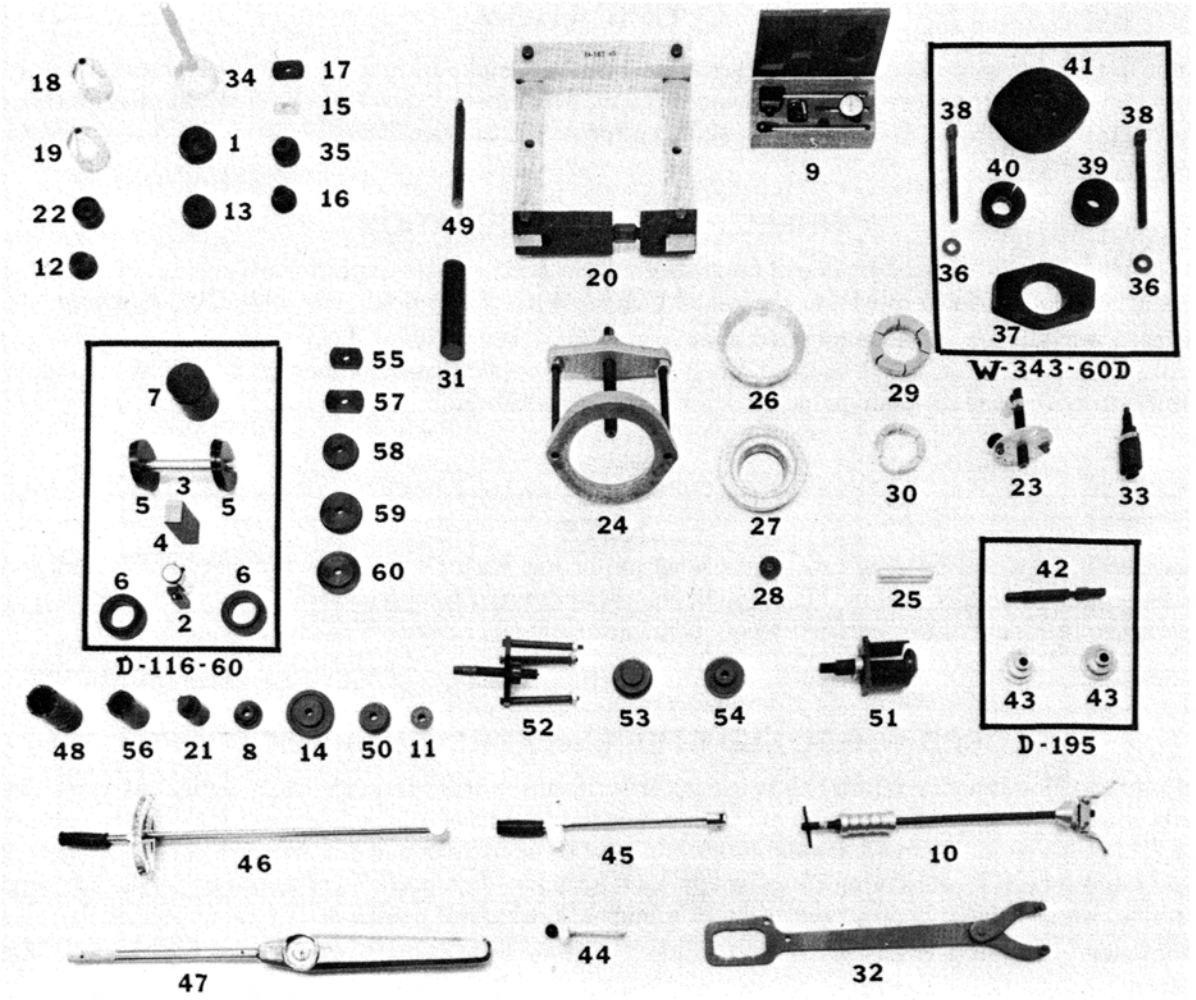


Figure 2 1019-2

The following is a detailed list of all special service tools required to service a Model 60 Front or Rear axle:

ITEM NO.	TOOL NO.	DESCRIPTION
1	D-111	Installer - Rear Pinion Bearing Cup
* 2	D-115	Scooter Gauge
* 3	D-115-3	Arbor
* 4	D-116-1	Pinion Height Block
* 5	D-116-2	Arbor Discs
* 6	D-117	Master Bearing Differential
* 7	D-120	Master Pinion Block
8	D-258	Installer - Front Spindle Needing Bearing
9	D-128	Dial Indicator Set
10	D-131	Puller - Slide Hammer
11	D-141	Installer - Front Spindle Bushing
12	D-142	Installer - King Pin Bearing Cup (Heavy Duty)
13	D-153	Installer - Front Brake Hub Inner Bearing Cup (Reg.)
14	D-155	Installer - Front Brake Hub Grease Seal (Reg. & Heavy Duty)
15	D-158	Remover - Front Pinion Bearing Cup
16	D-161	Installer - Closed Ball Spindle Bushing
17	D-162	Remover - Rear Pinion Bearing Cup
18	D-163	Installer - Pinion Oil Seal (National)
19	D-164	Installer - Pinion Oil Seal (Chicago Rawhide)
20	D-167	Spreader - Differential Carrier
21	D-192	Remover & Installer - Tapered King Pin Upper Ball Joint Pivot Stud
22	D-194	Installer - Steering Knuckle Lower Bearing Seal
23	C-452	Remover - Universal Joint Companion Flange or Yoke
24	DD-914-P	Puller Press
25	DD-914-7	Extension
26	DD-914-8	Reducer Ring
27	DD-914-9	Reducer Ring
28	DD-914-42	Button
29	DD-914-62	Adapter Set - Differential Bearing Cones
30	C-293-37	Adapter Set - Rear Pinion Bearing Cone
31	C-3095-A	Installer - Rear Pinion Bearing Cone

ITEM NO.	TOOL NO.	DESCRIPTION
32	C-3281	Wrench - Universal Joint Flange or Yoke
33	C-3718	Installer - Universal Joint Flange or Yoke
34	C-4025-A	Installer - Differential Side Bearings
35	C-4026-A	Installer - Axle Shaft Outer Oil Seal
**36	SP-320	Washers
**37	SP-5017	Adapter Ring
**38	SP-5026	Bolts
**39	SP-5440	Adapter Ring - Installer
**40	SP-5441	Adapter Set - Removing
**41	SP-5443-A	Flange Plate
***42	D-195-2	Screw
***43	D-195-1	Installer - Front Axle Differential Inner Oil Seal
44	D-193	Torque Wrench - 50 Inch Pound
45	C-524-A	Torque Wrench - 100 Foot Pound
46	C-4053	Torque Wrench - 300 Foot Pound
47	DD-994	Torque Wrench - 1000 Foot Pound
48	C-4170-A	Wrench - Wheel Bearing Lock Nut Adjusting
49	C-4171	Handle - Universal
50	C-4203	Installer - Front Pinion Bearing Cup
51	D-232-1	Remover - Bearing
52	D-247	Installer - Press
53	D-248	Installer - Bearing
54	D-233	Installer - Oil Seal
55	D-255	Cup Remover (Hub & Drum)
56	D-165A	Wheel Bearing Wrench
57	D-257	Cup Remover
58	D-254	Installer - Cup (Outer-Hub & Rotor)
59	D-256	Installer - Cup (Inner-Hub & Rotor)
60	D-253	Seal Installer

* Pinion Setting Gauge and Master Differential Bearing Kit D-116-60.

** Axle Shaft Bearing Removing and Installing Kit W-343-60D.

*** Inner Axle Shaft Seal Installing Kit D-195.

NOTE: Torque Wrenches D-193, C-524-A, C-4053, and DD-994 are optional and can be purchased separately. These torque wrenches are not included in the DW-60 Axle Tool Kit.

AXLE IDENTIFICATION

All Spicer axles are identified with a manufacturing date and the complete part number stamped in the right hand tube. Also each axle contains a gear ratio tag, and if the axle is equipped with a limited slip differential, it will contain a tag specifying the use of limited slip lubricant.

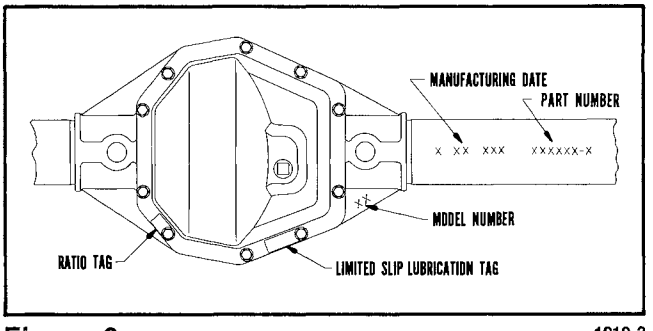


Figure 3 1019-3

In this figure the axle is identified with 1/8'' (3.17 mm) high numbers stamped in the tube. For Example: The manufacturing date or build date of the axle is interpreted as follows. The first number is the month, second number is the day of the month, the third number is the year, the letter is the shift, and the last number is the line that built the axle. The next number is the part (bill of material) number. The six digits reading from left to right is the basic number for identifying the particular axle assembly. The seventh digit following the dash will identify ratio, differential and end yoke options used in the assembly.

NOTE

In the event there are two build dates, the latter will be the date in which the brake components were assembled. The number stamped next to the manufacturing date is the complete axle assembly part number.

It is recommended that when referring to the axle, obtain the complete part number and build date. To do this, it may be necessary to wipe or scrape off the dirt etc., from the tube.

NOTE

On front driving axles, the above numbers can be either on the long or short tube.

AXLE IDENTIFICATION

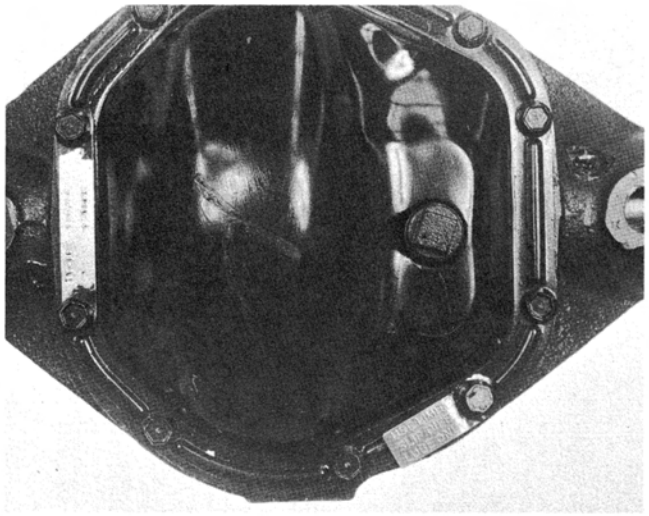


Figure 4 1019-4

The gear ratio tag is located on the left side of the cover plate/or at the bottom left hand side of the cover plate, and is held in place with one or two cover plate screws. This tag gives the tooth combination of the ring and pinion, and also the total gear ratio.

FRONT AXLE

DISASSEMBLY AND REASSEMBLY OF HUBS, DRUMS, WHEEL BEARINGS, ETC. (CLOSED KNUCKLE DESIGN)

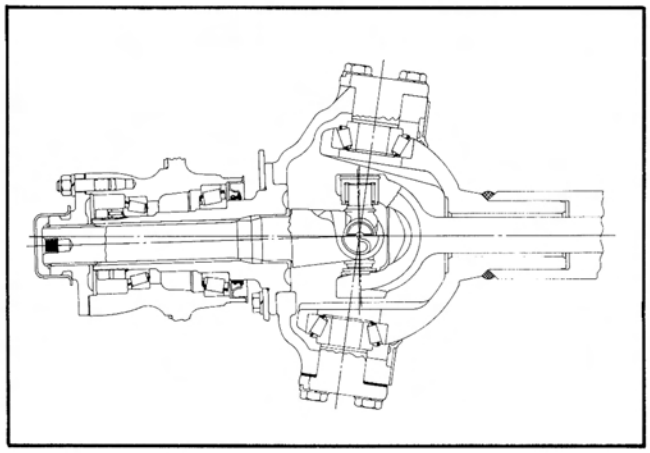


Figure L/D 5 1019-5

Remove wheel from drum assembly.

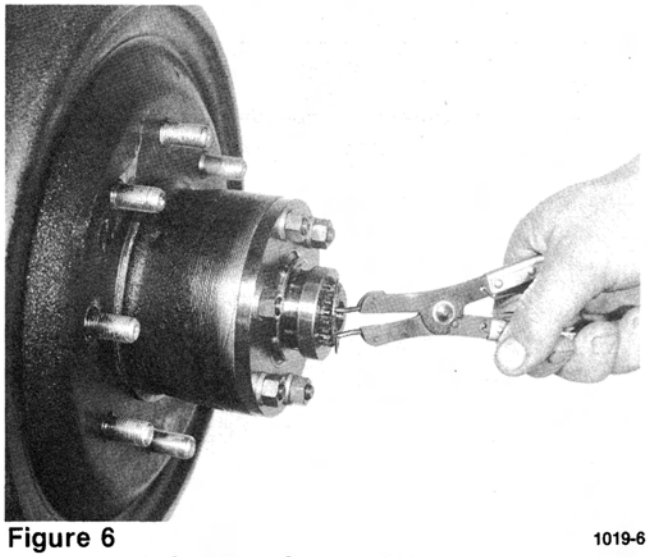


Figure 6 1019-6

Remove hub cap and snap ring.

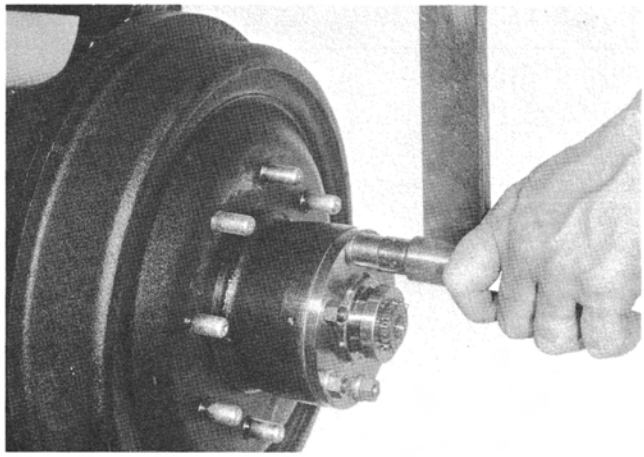


Figure 7 1019-7

Remove nuts and washers from drive flange studs.

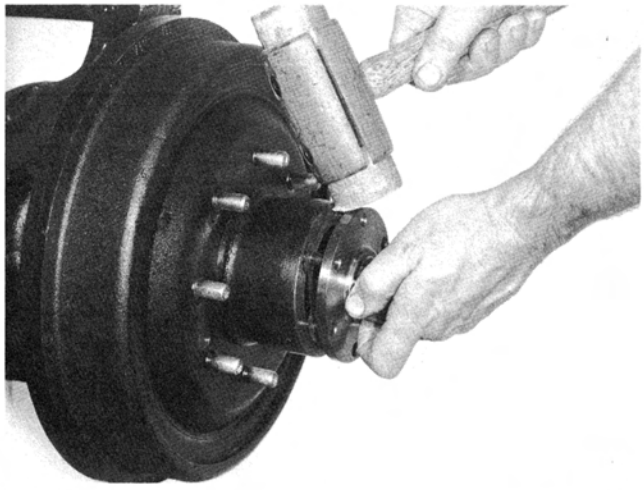


Figure 8 1019-8

Remove drive flange and gasket. Discard gasket. Replace with new one at time of assembly. To free flange from hub, tap lightly with a rawhide hammer.

FRONT AXLE

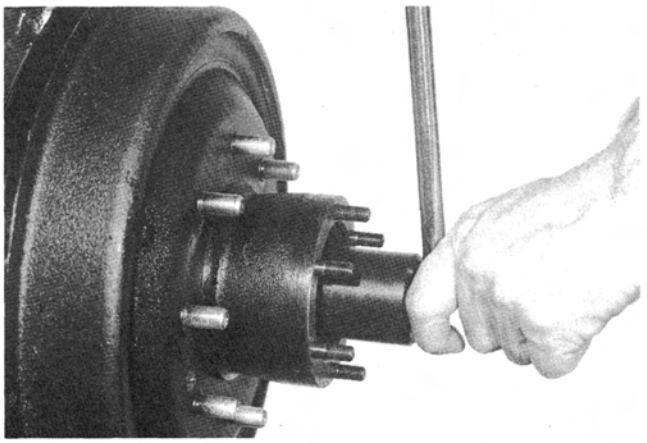


Figure 9 1019-9

Remove outer locknut, lockring, and inner wheel bearing adjusting nut.

Tool: #C-4170 Wheel Wrench.

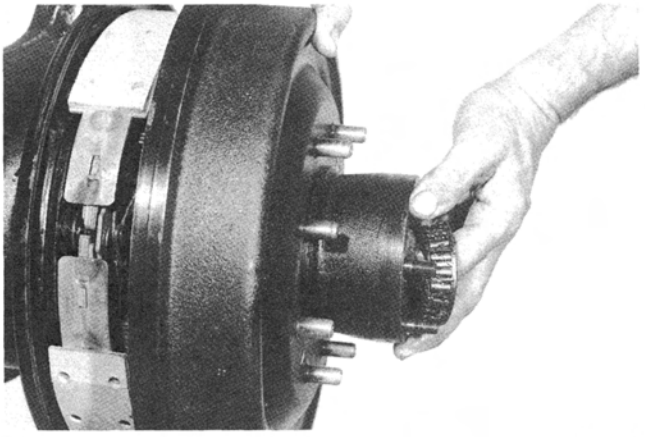


Figure 10 1019-10

Remove drum assembly. Outer wheel bearing will slide out as drum is removed.

> **NOTE**
>
> If it is necessary to replace brake components such as drums, shoes, backing plate, etc., refer to vehicle service manual.

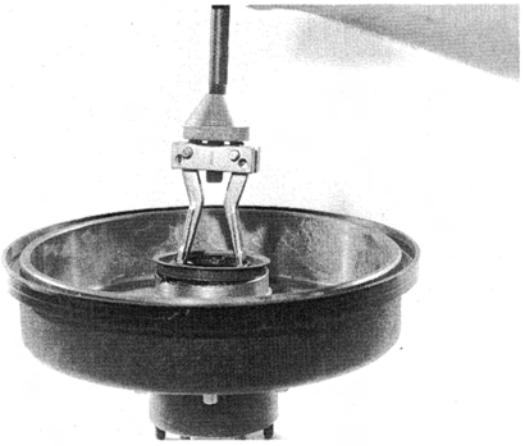


Figure 11 1019-11

Remove grease seal and inner bearing cone. Discard seal and replace with new one at time of assembly.

Tool: #D-131 Slide Hammer.

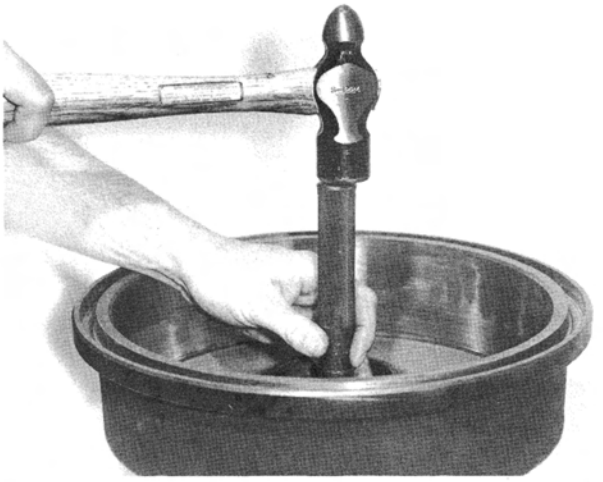


Figure 12 1019-12

Remove inner and outer wheel bearing cups.

Tools: #D-255 Cup Remover, #C-4171 Handle.

ASSEMBLY

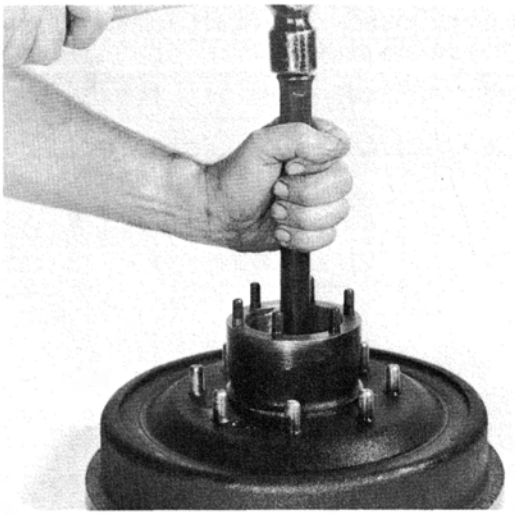


Figure 13 1019-13

Assemble outer wheel bearing cup.

Tools: #C-4023 Installer, #C-4171 Handle.



Figure 14 1019-14

Assemble inner wheel bearing cup.

Tools: #D-111 Installer, #C-4171 Handle.

Distribute a sufficient amount of grease inside the hub between the bearing cups.

Pack inner bearing cone full with the specified grease. Wipe the excess grease around the rollers. Assemble inner wheel bearing cone into cup.



Figure 15 1019-15

Assemble new grease seal. Apply a small amount of grease around lip of seal.

Tools: #D-155 Seal Installer, #C-4171 Handle.

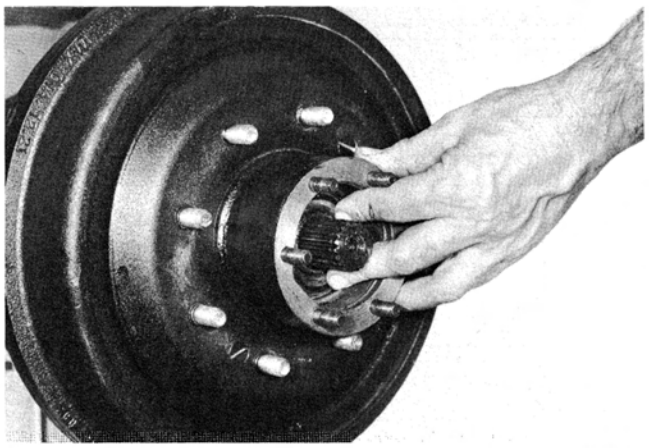


Figure 16 1019-16

Assemble hub and drum onto spindle. Pack outer wheel bearing with specified grease, wipe excess grease around the rollers. Assemble onto spindle.

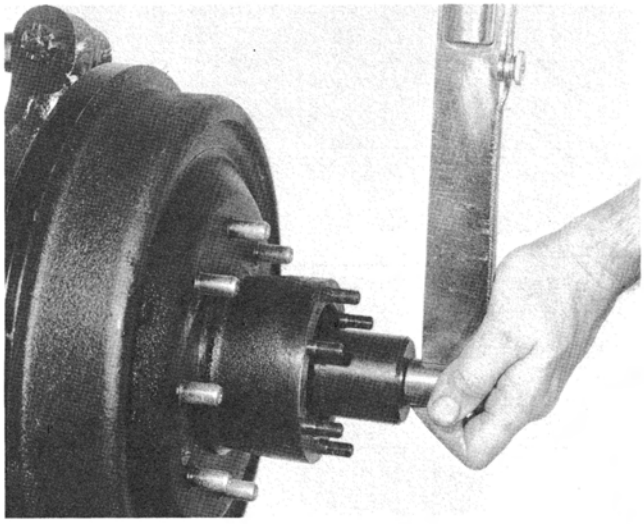


Figure 17 1019-17

To adjust wheel bearings, torque inner adjusting nut to 50 Lb. Ft. (68 N·m) to seat bearings. Rotate hub, then back off inner adjusting nut one fourth turn maximum. Assemble lock washer, turn nut to the nearest hole in washer. Assemble outer locknut and torque to 50 Lb. Ft. (68 N·m). Final bearings adjustment to be .001''-.010'' (.03-.25 mm) total end play.

Tools: #C-4170 Wheel Bearing Wrench, #C-524A Torque Wrench.

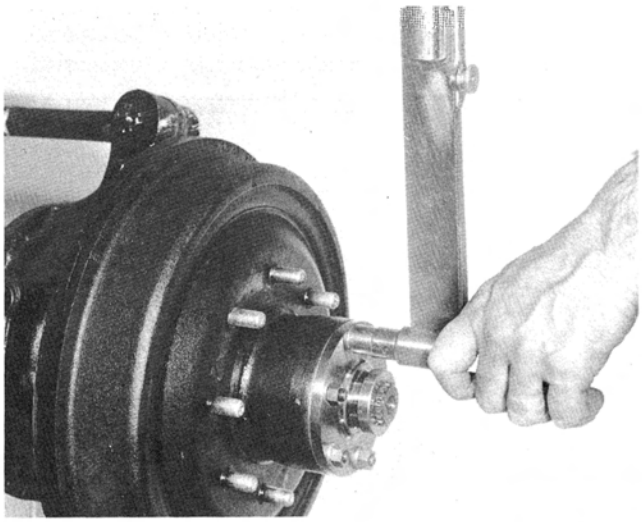


Figure 18 1019-18

Assemble new gasket, drive flange, lockwashers, and nuts. Refer to Vehicle Service Manual for proper torque specifications.

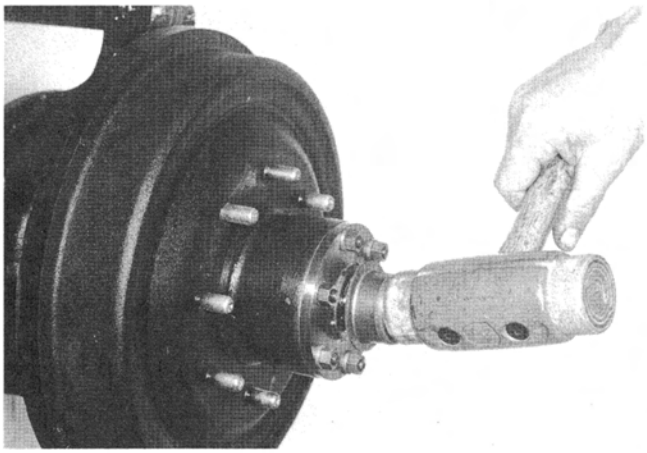


Figure 19 1019-19

Assemble snap ring and hub cap. Tap lightly with hammer to seat hub cap.

DISASSEMBLY AND REASSEMBLY OF SHAFTS, SPINDLE KNUCKLES, AND ETC., (CLOSED KNUCKLE DESIGN)

Remove wheel, hub and drum assembly as shown in Figure 6 thru 10.

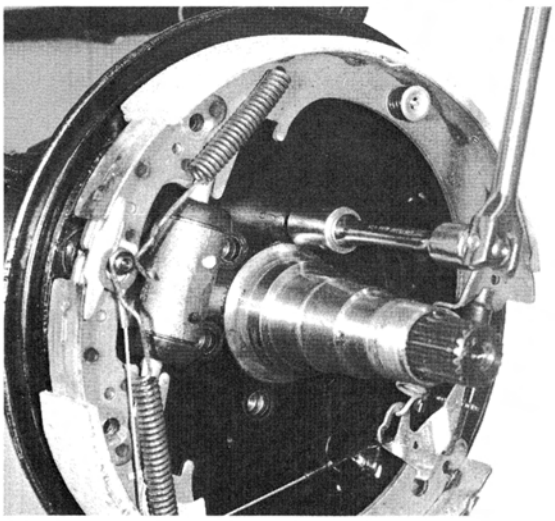


Figure 20 1019-20

Remove backing plate screws and remove backing plate.

NOTE

The brake backing plate assembly can be retained with screws or nuts. If the nuts are of the torque prevailing design, they are to be replaced with new ones.

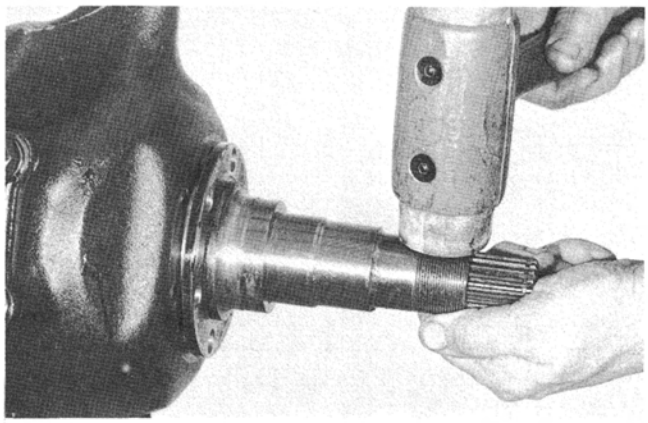


Figure 21 1019-21

Remove spindle. Tap lightly with a rawhide hammer to break the spindle loose from the knuckle.

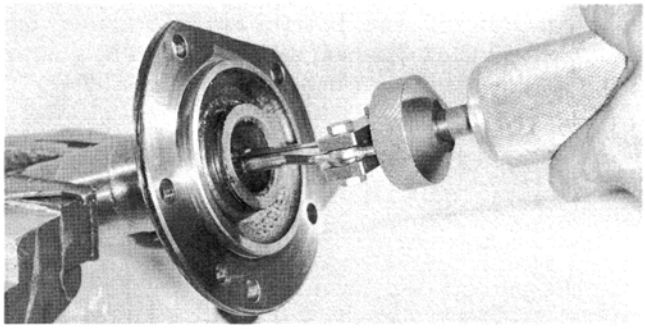


Figure 22 1019-22

Place spindle in vise, do not locate on bearing diameters.

CAUTION

Be sure that the vise jaws are equipped with brass protectors or similar type to protect the machined surfaces of any parts that are to be placed in the vise.

Remove bronze bushing with slide hammer puller.

Tool: #D-131 Slide Hammer.

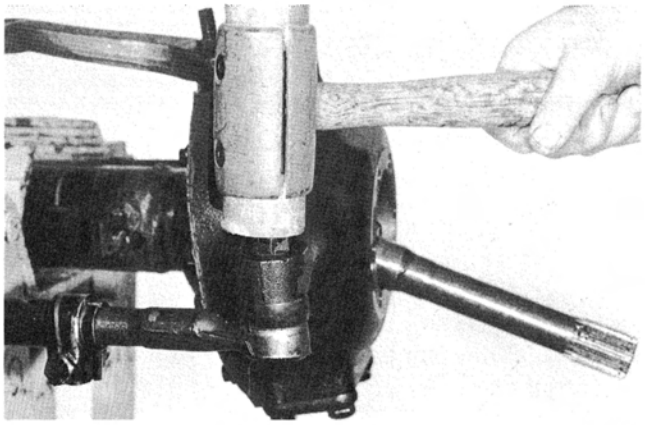


Figure 23 1019-23

Remove cotter key and loosen tie rod nut. Tap on nut with rawhide hammer to break the stud loose from the steering arm. Remove nut and disconnect tie rod.

FRONT AXLE

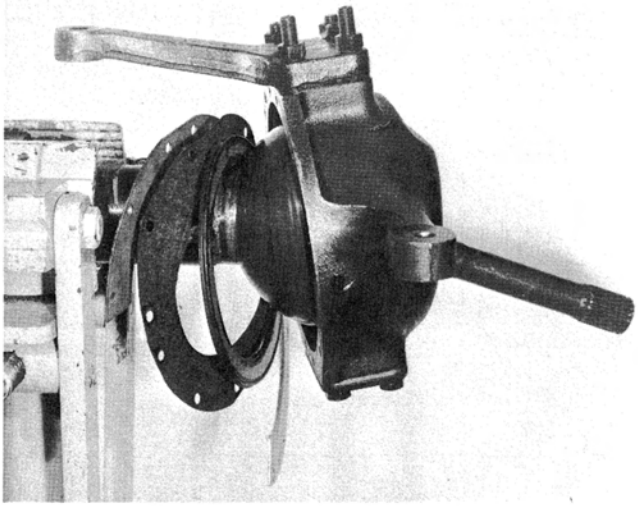


Figure 24 1019-24

Remove twelve cap screws, two retainer plates, felt seal, and oil seal. Discard retainer plates, felt seal, and oil seal. Replace with new ones at time of assembly. Cut felt seal in half to disassemble.

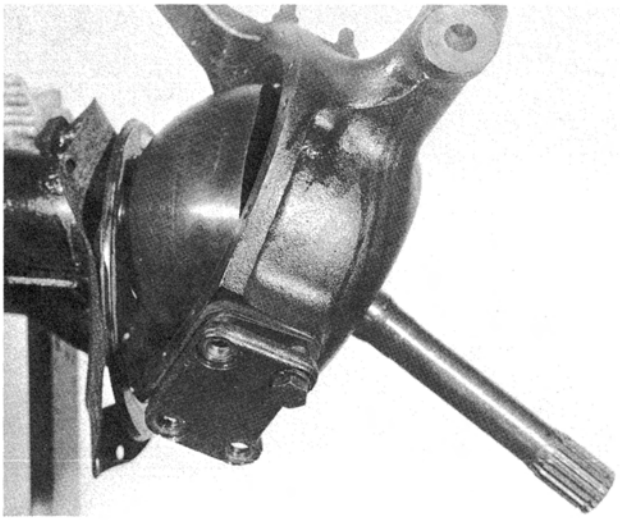


Figure 25 1019-25

Remove four cap screws from the bottom bearing cap. Use a screwdriver to loosen the bearing cap from the knuckle if necessary.

NOTE

King pin bearing preload shims are located between the bottom bearing cap and knuckle. Wire shims together as they will be used during assembly. Shims may stick to either the knuckle or bearing cap. Be sure you have them all collected.

Shims are available in thicknesses of .003'', .005'', .010'', and .030'' (mm .08, .13, .25, and .76). Remove axle shaft joint assembly.

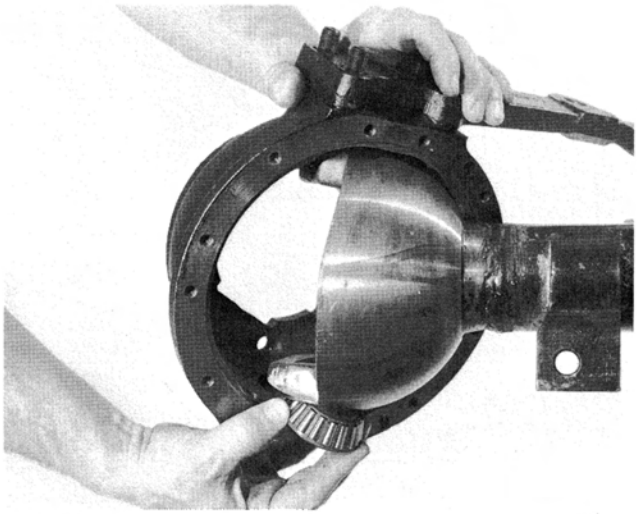


Figure 26 1019-26

Remove knuckle from ball yoke.

CAUTION

The bottom bearing cone will fall out as the knuckle is being removed. To prevent damage to the bearing, catch it with hand.

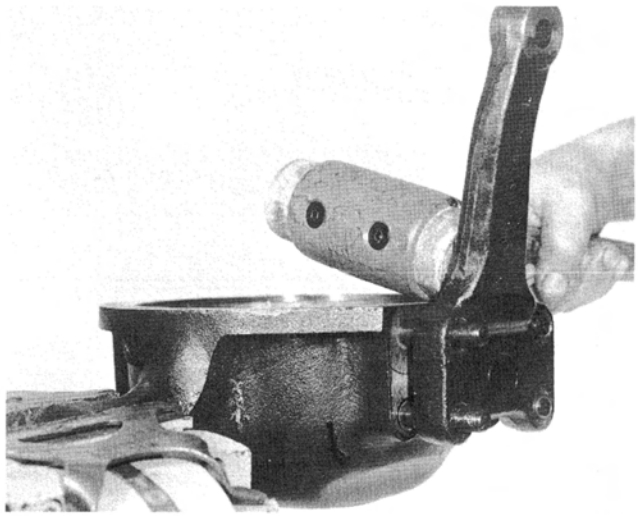
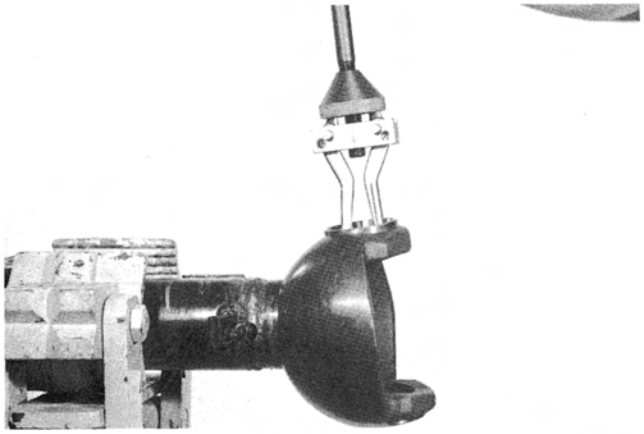


Figure 27 1019-27

Place knuckle in vise as shown. Remove steering arm. Tap lightly with a rawhide hammer to free it from the knuckle.

NOTE

Some axles are equipped with a constant shim pack between the steering arm bearing cap and knuckle. If used, this pack is to be saved and reused during assembly.

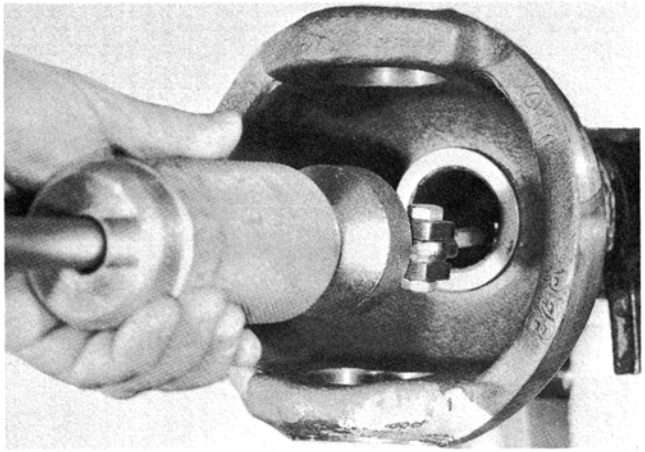


1019-28

Figure 28

Remove king pin bearing cups from spherical ball yoke, with tool as shown.

Tool: #D-131 Slide Hammer.



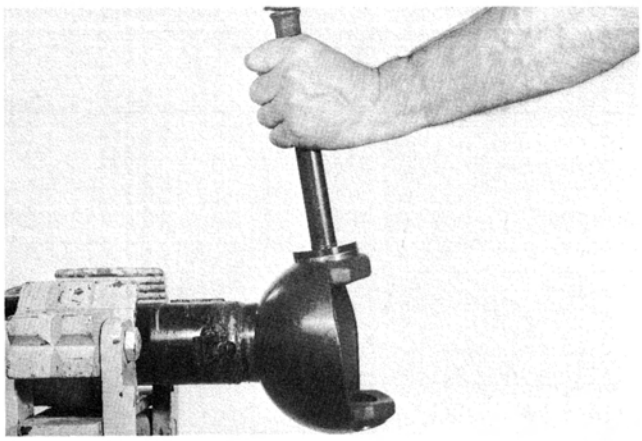
1019-29

Figure 29

Remove bronze bushing from ball yoke.

Tool: #D-131 Slide Hammer.

ASSEMBLY

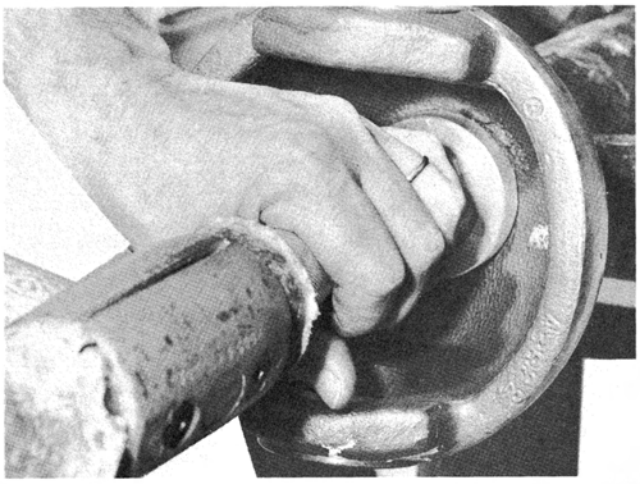


1019-30

Figure 30

Assemble new king pin bearing cups into spherical ball yoke. Use tools as shown.

Tools: #D-142 Installer, #C-4171 Handle.

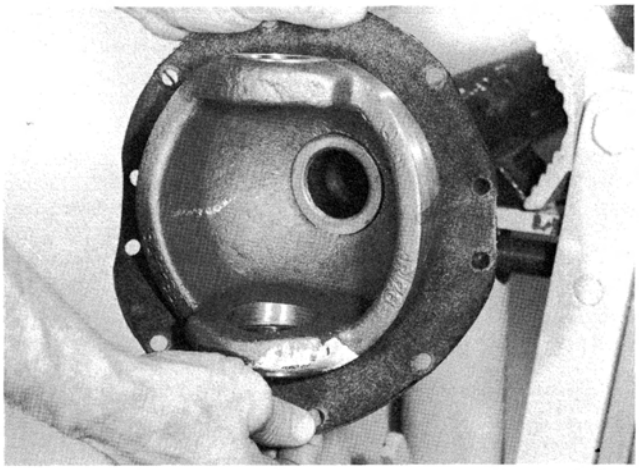


1019-31

Figure 31

Assemble new bronze bushing into ball yoke.

Tools: #D-161 Installer, #C-4171 Handle.



1019-32

Figure 32

Assemble new felt over spherical ball as shown.



1019-33

Figure 33

Assemble new oil seal with the metal part of the seal towards the end of the axle. Spread split of seal just enough to slip over the tube of the axle.

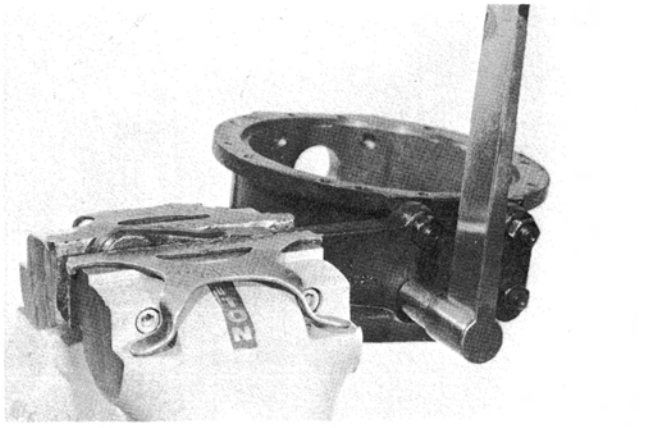


Figure 34 1019-34

Locate steering arm in vise as shown. Assemble constant shim pack to the knuckle (if used). Assemble knuckle to the steering are. Assemble the four nuts, tighten nuts alternately and evenly. Torque nuts to 70-90 Lb. Ft. (95-122 N·m).

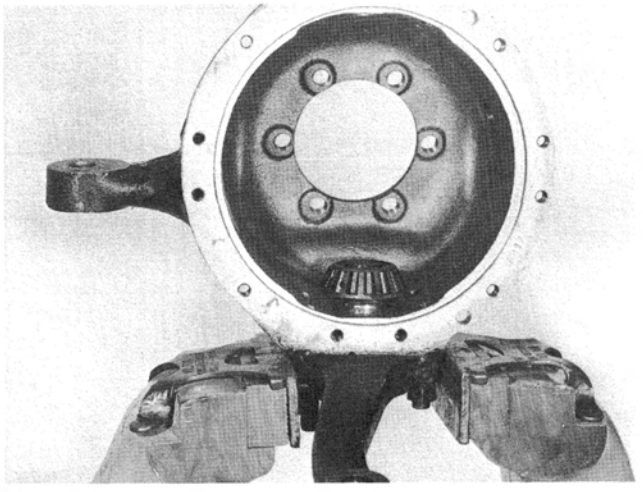


Figure 35 1019-35

Assemble new bearing cone to king pin, grease bearing with specified grease.

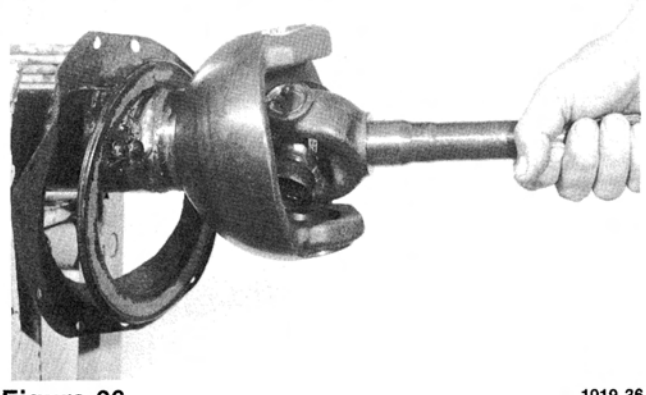


Figure 36 1019-36

Assemble axle shaft joint assembly into housing.

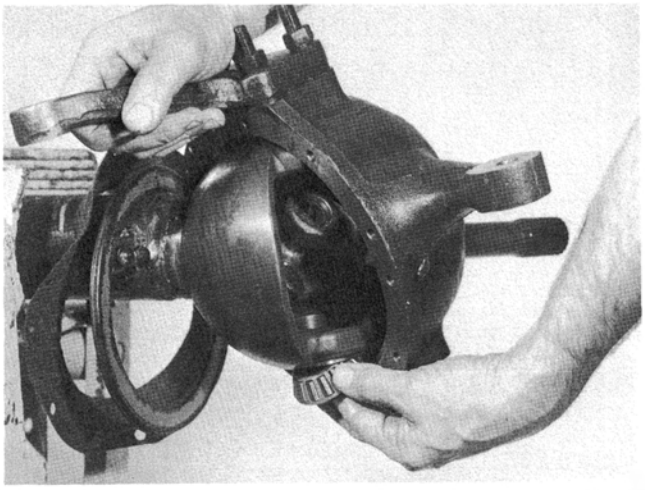


Figure 37 1019-37

Assemble knuckle to ball yoke. Hold bottom bearing (new) as shown to prevent it from falling out.

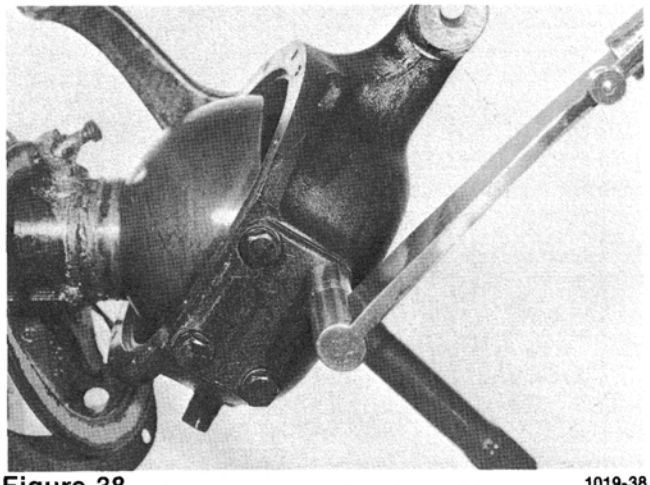


Figure 38 1019-38

Assemble bottom king pin bearing cap, with preload shims, and four cap screws. Torque screws to 70-90 Lb. Ft. (95-122 N·m).

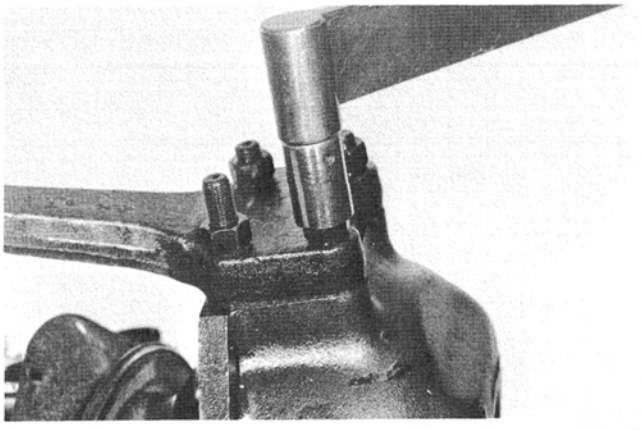


Figure 39 1019-39

Place a torque wrench on steering arm nut as shown. Torque to actuate knuckle to 9-15 Lb. Ft. (12-20 N·m). When checking torque rotation of knuckle, make sure tie rod and seals are not assembled to knuckle.

FRONT AXLE

NOTE

If preload is too tight, correct by adding shims. If preload is too loose, correct by removing shims. Preload shim pack is located on the bottom between the bearing cap and knuckle. Shims are available in thicknesses of .003'', .005'', .010'', and .030'' (mm .08, .13, .25, and .76).

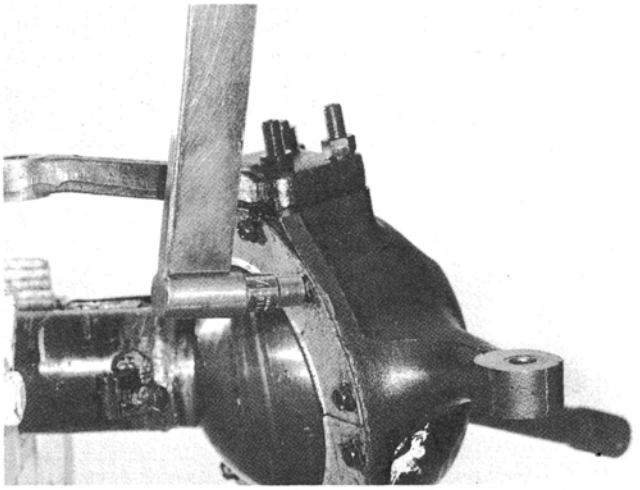


Figure 40 1019-40

Assemble new oil seal into knuckle. Be sure split of seal is to the top of the axle. Assemble new felt, two retainer plates and twelve cap screws. Torque screws to 15 Lb. Ft. (20 N·m).

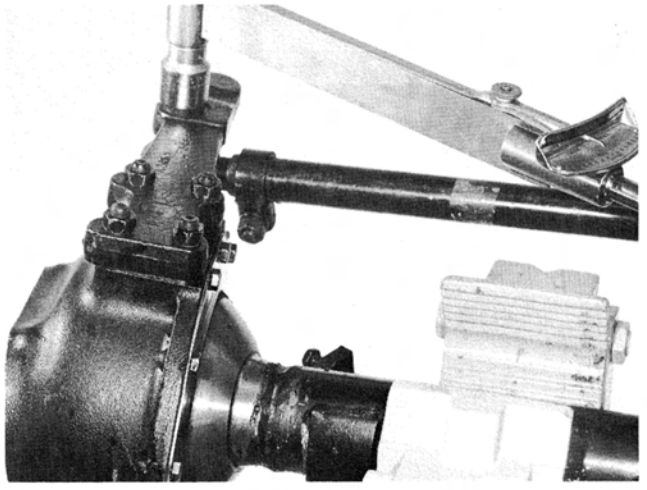


Figure 41 1019-41

Assemble tie rod to steering arm for specified torque on tie rod nut, refer to Vehicle Service Manual. Assemble cotter key.

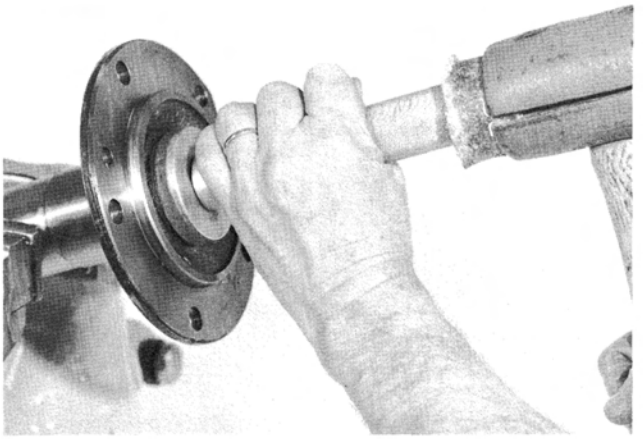


Figure 42 1019-42

Position spindle in vise as shown and assemble new bushing. Grease inside of bushing with specified grease.

Tools: #D-141 Installer, #C-4171 Handle.

Assemble spindle to knuckle.

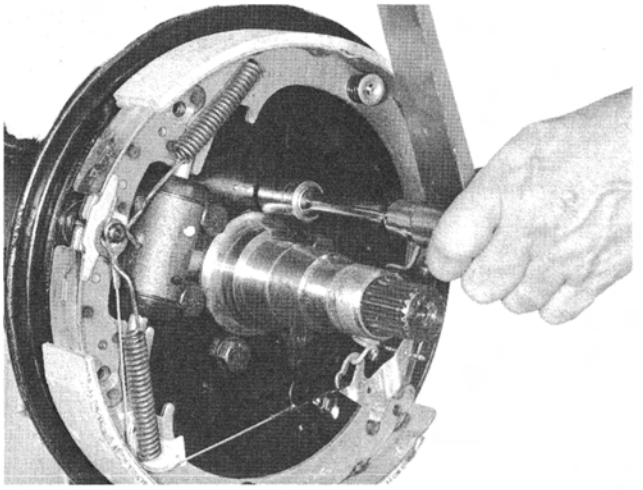


Figure 43 1019-43

Assemble brake backing plate assembly. Refer to Vehicle Service Manual for specified screw torque.

Remove inspection plug from knuckle and fill level to the plug hole with specified lubricant. Assemble inspection plug.

NOTE

To set toe-in refer to Vehicle Service Manual. Adjustments can be made by loosening clamps on the tie rod. After proper adjustments are made, retighten tie rod clamps.

FRONT AXLE

40° STEER SPRING LOADED

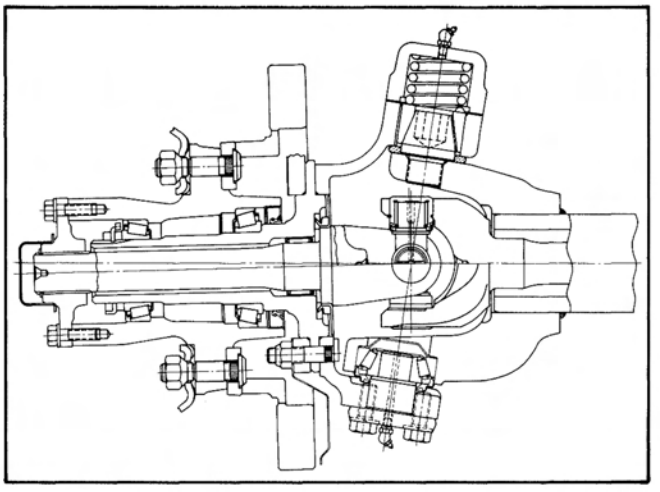


Figure 44 L/D 1019-44

DISASSEMBLY OF WHEEL ENDS - HUB AND ROTOR

NOTE

If it is necessary to replace brake components such as disc brake pads, backing plate, etc., refer to Vehilce Service Manual.

Remove Wheel from Hub and Rotor Assembly.

Follow the vehicle manufacturers recommendations for the removal of the hub-lok assembly, if used.

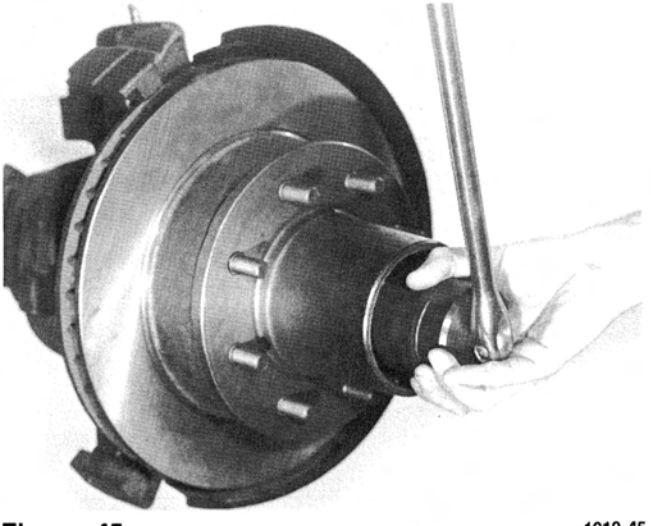


Figure 45 1019-45

Remove wheel bearing lock nut, lock ring and the wheel bearing adjusting nut.

Tool: #D-165A Wheel Bearing Wrench.



Figure 46 1019-46

Remove hub and rotor assembly, spring retainer and outer wheel bearing will slide out as rotor is removed.

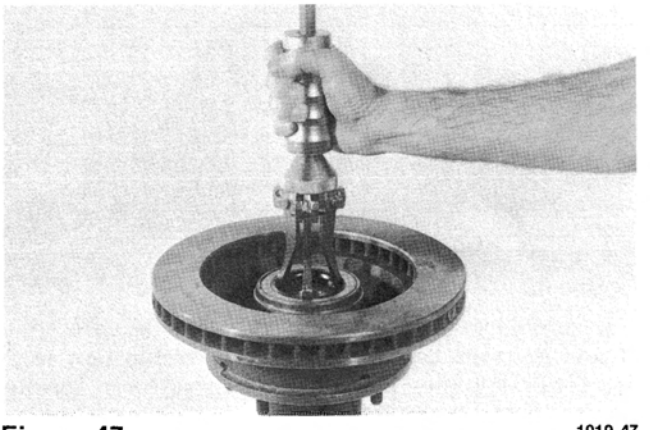


Figure 47 1019-47

Remove grease seal and inner bearing cone. Discard seal and replace with new one at time of assembly.

Tool: #D-131 Slide Hammer.



Figure 48 1019-48

Remove inner and outer wheel bearing cups.

Tools: #D-255 Bearing Cup Remover (outer). #D-257 Bearing Cup Remover (inner).

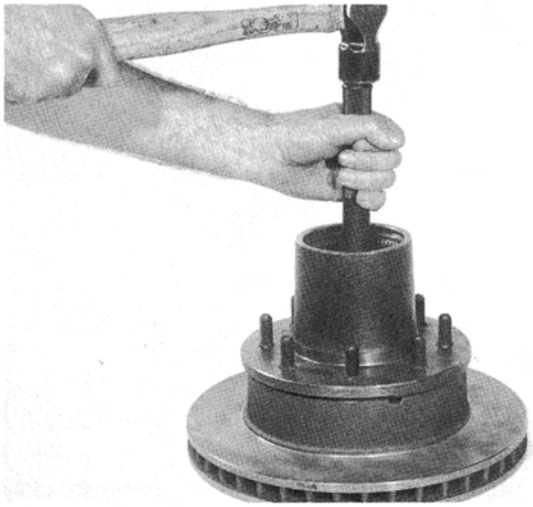


Figure 49 1019-49

Assemble outer wheel bearing cup.

Tools: #D-254 Installer, #C-4171 Handle.

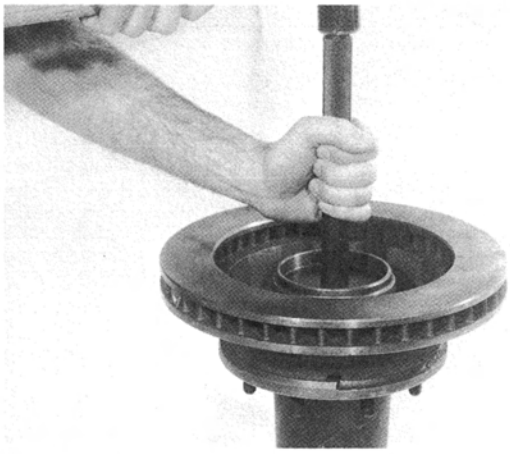


Figure 50 1019-50

Assemble inner wheel bearing cup.

Tools: #D-256 Installer, #C-4171 Handle.

Distribute a sufficient amount of grease inside the hub between the bearing cups. Pack inner bearing cone full with the specified grease. Wipe the excess grease around the rollers. Assemble inner wheel bearing cone into cup.

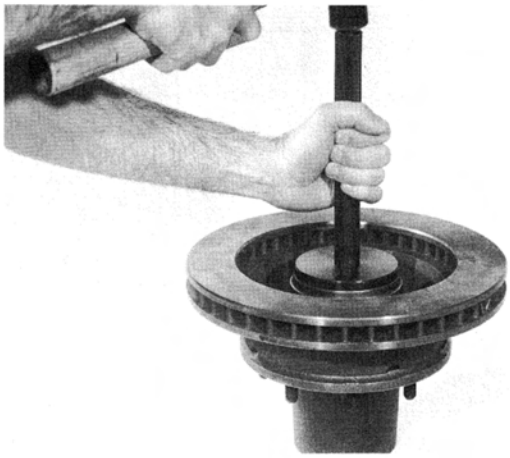


Figure 51 1019-51

Assemble new grease seal. Apply a small amount of grease around lip of seal.

Tools: #D-253 Seal Installer, #C-4171 Handle.

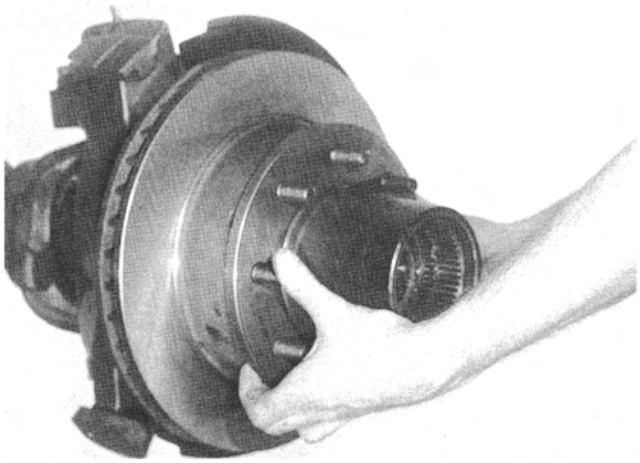


Figure 52 1019-52

Assemble hub and rotor onto spindle. Pack outer wheel bearing with specified grease, wipe excess grease around the rollers. Assemble onto spindle.

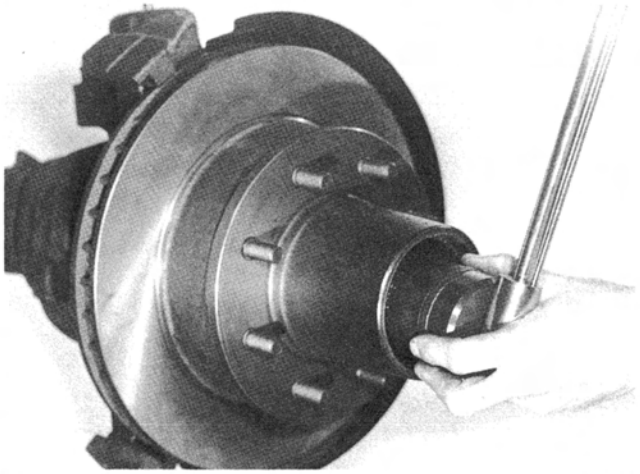


Figure 53 1019-53

To adjust wheel bearings, torque inner adjusting nut to 50 Lb. Ft. (68 N·m) to seat bearings. Rotate hub, then back off inner adjusting nut one-fourth turn maximum. Assemble lock washer, turn nut to nearest hole in washer. Assemble outer locknut and torque to 50 Lb. Ft. (68 N·m). Final bearings adjustment to be .001-.010 (.03-.25 mm) total end play.

Tools: #D-165A Wheel Bearing Wrench, #C-512A Torque Wrench.

NOTE

For servicing spindle and knuckle, remove hub and drum as described in figures 45 through 47.

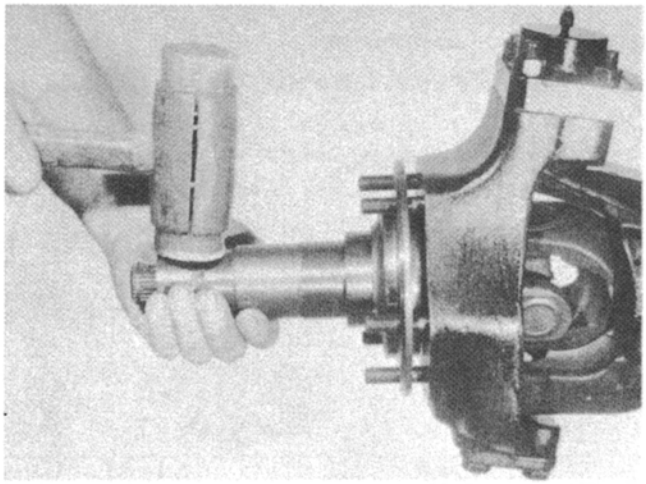


Figure 54 1019-54

Remove spindle. If necessary, tap lightly with a rawhide hammer to free it from the knuckle. Check bronze spacer located between axle shaft joint assembly and bearing. If wear is evident, replace with a new one.

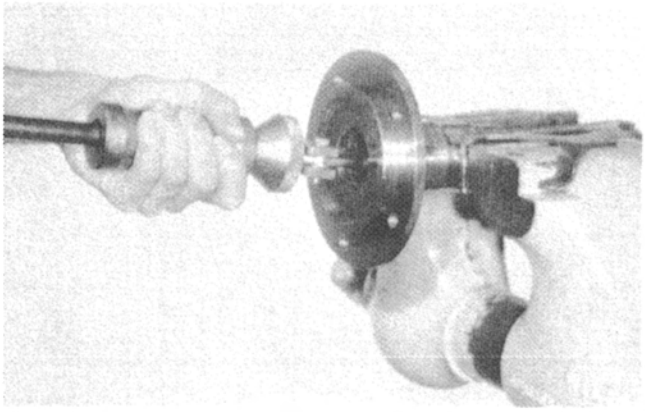


Figure 55 1019-55

Place spindle in vise. Do not locate on bearing diameters. Remove needle bearing.

Tool: #D-131 Slide Hammer.

CAUTION

Be sure that vise jaws are equipped with brass protectors or similar type to protect the machined surfaces of any parts that are to be placed in the vise.

Remove axle shaft joint assembly. Remove tie rod. Refer to Figure 23.

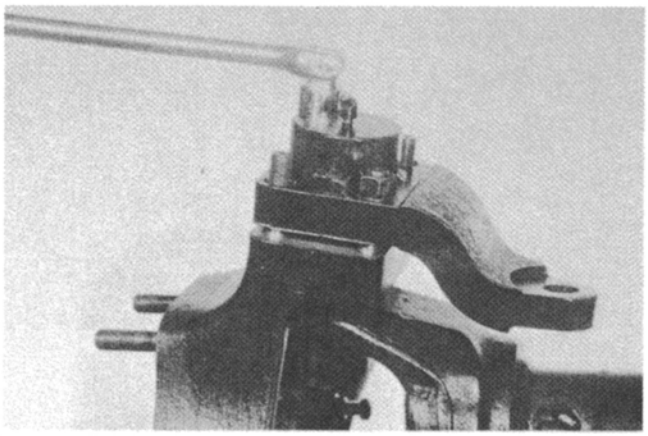


Figure 56 1019-56

Remove four nuts on steering arm. Remove nuts alternately as compression spring will force steering arm up.

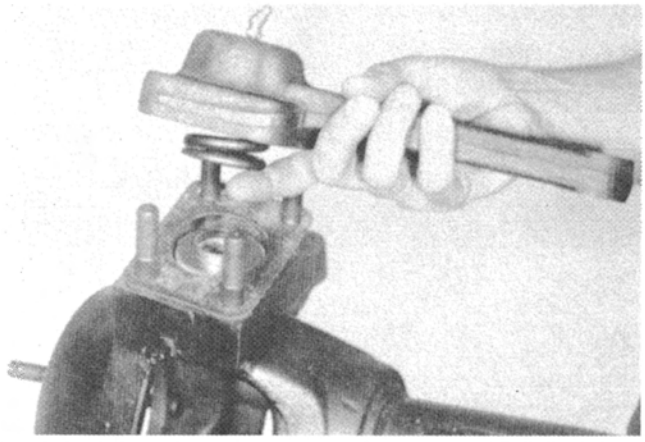


Figure 57 1019-57

Remove steering arm, compression spring, and gasket. Discard gasket, replace with new one at time of assembly.

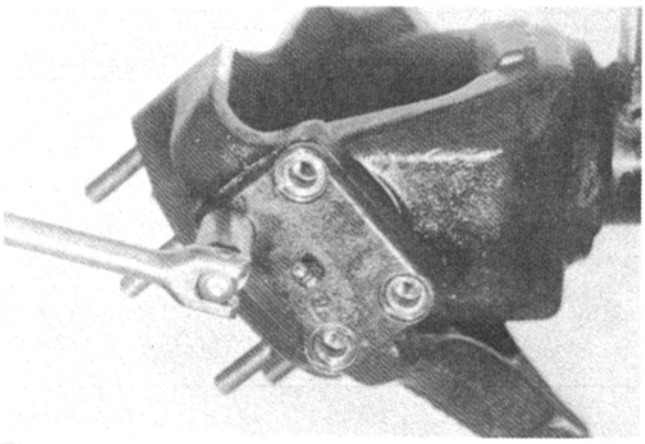


Figure 58 1019-58

Remove four cap screws on bearing cap. Remove bearing cap.

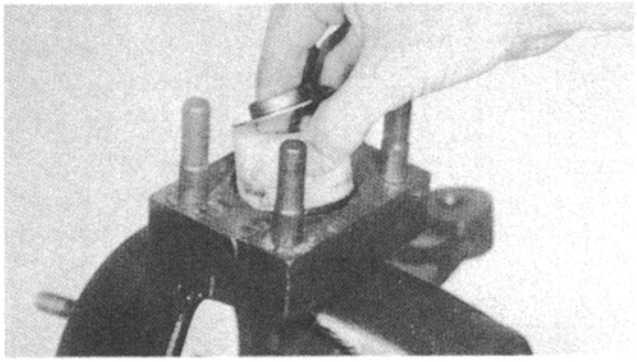


Figure 59 1019-59

Remove king pin tapered bushing, spring retainer, and knuckle from yoke. Remove king pin seal.

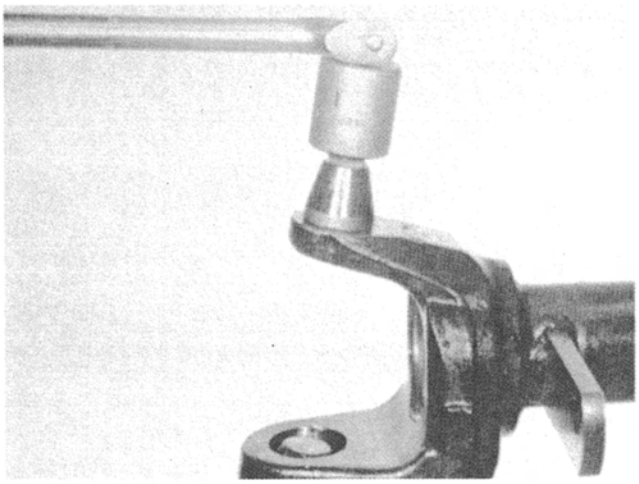


Figure 60 1019-60

Remove king pin as shown.

Tool: #D-192 King Pin Installer and Remover.

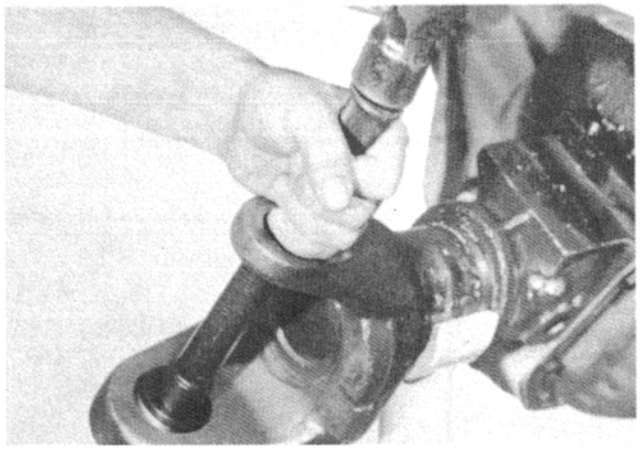


Figure 61 1019-61

Remove king pin bearing cup, cone, grease retainer, and seal all at the same time. Assemble and use tools exactly as shown in Figure 62. Discard seal and replace with new one at time of assembly. If grease retainer is damaged, replace with new one at time of assembly.

Tools: #D-141 Installer, #C-4171 Handle.

ASSEMBLY

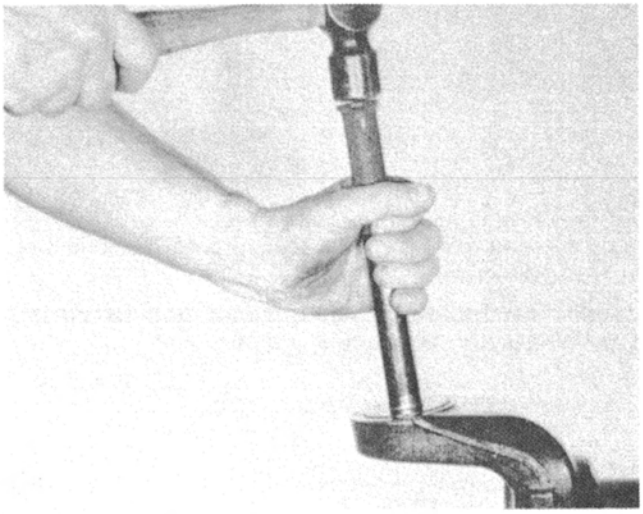


Figure 62 1019-62

Assemble new grease retainer and king pin bearing cup.

Tools: #D-142 Installer, #C-4171 Handle.

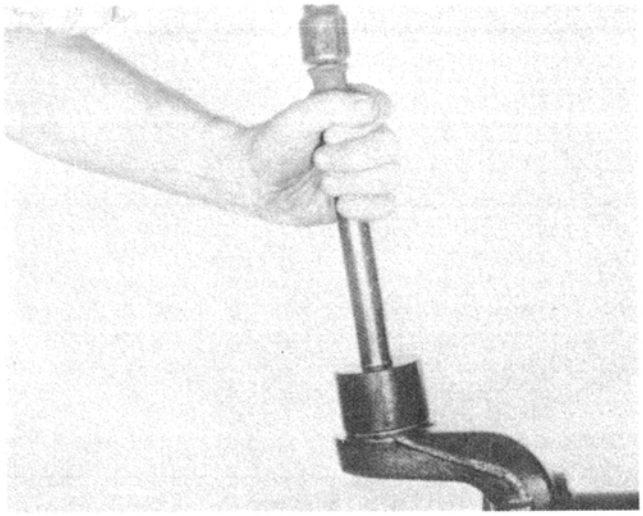


Figure 63 1019-63

Fill the area in grease retainer with specified grease, grease bearing cone and install. Install new king pin bearing oil seal.

Tools: #D- 194 Installer, #C-4171 Handle.

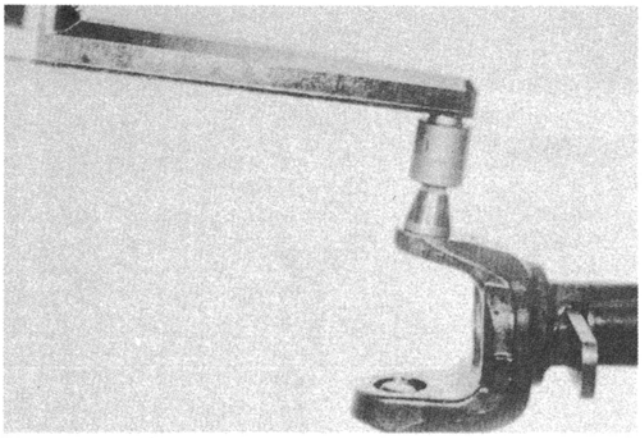


Figure 64 1019-64

Install king pin. Torque king pin to 500-600 Lb. Ft. (678-813 N·m).

Tools: #D-192 King Pin Installer and Remover, #DD-994 Torque Wrench.

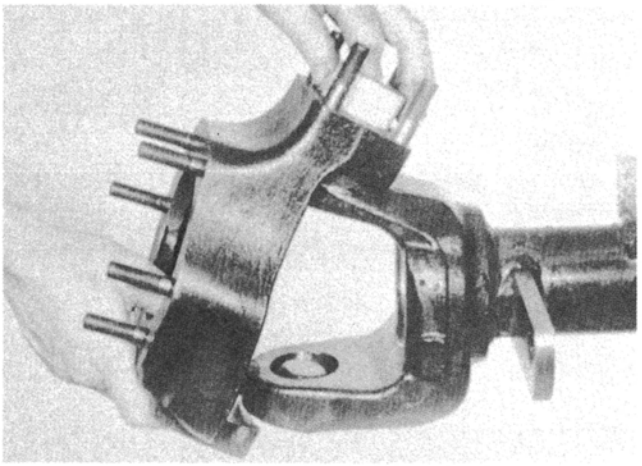


Figure 65 1019-65

Assemble felt seal to king pin, assemble knuckle assemble tapered bushing over king pin.

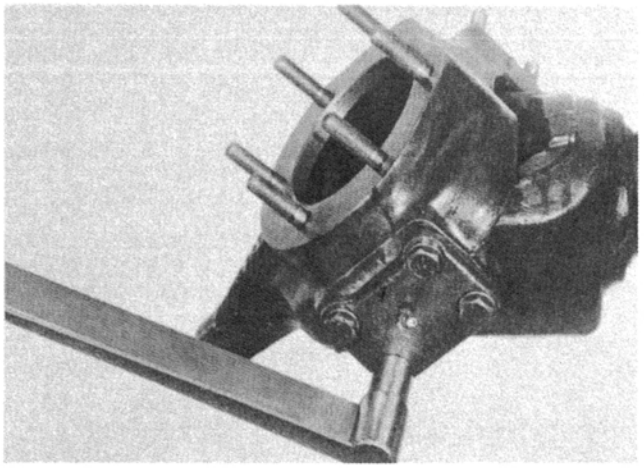


Figure 66 1019-66

Assemble bearing cap with four cap screws. Tighten cap screws alternately and evenly. Torque cap screws to 70-90 Lb. Ft. (95-122 N·m).

Tool: #C-524-A Torque Wrench.

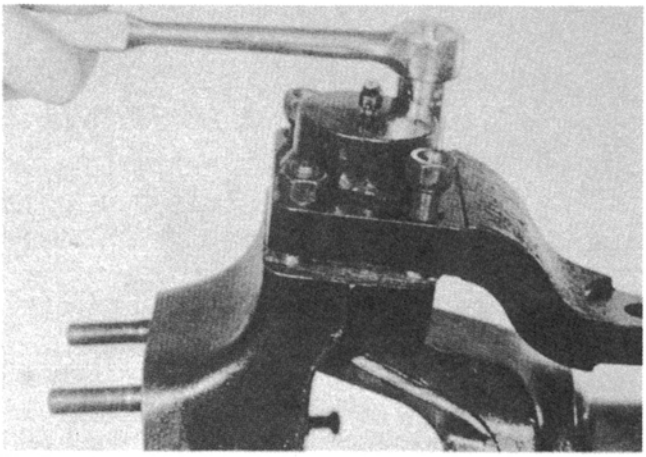


Figure 67 1019-67

Assemble spring retainer and compression spring on king pin bushing. Assemble steering arm, with new gasket, over four studs. Tighten nuts alternately and evenly. Torque nuts 70-90 Lb. Ft. (95-122 N·m).

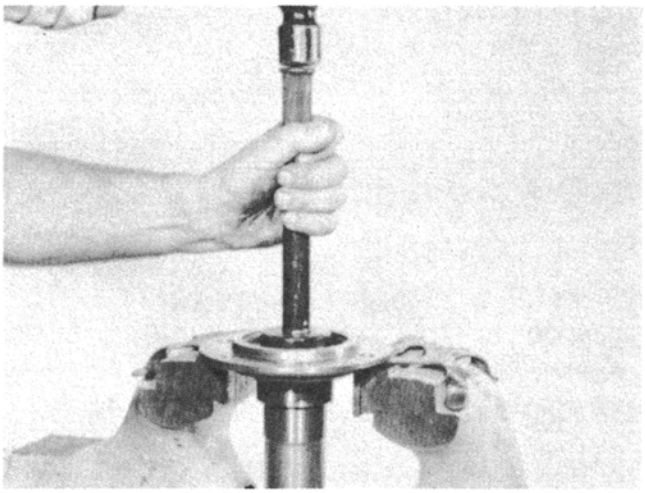


Figure 68 1019-68

Assemble new needle bearing into spindle.

Tools: #D-258 Installer, #C-4171 Handle.

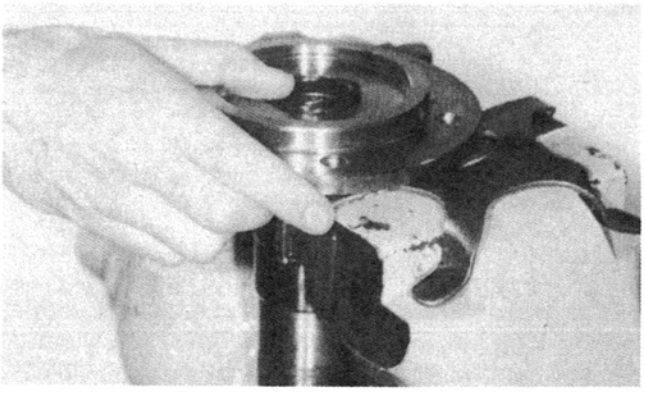


Figure 69 1019-69

Assemble grease seal into spindle. The lip of the seal is to be directed away from the spindle.

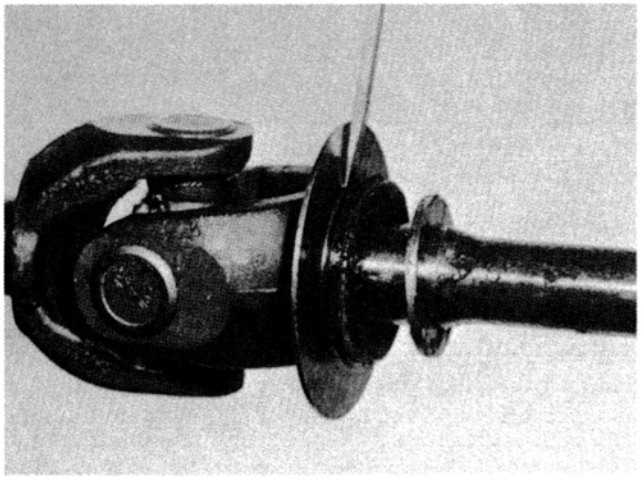


Figure 70 1019-70

Some front axles are equipped with a "V" seal, which is assembled to the axle shaft stone shield as shown. If seal is worn, remove and replace with a new one.



Figure 71 1019-71

Assemble new seal as shown. Lip of the seal is to be directed towards the spindle.

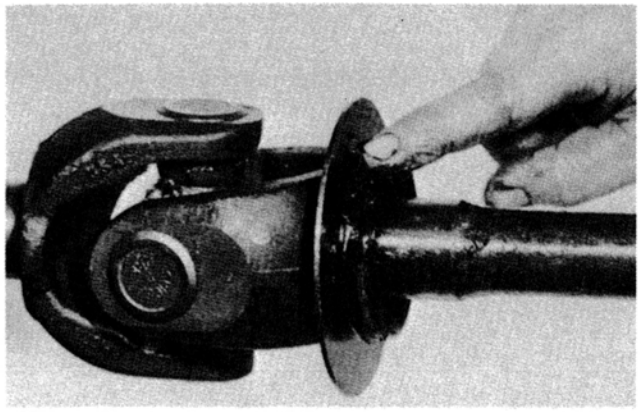


Figure 72 1019-72

Pack the area around the thrust face area of the shaft and seal full of grease. Also, fill the seal area of the spindle with grease.

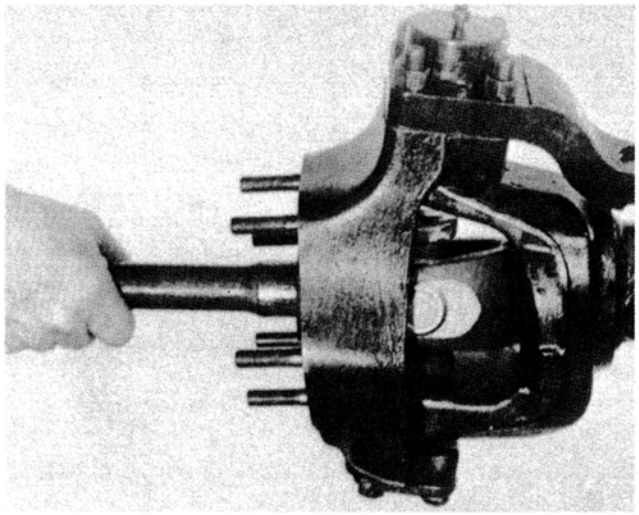


Figure 73 1019-73

Assemble axle shaft joint assembly into housing.

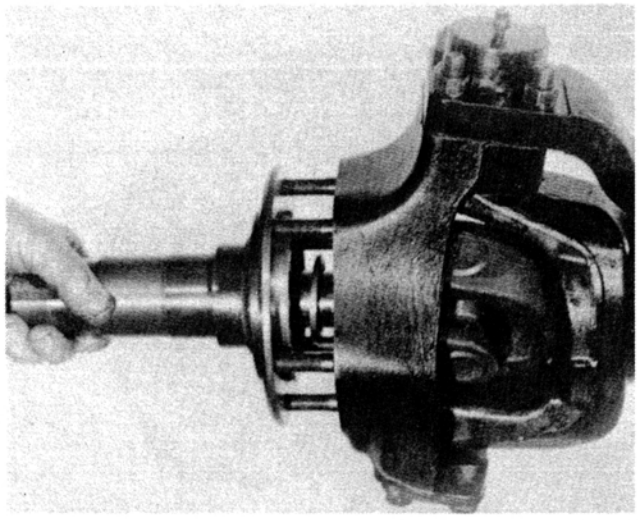


Figure 74 1019-74

Assemble new bronze spacer and spindle.

REAR AXLE

Unit wheel bearing design lubricated with hypoid lubricant.

NOTE

Unit wheel bearings that are dependent on lubrication from the hypoid gear lube in the axle housing, rather than grease, are not equipped with an inner axle shaft oil seal as shown in figure 75.

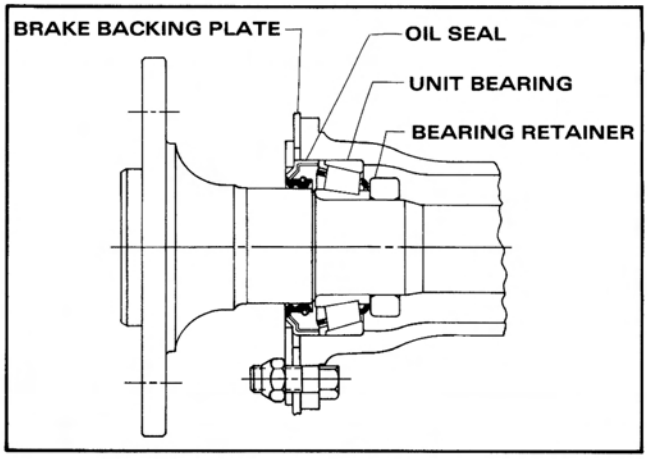


Figure 75 1019-75

Unit wheel bearing L/D without inner grease seal.

DISASSEMBLY

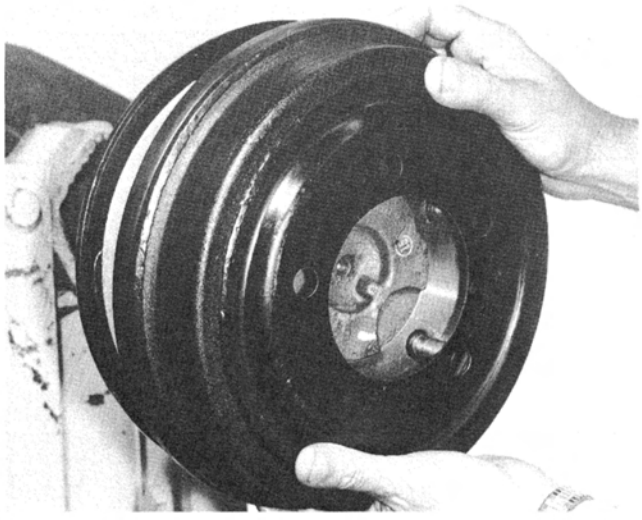


Figure 76 1019-76

After wheel is removed, remove brake drum.

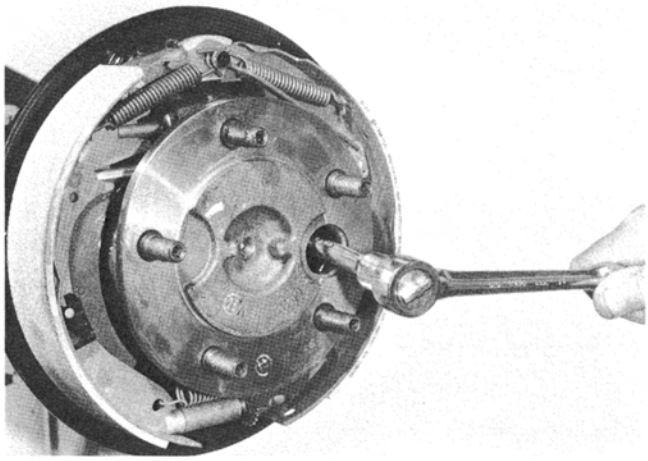


Figure 77 1019-77

Remove backing plate nuts which hold the brake backing plate to the axle housing. Discard nuts, replace with new ones at time of assembly. Nuts of torque prevailing design are not to be reused.

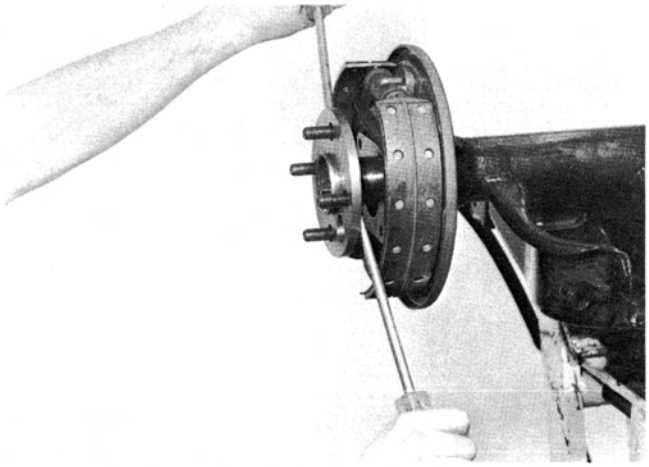


Figure 78 1019-78

Remove the axle shaft by pulling on the axle. It may be necessary to free the axle shaft by prying it loose with two screwdrivers or pry bars as shown.

NOTE

Backing plate can normally be wired to the frame, without loosening the hydraulic brake line connection at the wheel cylinder, if desired. Use caution to avoid damage to brake line.

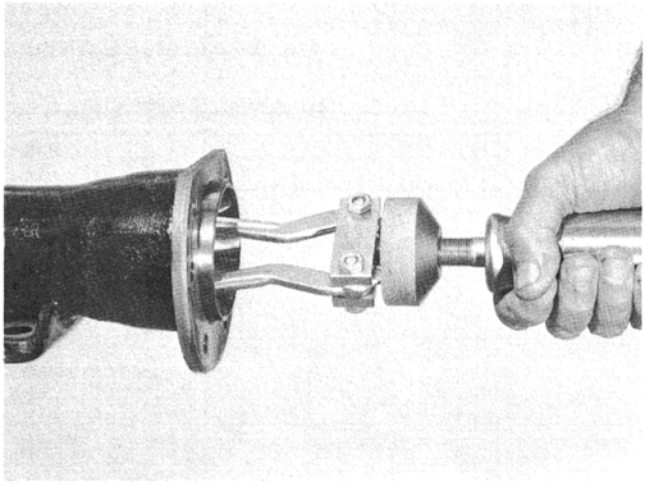


Figure 79 1019-79

The bearing cup will normally stay in place with the housing. To remove bearing cup, use puller as shown.

Tool: #D-131 Slide Hammer.

Cleaning, inspecting, and relubricating wheel unit bearing.

Clean bearing cup with any of the standard metal cleaning solvents. Inspect cup for any possible wear, nicks, etc.

The cone assembly can be cleaned in place on the axle shaft. Use any standard metal cleaning solvent and a stiff bristle brush to remove any dirt or any other contamination that might be present, then use compressed air. Air should be directed at the cone assembly so that it goes through the bearing from one end of the rollers to the other. It is important not to "Spin Dry" the bearing with compressed air. Spinning the dry bearing may score the raceways and rollers due to lack of lubricant.

Use a standard metal cleaning solvent to clean out the bearing bore in the housing. Wipe this area clean making sure it is free from dirt or any other contanination that might be present.

After the bearing has been inspected and approved for continued service, it must be lubricated prior to installation. The bearing must be lubricated by applying a small amount of the specified lube around the rollers of the bearing cone.

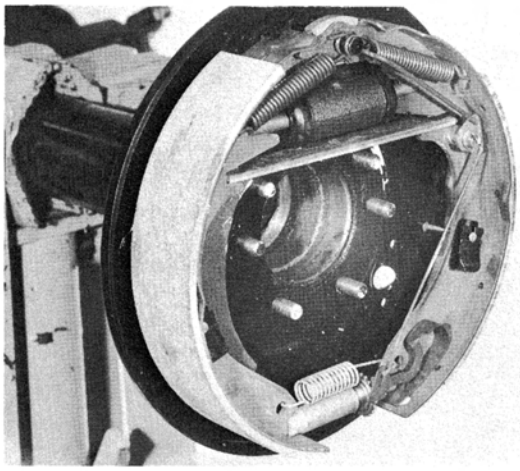


Figure 80 1019-80

Assemble backing plate bolts and backing plate assembly.

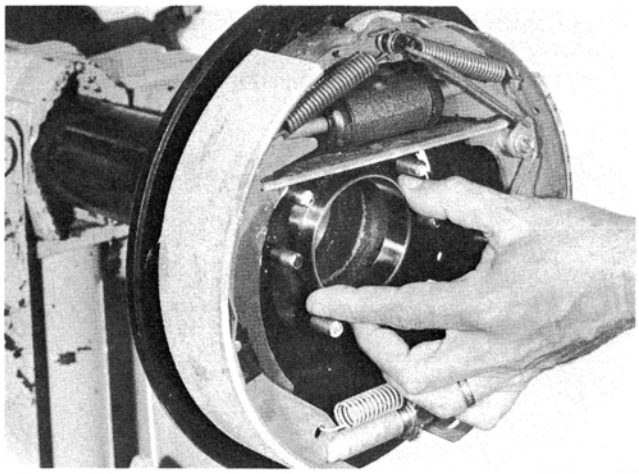


Figure 81 1019-81

Assemble bearing cup into bearing bore of the tube. Make sure the cup backface is against the bearing seat of the tube.

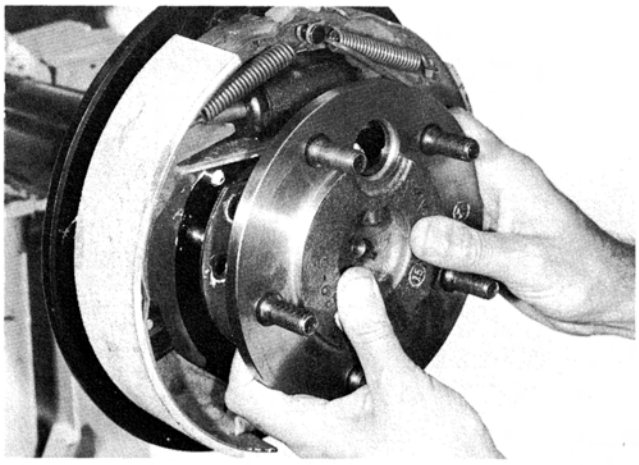


Figure 82 1019-82

Assemble axle shaft into housing. Care should be taken not to damage the bearing rollers.

Line up the holes of the retainer plate with the bolts, push axle shaft into the housing as far as possible.

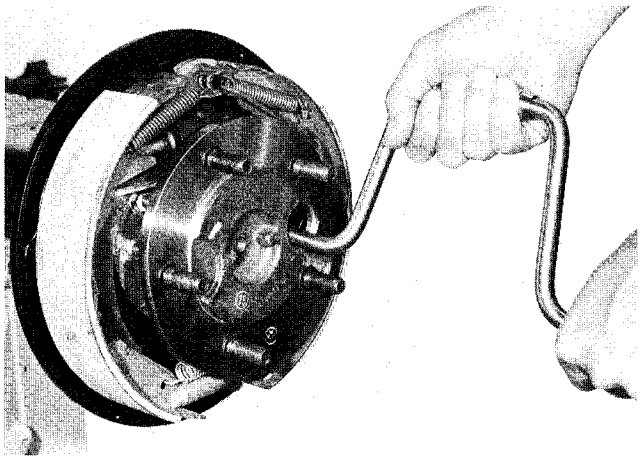


Figure 83 1019-83

Start nuts on backing plate bolts by hand. Use a speed wrench as shown and tighten to approximately 15 Lb. Ft. (20 N·m).

The units should be tightened in a manner that assures that the seal and cup rib ring are drawn evenly against the cup in the housing.

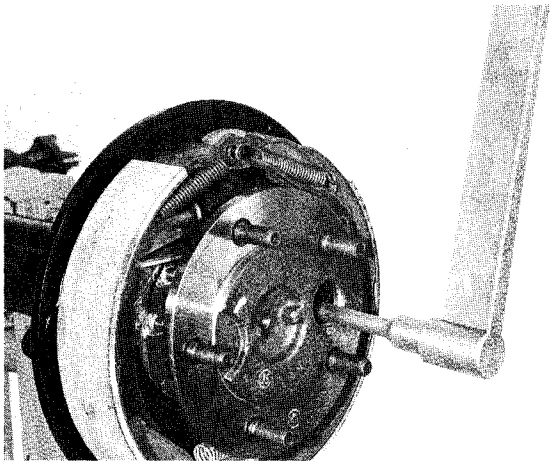


Figure 84 1019-84

Using a torque wrench as shown, torque nuts to 25-35 Lb. Ft. (34-47 N·m). Assemble brake drums, retainer nuts, wheels, etc.

Tool: #524-A Torque Wrench.

UNIT WHEEL BEARING DESIGN LUBRICATED WITH GREASE

NOTE

Unit wheel bearing that are dependent on grease for lubrication, rather than hypoid gear lube from the axle housing, are equipped with an inner axle shaft oil seal as shown in figure 85.

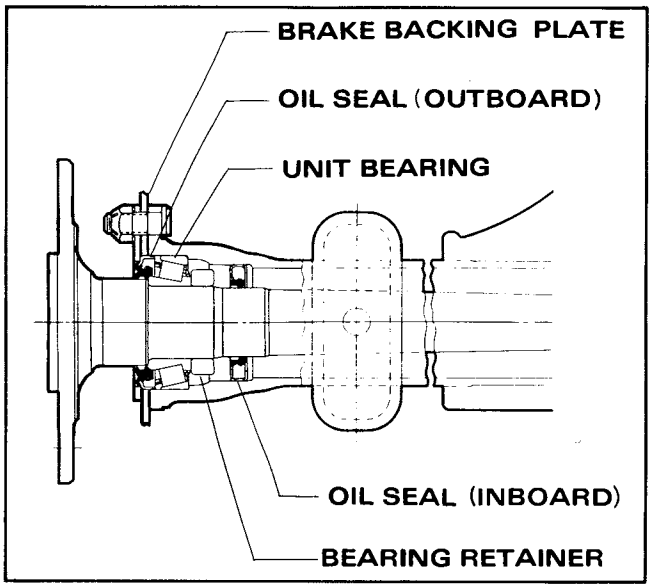


Figure 85 L/D 1019-85

Unit wheel bearing L/D with grease seal.

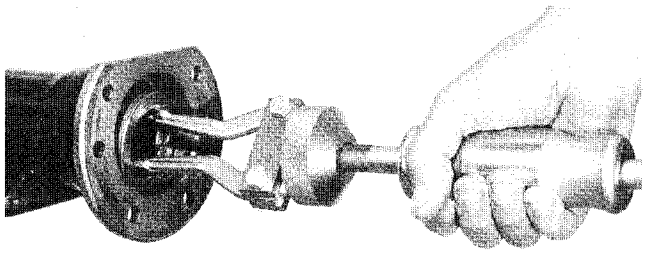


Figure 86 1019-86

Remove inner axle shaft seal using puller as shown.

Tool: #D-131 Slide Hammer.

Discard seal and replace with new one at time of assembly.

NOTE

Avoid contacting seals with cleaning solvent in cleaning operation.

CLEANING, INSPECTING, AND RELUBRICATING UNIT BEARINGS

Clean bearing cup with any of the standard metal cleaning solvents. Inspect cup for any possible wear, nicks, etc.

The cone assembly can be cleaned in place on the shaft. Use a standard metal cleaning solvent and a stiff bristle brush to loosen the old grease. To ensure removal of the old grease and any contamination that might be present, use compressed air. Air should be directed at the cone assembly so that it goes through the bearing from one end of the rollers to the other. It is important not to "Spin

Dry'' the bearing with compressed air. Spinning the dry bearing may score the raceways and rollers due to the lack of lubricant.

Use a standard metal cleaning solvent to clean out the bearing and oil seal bore in the housing. Wipe this area clean, making sure it is free from any old grease or other contamination that might be present.

After the bearing has been inspected and approved for continued service, it must be lubricated prior to installation.

The grease should be a good quality number 2 E.P. (Extreme Pressure) lithium soap, wheel bearing grease.

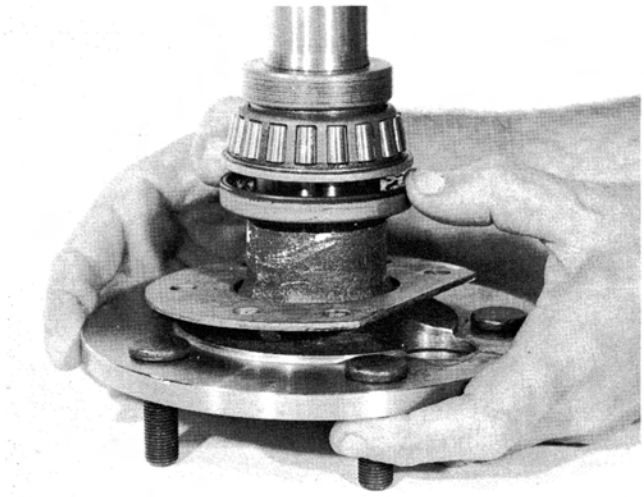


Figure 87 1019-87

Push seal and retainer away from the bearing to allow a cavity between the seal and bearing.

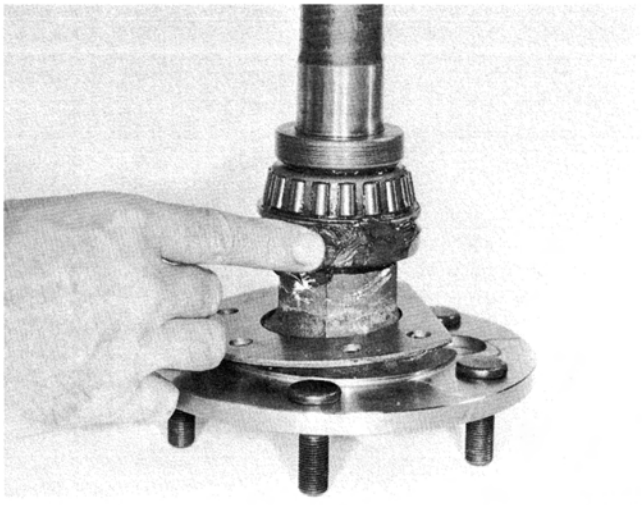


Figure 88 1019-88

Fill the area or cavity between the seal and bearing with the recommended grease.

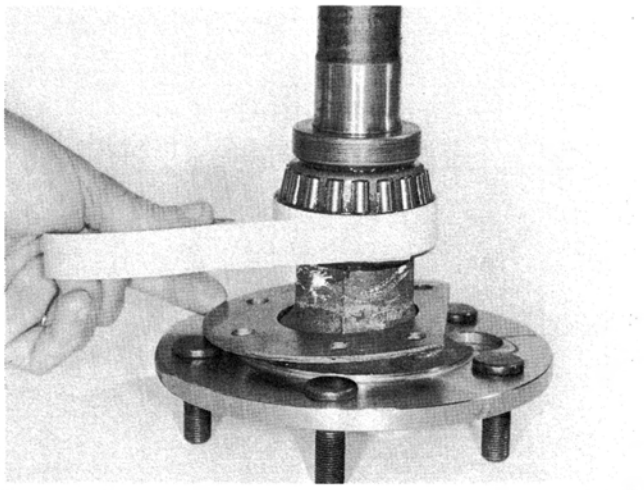


Figure 89 1019-89

After the cavity is full of grease, wrap tape completely around the rib ring and seal as shown to enclose the cavity.

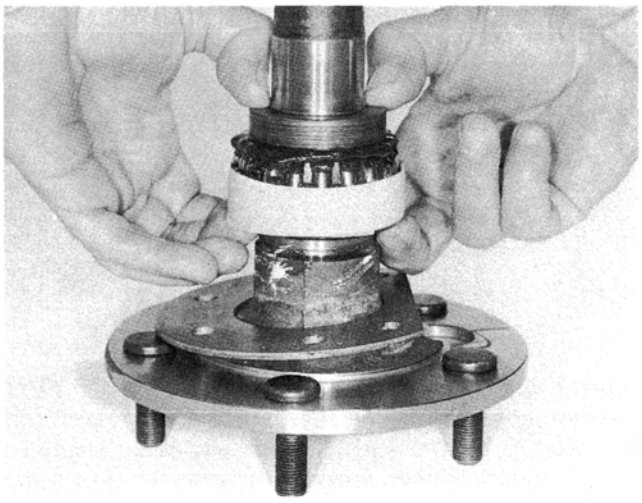


Figure 90 1019-90

With tape still wrapped around the ring, push seal up until it contacts the rib ring. This will force the grease up through the rollers.

NOTE

If grease is not apparent on small end of rollers, repeat these steps until grease appears.

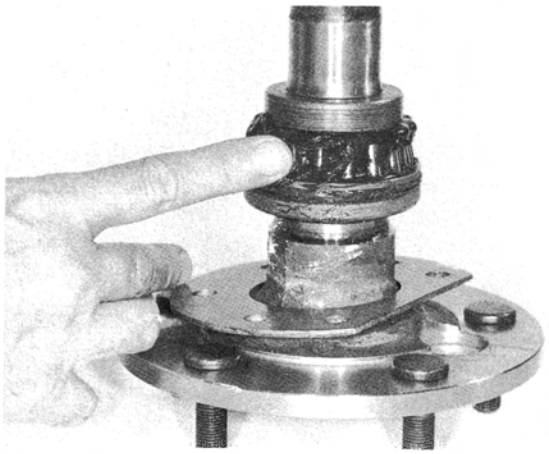


Figure 91 1019-91

Remove tape and wipe excess grease on roller bodies.

ASSEMBLY

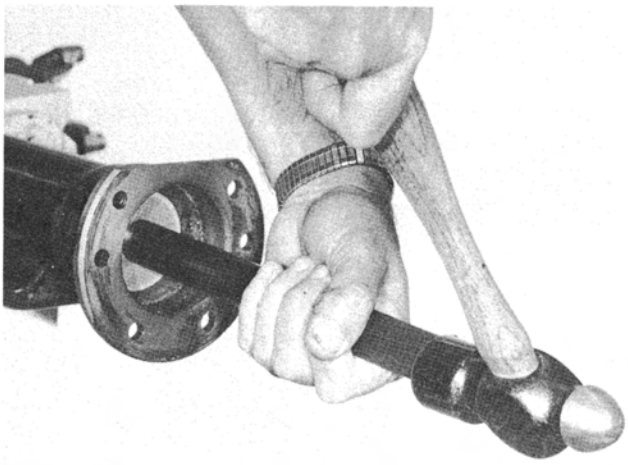


Figure 92 1019-92

Assemble new grease seal into housing.
Tools: #C-4026A Seal Installer, #C-4171 Handle.
After seal has been assembled, grease lip of seal.

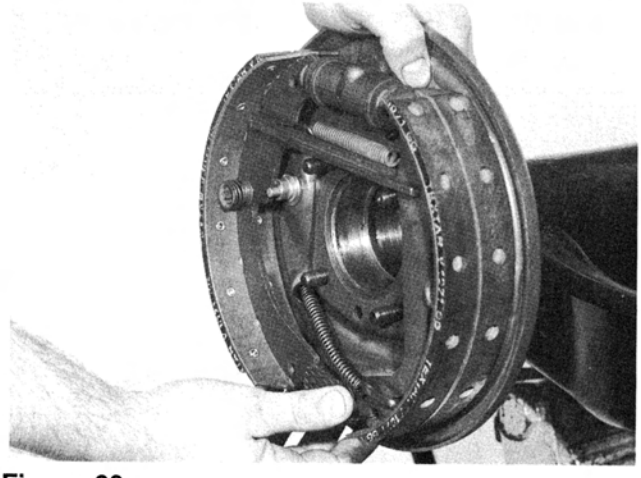


Figure 93 1019-93

Assemble backing plate bolts and backing plate assembly.

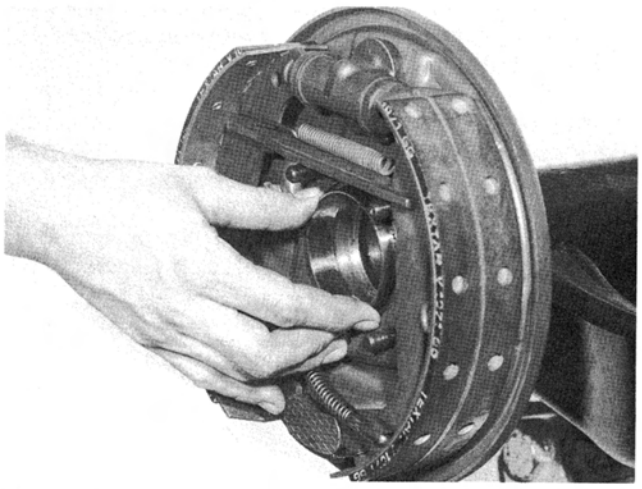


Figure 94 1019-94

Assemble bearing cup into bearing bore of the tube. Make sure the cup backface is against the bearing seat of the tube.

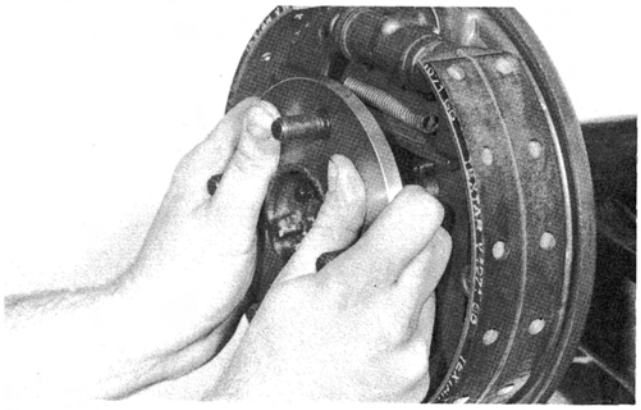


Figure 95 1019-95

Assemble axle shaft into housing. Care should be taken not to damage the seal lip and bearing rollers.

Line up the holes of the retainer plate with the bolts; push axle shaft into the housing as far as possible.

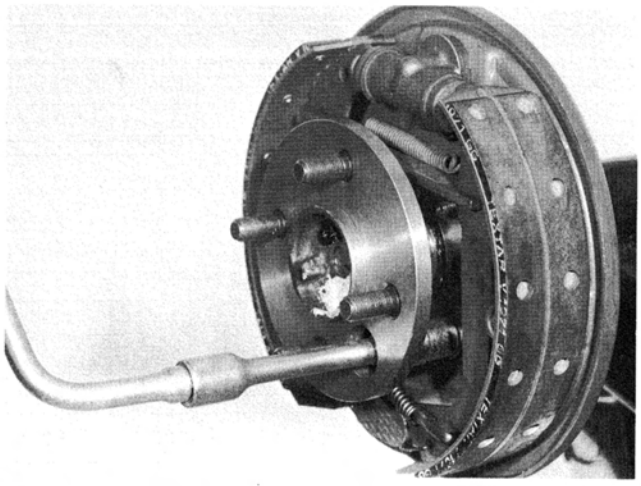


Figure 96 1019-96

Start nuts on backing plate by hand. Use a speed wrench as shown and tighten to snug fit.

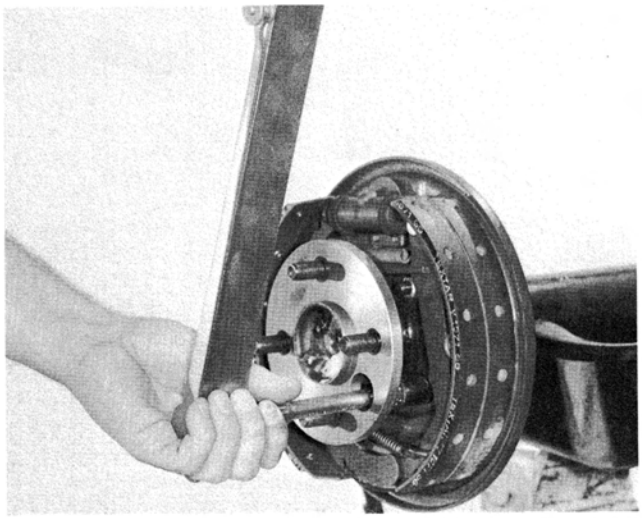


Figure 97 1019-97

Use a torque wrench and torque nuts to 25-35 Lb. Ft. (34-47 N·m).

REMOVAL OF UNIT BEARING FROM AXLE SHAFT

NOTE

To disassemble axle shaft from housing, follow the precedures illustrated in figures 75 thru 79.

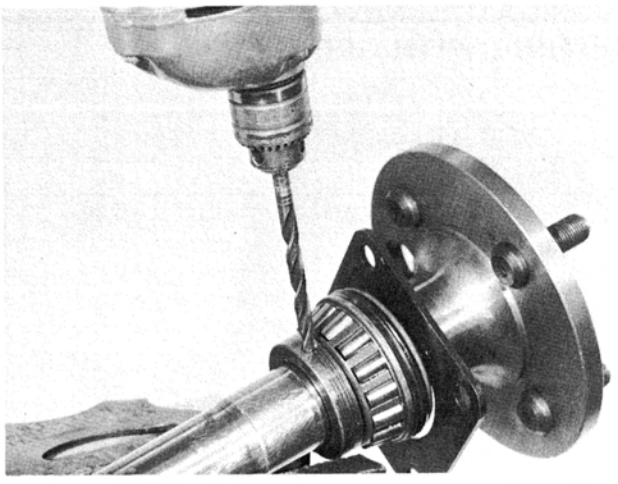


Figure 98 1019-98

Place axle shaft in a vise. Drill a 1/4'' (6.35 mm) hole in the outside of the retainer ring to a depth approximatley three fourths the tickness of the ring. Do not drill all the way through the ring; the drill could damage the axle shaft.

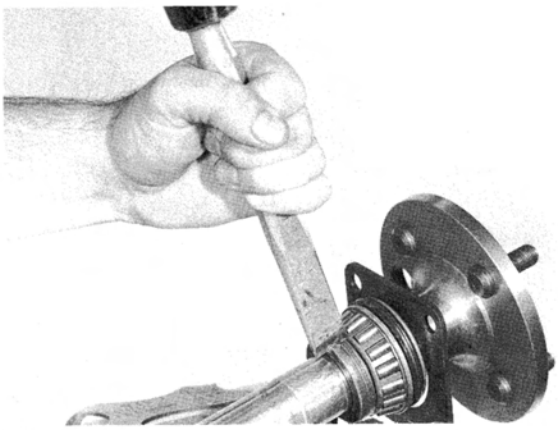


Figure 99 1019-99

After drilling the ring, use a chisel positioned across the hole and strike sharply to break the ring. Discard and replace with a new one at time of assembly.

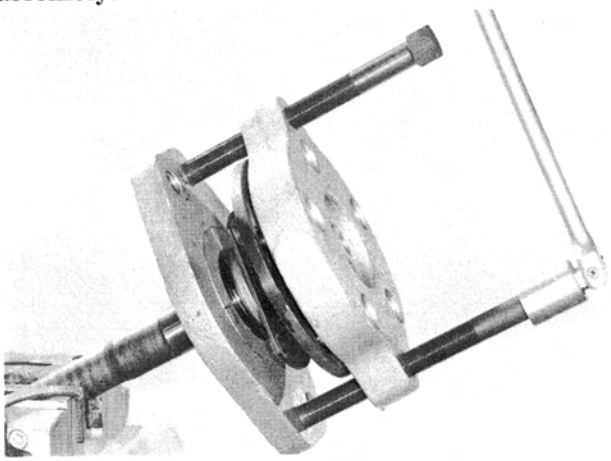


Figure 100 1019-100

Push retainer plate and seal towards flange of axle shaft. Install the flange plate to the flange of the axle shaft. Install bolts into flange plate. Slide forcing plate over the axle shaft. Install the adapters so they seat under the cup rib ring.

Gradually tighten the bolts until they are located in the dimples on the backside of the forcing plate.

Tools: #SP-5443-A Flange Plate, #SP-5017 Adapter Ring, #SP-5542-D Adapters, #SP-5026 Bolts.

Tighten bolts of tool alternately until bearing cone is removed from axle shaft. Be careful not to mark the machined surfaces of the axle shaft.

CAUTION

Do not heat or cut the bearing cone assembly with a torch to remove. Damage to the axle shaft will result.
Remove seal and retainer plate. Discard seal. Replace with new one at time of assembly.
Inspect retainer plate for possible distortion. If any portion of the retainer plate is damaged, it should be replaced. Inspect machined surfaces of the axle shaft, such as the seal and bearing diameters. Clean axle shaft, remove all nicks or burrs.

INSTALLATION OF NEW UNIT BEARING

NOTE

The retainer ring area of the shaft is 1.7727'' (45.01 mm) minimum in diameter, and the retainer ring inside diameter is 1.7675'' (44.88 mm) maximum, and therefore, should require some 6000 lb. (26688N) minimum press to seat the ring against the unit bearing.

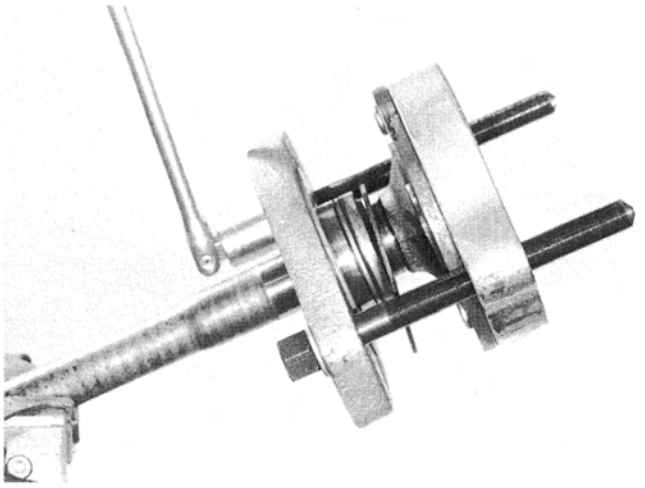


Figure 101 1019-101

Flange plate should still be assembled to the flange of the axle shaft. Remove bolts from flange plate. Assemble new retainer plate and oil seal.

The rubber portion of the oil seal, which extends beyond the casing has numbers bonded in the rubber. These numbers are to face toward the flange of the axle shaft.

Assemble new unit wheel bearing on axle shaft. Slide installing ring on axle shaft. Be sure to locate unit wheel bearing on the inside of the installing ring. Slide forcing plate on axle shaft and locate on installing ring. Install bolts and washer through the holes in the forcing plate and into flange plate.

Tools: #SP-5543-A Flange Plate, #SP-5017 Adapter Ring, #SP-5440 Adapter Plate Installer, #SP-5026 Bolts, #SP-3020 Washers.

Tighten bolts alternately and evenly, making sure bearing is not cocked on axle shaft. Continue until wheel bearing is seated. To make sure bearing is seated use a .0015'' (.0381 mm) feeler gage between bearing seat and bearing. If gage enters, force bearing further on the axle shaft, until gage does not enter.

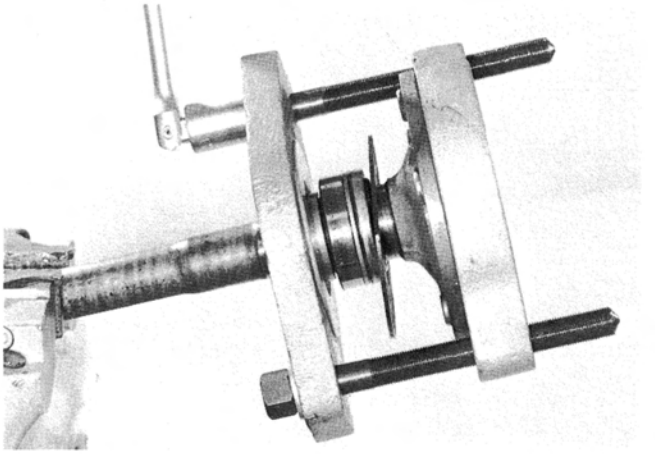


Figure 102 1019-102

Install retainer ring on axle shaft. Follow the same procedures in figure 101 to assemble the retainer ring.

Use a .0015'' (.0381 mm) feeler gage between the bearing and retainer ring to be sure that the retainer ring is seated. At least one point should exist, where the gage will not enter between the retainer ring and bearing. If gage enters completely around the diameter, retainer ring must be forced onto the axle shaft.

To assemble axle shaft assembly into housing, follow steps as illustrated in figure 82 through 84.

LUBRICATING NEW UNIT BEARING WITH GREASE

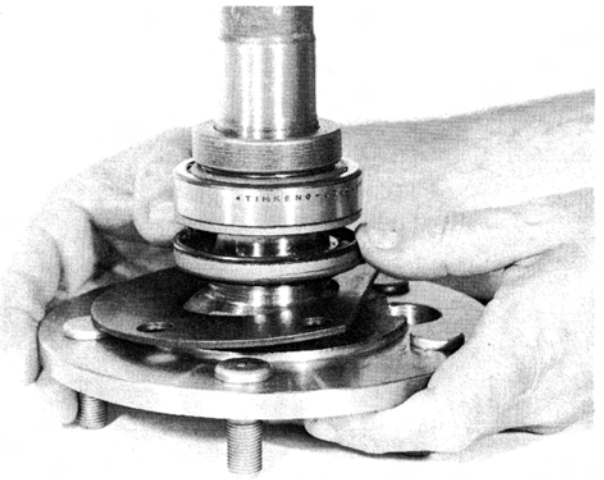


Figure 103 1019-103

Push seal and retainer away from bearing to allow a cavity between the seal and bearing.

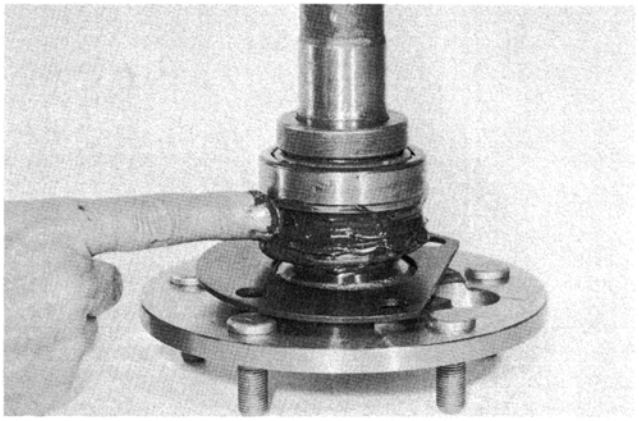


Figure 104 1019-104

Fill cavity with a good quality #2 E.P. (Extreme Pressure) lithium soap, wheel bearing grease.

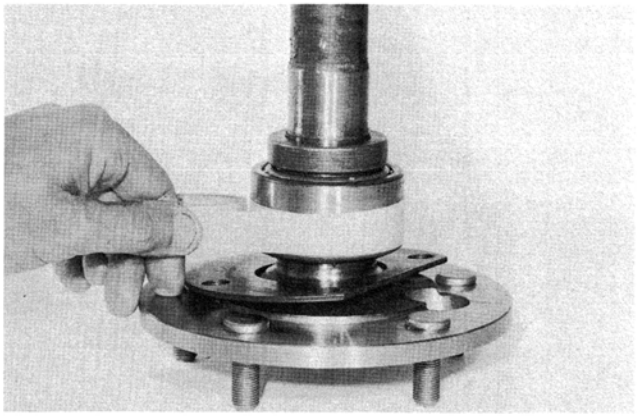


Figure 105 1019-105

After cavity is full of grease, wrap tape completely around rib ring, and seal to enclose the cavity.

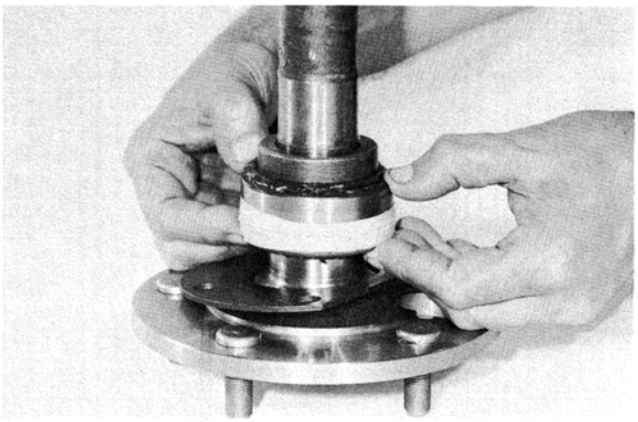


Figure 106 1019-106

Push seal towards the bearing until it contacts the rib ring. This will force the grease between the rollers and cup.

NOTE

If grease is not apparent on the small ends of the rollers, repeat the same steps until grease is evident between the small end of the roller and cup. Remove tape.

REAR AXLE SEMI-FLOAT SHAFT RIDING BEARING DESIGN LUBRICATED WITH HYPOID LUBRICANT

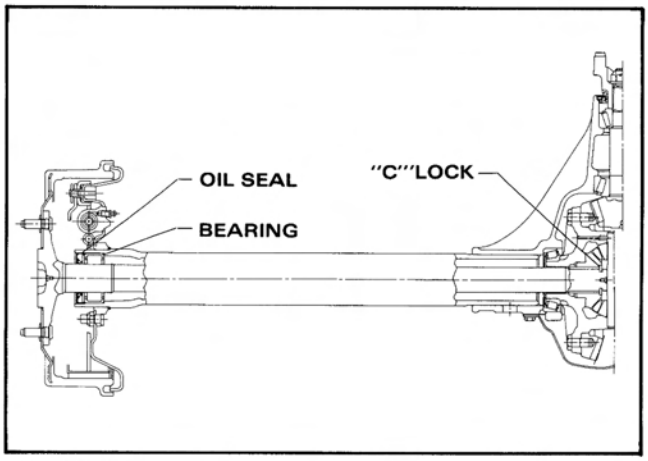


Figure 107 1019-107

(Picture of Shaft Riding Bearing Design)

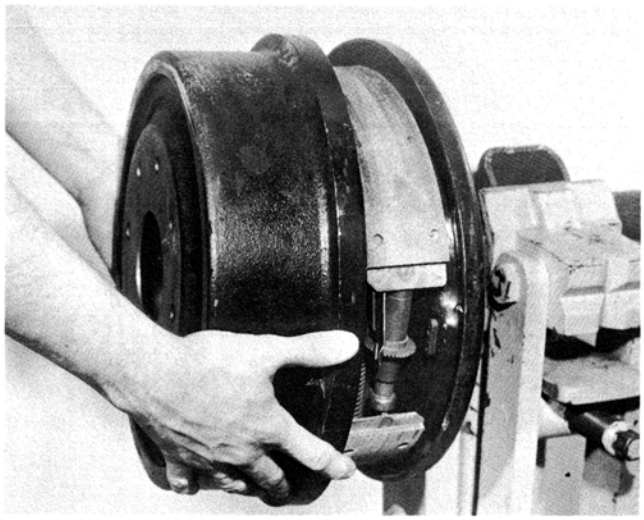


Figure 108 1019-108

After wheel is removed, remove brake drum.

Remove drain plug and drain lubricant. If there is no drain plug in the carrier, the lube will drain out as the cover plate is removed.

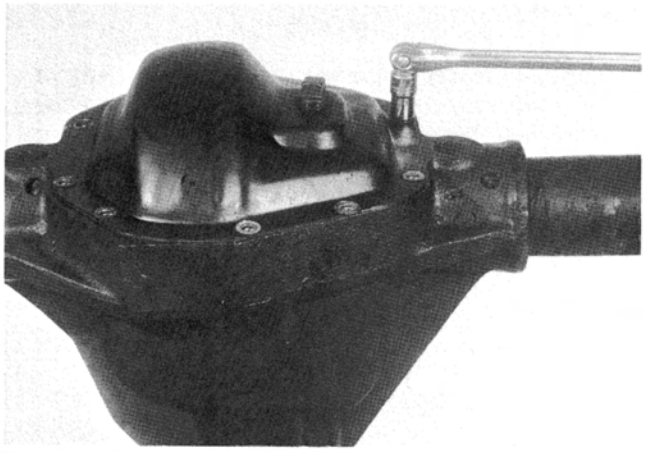


Figure 109 1019-109

Remove cover plate screws, cover plate, and cover plate gasket. Discard old gasket. Tip carrier to allow lube to drain completely. Also during this time clean the cover face of the carrier, making sure it is free from any nicks and any particles left by the old gasket. DO NOT USE CLEANING SOLVENTS OF ANY TYPE. Use of cleaning solvents may prevent the "RTV" sealer from adhering to the cover plate and carrier, resulting in leaks of axle lubricant.

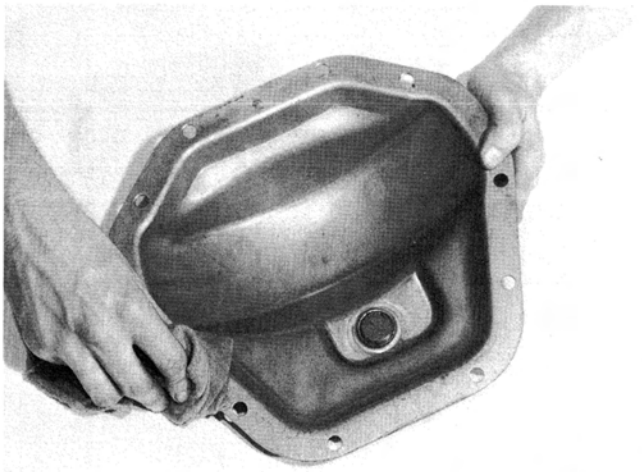


Figure 110 1019-110

Clean cover plate, making sure it is free from any nicks and any particles left by the old gasket material. Use a clean rag or a blunt tool for removing remaining gasket material. DO NOT USE CLEANING SOLVENTS OF ANY TYPE. Use of cleaning solvents may prevent the "RTV" sealer from adhering to the cover plate and carrier, resulting in leaks of axle lubricant.

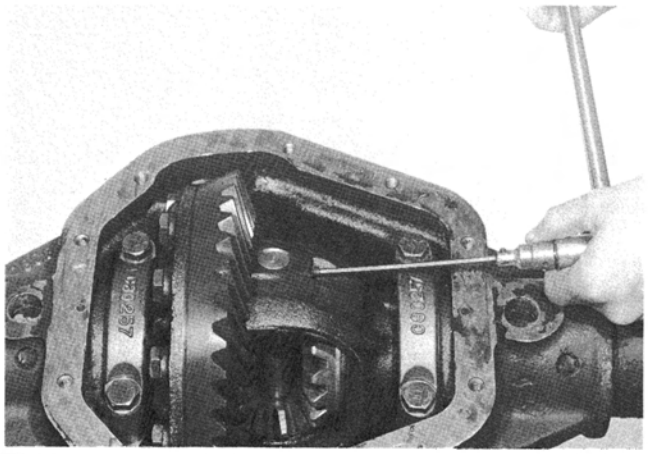


Figure 111 1019-111

Remove the differential pinion shaft lock screw as shown in Figure 111.

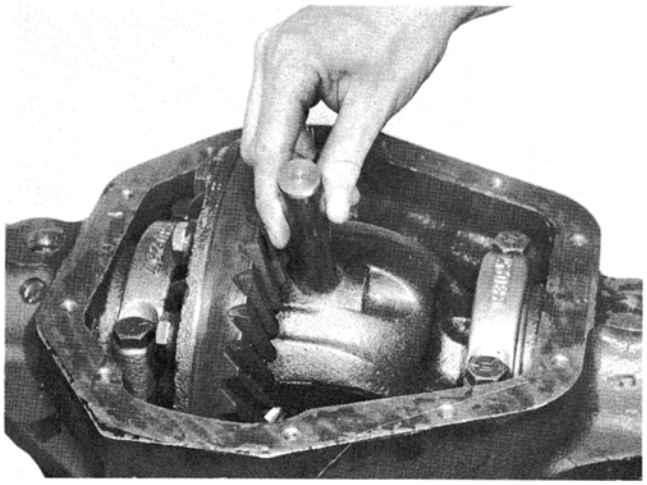


Figure 112 1019-112

Remove the differential pinion mate shaft.

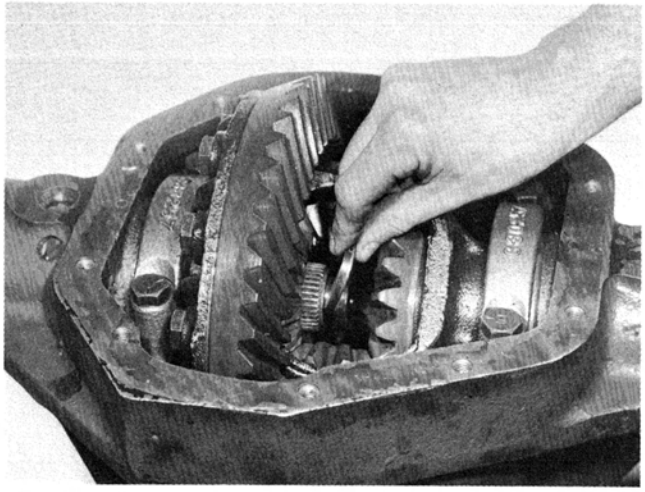


Figure 113 1019-113

Push flange end of axle shafts toward center of vehicle and remove the "C" locks from button end of both shafts.

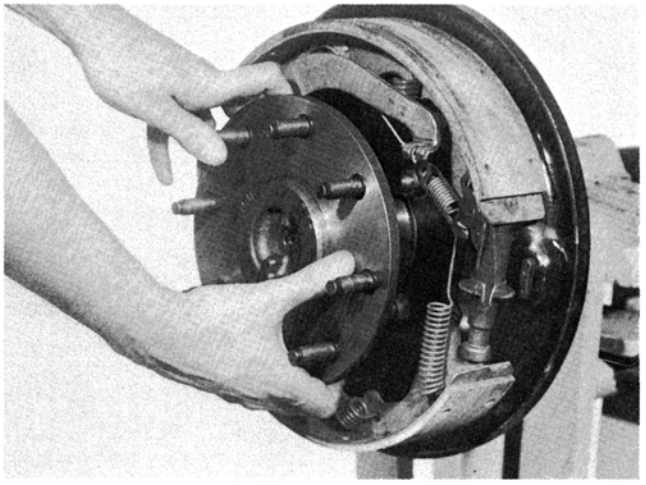


Figure 114 1019-114

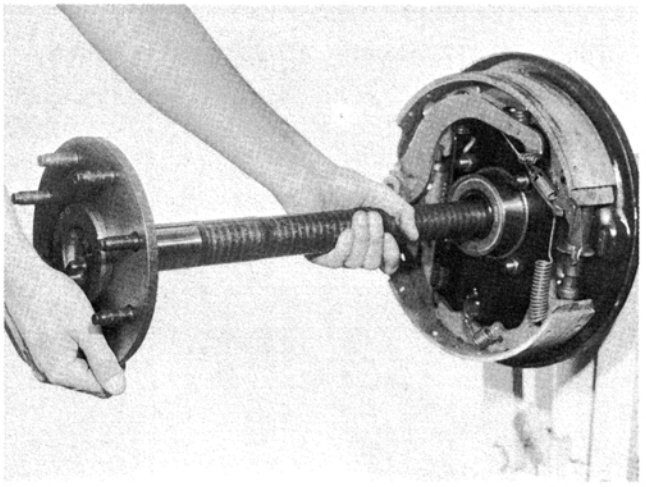


Figure 115 1019-115

Remove the axle shafts from the housing, being careful not to damage the oil seals, as shown in Figures 114 and 115.

CAUTION

When removing the axle shafts, be careful not to rotate the differential side gears. This will cause the pinion mate gears and thrust washers to turn to the opening of the case and drop out.

OIL SEAL AND WHEEL BEARING REPLACEMENT

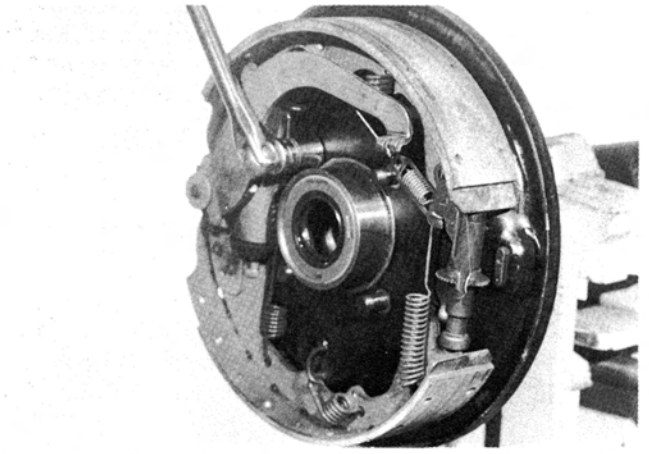


Figure 116 1019-116

Remove the backing plate nuts and bolts which hold the brake backing plate to the axle housing, (3) places. Discard nuts, replace with new ones at time of assembly. Nuts of torque prevailing design are not to be reused. Do not remove brake backing plate.

NOTE

The oil seal may be removed and installed without removing the brake backing plate, nuts and bolts. Care should be taken so as not to damage the bearing upon removing the seal.

Tools: #C-4171 Handle, #D-233 Seal Installer, Seal Remover (screwdriver or other similar tool).

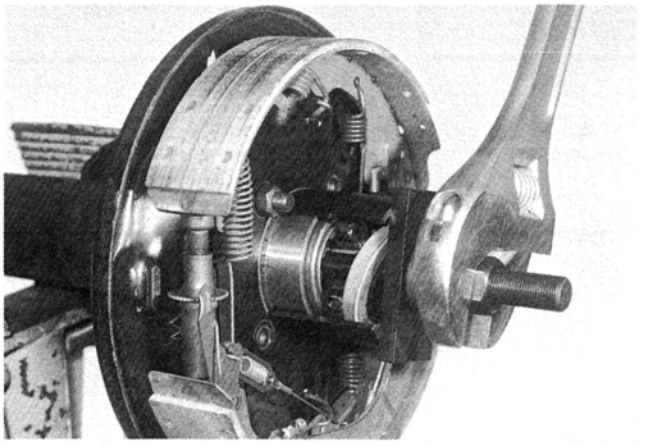


Figure 117 1019-117

Remove the wheel bearing and oil seal as shown. Discard old seal and bearing.

Tool: #D-232-1 Bearing Remover.

Use a standard metal cleaning solvent to clean out the bearing bore in the housing. Wipe this area clean, making sure it is free from dirt or any other contamination that might be present.

NOTE

The bearing bore must be free from nicks and burrs. Wipe the bore with emery cloth to assure a smooth surface. Clean bore out with a standard metal cleaning solvent. If bore has burrs or spalled areas and a new bearing is installed, it may lead to early fatiguing.

AXLE SHAFT AND WHEEL BEARING/ OIL SEAL ASSEMBLY

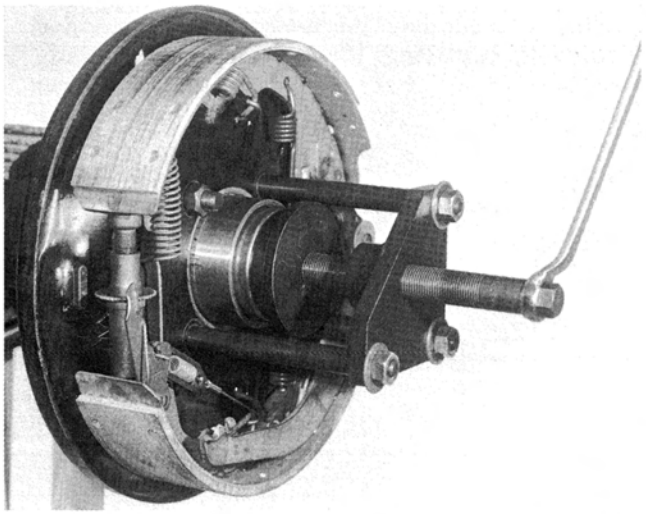


Figure 118 1019-118

Assemble bearing assembly into bearing bore of the tube as shown. Differential lube should be placed on the bearing for easier assembly and for the possible prevention of scoring the tube bore. The tool will stop against the tube end when bearing is seated to the proper depth

Tools: #D-247 Installer Press, #D-248 Bearing Installer.

CAUTION

DO NOT DRIVE THE BEARING INTO TUBE BORE WITH A BEARING DRIVER, AS DAMAGE TO THE BEARING MAY OCCUR.

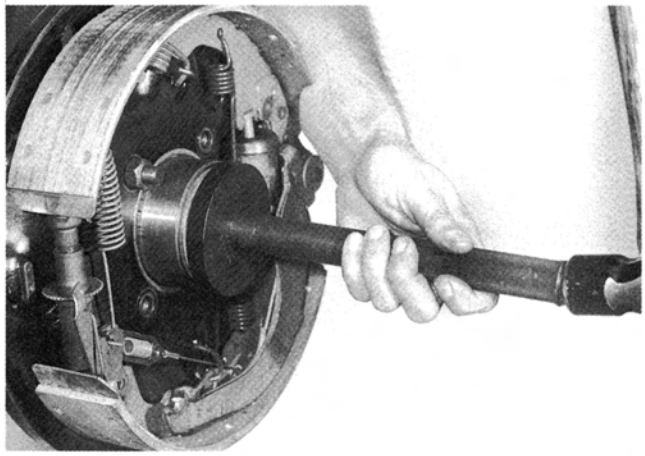


Figure 119 1019-119

Assemble new oil seal into housing as shown. Tool will stop against tube end when oil seal is seated to the proper depth.

Tools: #C-4171 Handle, #D-233 Seal Installer.

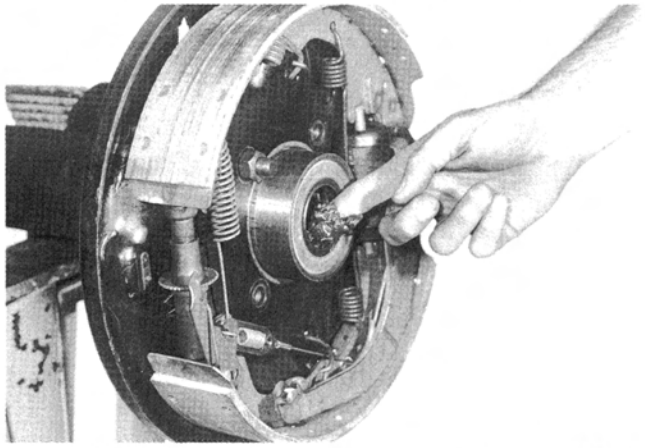


Figure 120 1019-120

Lubricate cavity between seal lips and lubricate new bearing with a good quality number 2 E.P. (Extreme Pressure), lithium soap, wheel bearing grease.

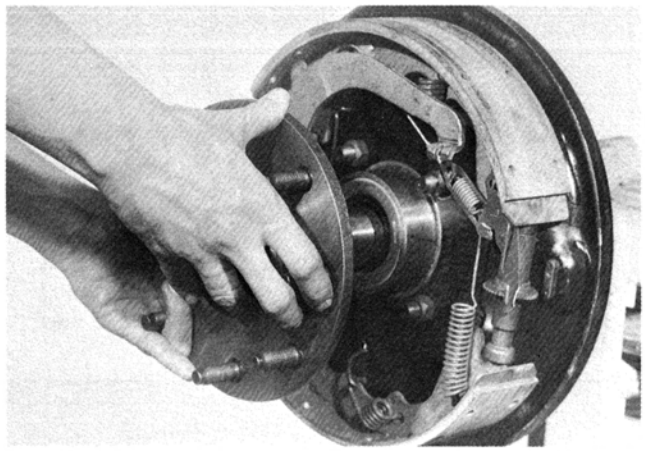


Figure 121 1019-121

Assemble axle shaft into housing. Care should be taken not to damage the seal lip and bearing rollers. and that the shaft spline engages with splines of differential side gears. Do not rotate side gears.

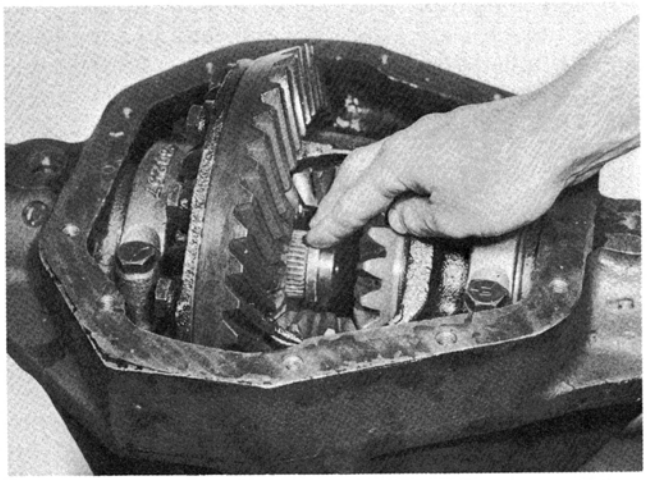


Figure 122 1019-122

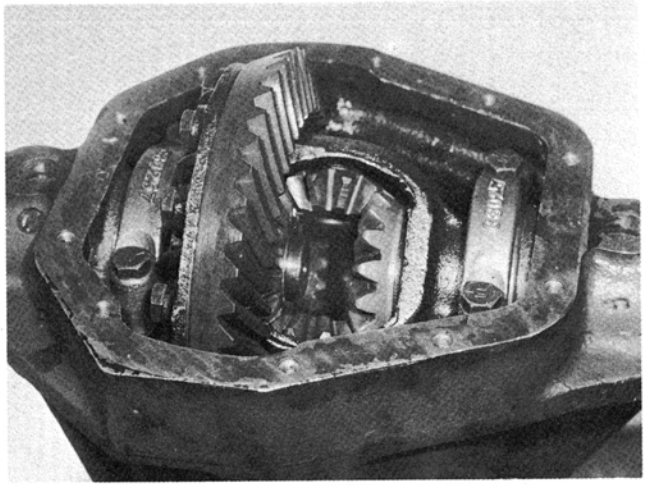


Figure 123 1019-123

Push flange end of axle shaft towards center of vehicle and install the "C" lock. Pull flange out from center of vehicle until "C" lock seats into differential side gears.



Figure 124 1019-124

Assemble pinion mate shaft. Be sure lock pin hole of the shaft is lined up with the lock pin hole of the case. Assemble lock pin.

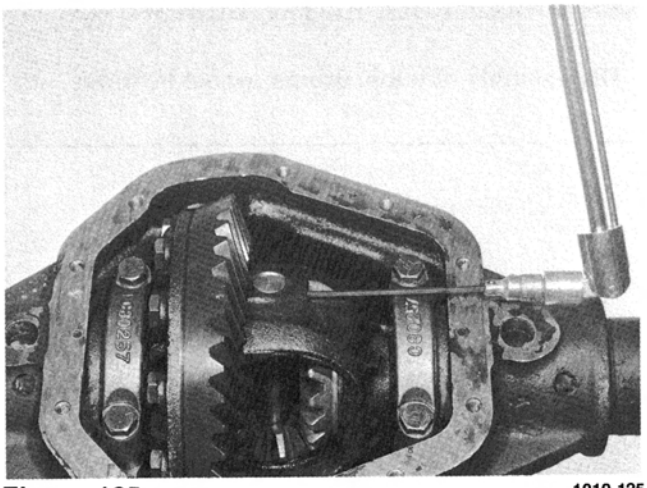


Figure 125 1019-125

Torque lock pin to 8 Lb. Ft. - minimum (11 N·m).

Tool: C-524-A Torque Wrench.

NOTE

Whenever the lock pin is removed, it is to be replaced with a new one. New lock pins have a locking type material on the threads that secures the pin when in place. Before installing lock pin, make sure hole is free of dirt and oil.

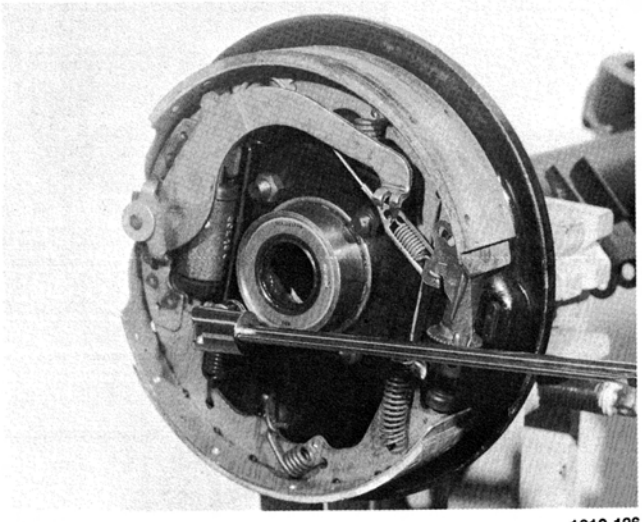


Figure 126 1019-126

Assemble backing plate assembly, using a torque wrench as shown, torque nuts to 50-85 Lbs. Ft. (68-115 N·m). Assemble brake drums, retainer nuts, wheels, etc.

Tool: #C-524-A Torque Wrench.

NOTE

Refer to carrier section for assembly of cover.

REAR AXLE

REAR AXLE FULL FLOAT DESIGN

Disassembly of hubs, drums, wheel bearings, etc.

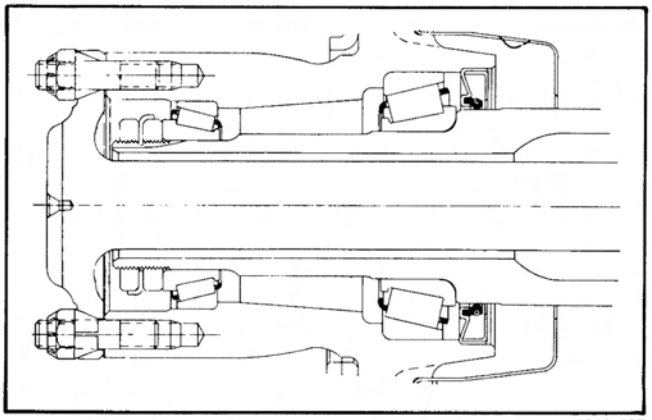


Figure 127 L/D 1019-127

Remove wheel from drum assembly.

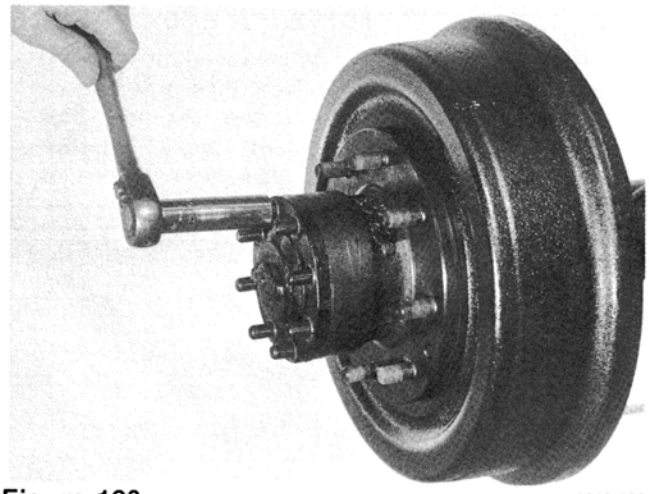


Figure 128 1019-128

Remove axle shaft nuts and/or cap screws, pull out axle shafts. If gasket is present between axle shaft flange and hub, discard gasket and replace with a new one at time of assembly.

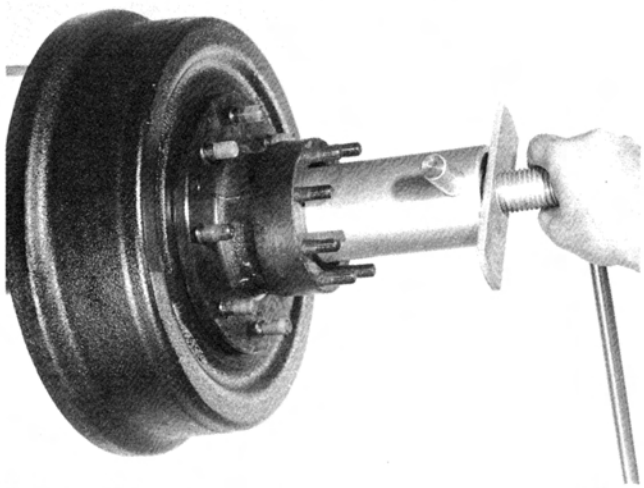


Figure 129 1019-129

If wheel bearing lockwasher is of the design in which the ears are bent over the flats of the wheel bearing nuts, bend ear up from the outerlock nut. Remove outer locknut, lockwasher and inner wheel bearing adjusting nut.

Tools: #DD-1241-J Wrench, #C-4202 Socket-Adapter.

> **NOTE**
>
> Due to various design wheel bearing nuts, wrenches of different sizes, which also use adapter C-4202 are avilable and are as follows:

WRENCH	OPENINGS	
DD-438	3-1/8'' x 3-5/8''	Octagon
DD-824	2-9/16''	Octagon
DD-917-B	3-1/4''	Octagon
DD-926	3-1/2'' x 4''	Hexagon
DD-1245	2-3/8''	Hexagon
DD-1280	2-3/4'' x 7/8''	Octagon

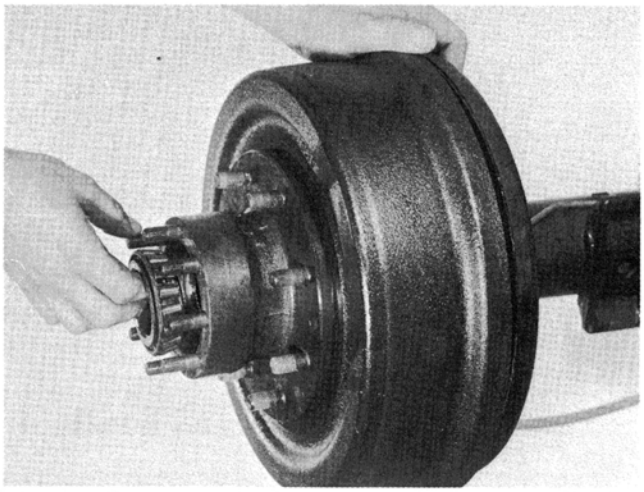


Figure 130 1019-130

Remove hub and drum assembly. The outer wheel bearing cone will slide out as the hub is removed.



Figure 131 1019-131

Place hub on bench and remove grease seal. Discard seal and replace with new one at time of assembly.

Tool: #D-131 Slide Hammer.

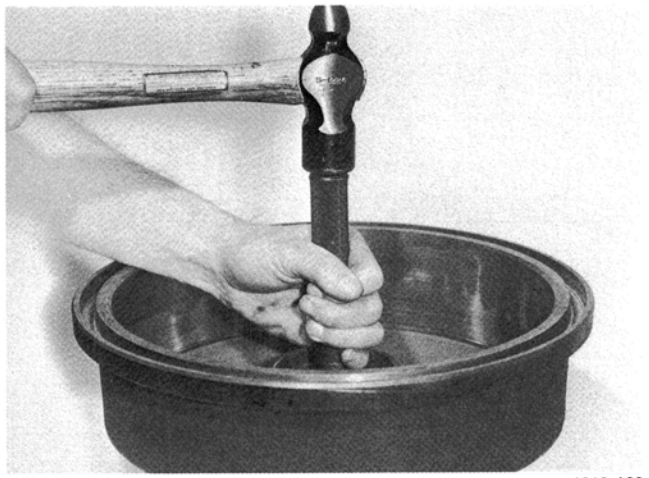


Figure 132 1019-132

Remove inner and outer bearing cups from hub.

Tools: #D-162 Bearing Cup Remover, #C-4171 Handle.

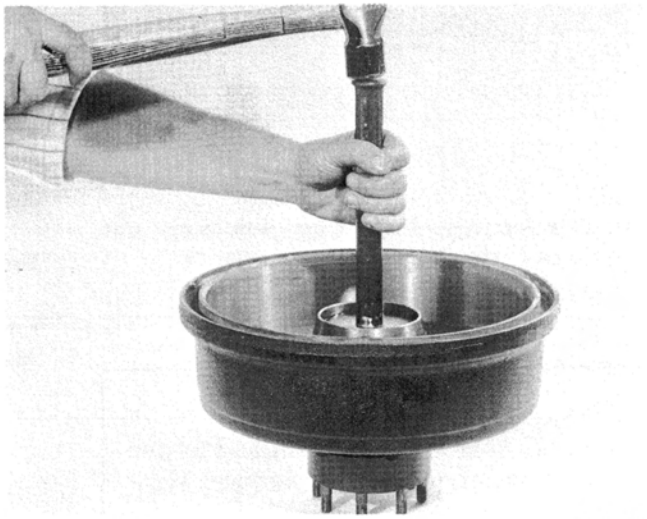


Figure 134 1019-134

Assemble new inner bearing cup.

Tools: #C-4308 Cup Installer, #C-4171 Handle.

Pack with grease and assemble new bearing cone.

ASSEMBLY

NOTE

It is recommended that whenever bearing cups and cones are removed they are to be replaced with new ones.

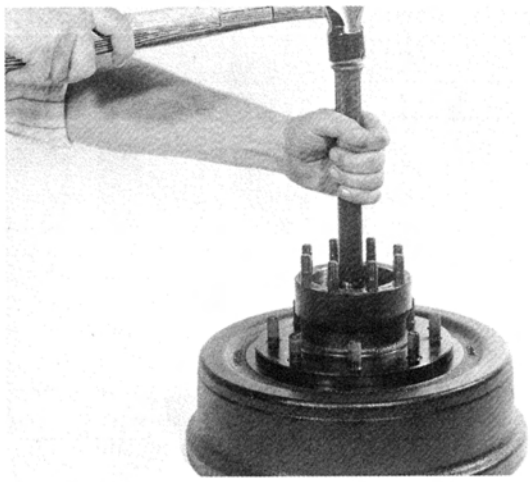


Figure 133 1019-133

Assemble new outer bearing cup.

Tools: #C-4308 Cup Installer, #C-4171 Handle.



Figure 135 1019-135

Assemble new grease seal. Apply a small amount of the specified grease around lip of seal.

Tools: #D-155 Seal Installer, #C-4171 Handle.

Assemble hub assembly onto spindle. Pack with grease and assemble new outer bearing cone.

REAR AXLE

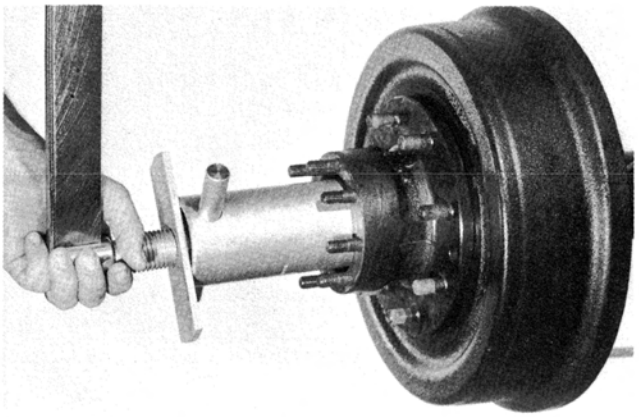


Figure 136 1019-136

Assemble inner wheel bearing adjusting nut, locktab and outer wheel bearing lock nut.

Tools: #DD-1241-J Wrench Socket, #C-4202 Adapter.

> **NOTE**
>
> For final wheel bearing adjustment and torque specifications, refer to Vehicle Service Manual.

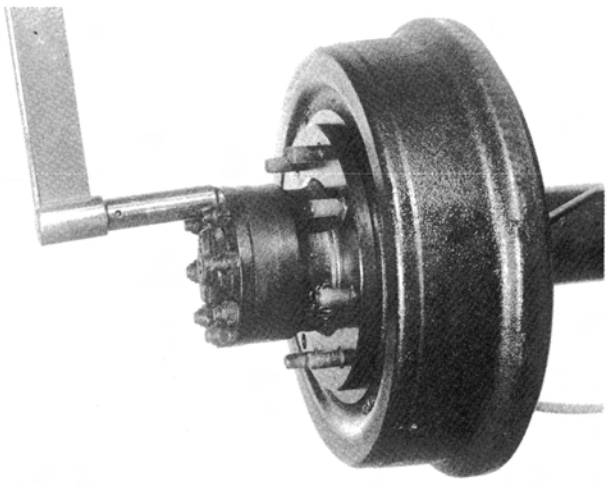


Figure 137 1019-137

Assemble new gasket, assemble axle shaft, torque nuts or cap screws. Refer to Vehicle Service Manual for proper torque specifications.

CARRIER SECTION

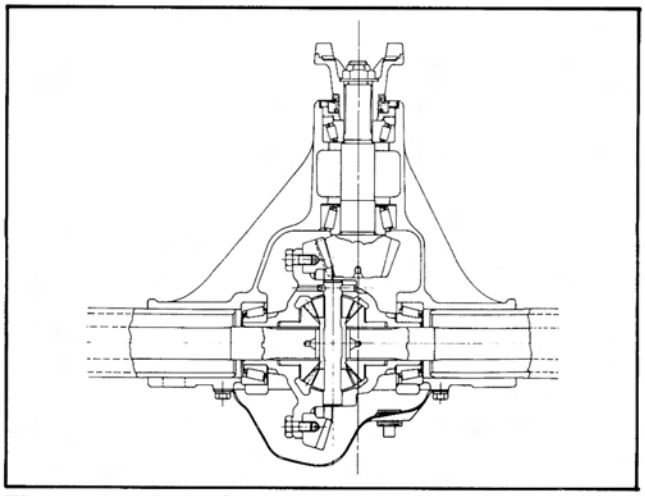


Figure 138 L/D Carrier Section 1019-138

DISASSEMBLY

> **NOTE**
>
> If it becomes necessary to disassemble any parts inside of the carrier, it is suggested that the entire axle be removed from the vehicle and held tight in a stand or rack.

Remove drain plug and drain lubricant. If there is no drain plug in the carrier, the lube will drain out as the cover plate is removed.

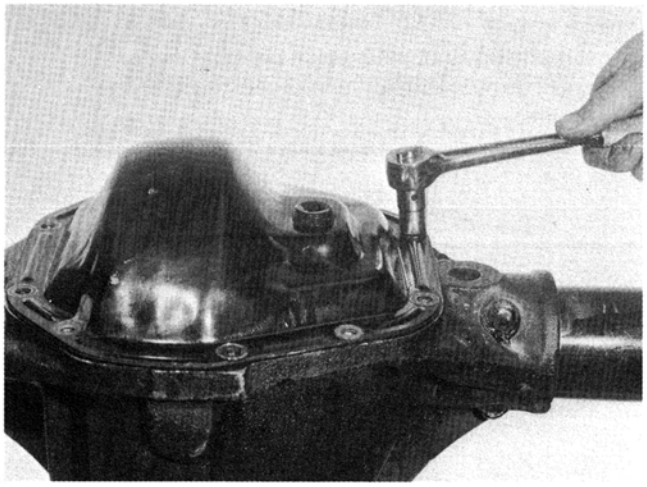


Figure 139 1019-139

Remove cover plate screws, cover plate, and cover plate gasket. Discard old gasket. Tip carrier to allow lube to drain completely. Also during this time clean the cover face of the carrier, making sure it is free from any nicks and any particles left by the old gasket. Do not use cleaning solvents of any type. Use of cleaning solvents may prevent the "RTV" sealer from adhering to the cover plate and carrier, resulting in leaks of axle lubricant.

CARRIER SECTION

CAUTION

Before removing differential case and ring gear, make sure the axle shafts are pulled out far enough for clearance to remove differential. Refer to section of manual covering the type of axle assembly being serviced for procedures on removing the axle shafts.

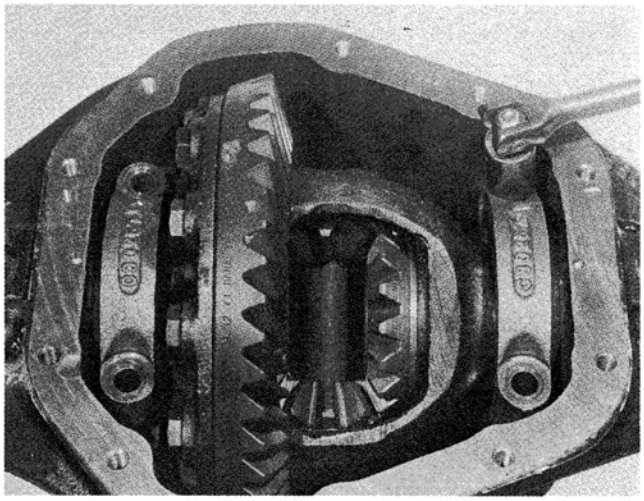


Figure 140 1019-140

Remove bearing caps. Note: Mating letters stamped on caps and carrier. This is important at time of assembly as they are to be assembled exactly as removed. Letters or numbers are in vertical and horizontal position.

NOTE

After removing axle shafts from the rear axle, semi-float shaft riding bearing unit, assemble pinion mate shaft and lock pin (finger tight only) into the differential case. This procedure is necessary to prevent the cross shaft from dropping out, and the differential side gears and differential pinion mate gears from rotating in the case and dropping out when servicing the carrier section.

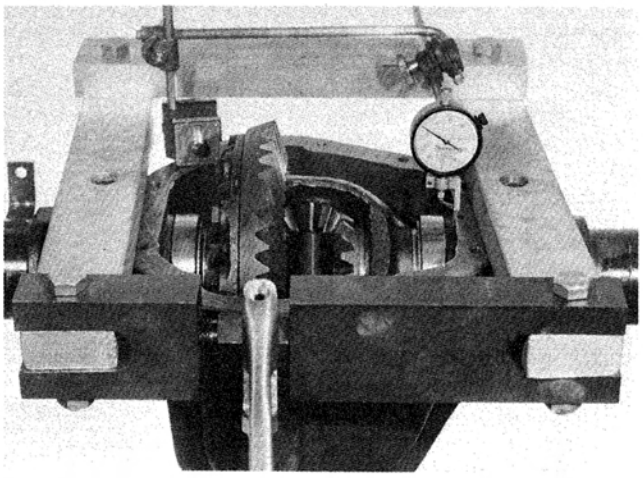


Figure 141 1019-141

Mount spreader to housing. **Do not spread carrier over .015″ (.38 mm).** Use dial indicator as shown. Note: This spreader can also be used on the Spicer Model 44 axle.

Tools: #D-167 Spreader, #D-128 Indicator Set.

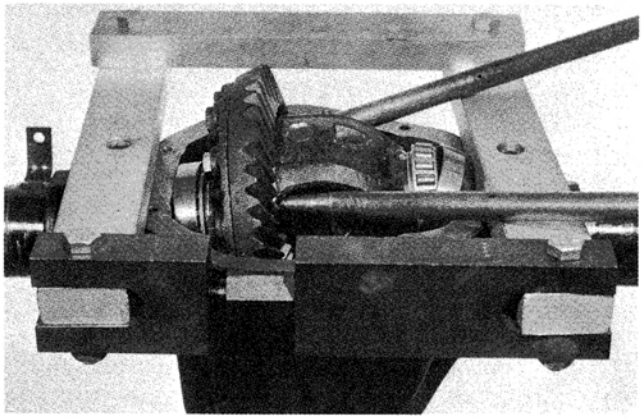


Figure 142 1019-142

Pry differential case from carrier with two pry bars as shown. After differential case has been removed, remove spreader. Use caution to avoid damage to ring and pinion. Mark or tag bearing cups indicating from which side they were removed.

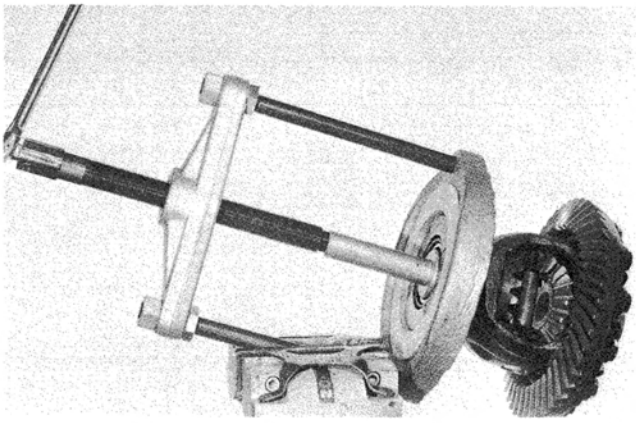


Figure 143 1019-143

Remove differential bearings with a puller as shown. Wire shims, bearing cup and bearing cone together. Identify from which side they were removed. (Ring gear side or opposite side). If shims are mutilated, replace with new ones at time of assembly. Shims are available in thicknesses of .003'', .005'', .010'', and .030'' (mm .08, .13, .25, and .76). Reposition case in puller and remove other bearing cone as described above.

Tools: #DD-914P Press, #DD-914-62 Adapter, #DD-914-8 Adapter Ring, #DD-914-7 Extension, #DD-914-42 Button.

NOTE

It is recommended that whenever bearings are removed, they are (regardless of milage) to be replaced with new ones.

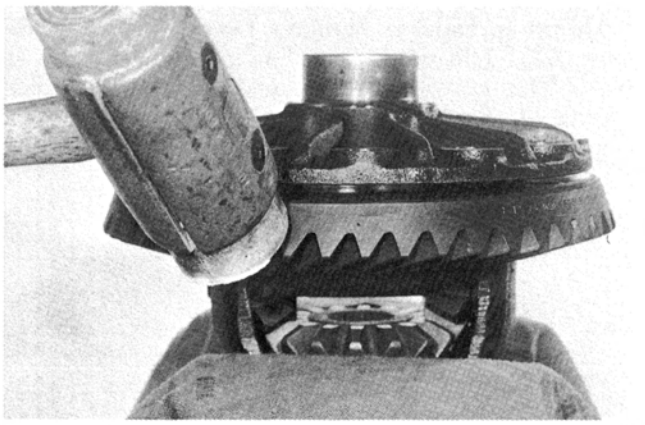


Figure 144 1019-144

Place a few shop towels over the vise to prevent the ring teeth from being nicked, after it is free from the case. Place case in vise. Remove ring gear screws. Tap ring gear with a rawhide hammer to free it from the case. Remove case and ring gear from vise.

NOTE

It is recommended that whenever the ring gear screws are removed they are to be replaced with new ones.



Figure 145 1019-145

Replace case in vise and drive out lock pin which secures the pinion mate shaft. Use a small drift as shown.

NOTE

The semi-float shaft riding bearing design has a lock pin that is removed with a wrench. The pinion mate shaft is of the slip fit design and can be removed by hand.

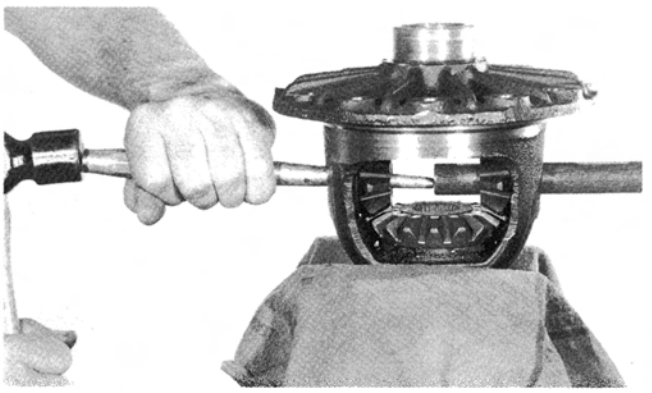


Figure 146 1019-146

Remove pinion mate shaft with drift as shown.

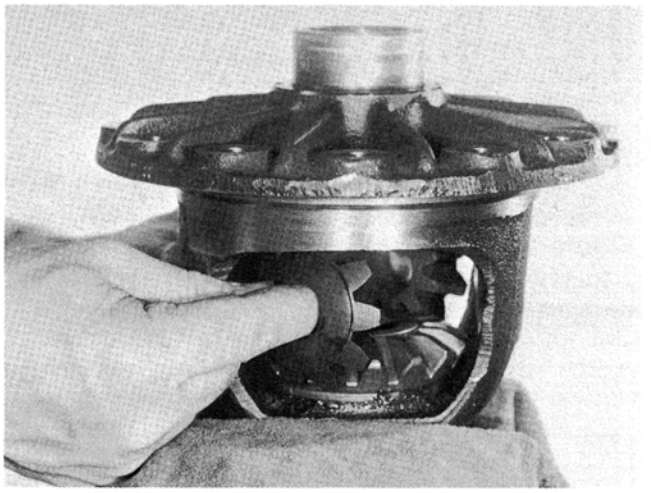


Figure 147 1019-147

To remove side gears and pinion mate gears, rotate the side gears. This will allow the pinion mate gears to turn to the opening of the case. Remove pinion mate gears and also the spherical washers behind the gears. Lift out side gears and thrust washers. Inspect all parts, including the machined surfaces of the case itself. If excessive wear is visible on all parts, it is suggested that the complete differential assembly be replaced. If any one of the gears are to be replaced, THEY ARE TO BE REPLACED AS A SET.

NOTE

Axle shafts which require end play adjustments have a spacer block in the differential case. The spacer block controls the end thrust of the axle shaft. If the ends of the spacer block are worn, it is to be replaced during assembly. Spacer block must not be used with ball or unitized wheel bearings.

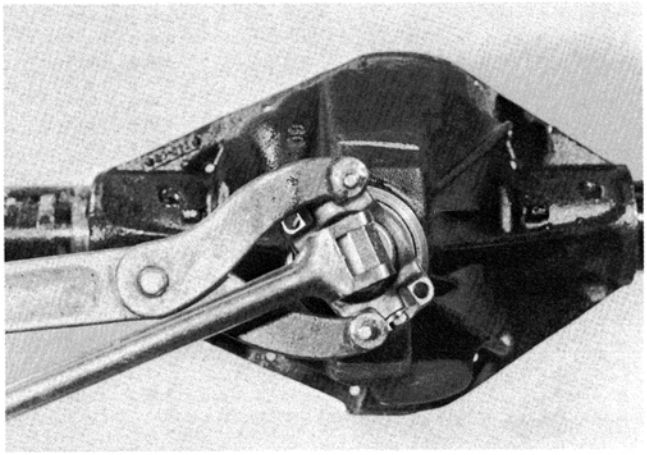


Figure 148 1019-148

Turn nose of carrier in a horizontal position, remove pinion nut. Hold end yoke or flange with tool, as shown, and remove pinion nut and washer.

Tool: #C-3281 Holding Wrench.

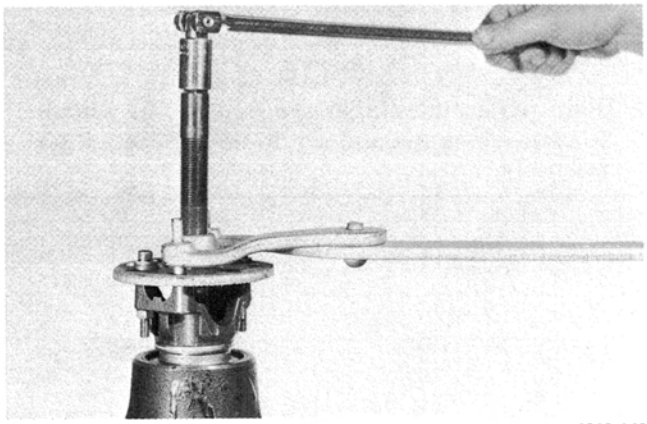


Figure 149 1019-149

Remove end yoke of flange with tools as shown. If end yoke or flange shows wear in the area of the seal contact, it should be replaced.

Tools: #C-3281 Holding Wrench, #C-452 Yoke Remover.



Figure 150 1019-150

Remove pinion by tapping with a rawhide hammer. Catch the pinion with your hand to prevent it from falling to the ground and being damaged.

NOTE

On the spline end of the pinion, there are bearing preload shims. These shims may stick to the pinion or bearing or even fall out. These shims are to be collected and kept together since they will be used later in assembly. Try not to mutilate shims. If shims are mutilated, replace with new ones. Shims are available in thicknesses of .003'', .005'', .010'', and .030'', (mm .08, .13, .25, and .76).

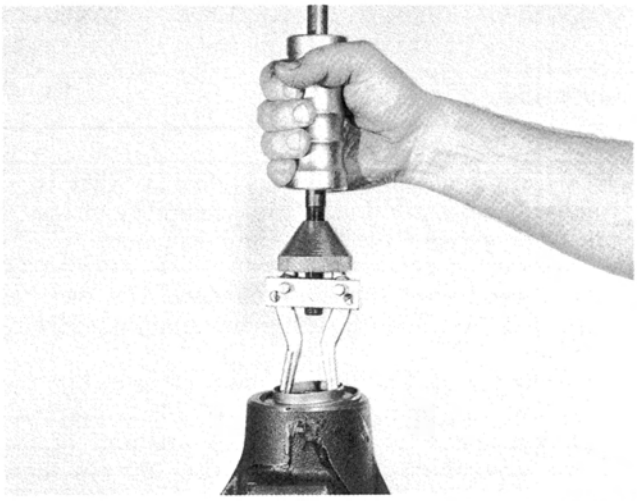


Figure 151 1019-151

Pull out pinion seal with puller as shown. Discard seal. REPLACE WITH NEW ONE AT TIME OF ASSEMBLY. Remove bearing cone and outer oil slinger.

Tool: #D-131 Slide Hammer.

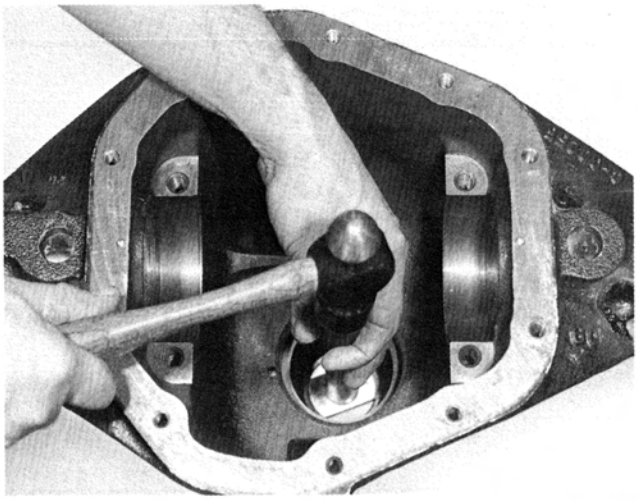


Figure 152 1019-152

Turn nose of carrier down. Remove outer pinion bearing cup. Locate driver on back edge of cup; drive cup out of carrier. **Caution: Do not nick carrier bore.**

Tools: #D-158 Cup Remover, #C-4171 Handle.

CARRIER SECTION

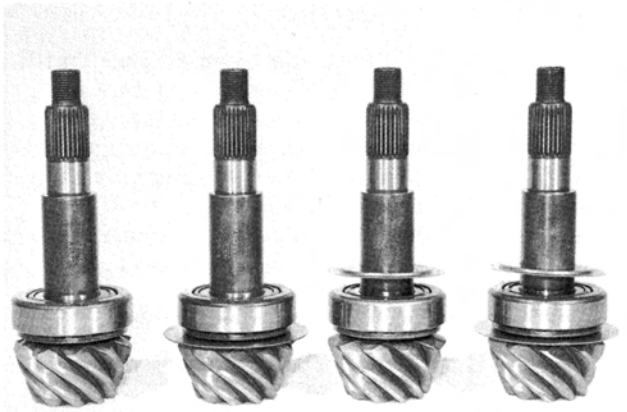


Figure 153 1019-153

> **NOTE**
> The front and rear carrier section may vary in pinion bore depth due to the possibility of the need for either a baffle or slinger or both.

The baffle serves the same purpose as a dam, to assure that the pinion bearings are maintained with lubricant.

The slinger serves the purpose of assisting the lube to flow up through the oil channels to lubricate the pinion bearings. If used, they are part of the pinion setting adjustment. In figure 153 we show the four different options.

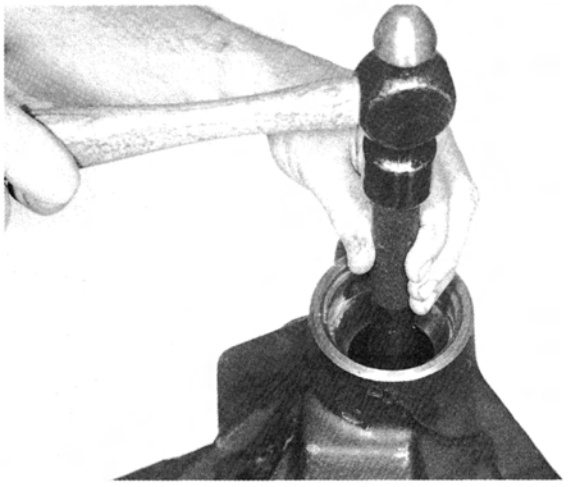


Figure 154 1019-154

Remove the inner bearing cup with tools as shown.

Tools: #C-4171 Handle, #D-162 Cup Remover.

> **NOTE**
> Shims are located between the bearing cup and carrier bore and may also include an oil baffle. If shims and baffles are bent or nicked, they should be replaced at time of assembly. Wire and stack together and measure each. If stack has to be replaced, replace with same thickness.

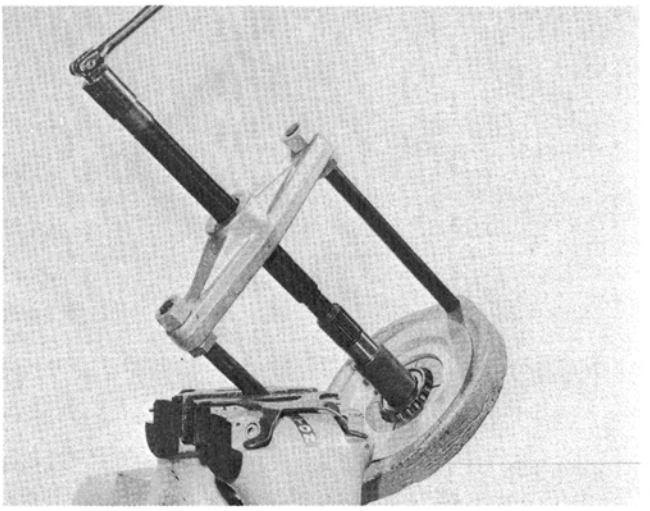


Figure 155 1019-155

Remove pinion bearing with tools as shown.

Tools: #DD-914-P Press, #DD-914-9 Adapter Ring, #C-293-37 Adpaters.

> **NOTE**
> Both baffle and slinger are part of the pinion adjustment shims and are to be kept intact for assembly.

ASSEMBLY

On all front driving axles there are axle shaft oil seals pressed into the tube ends of the carrier.

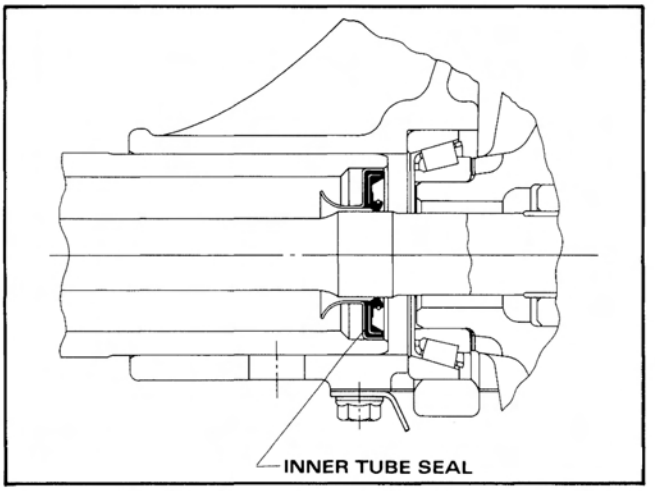


Figure L/D Carrier Seal 156 1019-156

As shown in figure 156, this design consists of the integral seal (unit) whereby the seal and guide are combined. (One seal for each side).

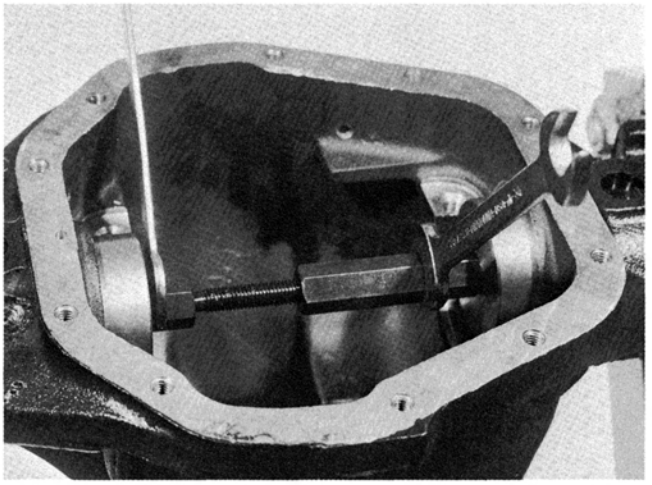


Figure 157 1019-157

Assemble inner axle shaft seals and guides. To assemble seals use tools as shown.

Tool: #D-195 Installer.

When assembling the seals, make sure they are positioned straight and do not get cocked. Turn forcing screw until it stops; seals will then be positioned. Grease lips of seals.



Figure 158 1019-158

Place differential case in vise as shown. Apply grease to new side gear thrust washers and to hubs and thrust face of the new side gears. Assemble both side gears. Apply grease to the new spherical washers, and the new pinion mate gears. Assemble new pinion mate gears and washers.

An easy way to assemble the side gears and pinion mate gears is to have all parts lubricated before assembly.

Assemble both side gears and thrust washers, hold them in place with hand, then assemble the pinion mate gears and washers to hold the side gears in place.

Rotate the side gears until the holes of the washers and pinion gears line up with the holes of the case, If the gears cannot be rotated by hand, install one of the axle shafts into the side gear spline and use a pipe wrench to turn the shaft.

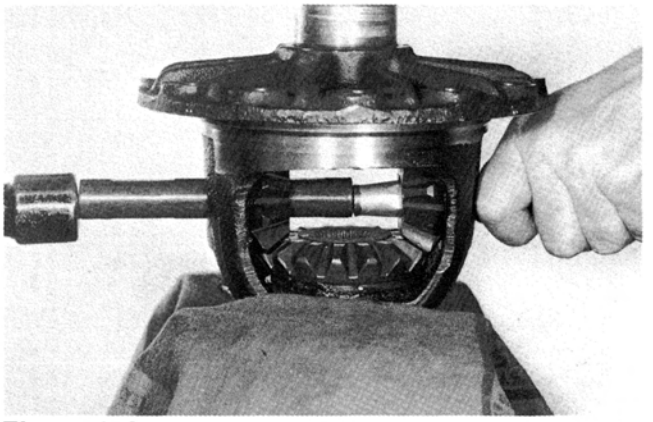


Figure 159 1019-159

Use a drift to line up the holes with those of the differential case.

Assemble pinion mate shaft, drive on shaft to remove drift. Be sure lock pin hole of the shaft is lined up with the lock pin hole of the case.



Figure 160 1019-160

Assemble lock pin. Peen metal of case over pin to lock in place.

NOTE

The semi-float shaft riding bearing design uses a lock pin that is assembled with the use of a wrench. Use lock pin and assemble finger tight only. This procedure is necessary to prevent differential side gears and differential pinion mate gears from rotating in the case and dropping out when servicing the carrier section. **A new lock pin will be installed after assembling the axle shafts.**

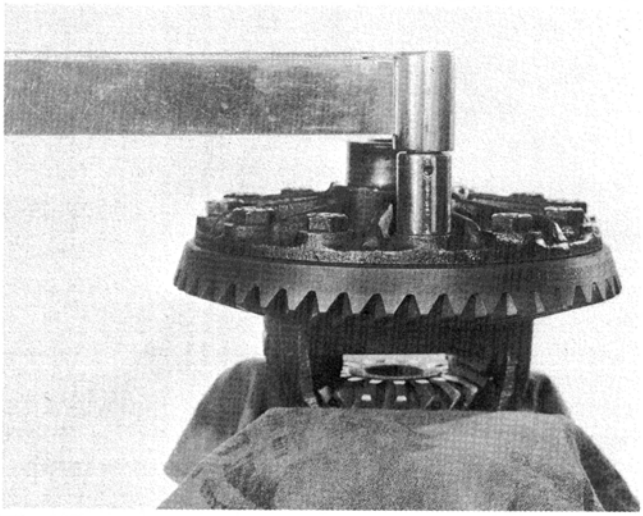


Figure 161 1019-161

Be sure flange face of the case is free of nicks or burrs. Assemble ring gear to case. Line up holes of the ring gear with those of the case. Use new ring gear screws. Draw up screws alternately and evenly. Torque ring gear screws to 100-120 Lb. Ft. (136-163 N·m).

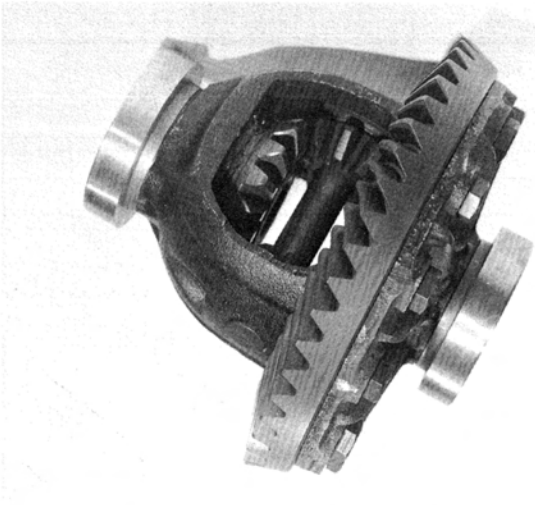


Figure 162 1019-162

Install master differential bearings onto case. Remove all nicks, burrs, dirt, etc., from hubs to allow master bearings to rotate freely.

Tool: #D-117 Master Differential Bearings.

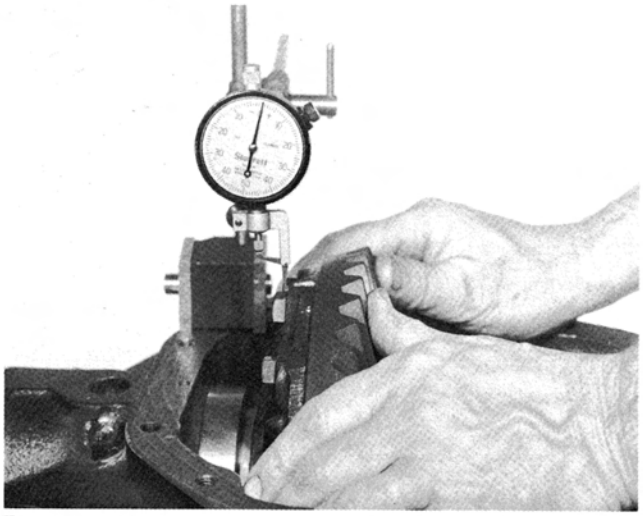


Figure 163 1019-163

Assemble differential case into carrier (less pinion). Mount dial indicator with a magnetic base as shown. Locate tip of indicator on flat surface of one of the ring gear screw spot faces. Mark location with a piece of chalk. Force differential assembly as far as possible in the direction towards the indicator. With force still applied, set indicator at zero (0).

Tool: #D-128 Indicator Set.

NOTE

Dial indicator should have a minimum travel of .200'' (5.08 mm).

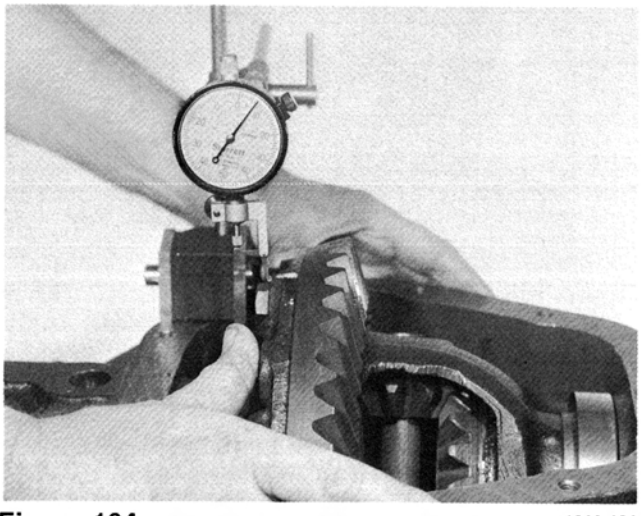


Figure 164 1019-164

Force the differential assembly as far as it will go in the opposite direction. Repeat these steps until you have obtained the same reading. Record the reading of the indicator. This will be the total amount of shims required (less preload) and will be calculated later during assembly. After making sure the readings are correct, remove indicator and differential assembly from housing. DO NOT REMOVE MASTER BEARINGS FROM DIFFERENTIAL CASE AT THIS TIME.

VIEW OF RING AND PINION SET

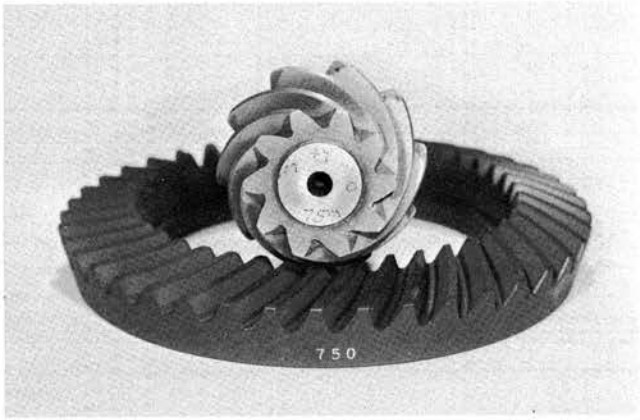


Figure 165 1019-165

Ring gears and pinions are supplied in matched sets only. Matching numbers on both the pinion and ring gear are etched for verification. If a new gear set is being used, varify the numbers of each pinion and ring gear before proceeding with assembly.

The nominal distance from the centerline of the ring gear to the end of the pinion for the model 60 (front and rear) axle is 3.125'' (79.37 mm).

On the button end of each pinion, there is etched a plus (+) number, a minus (-) number, or a zero (0) number which indicates the best running position for each particular gear set. This dimension is controlled by the shimming behind the inner pinion bearing cup.

For example - If a pinion is etched a plus +3 (m+8), this pinion would require .003'' (.08 mm) less shims than a pinion etched ''0''. This means by removing shims, the mounting distance of the pinion is increased to 3.128'' (79.45 mm), which is just what a +3 (m+8) indicates. Or if a pinion is etched -3 (m-8), we would want to add .003'' (.08 mm) more shims than would be required if the pinion were etched ''0''. By adding .003'' (.08 mm) shims, the mounting distance of the pinion was decreased to 3.122'' (79.30 mm) which is just what a -3 (m-8) indicated.

If the old ring and pinion set is to be reused, measure the old shim pack and build a new shim pack to this same dimension. If a baffle is used in the axle assembly, it is considered as part of the shim pack.

To change the pinion adjustments, shims are available in thicknesses of .003'', .005'', and .010'' (mm .08, .13, and .25).

NOTE

If baffle or slinger is bent or mutilated, it should be replaced.

Measure each shim separately with a micrometer and add together to get total shim pack thickness from the original build up.

If a new gear set is being used, notice the (+) or (-) etching on both the old and new pinion and adjust the thickness of the new shim pack to compensate for the difference of these two figures.

For example - If the old pinion reads (+) 2 (m+5) and the new pinion is (-) 2 (m-5), add .004'' (.10 mm) shims to the orginal shim pack.

The above procedures also apply to pinion adjustment on the front axle which includes the oil slinger between the inner bearing cone and pinion, and baffle between the inner bearing cup and carrier.

Old Pinion Marking	New Pinion Marking								
	−4	−3	−2	−1	0	+1	+2	+3	+4
+4	+0.008	+0.007	+0.006	+0.005	+0.004	+0.003	+0.002	+0.001	0
+3	+0.007	+0.006	+0.005	+0.004	+0.003	+0.002	+0.001	0	−0.001
+2	+0.006	+0.005	+0.004	+0.003	+0.002	+0.001	0	−0.001	−0.002
+1	+0.005	+0.004	+0.003	+0.002	+0.001	0	−0.001	−0.002	−0.003
0	+0.004	+0.003	+0.002	+0.001	0	−0.001	−0.002	−0.003	−0.004
−1	+0.003	+0.002	+0.001	0	−0.001	−0.002	−0.003	−0.004	−0.005
−2	+0.002	+0.001	0	−0.001	−0.002	−0.003	−0.004	−0.005	−0.006
−3	+0.001	0	−0.001	−0.002	−0.003	−0.004	−0.005	−0.006	−0.007
−4	0	−0.001	−0.002	−0.003	−0.004	−0.005	−0.006	−0.007	−0.008

Figure 166 1019-166

Pinion Setting Chart (English U.S. Standard).

Old Pinion Marking	New Pinion Marking								
	-10	-8	-5	-3	0	+3	+5	+8	+10
+10	+.20	+.18	+.15	+.13	+.10	+.08	+.05	+.03	0
+8	+.18	+.15	+.13	+.10	+.08	+.05	+.03	0	-.03
+5	+.15	+.13	+.10	+.08	+.05	+.03	0	-.03	-.05
+3	+.13	+.10	+.08	+.05	+.03	0	-.03	-.05	-.08
0	+.10	+.08	+.05	+.03	0	-.03	-.05	-.08	-.10
-3	+.08	+.05	+.03	0	-.03	-.05	-.08	-.10	-.13
-5	+.05	+.03	0	-.03	-.05	-.08	-.10	-.13	-.15
-8	+.03	0	-.03	-.05	-.08	-.10	-.13	-.15	-.18
-10	0	-.03	-.05	-.08	-.10	-.13	-.15	-.18	-.20

Figure 167 1019-167

Pinion Setting Chart Metric

If metric used pinion will be etched Exp. (m+5). Use these charts as a guideline to set pinion.

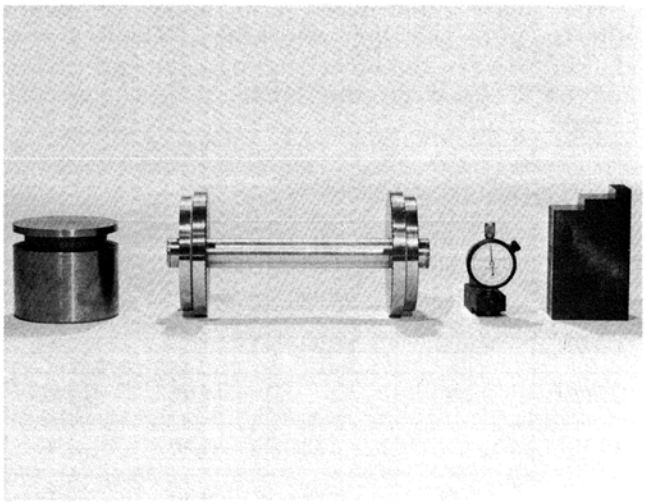


Figure 168 1019-168

View of master pinion block, pinion height block, scooter gage, cross pin, and master bearing discs.

NOTE

Cross arbor, master bearing discs, and scooter gage can be used on both Model 60 and Model 70 axles.

Make sure that all carrier bores are free from all nicks, dirt or any other contamination.

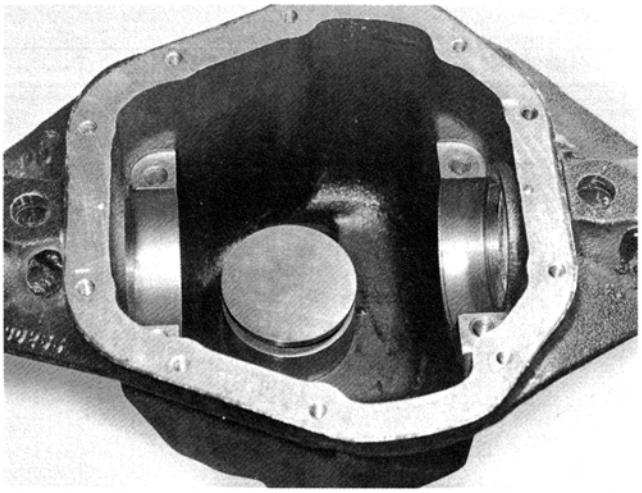


Figure 169 1019-169

Place master pinion block into the pinion bore of the carrier as shown.

Tool #D-120 Master Pinion Block.

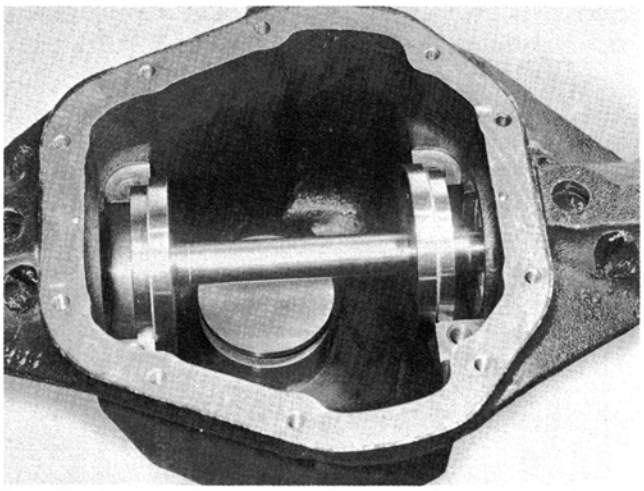


Figure 170 1019-170

Place arbor discs (small diameters) and arbor into cross bores of carrier as shown.

Tools: #D-116-2 Master Discs, #D-115-3 Arbor.

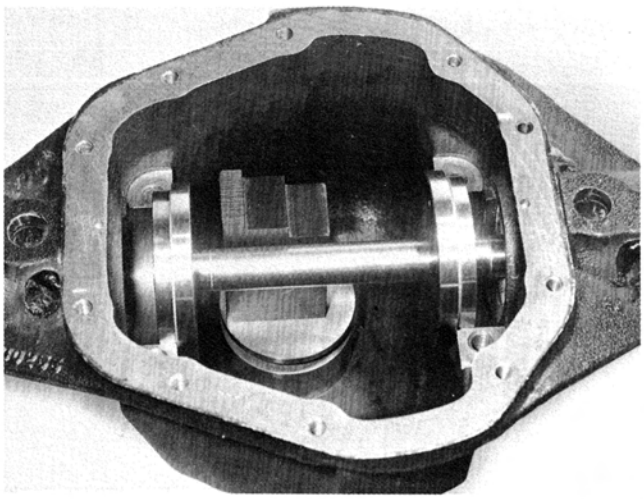


Figure 171 1019-171

Place pinion height block on top of master pinion block and against arbor as shown.

Tool: #D-116-1 Pinion Height Block.

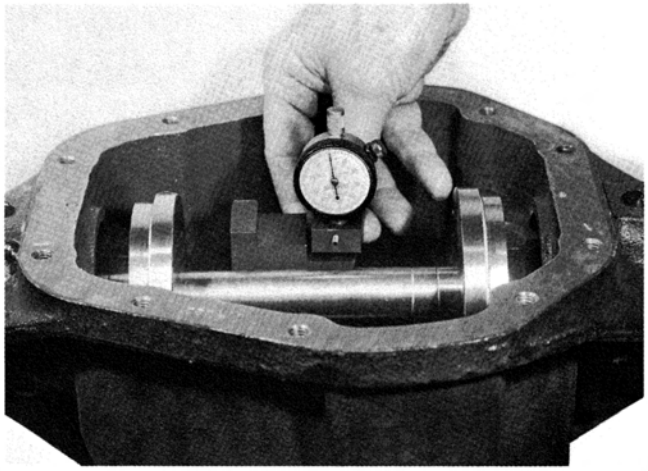


Figure 172 1019-172

Place scooter gage on small step of pinion height block. Apply pressure with fingers, making sure the gage is flat on the pinion block, while pressure is applied set indicator at zero ''0''.

Tool: #D-115 Scooter Gage.

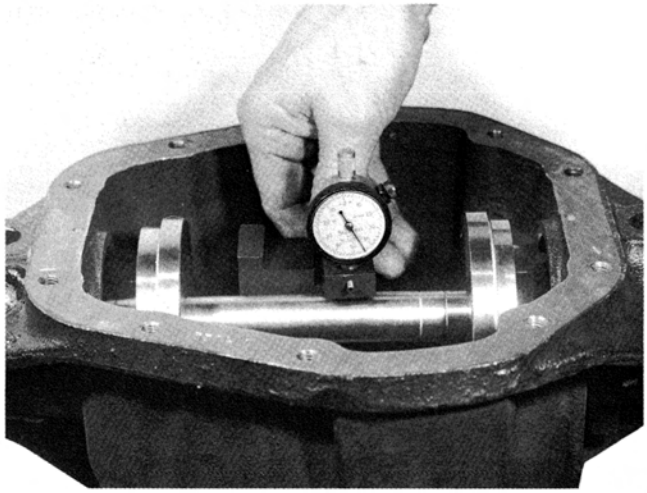


Figure 173 1019-173

Slide scooter gage over arbor. As gage slides over top of arbor, it will travel in a clockwise direction. When indicator is on center of arbor (on top) it will stop travelling in a clockwise direction. If indicator starts to travel in a counter-clockwise direction, this means you have passed the center (top) of the arbor. Record only the reading when the indicator is at the highest point.

This reading indicates the amount of shims necessary to obtain the shim pack, plus (+) or minus (-) the etching on the button end of the pinion.

If the etching is zero (0), the shim pack will remain unchanged.

For example: If the pinion is etched +3 (m+8), this pinion would require .003'' (.08 mm) less shims than a pinion etched zero (0).

If the pinion is etched -3 (m-8), this would require .003'' (.08 mm) more shims than a pinion etched zero (0).

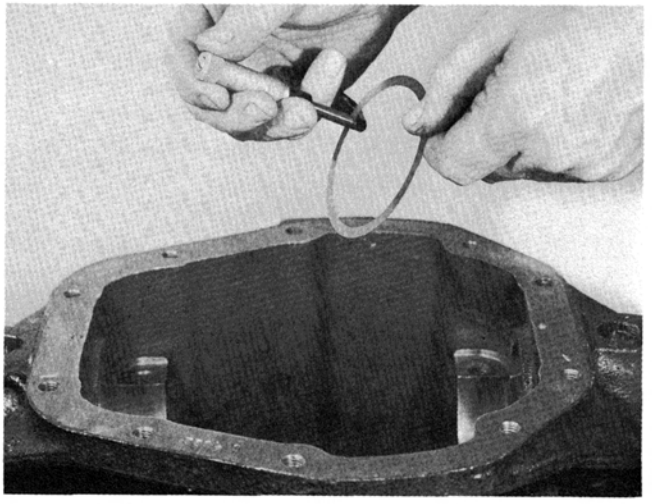


Figure 174 1019-174

Measure each shim separately with a micrometer and add together to get total shim pack thickness. If baffle is required it is to be included in the shim pack. If slinger is used between the inner bearing cone and thrust face of pinion, the slinger is also to be measured and included as part of the total shim pack.

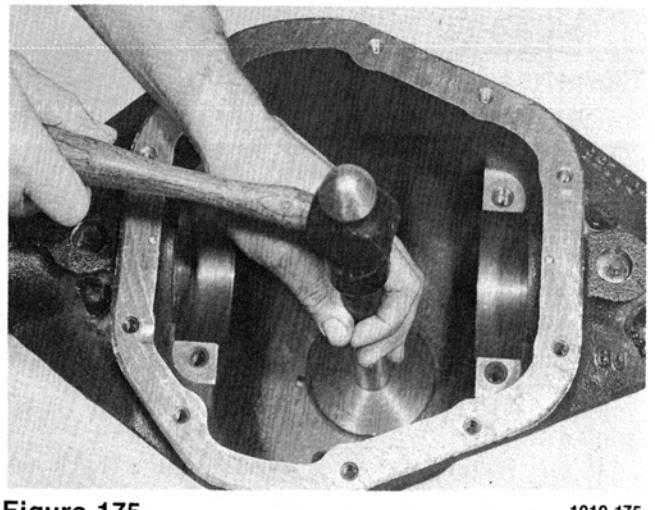


Figure 175 1019-175

Place the required amount of shims (and baffle if used) in the inner bearing bore; drive the inner bearing cup into the carrier. Make sure cup is seated.

Tools: #D-111 Cup Installer, #C-4171 Handle.

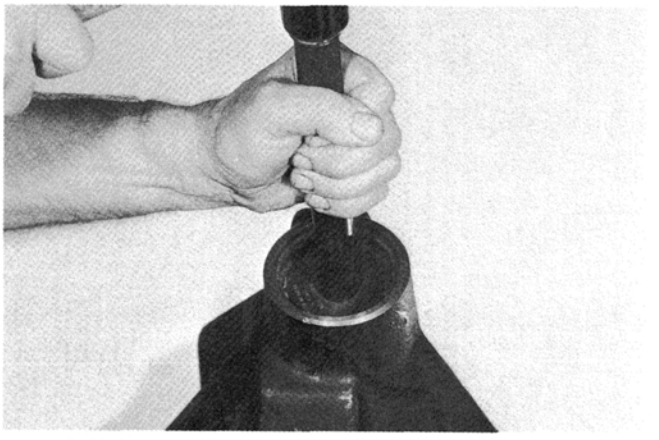


Figure 176 1019-176

Assemble the outer pinion bearing cup into carrier as shown, make sure cup is seated.

Tools: #C-4203 Cup Installer, #C-4171 Handle.

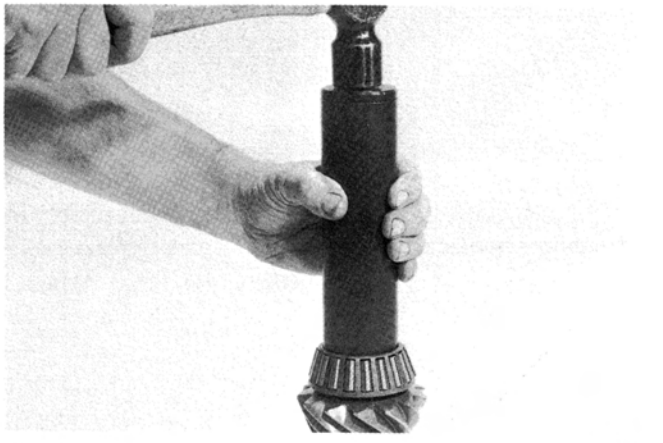


Figure 177 1019-177

Assemble inner bearing cone (and slinger if used) on pinion. Drive bearing on shaft until it is completely seated.

Tool: #C-3095-A Bearing Installer.

Assemble preload shims (which were removed during disassembly) onto pinion. Assemble bearing cone, slinger.



Figure 178 1019-181

Apply a light coat of hypoid lubricant on the lip of pinion seal and assemble into carrier.

Tools: #D-163 (National) Seal Installer, #D-164 (Chicago Rawhide) Seal Installer, #C-4171 Handle.

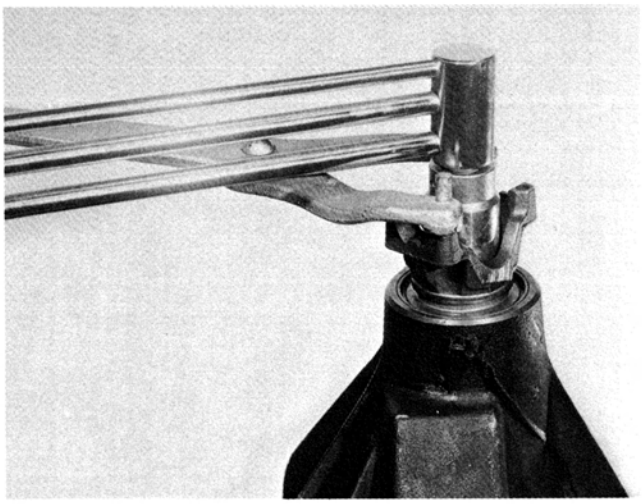


Figure 179 1019-182

Assemble end yoke, washer, and new pinion nut. Torque nut to 240-300 Lb. Ft. (325-406 N·m).

Tools: #C-4053 Torque Wrench, #C-3281 Yoke Holder.

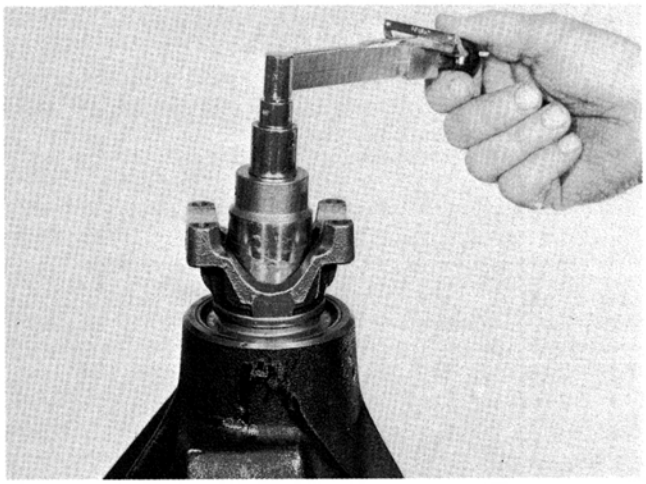


Figure 180 1019-183

Using an In. Lb. torque wrench as shown, rotate pinion. Torque to rotate pinion should read between 20-40 Lb. In. (2.26-4.53 N·m). To increase preload, remove shims; to decrease preload add shims.

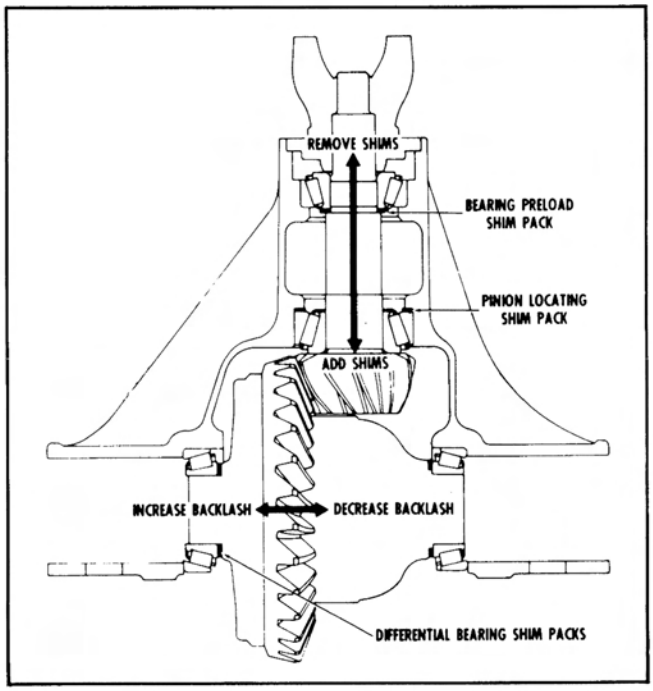


Figure 181 L/D Carrier 1019-184

The illustration in figure 181 shows the arrow in the pinion pointing in two directions. The direction pointing towards the end yoke indicates that by removing pinion position shims, the distance from the centerline of the axle to pinion button is increased giving a plus reading. The preload shim pack does not effect the pinion depth setting. Arrows on the ring gear illustrate the method to increase or decrease backlash and differential bearing preload.

ASSEMBLY OF DIFFERENTIAL

Place differential assembly (with pinion installed) into housing. Differential master bearings should still be assembled to case.

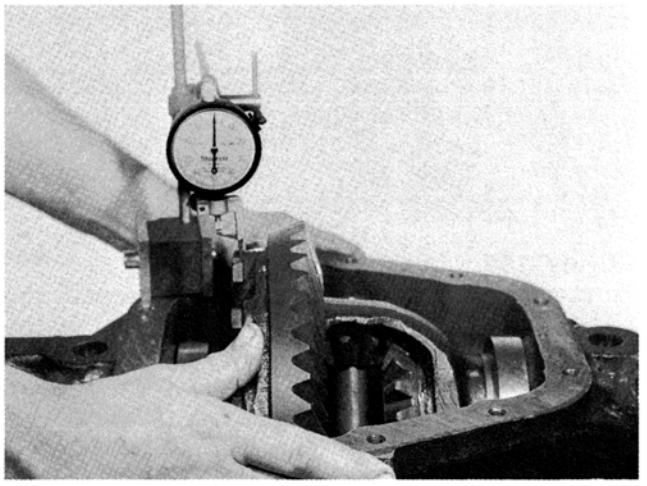


Figure 182 1019-185

Set up dial indicator as shown. Be sure to locate dial indicator on same location as marked in figure 163. Force ring gear into mesh with the pinion. Rock ring to allow the teeth of the gears to mesh. With force still applied to the differential case, set indicator at zero "0".

Tool: #D-128 Indicator.

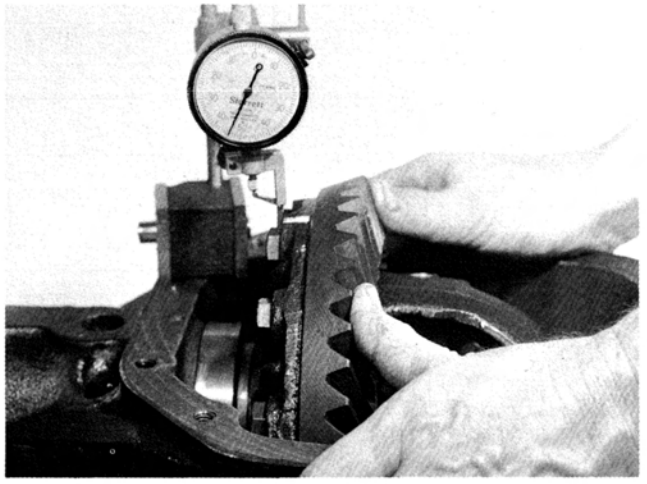


Figure 183 1019-186

Force the differential case (ring gear) away from the pinion gear to obtain an indicator reading. Repeat until the same reading is obtained each time. This reading will be the necessary amount of shims required between the differential case and differential bearings on the ring gear side. Remove indicator and differential case from the carrier. Remove master bearings from differential case.



Figure 184 1019-187

Assemble the required amount of shim onto hub (ring gear side) as determined in figure 186. Place bearing cone on hub of case. Use bearing installer to seat bearing cone as shown.

Tools: #C-4052-A Installer, #C-4171 Handle, #DD-914-42 Button.

Assemble the remaining of the total shim pack which was determined in figure 164 on the opposite side of the differential case. Add an additional .015" (.38 mm) of shims on this side to compensate for differential bearing preload. Assemble differential bearing, using the same tools as shown in figure 184.

In figure 164 (less pinion) a total of .107" indicator reading was recorded.

In figure 183 (with pinion) a total of .055" indicator reading was recorded. This leaves a balance .052" of shims for the opposite side and adds up to the .107" which was first recorded.

Add an additional .015" shims on the opposite side for bearing preload and backlash.

Ring Gear Side .055" (1.40 mm)
Opposite Side .052" (1.32 mm)
Opposite Side Preload .015" (.38 mm)

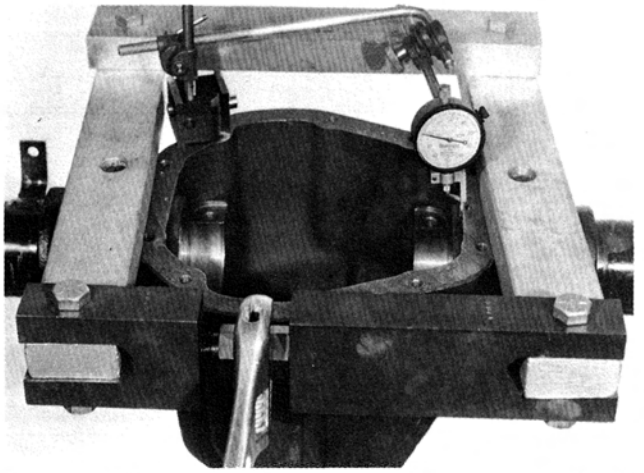


Figure 185 1019-188

Install spreader and indicator to carrier as shown. **Do not spread carrier over .015" (.38 mm).** Remove indicator.

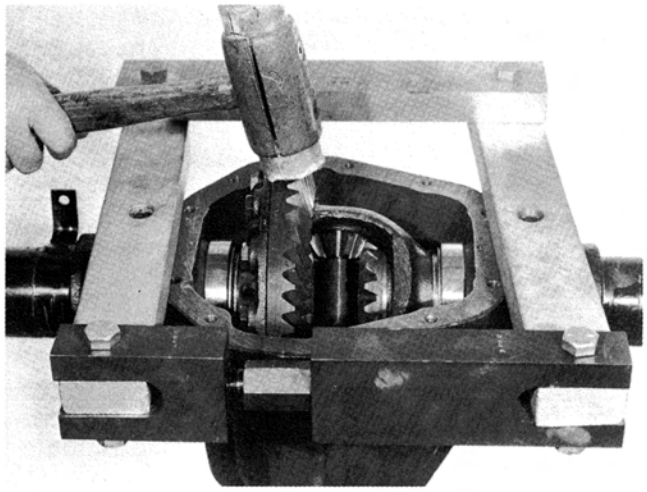


Figure 186 1019-189

Assemble differential bearing cups to differential bearing cones.

Install differential assembly into carrier.

Use a rawhide hammer to seat differential assembly into cross bore of carrier. Care should be taken to avoid nicking the teeth of the ring gear and pinion during assembly. Remove spreader.

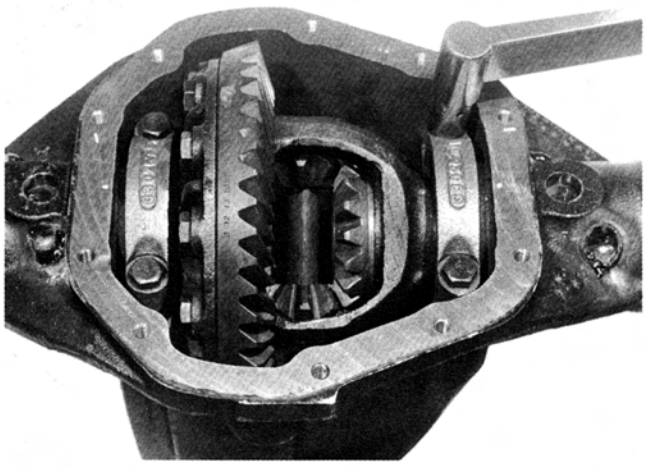


Figure 187 1019-190

Install bearing caps. Make sure the letters stamped on the caps correspond with those on the carriers. Torque bearing cap screws to 80-90 Lb. Ft. (108-122 N·m).

Tool: #C-524-A Torque Wrench.

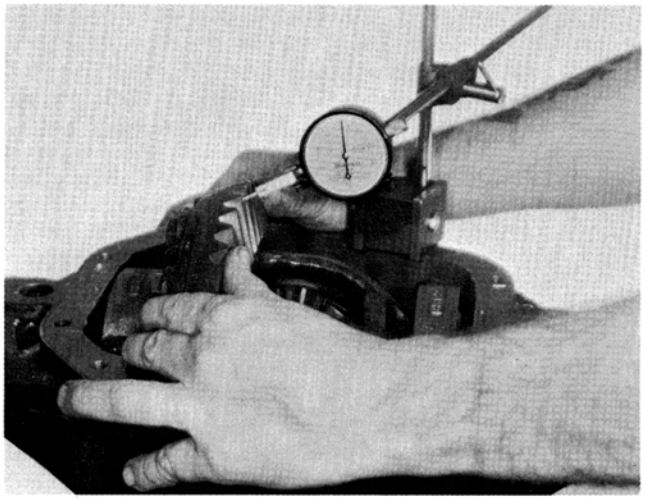


Figure 188 1019-191

Check ring gear and pinion backlash in three equally spaced points with dial indicator as shown.

Backlash tolerance is .004'' (mm .10-.23) to .009'' and cannot vary more than .002'' (mm .05) between points checked.

High backlash is corrected by moving the ring gear closer to the pinion.

Low backlash is corrected by moving ring gear away from the pinion.

These corrections are made by switching shims from one side of the differential case to the other.

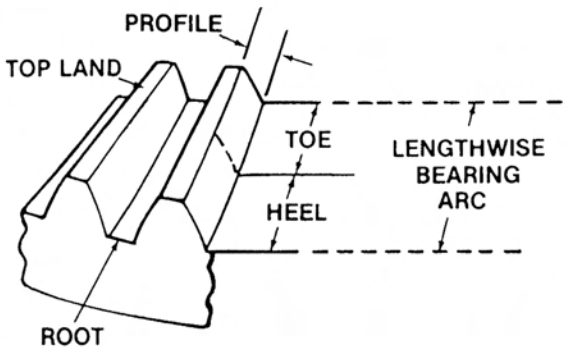
If backlash is to specification, check ring gear and pinion tooth contact pattern as follows and adjust accordingly.

RING GEAR & PINION TOOTH PATTERN INTERPRETATION

When setting the pinion position, many of the previous service manuals required a final pinion position check by using gauges that verified the dimension from the center line of the differential carrier (center line of ring gear) to the face of the pinion (button).

This surface (button) is not used on all new gears for verifying the pinion position. The service tools will be used to establish the proper amount of shims required prior to installing the pinion gear. The final pinion position will be verified by using the GEAR CONTACT PATTERN METHOD, as described below.

RING GEAR AND PINION TOOTH CONTACT PATTERN



RING GEAR TOOTH

The TOE of the gear tooth is the portion of the tooth surface at the end towards the center. The HEEL of the gear tooth is the portion of the tooth surface at the outer end. The TOP LAND of a gear tooth is the surface of the top of the tooth. Every gear has a characteristic pattern. The illustrations show typical patterns only, and explains how patterns shift as gear location is changed. When making pinion position changes, shims should be changed in the range of .002 inch (.05 mm) to .004 inch (.10 mm) until correct pattern has been obtained.

When a change in backlash is required, backlash shims should be changed in the range of 1½ times the amount of backlash required to bring the gears into specification. For example, if the backlash needed to be changed by .004 inch (.10 mm), the shim pack should be changed by .006 inch (.15 mm) as a starting point. The actual amount of backlash change obtained will vary depending upon the ratio and gear size.

High backlash is corrected by moving the ring gear closer to the pinion. Low backlash is corrected by moving the ring gear away from the pinion. These corrections are made by switching shims from one side of the differential case to the other.

NOTE

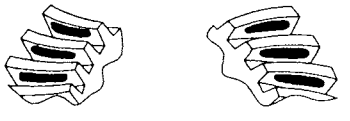
When making changes, note that two variables are involved. Example: If you have the backlash set correctly to specifications and you change the pinion position shim, you may have to readjust the backlash to the correct specification before checking the pattern. Refer to pattern interpretation.

WARNING: Gear teeth may have sharp edges. When handling gears, use care to avoid personal injury.

STEPS

(1) Paint ring gear teeth with a marking compound to both the drive and coast side.
(2) Rotate ring gear one complete revolution in both directions while load is being applied with a large screwdriver or similar tool between the carrier casting and differential case flange.

PATTERN INTERPRETATION (RING GEAR)

DRIVE SIDE HEEL TOE / COAST SIDE TOE HEEL	
	Normal or desirable pattern. The drive pattern should be centered on the tooth. The coast pattern should be centered on the tooth, but may be slightly toward the toe. There should be some clearance between the pattern and the top of the tooth.
	Backlash correct. Thinner pinion position shim required.
	Backlash correct. Thicker pinion position shim required.
	Pinion position shim correct. Decrease backlash.
	Pinion position shim correct. Increase backlash.

PATTERN MOVEMENTS SUMMARIZED

(1) Decreasing backlash moves the ring gear closer to the pinion.
Drive pattern (convex side of gear) moves slightly lower and toward the toe.
Coast pattern (concave side of gear) moves lower and toward the toe.

(2) Increasing backlash moves the ring gear away from the pinion.
Drive pattern moves slightly higher and toward the heel.
Coast pattern moves higher and towards the heel.

(3) Thicker pinion position shim with the backlash constant moves the pinion closer to the ring gear.
Drive pattern moves deeper on the tooth (flank contact) and slightly toward the toe.
Coast pattern moves deeper on the tooth and toward the heel.

(4) Thinner pinion position shim with the backlash constant moves the pinion further from the ring gear.
Drive pattern moves toward the top of the tooth (face contact) and toward the heel.
Coast pattern moves toward the top of the tooth and slightly toward the toe.

NOTE

If servicing the semi-float shaft riding bearing design unit, refer to the manual section for that unit. After installing axle shafts, a new lock pin is installed.

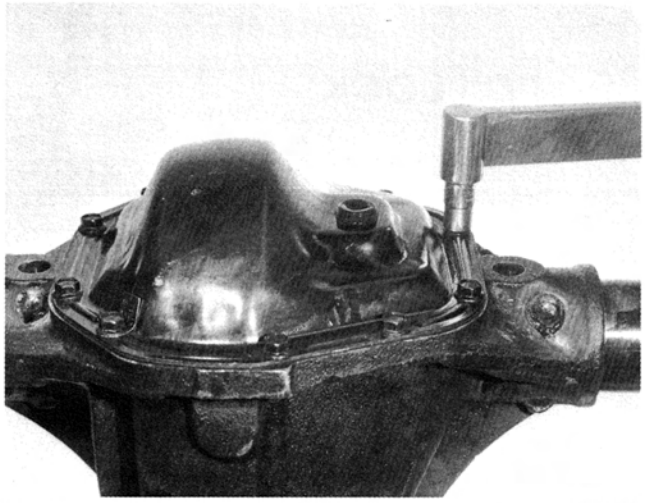


Figure 189 1019-192

Install new cover gasket and install cover plate. Torque screws to 30-40 Lb. Ft. (41-54 N·m).

Tool: #C-524-A Torque Wrench.

NOTE

There are two different design cover plates. One cover is of the flat mounting surface, and the other design is of the ribs between screw holes.

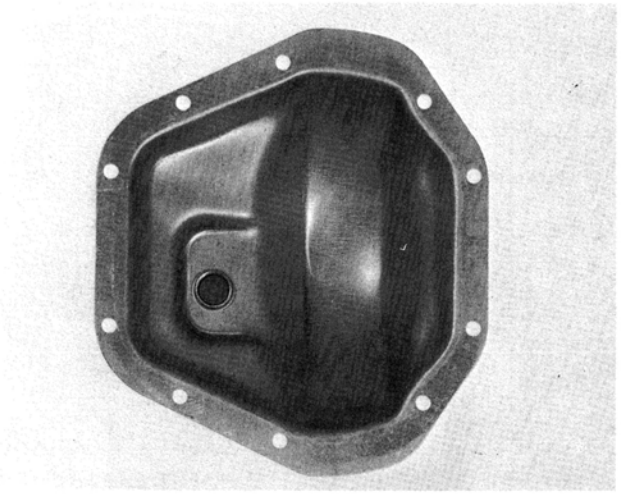


Figure 190 1019-193

Figure 190 shows the flat mounting surface cover plate on Dana design axles. This cover plate requires the use of a silicone rubber sealer material rather than a gasket.

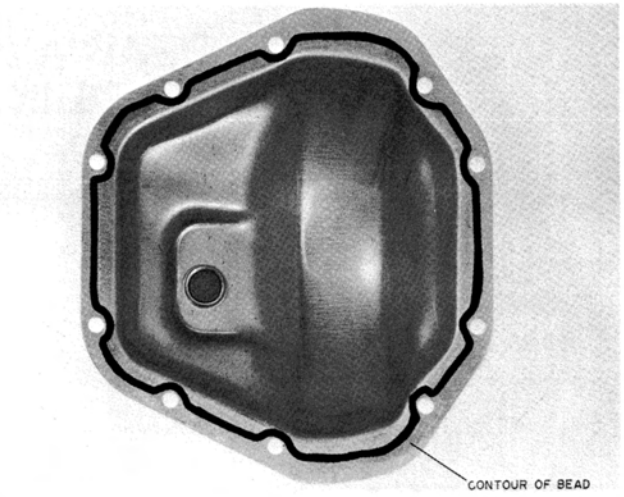


Figure 191 1019-194

The cover face of the carrier and the flat surface of the cover plate must be free of any oil film or foreign material.

Sealant material must meet specifications of ASTM3, GE303, A19, B37, E16, E36, Z1, Z2, and Z3 sealant.

Apply sealer to cover plate surface. Ensure that the sealer bead is laid on the inside of the cover screw holes. The bead is not to pass through the holes or outside of the holes.

The bead is to be 1/8" to 1/4" (3.18 - 6.35 mm) high and 1/8" to 1/4" (3.18 - 6.35 mm) wide.

Assemble two cover screws into cover at 8 o'clock and 2 o'clock position. Use these two holes to guide cover plate into position on the carrier.

Install remaining screws. Tighten alternately and evenly. Torque screws to 30-40 Lbs. Ft. (41-54 N•m).

Allow one hour cure time before filling carrier with the proper amount of specified lubricant and vehicle operation.

CARRIER SECTION

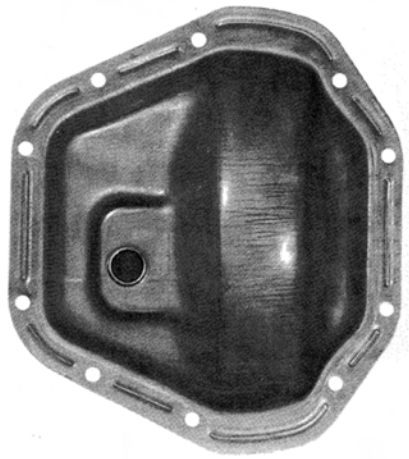


Figure 192 1019-195

On cover plate of the rib design, a gasket must be used. Do not use silicone sealer. Torque screws to 30-40 Lbs. Ft. (41-54 N·m).

REAR AXLE SEMI-FLOAT SHAFT RIDING BEARING DESIGN

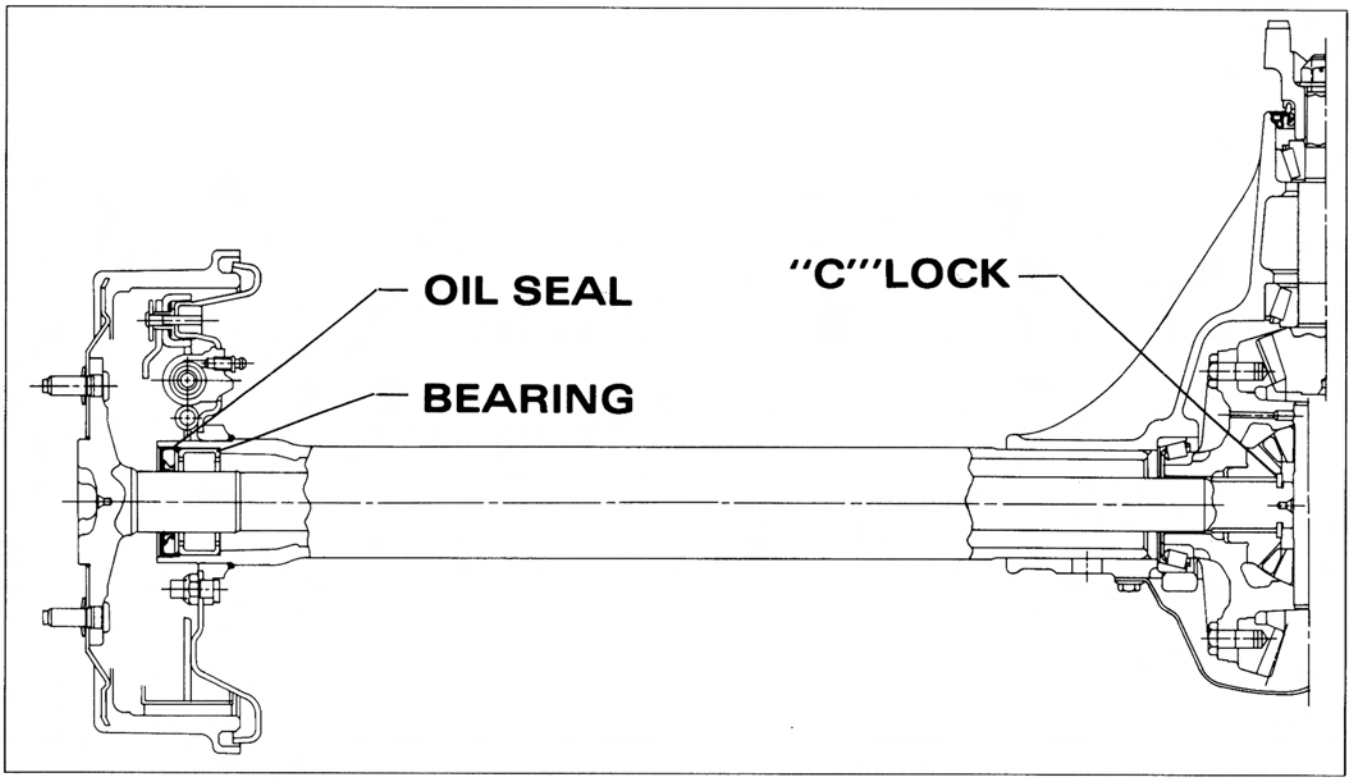


Figure 193 1019-196

REAR AXLE SEMI-FLOAT
SHAFT RIDING BEARING DESIGN

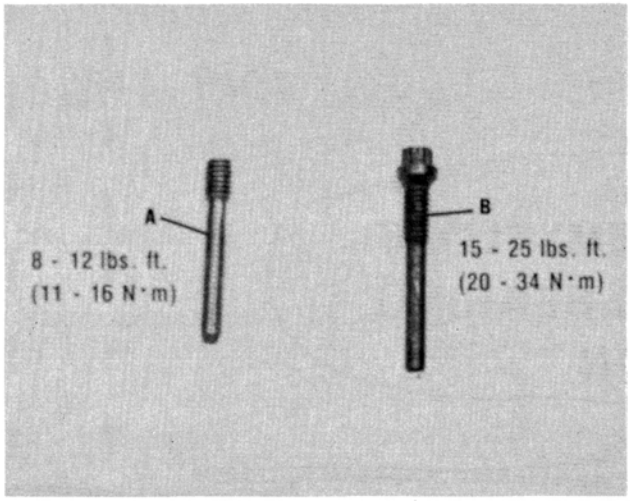


Figure 194 1019-197

Axles built in model year 1980 and model year 1981 used lockscrew style A. Starting in model year 1982, axles were built using lockscrew style B.

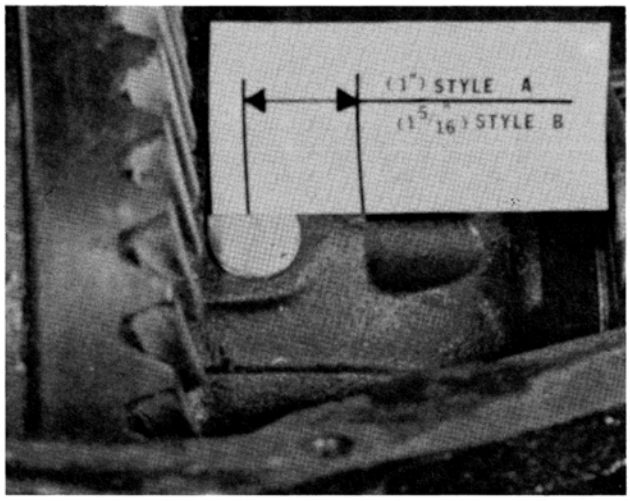


Figure 195 1019-198

CAUTION

THE LOCKSCREWS ARE NOT INTERCHANGEABLE. Care should be exercised to assure that the replacement lockscrew is identical to the one removed. To identify the case for proper screw selection, measure the distance from the centerline of the cross-shaft hole to the case surface where the lockscrew enters the case. If it measures approximately 1.000, it will require lockscrew style A. If it measures approximately 1.312, it will require lockscrew style B.

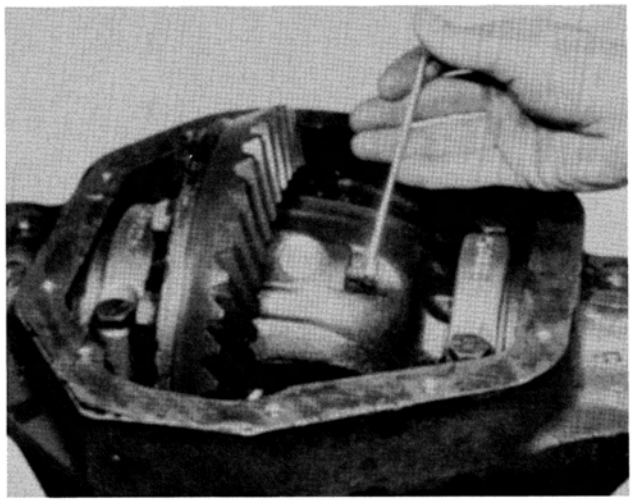


Figure 196 1019-199

Remove the differential pinion shaft lockscrew as shown.

NOTE

New lockscrews (style A) have locking type material on the threads that secures the pin when in place. New lockscrews (style B) have special threads that secures the pin when in place. Therefore, WHENEVER THE LOCKSCREW IS REMOVED, IT IS TO BE DISCARDED AND REPLACED WITH A NEW ONE. Before installing lockscrew, make sure hole is free of dirt and oil.

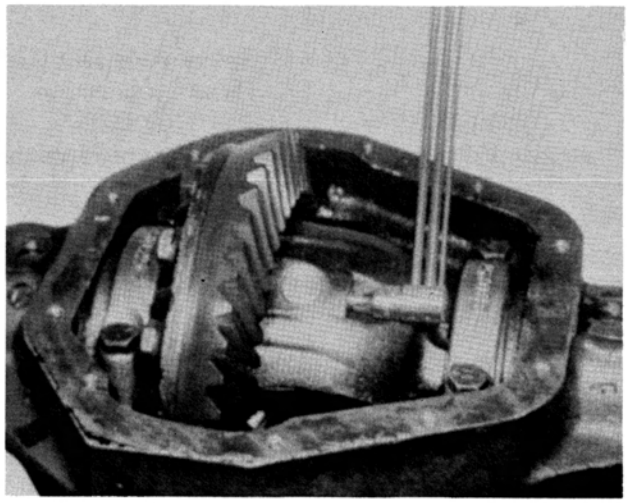


Figure 197 1019-200

Install lockscrew, making sure hole in the differential cross-shaft is lined up with the screw hole in the differential case. Make sure threads in differential case and on the lockscrew are free of dirt and oil. Torque lockscrew to 15-25 lbs. ft. (20-34 N•m) for style B and 8-12 lbs. ft. (11-16 N•m) for style A.

Tool: C-524-A Torque Wrench.

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