

DX60R

Shop Manual

K1042957E

Serial Number 50001 and Up

DOOSAN reserves the right to improve its products continuously, delivering the best possible product to the marketplace. These improvements can be implemented at any time with no obligation to change materials previously sold. It is recommended that consumers periodically contact their distributors for most recent documentation on purchased equipment.

This documentation may include attachments and optional equipment not available in your machine's package. Please call your distributor for additional items that you may require.

Illustrations used throughout this manual are used only as a representation of the actual piece of equipment, and may vary from the actual item.

DX60R

Serial Number 50001 and Up

Pub.No. K1042957E

Product Label



Instructions

**Trim Out The Label Along
The Lines And Insert Into
Pocket On The Binder Spine**

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Safety

Track Excavator Safety

Edition 1

MEMO

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Track Excavator Safety

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

TO THE OPERATOR OF A EXCAVATOR



DANGER

Unsafe use of the excavator could lead to serious injury or death. Operating procedures, maintenance and equipment practices or traveling or shipping methods that do not follow the safety guidelines on the following pages could cause serious, potentially fatal injuries or extensive damage to the machine or nearby property.

Please respect the importance of taking responsibility for your own safety, and that of other people who may be affected by your actions.

The safety information on the following pages is organized into the following sections:

1. "General Safety Essentials" on page 1-10
2. "Location of Safety Labels" on page 1-11
3. "Summary of Safety Precautions for Lifting in Digging Mode" on page 1-11
4. "Unauthorized Modifications" on page 1-13
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10. "Towing" on page 1-46
11. "Shipping and Transportation" on page 1-47
12. "Lifting With Sling" on page 1-47



WARNING

Improper operation and maintenance of this machine can be hazardous and could result in serious injury or death.

Operator and maintenance personnel should read this manual thoroughly before beginning operation or maintenance.

Keep this manual in the storage compartment to the rear of the operator's seat, and have all personnel involved in working on the machine read the manual periodically.

Some actions involved in operation and maintenance of the machine can cause a serious accident, if they are not done in a manner described in this manual.

The procedures and precautions given in this manual can be applied only to intended uses of the machine.

If you use your machine for any unintended uses that are not specifically prohibited, you must be sure that it is safe for any others. In no event should you or others engage in prohibited uses or actions as described in this manual.

DOOSAN delivers machines that comply with all applicable regulations and standards of the country to which it has been sent. If this machine has been purchased in another country or purchased from someone in another country, it may lack certain safety devices and specifications that are necessary for use in your country. If there is any question about whether your product complies with the applicable standards and regulations of your country, consult DOOSAN or your DOOSAN distributor before operating the machine.



SAFETY ALERT SYMBOL



Be Prepared - Get to Know All Operating and Safety Instructions.

This is the Safety Alert Symbol. Wherever it appears in this manual or on safety signs on the machine you should be alert to the potential for personal injury or accidents. Always observe safety precautions and follow recommended procedures.

Learn the Signal Words Used with the Safety Alert Symbol

The words **"CAUTION"**, **"WARNING"**, and **"DANGER"** used throughout this manual and on decals on the machine indicate degree of risk of hazards or unsafe practices. All three degrees of risk indicate that safety is involved. Observe precautions indicated whenever you see the Safety Alert "Triangle", no matter which signal word appears next to the "Exclamation Point" symbol.



CAUTION

This word is used on safety messages and safety labels and indicates potential threat of a hazardous situation that, if not avoided, could result in minor or moderate injury. It may also be used to alert against a generally unsafe practice.



WARNING

This word is used on safety messages and safety labels and indicates potential threat of a hazardous situation that, if not avoided, could result in serious injury or death. It may also be used to alert against highly unsafe practice.



DANGER

This word is used on safety messages and safety labels and indicates an imminent hazard of a situation that, if not avoided, is very likely to cause death or extremely serious injury. It may also be used to alert against equipment that may detonate or explode if handled or treated carelessly.

Safety precautions are described in SAFETY from page -11 on.

DOOSAN cannot predict every circumstance that might involve a potential hazard in operation and maintenance. Therefore the safety messages in this manual and on the machine may not include all possible safety precautions. If any procedures or actions not specifically recommended or allowed in this manual are used, you must be sure that you and others can do such procedures and actions safely and without damaging the machine. If you are unsure about the safety of any procedures, contact a DOOSAN distributor.

GENERAL SAFETY ESSENTIALS

Accessory Applications

The excavator has been primarily designed for moving earth with a bucket. For use as a grapple or for other object handling, contact DOOSAN for proper installation and application. Lifting-work applications (unless restricted or prohibited by local regulations) are permitted in approved lift configuration, to rated capacity only, with no side-loading. DO NOT use the machine for activities for which it was not intended. DO NOT use the bucket for lifting work, unless lift slings are used in the approved configuration.

Use of an accessory hydraulic hammer (breaker), work in rough terrain, demolition applications or other hazardous operation may require installation of additional protective structures to safeguard the operator.

Lifting Capacity Rating Configuration

Lifting capacity ratings that are printed at the end of this safety section are based on the machine being level, on a firm supporting surface, with hooks and slings attached in approved configuration. Loads must be balanced and supported evenly. Use tag lines to keep the load steady if wind conditions and large surface area are a problem. Work crew hand signals, individual tasks and safe procedures should all be universally understood before the lift is made.

IMPORTANT

Before using the excavator to make lifts check municipal and regional regulations or statutes that could apply. Governing ordinances may require that all heavy lifting be done with single purpose equipment specifically designed for making lifts, or other local restrictions may apply. Making heavy lifts with a general purpose excavator that can be used for digging, loading, grading or other work may be expressly forbidden by a regional injunction or other legal prohibition. Always follow all the other instructions, guidelines and restrictions for Safe Lifting in the Operation and Maintenance Manuals.

LOCATION OF SAFETY LABELS

Location of safety labels (decals) can vary from unit to unit. Refer to appropriate Operation and Maintenance Manual, and parts manual for your unit.

Always replace damaged or faded decals.

SUMMARY OF SAFETY PRECAUTIONS FOR LIFTING IN DIGGING MODE



DANGER

Unsafe use of the excavator while making rated lifts could cause serious, potentially fatal injuries or extensive damage to the machine or nearby property. Do not let anyone operate the machine unless they've been properly trained and understand the information in the Operation and Maintenance Manual.

To lift safely while in Digging Mode, the following items must be evaluated by the operator and the work site crew.

- Condition of ground support.
- Excavator configuration and attachments.
- Weight, lifting height and lifting radius.
- Safe rigging of the load.
- Proper handling of the suspended load.

Tag lines on opposite sides of the load can be very helpful in keeping a suspended load secure, if they are anchored safely to control points on the ground.



WARNING

NEVER wrap a tag line around your hands or body.

NEVER rely on tag lines or make rated lifts when wind gusts are more than 48.3 km/h (30 MPH). Be prepared for any wind gust when working with loads that have a large surface area.



WARNING

If you need more information or have any questions or concerns about safe operating procedures or working the excavator correctly in a particular application or in the specific conditions of your individual operating environment, please consult your local DOOSAN representative.

UNAUTHORIZED MODIFICATIONS

Any modification made without authorization or written approval from DOOSAN can create a safety hazard, for which the machine owner will be held responsible.

For safety's sake, replace all OEM parts with the correct authorized or genuine DOOSAN part. For example, not taking the time to replace fasteners, bolts or nuts with the correct replacement parts could lead to a condition where the safety of critical assemblies are dangerously compromised.

GENERAL HAZARD INFORMATION

Safety Rules

Only trained and authorized personnel can operate and maintain the machine.

Follow all safety rules, precautions and instructions when operating or performing maintenance on the machine.

Do not operate the machine if you are not feeling well, if you are taking medication that makes you feel sleepy, if you have been drinking, or if you are suffering from emotional problems. These problems will interfere with your sense of judgment in emergencies and may cause accidents.

When working with another operator or with a person on work site traffic duty, be sure that all personnel know the nature of the work and understand all hand signals that are to be used.

Always observe strictly any other rules related to safety.

Safety Features

Be sure that all guards and covers are installed in their proper position. Have guards and covers repaired immediately if damaged.

Be sure that you understand the method of use of safety features such as safety lock lever and the seat belt, and use them properly.

Never remove any safety features. Always keep them in good operating condition.

Failure to use safety features according to the instructions in the Operation and Maintenance Manual could result in serious bodily injury.

Inside Operator's Cabin

When entering the operator's cabin, always remove all mud and oil from the soles of your shoes. If you operate the travel pedal with mud or oil stuck to your shoes, your foot may slip and this may cause a serious accident.

After using the ashtray, make sure that any matches or cigarettes are properly extinguished, and be sure to close the ashtray. If the ashtray is left open, there is a danger of fire.

Do not stick suction pads to the window glass. Suction pads act as a lens and may cause fire.

Do not leave lighters laying around the operator's cabin. If the temperature inside the operator's cabin becomes high, there is a danger that the lighter may explode.

Do not use cellular telephones inside the operator's cabin when driving or operating the machine. There is a danger that this may lead to an unexpected accident.

Never bring any dangerous objects such as flammable or explosive items into the operator's cabin.

To ensure safety, do not use the radio or music headphones when operating the machine. There is a danger that this may lead to a serious accident.

When operating the machine, do not put your hands or head out of the window.

When standing up from the operator's seat, always place safety lock lever securely in the "LOCK" position. If you accidentally touch the work equipment levers when they are not locked, the machine may suddenly move and cause serious injury or damage.

When leaving the machine, lower the work equipment completely to the ground, set safety lock lever to the "LOCK" position and shut down engine. Use the key to lock all the equipment. Always remove the key and take it with you.

Clothing and Personal Protective Items

Secure long hair, and avoid loose clothing and jewelry. These items have the tendency to catch on controls or protrude into parts and cause serious injury or death.

Do not wear oily clothes. They are highly flammable.

Full eye protection, a hard hat, safety shoes and gloves may be required at the work site.

While working on the machine, never use inadequate tools. They could break or slip, causing injury, or they may not adequately perform intended functions.

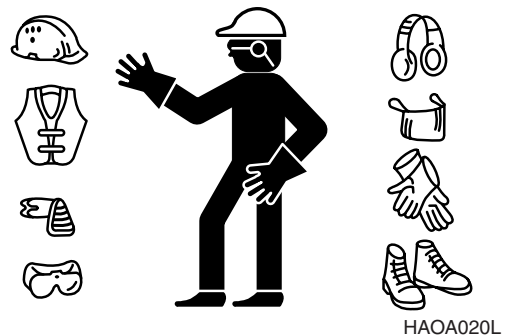


Figure 1

Breathing Masks, Ear Protection May Be Required

Do not forget that some risks to your health may not be immediately apparent. Exhaust gases and noise pollution may not be visible, but these hazards can cause disabling or permanent injuries.

NOTE: *The equivalent continuous A-weighted sound pressure level at the workstation for this machine is given in the operation manual.*

Measurement is obtained on a dynamic machine following the procedures and cabin conditions as described in ISO 6396.

NOTE: *The guaranteed sound power level emitted by the machinery for this machine is given in the operation manual.*

Measurement is obtained on a dynamic machine with the procedures as described in 2000/14/EC.

Vibration Level Information

Hands/Arms: The weighted root mean square acceleration to which the hands/arms are subjected, is less than 2.5 m/s^2 .

Whole body: The weighted root mean square acceleration to which the whole body is subjected, is less than 0.5 m/s^2 .

Measurements are obtained on a representative machine, using measuring procedures as described in the following standard: ISO 2631/1, ISO 5349, and SAE J1166.

Recommendations for Limiting Vibrations

1. Select the right machine, equipment and attachments for a particular application.
2. Replace any damaged seat by a genuine DOOSAN part. Keep the seat maintained and adjusted.
 - Adjust the seat and suspension for the weight and size of the operator.
 - Inspect and maintain the suspension and adjustment mechanisms of the seat regularly.
3. Check that the machine is properly maintained.
 - Tire pressure, brakes, steering, linkages, etc.
4. Steer, brake, accelerate, shift gears, move the attachments and load the attachments smoothly.
5. Adjust the machine speed and travel path to reduce the vibration level.

- Slow down if it is necessary when traveling through rough terrain.
 - When driving machine, avoid obstacles and excessive rough terrain.
6. Keep the machine on terrain where working and traveling conditions are good.
- Remove any large rocks or obstacles.
 - Fill any ditches and holes.
 - Provide machines for and schedule time to maintain good terrain conditions.
7. Travel over longer distance (e.g. on public roads) at adjusted (medium) speed.
- Always adjust the speed to prevent bouncing.

Mounting and Dismounting

Before getting on or off the machine, if there is any oil, grease, or mud on the handrails, steps, or track shoes, wipe it off immediately. Always keep these parts clean. Repair any damage and tighten any loose bolts.

Never jump on or off the machine. In particular, never get on or off a moving machine. These actions may lead to serious injury.

When getting on or off the machine, always face the machine, and maintain three-point contact (both feet and one hand or one foot and both hands) with the handrails, steps, and track shoes to ensure that you support yourself securely.

Never hold any control levers when getting on or off the machine.

Apply the door lock securely. If you grip the handrail inside the door when moving on top of the track shoes, and the door lock is not applied securely, the door may move and cause you to fall.

Use the points marked by arrows in the diagram when getting on or off the machine.

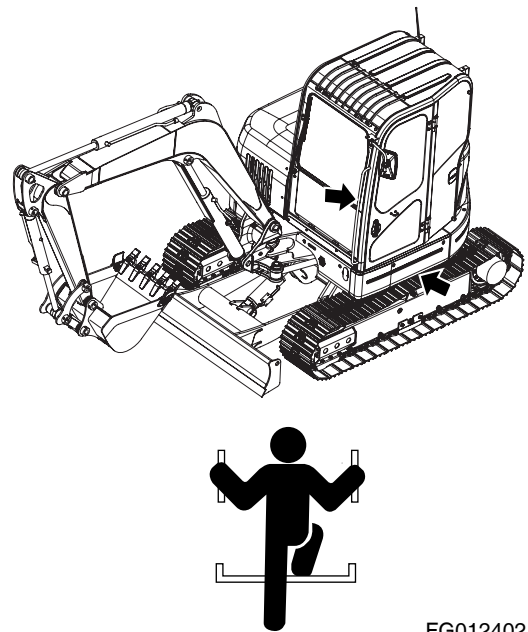


Figure 2

FG012402

Fuel, Oil and Hydraulic Fluid Fire Hazards

Fuel, oil and antifreeze will catch fire if it is brought close to a flame. Fuel is particularly flammable and can be hazardous.

Always strictly observe the following.

Add fuel, oil, antifreeze and hydraulic fluid to the machine only in a well ventilated area. The machine must be parked with controls, lights and switches turned "OFF". The engine must be "OFF" and any flames, glowing embers, auxiliary heating units or spark causing equipment must be extinguished, turned "OFF" and/or kept well clear of the machine.

Static electricity can produce dangerous sparks at the fuel filling nozzle. In very cold, dry weather or other conditions that could produce a static discharge, keep the tip of the fuel nozzle in constant contact with the neck of the fuel filling nozzle, to provide a ground.

Keep fuel and other fluid reservoir caps tight and do not start the engine until caps have been secured.

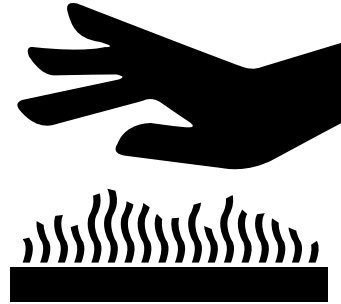


ARO1050S

Figure 3

Precautions When Handling Fluids at High Temperature

Immediately after operations are stopped, the coolant, engine oil, and hydraulic oil are at highest temperatures and the radiator and hydraulic tank are still under pressure. Attempting to remove the cap, drain the oil or coolant, or replace the filters may lead to serious burns. Always wait for the temperature to go down, and follow the specified procedures when carrying out these operations.



HAOA050L

Figure 4

To prevent hot coolant from spurting out, shut down engine, wait for the coolant to cool, then loosen the cap slowly to relieve the pressure.

To prevent hot oil from spurting out, shut down engine, wait for the oil to cool, then loosen the cap slowly to relieve the pressure.



HAOA060L

Figure 5

Asbestos Dust Hazard Prevention

Asbestos dust can be HAZARDOUS to your health if it is inhaled. Materials containing asbestos fiber can be present on work site. Breathing air that contains asbestos fiber can ultimately cause serious or fatal lung damage. To prevent lung damage from asbestos fiber, observe following precautions:

- Use a respirator that is approved for use in an asbestos-laden atmosphere.
- Never use compressed air for cleaning.
- Use water for cleaning to keep down the dust.
- Work on the machine or component with the wind at your back whenever possible.
- Always observe any regulations related to the work site and working environment.



ARO1770L

Figure 6

Injury from Work Equipment

Do not enter or put your hand, arm or any other part of your body between movable parts, such as between the work equipment and cylinders, or between the machine and work equipment.

If the control levers are operated, the clearance between the machine and the work equipment will change and this may lead to serious damage or personal injury.

If going between movable parts is necessary, always position and secure the work equipment so it cannot move.



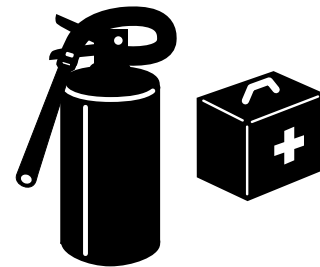
HDO1010L

Figure 7

Fire Extinguisher and First Aid Kit

As a precaution if any injury or fire should occur, always do the following.

- Be sure that fire extinguishers have been provided and read the labels to ensure that you know how to use them. It is recommended that an appropriately sized (2.27 kg [5 lb] or larger) multipurpose "A/B/C" fire extinguisher be mounted in the cabin. Check and service the fire extinguisher at regular intervals and make sure that all work site crew members are adequately trained in its use.
- Provide a first aid kit in the storage compartment and keep another at the work site. Check the kit periodically and make any additions if necessary.
- Know what to do in case of injury from fire.
- Keep emergency numbers for doctor, ambulance service, hospital and fire department near your telephone.



HDO1009L

Figure 8

If the machine catches fire, it may lead to serious personal injury or death. If a fire occurs during operation, escape from the machine as follows:

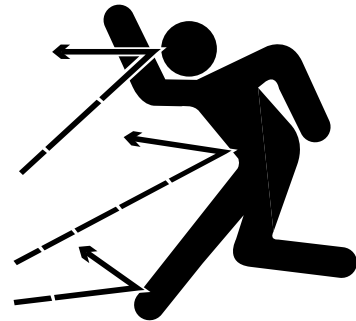
- Turn the starter switch to the "O" (OFF) position and shut down engine.
- If there is time, use the fire extinguisher to put out as much of the fire as possible.
- Use the handrails and steps to escape from the machine.

The above is the basic method for escaping from the machine, but changing the method may be necessary according to the conditions, so carry out practice drills at the work site.

Protection from Falling or Flying Objects

On work sites where there is a danger that falling objects or flying objects may hit the operator's cabin select a guard to match the operating conditions to protect the operator.

Working in mines, tunnels, deep pits or on loose or wet surfaces could produce danger of falling rock or hazardous flying objects. Additional protection for the operator's cabin could be required in the form of a FOPS (Falling Object Protective Structure) or window guards.



HAOA110L

Figure 9

Never attempt to alter or modify any protective structure reinforcement system, by drilling holes, welding, remounting or relocating fasteners. Any serious impact or damage to the system requires a complete integrity reevaluation. Reinstallation, recertification and/or replacement of the system may be necessary.

Contact your DOOSAN distributor for available safety guards and/or recommendations to prevent danger of getting hit by objects that could strike the operator's cabin. Make sure that all other work site crew members are kept well away from the excavator and safe from possible hazards.

For breaker operation, install a front guard and apply a laminated coating sheet to the front glass. Contact your DOOSAN distributor for recommendations.

When carrying out demolition or cutting operation, install a front guard and top guard, and apply a laminated coating sheet to the front glass.

When working in mines or quarries where there is a danger of falling rock, install FOPS (Falling Objects Protective Structure) and apply a laminated coating sheet to the front glass.

If any glass on the machine is broken, replace it with new glass immediately.



HAOA100L

Figure 10

Attachment Precautions

Option kits are available through your dealer. Contact DOOSAN for information on available one-way (single-acting) and two-way (double-acting) piping / valving / auxiliary control kits. Because DOOSAN cannot anticipate, identify or test all the attachments that owners may wish to install on their machines, please contact DOOSAN for authorization and approval of attachments, and their compatibility with optional kits.

Accumulator

The pilot control system is equipped with an accumulator. For a brief period of time after the engine has been shut down, the accumulator will store a pressure charge that may enable hydraulic controls to be activated. Activation of any controls may enable the selected function to operate under force of gravity.

When performing maintenance on the pilot control system, the hydraulic pressure in the system must be released as described in "Handling of Accumulator" in the Operation and Maintenance Manual.

The accumulator is charged with high-pressure nitrogen gas, so it is extremely dangerous if it is handled in the wrong way. Always observe the following precautions:

- Do not drill or make any holes in the accumulator or expose it to any flames, fire or heat source.
- Do not weld on the accumulator, or try attaching anything to it.
- When carrying out disassembly or maintenance of the accumulator, or when disposing of the accumulator, the charged gas must be properly released. Contact your DOOSAN distributor.
- Wear safety goggles and protective gloves when working on an accumulator. Hydraulic oil under pressure can penetrate the skin and cause serious injuries.

Indoor Ventilation

Engine exhaust gases can cause fatal accidents, and unconsciousness, loss of alertness, judgment and motor control and serious injury.

Make sure there is adequate ventilation before starting the engine in any enclosed area.

You should also be aware of open windows, doors or ductwork where exhaust may be carried, or blown by the wind, exposing others to danger.



ARO1770L

Figure 11

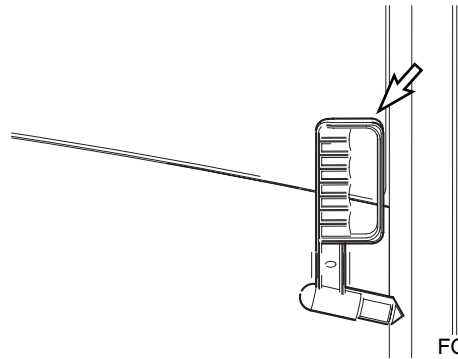
Emergency Exit

This machine is equipped with a glass breaking tool. It is to the left center of the cabin. This tool can be used in case of an emergency situation which requires the breaking of glass to exit from the cabin. Grip the handle firmly and use the sharp point to the glass.



WARNING

Protect your eyes when breaking the glass.



FG012452

Figure 12

BEFORE STARTING ENGINE

Work Site Precautions

Before starting operations, thoroughly check the area for any unusual conditions that could be dangerous.

Check the terrain and condition of the ground at the work site, and determine the best and safest method of operation.

Make sure the ground surface is as hard and horizontal as possible before carrying out operations. If there is a lot of dust and sand on the work site, spray water before starting operations.

If you need to operate on a street, protect pedestrians and cars by designating a person for work site traffic duty or by erecting fences and posting "No Entry" signs around the work site.

Erect fences, post "No Entry" signs, and take other steps to prevent people from coming close to or entering the work site. If people come close to a moving machine, they may be hit or caught by the machine, and this may lead to serious personal injury or death.

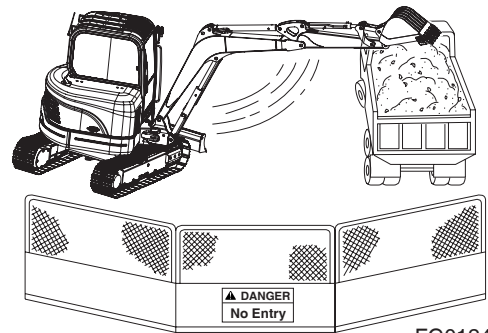
Waterlines, gas lines, phone lines and high-voltage electrical lines may be buried under the work site. Contact each utility and identify their locations. Be careful not to damage or cut any of these lines.

Check the condition of the riverbed, and the depth and flow of the water before operating in water or crossing a river. NEVER work in water that is more than the permissible water depth.

Any object in vicinity of boom could represent a potential hazard, or cause the operator to react suddenly and cause an accident. Use a spotter or signal person when working near bridges, phone lines, work site scaffolds, or other obstructions.

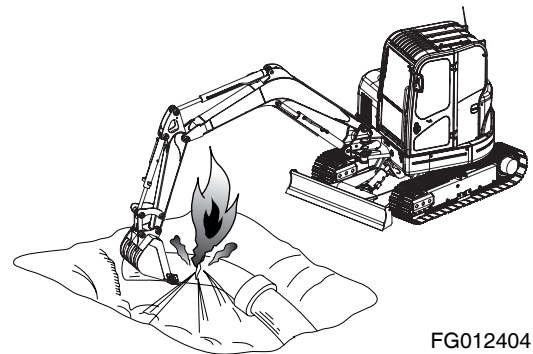
Minimum levels of insurance coverage, work permits or certification, physical barriers around the work site or restricted hours of operation may be mandated by governing authorities. There may also be regulations, guidelines, standards or restrictions on equipment that may have to be followed for local requirements. There may also be regulations related to performing certain kinds of work. If there is any question about whether your machine and work site complies with the applicable standards and regulations contact your local authorities and agencies.

Avoid entering soft ground. It will be difficult for the machine to escape.



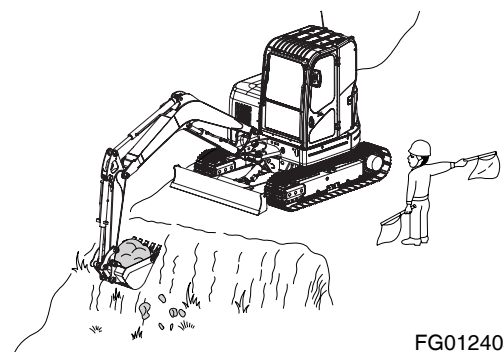
FG012403

Figure 13



FG012404

Figure 14



FG012405

Figure 15

Avoid operating your machine too close to the edge of cliffs, overhangs, and deep ditches. The ground may be weak in such areas. If the ground collapses, the machine could fall or tip over resulting in serious injury or death.

Remember that soil after heavy rain, blasting or after earthquakes, is weakened.

Newly laid earth and the soil near ditches is typically loose. It can collapse under the weight of vibration of your machine and cause your machine to tip over.

Install the head guard (FOPS) if working in areas where there is a danger of falling rocks.

Checks Before Starting Engine

Every day before starting the engine for the first time, carry out the following checks. If these checks are not carried out properly, there is a danger of serious injury.

Remove all wood chips, leaves, grass, paper and other flammable materials accumulated in the engine compartment and around the battery. They could cause a fire. Remove any dirt from the window glass, mirrors, handrails, and steps.

Do not leave tools or spare parts laying around in the operator's cabin. The vibration of the machine when traveling or during operations may cause them to fall and damage or break the control levers or switches. They may also get caught in the gap of the control levers and cause the work equipment to malfunction or move dangerously. This may lead to unexpected accidents.

Check the coolant level, fuel level, and hydraulic tank oil level, and check for clogged air cleaner and damage to the electrical wiring.

Adjust the operator's seat to a position where it is easy to operate the machine, and check the seat belt and mounts for damage and wear.

Check the operation of the gauges and the angle of the mirrors, and check that the safety lever is in "LOCKED" position.

If any abnormalities are found in the above checks, carry out repairs immediately.

Engine Starting

Walk around your machine before getting in the operator's cabin. Look for evidence of leaking fluid, loose fasteners, misaligned assemblies or any other indications of possible equipment hazard.

All equipment covers and machinery safety guards must be in place, to protect against injury while the machine is being operated.

Look around the work site area for potential hazards, people or property that could be at risk while operation is in progress.

NEVER start the engine if there is any indication that maintenance or service work is in progress, or if a warning tag is attached to controls in the cabin.

A machine that has not been used recently, or is being operated in extremely cold temperatures, could require a warm-up or maintenance service before start-up.

Check gauges and monitor displays for normal operation before starting the engine. Listen for unusual noises and remain alert for other potentially hazardous conditions at the start of the work cycle.

Do not short-circuit the starting motor to start the engine. This is not only dangerous, but may also damage the machine.

When starting the engine, sound the horn as an alert.

Start and operate the machine only while seated.

Before Operating Machine

If checks are not carried out properly after starting the engine, it may result in a delay in discovering abnormalities in the machine, and this may lead to personal injury or damage to the machine.

Carry out the checks in an open area where there are no obstructions. Do not let anyone near the machine when carrying out the checks.

- Check the operating condition of the equipment, and the movement of the bucket, arm, boom, travel, and swing systems.
- Check the machine for any abnormal noise, vibration, heat, smell, or abnormality with the gauges. Check also for leakage of air, oil, and fuel.
- If any abnormality is found, repair the problem immediately. If the machine is used without repairing the problems, it may lead to unexpected injury or failure.
- Clear all personnel from directly around machine and from the area.
- Clear all obstacles from the machine's path. Beware of hazards.
- Be sure that all windows are clean. Secure the doors and the windows in the open position or in the shut position.
- Adjust the rearview mirrors for best visibility close to the machine. Make sure that the horn, the travel alarm (if equipped), and all other warning devices are working properly.
- Fasten the seat belt securely.
- Warm up the engine and hydraulic oil before operating machine.
- Before moving the machine, check undercarriage position. The normal travel position is with idler wheels to the front under the cabin and the drive sprockets to the rear. When the undercarriage is in the reversed position, the travel controls must be operated in opposite directions.

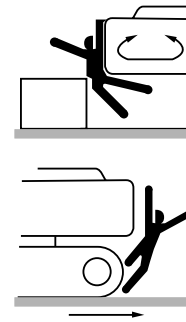
MACHINE OPERATION

When Swinging or Changing Direction of Travel

Before operating the machine or the work equipment, always observe the following precautions to prevent serious injury or death.

- Start and operate the machine only while seated.
- When changing travel direction from forward to reverse or from reverse to forward, reduce speed early and stop the machine before changing travel direction.
- Sound the horn to warn people in the area.
- Check that there is no one in the area around the machine. There are blind spots behind the machine, so if necessary, swing the upper structure to check that there is no one behind the machine before traveling in reverse.
- When operating in areas that may be hazardous or have poor visibility, designate a person to direct work site traffic.
- Ensure that no unauthorized person can come within the turning radius or direction of travel.

Be sure to observe the above precautions even if a travel alarm or mirrors are installed.



HAOA190L

Figure 16

Travel Precautions

Never turn the starting switch to the "O" (OFF) position when traveling. It is dangerous if the engine stops while the machine is traveling. It will be impossible to operate the steering.

Attachment control levers should not be operated while traveling.

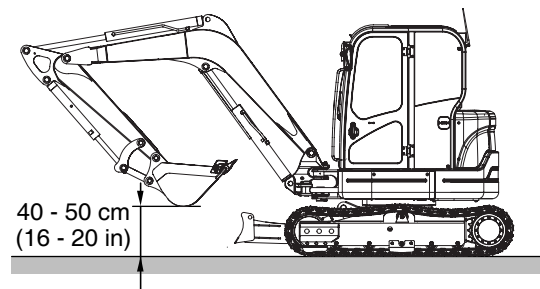
Do not change selected travel mode (FAST/SLOW) while traveling.

Fold in work equipment so the outer end of the boom is as close to the machine as possible, and is 40 - 50 cm (16 - 20 in) above ground.

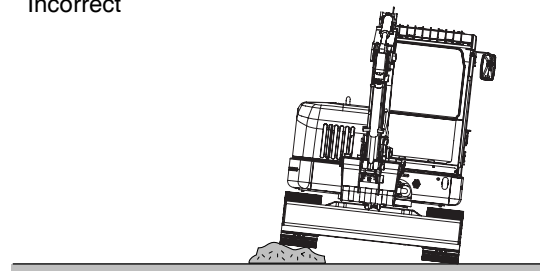
Never travel over obstacles or slopes that will cause the machine to tilt severely. Travel around any slope or obstacle that causes the machine to tilt 10 degrees or more to the right or left, or 30 degrees or more from front to rear.

Do not operate the steering suddenly. The work equipment may hit the ground and cause the machine to lose its balance, and this may damage the machine or structures in the area.

Travel Posture



Incorrect



FG012406

Figure 17

When traveling on rough ground, travel at low speed, and avoid sudden changes in direction.

Always keep to the permissible water depth. Permissible water depth is to the centerline of the upper track rollers.

When traveling over bridges or structures on private land, check first that the bridge or structure can withstand the weight of the machine. When traveling on public roads, check with the local authorities and follow their instructions.

Traveling on Slopes

Never jump onto a machine that is running away to stop it. There is a danger of serious injury.

Traveling on slopes could result in the machine tipping over or slipping.

On hills, banks or slopes, carry the bucket approximately 20 - 30 cm (8 - 12 in) above the ground. In case of an emergency, quickly lower the bucket to the ground to help stop the machine.

Do not travel on grass, fallen leaves, or wet steel plates. Even slight slopes may cause the machine to slip to the side, so travel at low speed and make sure that the machine is always traveling directly up or down the slope.

Avoid changing travel direction on a slope. This could result in tipping or sideslipping of the machine.

When possible, operate the machine up slopes and downslopes. Avoid operating the machine across the slope, when possible.

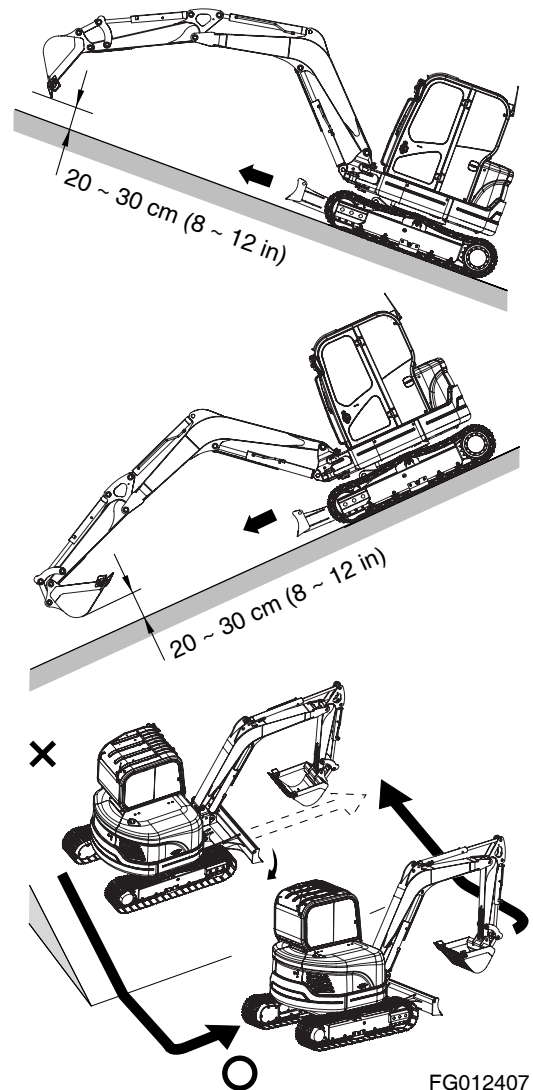


Figure 18

FG012407

Prohibited Operations

Do not dig the work face under an overhang. This may cause the overhang to collapse and fall on top of the machine.

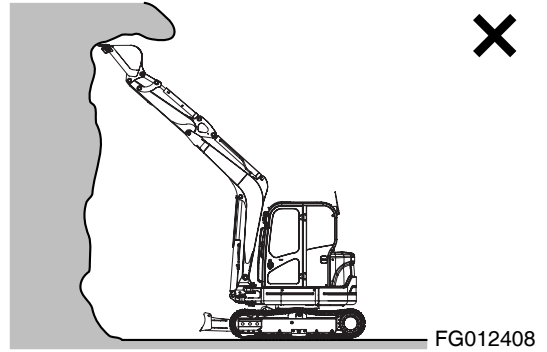


Figure 19

Do not carry out deep digging under the front of the machine. The ground under the machine may collapse and cause the machine to fall.

Working heavy loads over loose, soft ground or uneven, broken terrain can cause dangerous side load conditions and possible tipover and injury. Travel without a load or a balanced load may also be hazardous.

Never rely on lift jacks or other inadequate supports when work is being done. Block tracks fore and aft to prevent any movement.

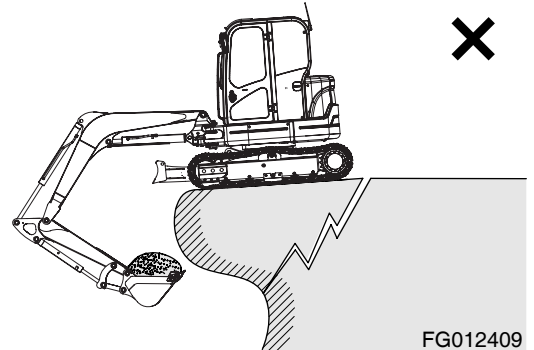


Figure 20

When using the machine, to prevent accidents caused by damage to the work equipment and overturning because of an excessive load, do not use the machine in excess of its ability (in terms of the maximum load and stability determined by the structure of the machine).

When working at the edge of an excavation or on a road shoulder, the machine could tip over, possibly resulting in serious injury or death. Investigate the configuration and ground conditions of the work site beforehand to prevent the machine from falling and to prevent the ground, stockpiles, or banks from collapsing.

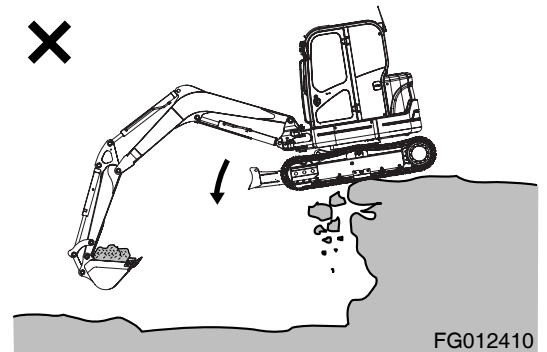


Figure 21

Precautions for Operation

Be careful not to mistakenly travel too close to the edge of a cliff.

Use the machine only for its main purpose. Using it for other purposes will cause failures.

To ensure a good view, always do the following:

- When working in dark areas, attach working lights and front lights to the machine. If necessary, set up lighting at the work site.
- Stop operations when the visibility is poor, such as in fog, mist, snow, and rain. Wait for the visibility to improve to a level which causes no problems for the operation.

To avoid hitting the work equipment, always do the following:

- When working in tunnels, on bridges, under electrical wires, or when parking the machine or carrying out other operations in places with limited height, be careful not to hit the bucket or other parts.
- To prevent collisions, operate the machine at a safe speed when working in confined spaces, indoors, or in crowded areas.
- Do not pass the bucket over the heads of workers or over the operator's cabin of dump truck.

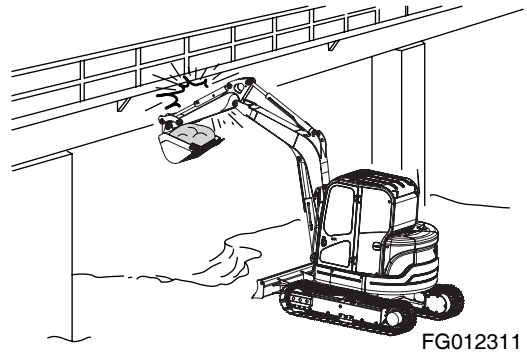


Figure 22

Avoid High-voltage Cables

Serious injury or death can result from contact or proximity to high-voltage electrical lines. The bucket does not have to make physical contact with power lines for current to be transmitted.

Use a spotter and hand signals to stay away from power lines not clearly visible to the operator.

Voltage	Minimum Safe Distance
6.6 kV	3 m (9' 10")
33.0 kV	4 m (13' 1")
66.0 kV	5 m (16' 5")
154.0 kV	8 m (26' 3")
275.0 kV	10 m (32' 10")

Use these minimum distances as a guideline only. Depending upon the voltage in the line and atmospheric conditions, strong current shocks can occur with the boom or bucket as faraway as 4 - 6 m (13 - 20 ft.) from the power line. Very high voltage and rainy weather could further decrease that safety margin.

NOTE: Before starting any operation near power lines (either above ground or buried cable type), you should

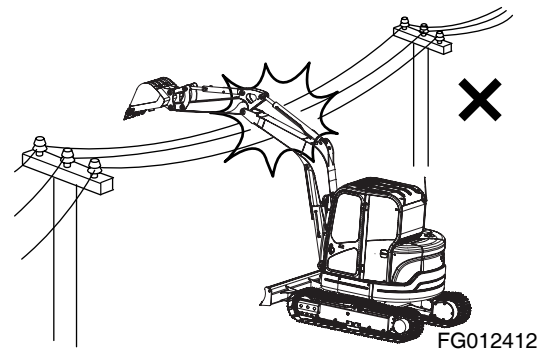


Figure 23

always contact the power utility company directly and work out a safety plan with them.

Operate Carefully on Snow, Ice and in Very Cold Temperatures

In icy cold weather avoid sudden travel movements and stay away from even slight slopes. The machine could skid off to one side very easily.

Snow accumulation could hide or obscure potential hazards. Use care while operating or while using the machine to clear snow.

Warming up the engine for a short period may be necessary, to avoid operating with sluggish or reduced working capacity. The jolting shocks and impact loads caused by bumping or bottoming the boom or attachment are more likely to cause severe stress in very cold temperatures. Reducing work cycle rate and workload may be necessary.

When the temperature rises, frozen road surfaces become soft, and machine travel becomes unstable.

In cold weather, do not touch metal surfaces with your bare hands. If you touch a metal surface in extremely cold weather, your skin may freeze to the metal surface.

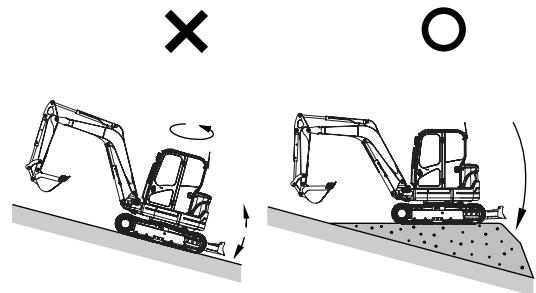
Operations on Slopes

When working on slopes, there is a danger that the machine may lose its balance and turn over, when swinging, or when work equipment is operated. Always carry out these operations carefully.

Do not swing the work equipment from the uphill side to the downhill side when the bucket is loaded. This operation is dangerous.

If the machine has to be used on a slope, pile the soil to make a platform that will keep the machine as horizontal as possible.

In addition, lower the bucket as far as possible, keep it pulled into the front, and keep the swing speed as low as possible.



FG012413

Figure 24

Parking Machine

Avoid making sudden stops, or parking the machine wherever it happens to be at the end of the workday. Plan so the excavator will be on firm, level ground away from traffic and away from high walls, cliff edges and any area of potential water accumulation or runoff. If parking on inclines is unavoidable, block the crawler tracks to prevent movement. Lower the bucket or other working attachment completely to the ground, or to an overnight support saddle. There should be no possibility of unintended or accidental movement.

When parking on public roads, provide fences, signs, flags, or lights, and put up any other necessary signs to ensure that passing traffic can see the machine clearly. Park the machine so the machine, flags, and fences do not obstruct traffic.

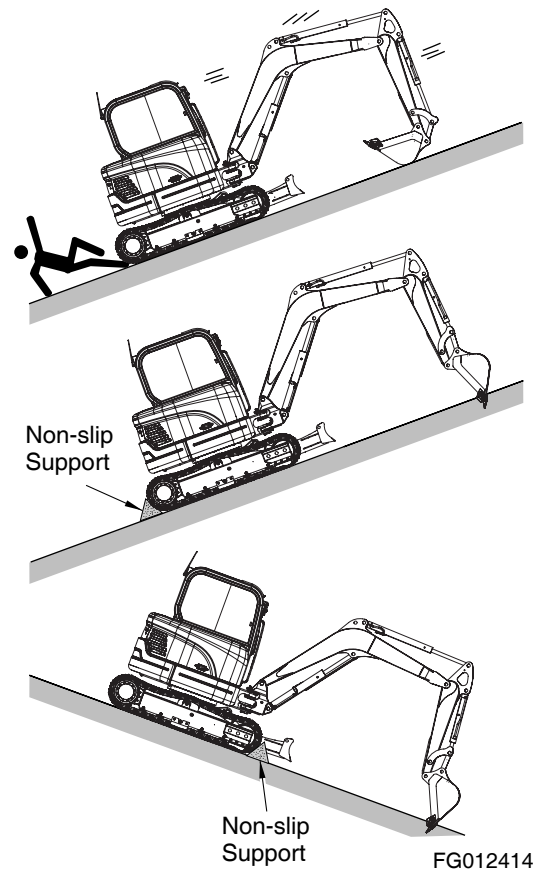


Figure 25

After the front attachment has been lowered to an overnight storage position and all switches and operating controls are in the "OFF" position, the safety lock lever must be set to the "LOCKED" position. This will disable all pilot circuit control functions.

Always close the door of the operator's cabin.

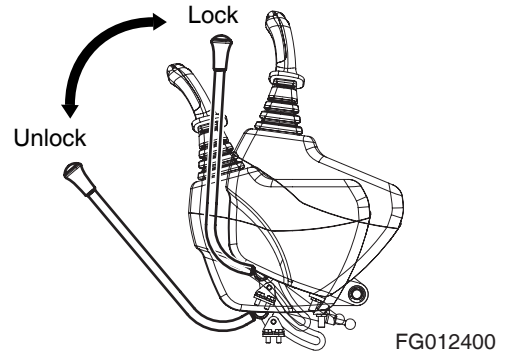


Figure 26

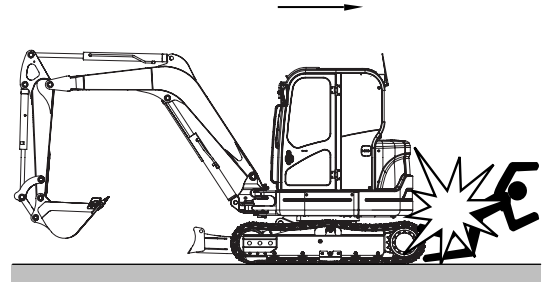
Precautions for Traveling in Reverse

Backing up is potentially dangerous because of restricted visibility.

Use a signalman when backing up.

- Watch for people nearby.
- Use horn or other signal to warn people nearby.
- Keep windows, mirrors and headlights clean and good repair at all times.

Slow down when visibility is poor because of dust, heavy rain, fog, or other conditions.

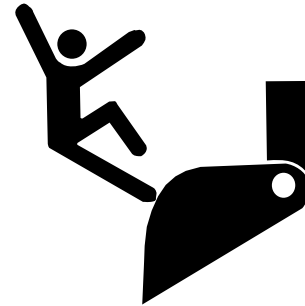


FG012415

Figure 27

Never Let Anyone Ride on Attachment

Never let anyone ride on any work attachment, such as the bucket, crusher, grapple, or clamshell (grab bucket). There is a danger of the person falling and suffering serious injury.



ARO1310L

Figure 28

MAINTENANCE

Warning Tag

Alert others that service or maintenance is being performed and tag operator's cabin controls – and other machine areas if required – with a warning notice. OSHA mandated control lever lockout can be made with any OSHA certified lockout device and a length of chain or cable to keep the safety lever in the fully lowered, nonactive position.

Warning tags, for controls are available from DOOSAN distributors.



FG012195

Figure 29

Clean Before Inspection or Maintenance

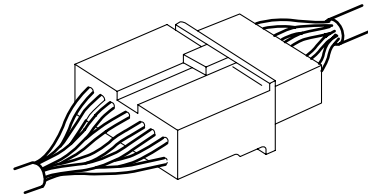
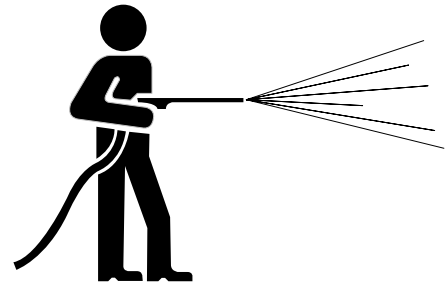
Clean the machine before carrying out inspection and maintenance. This prevents dirt from getting into the machine and ensures safety during maintenance.

If inspection and maintenance are carried out when the machine is dirty, it will become more difficult to locate the problems, and there is a danger that you may get dirt or mud in your eyes or that you may slip and injure yourself.

When washing the machine, do the following:

- Wear shoes with nonslip soles to prevent yourself from slipping and falling on wet places.
- Wear safety glasses and protective clothing when washing the machine with high-pressure steam.
- Take action to prevent touching high-pressure water and cutting your skin or having mud fly into your eyes.
- Do not spray water directly on electrical components (sensors, connector) (1, Figure 30). If water gets into the electrical system, there is a danger that it will cause defective operation and malfunction.

Pick up any tools or hammers that are laying in the workplace, wipe up any grease or oil or any other slippery substances, and clean the area to make it possible to carry out the operation in safety. If the workplace is left untidy, you may trip or slip and suffer injury.

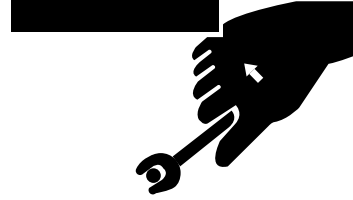


ARO1330L

Figure 30

Proper Tools

Use only tools suited to the task. Using damaged, low quality, faulty, or makeshift tools could cause personal injury. There is a danger that pieces from, chisels with crushed heads, or hammers, may get into your eyes and cause blindness.



HDO1037L

Figure 31

Use of Lighting

When checking fuel, oil, battery electrolyte, or window washing fluid, always use lighting with antiexplosion specifications. If such lighting equipment is not used, there is a danger of an explosion.

If work is carried out in dark places without using lighting, it may lead to injury, so always use proper lighting.

Even if the place is dark, never use a lighter or flame instead of lighting. There is a danger of fire. There is also danger that the battery gas may catch fire and cause an explosion.



HDO1040L

Figure 32

Fire Prevention and Explosion Prevention

All fuels, most lubricants and some coolant mixtures are flammable. Leaking fuel or fuel that is spilled onto hot surfaces or onto electrical components can cause a fire.

Store all fuels and all lubricants in properly marked containers and away from all unauthorized persons.

Store oily rags and other flammable material in a protective container.

Do not smoke while you refuel the machine or while you are in a refueling area.

Do not smoke in battery charging areas or in areas that contain flammable material.

Clean all electrical connections and tighten all electrical connections. Check the electrical wires daily for wires that are loose or frayed. Tighten all loose electrical wires before you operate the machine. Repair all frayed electrical wires before you operate the machine.

Remove all flammable materials before they accumulate on the machine.

Do not weld on pipes or on tubes that contain flammable fluids. Do not flame cut on pipes or on tubes that contain flammable fluids. Before you weld on pipes or on tubes or before you flame cut on pipes or on tubes, clean the pipes or tubes thoroughly with a nonflammable solvent.



HDO1015I

Figure 33

Burn Prevention

When checking the radiator coolant level, shut down engine, let the engine and radiator cool down, then check the coolant recovery tank. If the coolant level in the coolant recovery tank is near the upper limit, there is enough coolant in the radiator.

Loosen the radiator cap gradually to release the internal pressure before removing the radiator cap.

If the coolant level in the coolant recovery tank is below the lower limit, add coolant.

Cooling system conditioner contains alkali. Alkali can cause personal injury. Do not allow alkali to contact the skin, the eyes, or the mouth.

Allow cooling system components to cool before you drain the cooling system.

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

Remove the hydraulic tank filter plug only after the engine has been stopped. Make sure that the hydraulic tank filter plug is cool before you remove it with your bare hand. Remove the hydraulic tank filter plug slowly to relieve pressure.

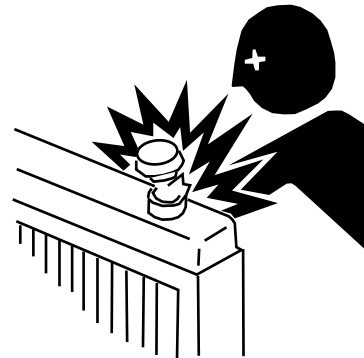
Relieve all pressure in the hydraulic oil system, in the fuel system, or in the cooling system before you disconnect any lines, fittings, or related items.

Batteries give off flammable fumes that can explode.

Do not smoke while you are checking the battery's electrolyte levels.

Electrolyte is an acid. Electrolyte can cause personal injury. Do not allow electrolyte to contact the skin or the eyes.

Always wear protective glasses when you work on batteries.



HAAE1980

Figure 34

Welding Repairs



CAUTION

When you connect or disconnect connectors between ECU and Engine or connector between ECU and the machine, always disconnect the source power to protect damage of the ECU.

If you don't observe this procedure, the ECU would be damaged or the engine would operate abnormally.

When carrying out welding repairs, carry out the welding in a properly equipped place. The welding should be performed by a qualified worker. During welding operations, there is the danger of, generation of gas, fire, or electric shock, so never let an unqualified worker do welding.

The qualified welder must do the following:

- To prevent explosion of the battery, disconnect the battery terminals and remove batteries.
- To prevent generation of gas, remove paint from the location of the weld.
- If hydraulic equipment, piping or places close to them are heated, a flammable gas or mist will be generated and there is a danger of it catching fire. To avoid this, never subject these places to heat.
- Do not weld on pipes or on tubes that contain flammable fluids. Do not flame cut on pipes or on tubes that contain flammable fluids. Before you weld on pipes or on tubes or before you flame cut on pipes or on tubes, clean the pipes or tubes thoroughly with a nonflammable solvent.
- If heat is applied directly to rubber hoses or piping under pressure, they may suddenly break, so cover them with a fireproof covering.
- Wear protective clothing.
- Make sure there is good ventilation.
- Remove all flammable objects and provide a fire extinguisher.

Preparation for Electrical Welding on Body Structure

To prevent damage to ECU by electrical welding, please observe the following procedures:

1. Open the hood of engine.
2. Detach the cover after loosening the bolts on the cover.
3. Detach the positive and negative terminal cables from the battery.
4. Open the door of cabin.
5. Detach the connector (1) from the ECU that is installed in the cabin.
6. Proceed with welding.
7. After welding, carefully reassemble the connector.
8. Connect the battery terminal cables.
9. Reassemble the cover over the battery.
10. Close the door of the battery cover.

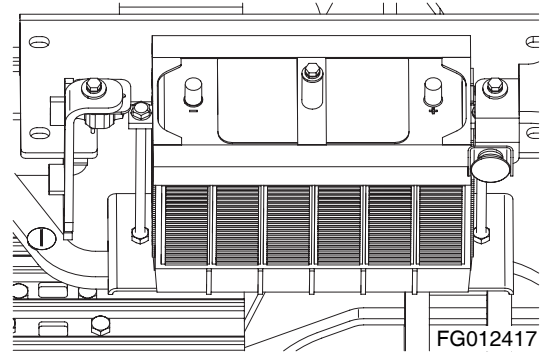


Figure 35

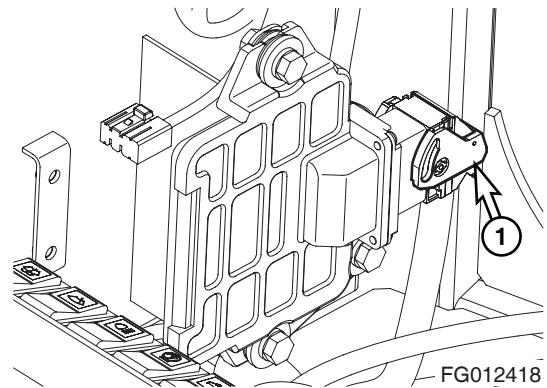


Figure 36

Warning for Counterweight and Front Attachment Removal

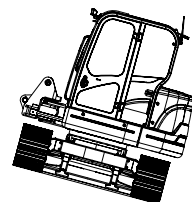
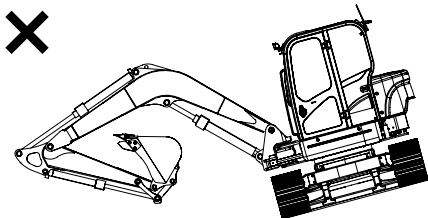


DANGER

DOOSAN warns any user, that removal of the counterweight from the machine, front attachment or any other part, may affect the stability of the machine. This could cause unexpected movement, resulting in death or serious injuries. DOOSAN is not liable for any misuse.

Never remove counterweight or front attachment unless the upper structure is in-line with the lower structure.

Never rotate the upper structure once the counterweight or front attachment has been removed.



FG012419

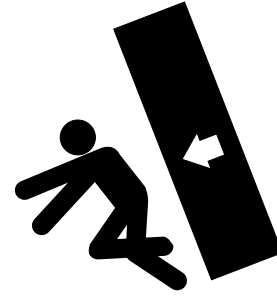
Figure 37

Precautions for Removal, Installation, and Storage of Attachments

Before starting removal and installation of attachments, decide on the team leader.

Do not allow anyone except the authorized workers close to the machine or attachment.

Place attachments that have been removed from the machine in a safe place so they do not fall. Put up a fence around the attachments and take other measures to prevent unauthorized persons from entering.



HDO1041L

Figure 38

Precautions When Working on Machine

When carrying out maintenance operations on the machine, keep area around your feet clean and tidy to prevent falls. Always do the following:

- Do not spill oil or grease.
- Do not leave tools laying about.
- Watch your step when walking.

Never jump down from the machine. When getting on or off the machine, use the steps and handrails, and maintain a three-point contact (both feet and one hand or both hands and one foot) to support yourself securely.

If the job requires it, wear protective clothing.

To prevent injury from slipping or falling, when working on the hood or covers, never use any area except the area equipped with nonslip pads.



ARO1380L

Figure 39

Lock Inspection Covers

When carrying out maintenance with the inspection cover open, lock the cover securely in position with the lock bar.

If maintenance work is carried out with the inspection cover open but not locked, there is a danger that it may suddenly close and cause injury if there is a gust of wind.

Prevention of Crushing and Cutting

You should always have at least two people working together if the engine must be run during service. One person needs to remain in the operator's seat, ready to work the controls or stop the machine and shut off the engine.

Unless you are instructed otherwise, never attempt adjustments while the machine is moving or while the engine is running.

Stay clear of all rotating parts and moving parts.

Keep objects away from moving fan blades. The fan blades will throw objects and the fan blades can cut objects.

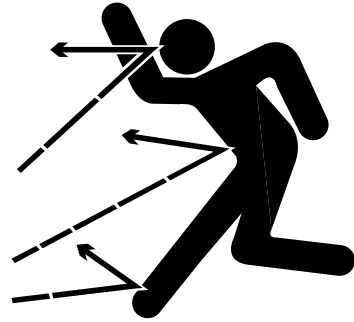
Do not use a wire rope cable that is kinked or flayed. Wear gloves when you handle a wire rope cable.

When you strike a retainer pin, the retainer pin might fly out. The loose retainer pin can injure personnel. Make sure that area is clear of people when you strike a retainer pin. To avoid injury to your eyes, wear protective glasses when you strike a retainer pin.

Track Tension Adjustment Requires Caution

Never turn out the track tension grease valve. To release pressure from the crawler frame track tension assembly, you should NEVER attempt to disassemble the track adjuster or attempt to remove grease fitting or valve assembly.

Keep your face and body away from the valve. Refer to the track adjustment procedure in the Operator and Maintenance Manual or Shop Manual.



HAOA110L

Figure 40

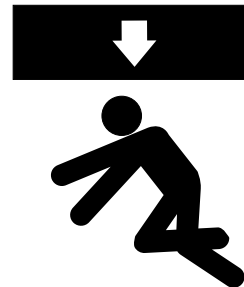
Supports and Blocks for Work Equipment

Do not allow weight or equipment loads to remain suspended.

Lower everything to the ground before leaving the operator's seat.

Do not use hollow, cracked or unsteady wobbling supports.

Do not work under any equipment supported only by a lifting jack.



HDO1042L

Figure 41

Action When Abnormality Is Found During Inspection

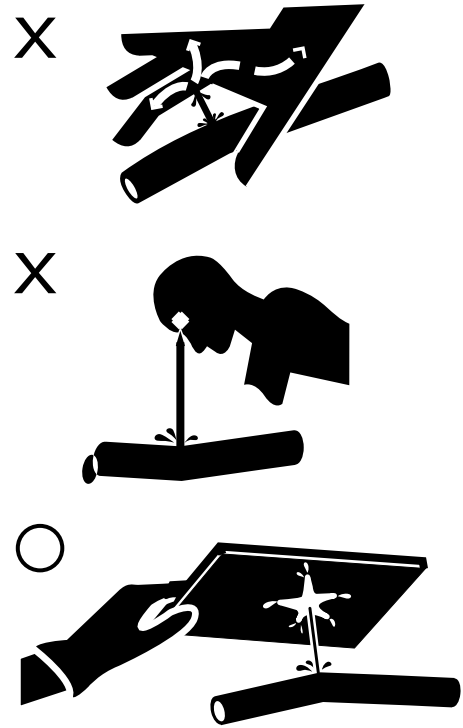
If any abnormality is found during inspection, always carry out repairs. In particular, if the machine is used when there are still problems with the brake or work equipment systems, it may lead to serious injury.

If necessary depending on the type of failure, please contact your DOOSAN distributor for repairs.

Precautions with High-pressure Lines, Tubes and Hoses

When inspecting or replacing high-pressure piping or hoses, check to verify that pressure has been released from the circuit. Failure to release the pressure may lead to serious injury. Always do the following:

- Wear protective glasses and leather gloves.
- Fluid leaks from hydraulic hoses or pressurized components can be difficult to see but pressurized oil has enough force to pierce the skin and cause serious injury. Always use a piece of wood or cardboard to check for suspected hydraulic leaks. Never use your hands or expose your fingers.
- Do not bend high-pressure lines. Do not strike high-pressure lines. Do not install lines, tubes or hoses that are bent or damaged.
- Make sure that all clamps, guards and heat shields are installed correctly to prevent vibration, rubbing against other parts, and excessive heat during operation.
 - If any of the following conditions are found, replace the part:
 - Damage or leakage from hose end.
 - Wear, damage, cutting of covering, or exposure of strengthening wire layer.
 - Cover portion is swollen in places.
 - There is twisting or crushing at movable parts of hose.
 - Foreign material is embedded in the covering.
 - Hose end is deformed.



HDO1045I

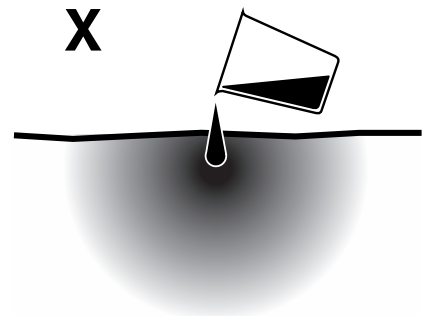
Figure 42

Waste Materials

Physical contact with used motor oil may pose a health risk. Wipe oil from your hands promptly and wash off any remaining residue.

Used motor oil is an environmental contaminant and may only be disposed of at approved collection facilities. To prevent pollution of the environment, always do the following:

- Never dump waste oil in a sewer system, rivers, etc.
- Always put oil drained from your machine in containers. Never drain oil directly onto the ground.
- Obey appropriate laws and regulations when disposing of harmful materials such as oil, fuel, solvent, filters, and batteries.



HAOA470L

Figure 43

Cabin Tilting

The machine has a tilting cabin for maintenance.

If it is necessary to work or look under cabin, use following procedure.

1. Fully extend arm and boom, and rest bucket on ground.
2. Shut down engine and "LOCK" left stand.
3. Remove two nuts and plain washers from rear floor.
4. Remove four screws and cover (1).
5. Remove two screws and cover (2)

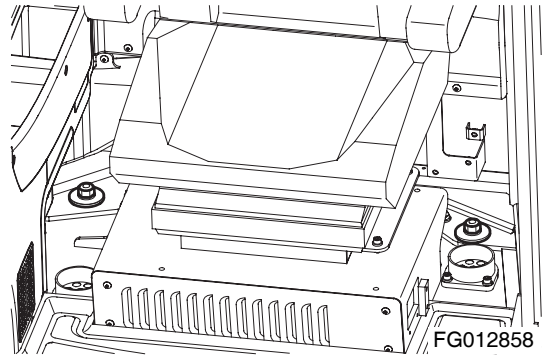


Figure 44



WARNING

1. **Only use a hand tool to raise cabin. Do not use an impact wrench.**
 2. **This operation should be done on firm, level ground.**
 3. **Make sure there is no one inside cabin when doing this operation.**
 4. **When raising cabin, do not allow anyone or any portion of their body under the cabin. Do not place any items under the cabin during this operation.**
 5. **Clear all personnel from surrounding area before tilting cabin.**
6. Rotate the cabin crank (3) with a M27 wrench to raise cabin.

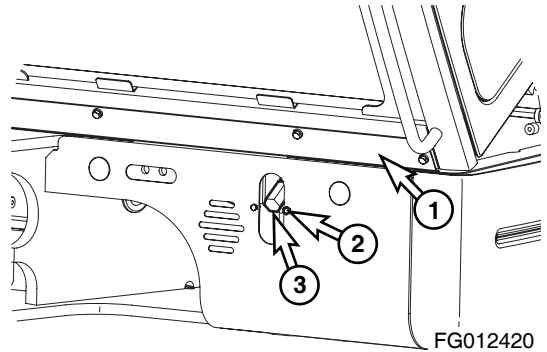


Figure 45



Figure 46

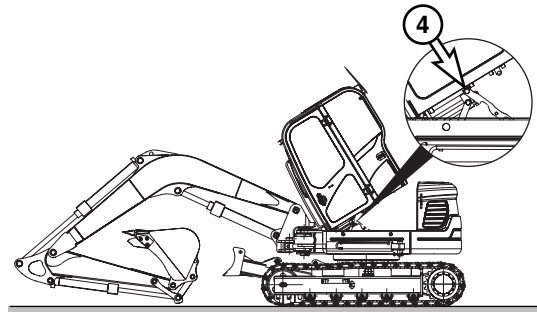
7. When cabin is raised to its proper angle, lower safety bar (4) and secure it to the main frame.



WARNING

Make sure that safety bar is secured before operating.

Do not replace tilting mechanism components with cabin tilted. (This may result in machine damage or personal injuries.)



FG012421

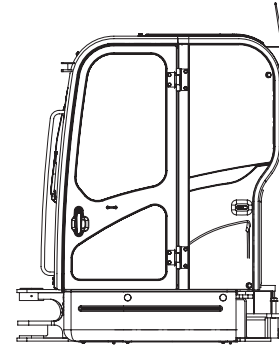
Figure 47

8. Follow this procedure in reverse order when finished.



WARNING

1. **Make sure there is nothing between cabin and main frame. This includes tools used for servicing machine or used to raise cabin.**
 2. **Watch cabin until it is resting on main frame.**
 3. **After releasing safety bar immediately lower cabin. Do not leave cabin raised with safety bar removed.**
-



FG012422

Figure 48

BATTERY

Battery Hazard Prevention

Battery electrolyte contains diluted sulfuric acid and batteries generate hydrogen gas. Hydrogen gas is highly explosive, and mistakes in handling them can cause serious injury or fire. To prevent problems, always do the following:

- Do not smoke or bring any flame near the battery.
- When working with batteries, ALWAYS wear safety glasses and rubber gloves.
- If you spill battery electrolyte on yourself or your clothes, immediately flush the area with water.
- If battery electrolyte gets into your eyes, flush them immediately with large quantities of water and see a doctor at once.
- If you accidentally drink battery electrolyte, drink a large quantity of water or milk, raw egg or vegetable oil. Call a doctor or poison prevention center immediately.
- When cleaning the top surface of the battery, wipe it with a clean, damp cloth. Never use gasoline, thinner, or any other organic solvent or detergent.
- Tighten the battery caps securely.
- If the battery electrolyte is frozen, do not charge the battery or start the engine with power from another source. There is danger that the battery may catch fire.
- When charging the battery or starting with power from another source, let the battery electrolyte melt and check that there is no leakage of battery electrolyte before starting the operation.
- Always remove the battery from the machine before charging.



Figure 49

HAAE2100

Boost Starting or Charging Engine Batteries

If any mistake is made in the method of connecting the booster cables, it may cause an explosion or fire. Always do the following:

- Turn off all electrical equipment before connecting leads to the battery. This includes electrical switches on the battery charger or boost starting equipment.
- When boost starting from another machine or vehicle do not allow the two machines to touch. Wear safety glasses or goggles while required battery connections are made.
- Connect positive cable first when installing cables and disconnect the negative cable first when removing them. The final cable connection, at the metal frame of the machine being charged or boost started, should be as far away from the batteries as possible.

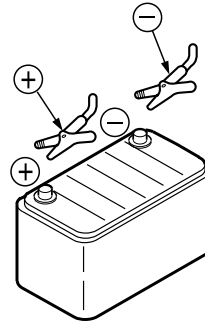


Figure 50

HAOA310L

TOWING

Precautions When Towing

If any mistake is made in the method of selecting or inspecting the towing wire or in the method of towing, it may lead to serious personal injury. Always do the following:

- Always use the method of towing given in this Operation and Maintenance Manual. Do not use any other method.
- Use leather gloves when handling the wire rope.
- When carrying out the preparation work for towing with two or more workers, determine the signals to use and follow these signals correctly.
- Always fit the towing rope to the left and right hooks and secure in position.
- If the engine on the problem machine will not start or there is a failure in the brake system, always contact your DOOSAN distributor.
- Never go between the towing machine and the towed machine during the towing operation.
- It is dangerous to carry out towing on slopes, so select a place where the slope is gradual. If there is no place where the slope is gradual, carry out operations to reduce the angle of the slope before starting the towing operation.
- When towing a problem machine, always use a wire rope with a sufficient towing capacity.
- Do not use a frayed, kinked rope or a rope with any loss of diameter.
- Do not use the lightweight towing hook for towing another machine.

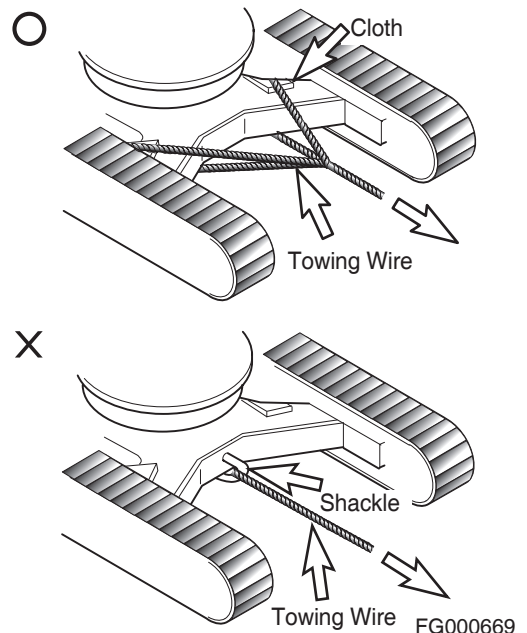


Figure 51

SHIPPING AND TRANSPORTATION

Obey State and Local Over-the-Road Regulations

Check state and local restrictions regarding weight, width and length of a load before making any other preparation for transport.

The hauling vehicle, trailer and load must all be in compliance with local regulations governing the intended shipping route.

Partial disassembly or teardown of the excavator may be necessary to meet travel restrictions or particular conditions at the work site. See the Shop Manual for information on partial disassembly.

Refer to the Transportation and Shipping section of this Operation and Maintenance Manual for information on loading, unloading and towing.

LIFTING WITH SLING

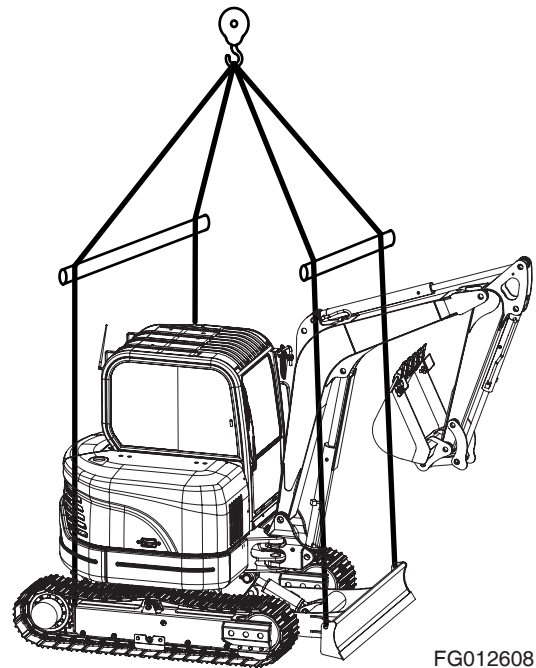


WARNING

Improper lifting can allow load to shift and cause injury or damage.

1. Refer to Specification section of this manual for information on weight and dimensions.
2. Use properly rated cables and slings for lifting.
3. Position machine for a level lift.
4. Lifting cables should have a long enough length to prevent contact with the machine. Spreader bars may be required.

NOTE: *If spreader bars are used, be sure that cables are properly secured to them and that angle of the cables is factored into the lift strength.*



FG012608

Figure 52

Specifications

Specification for DX60R

Edition 1

MEMO

Table of Contents

Specification for DX60R

Safety Precautions.....	5
Applicable Models	5
General Description	7
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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

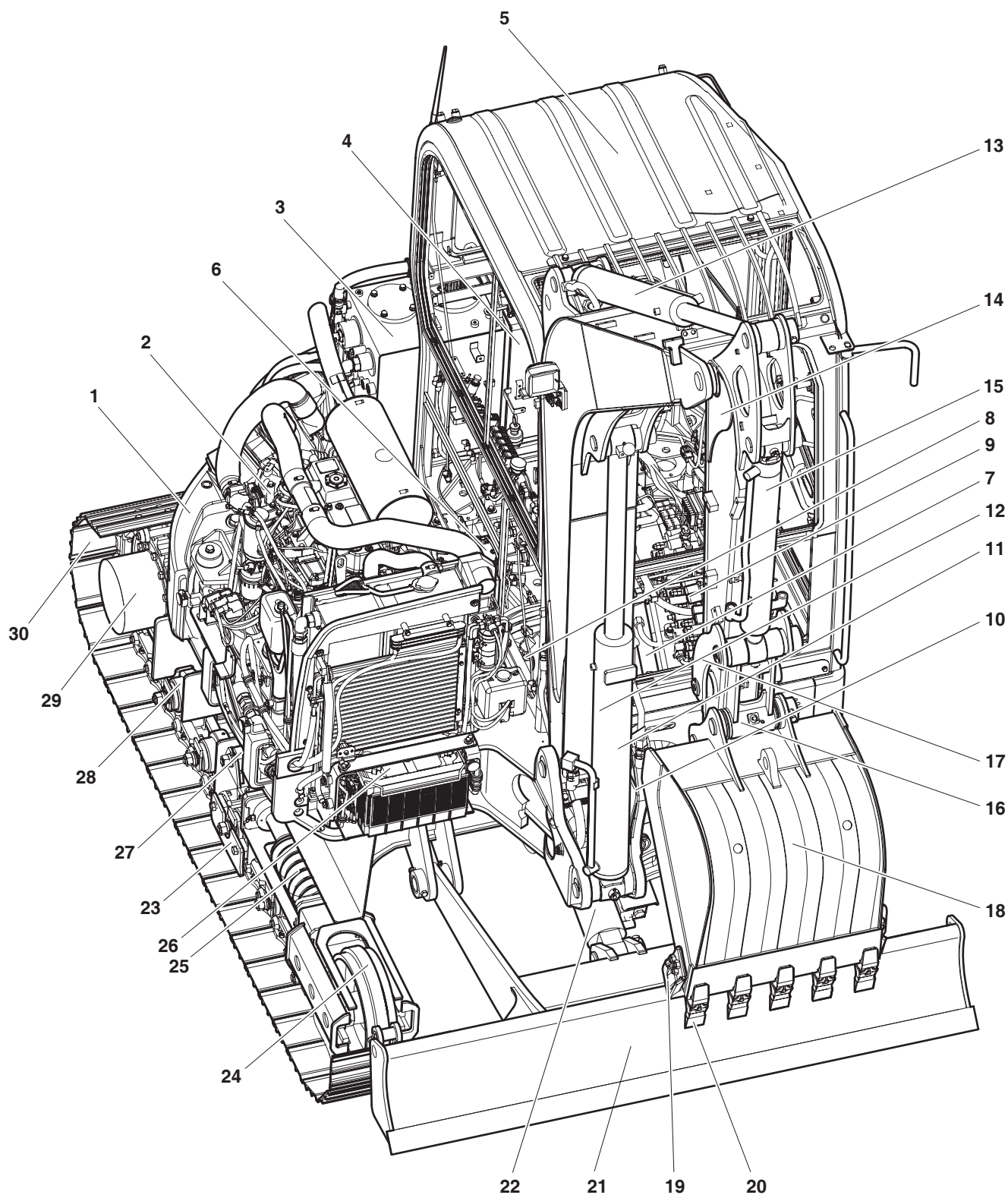
GENERAL DESCRIPTION

The excavator has three main component sections:

- The Upper Turntable
- The Lower Undercarriage and Track Frames
- The Excavator Front-end Attachment

The following illustration identifies main components and their locations. (See Figure 1 on page -8.)

COMPONENT LOCATIONS



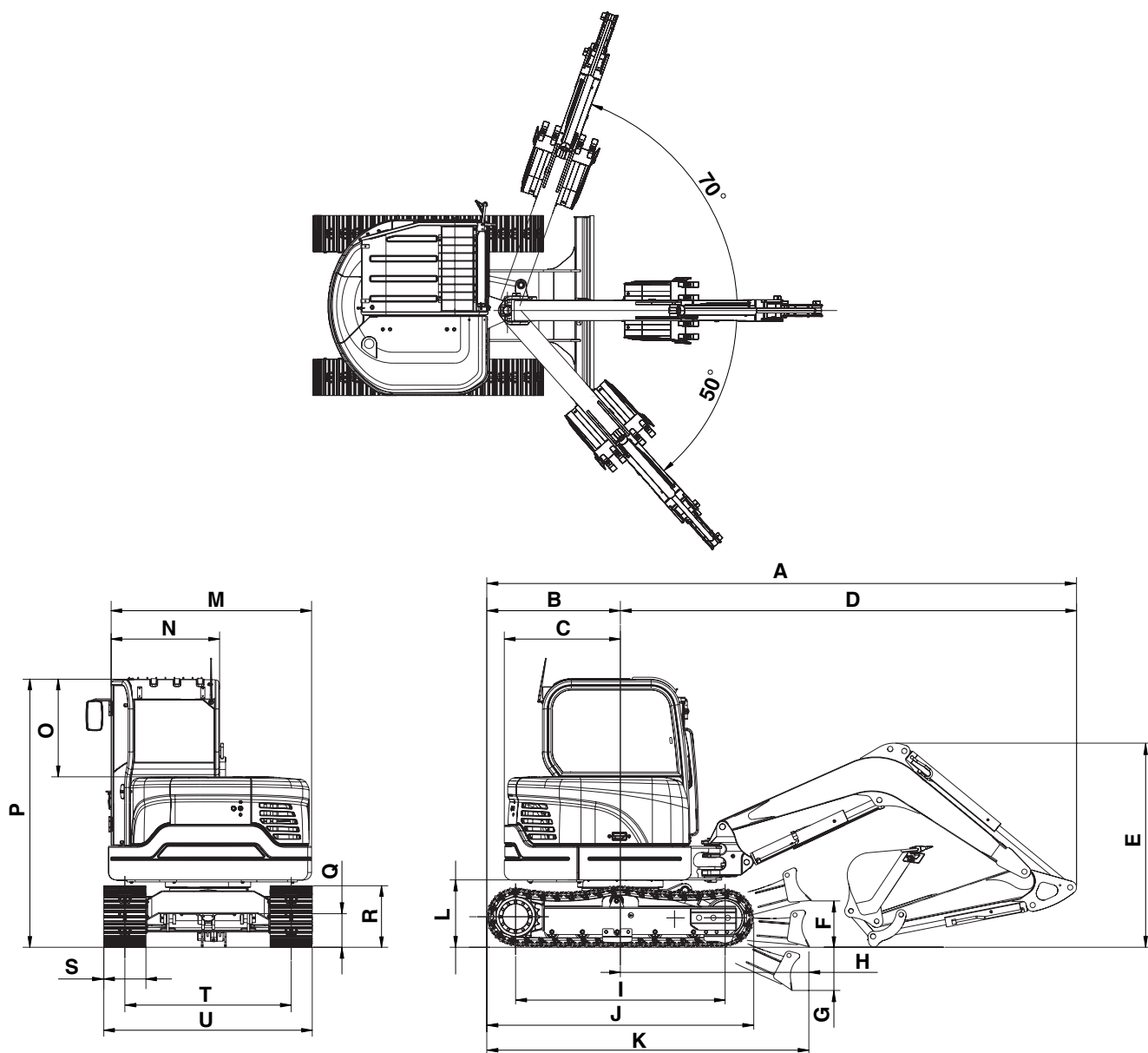
FG012434

Figure 1

Reference Number	Description
1	Counterweight
2	Engine
3	Hydraulic Oil Tank
4	Fuel Tank
5	Cabin
6	Swing Motor
7	Boom Swing Cylinder
8	Center Joint
9	Control Valves
10	Swing Bracket
11	Boom Cylinder
12	Boom
13	Arm Cylinder
14	Arm
15	Bucket Cylinder

Reference Number	Description
16	Push Link
17	Guide Link
18	Bucket
19	Side Cutter
20	Tooth Point
21	Blade
22	Blade Cylinder
23	Track Guide
24	Idler
25	Track Adjuster Idler
26	Battery
27	Upper Roller
28	Lower Roller
29	Travel Motor
30	Track Link and Shoe

OVERALL DIMENSIONS



FG012609

Figure 2

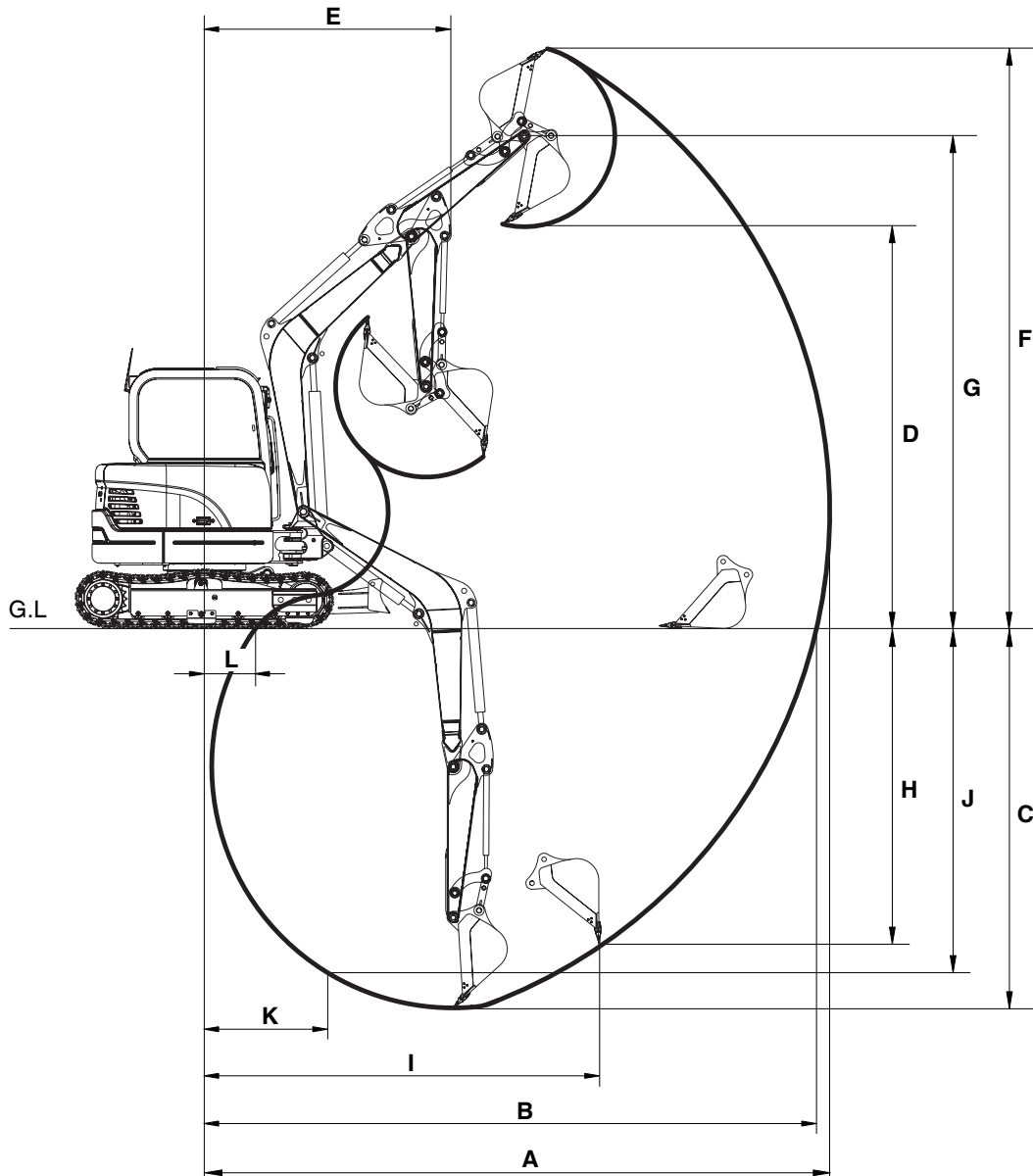
DIMENSION	2.9 m (9' 6") BOOM
	1.48 m (4' 10") ARM
A	5,602 mm (18' 4")
B	1,269 mm (4' 2")
C	1,102 mm (3' 7")
D	4,334 mm (14' 3")
E	1,939 mm (6' 4")
F	440 mm (1' 5")
G	410 mm (1' 4")
H	1,791 mm (5' 10")
I	1,990 mm (6' 6")
J	2,538 mm (8' 4")
K	3,060 mm (10' 0")
L	640 mm (2' 1")
M	1,904 mm (6' 3")
N	1,030 mm (3' 5")
O	927 mm (3' 0")
P	2,546 mm (8' 4")
Q	319 mm (1' 1")
R	584 mm (1' 11")
S	400 mm (1' 4")
T	1,580 mm (5' 2")
U	1,980 mm (6' 6")

WORKING RANGE



WARNING

The actual value for dimension "L" digging reach, depends on the stability and support provided by ground conditions. Digging too far underneath the excavator when soil conditions are wet, loose or unstable can collapse ground support, which could cause injury and/or equipment damage.



FG013195

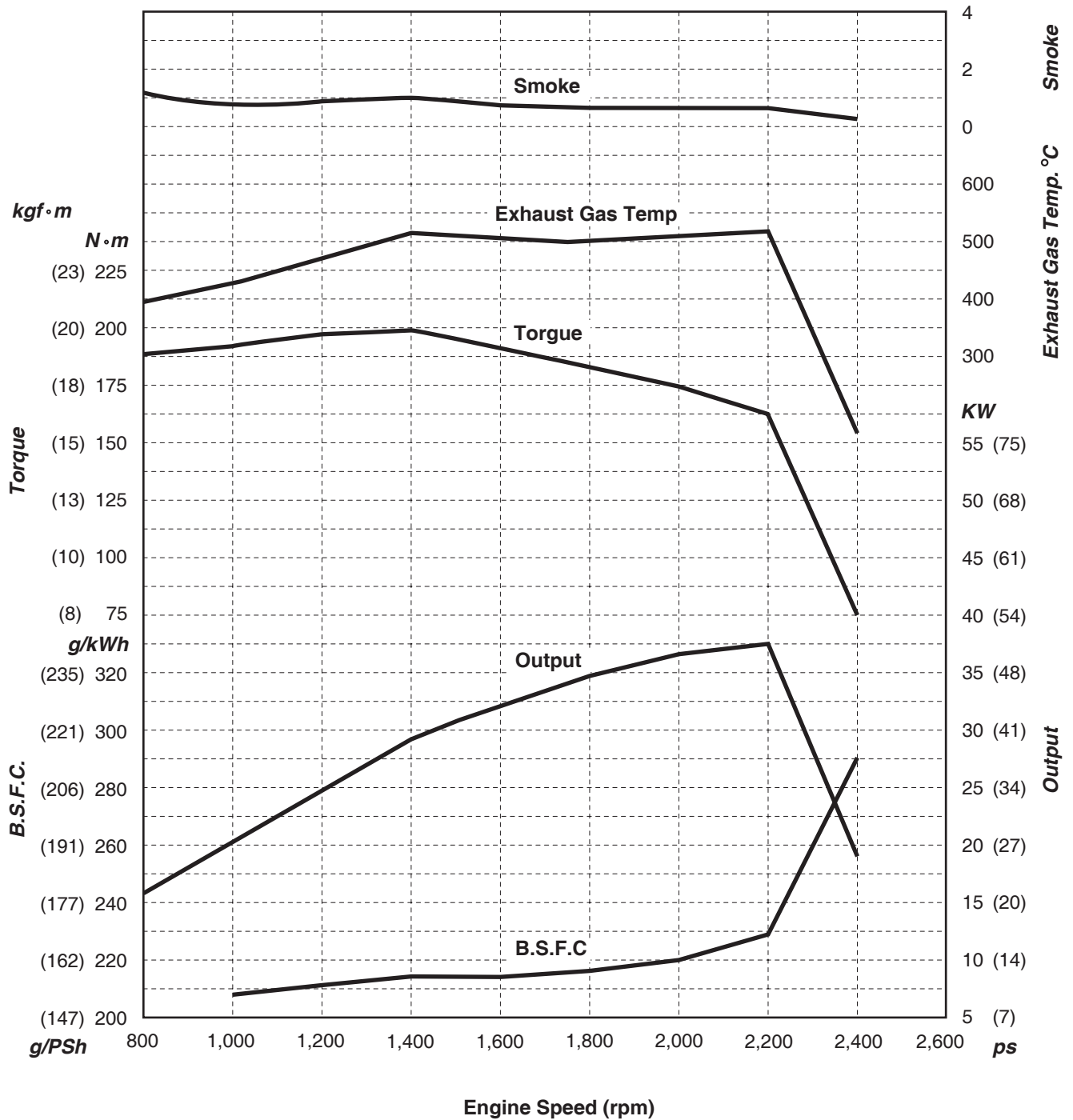
Figure 3

DIM.	BOOM TYPE	2.9 m (9' 6") BOOM	
	ARM TYPE	1.48 m (4' 10") ARM	1.9 m (6' 3") ARM
	BUCKET TYPE (PCSA / CECE)	0.175 m ³ (0.229 yd ³) / 0.151 m ³ (0.197 yd ³)	
A	Max. Digging Reach	6,130 mm (20' 1")	6,500 mm (21' 4")
B	Max. Digging Reach (Ground)	6,005 mm (19' 8")	6,380 mm (20' 11")
C	Max. Digging Depth	3,725 mm (12' 3")	4,145 mm (13' 7")
D	Max. Loading Height	3,940 mm (12' 11")	4,125 mm (13' 6")
E	Min. Swing Radius	2,415 mm (7' 11")	2,500 mm (8' 2")
F	Max. Digging Height	5,685 mm (18' 8")	5,855 mm (19' 2")
G	Max. Bucket Pin Height	4,830 mm (15' 10")	5,010 mm (16' 5")
H	Max. Vertical Wall Depth	3,095 mm (10' 2")	3,165 mm (10' 5")
I	Max. Radius Vertical	3,870 mm (12' 8")	4,415 mm (14' 6")
J	Max. Depth to 8 ft Line	3,320 mm (10' 11")	3,770 mm (12' 4")
K	Min. Radius 8 ft Line	1,115 mm (3' 8")	1,050 mm (3' 5")
L	Min. Digging Reach	485 mm (1' 7")	0 mm (0' 0")

STANDARD SPECIFICATIONS

COMPONENT			SPECIFICATION	
			1.48 m (4' 10") STANDARD ARM	1.9 m (6' 3") ARM
Bucket capacity	SAE (CECE)		0.175 m ³ (0.151 m ³)	
Operating weight			6.0 tons	6.13 tons
Engine	Model		4TNV98-ESDB6	
	Displacement (Total dis. Volume)		3,319 cc	
	Rated power (Gross)		50.4 hp @ 2,200 rpm	
			37.6 kW @ 2,200 rpm	
Front Attachment	Boom length		2,900 mm (9' 6")	
	Arm length		1,480 mm (4' 10")	1,900 mm (6' 3")
Transport Dimension	Length		5,600 mm (18' 4")	5,664 mm (18' 7")
	Height		2,560 mm (8' 5")	2,560 mm (8' 5")
	Height (Boom)		1,940 mm (6' 4")	2,188 mm (7' 2")
	Width		1,980 mm (6' 6")	1,980 mm (6' 6")
Performance	Max.digging force (ISO)	Bucket	39.9 KN	39.9 KN
		Arm	26 KN	22.6 KN
	Traveling speed	1-speed	2.07 km/h	
		2-speed	3.9 km/h	
	Swing speed		9.58 rpm	
	Drawbar pull		5,300 kg	
Hydraulic pump	Type		Variable displacement axial piston pump	
	Max. flow rate		49.3 x 2 l/min + 35.6 l/min (Gear pump: 9.9 l/min)	
	Main relief set pressure		230/210 kg/cm ² (21 - 23 MPa)	
Track	Shoe width		400 mm (1' 4")	
	Tumbler distance		1,990 mm (6' 7")	
Control	Lever control type		Hydraulic pilot	
	Lever pattern		SAE	
Tank	Fuel tank		78 ℓ	
	Hydraulic tank		65 ℓ	
Ground pressure			0.34 kg/cm ² (0.034 MPa)	

ENGINE PERFORMANCE CURVES



FG013211

Figure 4

MODEL NAME		4TNV98-ESDB6		REMARKS
Type		4 cycle, Inline, Water-cooled Diesel		
No.of cylinders - Bore × Stroke		mm	4 - ø98 × 110	
Combustion System			Direct Injection	
Compression Ratio			18.5	
Displacement		liter	3.319	
Net Rated Output		kW (PS)	37.3 (50.7)	With Yanmar US fan.
		min ⁻¹	2,200	
Gross Rated Output		kW (PS)	38.9 (52.9)	Without fan.
		min ⁻¹	2,200	
Max. Torque		kW (PS)	189 ~ 205.9	With Yanmar US fan.
		min ⁻¹	1,400 (+100/-100)	
Specific Fuel Consumption		g/kW-h (g/PS-h)	240 (177)	At net rated output
Ambient Condition			25°C, 750 mmHg, 30%	
Engine Speed at No Load	Max.	min ⁻¹	2,350	+10/-10
	Min.	min ⁻¹	1,050	+10/-10
Governorability	Governor Type		Electric governor ("ECO")	
	Temporary	%	Max. 12	Load 100% ↓ 0%
	Permanent	%	Max. 7	
	Recovery Time	sec	Max. 6	
	Stability	min ⁻¹	Max. 22	
Gradients	Longitudinal	deg	35 (30)	Intermitted (): continuous
	Lateral	deg	35 (30)	
Firing Order			1-3-4-2-1	Order from F.W.
Direction of Rotation			Counterclockwise	Viewed from F.W.
Engine Dry Weight		kg	Approx. 270	
Fuel Injection Timing		deg	FIR 3 +0.5/-0.5	FIT 14.0 B.T.D.C.
Fuel System	Fuel Type		Diesel oil	Sulfur : below 1,000 ppm
	Fuel Injection Pump		Distributor type (YPD-MP4), Yanmar made	
	Fuel Injection Nozzle		Hole type	
	Fuel Filter		Paper element	
Lubrication System	System		Forced feed	
	Oil Grade		API class CF, SAE grade 10W30	
	Oil Pump		Trochoid pump	
	Oil Filter		Paper element	
	Oil Capacity	liter	11.6	Max.
		liter	5.2	Effective.
	Oil Pressure	kgf/cm ²	3.5	At rated output
		kgf/cm ²	0.6	At low idle

MODEL NAME		4TNV98-ESDB6		REMARKS
Cooling System	Heat Exchanger		None	
	Pulley Ratio		1.125	
	Fan		7 - ø 460	
Air Cleaner			Not applicable	To be set by the technical bulletin, 071001 Technical Bullete in 07_105 (Intake_Exhaust pressure matching).pdf. Intial maximum restrictions: 2.9 kPa (300 mmAq).
Breather System			Closed type	
Muffler			ø 170 × 460	To be set by the technical bulletin, 071001 Technical Bullete in 07_105 (Intake_Exhaust pressure matching).pdf. Intial maximum restrictions: 12.7 kPa (1,300 mmAq).
Starting System	Starter		12V-3.0kW	
	Battery		130E41	
	Starting Aid		Air heater 500W	
Generator			12V-6A	
Engine Color			Black	
Applied Regulation		EPA Intermediate Tier 4, and EC stage 3A.		

APPROXIMATE WEIGHT OF WORKLOAD MATERIALS

IMPORTANT

Weights are approximations of estimated average volume and mass. Exposure to rain, snow or groundwater; settling or compaction because of overhead weight and chemical or industrial processing or changes because of thermal or chemical transformations could all increase value of weights listed in table.

MATERIAL	LOW WEIGHT OR DENSITY 1,100 kg•m ³ (1,850 LB/YD ³), OR LESS	MEDIUM WEIGHT OR DENSITY 1,600 kg•m ³ (2,700 LB/YD ³), OR LESS	HIGH WEIGHT OR DENSITY 2,000 kg•m ³ (3,370 LB/YD ³), OR LESS
Charcoal	401 kg•m ³ (695 lb/yd ³)	-----	-----
Coke, blast furnace size	433 kg•m ³ (729 lb/yd ³)	-----	-----
Coke, foundry size	449 kg•m ³ (756 lb/yd ³)	-----	-----
Coal, bituminous slack, piled	801 kg•m ³ (1,350 lb/yd ³)	-----	-----
Coal, bituminous r. of m., piled	881 kg•m ³ (1,485 lb/yd ³)	-----	-----
Coal, anthracite	897 kg•m ³ (1,512 lb/yd ³)	-----	-----
Clay, DRY, in broken lumps	1,009 kg•m ³ (1,701 lb/yd ³)	-----	-----
Clay, DAMP, natural bed	-----	1,746 kg•m ³ (2,943 lb/yd ³)	-----
Cement, Portland, DRY granular	-----	1,506 kg•m ³ (2,583 lb/yd ³)	-----
Cement, Portland, DRY clinkers	-----	1,362 kg•m ³ (2,295 lb/yd ³)	-----
Dolomite, crushed	-----	1,522 kg•m ³ (2,565 lb/yd ³)	-----
Earth, loamy, DRY, loose	-----	1,202 kg•m ³ (2,025 lb/yd ³)	-----
Earth, DRY, packed	-----	1,522 kg•m ³ (2,565 lb/yd ³)	-----
Earth, WET, muddy	-----	-----	1,762 kg•m ³ (2,970 lb/yd ³)
Gypsum, calcined, (heated, powder)	961 kg•m ³ (1,620 lb/yd ³)	-----	-----

MATERIAL	LOW WEIGHT OR DENSITY 1,100 kg•m³ (1,850 LB/YD³), OR LESS	MEDIUM WEIGHT OR DENSITY 1,600 kg•m³ (2,700 LB/YD³), OR LESS	HIGH WEIGHT OR DENSITY 2,000 kg•m³ (3,370 LB/YD³), OR LESS
Gypsum, crushed to 3 inch size	-----	1,522 kg•m ³ (2,565 lb/yd ³)	-----
Gravel, DRY, packed fragments	-----	-----	1,810 kg•m ³ (3,051 lb/yd ³)
Gravel, WET, packed fragments	-----	-----	1,922 kg•m ³ (3,240 lb/yd ³)
Limestone, graded above 2	-----	1,282 kg•m ³ (2,160 lb/yd ³)	-----
Limestone, graded 1-1/2 or 2	-----	1,362 kg•m ³ (2,295 lb/yd ³)	-----
Limestone, crushed	-----	1,522 kg•m ³ (2,565 lb/yd ³)	-----
Limestone, fine	-----	-----	1,602 kg•m ³ (2,705 lb/yd ³)
Phosphate, rock	-----	1,282 kg•m ³ (2,160 lb/yd ³)	-----
Salt	929 kg•m ³ (1,566 lb/yd ³)	-----	-----
Snow, light density	529 kg•m ³ (891 lb/yd ³)	-----	-----
Sand, DRY, loose	-----	1,522 kg•m ³ (2,565 lb/yd ³)	-----
Sand, WET, packed	-----	-----	1,922 kg•m ³ (3,240 lb/yd ³)
Shale, broken	-----	1,362 kg•m ³ (2,295 lb/yd ³)	-----
Sulfur, broken	529 kg•m ³ (1,620 lb/yd ³)	-----	-----

PERFORMANCE TESTS

1. Main Relief Pressure: 230 kg•cm² (3,271 psi)
2. Actuator Speeds

Operation		Unit	Basic Value
Boom	Up	sec	2.2 ± 0.3
	Down	sec	2.0 ± 0.3
Arm	Dump	sec	2.5 ± 0.3
	Crowd	sec	2.2 ± 0.3
Bucket	Dump	sec	3.6 ± 0.3
	Crowd	sec	2.3 ± 0.3
Dozer	Up	sec	2.4 ± 0.3
	Down	sec	3.1 ± 0.3
Boom Swing	L→R	sec	7.7 ± 0.5
	R→L	sec	8.8 ± 0.5
Swing (3 Revolutions)		sec	19.2 ± 1.0
Jack-up Speed (3 Turns)	1-speed	sec	28.4 ± 1.5
	2-speed	sec	14.8 ± 1.0
Travel Speed 20 m (66 ft)	1-speed	sec	34.9 ± 2.0
	2-speed	sec	18.6 ± 1.5
Travel Deviation 20 m (66 ft)	1-speed	mm (in)	300 (11.8)
	2-speed	mm (in)	300 (11.8)

EXCAVATOR PERFORMANCE STANDARDS

Evaluation of equipment performance and operating condition can be made by running the excavator through a series of different tests, and recording results with a stopwatch and tape measure.

Compare results of performance tests against the specifications and standards that follow, which are for equipment in new or renewed condition.

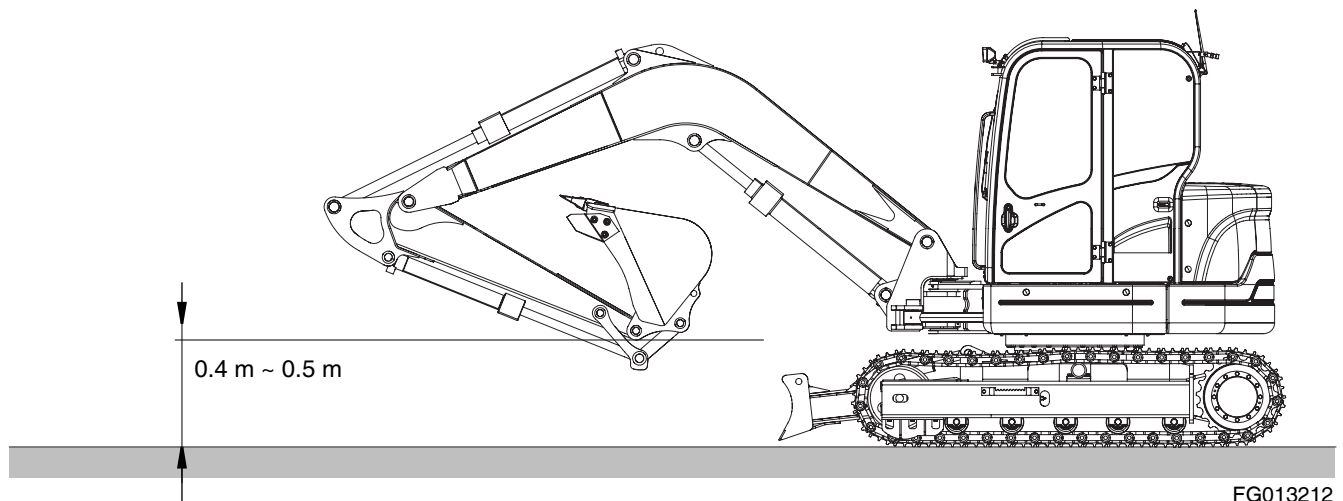
Test Conditions

1. All tests should be performed on a flat, level, firm supporting ground surface.
2. All recommended, applicable maintenance and adjustment service should be completed before testing.
3. Hydraulic fluid and engine oil should be of appropriate viscosity for ambient weather. Warm up hydraulic oil to standard operating temperature, between 45° - 55°C (112° - 135°F).
4. Run all tests with the engine speed control set to maximum rpm.
5. Repeat tests with engine control settings at maximum rpm. Travel speed tests should also be repeated at both 1-speed and 2-speed.

Travel Speed and Travel Motor Balance (Steering Deviation) Tests

Speed Test

Prepare the excavator for travel speed tests by extending all hydraulic cylinders - boom, arm and bucket - to the fully extended position, shown in Figure 5.*



FG013212

Figure 5

The lowest part of the bucket linkage should be 0.4 - 0.5 m (1' - 4') off the ground. Raise dozer blade all the way up.

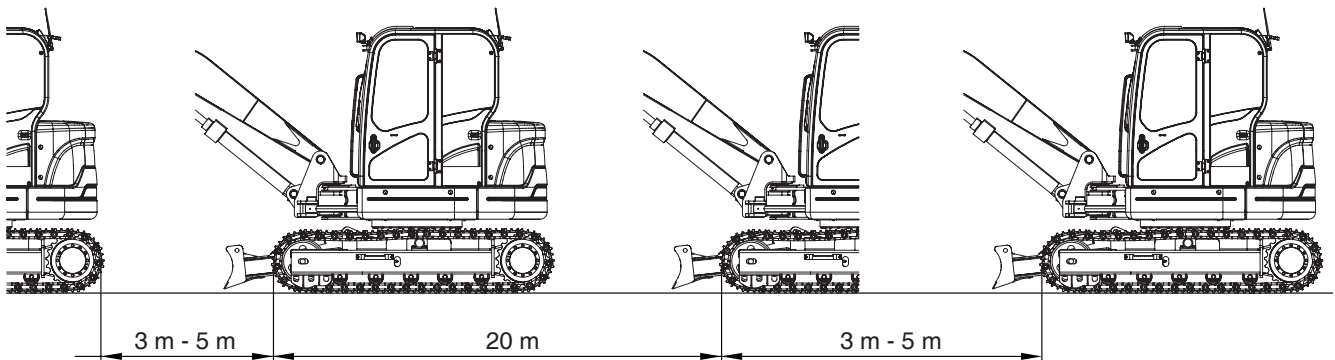
Mark off a 20 m (65' 7-1/2") test distance, with a 3 - 5 m (10' - 15') run-up area, and a 3 - 5 m (10' - 15', or longer) speed run-off distance.

Travel the excavator back and forth to be sure steering is centered and side frames are parallel with the test course.

Operate both travel levers at the fully engaged position and measure the time it takes to cross 20 m (65' 7-1/2"). Compare measured results against the standard for new machines:

Rate of Travel	Basic Valve
1-speed	34.9 ± 2.0 sec
2-speed	18.6 ± 1.5 sec

Rotate the turntable 180°. Both tests should be repeated three times. Average all results to obtain a final value.



FG013215

Figure 1

Travel Deviation

To check steering deviation (travel motor balance), use a long tape or rope, or the edge of an undeviating straight road curb or other marker to verify side to side travel motor uniformity.

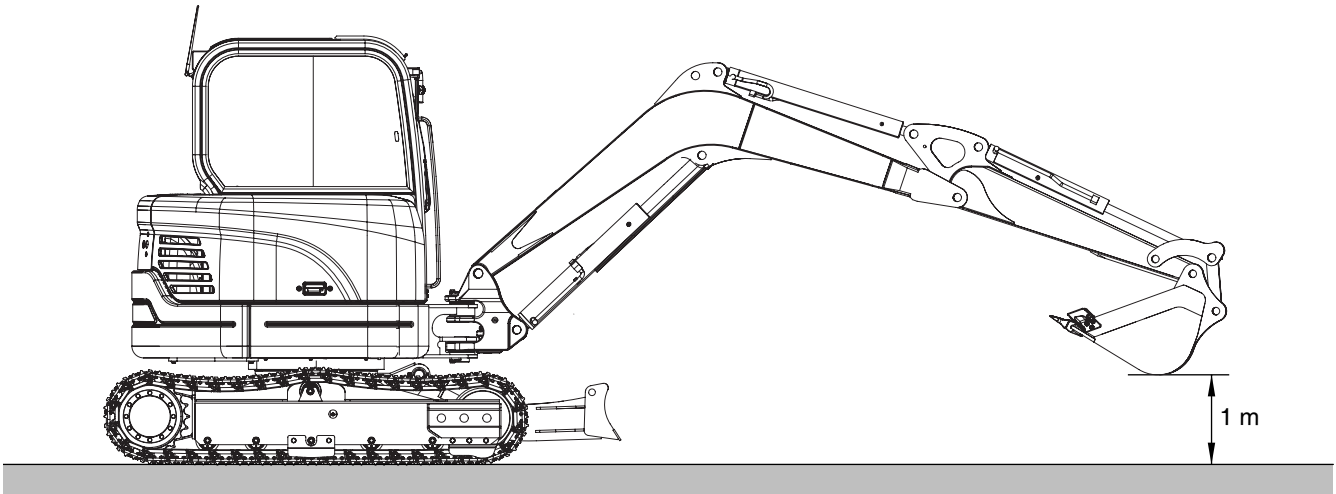
Deviation distance should always be measured at the 20 m (65' 7-1/2") "finish line". Repeat the test in reverse to measure in both directions, with starting point becoming the finish line, and vice versa. (Figure 1)

A greater amount of deviation is allowed with the travel control set for 2-speed.

Rate of Travel	Max. Distance
1-speed	300 mm (5.9 in)
2-speed	300 mm (5.9 in)

Swing Speed and Deceleration Force Test

Swing Speed Test



FG013215

Figure 6

Extend the bucket cylinder completely and retract the arm cylinder, as shown in Figure 6, to test swing speed. The lowest point of the bucket will be approximately 1.0 m (3') off the ground.

Use paint marks at the same point on the turntable and undercarriage, or select alternate measuring locations and use a stopwatch to time 3 full 360° rotations. The time required for 3 revolutions should be between 17.4 and 19.4 seconds.

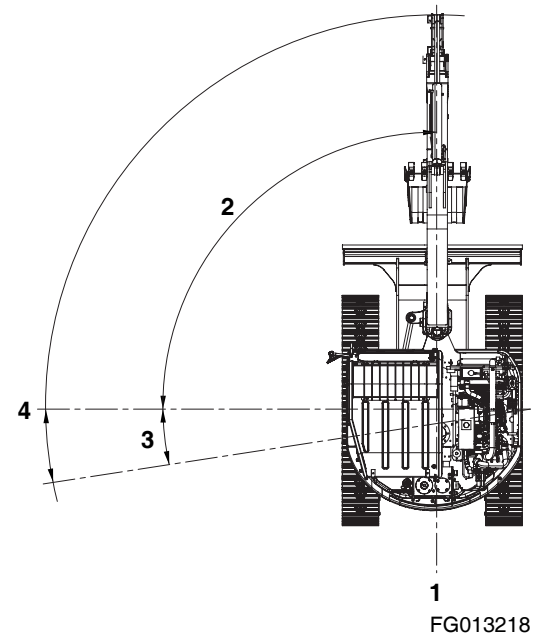
Swing Deceleration Force Test

With the boom, arm and bucket in the same position as for the swing speed test, rotate the turntable so the boom is evenly centered between the side frames, pointing straight ahead. Locate the 90° reference point, perpendicular to the boom. Mark the turntable and undercarriage with paint at the 90° point.

Make several attempts to rotate the turntable exactly 90°, starting from the boom straight ahead position. Engage the swing lever and brake at the 90° point, shown as "swing stop" in Figure 7.

Record how far the turntable drifts past the stop point, measuring the distance between paint marks. Maximum distance should be less than 260 mm (10-1/4").

Reference Number	Description
1	Start Swing
2	90° Swing
3	Swing Force
4	Swing Stop



FG013218

Figure 7

Cylinder Performance Tests

NOTE: All tests are performed with standard boom, arm and bucket configuration. The bucket should be empty.

Hydraulic Cylinder

	Boom	Arm	Bucket	Dozer	B/Swing
Quantity (EA)	1	1	1	1	1
Bore	ø 105	ø 85	ø 80	ø 100	ø 110
Stroke	731	811	600	183	550
Rod Dia.	ø 60	ø 55	ø 50	ø 60	ø 55
Closed Length	1,121	1,229	945	538	955
Head End Cushion	X	O	X	X	X
Rod End Cushion	O	O	X	X	X

Boom Cylinders Test

The starting points for the test are with the boom and arm extended away from the excavator, and the bucket curled inward. The arm cylinder should be fully retracted; boom and bucket cylinders must be extended. Test movement in both directions, several times, and average results.

Arm Cylinder Test

Start with the boom up and the arm cylinder fully retracted. Test movement in both directions several times, between the "crowd" and "dump" positions, and average the results of both tests.

Bucket Cylinder Test

Start with the boom up and the teeth of the bucket hanging vertically, 500 mm (1-1/2' - 2') above the ground. Dump and crowd the bucket several times, and average results.

Operation	Basic Value
Boom Up	2.2 ± 0.3 sec
Boom Down	2.0 ± 0.3 sec
Arm Crowd	2.2 ± 0.3 sec
Arm Dump	2.5 ± 0.3 sec
Bucket Crowd	2.3 ± 0.3 sec
Bucket Dump	3.6 ± 0.3 sec

Hydraulic Cylinder Natural Drop Test

To check boom and arm cylinder tightness against the specified performance standard for new cylinders, put a full load of dirt in the bucket and move the attachment cylinders so the arm cylinder is extended 20 - 50 mm (1" - 2") and boom cylinders are retracted the same amount, 20 - 50 mm (1" - 2"). The top of the bucket should be approximately 2 m (6' - 7') off the ground.

Shut down engine and measure cylinder drop after 5 minutes. Bucket cylinder should not show more than 40 mm (1.57") change, while the arm and boom cylinders should not fall more than 10 mm (0.39").

Travel Motor Jack-up Test

Test travel motor operation on each side by painting or chalking a mark on one crawler shoe, with a corresponding mark on the travel frame. Use the attachment to jack up one side of the machine and operate the raised travel motor. Record the number of seconds it takes the crawler shoe to make 3 full rotations, during both 1-speed and 2-speed operation.

Operation	Basic Value
1-speed	28.36 ± 1.5 sec
2-speed	16.24 ± 1.0 sec

General Maintenance

General Maintenance Procedures

Edition 1

MEMO

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General Maintenance Procedures

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
ALL MODELS	ALL RANGES

WELDING PRECAUTIONS AND GUIDELINES

IMPORTANT

To avoid accidents, personal injury and the possibility of causing damage to the machine or to components, welding must only be performed by properly trained and qualified personnel, who possess the appropriate certification (when required) for the specific welding fabrication or specialized repair being performed.

WARNING

Structural elements of the machine may be built from a variety of steels. These could contain unique alloys or may have been heat-treated to obtain particular strength characteristics. It is extremely important that welding repairs on these types of steel are performed with the proper procedures and equipment. If repairs are performed incorrectly, structural weakening or other damage to the machine (that is not always readily visible) could be caused. Always consult DOOSAN After Sales Service Distributor before welding on integral components (loader arm, frames, car body, track frames, turntable, attachment, etc.) of the machine. It is possible that some types of structurally critical repairs may require Magnetic Particle or Liquid Penetrant testing, to make sure there are no hidden cracks or damage, before the machine can be returned to service.

CAUTION

Always perform welding procedures with the proper safety equipment. Adequate ventilation and a dry work area are absolutely essential. Keep a fire extinguisher nearby and always wear protective clothing and the recommended eye protection.



CAUTION

Observe the following safety precautions:

1. Use extra caution and adequate safety shielding when welding near fuel and oil tanks, batteries, hydraulic piping lines or other fire hazards.
 2. Never weld when the engine is running. Battery cables must be disconnected before the welding procedure is started.
 3. Never weld on a wet or damp surface. The presence of moisture causes hydrogen embrittlement and structural weakening of the weld.
 4. If welding procedures are being performed near cylinder rods, operator's cabin window areas or any other assemblies that could be damaged by weld spatters, use adequate shielding in front of them.
 5. During equipment setup, always attach ground cables directly to the area or component being welded to prevent arcing through bearings, bushings, or spacers.
 6. Always use correct welding rods for the type of weld being performed and observe recommended precautions and time constraints. AWS Class E7018 welding rods for low alloy to medium carbon steel must be used within two hours after removal from a freshly opened container. Class E11018G welding rods for T-1 and other higher strength steel must be used within 1/2 hour.
-

HYDRAULIC SYSTEM - GENERAL PRECAUTIONS

Always maintain oil level in the system at recommended levels. Assemblies that operate under heavy loads, at high-speed, with extremely precise tolerances between moving parts - pistons and cylinders, or shoes and swash plates, for example - can be severely damaged if oil supply runs dry.

Assemblies can run dry and be damaged severely in a very short time when piping or hoses are disconnected to repair leaks and/or replacement of damaged components. Hoses that are inadvertently switched during disassembly (inlet for outlet and vice versa), air introduced into the system or assemblies that are low on oil because of neglect or careless maintenance, could all produce sufficient fluid loss to cause damage.

When starting the engine (after long shutdown or storage intervals), make sure that all hydraulic controls and operating circuits are in neutral, or "OFF". This will prevent pumps or other components that may be temporarily being starved of oil from being run under a load.

Replacement of any hydraulic system component could require thorough cleaning, flushing, and some amount of prefilling with fresh, clean oil if the protective seal on replacement parts has obviously been broken or if seal integrity may have been compromised. When protective seals are removed before installation and reassembly, inspect all replacement parts carefully, before they are installed. If the replacement part is bone-dry (with no trace of factory prelube) or has been contaminated by dirt or by questionable oils, flushing and prefilling with clean hydraulic fluid is recommended.

Vibration, irregular or difficult movement or unusual noise from any part of the hydraulic system could be an indication of air in the system (and many other types of problems). As a general precaution (and to help lessen the risk of potential long-term damage), allow the engine to run at no-load idle speed immediately after initial start-up. Hydraulic fluid will circulate, releasing any air that may have been trapped in the system before load demands are imposed.

A daily walk-around prestart equipment safety inspection, including a quick visual scan for any exterior evidence of leaking hydraulic fluid, can help extend the service life of system components.

IMPORTANT

Hydraulic system operating under conditions such as repetitive cycling, heavy workloads, fluid circulating under high-pressure, make it extremely critical that dust, grit or any other contamination be kept out of the system. Observe fluid and filter change maintenance interval recommendations and always preclean any exterior surface of the system before it is exposed to air. For example, the reservoir fill cap and neck area, hoses that have to be disassembled, and the covers and external surfaces of filter canisters should all be cleaned before disassembly.

MAINTENANCE SERVICE AND REPAIR PROCEDURE

General Precautions

Fluid level and condition should always be checked whenever any other maintenance service or repair is being performed.

NOTE: *If the unit is being used in an extreme temperature environment (in subfreezing climates or in high temperature, high humidity tropical conditions), frequent purging of moisture condensation from the hydraulic reservoir drain tap should be a regular and frequent part of the operating routine. In more moderate, temperate climates, draining reservoir sediment and moisture may not be required more than once or twice every few months.*

Inspect drained oil and used filters for signs of abnormal coloring or visible fluid contamination at every oil change. Abrasive grit or dust particles will cause discoloration and darkening of the fluid. Visible accumulations of dirt or grit could be an indication that filter elements are overloaded (and will require more frequent replacement) or that disintegrating bearings or other component failures in the hydraulic circuit may be imminent or have already occurred. Open the drain plugs on the main pump casings and check and compare drain oil in the pumps. Look for evidence of grit or metallic particles.

Vibration or unusual noise during operation could be an indication of air leaking into the circuit (Refer to the appropriate Troubleshooting section for component or unit for procedures.), or it may be evidence of a defective pump. The gear type pilot pump could be defective, causing low pilot pressure, or a main pump broken shoe or piston could be responsible.

NOTE: *If equipped, indicated operating pressure, as shown on the multidisplay digital gauge on the Instrument Panel ("F-Pump" and "R-Pump") will be reduced because of a mechanical problem inside the pump. However, pressure loss could also be because of cavitation or air leakage, or other faults in the hydraulic system.*

Check the exterior case drain oil in the main pumps. If no metallic particles are found, make sure there is no air in the system. Unbolt and remove the tank return drain line from the top part of the swing motor, both travel motors and each main pump. If there is air in any one of the drain lines, carefully prefill the assembly before bolting together the drain line piping connections. Run the system at low rpm.

HYDRAULIC SYSTEM CLEANLINESS AND OIL LEAKS

Maintenance Precautions for Hydraulic System Service

Whenever maintenance, repairs or any other troubleshooting or service is being performed, it's important to remember that the hydraulic system - including both the interior and exterior surfaces of assemblies, and every drop of operating fluid - must be protected from contamination.

Dust and other foreign contaminants are major contributors to premature wear in hydraulic circuits. The narrow tolerances, rapidly moving parts and high operating pressures of the system require that fluid be kept as clean as possible. The performance and dependability of the machine (and the service life of individual components) can be noticeably reduced if proper precautions are not observed:

- Use a safe, noncombustible, evaporative type, low-residue solvent and thoroughly clean exterior surfaces of assemblies before any part of the circuit is opened or disassembled.

NOTE: *It's just as important to clean the cap and reservoir top before routine fluid changes or quick checks as it is before major repairs. (Accumulated dirt attracts moisture, oil and other fluids - and more dirt.)*

- Keep dismantled parts covered during disassembly. Use clean caps, plugs or tape to protect the disconnected openings of flanges, manifolds and piping.
- Do not allow cleaning solvents or other fluids to mix with the oil in the system. Use clean oil to flush any traces of solvent or other residue before reassembly.
- If metal or rubber fragments are found in the system, flush and replace all fluid in the system and troubleshoot the circuit to identify the source of contamination.

IMPORTANT

Make sure that cleaning solvents will be compatible with rubber materials used in the hydraulic system. Many petroleum based compounds can cause swelling, softening, or other deterioration of system sealing elements, such as O-rings, caps and other seals.

Oil Leakage Precautions

Oil that is visibly seeping from joints or seals should always serve as a "red flag" alarm.

Leaks must alert the machine operator and maintenance crew that air, water and dirt have an open, free passageway through which to enter the circuit. Harsh, corrosive salt air, freezing and thawing condensation cycles and working environments that are full of fine dust are especially hazardous. Clogging of valve spools or external piping (especially pilot circuit piping) can gradually diminish or suddenly put a stop to normal hydraulic function. You can prevent having to make these types of repairs by following recommended assembly procedures:

1. Use new O-rings and oil seals whenever hydraulic assemblies are rebuilt.
2. Prepare joint surfaces before assembly by checking alignment and flatness. Clean and repair corrosion or any other damage.
3. Follow bolt torque recommendations and all other assembly requirements.

NOTE: *Grease lip seals before assembly.*

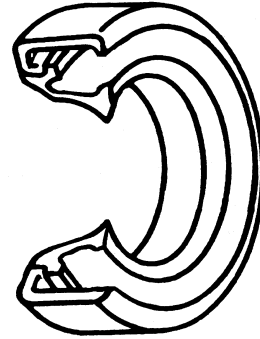


Figure 1

0565A

CLEANING AND INSPECTION

General Guidelines

All parts must be clean to permit an effective inspection. During assembly, it is very important that no dirt or foreign material enters unit being assembled. Even minute particles can cause malfunction of close fitting parts such as thrust bearing, matched parts, etc.



WARNING

Care should be exercised to avoid inhalation of vapors, exposure to skin and creating fire hazards when using solvent type cleaners.

1. Clean all metal parts thoroughly using a suitable cleaning fluid. It is recommended that parts be immersed in cleaning fluid and moved up and down slowly until all oils, lubricants, and/or foreign materials are dissolved and parts are thoroughly clean.
2. For bearings that can be removed, soak them in a suitable cleaning fluid for a minute or two, then remove bearings from cleaning fluid and strike flat against a block of wood to dislodge solidified particles of lubricant. Immerse again in cleaning fluid to flush out particles. Repeat above operation until bearings are thoroughly clean. To dry bearings, use moisture-free compressed air. Be careful to direct airstream across bearing to avoid spinning bearings that are not lubricated. DO NOT SPIN BEARINGS WHEN DRYING; bearings may be rotated slowly by hand to facilitate drying process.
3. Carefully inspect all bearing rollers, cages and cups for wear, chipping or nicks to determine condition. Do not replace a bearing cone or cup individually without replacing mating cup or cone at the same time. After inspection, dip bearings in lightweight oil and wrap in clean lintless cloth or paper to protect them until installation.

For those bearings that are to be inspected in place; inspect bearings for roughness of rotation, scoring, pitting, cracked or chipped races. If any of these defects are found, replace bearings. Also, inspect defective bearing housing and/or shaft for grooved, galled or burred conditions that indicate bearing has been turning in its housing or on its shaft.

4. It is more economical to replace oil seals, O-rings, sealing rings, gaskets and retaining rings when unit is disassembled than waiting for premature failures; refer to latest Micro Fiche and/or Parts Book for replacement items. Be careful when installing sealing members, to

avoid cutting or scratching. Curling under of any seal lip will seriously impair its efficiency. Apply a thin coat of loctite #120 to outer diameter, of metal casing, on oil seals to assure an oil tight fit into retainer. Use extreme care not to get loctite on lips of oil seals. If this happens, that portion of the seal will become brittle and allow leakage.

When replacing lip type seals, make sure spring loaded side is towards oil to be sealed.

5. If available, use magna-flux or similar process for checking for cracks that are not visible. Examine teeth on all gears carefully for wear, pitting, chipping, nicks, cracks or scores. Replace all gears showing cracks or spots where case-hardening has worn through. Small nicks may be removed with suitable hone. Inspect shafts and quills to make certain they have not been sprung, bent, or splines twisted, and that shafts are true.

NOTE: *Spline wear is not considered detrimental except where it affects tightness of splined parts.*

Inspect thrust washers for distortion, scores, burs, and wear. Replace thrust washer if defective or worn.

6. Inspect bores and bearing surfaces of cast parts and machined surfaces for scratches, wear, grooves and dirt. Remove any scratches and burrs with crocus cloth. Remove foreign material. Replace any parts that are deeply grooved or scratched which would affect their operation.

Bearing Inspection

The condition of the bearings are vital to the smooth and efficient operation of the machinery. When any component containing bearings is disassembled, always carefully examine the condition of the bearings and all of its components for wear and damage.

Once the bearing is removed, clean all parts thoroughly using a suitable cleaning solution. If the bearing is excessively dirty soak the bearing assembly in a light solution and move the bearing around until all lubricants and or foreign materials are dissolved and the parts are thoroughly clean.

When drying bearings, moisture free compressed air can be used. Be careful not to direct the air in a direction which will force the bearing to dry spin while not being properly lubricated.

After the bearings have been cleaned and dried, carefully inspect all bearing rollers, cages and cups for wear, chipping or nicks. If the bearing cannot be removed and is to be inspected in place, check for roughness of rotation, scoring, pitting, cracked or chipped races. If any of these defects are found replace the whole bearing assembly. NEVER replace the

bearing alone without replacing the mating cup or the cone at the same time.

After inspection lightly coat the bearing and related parts with oil and wrap in a clean lintless cloth or paper and protect them from moisture and other foreign materials until installation.

It is also important to inspect the bearing housing and/or shaft for grooved, galled or burred conditions that indicate the bearing has been turning in its housing or on its shaft.

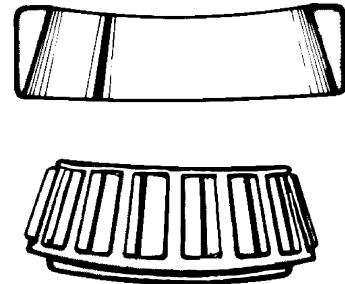
If available, use magna-flux or similar process for checking for cracks that are not visible.

The following illustrations will aid in identifying and diagnosing some of the bearing related problems.

NOTE: *The illustrations will only show tapered roller bearings, but the principles of identifying, diagnosing and remedying the defects are common to all styles and types of bearings.*

Normal Bearing

Smooth even surfaces with no discoloration or marks.

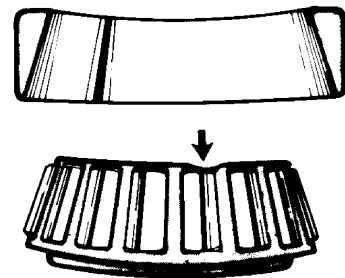


HASA620S

Figure 2

Bent Cage

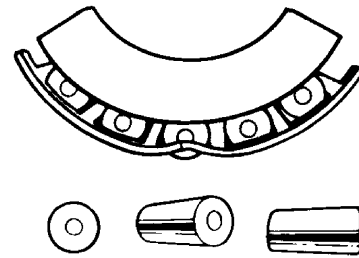
Cage damage because of improper handling or tool usage.



HASA460S

Figure 3

Replace bearing.



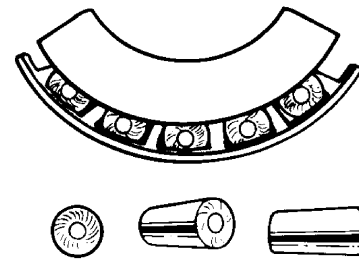
HASA470S

Figure 4

Galling

Metal smears on roller ends because of overheating, lubricant failure or overload.

Replace bearing - check seals and check for proper lubrication.



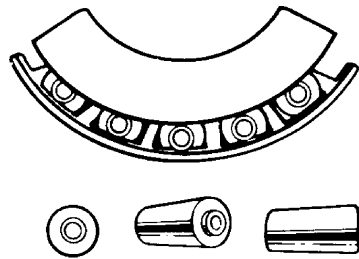
HASA480S

Figure 5

Abrasive Step Wear

Pattern on roller ends caused by fine abrasives.

Clean all parts and housings, check all parts and housings, check seals and bearings and replace if leaking, rough or noisy.



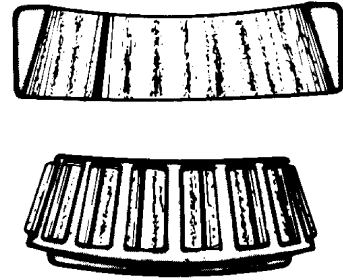
HASA490S

Figure 6

Etching

Bearing surfaces appear gray or grayish black in color with related etching away of material usually at roller spacing.

Replace bearings - check seals and check for proper lubrication.



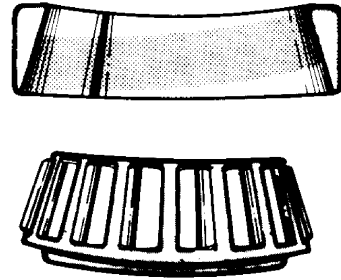
HASA500S

Figure 7

Misalignment

Outer race misalignment because of foreign object.

Clean related parts and replace bearing. Make sure races are properly seated.



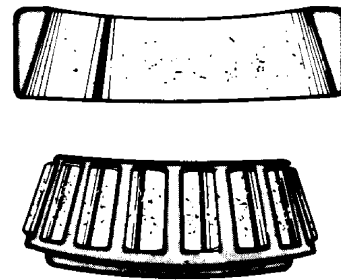
HASA510S

Figure 8

Indentations

Surface depressions on race and rollers caused by hard particles of foreign materials.

Clean all parts and housings, check seals and replace bearings if rough or noisy.



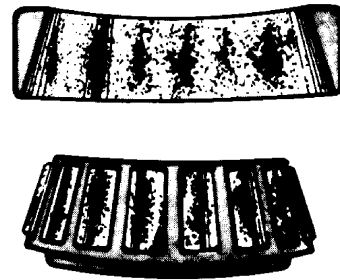
HASA520S

Figure 9

Fatigue Spalling

Flaking of surface metal resulting from fatigue.

Replace bearing - clean all related parts.



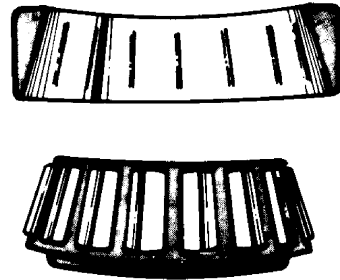
HASA530S

Figure 10

Brinelling

Surface indentations in raceway caused by rollers either under impact loading or vibration while the bearing is not rotating.

Replace bearing if rough or noisy.



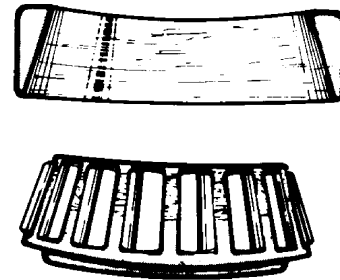
HASA540S

Figure 11

Cage Wear

Wear around outside diameter of cage and roller pockets caused by abrasive material and inefficient lubrication.

Replace bearings - check seals.



HASA550S

Figure 12

Abrasive Roller Wear

Pattern on races and rollers caused by fine abrasives.

Clean all parts and housings, check seals and bearings and replace if leaking, rough or noisy.

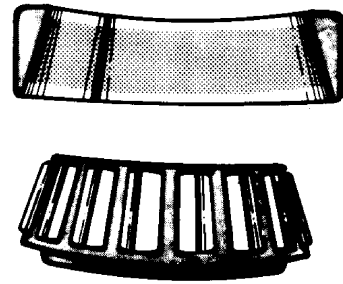


Figure 13

HASA560S

Cracked Inner Race

Race cracked because of improper fit, cocking or poor bearing seat.

Replace all parts and housings, check seals and bearings and replace if leaking.

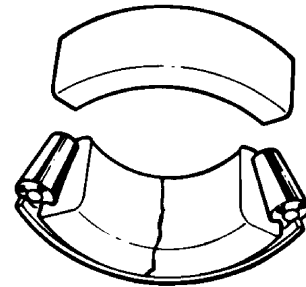


Figure 14

HASA570S

Smears

Smearing of metal because of slippage caused by poor fitting, lubrication, overheating, overloads or handling damage.

Replace bearings, clean related parts and check for proper fit and lubrication.

Replace shaft if damaged.

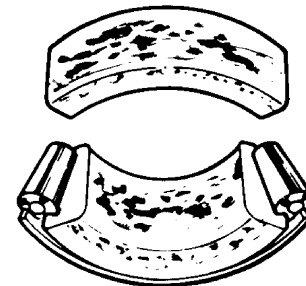


Figure 15

HASA580S

Fretting

Corrosion set up by small relative movement of parts with no lubrication.

Replace bearing. Clean all related parts. Check seals and check for proper lubrication.

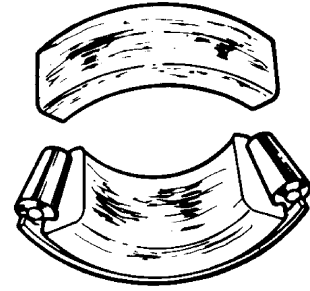


Figure 16

HASA590S

Heat Discoloration

Heat discoloration can range from faint yellow to dark blue resulting from overload or incorrect lubrication.

Excessive heat can cause softening of races or rollers.

To check for loss of temper on races or rollers, a simple file test may be made. A file drawn over a tempered part will grab and cut metal, whereas a file drawn over a hard part will glide readily with no metal cutting.

Replace bearing if overheating damage is indicated. Check seals and other related parts for damage.

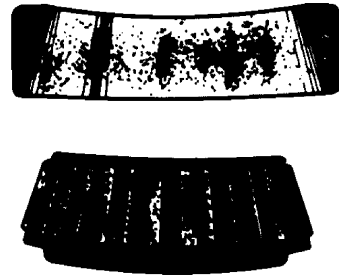


Figure 17

HASA600S

Stain Discoloration

Discoloration can range from light brown to black caused by incorrect lubrication or moisture.

If the stain can be removed by light polishing or if no evidence of overheating is visible, the bearing can be reused.

Check seals and other related parts for damage.

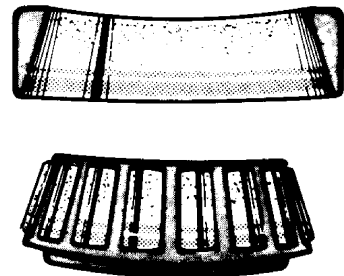


Figure 18

HASA610S

Standard Torques

Edition 1

MEMO

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Standard Torques

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling load.

Remember that ultimate safety is your own personal responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
ALL MODELS	ALL RANGES

TORQUE VALUES FOR STANDARD METRIC FASTENERS

NOTE: The units for the torque values are kg•m (ft lb).

Dia. x Pitch (mm)	Grade										
	3.6 (4A)	4.6 (4D)	4.8 (4S)	5.6 (5D)	5.8 (5S)	6.6 (6D)	6.8 (6S)	6.9 (6G)	8.8 (8G)	10.9 (10K)	12.9 (12K)
M5 x Std.	0.15 (1.08)	0.16 (1.15)	0.25 (1.80)	0.22 (1.59)	0.31 (2.24)	0.28 (2.02)	0.43 (3.11)	0.48 (3.47)	0.50 (3.61)	0.75 (5.42)	0.90 (6.50)
M6 x Std.	0.28 (2.02)	0.30 (2.16)	0.45 (3.25)	0.40 (2.89)	0.55 (3.97)	0.47 (3.39)	0.77 (5.56)	0.85 (6.14)	0.90 (6.50)	1.25 (9.04)	1.50 (10.84)
M7 x Std.	0.43 (3.11)	0.46 (3.32)	0.70 (5.06)	0.63 (4.55)	0.83 (6.00)	0.78 (5.64)	1.20 (8.67)	1.30 (9.40)	1.40 (10.12)	1.95 (14.10)	2.35 (16.99)
M8 x Std.	0.70 (5.06)	0.75 (5.42)	1.10 (7.95)	1.00 (7.23)	1.40 (10.12)	1.25 (9.04)	1.90 (13.74)	2.10 (15.18)	2.20 (15.91)	3.10 (22.42)	3.80 (27.48)
M8 x 1	0.73 (5.28)	0.80 (5.78)	1.20 (8.67)	1.00 (7.23)	1.50 (10.84)	1.35 (9.76)	2.10 (15.18)	2.30 (16.63)	2.40 (17.35)	3.35 (24.23)	4.10 (29.65)
M10 x Std.	1.35 (9.76)	1.40 (10.12)	2.20 (15.91)	1.90 (13.74)	2.70 (19.52)	2.35 (19.99)	3.70 (26.76)	4.20 (30.37)	4.40 (31.18)	6.20 (44.84)	7.20 (52.07)
M10 x 1.25	1.50 (10.84)	1.60 (11.57)	2.50 (18.08)	2.10 (15.18)	3.10 (22.42)	2.80 (20.25)	4.30 (31.10)	4.90 (35.44)	5.00 (36.16)	7.00 (50.63)	8.40 (60.75)
M12 x Std.	2.40 (17.35)	2.50 (18.08)	3.70 (26.76)	3.30 (23.86)	4.70 (33.99)	4.20 (30.37)	6.30 (45.56)	7.20 (52.07)	7.50 (54.24)	10.50 (75.94)	12.50 (90.41)
M12 x 1.25	2.55 (18.44)	2.70 (19.52)	4.00 (28.93)	3.50 (25.31)	5.00 (36.16)	4.50 (32.54)	6.80 (49.18)	7.70 (55.69)	8.00 (57.86)	11.20 (81.00)	13.40 (96.92)
M14 x Std.	3.70 (26.76)	3.90 (28.20)	6.00 (43.23)	5.20 (37.61)	7.50 (54.24)	7.00 (50.63)	10.00 (72.33)	11.50 (83.17)	12.00 (86.79)	17.00 (122.96)	20.00 (144.66)
M14 x 1.5	4.10 (29.65)	4.30 (31.10)	6.60 (47.73)	5.70 (41.22)	8.30 (60.03)	7.50 (54.24)	11.10 (80.28)	12.50 (90.41)	13.00 (94.02)	18.50 (133.81)	22.00 (159.12)
M16 x Std.	5.60 (40.50)	6.00 (43.39)	9.00 (65.09)	8.00 (57.86)	11.50 (83.17)	10.50 (75.94)	15.50 (112.11)	17.90 (129.47)	18.50 (133.81)	26.00 (188.05)	31.00 (224.22)
M16 x 1.5	6.20 (44.84)	6.50 (47.01)	9.70 (70.16)	8.60 (62.20)	12.50 (90.41)	11.30 (81.73)	17.00 (122.96)	19.50 (141.04)	20.00 (144.66)	28.00 (202.52)	35.50 (256.77)
M18 x Std.	7.80 (56.41)	8.30 (60.03)	12.50 (90.41)	11.00 (79.56)	16.00 (115.72)	14.50 (104.87)	21.00 (151.89)	27.50 (198.90)	28.50 (206.14)	41.00 (296.55)	43.00 (311.01)
M18 x 1.5	9.10 (65.82)	9.50 (68.71)	14.40 (104.15)	12.50 (90.41)	18.50 (133.81)	16.70 (120.79)	24.50 (177.20)	27.50 (198.90)	28.50 (206.14)	41.00 (296.55)	49.00 (354.41)
M20 x Std.	11.50 (83.17)	12.00 (86.79)	18.00 (130.19)	16.00 (115.72)	22.00 (159.12)	19.00 (137.42)	31.50 (227.83)	35.00 (253.15)	36.00 (260.38)	51.00 (368.88)	60.00 (433.98)
M20 x 1.5	12.80 (92.58)	13.50 (97.64)	20.50 (148.27)	18.00 (130.19)	25.00 (180.82)	22.50 (162.74)	35.00 (253.15)	39.50 (285.70)	41.00 (296.55)	58.00 (419.51)	68.00 (491.84)
M22 x Std.	15.50 (112.11)	16.00 (115.72)	24.50 (177.20)	21.00 (151.89)	30.00 (216.99)	26.00 (188.05)	42.00 (303.78)	46.00 (332.71)	49.00 (354.41)	67.00 (484.61)	75.00 (542.47)
M22 x 1.5	17.00 (122.96)	18.50 (133.81)	28.00 (202.52)	24.00 (173.59)	34.00 (245.92)	29.00 (209.75)	47.00 (339.95)	52.00 (44.76)	56.00 (405.04)	75.00 (542.47)	85.00 (614.80)
M24 x Std.	20.50 (148.27)	21.50 (155.50)	33.00 (238.68)	27.00 (195.29)	40.00 (289.32)	34.00 (245.92)	55.00 (397.81)	58.00 (419.51)	63.00 (455.67)	82.00 (593.10)	92.00 (655.43)
M24 x 2.0	23.00 (166.35)	35.00 (253.15)	37.00 (267.62)	31.00 (224.22)	45.00 (325.48)	38.00 (202.52)	61.00 (441.21)	67.00 (484.61)	74.00 (535.24)	93.00 (672.66)	103.00 (744.99)

TORQUE VALUES FOR STANDARD U.S. FASTENERS

Type	S.A.E. Grade	Description	Bolt Head Marking
1	1 OR 2	WILL HAVE NO MARKINGS IN THE CENTER OF THE HEAD. Low or Medium Carbon Steel Not Heat Treated.	
5	5	WILL HAVE THREE RADIAL LINES. Quenched and Tempered Medium Carbon Steel.	
8	8	WILL HAVE 6 RADIAL LINES. Quenched and Tempered Special Carbon or Alloy Steel.	

Recommended torque, in foot pounds, for all Standard Application Nuts and Bolts, provided:

1. All thread surfaces are clean and lubricated with SAE-30 engine oil. (See Note.)
2. Joints are rigid, that is, no gaskets or compressible materials are used.
3. When reusing nuts or bolts, use minimum torque values.

NOTE: *Multiply the standard torque by:*

- | | |
|------|--|
| 0.65 | When finished jam nuts are used. |
| 0.70 | When Molykote, white lead or similar mixtures are used as lubricants. |
| 0.75 | When Parkerized bolts or nuts are used. |
| 0.85 | When cadmium plated bolts or nuts and zinc bolts w/waxed zinc nuts are used. |
| 0.90 | When hardened surfaces are used under the nut or bolt head. |

NOTE: *When reusing bolts and nuts in service, use minimum torque values.*

The following General Torque Values must be used in all cases where **SPECIAL TORQUE VALUES** are not given.

NOTE: <i>Torque values listed throughout this manual are lubricated (wet) threads; values should be increased 1/3 for nonlubricated (dry) threads.</i>				
Thread Size	Heat Treated Material Grade 5 and Grade 8			
	Grade 5 (3 Radial Dashes On Head)		Grade 8 (6 Radial Dashes On Head)	
	Foot Pounds (ft lb)	Newton Meter (Nm)	Foot Pounds (ft lb)	Newton Meter (Nm)
1/4" - 20	6	8	9	12
1/4" - 28	7	9	11	15
5/16" - 18	13	18	18	24
5/16" - 24	15	20	21	28
3/8" - 16	24	33	34	46
3/8" - 24	27	37	38	52
7/16" - 14	38	52	54	73
7/16" - 20	42	57	60	81
1/2" - 13	58	79	82	111
1/2" - 20	65	88	90	122
9/16" - 12	84	114	120	163
9/16" - 18	93	126	132	179
5/8" - 11	115	156	165	224
5/8" - 18	130	176	185	251
3/4" - 10	205	278	290	393
3/4" - 16	240	312	320	434
7/8" - 9	305	414	455	617
7/8" - 14	334	454	515	698
1" - 8	455	617	695	942
1" - 14	510	691	785	1064
1 1/8" - 7	610	827	990	1342
1 1/8" - 12	685	929	1110	1505
1 1/4" - 7	860	1166	1400	1898
1 1/4" - 12	955	1295	1550	2102
1 3/8" - 6	1130	1532	1830	2481
1 3/8" - 12	1290	1749	2085	2827
1 1/2" - 6	1400	2034	2430	3295
1 1/2" - 12	1690	2291	2730	3701
1 3/4" - 5	2370	3213	3810	5166
2" - 4 1/2	3550	4813	5760	7810

NOTE: *If any bolts and nuts are found loose or at values less than what the chart states, it is recommended that the loose bolt and/or nut be replaced with a new one.*

TYPE 8 PHOSPHATE COATED HARDWARE

This chart provides tightening torque for general purpose applications using original equipment standard hardware as listed in the Parts Manual for the machine involved. **DO NOT SUBSTITUTE.** In most cases, original equipment standard hardware is defined as Type 8, coarse thread bolts and nuts and thru hardened flat washers (Rockwell "C" 38 - 45), all phosphate coated and assembled without supplemental lubrication (as received) condition.

The torques shown below also apply to the following:

1. Phosphate coated bolts used in tapped holes in steel or gray iron.
2. Phosphate coated bolts used with phosphate coated prevailing torque nuts (nuts with distorted threads or plastic inserts).
3. Phosphate coated bolts used with copper plated weld nuts.

Markings on bolt heads or nuts indicate material grade ONLY and are NOT to be used to determine required torque.

Nominal Thread Diameter	Standard Torque $\pm 10\%$	
	Kilogram Meter (kg•m)	Foot Pounds (ft lb)
1/4"	1.1	8
5/16"	2.2	16
3/8"	3.9	28
7/16"	6.2	45
1/2"	9.7	70
9/16"	13.8	100
5/8"	19.4	140
3/4"	33.2	240
7/8"	53.9	390
1"	80.2	580
1 - 1/8"	113.4	820
1 - 1/4"	160.4	1160
1 - 3/8"	210.2	1520
1 - 1/2"	279.4	2020
1 - 3/4"	347.1	2510
2	522.8	3780

TORQUE VALUES FOR HOSE CLAMPS

The following chart provides the tightening torques for hose clamps used in all rubber applications (radiator, air cleaner, operating lever boots, hydraulic system, etc.).

Clamp Type And Size	Torque			
	Radiator, Air Cleaner, Boots, Etc.		Hydraulic System	
	Kilogram Meter (kg•m)	Inch Pounds (in lb)	Kilogram Meter (kg•m)	Inch Pounds (in lb)
"T" Bolt (Any Diameter)	0.68 - 0.72	59 - 63	-----	-----
Worm Drive - Under 44 mm (1-3/4 in) Open Diameter	0.2 - 0.3	20 - 30	0.5 - 0.6	40 - 50
Worm Drive - Over 44 mm (1-3/4 in) Open Diameter	0.5 - 0.6	40 - 50	-----	-----
Worm Drive - All "Ultra-Tite"	0.6 - 0.7	50 - 60	0.5 - 0.6	40 - 50

TORQUE VALUES FOR SPLIT FLANGES

The following chart provides the tightening torques for split flange connections used in hydraulic systems. Split flanges and fitting shoulders should fit squarely. Install all bolts, finger tight and then torque evenly.

NOTE: *Over torquing bolts will damage the flanges and/or bolts, which may cause leakage.*

Flange Size (*)	Bolt Size	Bolt Torque	
		Kilogram Meter (kg•m)	Foot Pounds (ft lb)
1/2"	5/16"	2.1 - 2.5	15 - 18
3/4"	3/8"	3.0 - 3.7	22 - 27
1"	3/8"	3.7 - 4.8	27 - 35
1 - 1/4"	7/16"	4.8 - 6.2	35 - 45
1 - 1/2"	1/2"	6.4 - 8.0	46 - 58
2"	1/2"	7.6 - 9.0	55 - 65
2 - 1/2"	1/2"	10.9 - 12.6	79 - 91
3"	5/8"	19.1 - 20.7	138 - 150
3 - 1/2"	5/8"	16.2 - 18.4	117 - 133

(*) - Inside diameter of flange on end of hydraulic tube or hose fitting.

NOTE: *Values stated in chart are for Standard Pressure Series (Code 61) Split Flanges.*

TORQUE WRENCH EXTENSION TOOLS

Very large diameter, high grade fasteners (nuts, bolts, cap screws, etc.) require a great deal of turning force to achieve recommended tightening torque values.

Common problems that could occur as a result are:

- Recommended torque exceeds the measuring capacity of the torque wrench.
- Specialized sockets do not fit the adapter on the front end (nose) of the torque wrench.
- Generating adequate force on the back end (handle) of the wrench is difficult or impossible.
- Restricted access or an obstruction may make use of the torque wrench impossible.
- A unique application requires fabrication of an adapter or other special extension.

Most standard torque wrenches can be adapted to suit any one of the proceeding needs or situations, if the right extension tool is used or fabricated.

Torque Multiplication

A wrench extension tool can be used to increase the tightening force on a high capacity nut or bolt.

For example, doubling the distance between the bolt and the back (handle) end of the torque wrench doubles the tightening force on the bolt. It also halves the indicated reading on the scale or dial of the torque wrench. To accurately adjust or convert indicated scale or dial readings, use the following formula:

$I = A \times T / A + B$ where:

I = Indicated force shown on the torque wrench scale or dial.

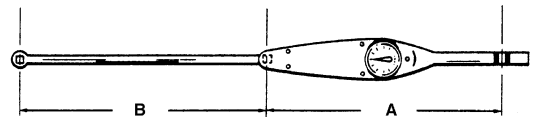
T = Tightening force applied to the nut or bolt (actual Torque).

A = Length of the torque wrench (between the center of the nut or bolt and the center of the handle).

B = Length of the extension.

As an example, if a 12" extension is added to a 12" torque wrench, and the indicated torque on the dial reads "150 ft lb," the real force applied to the bolt is 300 ft lb:

$$I = \frac{A \times T}{A + B} = \frac{12 \times 300}{12 + 12} = \frac{3600}{24} = 150$$



0552A

Figure 1

NOTE: *The formula assumes that there is no added deflection or "give" in the joint between the extension and torque wrench. Readings may also be inaccurate:*

- If the extension itself absorbs some of the tightening force and starts to bend or bow out.
- If an extension has to be fabricated that is not perfectly straight (for example, an extension made to go around an obstruction, to allow access to a difficult to tighten fastener), the materials and methods used must be solid enough to transmit full tightening torque.

Other Uses for Torque Wrench Extension Tools

Torque wrench extensions are sometimes made up for reasons other than increasing leverage on a fastener.

For example, a torque wrench and extension can be used to measure adjustment "tightness" of a linkage or assembly. Specially fabricated extensions can be used to make very precise checks of the force required to engage or disengage a clutch mechanism, release a spring-applied brake assembly, or "take up" free play in most any movable linkage.

Once the value of the adjustment force is established, repeated checks at regular intervals can help to monitor and maintain peak operating efficiency. These types of adjustment checks are especially useful if physical measurements of linkage travel are difficult to make or will not provide the needed degree of precision and accuracy.

To allow the assembly or mechanism to accept a torque wrench, welding a nut or other adapter on the end of a linkage shaft or other leverage point will allow turning the shaft or assembly manually.

Tightening Torque Specifications (Metric)

(For coated threads, prelubricated assemblies.)



CAUTION

Disassembly, overhaul and replacement of components on the machine, installation of new or replacement parts and/or other service-related maintenance may require the use of thread or flange sealing assembly compound.

Use the information on this page as a general guide in selecting specific formulas that will meet the particular requirements of individual assembly installations. DOOSAN does not specifically endorse a specific manufacturer or brand name but the following table of "Loctite" applications is included for which cross-references to other makers' products should also be widely available.

IMPORTANT

Use primer "T" or "N" for all cold weather assembly of fastener adhesives, with Thread locker sealers 222, 242/243, 262, 271, 272, or 277.

I. "Loctite" Fastener Adhesives

Product	Application	Color	Removal	Breakaway Cure Strength (in lb) of Sealer Alone
222	Low strength for 6 mm (1/4") or smaller fasteners.	Purple	Hand tools	45
242 or 243	Medium strength for 6 mm (1/4") and larger fasteners.	Blue	Hand tools	80
262	High strength for high grade fasteners subject to shock, stress and vibration.	Red	Heat/260°C (500°F) Remove HOT (NO solvent)	160
271	Extra high strength for fine thread fasteners up to 25 mm (1") diameter.	Red	Heat/260°C (500°F) Remove HOT	160
272	High temperature/high strength for hostile environments to 232°C (450°F).	Red	Heat/316°C (600°F) Remove HOT	180
277	Extra high strength for coarse thread fasteners 25 mm (1") diameter and larger.	Red	Heat/260°C (500°F) Remove HOT	210

II. "Loctite" Pipe Thread Sealant

Product	Application	Color	Removal	Required Setup
545	"No-filler/nonclog" formula for high-pressure hydraulic systems. Over application will not restrict or foul system components.	Purple	Hand tools	4 Hours (or 1/2 hour with Locquic "T" Primer)
656	Solvent resistant, higher viscosity tapered thread sealer.	White	Hand tools	4 Hours (or 1/2 hour with Locquic "T" Primer)

III. "Loctite" gasket/flange sealer

Product	Application	Color	Notes
518	Gasket eliminator specifically made for aluminum flanges/surfaces. For hydraulic systems to 34,475 kPa (5,000 psi).	Red	Use Locquic "N" primer for fast (1/2 - 4 hours) setup. Unprimed setup 4 - 24 hours.
504	Low-pressure/wide-gap gasket eliminator compound. Fills gaps to 0.0012 mm (0.030"), cures to rigid seal.	Orange	Use Locquic "N" primer for faster (1/2 - 4 hours) setup. Unprimed setup 4 - 24 hours.
515	General purpose, fast setup, flexible-cure gasket eliminator. For nonrigid assemblies subject to shock, vibration or deflection.	Purple	Use Locquic "N" primer for faster (1/4 - 2 hours) setup. Unprimed setup 1 - 12 hours.

IV. "Loctite" retaining compounds

Product	Application	Color	Notes
609	For bushings, sleeves, press fit bearings, splines and collars. For gaps to 0.0002 mm (0.005"), temperatures to 121°C (250°F).	Green	Use Locquic "N" primer for increased bond strength and all cold temperature applications.
620	For high temperatures to 232°C (450°F).	Green	Same as 609, above.
680	For high strength bonds and tight clearance gaps, to 0.00008 mm (0.002").	Green	Same as 609, above.

V. "Loctite" Adhesives

Product	Application	Color	Notes
380	Black Max instant adhesive for shock and vibration-resistant bonds.	Black	May take 120 hours to reach full cure strength.
454	Adhesive for porous surfaces.	Clear	Full strength in 24 hours.
480	Increased strength (+50%), shock and vibration-resistant.	Black	Full strength in 24 hours.

Upper Structure

Cabin

Edition 1

MEMO

Table of Contents

Cabin

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up
DX80R	50001 and Up

REMOVAL

CAUTION

Avoid disassembling cabin if there are strong wind gusts, which could catch large surface area of cabin shell and push it sideways during lift.

1. Park on firm and level ground.
2. Lower front attachment (bucket) to ground.
3. Shut down engine.
4. Set safety lever on "RELEASED" position.
5. Turn starter switch to "I" (ON) position.

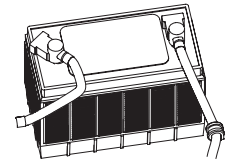
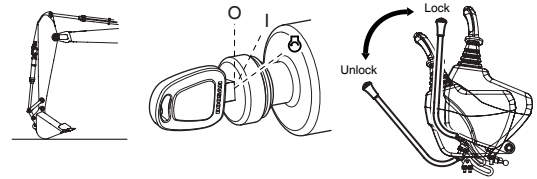
WARNING

If engine must be run while performing maintenance, use extreme care. Always have one person in the cabin at all times. Never leave the cabin with the engine running.

6. Fully stroke work levers (joysticks) in all directions to relieve pressure from accumulators.
7. Set safety lever on "LOCK" position.
8. Turn key to "O" (OFF) position and remove from starter switch.
9. Hang maintenance warning tag on controls.
10. Disconnect the battery cable from the negative (-) battery terminal.
11. Prepare cabin shell for removal by disconnecting wiring connectors for:
 - A. Main harness.
 - B. Left stand harness.
 - C. Right stand harness.
 - D. Harness passing next to the air conditioner box.

NOTE: *Control console wiring harnesses and hydraulic piping lines that pass through the floor of the cabin do not need to be disassembled.*

NOTE: *If unit is equipped with a cabin protective structure (for forestry, or hazardous working conditions), it must be removed.*



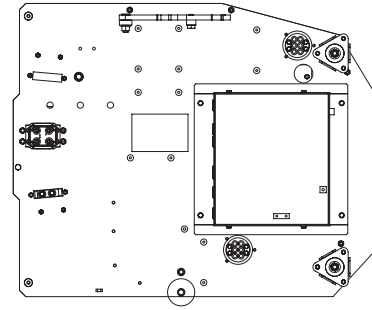
FG013223

Figure 1

12. Tilt up cabin.
Remove a bolt (Figure 2).
Disconnect pilot hoses as required.
Tilt down cabin.

NOTE: *Please refer to cabin tilting.*

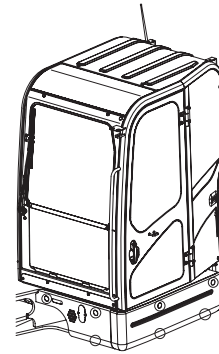
NOTE: *Be careful about hydraulic oil leak.*



FG013471

Figure 2

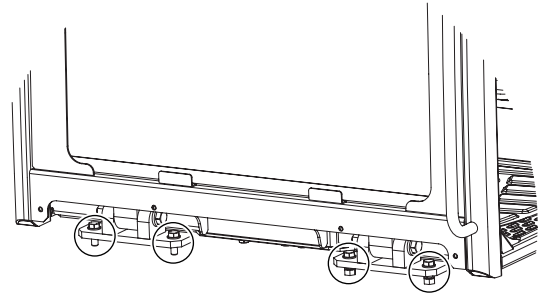
13. Remove seven M8 bolts Then open side cover of main frame (Figure 3).
Remove front pivot bracket four bolts (M12) and washers outside of cabin (Figure 4).
Remove two M16 bolts and washers to split tilting lever from main frame (Figure 5).



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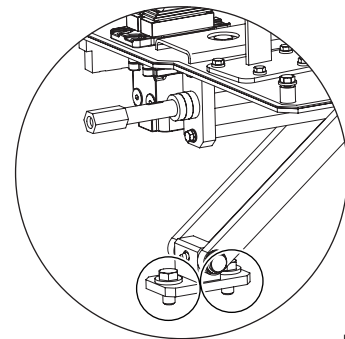
Figure 3

14. Remove floor mat.



FG013823

Figure 4



FG013822

Figure 5

15. First, separate the main harness connector (A, Figure 6).
Separate the left stand harness (B, Figure 7) and right
stand harness (C, Figure 8).
After separating the air conditioner box cover (E, Figure 9)
under the seat, separate the harness passing next to the
air conditioner box (D, Figure 10).

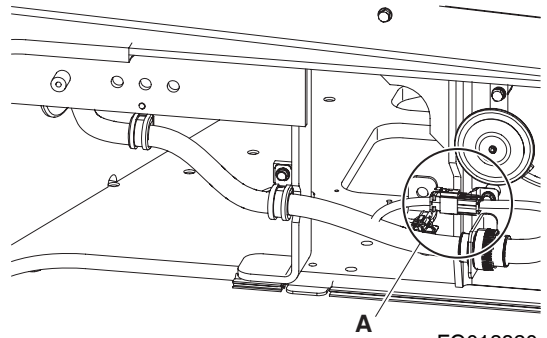


Figure 6

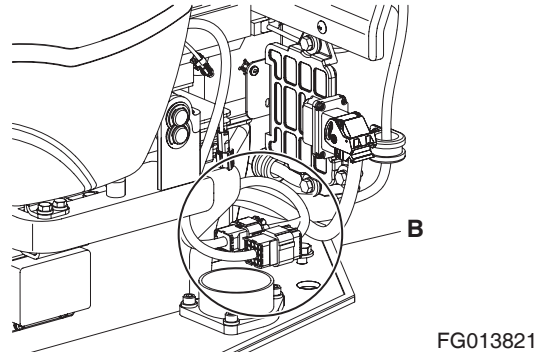


Figure 7

16. Disconnect washer hose located at floor plate.

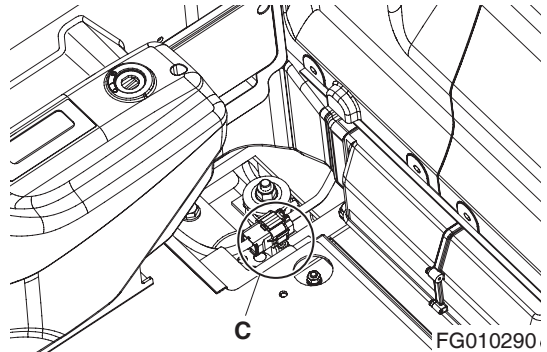


Figure 8

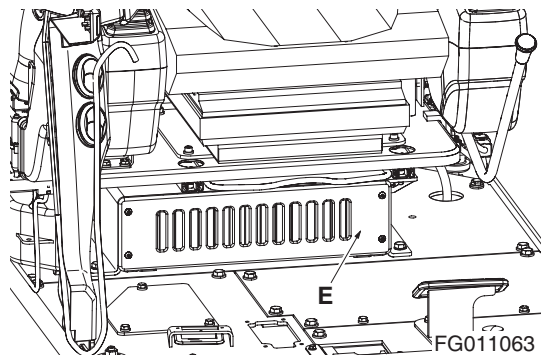


Figure 9

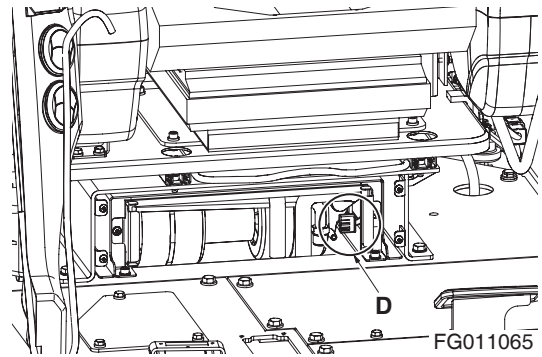


Figure 10

17. Remove six bolts (M10) and washer, a nut (M10), two nuts (M16) and washers (Figure 11).

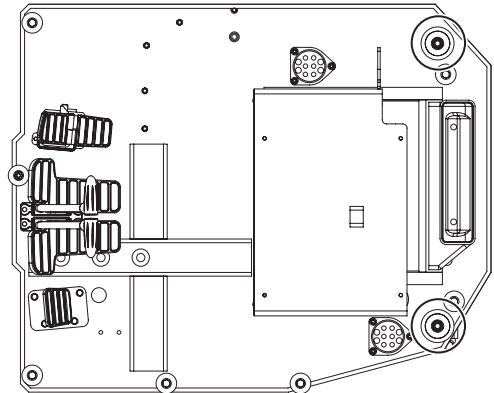


Figure 11

18. Install sling on four places above cabin with proper device for lifting (Figure 12).

NOTE: *The weight of cabin is about 480 kg (1,058.2 lb).*

19. Lift cabin approximately 25 - 50 mm (1" - 2") above deck. Check that all electrical connections have been disconnected and all other items unbolted.
20. Continue lifting with the assist crane to remove the cabin. Lower the cabin to a prepared safe blocking support.

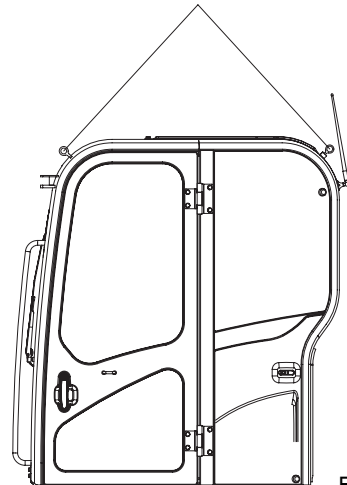


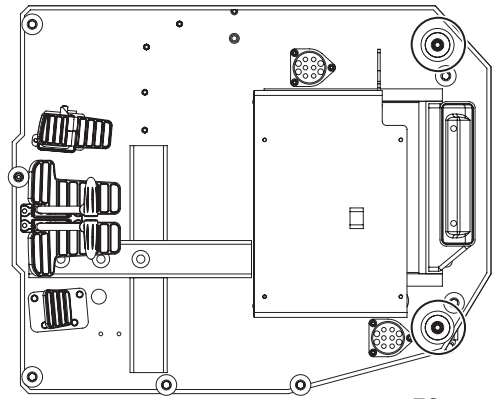
Figure 12

INSTALLATION

1. Install sling on four places above cabin with proper device for lifting.

NOTE: *The weight of cabin is about 480 kg (1,058.2 lb).*

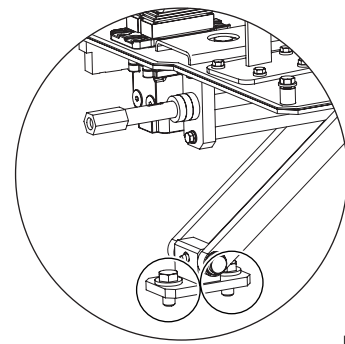
2. Lower cabin into position on floor.



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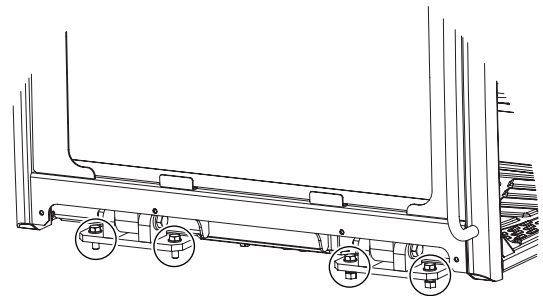
Figure 13

3. Install six bolts (M10) and washer, a nut (M10), two nuts (M16) and washers (Figure 14).
Install two M16 bolts and washers to split tilting lever from main frame (Figure 14).
Install front pivot bracket(2) four bolts (M12) and washers outside of cabin (Figure 15).



FG013822

Figure 14



FG013823

Figure 15

4. Once cabin is mounted to floor, unhook lifting device.
5. Connect the main harness, the harness of stand of both ends and the harness passing next to the air conditioner box in that order (A ~ D, Figure 16 ~ Figure 19).

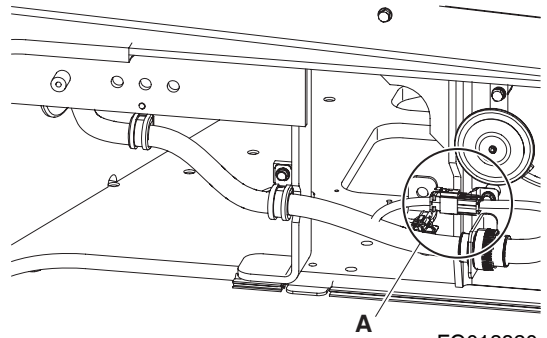


Figure 16

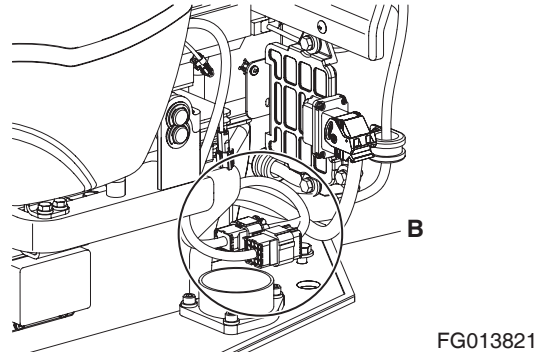


Figure 17

6. Assemble the air conditioner filter and air conditioner box cover.
7. Connect washer hose located at floor plate.

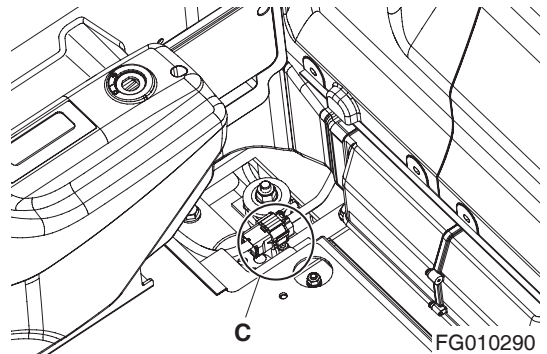


Figure 18

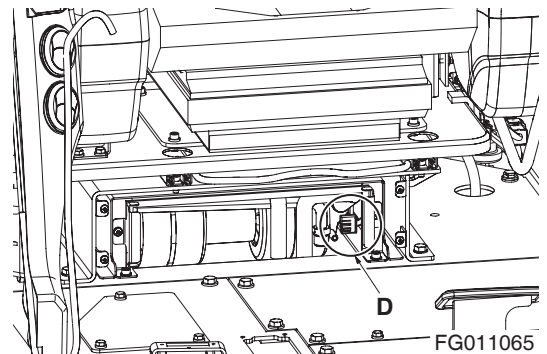
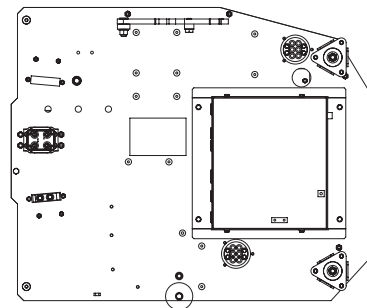


Figure 19

8. Install seven M8 bolts Then open side cover (3) of main frame (Figure 21).
9. Tilt up cabin.
Install a bolt (Figure 20).
Connect all hydraulic hoses.
Tilt down cabin.

NOTE: *Please refer to cabin tilting.*

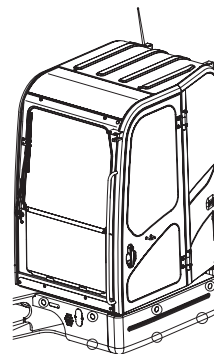
NOTE: *Be careful about hydraulic oil leak.*



FG013471

Figure 20

10. Install floor mat.
11. Connect negative (-) battery cable leading to frame from battery.



FG013818

Figure 21

Swing Bearing

Edition 1

MEMO

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Swing Bearing

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

SWING BEARING MAINTENANCE

Operating Recommendation

The service life of the swing bearing may be extended if a conscious, daily effort is made to equalize usage over both ends of the excavator. If the excavator is used in the same operating configuration day in and day out (for example, with the travel motors always under the counterweight, or with the attachment over one side of the machine more than the other), the bearing's service life could be reduced. Taking a few minutes in the middle of each work shift to reposition the excavator, to work the opposite end of the bearing, will provide a payoff with more even, gradual rate of wear and extended service life.

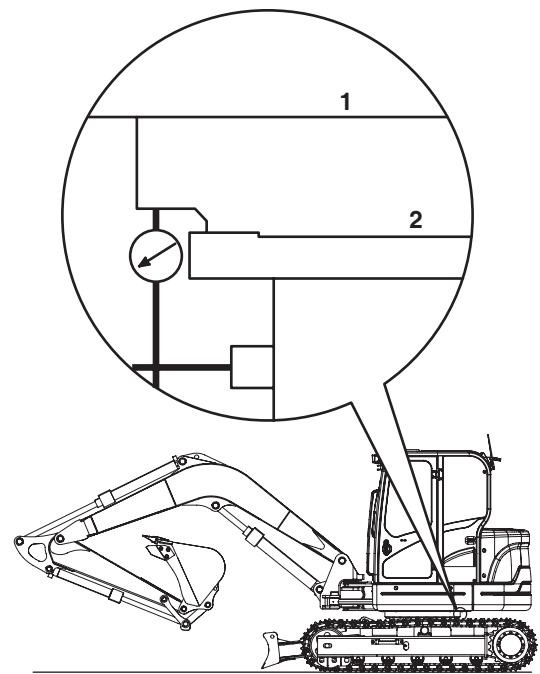
Measuring Swing Bearing Axial Play

Periodic, regular checks of bearing displacement should be made at least twice a year. Use a dial indicator. Push the attachment against the ground to lift the excavator off the ground and take measurements at 4 points, 90° apart, around the circumference of the bearing (Figure 1).

Record and keep all measurements. Play in the bearing should increase minimally from one inspection to the next. Eventually, however, as the bearing begins to approach the limit of its service life, clearance increases become much more pronounced and the actual measured play in the bearing could exceed twice the value that was measured when the machine was new.

Measuring Bearing Lateral Play

When vertical checks are made, the side to side play in the bearing can be checked by fully retracting the arm and bucket cylinders and extending the tip of the bucket as far forward as it will go. With the excavator parked on a flat, level surface and the bucket tip just off the ground, push against the bucket sideways to take up all the lateral clearance in the bearing. (Less than 100 lb of force should be required to move the bucket over all the way.) Check lateral play in both directions and record the values. When the bearing is beginning to approach the end of its service life, measured lateral clearance should start to show larger and larger increases.



FG013224

Figure 1

Swing Bearing Basic Operation

The swing bearing, which connects the upper structure with the lower structure, consists of an inner ring, outer ring and ball bearings. During swing movement, power from the swing motor is transferred to the pinion by planetary gears connected to gears on the inner ring, which is fixed in the undercarriage. Ball bearings turn the outer ring.

Reference Number	Description
1	Ball
2	Seal A
3	Retainer
4	Outer Ring
5	Inner Ring
6	Tapered Pin
7	Plug

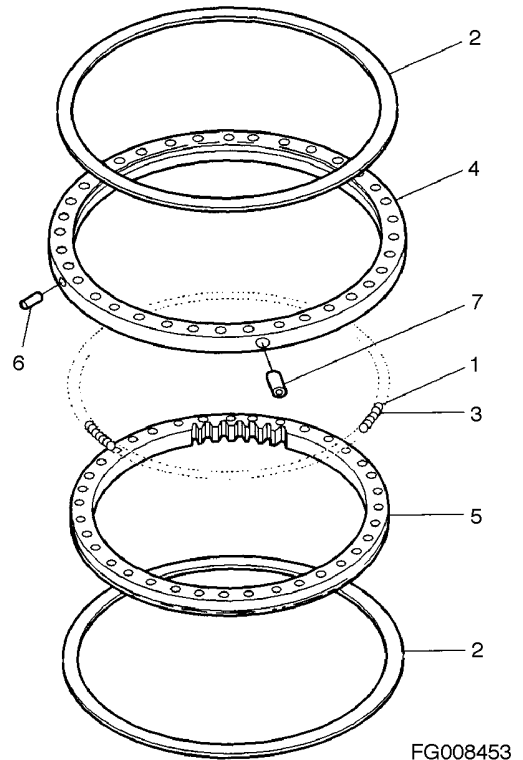


Figure 2

Rebuilding Swing Bearing

1. Remove tip of tapered pin (1, Figure 3) using grinder and tap lightly to remove debris.

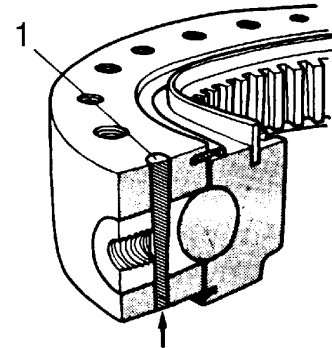


Figure 3

2. Remove plug (1, Figure 4) using a M10 x 1.25 bolt (2).

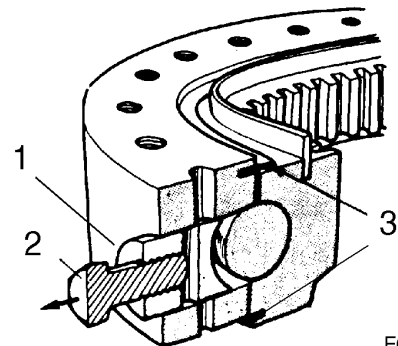
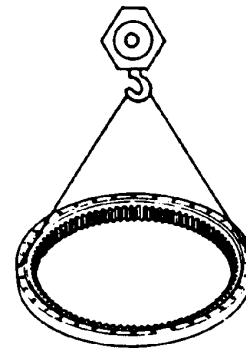


Figure 4

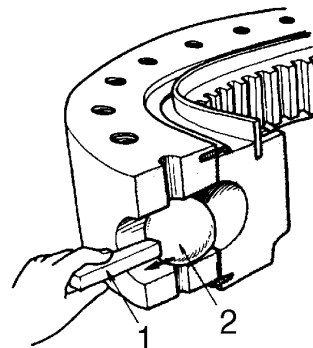
3. Lift outer ring and check that inner ring can move freely.
See Figure 5, if not, replace seal (3, Figure 4).



1588A

Figure 5

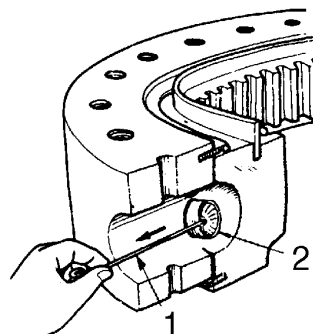
4. Turn inner ring and use magnet bar (1, Figure 6) to remove steel balls (2).



1589A

Figure 6

5. Turn inner ring and use wire (1, Figure 7) to remove retainers (2).



1590A

Figure 7

Lower Structure and Chassis

Track Assembly

Edition 1

MEMO

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Track Assembly

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SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

TRACKS

Specification and Construction

Steel Tracks

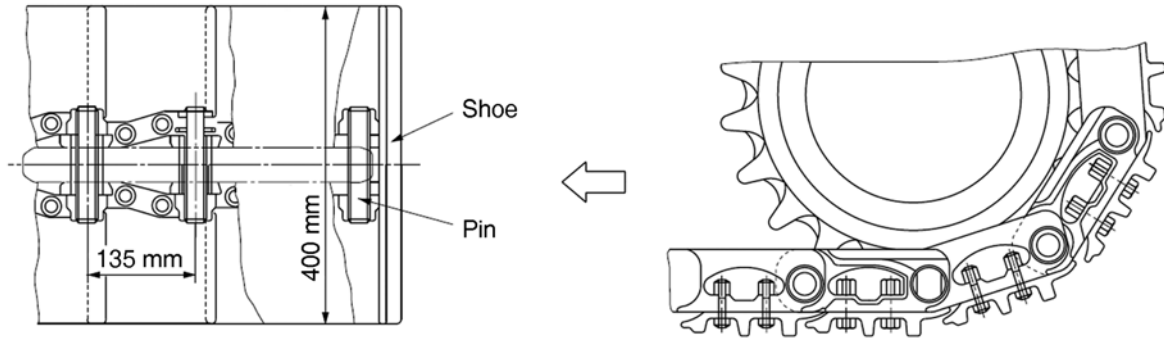


Figure 1

FG011227

Track Frame

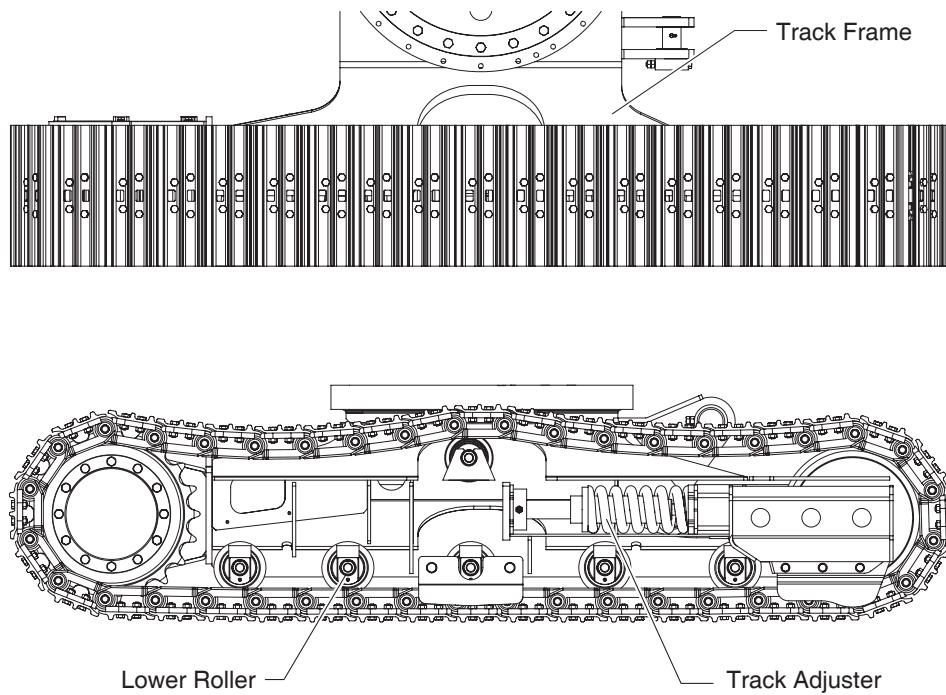


Figure 2

FG013225

TRACK TENSION



WARNING

Safely measuring track tension requires two people. One person must be in the operator's seat, running the controls to keep one side frame in the air, while the other person makes dimensional checks. Take all necessary precautions to make sure the machine won't move or shift position during service. Warm up the engine to prevent stalls, travel the excavator to an area that provides level, uniform ground support and/or use support blocks when necessary.

The track adjusting mechanism is under very high-pressure. NEVER release pressure too suddenly. The track tension grease valve should never be backed off more than 1 complete turn from the fully tightened down position. Bleed off pressure slowly and keep your body away from the valve at all times. If there is a problem with the valve threads, the valve might be ejected at a high-speed, causing a fatal injury.

Track shoe link pins and bushings wear with normal usage, reducing track tension. Periodic adjustment is necessary to compensate for wear and it may also be required by working conditions.

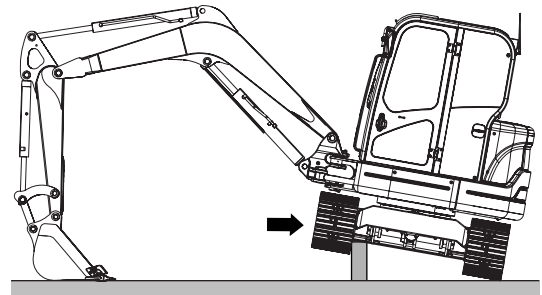
Inspection

1. Turn upper body so it is at a 90° angle to tracks.

NOTE: On rubber tracks, move machine body so seam of tracks pad is on axle centerline, then turn body.

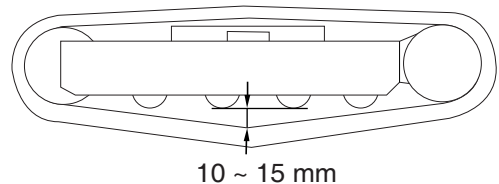
2. Track tension is checked by jacking up one side of excavator. See Figure 2. Place blocking under frame while taking measurement.
3. Measure clearance between track roller and track contact surfaces. Clearance should be approximately 10 - 15 mm (0.39 - 0.59 in)

NOTE: This measurement can be thrown off if there is too much mud or dirt or other material in track assembly. Clean off tracks before checking clearance.



FG013226

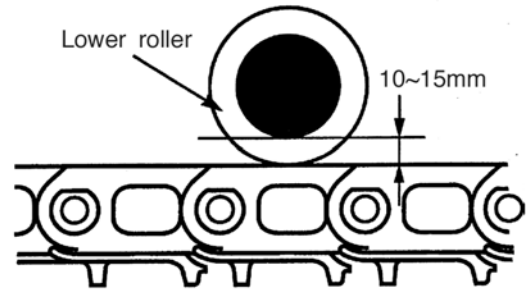
Figure 2



FG007705

Figure 3

NOTE: For machines with steel tracks, checking and adjustment steps and clearance are the same.



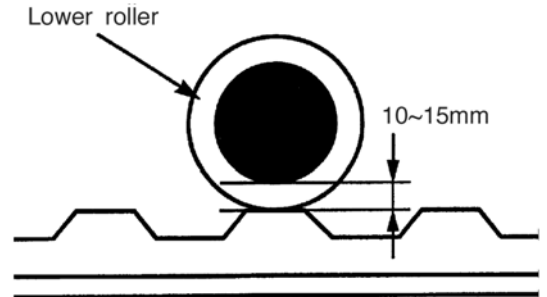
FG007706

Figure 4



WARNING

The track adjusting mechanism is under very high-pressure. NEVER release pressure too suddenly. The track tension grease valve should never be backed off more than 1 complete turn from the fully tightened down position. Bleed off pressure slowly and keep your body away from the valve at all times. If there is a problem with the valve threads, the valve might be ejected at a high-speed, causing a fatal injury.

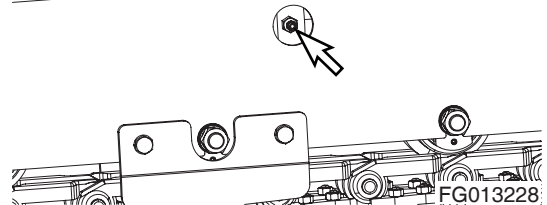
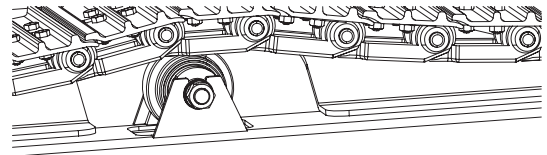


FG007708

Figure 5

How to Adjust Tension

1. Apply grease through grease fitting.
2. Move track forward and backward to distribute grease and readjust tension if necessary.
3. If tension cannot be increased, replace pin and bushing, or, on rubber tracks, replace cylinder seal or tracks.

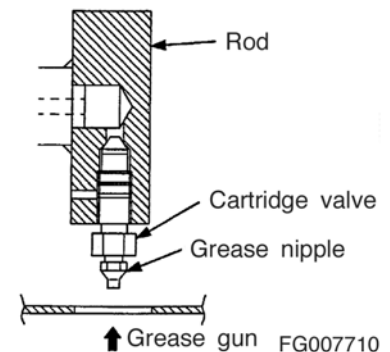


FG013228

Figure 6

To Reduce Tension

1. Loosening track tension grease valve causes grease to drain out and track tension to decrease. Loosen valve slowly a maximum of 1 to turns.
2. When track tension is correct, tighten track tension grease valve to 59 - 88 Nm / 6 - 9 kg•m (43 - 65 ft lb)
3. Recheck tension by moving track forward and backward.
4. Recheck tension and adjust as necessary.



FG007710

Figure 7

CLEANING AND INSPECTION (WEAR LIMITS AND TOLERANCES)



CAUTION

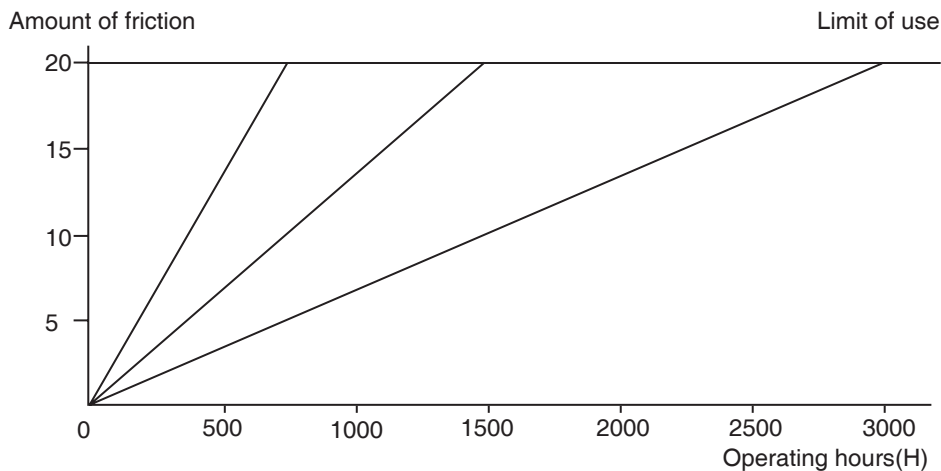
Refer to the "Welding Precautions and Guidelines" information in "General Maintenance Procedures" section for general recommendations and specific safety precautions, before starting any lower travel frame component rebuilding procedure.

The tables that follow provide factory specified dimensional limits (as new condition, recommended service and replacement limit) for lower travel frame components.

Recommended maintenance to renew most listed components requires welding on additional material and grinding off excess. Some components must be replaced before the service limit is exceeded. No maintenance or renewal is possible.

Compare the values in the tables with dimensions and profiles shown in the following figures.

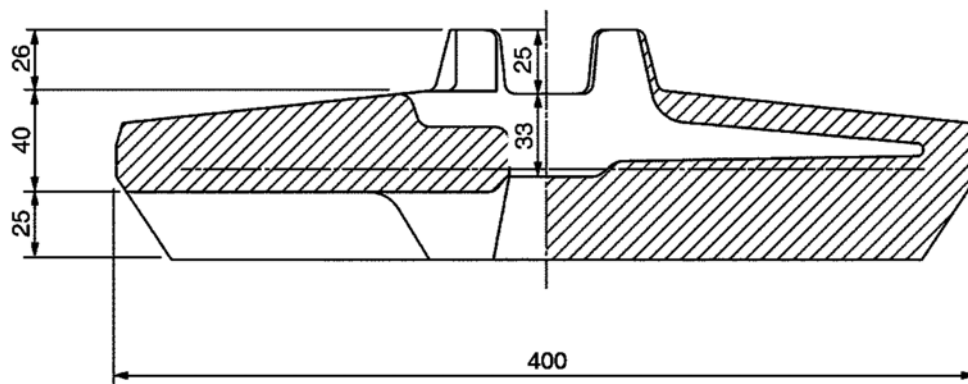
Rubber Track Features



FG008467

Figure 8

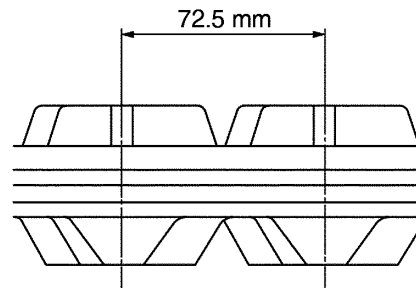
The amount of friction of rubber track sets limit of use. However, it is subject to change depending upon work condition and environment.



FG010285

Figure 9

Item		DX60R
Distance Between Centers of Tracks		5,365 ± 10 mm (211.22 ± 0.39 in)
Scale Cord	Rigid	1,000.0 kg (2,200 lb)
Scale Cord	Number of Coils	44 ± 4
Range of Temperature for Use		-25°C - 55°C (-13° - 131°F)
Width x Pitch		400 x 72.5 mm (15.74 x 2.85 in)



FG010286

Figure 10

Steel Tracks

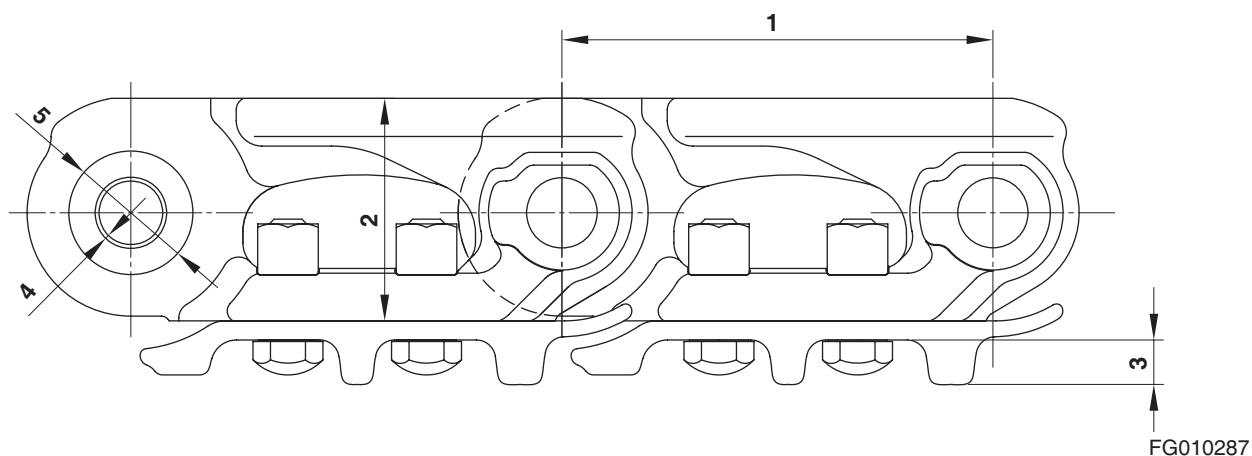
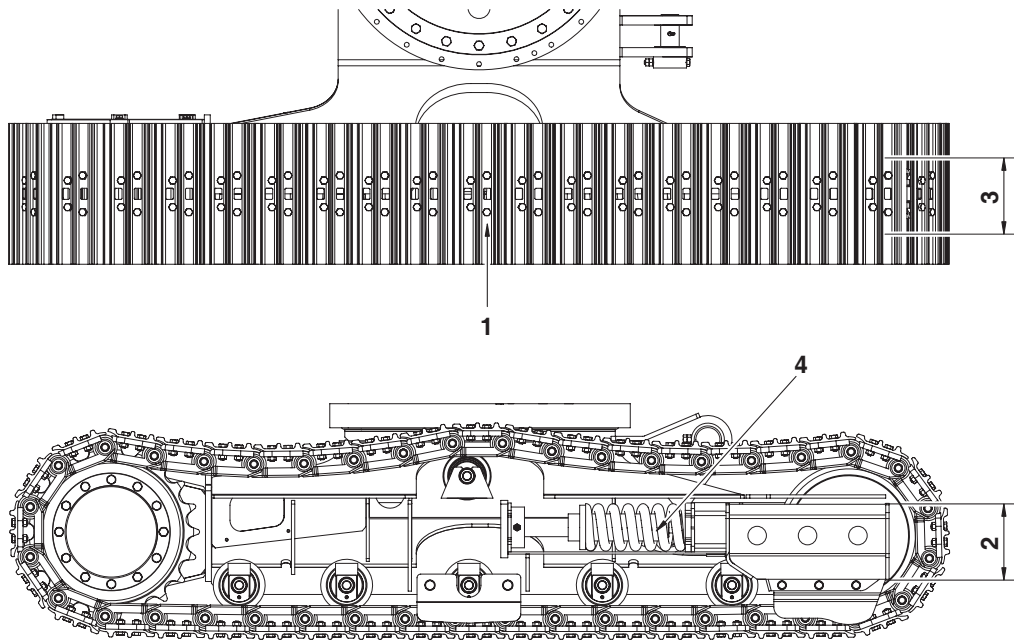


Figure 11

No.	Item	Standard	Limits	Remarks
1	Link Pitch	135 mm (5.32 in)	137 mm (5.4 in)	
2	Link Height	70.0 mm (2.75 in)	67.5 mm (2.66 in)	Build up or replace.
3	Track Height	14 ±1 mm (0.55 ±0.04 in)	9.0 mm (0.35 in)	Build up or replace.
4	Pin Clearance	0.15 mm (0.01 in)	2.0 mm (0.08 in)	Replace.
5	Bushing Thickness	39 mm (1.53 in)	37.6 mm (1.48 in)	Replace.

Track Frame Spring



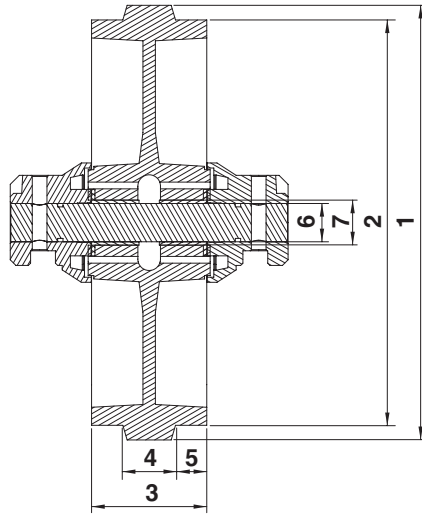
FG013227

Figure 12

No.	Item	Criteria			Remarks
1	Deformed frame		Limit		Bent
		Bending	5 (Overall length of track frame)		
		Distorted	10 (Distortion between left and right track frames)		
		Widened idler	5.0 mm (0.20 in)		
2	Gap between upper and lower sides of idler guide.		Standards	Limits	Build up or replace
		Track frame	69.0 mm (2.71 in)	74.0 mm (2.91 in)	
		Idler frame	67.0 mm (2.64 in)	62.0 mm (2.44 in)	
3	Gap between left and right of idler guide.	Idler support	166.0 mm (6.54 in)	171.0 mm (6.73 in)	Build up or replace
		Track frame	170 ±0.5 mm (6.69 ±0.02 in)	165.0 mm (6.5 in)	
4	Track spring (Standards)	Free length	Installed load	Installed length	Replace
		303.6 mm (11.95 in)	2,600.0 kg (5,730 lb)	269.0 mm (10.6 in)	

Idler

Steel Tracks

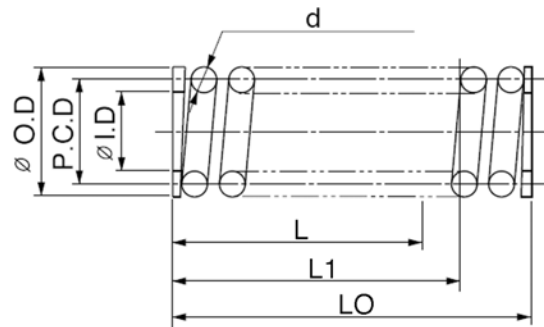


FG010668

Figure 13

No.	Item	Standard	Limits	Remarks
1	Diametre of Flange	365.0 mm (14.37 in)	-	-
2	Diametre of Link	328 mm (12.91 in)	316 mm (12.44 in)	Repair
3	Front Width	98 mm (3.86 in)	-	--
4	Flange Width	46.6 mm (1.83 in)		
5	Thread width	25.6 mm (1.01 in)	31.1 mm (1.22 in)	Repair
6	Shaft-Bushing Clearance	Standard dimension	Tolerance	Standard Clearance
			Shaft	Hole
		34 mm (1.34 in)	33.95	34.32
			33.925	34.21
				Max: 0.39
				Min: 0.26
				Allowable wear limit
				Undefinable
7	Body-Bushing Press Fit	Standard dimension	Tolerance	Standard Press Fit
			Bushing	Hole
		38 mm (1.49 in)	38.103	38.05
			38.078	38.02
				Max: -0.083
				Min: 0.28
				Allowable wear limit
				Nonoccurrence

Spring Specifications



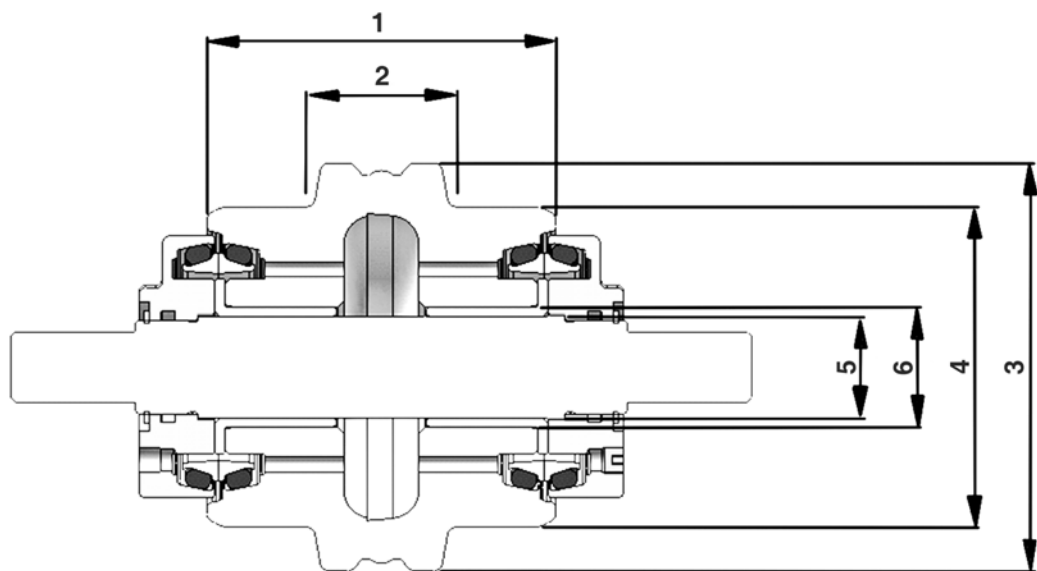
FG008473

Figure 14

Designation	Dimensions
No. of Active Coils	5.7
Total No. of Coils	7.7
Spring Constant	75.5 kgf/mm (4,227 lb/in)
Set Load	2,600.0 kg (5,730 lb)
Compressive Load	5,780.0 kg (12,740 lb)
Free Length: LO	303.6 mm (11.95 in)
Minimum Closed Length	227.0 mm (8.94 in)
Outside Diameter	128.0 mm (5.04 in)
Mean Diameter	102.0 mm (4.02 in)
Inside Diameter	76.0 mm (3.00 in)
Wire Diameter	26.0 mm (1.02 in)
Set Length	269.0 mm (10.6 in)

LOWER ROLLER

Steel Track



FG011230

Figure 15

No.	Item	Standard	Limits	Remarks
1	Body Length	120.0 mm (4.72 in)	-	-
2	Flange Width	46.6 mm (1.83 in)	40.6 mm (1.59 in)	Repair
3	Diameter of Flange	140 mm (5.5 in)	-	-
4	Diameter of Link	110 mm (4.33 in)	102 mm (4.02 in)	Repair
5	Shaft-Bushing Clearance	Standard dimension	Tolerance	Standard Clearance
			Shaft	Hole
		35 mm (1.38 in)	34.95	35.36
			34.925	35.22
				Max: 0.44
				Min: 0.27
6	Body-Bushing Press Fit	Standard dimension	Tolerance	Standard Fit
			Bushing	Hole
		41.15 mm (1.6 in)	41.15	41.18
			41.1	41.15
				Max: -0.15
				Min: -0.07

Rubber Track

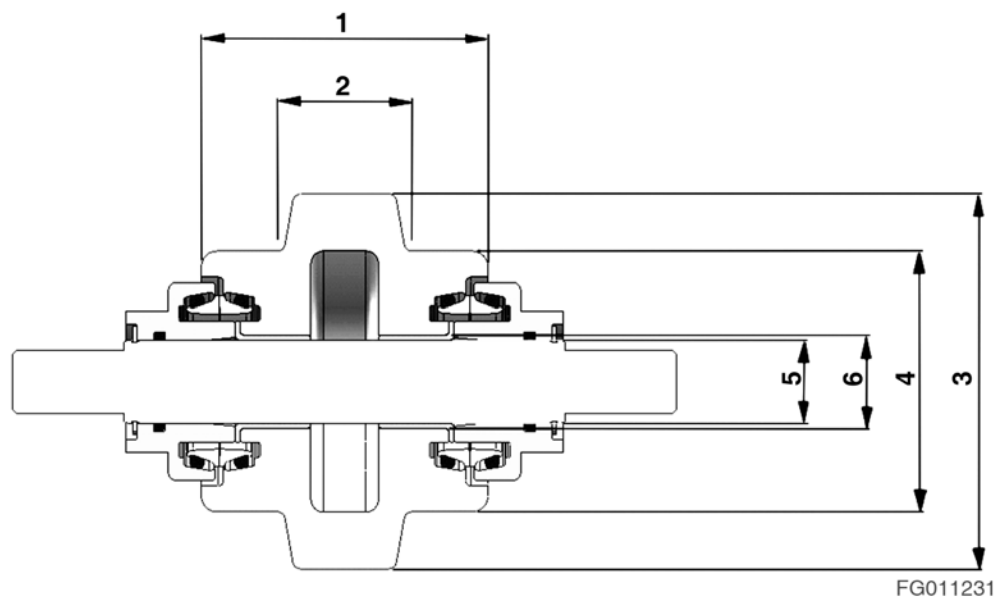
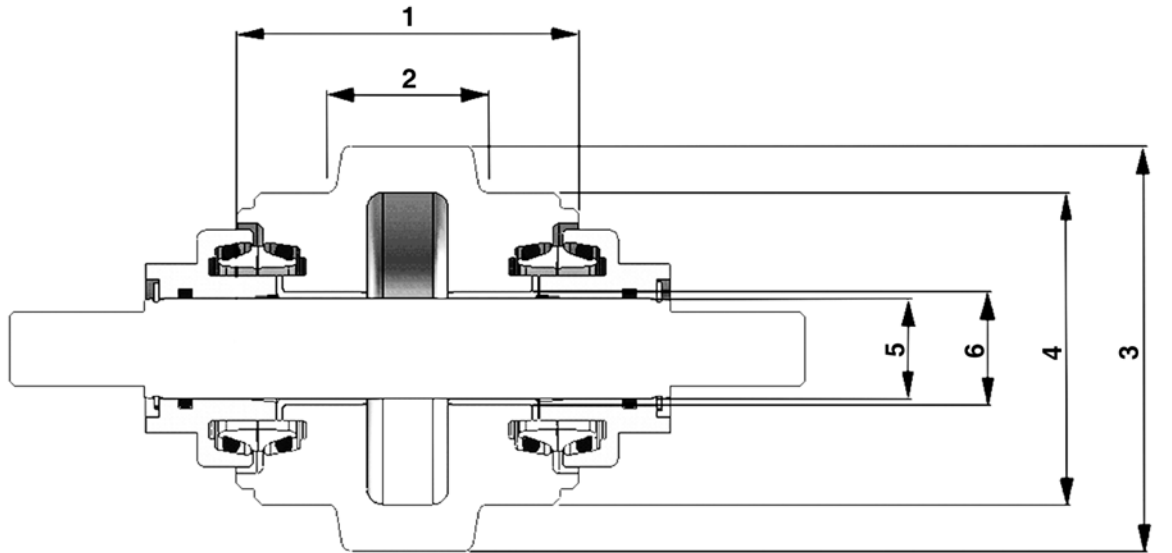


Figure 16

No.	Item	Standard		Limits		Remarks
1	Body Length	110.0 mm (4.33 in)		-		-
2	Flange Width	46.6 mm (1.83 in)		40.6 mm (1.59 in)		Repair
3	Diameter of Flange	144 mm (5.11 in)		-		-
4	Diameter of Link	100 mm (3.93 in)		92 mm (3.62 in)		Repair
5	Shaft-Bushing Clearance	Standard dimension	Tolerance		Standard Clearance	Allowable wear limit
			Shaft	Hole		
		32 mm (1.26 in)	31.95	32.33	Max: 0.37	Undefinable
			31.925	32.28	Min: 0.20	
6	Body-Bushing Press Fit	Standard dimension	Tolerance		Standard Fit	Allowable wear limit
			Bushing	Hole		
		36 mm (1.41 in)	36.15	36.05	Max: -0.13	Nonoccurrence
			36.10	36.02	Min: -0.05	

UPPER ROLLER

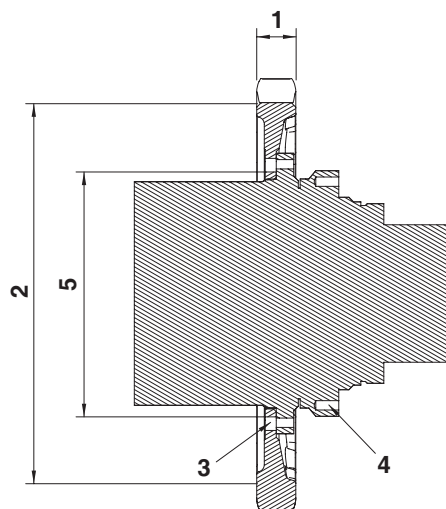


FG011232

Figure 17

No.	Item	Standard	Limits	Remarks
1	Body Length	110 mm (4.33 in)	-	-
2	Flange Width	46.6 mm (1.83 in)	40.6 mm (1.59 in)	Repair
3	Diameter of Flange	130 mm (5.11 in)	-	-
4	Diameter of Link	100 mm (3.93 in)	92 mm (3.62 in)	Repair
5	Shaft-Bushing Clearance	Standard dimension	Tolerance	Standard Clearance
			Shaft	Hole
		32 mm (1.26 in)	31.95	32.33
			31.925	32.28
				Max: 0.37
				Min: 0.20
6	Body-Bushing Press Fit	Standard dimension	Tolerance	Standard Fit
			Bushing	Hole
		36 mm (1.41 in)	36.15	36.05
			36.10	36.02
				Max: -0.13
				Min: -0.05

SPROCKET



FG010671

Figure 18

No.	Item	Standard	Limits	Remarks
1	Sprocket Tooth Width	42.5 mm (1.67 in)	36.0 mm (1.42 in)	Build up or replace
2	Sprocket Dedendum Diameter	ø377 mm (14.84 in)	ø411.0 mm (16.18 in)	Build up or replace
3	Mounting Bolt Tightening Torque	18 kg•m (130 ft lb)		M14 x 2.0
4	Motor Mounting Bolt Tightening Torque	18 kg•m (130 ft lb)		M14 x 2.0
5	Travel Motor Mounting Hole	ø230.0 mm (8.03 in)		

TRACK REMOVAL AND INSTALLATION

Track Removal

The track removal is a dangerous operation. It must be done with machine jacked up on one side resting on adequate blocking. Never move machine during removal operation. Be careful not to tipped machine over.

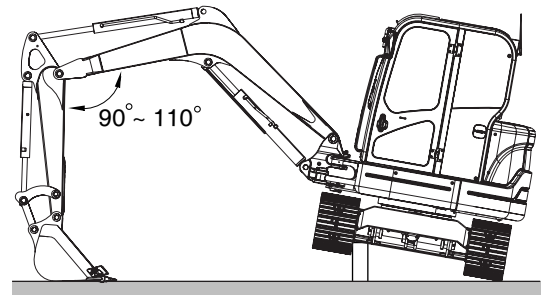


WARNING

The track adjusting mechanism is under very high-pressure. NEVER release pressure too suddenly. The track tension grease valve should never be backed off more than 1 complete turn from the fully tightened down position. Bleed off pressure slowly and keep your body away from the valve at all times. If there is a problem with the valve threads, the valve might be ejected at a high-speed, causing a fatal injury.

1. When removing tracks, position machine as shown and install nonslip supports under frames.
2. After completing tension adjustment, securely tighten track tension grease valve.

NOTE: Tightening torque: 6 - 9 kg·m (43 - 65 ft lb)



FG012464

Figure 19

Track Loosening

1. Loosening track tension grease valve of tension adjusting cylinder will drain grease and loosen tracks. Loosen track tension grease valve slowly.

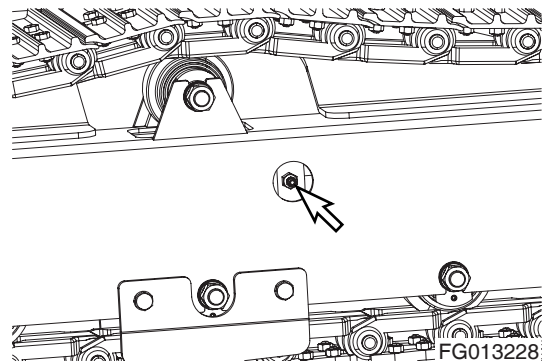
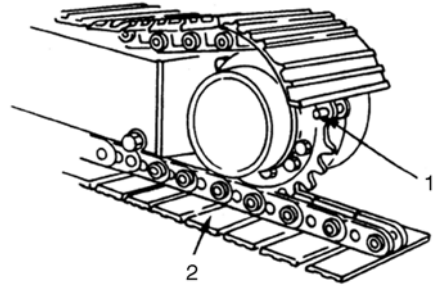


Figure 20

Track Removal

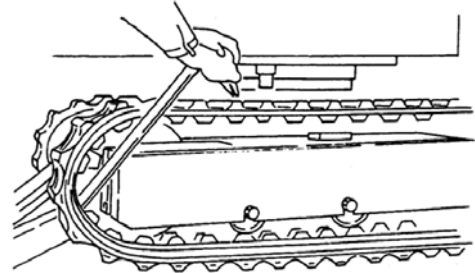
1. Lift machine on one side using front attachment and install wood blocks under machine.
2. Steel Tracks
Remove master pin (1) from linkage by turning it to idler side, and then remove track (2).



FG008458

Figure 21

3. Rubber Tracks
Retract idler all the way, and remove rubber track from idler using a steel bar.



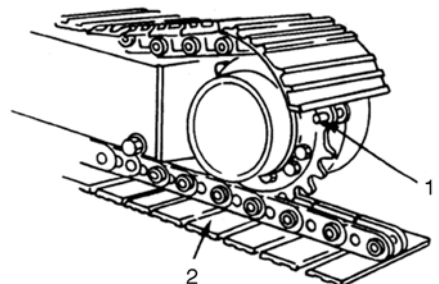
FG008459

Figure 22

Track Installation

Track installation operation may very dangerous as it should be done with machine inclined. Never move machine during removal operation so machine may not be tipped over.

1. Track installation
 - Lift machine in one side using front and install wood block under machine.
 - Index track (2) with sprocket teeth and then install it on top of idler.
 - For steel tracks, insert master pin (1).
 - For rubber tracks, install track over idler.

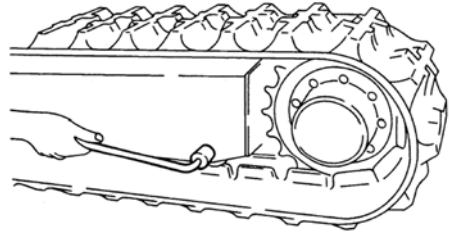


FG008458

Figure 23

Replacement of Rubber Tracks with Steel Tracks

1. Remove tracks and idlers.
2. Loosen track roller mounting bolt to remove track roller.

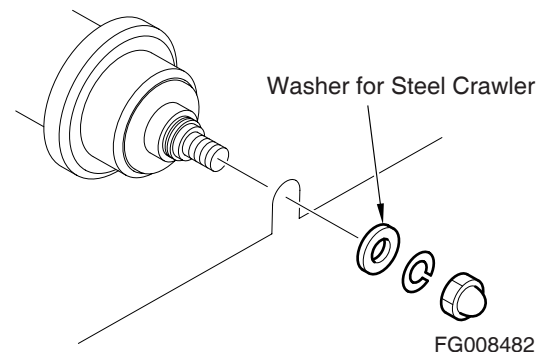


FG008481

Figure 24

3. Mount track roller for steel track.

NOTE: *Be sure to install a washer for steel track.*



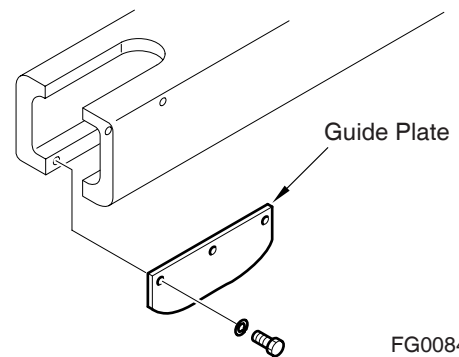
FG008482

Figure 25

4. Install guide plate.

NOTE: *Tightening torque: 4.30 kg·m (31.1 ft lb)*

5. Assemble idler for steel track.
6. After installing tracks, adjust track tension.

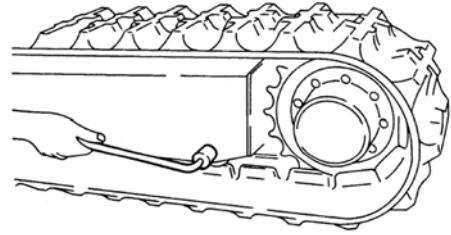


FG008483

Figure 26

Replacement of Steel Tracks with Rubber Tracks

1. Remove steel tracks and track rollers.
2. Remove idlers for steel track.



FG008481

Figure 27

3. Install track rollers for rubber tracks.

NOTE: Nut tightening torque: 34.50 kg•m (250 ft lb)

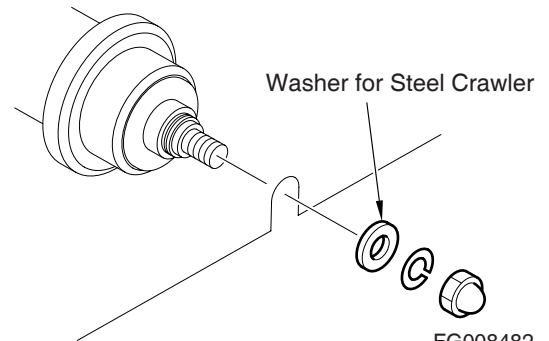


Figure 28

4. Remove guide plate.
5. Install idlers for rubber track.
6. After assembling rubber tracks, adjust track tension.

NOTE: Track shoe link pins and bushings wear with normal usage, reducing track tension. Periodic adjustment is necessary to compensate for wear and it may also be required by working conditions.

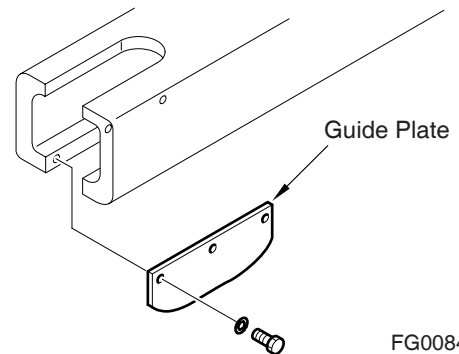
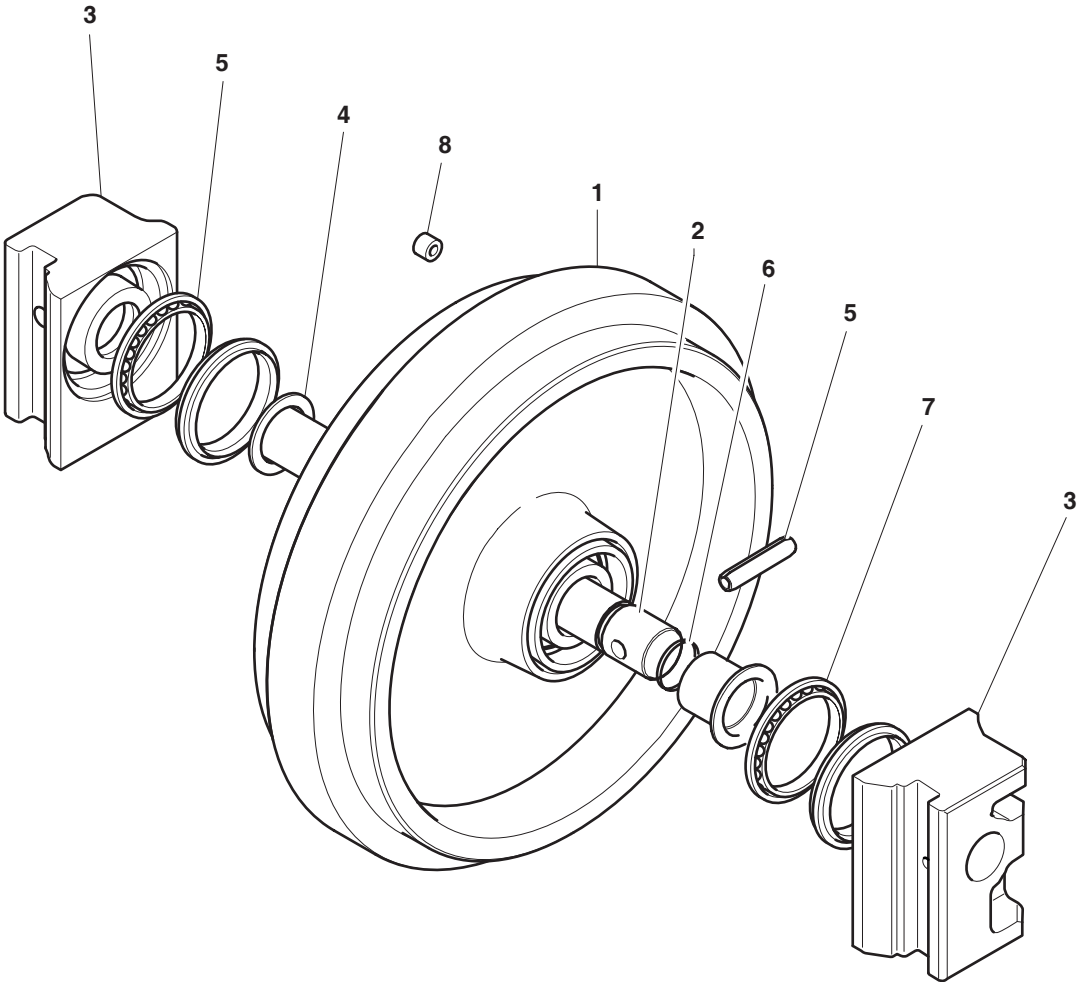


Figure 29

IDLER

Parts List



FG011233

Figure 30

Reference Number	Description
1	Idler
2	Shaft
3	Support
4	Bushing
5	F/Seal

Reference Number	Description
6	O-ring
7	Pin
8	Plug

Disassembly

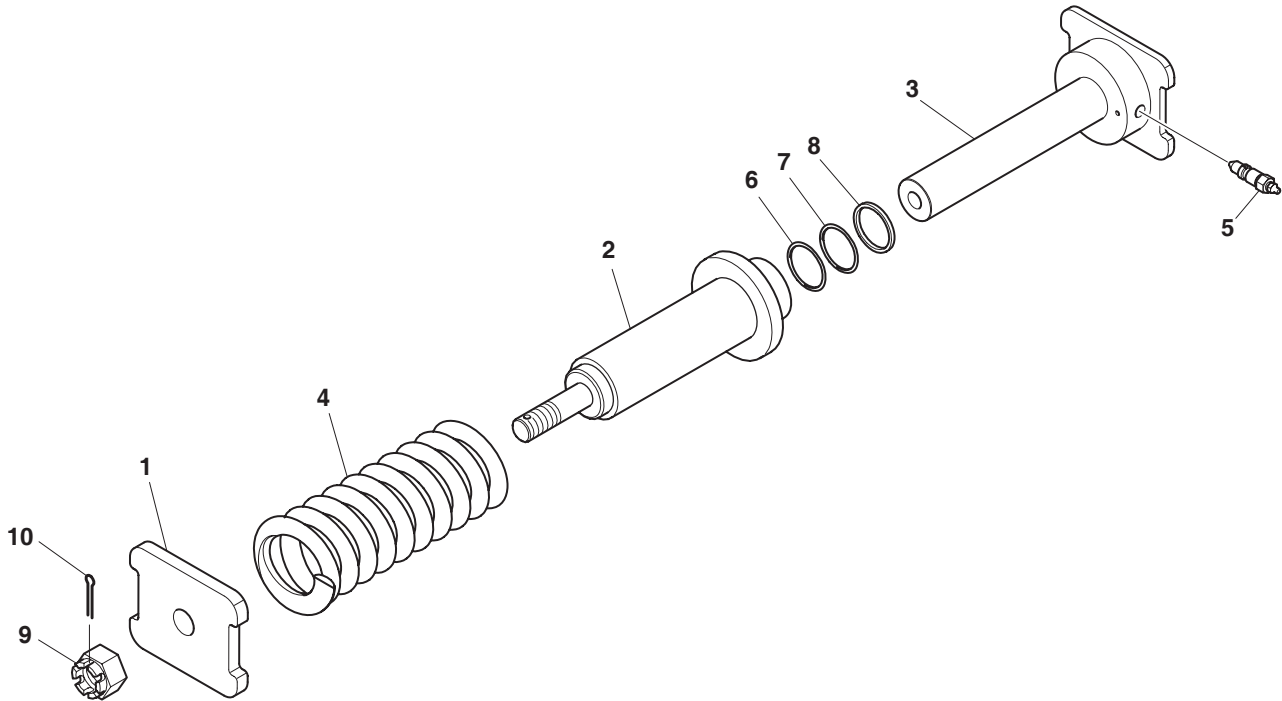
1. Refer to "Track Disassembly" to remove track and idler assembly.
2. Remove spring pin (7) from support (3).
3. Remove support (3) from shaft (2).
4. Remove O-ring (6) using a screwdriver (-).
 - Once removed, O-ring (6) should not be reused.
5. Remove floating seal (5), bushing (4), shaft (2) and plug (8).

Reassembly

1. For reassembly, reverse disassembly procedures.
 - Clean separated parts.
 - Coat clean gear oil or engine oil (80.0 cc (2.71 oz)) before assembling oil seal (5).
 - See "Track Installation" on page -20. for track reassembly.

TRACK TENSION ADJUSTING CYLINDER

Parts List



FG013472

Figure 31

Reference Number	Description
1	Flange
2	Cylinder
3	Rod
4	Spring
5	Valve

Reference Number	Description
6	U-packing
7	Back up Ring
8	Dust Ring Nok DSI-50
9	Nut
10	Split Pin

Disassembly

NOTE: *Be sure to use a special tool when removing spring.*

NOTE: *Take care as spring may pop out.*

1. Remove tracks and idlers.
2. Use a press to relieve spring force.
3. Remove split pin (10) and nut (9).
4. Remove spring (4) from tension cylinder (2).
5. Remove track tension valve (5) from tension rod (3).
6. Remove tension rod (3) from tension cylinder (2).
7. Remove U-packing (6), Back up ring (7) and Dust ring nok DSI-50 (8).

Reassembly

1. Install U-packing (6), backup ring (7), and Dust ring nok DSI-50 (8).

NOTE: *To prevent damage, coat great to O-ring and Dust wiper.*

2. Assemble rod (3) to cylinder (2). First, inject grease into cylinder. Install track tension valve (5) into tension adjusting cylinder rod until two threaded portions contact threaded hole, and then assemble rod. At this time, ensure that grease is drained from grease drain port, and then tighten track tension grease valve.

NOTE: *Track tension grease valve tightening torque: 6 - 9 kg•m (43 - 65 ft lb)*

3. Use a special tool to install spring (4) to cylinder (2) and secure spring in place with a nut (9).
4. After adjusting spring set length, bend split pin (10) completely.

NOTE: *Spring set length: 269.0 mm (10.59 in)*



CAUTION

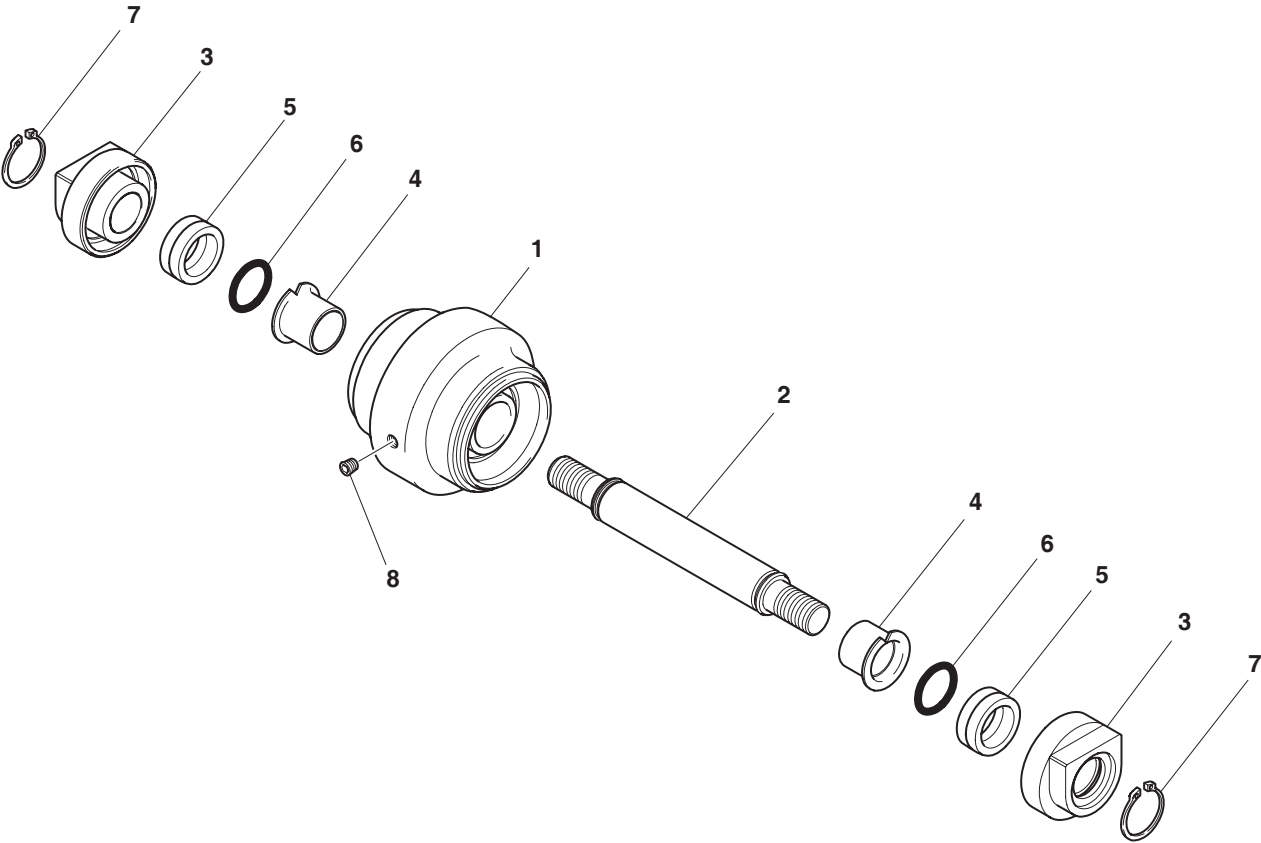
Release air from cylinder completely before assembly.

Be sure to apply grease to piston area of rod before assembly.

LOWER ROLLER

Steel Track

Parts List



FG013473

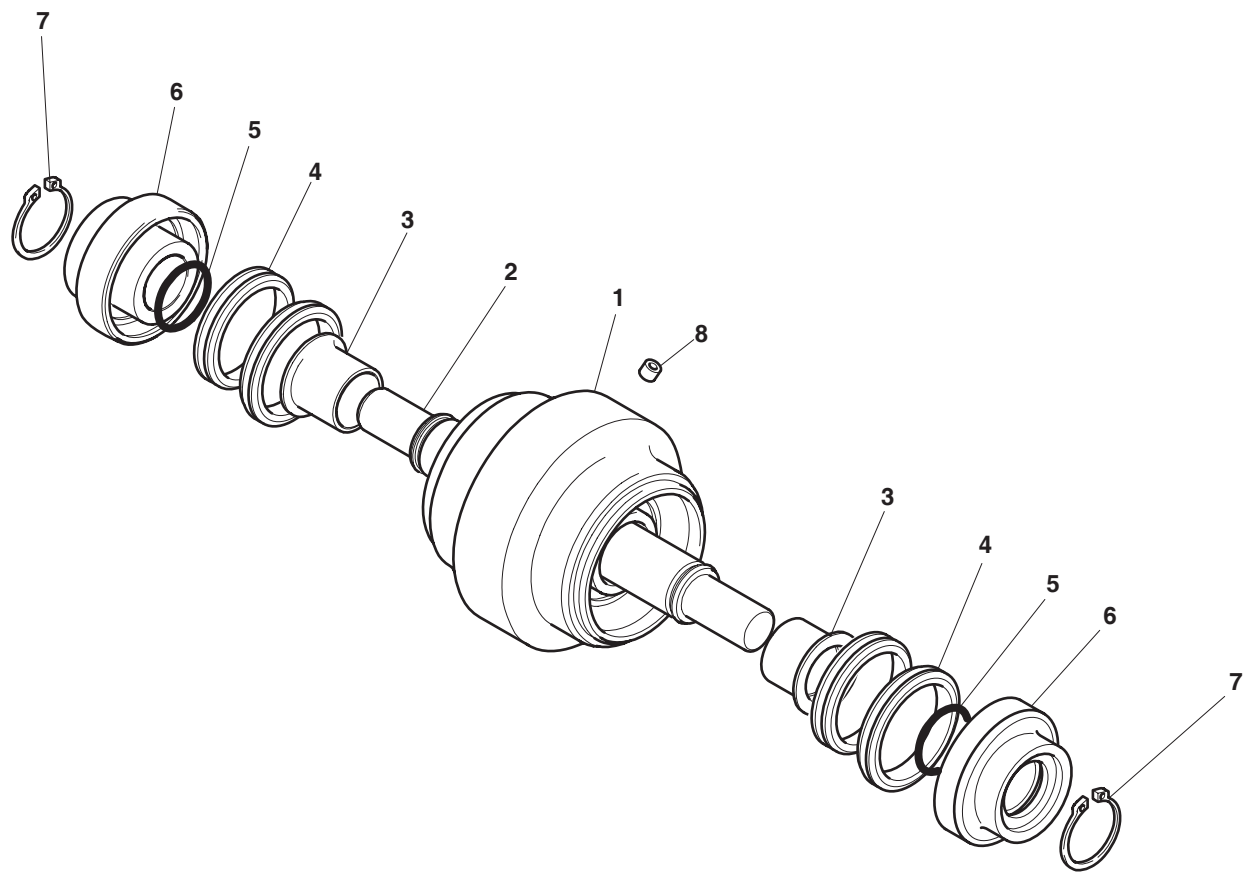
Figure 32

Reference Number	Description
1	Roller
2	Shaft
3	Collar
4	Bushing

Reference Number	Description
5	Floating Seal
6	O-ring
7	Retaining Ring
8	Plug PT1/8

Rubber Track

Parts List



FG011235

Figure 33

Reference Number	Description
1	Body
2	Shaft
3	Bushing
4	F/Seal
5	O-ring

Reference Number	Description
6	Collar
7	Snap Ring
8	Plug

Disassembly

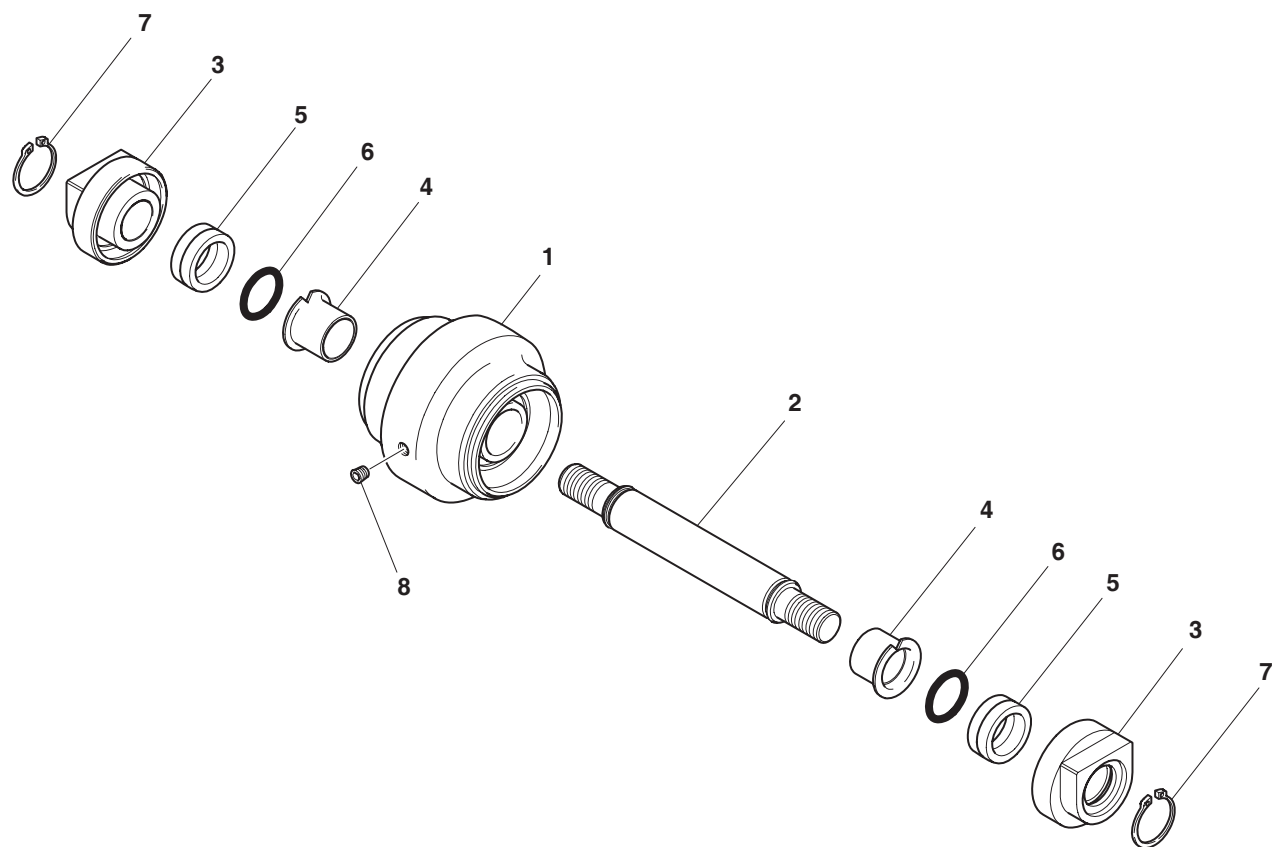
1. Remove track.
2. Loosen nut (M24) and remove track roller from track frame.
3. Remove C-type stopper ring (7) and plug (8) then Collar (6).
4. Remove floating seal (4) and bushing (3).
5. Use a screwdriver (-), to take out O-ring (5).
 - Once removed, oil seal should not be reused.
6. Remove shaft (2) from body (1).

Reassembly

1. Clean separated parts with cleansing oil.
2. Inject clean gear oil or engine oil (100.0 cc (3.38 oz)) before assembling O-ring (5).
3. See "Track Installation" on page -20. to assemble tracks.

UPPER ROLLER

Parts List



FG013473

Figure 34

Reference Number	Description
1	Roller
2	Shaft
3	Collar
4	Bushing

Reference Number	Description
5	Floating Seal
6	O-ring
7	Retaining Ring
8	Plug PT1/8

Disassembly

1. Remove track.
2. Loosen nut (M24) and remove upper roller from track frame.
3. Remove pin and collar.
4. Use a screwdriver (-) to take out O-ring (6).

NOTE: *Once removed, oil seal should not be reused.*

5. Remove floating seal (5) and bushing (4) then shaft (2) from body.

Reassembly

1. Clean separated parts with cleaning fluid.
2. Inject clean gear oil or engine oil (100.0 cc (3.38 oz)) before assembling O-ring (6).
3. See "Track Installation" on page -20. to assemble tracks.

SPROCKET

Disassembly

1. Remove tracks.
2. Remove sprocket clamping bolt (1) and sprocket (2) from travel motor.

Reassembly

1. Install sprocket to travel motor and tighten clamping bolt.

NOTE: *Tightening torque: 11.50 kg•m (83 ft lb)*

2. Assembly tracks.

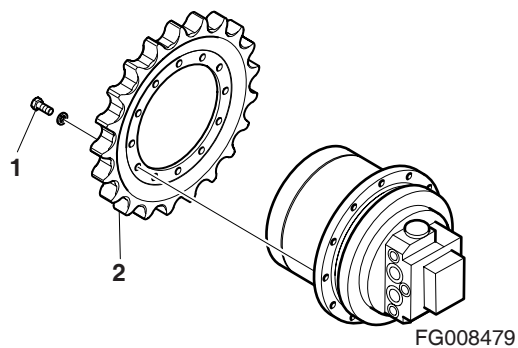


Figure 35

Engine and Drive Train

Engine

Edition 1

MEMO

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling load.

Remember, that ultimately safety is your own personal responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

SAFETY

Safety Precautions



DANGER

Scald Hazard!

Never Remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.

Always check the level of the engine coolant by observing the reserve tank.

Failure to comply will result in death or serious injury.



HAOA060L

Figure 1



DANGER

Explosion Hazard!

Keep the area around the battery well-ventilated. While the engine is running or the battery is charging, hydrogen gas is produced which can be easily ignited.

Keep sparks, open flame and any other form of ignition away while the engine is running or battery is charging.

Failure to comply will result in death or serious injury.



HAOA311P

Figure 2



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 3



DANGER

Fire And Explosion Hazard!

Only use the key switch to start the engine.

Never jump-start the engine. Sparks caused by shorting the battery to the starter terminals may cause a fire or explosion.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 4



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

If the unit has an electric fuel pump, when you prime the fuel system, turn the key switch to the ON position for 10 to 15 seconds to allow the electric fuel pump to prime the system.

If the unit has a mechanical fuel pump, when you prime the fuel system, operate the fuel priming lever of the mechanical fuel pump several times until the fuel filter cup is filled with fuel.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 5



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Only fill the fuel tank with diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.

Never refuel with the engine running.

Wipe up all spills immediately.

Keep sparks, open flames or any other form of ignition (match, cigarette, static electric source) well away when refueling.

Never overfill the fuel tank.

Fill the fuel tank. Store any containers containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 6



DANGER

Fire And Explosion Hazard!

Diesel fuel is extremely flammable and explosive under certain conditions.

Be sure to place the diesel fuel container on the ground when transferring the diesel fuel from the pump to the container. Hold the hose nozzle firmly against the side of the container while filling it. This prevents static electricity buildup which could cause sparks and ignite fuel vapors.

Never place diesel fuel or other flammable material such as oil, hay or dried grass close to the engine during engine operation or shortly after shutdown.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 7



DANGER

Crush Hazard!

When you need to transport an engine for repair, have a helper assist you to attach it to a hoist and load it on a truck.

Never stand under a hoisted engine. If the hoist mechanism fails, the engine will fall on you, causing death or serious injury.

Failure to comply will result in death or serious injury.



HDO1042L

Figure 8



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Before you operate the engine, check for fuel leaks. Replace rubberized fuel hoses every two years or every 2000 hours of engine operation, whichever comes first, even if the engine has been out of service. Rubberized fuel lines tend to dry out and become brittle after two years or 2000 hours of engine operation, whichever comes first.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 9



DANGER

Explosion Hazard!

Never check the remaining battery charge by shorting out the terminals. This will result in a spark and may cause an explosion or fire. Use a hydrometer to check the remaining battery charge.

If the electrolyte is frozen, slowly warm the battery before you recharge it.

Failure to comply will result in death or serious injury.



HAOA311P

Figure 10



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Never use diesel fuel as a cleaning agent.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 11



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Never remove the fuel cap with the engine running.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 12



WARNING

Sever Hazard!

Keep hands and other body parts away from moving / rotating parts such as the cooling fan, flywheel or PTO shaft.

Wear tight-fitting clothing and keep your hair short or tie it back while the engine is running.

Remove all jewelry before you operate or service the machine.

Never start the engine in gear. Sudden movement of the engine and / or machine could cause death or serious personal injury.

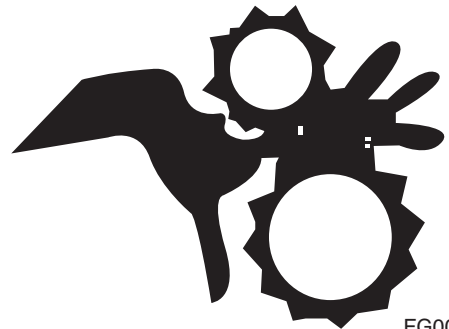
Never operate the engine without the guards in place.

Before you start the engine make sure that all bystanders are clear of the area.

Keep children and pets away while the engine is operating.

Check before starting the engine that any tools or shop rags used during maintenance have been removed from the area.

Failure to comply could result in death or serious injury.



FG009148

Figure 13



WARNING

Exhaust Hazard!

Never operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.

Never block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.

Make sure that all connections are tightened to specifications after repair is made to the exhaust system.

Failure to comply could result in death or serious injury.



WARNING

Alcohol And Drug Hazard!

Never operate the engine while you are under the influence of alcohol or drugs.

Never operate the engine when you are feeling ill.

Failure to comply could result in death or serious injury.



WARNING

Exposure Hazard!

Wear personal protective equipment such as gloves, work shoes, eye and hearing protection as required by the task at hand.

Never wear jewelry, unbuttoned cuffs, ties or loose-fitting clothing when you are working near moving / rotating parts such as the cooling fan, flywheel or PTO shaft.

Always tie back long hair when you are working near moving / rotating parts such as a cooling fan, flywheel, or PTO shaft.

Never operate the engine while wearing a headset to listen to music or radio because it will be difficult to hear the alert signals.

Failure to comply could result in death or serious injury.



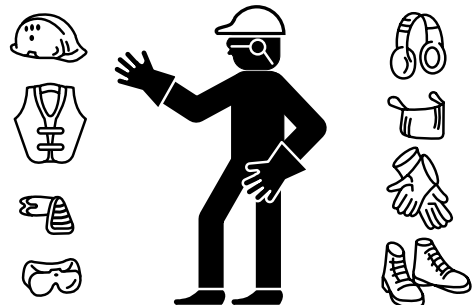
ARO1770L

Figure 14



FG009149

Figure 15



HAOA020L

Figure 16



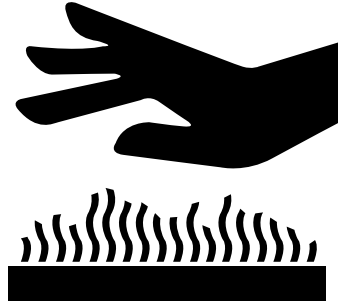
WARNING

Burn Hazard!

If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.

Always wear eye protection.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 17



WARNING

Burn Hazard!

Batteries contain sulfuric acid. Never allow battery fluid to come in contact with clothing, skin or eyes. Severe burns could result. Always wear safety goggles and protective clothing when servicing the battery. If battery fluid contacts the eyes and / or skin, immediately flush the affected area with a large amount of clean water and obtain prompt medical treatment.

Failure to comply could result in death or serious injury.



FG008465

Figure 18



WARNING

High-pressure Hazard!

Avoid skin contact with the high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.

Never check for a fuel leak with your hands. Always use a piece of wood or cardboard. Consult authorized DOOSAN dealer or DOOSAN after sales service if you have any questions or require more information.

Failure to comply could result in death or serious injury.



FG009150

Figure 19



WARNING

Shock Hazard!

Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. Always keep the connectors and terminals clean.

Failure to comply could result in death or serious injury.



FG009151

Figure 20



WARNING

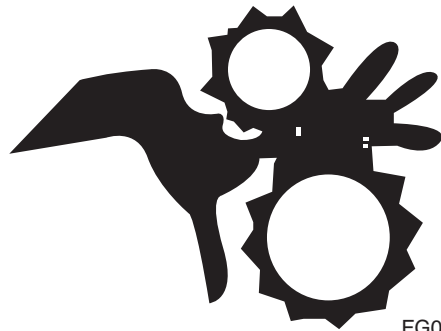
Entanglement Hazard!

Stop the engine before you begin to service it.

Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.

Failure to comply could result in death or serious injury.



FG009148

Figure 21

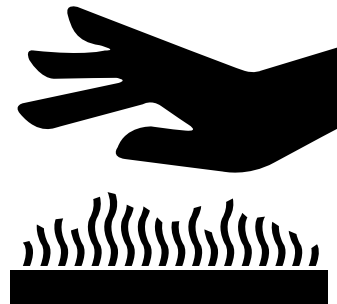


WARNING

Burn Hazard!

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 22



WARNING

Sudden Movement Hazard!

Engaging the transmission or PTO at an elevated engine speed could result in unexpected movement of the equipment.

Failure to comply could result in death or serious injury.

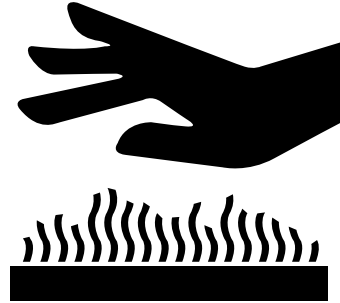


WARNING

Burn Hazard!

Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.

Failure to comply could result in death or serious injury.



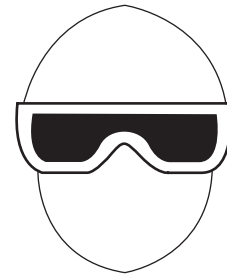
HAOA050L

Figure 23



WARNING

To prevent possible eye injury, always wear SAFETY GLASSES while servicing the engine.



FG009152

Figure 24



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.



FG009153

Figure 25



WARNING

Never apply over 40 psi (2.8 kgf/cm) to the waste gate actuator.



WARNING

Never inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.

Never inject fuel toward a fire source. Atomized fuel is highly flammable and may cause a fire or burn skin.

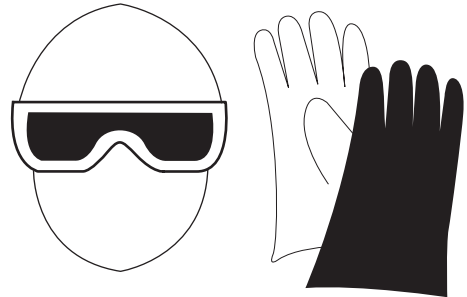


CAUTION

Coolant Hazard!

Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

Failure to comply may result in minor or moderate injury.



FG009154

Figure 26

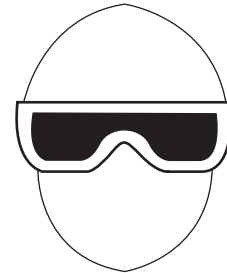


CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.



FG009152

Figure 27



CAUTION

Be sure to secure the engine solidly to prevent injury or damage to parts due to the engine falling during work on the engine.



CAUTION

Pinch Hazard!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

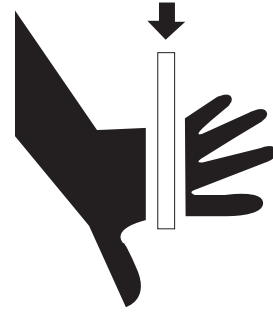


Figure 28

FG009155



CAUTION

If any oil pump component clearance exceeds its limit, the oil pump must be replaced as an assembly.



CAUTION

Only use diesel fuels recommended by DOOSAN for the best engine performance, to prevent engine damage and to comply with EPA / ARB warranty requirements.

Only use clean diesel fuel.

Never remove the primary strainer (if equipped) from the fuel tank filler port. If removed, dirt and debris could get into the fuel system causing it to clog.



CAUTION

Never attempt to adjust the low or high idle speed limit screw. This may impair the safety and performance of the machine and shorten its life. If adjustment is ever required, contact your authorized DOOSAN dealer or distributor.



CAUTION

If any problem is noted during the visual check, the necessary corrective action should be taken before you operate the engine.



CAUTION

Never hold the key in the START position for longer than 15 seconds or the starter motor will overheat.



CAUTION

Make sure the engine is installed on a level surface. If a continuously running engine is installed at an angle greater than 30° (in any direction) or if an engine runs for short periods of time (less than three minutes) at an angle greater than 35° (in any direction) engine oil may enter the combustion chamber causing excessive engine speed and white exhaust smoke. This may cause serious engine damage.



CAUTION

Make sure the engine is installed on a level surface. If a continuously running engine is installed at an angle greater than 30° (in any direction) or if an engine runs for short periods of time (less than three minutes) at an angle greater than 35° (in any direction) engine oil may enter the combustion chamber causing excessive engine speed and white exhaust smoke. This may cause serious engine damage.



CAUTION

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

Avoid operating in extremely dusty conditions.

Avoid operating in the presence of chemical gases or fumes.

Avoid operating in a corrosive atmosphere such as salt water spray.

Never install the engine in a floodplain unless proper precautions are taken to avoid being subject to a flood.

Never expose the engine to the rain.



CAUTION

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

The standard range of ambient temperatures for the normal operation of 4TNV98-E engines is from +5°F (-15°C) to +113°F (+45°C).

If the ambient temperature exceeds +113°F (+45°C) the engine may overheat and cause the engine oil to break down.

If the ambient temperature is below +5°F (-15°C) the engine will be hard to start and the engine oil may not flow easily.

Contact your authorized DOOSAN dealer or distributor if the engine will be operated outside of this standard temperature range.



CAUTION

The illustrations and descriptions of optional equipment in this manual, such as the operator's console, are for a typical engine installation. Refer to the documentation supplied by the optional equipment manufacturer for specific operation and maintenance instructions.



CAUTION

If any indicator illuminates during engine operation, stop the engine immediately. Determine the cause and repair the problem before you continue to operate the engine.



CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.

Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

Never overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.



CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and / or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

Never mix different types of engine coolants. This may adversely affect the properties of the engine coolant.



CAUTION

Never overfill the engine with engine oil.

Always keep the oil level between the upper and lower lines on the oil cap / dipstick.



CAUTION

For maximum engine life, DOOSAN recommends that when shutting the engine down, you allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the turbocharger (if equipped) and exhaust system, to cool slightly before the engine itself is shut down.



CAUTION

Never use an engine starting aid such as ether. Engine damage will result.



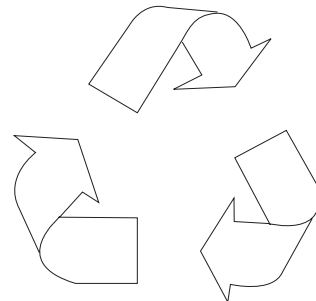
CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.



FG009156

Figure 29



CAUTION

Never engage the starter motor while the engine is running. This may damage the starter motor pinion and / or ring gear.



CAUTION

New Engine Break-in:

On the initial engine start-up, allow the engine to idle for approximately 15 minutes while you check for proper engine oil pressure, diesel fuel leaks, engine oil leaks, coolant leaks, and for proper operation of the indicators and / or gauges.

During the first hour of operation, vary the engine speed and the load on the engine. Short periods of maximum engine speed and load are desirable. Avoid prolonged operation at minimum or maximum engine speeds and loads for the next four to five hours.

During the break-in period, carefully observe the engine oil pressure and engine temperature.

During the break-in period, check the engine oil and coolant levels frequently.



CAUTION

Never attempt to modify the engine's design or safety features such as defeating the engine speed limit control or the fuel injection quantity control.

Failure to comply may impair the engine's safety and performance characteristics and shorten the engine's life. Any alterations to this engine may affect the warranty coverage of your engine.



CAUTION

Protect the air cleaner, turbocharger (if equipped) and electric components from damage when you use steam or high-pressure water to clean the engine.



CAUTION

Never use high-pressure water or compressed air at greater than 28 psi (193 kPa; 19 686 mm Aq) or a wire brush to clean the radiator fins. Radiator fins damage easily.



CAUTION

Never attempt to adjust the low or high idle speed limit screw. This may impair the safety and performance of the machine and shorten its life. If the idle speed limit screws require adjustment, consult authorized DOOSAN dealer or DOOSAN after sales service.



CAUTION

The tightening torque in the standard Torque Chart(see General Service Information section) should be applied only to the bolts with a "7" head,(JIS strength classification:7T)

Apply 60% torque to bolts that are not listed.

Apply 80% torque when tightened to aluminum alloy.



Figure 30

FG009157



CAUTION

If any indicator fails to illuminate when the key switch is in the ON position, see your authorized DOOSAN dealer or distributor for service before operating the engine.



CAUTION

Establish a periodic maintenance plan according to the engine application and make sure you perform the required periodic maintenance at the intervals indicated. Failure to follow these guidelines will impair the engine's safety and performance characteristics, shorten the engine's life and may affect the warranty coverage on your engine.

Consult your authorized DOOSAN dealer or distributor for assistance when checking items marked with a ●.



CAUTION

If the fuel filter / water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter / water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter / water separator 2-3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.



CAUTION

When the engine is operated in dusty conditions, clean the air cleaner element more frequently.

Never operate the engine with the air cleaner element(s) removed. This may allow foreign material to enter the engine and damage it.



CAUTION

The maximum air intake restriction, in terms of differential pressure measurement, must not exceed 0.90 psi (6.23 kPa; 635 mmAq). Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.



CAUTION

It is important to perform daily checks.

Periodic maintenance prevents unexpected downtime, reduces the number of accidents due to poor machine performance and helps extend the life of the engine.



CAUTION

If the oil pump must be replaced, replace it as an assembly only. Do not replace individual components.



CAUTION

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub. Correct fuel injection timing will be very difficult or impossible to achieve.



CAUTION

The starter motor can be damaged if operated continuously longer than 10 seconds while performing the no-load test.



CAUTION

Do not short-circuit the charging system between alternator terminals IG and L. Damage to the alternator will result.



CAUTION

Do not connect a load between alternator terminals L and E. Damage to the alternator will result.



CAUTION

Do not remove the positive (+) battery cable from alternator terminal B while the engine is operating. Damage to the alternator will result.



CAUTION

Do not turn the battery switch OFF while the engine is operating. Damage to the alternator will result.



CAUTION

Do not operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.



CAUTION

If the engine coolant pump must be replaced, replace the engine coolant pump as an assembly only. Do not attempt to repair the engine coolant pump or replace individual components.



CAUTION

Use a new special O-ring between the engine coolant pump and the joint. Be sure to use the special O-ring for each engine model. Although the O-ring dimensions are the same as a commercially available O-ring, the material is different.



CAUTION

Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.



CAUTION

After marking the position of the pump drive gear, do not rotate the engine crankshaft. Rotating the crankshaft will cause the fuel injection pump to become misaligned.



CAUTION

Do not use a high-pressure wash directly on the alternator. Water will damage the alternator and result in inadequate charging.



CAUTION

Do not reverse the positive (+) and negative (-) ends of the battery cable. The alternator diode and stator coil will be damaged.



CAUTION

When the battery indicator goes out, it should not come on again. The battery indicator only comes on during operation if the alternator fails or if the V-belt breaks. However, if an LED is used in the battery indicator, the LED will shine faintly during normal operation.



CAUTION

Using a non-specified V-belt will cause inadequate charging and shorten the belt life. Use the specified belt.



CAUTION

Agricultural or other chemicals, especially those with a high sulfur content, can adhere to the IC regulator. This will corrode the conductor and result in battery over-charging (boiling) and charging malfunctions. Consult authorized DOOSAN dealer or distributor before using the equipment in such an environment or the warranty is voided.



CAUTION

Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated on the wiring diagram. The starter motor will malfunction or break down if the resistance is higher than the specified value.



CAUTION

The starter motor is water-proofed according to JIS D 0203, R2 which protects the motor from rain or general cleaning. Do not use high-pressure wash or submerge the starter motor in water.



CAUTION

Use a specialized battery charger to recharge a battery with a voltage of 8 volts or less. Booster starting a battery with a voltage of 8 volts or less will generate an abnormally high voltage and destroy electrical equipment.



CAUTION

Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated in the Battery Cable Resistance chart in the Electric Wiring Section of this manual. The starter motor will malfunction and fail if the resistance is higher than the specified value.



CAUTION

Removing the battery cables or the battery while the engine is operating may cause damage to the current limiter depending on the electrical equipment being used. This situation could cause loss of control of output voltage. The continuous high voltage of 23-24 volts (for 5,000 rpm dynamo) will damage the current limiter and other electrical equipment.



CAUTION

Reversing the battery cable connections at the battery or on the engine will destroy the SCR diode in the current limiter. This will cause the charging system to malfunction and may cause damage to the electrical harnesses.



CAUTION

Avoid damage to the turbocharger or the engine. Do not spray blower wash fluid or water too quickly.

Use short strokes from a spray bottle to inject blower wash fluid or water into the turbocharger.

Spraying too much wash fluid or water, or spraying too quickly will damage the turbocharger.



CAUTION

Do not allow any material to fall into the oil lines or the oil inlet and outlet ports of the turbocharger.



CAUTION

If the waste valve does not meet specifications, replace the turbocharger or have it repaired by a qualified repair facility.



CAUTION

Never attempt to modify the engine's design or safety features such as defeating the engine speed limit control or the diesel fuel injection quantity control.

Modifications may impair the engine's safety and performance characteristics and shorten the engine's life. Any alterations to this engine may void its warranty. Be sure to use genuine replacement parts.



CAUTION

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.



CAUTION

Each pressure adjusting shim removed or added changes the pressure threshold by approximately 275 psi (1.9 MPa, 19 kgf/cm²). Adding adjusting shims increases the threshold pressure.

Removing adjusting shims reduces the pressure threshold.



CAUTION

Do not rotate the crankshaft with the injection pump removed.



CAUTION

Keep the piston pin parts, piston assemblies, and connecting rod assemblies together to be returned to the same position during the reassembly process. Label the parts using an appropriate method.



CAUTION

Do not allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.



CAUTION

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.



CAUTION

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.



CAUTION

Never remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

Never attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations and then replace the tamper-proof seals.



CAUTION

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

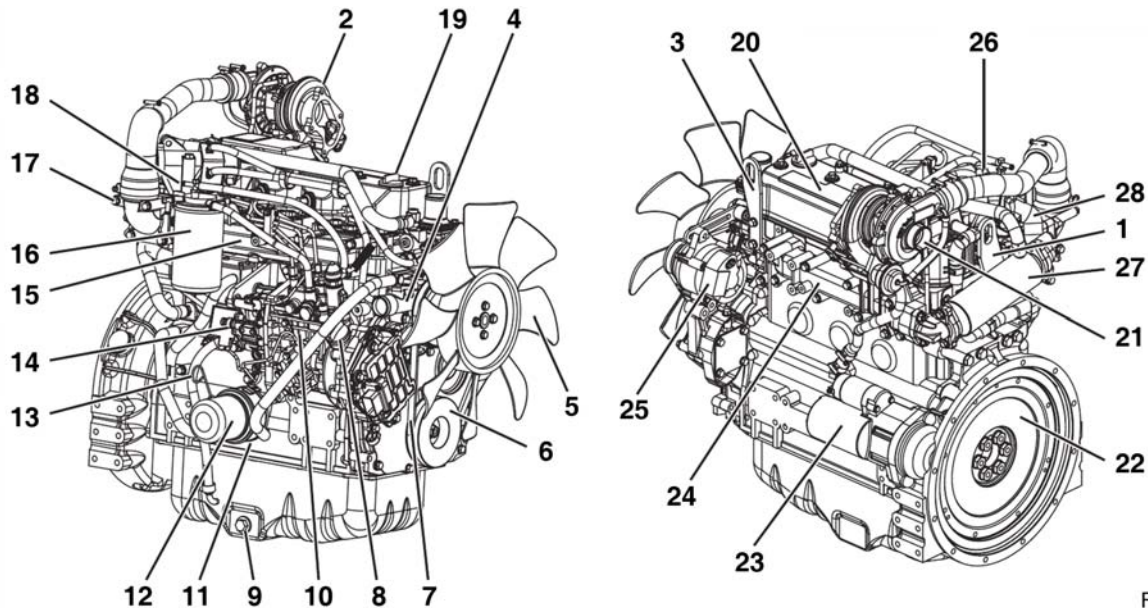


CAUTION

Allow the engine to warm-up for at least five minutes and the idle speed of the engine to return to normal before engaging the transmission or any PTOs. Engaging the transmission or PTO at an elevated engine speed could result in an unexpected movement of the equipment.

GENERAL SERVICE INFORMATION

Component Identification



FG010622

Figure 31

Reference Number	Description
1	Lifting Eye (Flywheel End)
2	Turbocharger*
3	Lifting Eye (Engine Cooling Fan End)
4	Engine Coolant Pump
5	Engine Cooling Fan
6	Crankshaft V-Pulley
7	V-Belt
8	Side Filler Port (Engine Oil)
9	Drain Plug (Engine Oil)**
10	Fuel Injection Pump
11	Engine Oil Cooler***
12	Engine Oil Filter
13	Dipstick (Engine Oil)
14	Eco-Governor

Reference Number	Description
15	Intake Manifold
16	Fuel Filter
17	Fuel Inlet
18	Fuel Return to Fuel Tank
19	Top Filler Port (Engine Oil)
20	Rocker Arm Cover
21	Air Intake Port (From Air Cleaner)
22	Flywheel
23	Starter Motor
24	Exhaust Manifold
25	Alternator
26	EGR valve
27	EGR cooler****
28	EGR pipe

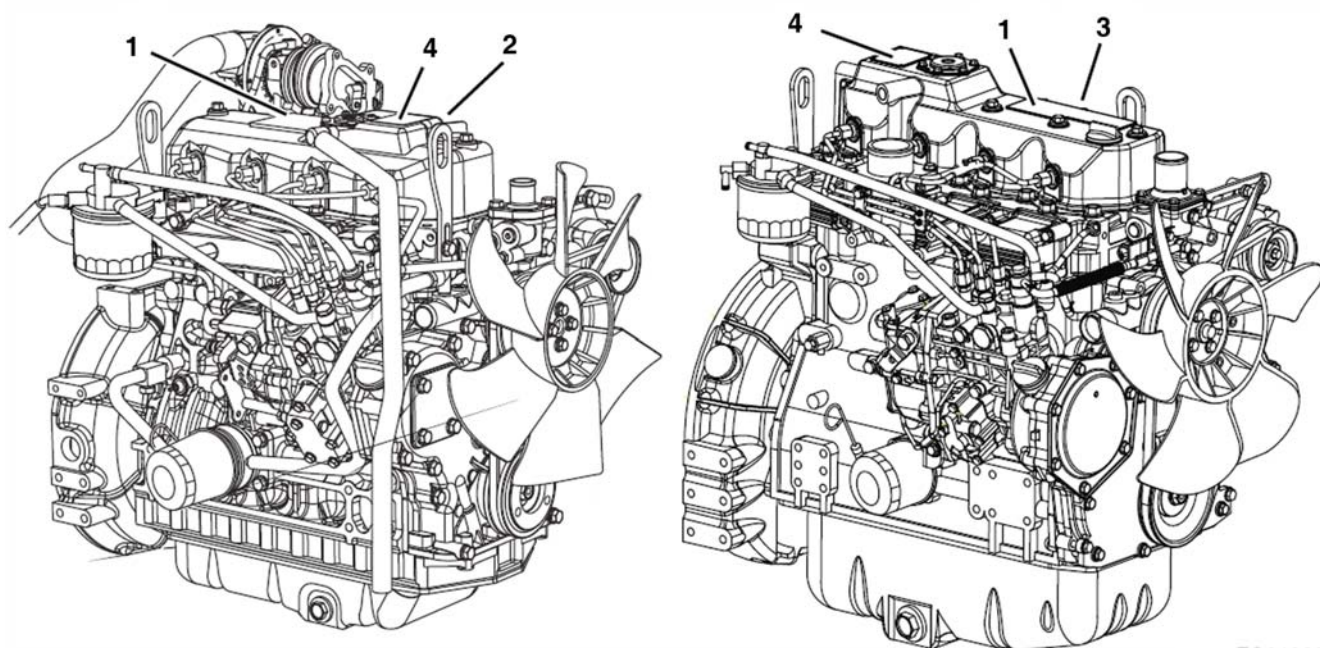
NOTE: * Only applies to 4TNV98T-Z

** Engine oil drain plug location may vary based on oil pan options.

*** Not standard on all direct injection models.

**** Only applies to 4TNV98T-Z

Location of Labels



FG010623

Figure 32

Model	Engine Nameplate	EPA.ARB Certification Label	97/68/EC Emission Control Label
4TNV98-E	On the top of the locker arm cover(flywheel end) (Figure 32 right, 4)	On the top of the locker arm cover(Center) (Figure 32 right, 1)	On the top of the locker arm cover(fan end) (Figure 32 right, 3)

Function of Major Engine Components

Components	Functions
Air Cleaner	The air cleaner prevents airborne contaminants from entering the engine. Since the air cleaner is application specific, it must be carefully selected by an application engineer. Periodic replacement of the air cleaner filter element is necessary. See "Periodic Maintenance Schedule" on page -65 for the replacement frequency.
Alternator	The alternator is driven by a V-belt which is powered by the crankshaft V-pulley. The alternator supplies electricity to the engine systems and charges the battery while the engine is running.
Dipstick (Engine Oil)	The engine oil dipstick is used to determine the amount of engine oil in the crankcase.
Electric Fuel Pump	The electric fuel pump makes sure there is a constant supply of diesel fuel to the fuel injection pump. The electric fuel pump is electro-magnetic and runs on 12 VDC. It must be installed on every application. This is standard equipment with every engine.
Engine Oil Filter	The engine oil filter removes contaminants and sediments from the engine oil. Periodic replacement of the engine oil filter is necessary. See "Periodic Maintenance Schedule" on page -65 for the replacement frequency.
Engine Oil Cooler (If Equipped)	The engine oil cooler helps to keep the engine oil cool. Engine coolant from the cooling system is circulated through an adapter at the base of the engine oil filter assembly and then returned to the coolant pump inlet.
Fuel Filter	The fuel filter removes contaminants and sediments from the diesel fuel. Periodic replacement of the fuel filter is necessary. See "Periodic Maintenance Schedule" on page -65 for the replacement frequency. Please note that the word "diesel" is implied throughout this manual when the word "fuel" is used.
Fuel Filter / Water Separator	The fuel filter / water separator removes contaminants, sediments and water from the diesel fuel going to the fuel filter. This is a required component of the fuel system. This is standard equipment with every engine. The separator is installed between the fuel tank and the electric fuel pump. Periodically drain the water from the fuel filter / water separator.
Fuel Tank	The fuel tank is a reservoir that holds diesel fuel. When the fuel leaves the fuel tank it goes to the fuel filter / water separator. Next the fuel is pumped to the fuel filter by the electric fuel pump. Then the fuel goes to the fuel injection pump. Since the fuel is used to keep the fuel injection pump cool and lubricated, more fuel than necessary enters the injection pump. When the injection pump pressure reaches a preset value, a relief valve allows the excess fuel to be returned back to the fuel tank. The fuel tank is a required engine component.
Side and Top Filler Port (Engine Oil)	You can fill the crankcase with engine oil from either the side or the top filler port depending upon which one is most convenient.
Starter Motor	The starter motor is powered by the battery. When you turn the key switch in the operator's console to the START position, the starter motor engages with the ring gear installed on the flywheel and starts the flywheel in motion.
Turbocharger	The turbocharger pressurizes the air coming into the engine. It is driven by a turbine that is energized by exhaust gases.

Main Electronic Control Components and Features

Component/Feature		Description
Engine controller (E-ECU)		Adjusts the rack position of the fuel injection pump depending on the speed command signal from the accelerator sensor, thus regulating the engine speed and power. The engine controller also regulates the opening of the EGR valve depending on the engine speed and power. It serves as the master station for the following components/control features.
Electronic governor (Eco-governor)		Consists of the engine speed sensor, rack actuator, etc., and is directly connected to the fuel injection pump in order to regulate the rack position of the fuel injection pump depending on the signals communicated with the EECU.
Fuel injection pump (for Eco-governor)		Is of single plunger type and equipped with a CSD solenoid valve that allows the fuel injection timing to advance and the injection quantity to increase, thereby improving the cold start performance of the engine.
EGR valve		Controls the exhaust gas recirculation flow rate depending on the engine speed/load signals from the EECU. It is installed on the top of the exhaust manifold.
Accelerator sensor		Unlike mechanical governors, the Eco-governor has no governor lever. The accelerator sensor serves as the governor lever to provide the speed command signal (voltage signal) to the E-ECU for engine speed control. It is installed in the operator cabin of the driven machine. Constant speed engines for e.g. generator use do not require accelerator sensors because the engine speed can be shifted via a switch on the operator's console.
	Optional	CAN communication capability is available as an option.
Fault indicator		Is installed on the operator's console. If a fault occurs in the E-ECU or Eco-governor, the fault indicator flashes alerting the operator to a fault. The number of flashes and/or the flashing pattern vary depending on the type or source of the fault, enabling quick-fix.
	Optional	
Engine diagnosis tool		Allows the operator to troubleshoot the cause of a problem based on detailed information regarding the problem occurring in the E-ECU or Eco-governor. This tool can also be used for data maintenance tasks including programming and mapping.
	Option for service	
Engine coolant temperature sensor		Allows the CSD and ERG to be controlled in engine cold-start conditions.
Glow plugs Air heater	Optional	When the key switch is turned to the ON position, the glow plugs/air heater are/is energized for up to 15 seconds (glow plugs) or up to 23 seconds (air heater). The duration of energization depends on the engine coolant temperature. The HEAT indicator is on during energization. When the indicator goes out, turn the key switch to the START position to start the engine.
After heater	Optional	In extreme cold start conditions, the after heater is energized for up to 80 seconds or until the coolant temperature reaches 10°C after the engine has started, in order to help ensure the engine continues to run without stall.This option is not available for glow plug engines.

Component/Feature		Description
Droop control	Standard with VM series	Reduces the engine speed by a certain percentage from no load to full (rated) load in steady state operation. The same percentage droop is maintained even when the load increases at any no-load speed.
Isochronous control	Standard with CL series Optional with VM series	Offers a constant engine speed from no load to full load. The engine speed does not decrease even when the load increases at any no-load speed.
Low-idling speed up		Increases the low-idling speed to up to 1,000 rpm depending on the engine coolant temperature. When the coolant temperature reaches a predetermined value, this feature returns the engine speed to the normal low idle setting, thus reducing the warm-up time.
High-idling speed down	Optional	Decreases the high-idling speed depending on the engine coolant temperature. When the coolant temperature falls to a predetermined value, this feature returns the engine speed to the normal high idle setting, thus minimizing the emission of white smoke at low temperatures.
Auto deceleration	Optional	Brings the running engine in low idle mode automatically when the accelerator pedal is not operated for a predetermined period of time. When the pedal is operated, i.e., the accelerator sensor is activated, the low idle mode is cancelled.

Function of Cooling System Components

Components	Functions
Cooling System	The TNV engine is liquid-cooled by means of a cooling system. The cooling system consists of a radiator, radiator cap, engine cooling fan, engine coolant pump, thermostat, and reserve tank. NOTE: <i>That all cooling system components are required for proper engine operation. Since some of the components are application specific, they must be carefully selected by an application engineer.</i>
Engine Cooling Fan	The engine cooling fan is driven by a V-belt which is powered by the crankshaft V-pulley. The purpose of the engine cooling fan is to circulate air through the radiator.
Engine Coolant Pump	The engine coolant pump circulates the engine coolant through the cylinder block and the cylinder head and returns the engine coolant to the radiator.
Radiator	The radiator acts as a heat exchanger. As the engine coolant circulates through the cylinder block it absorbs heat. The heat in the engine coolant is dissipated in the radiator. As the engine cooling fan circulates air through the radiator, the heat is transferred to the air.
Radiator Cap	The radiator cap controls the cooling system pressure. The cooling system is pressurized to raise the boiling point of the engine coolant. As the engine coolant temperature rises, the system pressure and the coolant volume increases. When the pressure reaches a preset value, the release valve in the radiator cap opens and the excess engine coolant flows into the reserve tank. As the engine coolant temperature is reduced, the system pressure and volume is reduced and the vacuum valve in the radiator cap opens allowing the engine coolant to flow from the reserve tank back into the radiator.
Reserve Tank	The reserve tank contains the overflow of engine coolant from the radiator. If you need to add engine coolant to the system, add it to the reserve tank; not the radiator.
Thermostat	A thermostat is placed in the cooling system to prevent the engine coolant from circulating into the radiator until the engine coolant temperature reaches a preset temperature. When the engine is cold, no engine coolant flows through the radiator. Once the engine reaches its operating temperature, the thermostat opens and allows the engine coolant to flow through the radiator. By letting the engine warm up as quickly as possible, the thermostat reduces engine wear, deposits and emissions.

Diesel Fuel

Diesel Fuel Specifications

Diesel fuel should comply with the following specifications. The table lists several worldwide specifications for diesel fuels.

Diesel Fuel Specification	Location
No. 2-D, No. 1-D, ASTM D975-94	USA
EN590:96	European Union
ISO 8217 DMX	International
BS 2869-A1 or A2	United Kingdom
JIS K2204 Grade No. 2	Japan
KSM-2610	Korea
GB252	China

Additional Technical Fuel Requirements

The fuel cetane number should be equal to 45 or higher.

The sulfur content must not exceed 0.5% by volume. Less than 0.05% is preferred.

For electronically controlled engine 4TNV98-E, it is mandatory to use fuel that does not contain 0.05% or more sulfur content.

In general, using a high sulfur fuel may possible result in corrosion inside the cylinder.

Bio-Diesel fuels. "Bio-Diesel Fuels" on page 1-38.

Never mix kerosene, used engine oil, or residual fuels with the diesel fuel.

The water and sediment in the fuel should not exceed 0.05% by volume.

Keep the fuel tank and fuel-handling equipment clean at all times.

Poor quality fuel can reduce engine performance and / or cause engine damage.

Fuel additives are not recommended. Some fuel additives may cause poor engine performance. Consult your DOOSAN representative for more information.

The ash content must not exceed 0.01% by volume.

The carbon residue content must not exceed 0.35% by volume. Less than 0.1% is preferred.

The total aromatics content should not exceed 35% by volume. Less than 30% is preferred.

The PAH (polycyclic aromatic hydrocarbons) content should be below 10% by volume.

The metal content of Na, Mg, Si, and Al should be equal to or lower than 1 mass ppm. (Test analysis method JPI-5S-44-95)

Lubricity: The wear mark of WS1.4 should be Max. 0.018 in (460 µm) at HFRR test.

Bio-Diesel Fuels

In Europe and in the United States, as well as some other countries, non-mineral oil based fuel resources such as RME (Rapeseed Methyl Ester) and SOME (Soybean Methyl Ester), collectively known as FAME (Fatty Acid Methyl Esters), are being used as extenders for mineral oil derived diesel fuels.

DOOSAN approves the use of bio-diesel fuels that do not exceed a blend of 5% (by volume) of FAME with 95% (by volume) of approved mineral oil derived diesel fuel. Such bio-diesel fuels are known in the marketplace as B5 diesel fuels.

These B5 diesel fuels must meet certain requirements.

The bio-fuels must meet the minimum specifications for the country in which they are used.

1. In Europe, bio-diesel fuels must comply with the European Standard EN14214.
2. In the United States, bio-diesel fuels must comply with the American Standard ASTM D-6751.

Bio-fuels should be purchased only from recognized and authorized diesel fuel suppliers

Precautions and concerns regarding the use of bio-fuels:

1. Free methanol in FAME may result in corrosion of aluminum and zinc FIE components.
2. Free water in FAME may result in plugging of fuel filters and increased bacterial growth.
3. High viscosity at low temperatures may result in fuel delivery problems, injection pump seizures, and poor injection nozzle spray atomization.
4. FAME may have adverse effects on some elastomers (seal materials) and may result in fuel leakage and dilution of the engine lubricating oil.
5. Even bio-diesel fuels that comply with a suitable standard as delivered, will require additional care and attention to maintain the quality of the fuel in the equipment or other fuel tanks. It is important to maintain a supply of clean, fresh fuel. Regular flushing of the fuel system, and / or fuel storage containers, may be necessary.
6. The use of bio-diesel fuels that do not comply with the standards as agreed to by the diesel engine manufacturers and the diesel fuel injection equipment manufacturers, or bio-diesel fuels that have degraded as per the precautions and concerns above, may affect the warranty coverage of your engine.

Filling The Fuel Tank



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Only fill the fuel tank with diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.

Never refuel with the engine running.

Wipe up all spills immediately.

Keep sparks, open flames or any other form of ignition (match, cigarette, static electric source) well away when refueling.

Never overfill the fuel tank.

Fill the fuel tank. Store any containers containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 33



DANGER

Fire And Explosion Hazard!

Diesel fuel is extremely flammable and explosive under certain conditions.

Be sure to place the diesel fuel container on the ground when transferring the diesel fuel from the pump to the container. Hold the hose nozzle firmly against the side of the container while filling it. This prevents static electricity buildup which could cause sparks and ignite fuel vapors.

Never place diesel fuel or other flammable material such as oil, hay or dried grass close to the engine during engine operation or shortly after shutdown.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 34



CAUTION

Only use diesel fuels recommended by DOOSAN for the best engine performance, to prevent engine damage and to comply with EPA / ARB warranty requirements.

Only use clean diesel fuel.

Never remove the primary strainer (if equipped) from the fuel tank filler port. If removed, dirt and debris could get into the fuel system causing it to clog.



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Before you operate the engine, check for fuel leaks. Replace rubberized fuel hoses every two years or every 2000 hours of engine operation, whichever comes first, even if the engine has been out of service. Rubberized fuel lines tend to dry out and become brittle after two years or 2000 hours of engine operation, whichever comes first.

Failure to comply will result in death or serious injury.

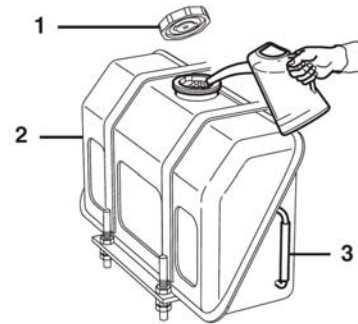
Note that a typical fuel tank is shown. The fuel tank on your equipment may be different.

1. Clean the area around the fuel cap (1, Figure 36).
2. Remove the fuel cap (1, Figure 36) from the fuel tank (2, Figure 36).
3. Observe the fuel level sight gauge (3, Figure 36) and stop fueling when the gauge shows the fuel tank is full. NEVER overfill the fuel tank.
4. Replace the fuel cap (1, Figure 36) and hand tighten. Over-tightening the fuel cap will damage it.



HDO10151

Figure 35



FG008848

Figure 36

Priming the Fuel System

The fuel system needs to be primed under certain conditions:

- Before starting the engine for the first time.
- After running out of fuel and fuel has been added to the fuel tank.
- After fuel system maintenance such as changing the fuel filter and draining the fuel filter / water separator, or replacing a fuel system component.

To prime the fuel system:

1. Turn the key to the ON position for 10 - 15 seconds. This will allow the electric fuel pump to prime the fuel system.
2. Never use the starter motor to crank the engine in order to prime the fuel system. This may cause the starter motor to overheat and damage the coils, pinion and / or ring gear.

Engine Oil



CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.

Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

Never overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

Engine Oil Specifications

Use an engine oil that meets or exceeds the following guidelines and classifications:

Service Categories

- API Service Categories CD or higher (Grade CF or higher for EGR-equipped engines 4TNV84T-Z, 4TNV98-Z, 4TNV98-E, and 4TNV98T-Z)
- ACEA Service Categories E-3, E-4, and E-5
- JASO Service Category DH-1

Definitions

API Classification (American Petroleum Institute)

- ACEA Classification (Association des Constructeurs Europeens d'Automobilies)
- JASO (Japanese Automobile Standards Organization)

NOTE: *Be sure the engine oil, engine oil storage containers, and engine oil filling equipment are free of sediment and water.*

Change the engine oil after the first 50 hours of operation and then every 250 hours thereafter.

Select the oil viscosity based on the ambient temperature where the engine is being operated (Figure 37).

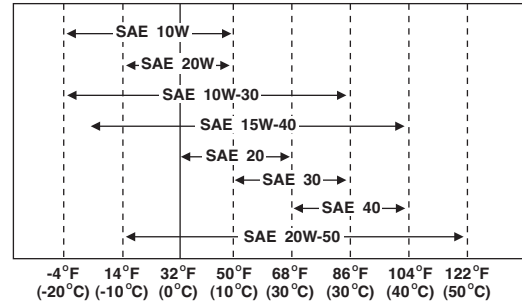
DOOSAN does not recommend the use of engine oil "additives".

Additional Technical Engine Oil Requirements:

The engine oil must be changed when the Total Base Number (TBN) has been reduced to 2.0. TBN (mgKOH/g) test method; JIS K-201-5.2-2 (HCl), ASTM D4739 (HCl).

Engine Oil Viscosity

Select the appropriate engine oil viscosity based on the ambient temperature and use the SAE Service Grade Viscosity Chart in Figure 37.



FG008849

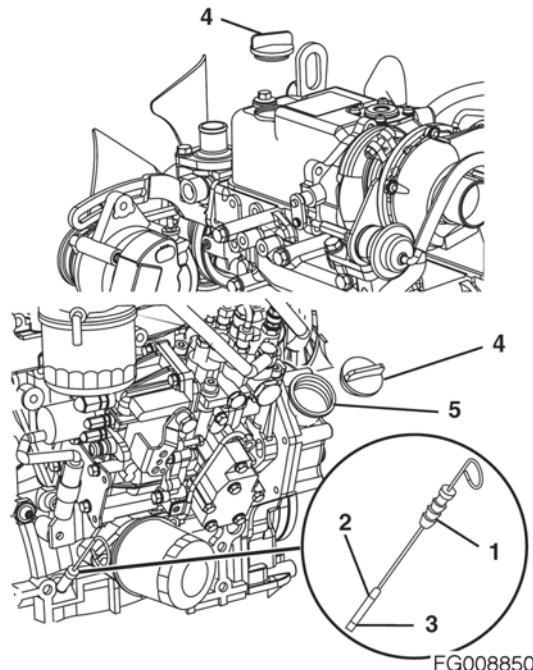
Figure 37

Checking Engine Oil

1. Make sure the engine is level.
2. Remove the dipstick (1, Figure 38) and wipe it with clean cloth.
3. Fully reinsert the dipstick.
4. Remove the dipstick. The oil level should be between the upper (2, Figure 38) and lower (3, Figure 38) lines on the dipstick.
5. Fully reinsert the dipstick.

Adding Engine Oil

1. Make sure the engine is level.
2. Remove the oil cap (4, Figure 38).
3. Add the indicated amount of engine oil at the top or the side engine oil filler port (5, Figure 38).
4. Wait three minutes and check the oil level.
5. Add more oil if necessary.
6. Reinstall the oil cap (4, Figure 38) and hand-tighten. Over-tightening may damage the cap.



FG008850

Figure 38

Engine Coolant



WARNING

Exhaust Hazard!

Never operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.

Never block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.

Make sure that all connections are tightened to specifications after repair is made to the exhaust system.

Failure to comply could result in death or serious injury.



WARNING

Burn Hazard!

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Failure to comply could result in death or serious injury.



CAUTION

Coolant Hazard!

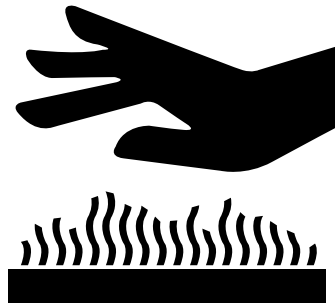
Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

Failure to comply may result in minor or moderate injury.



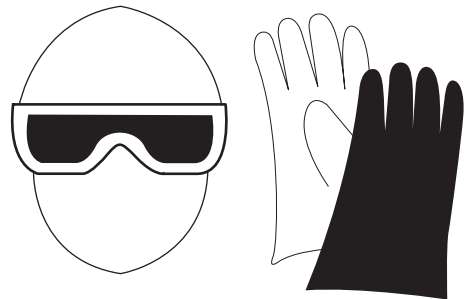
ARO1770L

Figure 39



HAOA050L

Figure 40



FG009154

Figure 41



CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and / or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

Never mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

Engine Coolant Specifications

Use a Long Life Coolant (LLC) or an Extended Life Coolant (ELC) that meets or exceeds the following guidelines and specifications:

Additional Technical Coolant Specifications:

- ASTM D6210, D4985 (US)
- JIS K-2234 (Japan)
- SAE J814C, J1941, J1034 or J2036 (International)

Alternative Engine Coolant

If an Extended or Long Life Coolant is not available, alternatively, you may use an ethylene glycol or propylene glycol based conventional coolant (green).

NOTE: *ALWAYS use a mix of coolant and water. NEVER use water only.*

Mix the coolant and water per the mixing instructions on the coolant container.

Water quality is important to coolant performance. DOOSAN recommends that soft, distilled, or demineralized water be used to mix with coolants.

NEVER mix extended or long life coolants and conventional (green) coolants.

NEVER mix different types and / or colors of extended life coolants.

Replace the coolant every 1000 engine hours or once a year.

Filling Radiator with Engine Coolant

Fill the radiator and reserve tank as follows. This procedure is for filling the radiator for the first time or refilling it after it is flushed. Note that a typical radiator is illustrated (Figure 42).

1. Check to be sure the radiator drain plug is installed and tightened or the drain cock (1, Figure 42) is closed. Also make sure the coolant drain plug (1, Figure 43) in the cylinder block is closed or the oil coolant hoses (1, Figure 44) are installed at the oil cooler.
2. Remove the radiator cap (2, Figure 42) by turning it counter-clockwise about 1/3 of a turn.
3. Pour the engine coolant slowly into the radiator until it is even with the lip of the engine coolant filler port. Make sure that air bubbles do not develop as you fill the radiator.
4. Reinstall the radiator cap (2, Figure 42). Align the tabs on the back side of the radiator cap with the notches on the engine coolant filler port. Press down and turn the cap clockwise about 1/3 of a turn.
5. Remove the cap on the reserve tank (3, Figure 42), and fill it to the LOW (COLD) mark (4, Figure 42) with engine coolant. Reinstall the cap.
6. Check the hose (5, Figure 42) that connects the reserve tank (3, Figure 42) to the radiator. Be sure it is securely connected and there are no cracks or damage. If the hose is damaged, the engine coolant will leak out instead of going into the reserve tank.
7. Run the engine until it is at operating temperature. Check the level of engine coolant in the reserve tank. When the engine is running and the engine coolant is at normal temperature, the coolant level in the tank should be at the FULL (HOT) mark (6, Figure 42). If the engine coolant is not at the FULL (HOT) mark (6, Figure 42), add additional engine coolant to the reserve tank to bring the level to the FULL (HOT) mark.

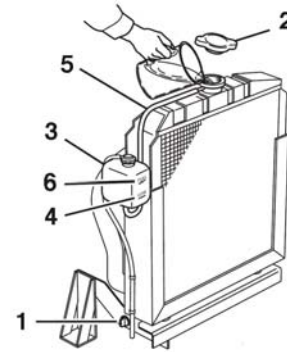


Figure 42

FG008851

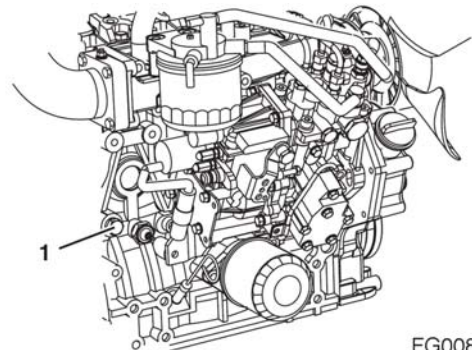


Figure 43

FG008852

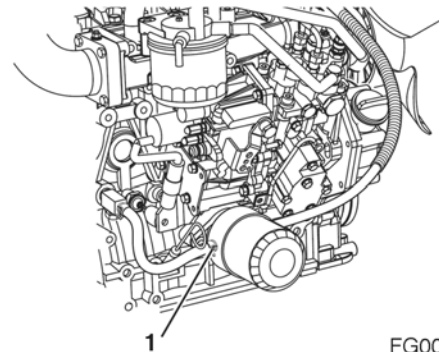


Figure 44

FG008853

Principal Engine Specifications

4TNV98-E

Engine Model		4TNV98-E							
Version		CL		VM					
Type		Vertical, 4-cycle water-cooled diesel engine							
Combustion System		Direct Injection							
Aspiration		Natural Aspiration							
No. of Cylinders		4							
Bore x Stroke		98 x 110 mm							
Displacement		3.319 L							
Continuous Rated Output	min ⁻¹								
	kW								
	PS								
Max. Rated Output (Net)	min ⁻¹				2,100	2,200	2,300	2,400	2,500
	kW				36.8	38.2	39.7	41.6	43.0
	PS				50.0	52.0	54.0	56.5	58.5
High Idling	min ⁻¹				2,250 ± 25	2,350 ± 25	2,450 ± 25	2,550 ± 25	2,650 ± 25
Engine Weight (Dry) *with Flywheel Housing				240 kg					
PTO Position		Flywheel End							
Direction of Rotation		Counterclockwise Viewed From the Flywheel End							
Governor		Electronic governor (All-speed governor)							
Cooling System		Liquid-Cooled with Radiator							
Lubricating System		Forced Lubrication with Trochoid Pump							
Normal Oil Pressure	Rated Engine Speed	0.29 - 0.39 (3.0 - 4.0) MPa							
	Low Idle Speed	0.06 (0.6) MPa							
Starting System		Electric Starting (Starter Motor: DC12V (2.3 kW)***							
Charging system		Alternator (DC12V/ 40A)***							
Recommended Battery Capacity		: 12V-64Ah*** (5h rating)							
Starting aid device		Air Heater (12VDC/500w)							
Dimensions (L x W x H)*		719 x 540 x 721 mm							
Engine Oil Pan Capacity**		10.2 L / 5.7 L (Dipstick Upper Limit / Lower Limit)							
Engine Coolant Capacity		4.2 L Engine Only							
Standard Cooling Fan		Resin F type pusher fan - ø410(Al) x 6							
Crank V-pulley dia./ Fan V-pulley dia.		ø130/ ø130 mm							

* Engine specifications without radiator.

** Engine oil capacity for a "deep standard" oil pan. Refer to the operation manual provided by the driven machine manufacturer for the actual engine oil capacity of your machine.

*** May vary depending on the application.

Engine Service Standards

Inspection Item		Standard	Limit	Reference page
Intake / Exhaust Valve Clearance	All models except	0.006 - 0.010 in. (0.15 - 0.25 mm)	-	See "Measuring and Adjusting Valve Clearance" on page -123
Fuel Injection Timing	See "Checking and Adjusting Fuel Injection Timing" on page -189			
Fuel Injection Pressure	See "Test and Adjustment Specifications" on page -174			
Compression Pressure at 250 rpm (250 min ⁻¹)	4TNV98-E	483 - 513 psi (3.33 - 3.53 MPa; 34 - 36 kgf/cm ²)	384 - 414 psi (2.65 - 2.85 MPa; 27 - 29 kgf/cm ²)	See "Troubleshooting by Measuring Compression Pressure" on page -265
Deviation Between Cylinders	All Models	29 - 43 psi (0.2 - 0.3 MPa; 2 - 3 kgf/cm ²)	-	-
Oil Pressure Switch Operating Pressure		5.8 - 8.8 psi (0.04 - 0.06 MPa; 0.4 - 0.6 kgf/cm ²)	-	-
Thermostat		Valve Opening Temperature	Full Opening Lift Temperature	See "Thermostat" on page -208
	All Models	157°F - 163°F (70°C - 73°C)	0.32 in (8 mm) or above 185°F (85°C)	
	All Models Option	176°F - 183°F (80°C - 84°C)	0.39 in (10 mm) or above 203°F (95°C)	
Coolant Temperature Switch		225°F - 235°F (107°C - 113°C)	-	See "Temperature Switch" on page -207

Tightening Torques for Standard Bolts and Nuts

Use the correct amount of torque when you tighten the fasteners on the machine. Applying excessive torque may damage the fastener or component and not enough torque may cause a leak or component failure.



CAUTION

The tightening torque in the standard Torque Chart (see General Service Information section) should be applied only to the bolts with a "7" head, (JIS strength classification: 7T)

Apply 60% torque to bolts that are not listed.

Apply 80% torque when tightened to aluminum alloy.



FG009157

Figure 45

Item	Nominal Thread Diameter x Pitch	Tightening Torque	Remarks
Hexagon Bolt (7T) and Nut	M6 x 1.0 mm	7 - 9 ft-lb (87 - 104 in.-lb, 9.8 - 11.8 N•m, 1.0 - 1.2 kgf•m)	Use 80% of the value at left when the tightening part is aluminum. Use 60% of the value at left for 4T bolts and lock nuts.
	M8 x 1.25 mm	17 - 21 ft-lb (200 - 251 in.-lb, 22.6 - 28.4 N•m, 2.3 - 2.9 kgf•m)	
	M10 x 1.5 mm	33 - 40 ft-lb (44.1 - 53.9 N•m, 4.5 - 5.5 kgf•m)	
	M12 x 1.75 mm	58 - 72 ft-lb (78.4 - 98.0 N•m, 8.0 - 10 kgf•m)	
	M14 x 1.5 mm	94 - 108 ft-lb (127.5 - 147.1 N•m, 13 - 15 kgf•m)	
	M16 x 1.5 mm	159 - 174 ft-lb (215.7 - 235.4 N•m, 22 - 24 kgf•m)	
PT PLug	1/8 mm	7 ft-lb (87 in.-lb, 9.8 N•m, 1.0 kgf•m)	-
	1/4 mm	14 ft-lb (173 in.-lb, 19.6 N•m, 2.0 kgf•m)	
	3/8 mm	22 ft-lb (29.4 N•m, 3.0 kgf•m)	
	1/2 mm	43 ft-lb (58.8 N•m, 6.0 kgf•m)	

Item	Nominal Thread Diameter	x Pitch	Tightening Torque	Remarks
Pipe Joint Bolt	M8		9 - 12 ft-lb (112 - 148 in.-lb, 12.7 - 16.7 N•m, 1.3 - 1.7 kgf•m)	-
	M10		14 - 19 ft-lb (173 - 225 in.-lb, 19.6 - 18.734 N•m, 2.0 - 3.5 kgf•m)	
	M12		18 - 25 ft-lb (24.5 - 34.3 N•m, 2.5 - 3.5 kgf•m)	
	M14		29 - 36 ft-lb (39.2 - 49.0 N•m, 4.0 - 5.0 kgf•m)	
	M16		36 - 43 ft-lb (49.0 - 58.8 N•m, 5.0 - 6.0 kgf•m)	

Note: Torque values shown in this manual are for clean, non-lubricated fasteners unless otherwise

PERIODIC MAINTENANCE

Before You Begin Servicing



DANGER

Explosion Hazard!

Never check the remaining battery charge by shorting out the terminals. This will result in a spark and may cause an explosion or fire. Use a hydrometer to check the remaining battery charge.

If the electrolyte is frozen, slowly warm the battery before you recharge it.

Failure to comply will result in death or serious injury.



DANGER

Fire And Explosion Hazard!

Only use the key switch to start the engine.

Never jump-start the engine. Sparks caused by shorting the battery to the starter terminals may cause a fire or explosion.

Failure to comply will result in death or serious injury.



DANGER

Scald Hazard!

Never Remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.

Always check the level of the engine coolant by observing the reserve tank.

Failure to comply will result in death or serious injury.



HAOA311P

Figure 46



HDO1015I

Figure 47



HAOA060L

Figure 48



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Only fill the fuel tank with diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.

Never refuel with the engine running.

Wipe up all spills immediately.

Keep sparks, open flames or any other form of ignition (match, cigarette, static electric source) well away when refueling.

Never overfill the fuel tank.

Fill the fuel tank. Store any containers containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 49



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Before you operate the engine, check for fuel leaks. Replace rubberized fuel hoses every two years or every 2000 hours of engine operation, whichever comes first, even if the engine has been out of service. Rubberized fuel lines tend to dry out and become brittle after two years or 2000 hours of engine operation, whichever comes first.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 50



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Never remove the fuel cap with the engine running.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 51



DANGER

Fire And Explosion Hazard!

Diesel fuel is extremely flammable and explosive under certain conditions.

Be sure to place the diesel fuel container on the ground when transferring the diesel fuel from the pump to the container. Hold the hose nozzle firmly against the side of the container while filling it. This prevents static electricity buildup which could cause sparks and ignite fuel vapors.

Never place diesel fuel or other flammable material such as oil, hay or dried grass close to the engine during engine operation or shortly after shutdown.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 52



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Never use diesel fuel as a cleaning agent.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 53



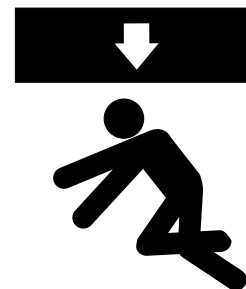
DANGER

Crush Hazard!

When you need to transport an engine for repair, have a helper assist you to attach it to a hoist and load it on a truck.

Never stand under a hoisted engine. If the hoist mechanism fails, the engine will fall on you, causing death or serious injury.

Failure to comply will result in death or serious injury.



HDO1042L

Figure 54



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 55



DANGER

Fire And Explosion Hazard!

Diesel fuel is extremely flammable and explosive under certain conditions.

Place an approved container under the air bleed port when you prime the fuel system. Never use a shop rag to catch the fuel. Wipe up any spills immediately. ALWAYS close the air bleed port after you complete priming the system.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you open the air bleed port.

If the unit has an electric fuel pump, turn the key switch to the ON position for 10 to 15 seconds, or until the fuel coming out of the air bleed port is free of bubbles, to allow the electric fuel pump to prime the system.

If the unit has a mechanical fuel pump, operate the fuel priming pump several times until the fuel coming out of the air bleed port is free of bubbles.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 56



WARNING

Exhaust Hazard!

Never operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.

Never block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.

Make sure that all connections are tightened to specifications after repair is made to the exhaust system.

Failure to comply could result in death or serious injury.



WARNING

Sever Hazard!

Keep hands and other body parts away from moving / rotating parts such as the cooling fan, flywheel or PTO shaft.

Wear tight-fitting clothing and keep your hair short or tie it back while the engine is running.

Remove all jewelry before you operate or service the machine.

Never start the engine in gear. Sudden movement of the engine and / or machine could cause death or serious personal injury.

Never operate the engine without the guards in place.

Before you start the engine make sure that all bystanders are clear of the area.

Keep children and pets away while the engine is operating.

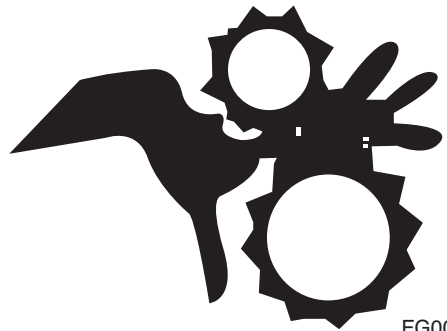
Check before starting the engine that any tools or shop rags used during maintenance have been removed from the area.

Failure to comply could result in death or serious injury.



ARO1770L

Figure 57



FG009148

Figure 58



WARNING

Sudden Movement Hazard!

Engaging the transmission or PTO at an elevated engine speed could result in unexpected movement of the equipment.

Failure to comply could result in death or serious injury.

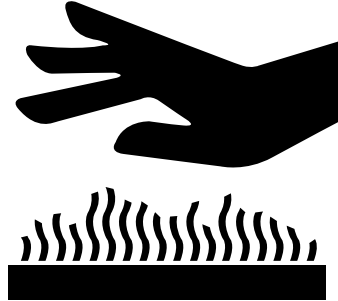


WARNING

Burn Hazard!

Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 59



WARNING

Alcohol And Drug Hazard!

Never operate the engine while you are under the influence of alcohol or drugs.

Never operate the engine when you are feeling ill.

Failure to comply could result in death or serious injury.



FG009149

Figure 60



WARNING

Exposure Hazard!

Wear personal protective equipment such as gloves, work shoes, eye and hearing protection as required by the task at hand.

Never wear jewelry, unbuttoned cuffs, ties or loose-fitting clothing when you are working near moving / rotating parts such as the cooling fan, flywheel or PTO shaft.

Always tie back long hair when you are working near moving / rotating parts such as a cooling fan, flywheel, or PTO shaft.

Never operate the engine while wearing a headset to listen to music or radio because it will be difficult to hear the alert signals.

Failure to comply could result in death or serious injury.



Figure 61

HAOA020L



WARNING

Burn Hazard!

Batteries contain sulfuric acid. Never allow battery fluid to come in contact with clothing, skin or eyes. Severe burns could result. Always wear safety goggles and protective clothing when servicing the battery. If battery fluid contacts the eyes and / or skin, immediately flush the affected area with a large amount of clean water and obtain prompt medical treatment.

Failure to comply could result in death or serious injury.



Figure 62

FG008465



WARNING

High-pressure Hazard!

Avoid skin contact with the high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.

Never check for a fuel leak with your hands. Always use a piece of wood or cardboard. Consult authorized DOOSAN dealer or DOOSAN after sales service if you have any questions or require more information.

Failure to comply could result in death or serious injury.



Figure 63

FG009150



WARNING

Shock Hazard!

Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. Always keep the connectors and terminals clean.

Failure to comply could result in death or serious injury.



FG009151

Figure 64



WARNING

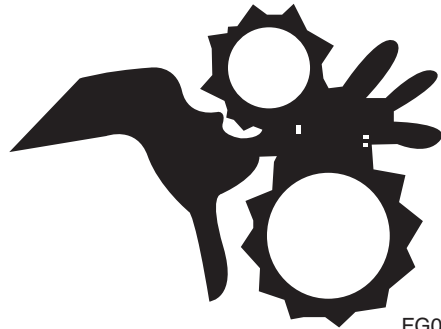
Entanglement Hazard!

Stop the engine before you begin to service it.

Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.

Failure to comply could result in death or serious injury.



FG009148

Figure 65



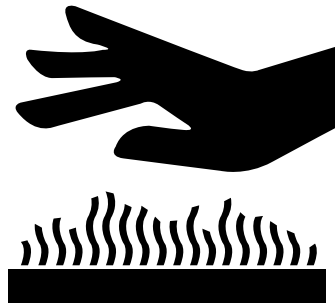
WARNING

Burn Hazard!

If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.

Always wear eye protection.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 66

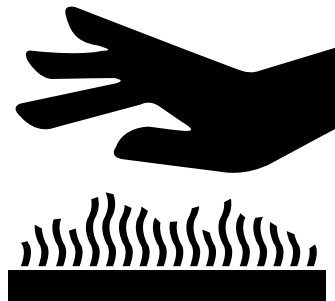


WARNING

Burn Hazard!

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 67

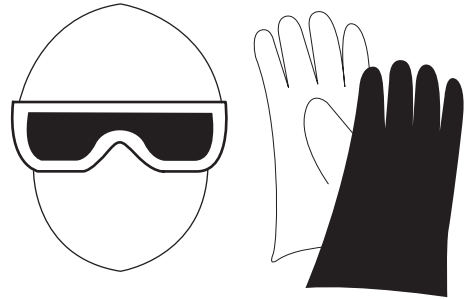


CAUTION

Coolant Hazard!

Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

Failure to comply may result in minor or moderate injury.



FG009154

Figure 68

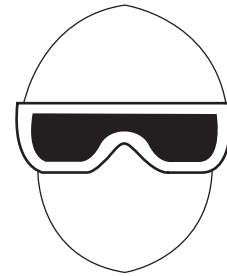


CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.



FG009152

Figure 69



CAUTION

Only use diesel fuels recommended by DOOSAN for the best engine performance, to prevent engine damage and to comply with EPA / ARB warranty requirements.

Only use clean diesel fuel.

Never remove the primary strainer (if equipped) from the fuel tank filler port. If removed, dirt and debris could get into the fuel system causing it to clog.



CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.

Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

Never overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.



CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and / or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

Never mix different types of engine coolants. This may adversely affect the properties of the engine coolant.



CAUTION

Never attempt to modify the engine's design or safety features such as defeating the engine speed limit control or the diesel fuel injection quantity control.

Modifications may impair the engine's safety and performance characteristics and shorten the engine's life. Any alterations to this engine may void its warranty. Be sure to use genuine replacement parts.



CAUTION

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

Avoid operating in extremely dusty conditions.

Avoid operating in the presence of chemical gases or fumes.

Avoid operating in a corrosive atmosphere such as salt water spray.

Never install the engine in a floodplain unless proper precautions are taken to avoid being subject to a flood.

Never expose the engine to the rain.



CAUTION

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

The standard range of ambient temperatures for the normal operation of 4TNV98-E engines is from +5°F (-15°C) to +113°F (+45°C).

If the ambient temperature exceeds +113°F (+45°C) the engine may overheat and cause the engine oil to break down.

If the ambient temperature is below +5°F (-15°C) the engine will be hard to start and the engine oil may not flow easily.

Contact your authorized DOOSAN dealer or distributor if the engine will be operated outside of this standard temperature range.



CAUTION

Never hold the key in the START position for longer than 15 seconds or the starter motor will overheat.



CAUTION

For maximum engine life, DOOSAN recommends that when shutting the engine down, you allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the turbocharger (if equipped) and exhaust system, to cool slightly before the engine itself is shut down.



CAUTION

Never use an engine starting aid such as ether. Engine damage will result.



CAUTION

Make sure the engine is installed on a level surface. If a continuously running engine is installed at an angle greater than 30° (in any direction) or if an engine runs for short periods of time (less than three minutes) at an angle greater than 35° (in any direction) engine oil may enter the combustion chamber causing excessive engine speed and white exhaust smoke. This may cause serious engine damage.



CAUTION

New Engine Break-in:

On the initial engine start-up, allow the engine to idle for approximately 15 minutes while you check for proper engine oil pressure, diesel fuel leaks, engine oil leaks, coolant leaks, and for proper operation of the indicators and / or gauges.

During the first hour of operation, vary the engine speed and the load on the engine. Short periods of maximum engine speed and load are desirable. Avoid prolonged operation at minimum or maximum engine speeds and loads for the next four to five hours.

During the break-in period, carefully observe the engine oil pressure and engine temperature.

During the break-in period, check the engine oil and coolant levels frequently.



CAUTION

Never engage the starter motor while the engine is running. This may damage the starter motor pinion and / or ring gear.



CAUTION

It is important to perform daily checks.

Periodic maintenance prevents unexpected downtime, reduces the number of accidents due to poor machine performance and helps extend the life of the engine.



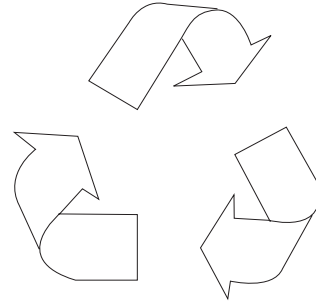
CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.



FG009156

Figure 70



CAUTION

Protect the air cleaner, turbocharger (if equipped) and electric components from damage when you use steam or high-pressure water to clean the engine.



CAUTION

Never overfill the engine with engine oil.

Always keep the oil level between the upper and lower lines on the oil cap / dipstick.



CAUTION

Never use high-pressure water or compressed air at greater than 28 psi (193 kPa; 19 686 mm Aq) or a wire brush to clean the radiator fins. Radiator fins damage easily.



CAUTION

Never attempt to adjust the low or high idle speed limit screw. This may impair the safety and performance of the machine and shorten its life. If the idle speed limit screws require adjustment, see your authorized DOOSAN industrial engine dealer or distributor.



CAUTION

Establish a periodic maintenance plan according to the engine application and make sure you perform the required periodic maintenance at the intervals indicated. Failure to follow these guidelines will impair the engine's safety and performance characteristics, shorten the engine's life and may affect the warranty coverage on your engine.

Consult your authorized DOOSAN dealer or distributor for assistance when checking items marked with a •.



CAUTION

If the fuel filter / water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter / water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter / water separator 2-3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.



CAUTION

When the engine is operated in dusty conditions, clean the air cleaner element more frequently.

Never operate the engine with the air cleaner element(s) removed. This may allow foreign material to enter the engine and damage it.



CAUTION

The maximum air intake restriction, in terms of differential pressure measurement, must not exceed 0.90 psi (6.23 kPa; 635 mmAq). Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.

Introduction

This section of the Service Manual describes the procedures for proper care and maintenance of the engine.

The Importance of Periodic Maintenance

Engine deterioration and wear occurs in proportion to length of time the engine has been in service and the conditions the engine is subject to during operation. Periodic maintenance prevents unexpected downtime, reduces the number of accidents due to poor machine performance and helps extend the life of the engine.

Performing Periodic Maintenance



WARNING

Exhaust Hazard!

Never operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.

Never block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.

Make sure that all connections are tightened to specifications after repair is made to the exhaust system.

Failure to comply could result in death or serious injury.

Perform periodic maintenance procedures in an open, level area free from traffic. If possible, perform the procedures indoors to prevent environmental conditions, such as rain, wind, or snow, from damaging the machine.

DOOSAN Replacement Parts

DOOSAN recommends that you use genuine *replacement* parts when replacement parts are needed. Genuine replacement parts help ensure long engine life.

Required EPA / ARB Maintenance - USA Only

To maintain optimum engine performance and compliance with the Environmental Protection Agency (EPA) Regulations Non-road Engines and the California Air Resources Board (ARB, California), it is essential that you follow the See "Periodic Maintenance Schedule" on page -65 and See "Periodic Maintenance Procedures" on page -67



ARO1770L

Figure 71

EPA / ARB Installation Requirements -USA Only

The following are the installation requirements for the EPA / ARB. Unless these requirements are met, the exhaust gas emissions will not be within the limits specified by the EPA and ARB.

Maximum Exhaust Gas Restriction shall be:

4TNV98 : 2.22 psi (15.3 kPa; 1560 mm Aq) or less

Maximum air intake restriction shall be 0.90 psi (6.23 kPa; 635 mm Aq) or less. Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.

Periodic Maintenance Schedule

Daily and periodic maintenance is important to keep the engine in good operating condition. The following is a summary of maintenance items by periodic maintenance intervals. Periodic maintenance intervals vary depending on engine application, loads, diesel fuel and engine oil used and are hard to establish definitively. The following should be treated only as a general guideline.



CAUTION

Establish a periodic maintenance plan according to the engine application and make sure you perform the required periodic maintenance at the intervals indicated. Failure to follow these guidelines will impair the engine's safety and performance characteristics, shorten the engine's life and may affect the warranty coverage on your engine.

Consult your authorized DOOSAN dealer or distributor for assistance when checking items marked with a •.

System	Check Item	Daily	Periodic Maintenance Interval					
			Every 50 hours	Every 250 hours	Every 500 hours	Every 1000 hours	Every 1500 hours	Every 2000 hours
Cooling System	Check and Refill Engine Coolant	C						
	Check and Clean Radiator Fins		C					
	Check and Adjust Cooling Fan V-Belt		C 1st time	C 2nd and after				
	Drain, Flush and Refill Cooling System with New Coolant					R or every year whichever comes first		
Cylinder Head	Adjust Intake / Exhaust Valve Clearance					D		
	Lap Intake / Exhaust Valve Seats. If necessary							D
Electrical Equipment	Check Indicators	C						
	Check Battery		C					
Engine Oil	Check Engine Oil Level	C						
	Drain and Fill Engine Oil			R 1st time	R 2nd and after			
	Replace Engine Oil Filter							
Engine Speed Control	Check and Adjust Governor Lever and Engine Speed Control	C		C				
Emission Control Warranty	Inspect, Clean and Test Fuel Injectors						D	
	Inspect Turbocharger (Blower Wash as Necessary)						D	
	Inspect Crankcase Breather System						D	
Fuel	Check and Refill Fuel Tank Level	C						
	Drain Fuel Tank			C				
	Drain Fuel Filter / Water Separator		C					
	Check Fuel Filter / Water Separator	C						
	Clean Fuel Filter / Water Separator				C			
	Replace Fuel Filter				R			
Hoses	Replace Fuel System and Cooling System Hoses							D or every 2 years
Intake and Exhaust	Clean or Replace Air Cleaner Element			C	R			
Complete Engine	Overall Visual Check Daily	C						

C : Check R : Replace D : Contact your authorized DOOSAN dealer or distributor

Note: These procedures are considered normal maintenance and are performed at the owner's expense.

Periodic Maintenance Procedures

After Initial 50 Hours of Operation

Perform the following maintenance after the initial 50 hours of operation.

- Replace Engine Oil and Engine Oil Filter
- Check and Adjust Cooling Fan V-Belt

Replace Engine Oil and Engine Oil Filter



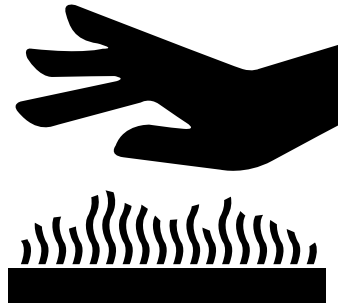
WARNING

Burn Hazard!

If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.

Always wear eye protection.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 72



WARNING

Sudden Movement Hazard!

Engaging the transmission or PTO at an elevated engine speed could result in unexpected movement of the equipment.

Failure to comply could result in death or serious injury.



CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.

Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

Never overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.



CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

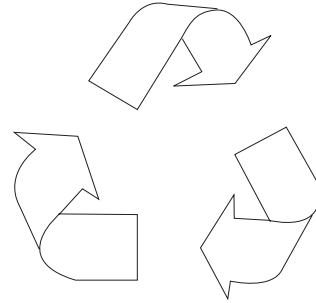
Failure to follow these procedures may seriously harm the environment.

The engine oil in a new engine becomes contaminated from the initial break-in of internal parts. It is very important that the initial oil and filter change is performed as scheduled.

NOTE: *The oil drain plug may be in another location if an optional oil pan is used.*

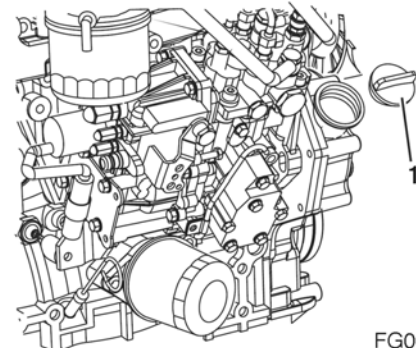
Drain the engine oil as follows:

1. Make sure the engine is level.
2. Start the engine and bring it up to operating temperature.
3. Stop the engine.
4. Remove one of the oil filler caps (4) (1, Figure 74, Figure 75) to vent the engine crankcase and allow the engine oil to drain more easily.
5. Position a container under the engine to collect waste oil.
6. Remove the oil drain plug (1, Figure 76) from the engine oil pan. Allow oil to drain.
7. After all oil has been drained from the engine, reinstall the oil drain plug (1, Figure 76) and tighten to 14 -17 ft•lb (19.6 -23.5 N•m; 2.0 -2.4 kgf•m).
8. Dispose of used oil properly.



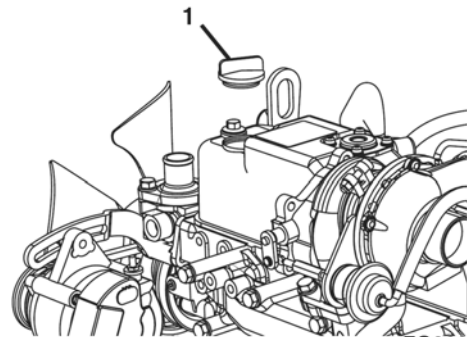
FG009156

Figure 73



FG008854

Figure 74



FG008855

Figure 75

Remove the engine oil filter as follows:

1. Turn the engine oil filter (2, Figure 76) counterclockwise (3, Figure 76) using a filter wrench.
2. Clean the engine oil filter mounting face.
3. Lightly coat the gasket on the new oil filter with engine oil. Install the new engine oil filter manually by turning it clockwise (4, Figure 76) until it contacts the mounting surface. Tighten an additional 3/4 of a turn using the filter wrench.

Engine Oil Fliter Part No.		
	Standard	Dust proof*
4TNV98-E	129150-35153	119005-35151

*Consult the operation manual for the driven machine for applicability of the dust proof filter.

4. Add new engine oil to the engine as specified in Adding Engine Oil on page 4-14.



CAUTION

Never overfill the engine with engine oil.

Always keep the oil level between the upper and lower lines on the oil cap / dipstick.

5. Warm up the engine by running it for five minutes and check for any engine oil leaks.
6. After engine is warm, shut it off and let it sit for 10 minutes.
7. Recheck the engine oil level.
8. Add engine oil (5, Figure 77) as needed until the level is between the upper (2, Figure 77) and lower lines (3, Figure 77) shown on the dipstick (1, Figure 77).
9. Reinstall the oil filler cap (4, Figure 77). If any engine oil is spilled, wipe it away with a clean cloth.

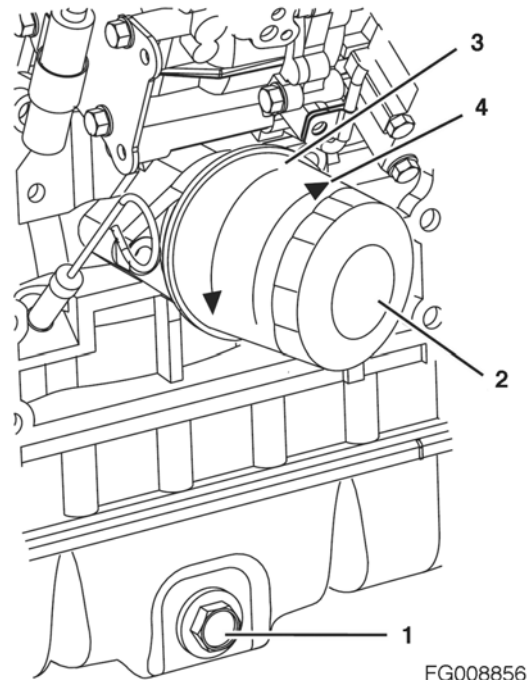


Figure 76

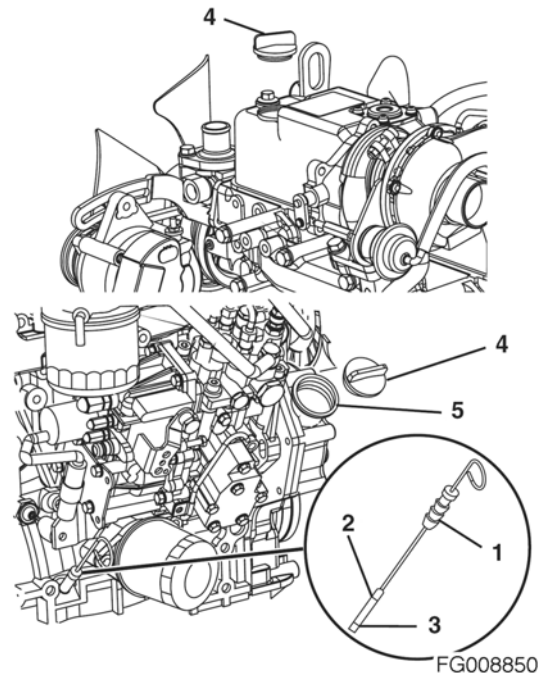


Figure 77

Check and Adjust Cooling Fan V-Belt

The V-belt will slip if it does not have the proper tension. This will prevent the alternator from generating sufficient power. Also, the engine will overheat due to the engine coolant pump pulley slipping.

Check and adjust the V-belt tension (deflection) as follows:

1. Press the V-belt down with your thumb with a force of approximately 22 ft•lb (98 N•m; 10 kgf) to check the deflection.

There are three positions to check for V-belt tension (A, B and C, Figure 78). You can check the tension at whichever position is the most accessible. The proper deflection of a used V-belt at each position is:

Used V-Belt Tension		
A	B	C
3/8 - 1/2 in. (10 - 14 mm)	1/4 - 3/8 in. (7 - 10 mm)	5/16 - 1/2 in. (9 - 13 mm)

NOTE: A "Used V-Belt" refers to a V-belt which has been used on a running engine for five minutes or more.

2. If necessary, adjust the V-belt tension. Loosen the adjusting bolt (1, Figure 79) and move the alternator (2, Figure 79) with a pry bar (3, Figure 79) to tighten the V-belt to the desired tension. Then tighten the adjusting bolt.

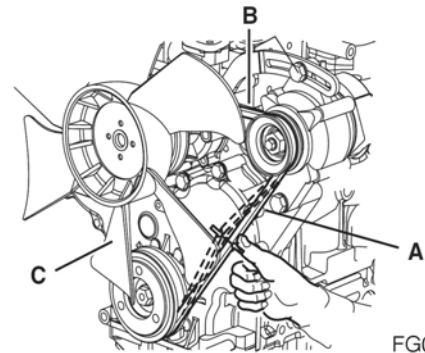


Figure 78

FG008857

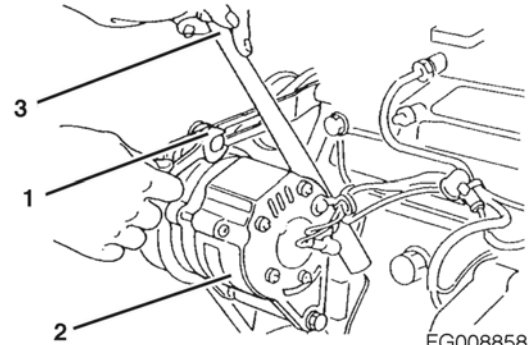


Figure 79

FG008858

3. Tighten the V-belt to the proper tension. There must be clearance (1, Figure 80) between the V-belt and the bottom of the pulley groove. If there is no clearance (2, Figure 80) between the V-belt and the bottom of the pulley groove, replace the V-belt.
4. Check the V-belt for cracks, oil or wear. If any of these conditions exist, replace the V-belt.
5. Install the new V-belt. Refer to the table for proper tension.

Used V-Belt Tension		
A	B	C
5/16 - 7/16 in. (8 - 12 mm)	3/16 - 5/16 in. (5 - 8 mm)	1/4 - 7/16 in. (7 - 11 mm)

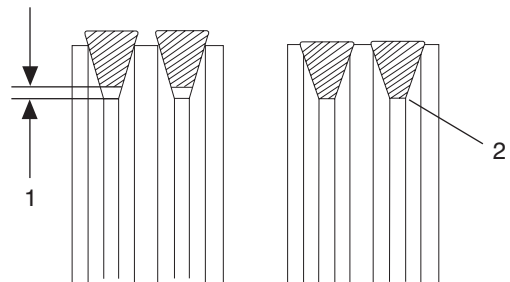


Figure 80

FG008859

6. After adjusting, run the engine for 5 minutes or more. Check the tension again using the specifications for a used V-belt.

Used V-Belt Tension		
A	B	C
3/8 - 1/2 in. (10 - 14 mm)	1/4 - 3/8 in. (7 - 10 mm)	5/16 - 1/2 in. (9 - 13 mm)



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.

Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 81



DANGER

For maximum engine life, DOOSAN recommends that when shutting the engine down, you allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the exhaust system, to cool slightly before the engine itself is shut down.



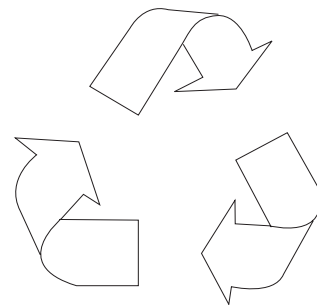
CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.



FG009156

Figure 82

Replace the fuel filter at specified intervals to prevent contaminants from adversely affecting the diesel fuel flow.

1. Stop the engine and allow it to cool.
2. Close the fuel cock of the fuel filter / water separator.
3. Remove the fuel filter with a filter wrench, turning it to the left (1, Figure 83). When removing the fuel filter, carefully hold it to prevent the fuel from spilling. Wipe up all spilled fuel.
4. Clean the filter mounting surface and apply a small amount of diesel fuel to the gasket of the new fuel filter.
5. Install the new fuel filter. Turn to the right (2, Figure 83) and hand-tighten it only until it comes in contact with the mounting surface. Tighten to 14 - 17 ft•lb (19.6 - 23.5 N•m; 2.0 - 2.4 kgf•m) or one additional turn using the filter wrench.
6. Open the fuel cock of the fuel filter / water separator.
7. Prime the fuel system. See "Priming the Fuel System" on page -40
8. Check for leaks.

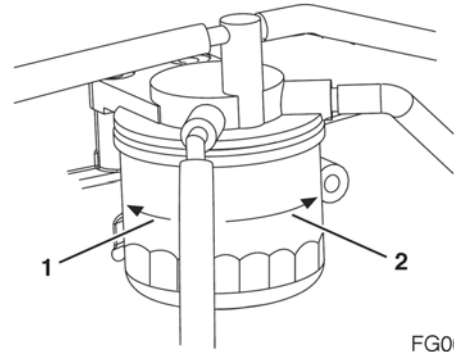


Figure 83

FG008867

Every 50 Hours of Operation

After you complete the initial 50 hour maintenance procedures, perform the following procedures every 50 hours thereafter.

- Drain Fuel Filter / Water Separator
- Check Battery

Drain Fuel Filter / Water Separator



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.

Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.



HDO10151

Figure 84



CAUTION

If the fuel filter / water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter / water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter / water separator 2-3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.



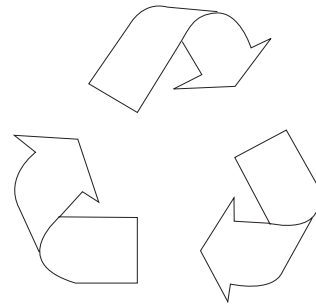
CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.



FG009156

Figure 85

Drain the fuel filter / water separator whenever there are contaminants, such as water, collected in the bottom of the cup. Never wait until the scheduled periodic maintenance if contaminants are discovered.

The cup of the separator is made from semi-transparent material. In the cup is a red colored float ring. The float ring will rise to the surface of the water to show how much needs to be drained. Also, some optional fuel filter / water separators are equipped with a sensor to detect the amount of contaminants. This sensor sends a signal to an indicator to alert the operator.

Drain the fuel filter / water separator as follows:

1. Position an approved container under the fuel filter / water separator (1, Figure 86) to collect the contaminants.
2. Close (2, Figure 86) the fuel cock (3, Figure 86).
3. Loosen the drain cock (4, Figure 86) at the bottom of the fuel filter / water separator. Drain any water collected inside.
4. Hand-tighten the drain cock.



CAUTION

If the fuel filter / water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter / water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter / water separator 2-3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.

5. Open the fuel cock (3, Figure 86).
6. Be sure to prime the diesel fuel system when you are finished. Priming the Fuel System on page 4-12.
7. Check for leaks.

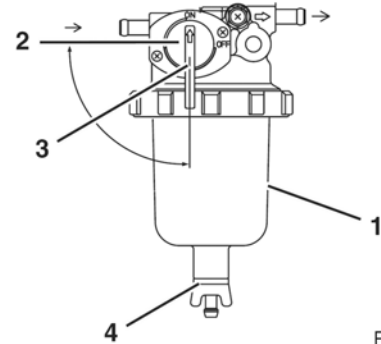


Figure 86

FG008860



WARNING

Battery electrolyte contains sulfuric acid and can quickly burn the skin and eat holes in clothing. If you spill acid on yourself, immediately flush the area with water.

Battery acid could cause blindness if splashed into the eyes. If acid gets into the eyes, flush them immediately with large quantities of water and see a doctor at once.

If you accidentally drink acid, drink a large quantity of water or milk, beaten egg or vegetable oil. Call a doctor or poison prevention center immediately.

When working with batteries, always wear safety glasses or goggles.

Battery generates hydrogen gas, so there is a danger of an explosion. Do not bring lighted cigarettes near the battery, or do anything that will cause sparks.

Before working with batteries, shut down engine and turn the starter switch to the "O" (OFF) position.

Avoid short-circuiting the battery terminals through accidental contact with metallic objects, such as tool.

When removing or installing, check which is the positive (+) terminal and negative (-) terminal.

When removing the battery, first disconnect the negative (-) terminal. When installing the battery, first connect the positive (+) terminal.

If the terminals are loose, there is a danger that defective contact may generate sparks that will cause an explosion. When installing the terminals, install them tightly.

Batteries in Cold Weather

In colder weather a greater drain is placed on the batteries when they are used for the preheat cycle and when starting a cold engine. Battery performance decreases as the temperature gets lower.

In extremely cold weather, remove batteries at night and move them to a warm location. This will help to keep them at a higher power level.

Inspection of Battery Electrolyte Level

This machine has two maintenance free battery. It never requires the addition to water.

When the charge indicator becomes transparent, it means low electrolyte state because of the leakage or charging system error. Determine the cause of problem and replace the battery immediately.

Check Charging State

Check charging state through the charging indicator.

- GREEN: Sufficiently charged.
- BLACK: Insufficient charged.
- TRANSPARENT: Replace battery.

Check the Battery Terminals

Be certain that battery is held securely in its compartment. Clean the battery terminals and the battery cable connectors. A solution of baking soda and water will neutralize acid on the battery surface, terminals, and cable connectors. Petroleum jelly or grease can be applied to the connectors to help prevent corrosion.

Battery Replacement

When the charging indicator indicates transparency state, replace the battery.

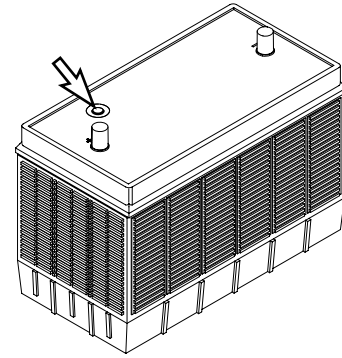


Figure 87

FG010161

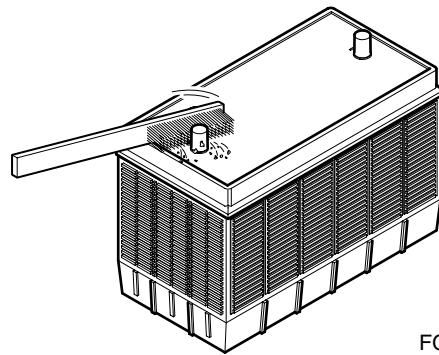


Figure 88

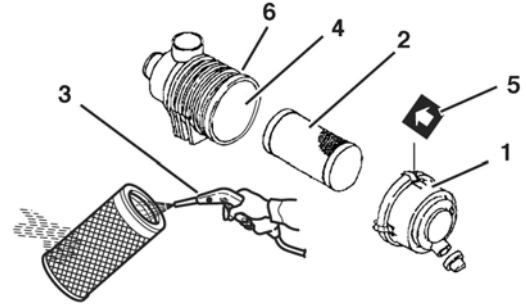
FG010162

Clean Air Cleaner Element

Note that a typical air cleaner is shown in Figure 89 and Figure 91 for illustrative purposes only.

The engine performance is adversely affected when the air cleaner element is clogged with dust. Be sure to clean the air filter element periodically.

1. Unlatch and remove the air cleaner cover (1, Figure 89).
2. Remove the element (2, Figure 89) (outer element if equipped with two elements).



FG008865

Figure 89



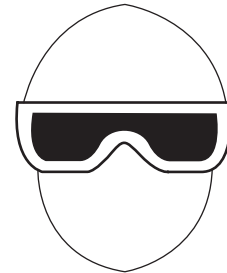
CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

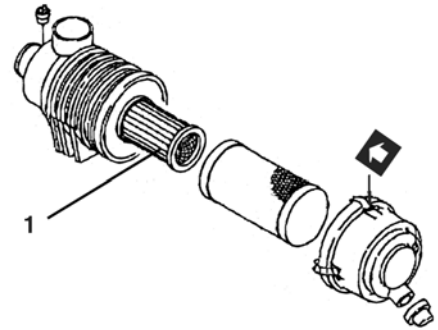
Failure to comply may result in minor or moderate injury.

3. Blow air (3, Figure 89) through the element from the inside out using 42 -71 psi (0.29 -0.49 MPa; 3.0 -5.0 kgf/cm²) compressed air to remove the particulates. Use the lowest possible air pressure to remove the dust without damaging the element.
4. If the air cleaner is equipped with a double element, only remove and replace the inner element (1, Figure 91) if the engine lacks power or the dust indicator actuates (if equipped).
5. The inner element should not be removed when cleaning or replacing the outer element. The inner element is used to prevent dust from entering the engine while servicing the outer element.
6. Replace the element with a new one if the element is damaged, excessively dirty or oily.
7. Clean inside of the air cleaner cover.
8. Install the element into the air cleaner case (4, Figure 89).
9. Reinstall the air cleaner cover making sure you match the arrow (5, Figure 89) on the cover with the arrow on the case (6, Figure 89).
10. Latch the air cleaner cover to the case.



FG009152

Figure 90



FG008866

Figure 91



CAUTION

When the engine is operated in dusty conditions, clean the air cleaner element more frequently.

Never operate the engine with the air cleaner element(s) removed. This may allow foreign material to enter the engine and damage it.

Every 250 Hours of Operation

Perform the following maintenance every 250 hours of operation.

- Drain Fuel Tank
- Replace Engine Oil
- Check and Clean Radiator Fins
- Check and Adjust Cooling Fan V-Belt

Drain Fuel Tank



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.



HDO10151

Figure 92



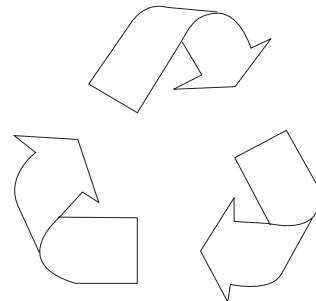
CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.



FG009156

Figure 93

That a typical fuel tank is illustrated.

1. Position an approved container under the diesel fuel tank (1, Figure 94) to collect the contaminants.
2. Remove the fuel cap (3, Figure 94).
3. Remove the drain plug (2, Figure 94) of the fuel tank to drain the contaminants (water, dirt, etc.) from the bottom of the tank.
4. Drain the tank until clean diesel fuel with no water and dirt flows out. Reinstall and tighten the drain plug firmly.
5. Reinstall the fuel cap.
6. Check for leaks.

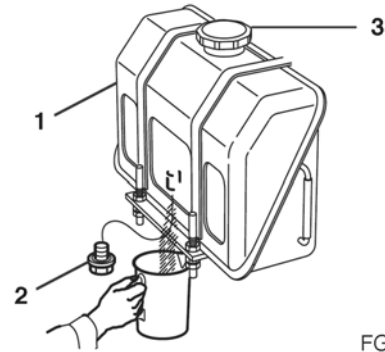


Figure 94

FG008862

Replace Engine Oil and Engine Oil Filter



CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.

Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

Never overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.



CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Change the engine oil every 250 hours of operation after the initial change at 50 hours. Replace the engine oil filter at the same time. See "Replace Engine Oil and Engine Oil Filter" on page -79

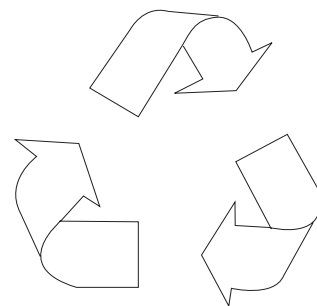


Figure 95

FG009156

Check and Clean Radiator Fins



CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

Dirt and dust adhering to the radiator fins reduce the cooling performance, causing overheating. Make it a rule to check the radiator fins daily and clean as needed.

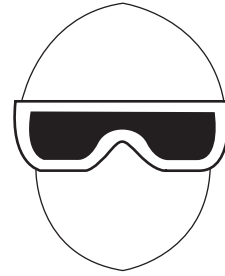
Note that a typical radiator is shown in Figure 97 for illustrative purposes only.

- Blow off dirt and dust from fins and radiator with 28 psi (0.19 MPa; 2 kgf/cm²) or less of compressed air (1, Figure 97). Be careful not to damage the fins with the compressed air.
- If there is a large amount of contamination on the fins, apply detergent, thoroughly clean and rinse with tap water.



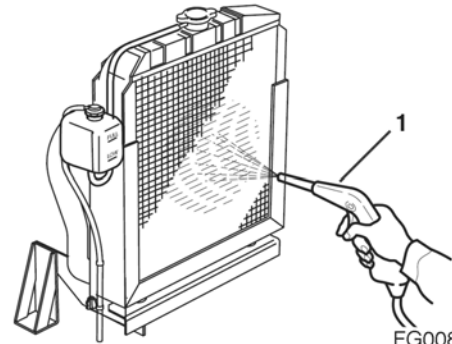
CAUTION

Never use high-pressure water or compressed air at greater than 28 psi (193 kPa; 19 686 mm Aq) or a wire brush to clean the radiator fins. Radiator fins damage easily.



FG009152

Figure 96



FG008863

Figure 97

Check and Adjust Cooling Fan V-Belt

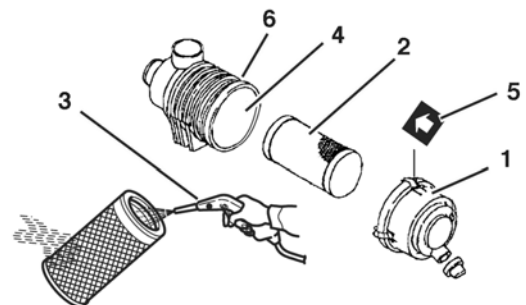
Check and adjust the cooling fan V-belt every 250 hours of operation after the initial 50 hour V-belt maintenance. See "Check and Adjust Cooling Fan V-Belt" on page -80

Clean Air Cleaner Element

Note that a typical air cleaner is shown in Figure 98 and Figure 100 for illustrative purposes only.

The engine performance is adversely affected when the air cleaner element is clogged with dust. Be sure to clean the air filter element periodically.

1. Unlatch and remove the air cleaner cover (1, Figure 98.).
2. Remove the element (2, Figure 98) (outer element if equipped with two elements).



FG008865

Figure 98

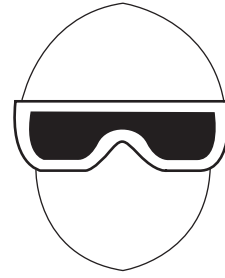


CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.



FG009152

3. Blow air (3, Figure 98) through the element from the inside out using 42 -71 psi (0.29 -0.49 MPa; 3.0 -5.0 kgf/cm²) compressed air to remove the particulates. Use the lowest possible air pressure to remove the dust without damaging the element.
4. If the air cleaner is equipped with a double element, only remove and replace the inner element (1, Figure 100) if the engine lacks power or the dust indicator actuates (if equipped).
5. The inner element should not be removed when cleaning or replacing the outer element. The inner element is used to prevent dust from entering the engine while servicing the outer element.
6. Replace the element with a new one if the element is damaged, excessively dirty or oily.
7. Clean inside of the air cleaner cover.
8. Install the element into the air cleaner case (4, Figure 98).
9. Reinstall the air cleaner cover making sure you match the arrow (5, Figure 98) on the cover with the arrow on the case (6, Figure 98).
10. Latch the air cleaner cover to the case.

Figure 99

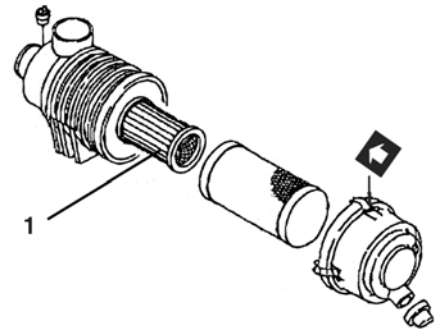


Figure 100



CAUTION

When the engine is operated in dusty conditions, clean the air cleaner element more frequently.

Never operate the engine with the air cleaner element(s) removed. This may allow foreign material to enter the engine and damage it.

Every 500 Hours of Operation

Perform the following maintenance every 500 hours of operation.

- Replace Air Cleaner Element
- Replace Fuel Filter
- Clean Fuel Filter / Water Separator
- Replace Engine Oil Filter

Replace Air Cleaner Element



CAUTION

The maximum air intake restriction, in terms of differential pressure measurement, must not exceed 0.90 psi (6.23 kPa; 635 mmAq). Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.

Replace the air cleaner element (2, Figure 98) every 500 hours even if it is not damaged or dirty.

When replacing the element, clean the inside of the air cleaner case (4, Figure 98).

If the air cleaner is equipped with a double element,

only remove and replace the inner element (1, Figure 99) if the engine lacks power or the dust indicator actuates (if equipped). This is in addition to replacing the outer element.

Replace Fuel Filter



DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.

Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 101



DANGER

For maximum engine life, DOOSAN recommends that when shutting the engine down, you allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the exhaust system, to cool slightly before the engine itself is shut down.



CAUTION

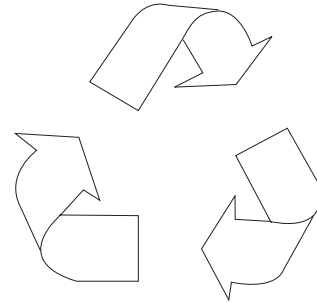
Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Change the fuel filter every 500hours of operation after initial change at 50 hours. See "Replace Fuel Filter" on page -71



FG009156

Figure 102

 DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

Never use diesel fuel as a cleaning agent.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 103

 DANGER

Fire And Explosion Hazard!

Diesel fuel is flammable and explosive under certain conditions.

When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.

Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.

Wipe up any spills immediately.

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Failure to comply will result in death or serious injury.



HDO1015I

Figure 104

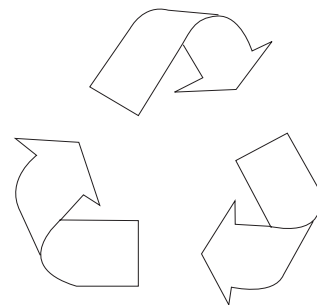
 CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.



FG009156

Figure 105

Periodically clean the fuel filter / water separator element and inside cup.

1. Position an approved container under the cup (1, Figure 106) of the fuel filter / water separator to collect the contaminants.
2. Close (2, Figure 106) the fuel cock (3, Figure 106).
3. Loosen the drain cock (4, Figure 106) and drain the contaminants. See "Drain Fuel Filter / Water Separator" on page -73
4. Turn the retaining ring (5, Figure 106) to the left (10, Figure 106) and remove the cup (6, Figure 106). If equipped, disconnect the sensor wire (7, Figure 106) from the cup before removing the cup.
5. Carefully hold the cup to prevent fuel from spilling. If you spill any fuel, clean up the spill completely.
6. Remove the float ring (8, Figure 106) from the cup. Pour the contaminants into the container and dispose of it properly.
7. Clean the element (9, Figure 106) and inside cup. Replace the element if it is damaged.
8. Install the element and O-ring in the bracket.
9. Position the float ring in the cup.
10. Check the condition of the cup O-ring. Replace if necessary.
11. Install the cup to the bracket by tightening the retaining ring to the right (6, Figure 106) to a torque of 11 -15 ft•lb (15 -20 N•m; 1.5 -2.0 kgf•m).
12. Close the drain cock. Reconnect the sensor wire if equipped.
13. Open the fuel cock (3, Figure 106).
14. Prime the fuel system. See "Priming the Fuel System" on page -40
15. Check for leaks.

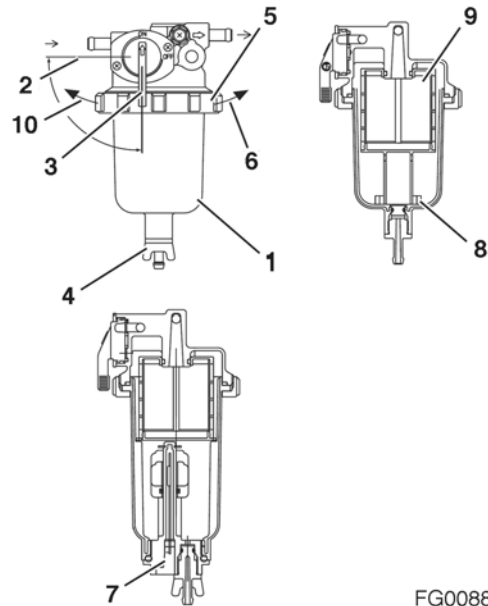


Figure 106

FG008868

Every 1000 Hours of Operation

Perform the following maintenance every 1000 hours of operation.

- Adjust Intake / Exhaust Valve Clearance

Adjust Intake / Exhaust Valve Clearance

Proper adjustment is necessary to maintain the correct timing for opening and closing the valves. Improper adjustment will cause the engine to run noisily, resulting in poor engine performance and engine damage. See "Intake / Exhaust Valve and Guide" on page -95

Every 1500 Hours of Operation

Perform the following maintenance every 1500 hours of operation.

- Inspect, Clean and Test Fuel Injectors
- Inspect, Clean and Test EGR valve 4TNV98-E
- Inspect Crankcase Breather System

Inspect, Clean and Test Fuel Injectors



WARNING

High-pressure Hazard!

Avoid skin contact with the high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.

Never check for a fuel leak with your hands. Always use a piece of wood or cardboard. Consult authorized DOOSAN dealer or DOOSAN after sales service if have any questions or required more information.

Failure to comply could result in death or serious injury.

Proper operation of the fuel injectors is required to obtain the optimum injection pattern for full engine performance. The EPA / ARB requires that the fuel injectors are inspected, cleaned and tested every 1500 hours. See "Testing of Fuel Injectors" on page -194

This procedure is considered normal maintenance and is performed at the owner's expense.

Inspect, Clean and Test EGR Valve 4TNV98-E

The EGR valve is a key component for cleaning exhaust gas.

To prevent the valve from deteriorating in exhaust gas recirculation performance due to carbon accumulation, inspect, clean and test the valve at least every 1500 hours.

Consult your local DOOSAN dealer for this service.



Figure 107

FG009150

Inspect Crankcase Breather System

Proper operation of the crankcase breather system is required to maintain the emission requirements of the engine. The EPA / ARB requires that the crankcase breather system is inspected every 1500 hours.

There are three different crankcase breather systems used on the TNV engines. Only the non-turbo TNV engines crankcase breather system requires periodic maintenance.

The non-turbo TNV engines use a crankcase breather system that has a spring-backed diaphragm (2, Figure 108) in the valve cover (2, Figure 108). When the crankcase pressure reaches a predetermined value, the diaphragm opens a passage that allows crankcase fumes to be routed to the intake manifold.

To inspect the diaphragm and spring (3, Figure 108):

1. Remove the bolts retaining the diaphragm cover (4, Figure 108).
2. Remove the diaphragm cover, spring, diaphragm plate (5, Figure 108) and diaphragm.
3. Inspect the diaphragm for tears. Inspect the spring for distortion. Replace components if necessary.
4. Reinstall the diaphragm, diaphragm plate, spring and diaphragm cover. Tighten the diaphragm bolts to specified torque.

Failure of the diaphragm and / or spring will cause the loss of pressure control and allow an excessive amount of crankcase fumes to be routed to the intake manifold. This could result in excessive deposits in the intake system, high engine exhaust smoke levels, excessive engine oil consumption, and / or engine run-on due to the burning of the engine oil.

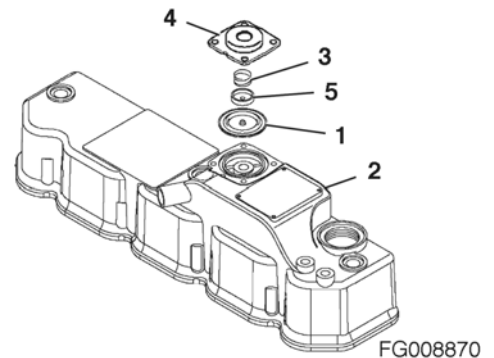


Figure 108

Every 2000 Hours of operation

Perform the following maintenance every 2000 hours of operation.

- Drain, Flush and Refill Cooling System With New Coolant
- Check and Replace Fuel Hoses and Engine Coolant Hoses
- Lap the Intake and Exhaust Valves

Drain, Flush and Refill Cooling System with New Coolant



DANGER

Scald Hazard!

Never Remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.

Always check the level of the engine coolant by observing the reserve tank.

Failure to comply will result in death or serious injury.



HAOA060L

Figure 109

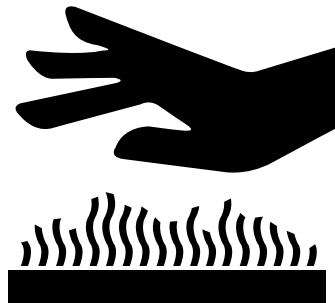


WARNING

Burn Hazard!

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 110

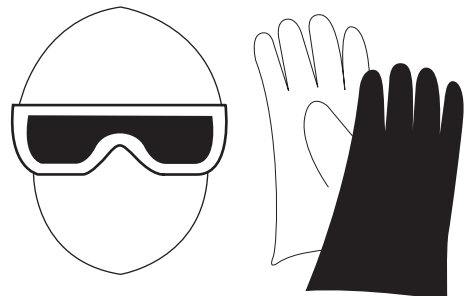


CAUTION

Coolant Hazard!

Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

Failure to comply may result in minor or moderate injury.



FG009154

Figure 111



CAUTION

Always be environmentally responsible.

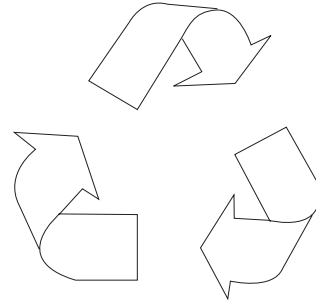
Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

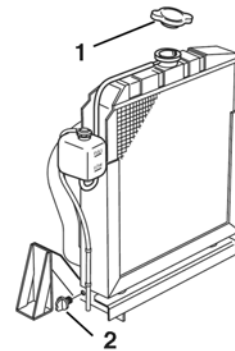
Engine coolant contaminated with rust or scale reduces the cooling effect. Even when extended life engine coolant is properly mixed, the engine coolant gets contaminated as its ingredients deteriorate. Drain, flush and refill the cooling system with new coolant every 1000 hours or once a year, whichever comes first.

1. Allow engine and coolant to cool.
2. Remove the radiator cap (1, Figure 113).
3. Remove the drain plug or open the drain cock (2, Figure 113) at the lower portion of the radiator and drain the engine coolant.



FG009156

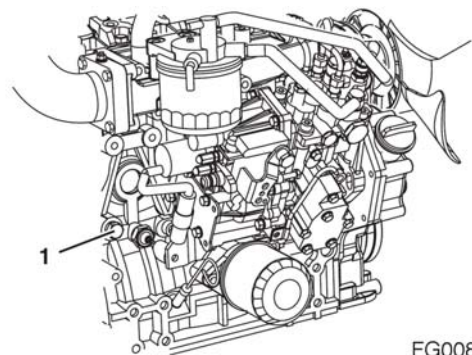
Figure 112



FG008869

Figure 113

4. Drain the coolant from the engine block.
 - On models not equipped with an oil cooler, remove the coolant drain plug (1, Figure 114) from the engine block.



FG008852

Figure 114

- On models equipped with an oil cooler, remove the coolant hose (1, Figure 115) at the oil cooler.

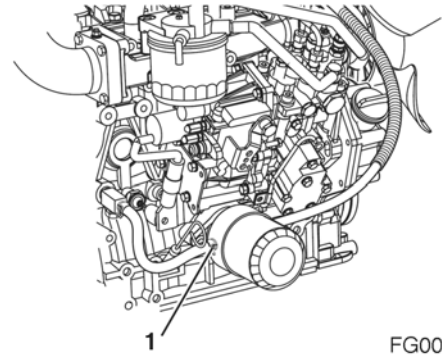


Figure 115

FG008853

5. After draining the engine coolant, flush the radiator and engine block to remove any rust, scale and contaminants. Then reinstall and tighten the drain plug or close the drain cock in the radiator. Reinstall and tighten the cylinder block drain plug or reconnect the coolant hose at the oil cooler.
6. Fill radiator and engine with engine coolant. See "Filling Radiator with Engine Coolant" on page -45

Check and Replace Fuel Hoses and Engine Coolant Hoses



CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Regularly check the fuel system and engine coolant system hoses. If they are cracked or degraded, replace them. Replace the hoses at least every two years.

Lap the Intake and Exhaust Valves

Adjustment is necessary to maintain proper contact of the valves and seats. See "Inspection of Intake and Exhaust Valves" on page -114

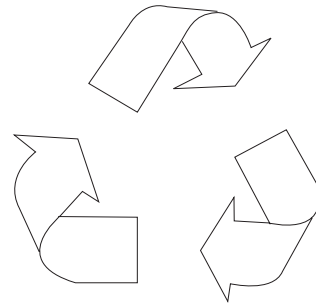


Figure 116

FG009156

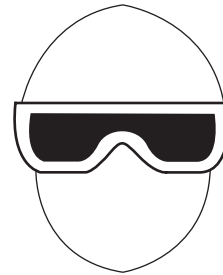
ENGINE

Before You Begin Servicing



WARNING

To prevent possible eye injury, always wear SAFETY GLASSES while servicing the engine.



FG009152

Figure 117



WARNING

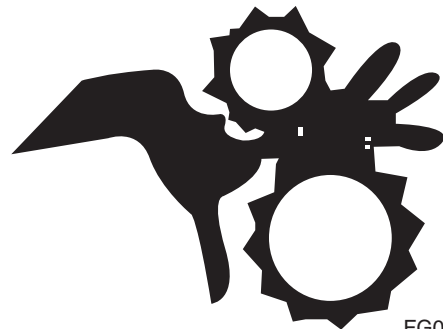
ENTANGLEMENT HAZARD!

Stop the engine before you begin to service it.

Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.

Failure to comply could result in death or serious injury.



FG009148

Figure 118



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.



FG009153

Figure 119

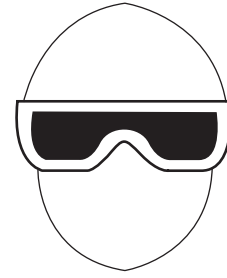


CAUTION

Flying Object Hazard!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.



FG009152

Figure 120



CAUTION

Be sure to secure the engine solidly to prevent injury or damage to parts due to the engine falling during work on the engine.



CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.

Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

Never overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.



CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and / or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

Never mix different types of engine coolants. This may adversely affect the properties of the engine coolant.



CAUTION

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.



CAUTION

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.



CAUTION

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.



CAUTION

Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.



CAUTION

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub. Correct fuel injection timing will be very difficult or impossible to achieve.



CAUTION

Keep the piston pin parts, piston assemblies, and connecting rod assemblies together to be returned to the same position during the reassembly process. Label the parts using an appropriate method.



CAUTION

Do not allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

Introduction

This section of the Service Manual describes servicing of the engine.

Cylinder Head Specifications

Adjustment Specifications

Valve Clearance	Valve Bridge Clearance (4-Valve Head Only)
0.006 - 0.010 in. (0.15 - 0.25 mm)	0

Cylinder Head

Inspection Item			Standard	Limit	Reference Page
Combustion Surface Distortion (Flatness)			0.0020 in. (0.05 mm) or less	0.0059 in. (0.15 mm)	See "Valve Recession" on page -115
Valve Recession	Intake		0.0142 - 0.0220 in. (0.36 - 0.56 mm)	0.0315 in. (0.8 mm)	
	Exhaust		0.0138 - 0.0217 in. (0.35 - 0.55 mm)	0.0315 in. (0.8 mm)	
Valve Seat (4-Valve)	Seat Angle	Intake	120°	-	See "Valve Face and Valve Seat" on page -116
		Exhaust	90°	-	
	Seat Correction Angle		40°, 150°	-	

Intake / Exhaust Valve and Guide

Inspection Item		Standard	Limit	Reference Page
Intake	Guide Inside Diameter	0.2756 - 0.2762 in. (7.000 - 7.015 mm)	0.2787 in. (7.08 mm)	See "Inspection of Valve Guides" on page -114
	Valve Stem Outside Diameter	0.2734 - 0.2740 in. (6.945 - 6.960 mm)	0.2717 in. (6.90 mm)	
	Valve Stem Bend	0.0016 - 0.0028 in. (0.040 - 0.070 mm)	0.0067 in. (0.17 mm)	
Exhaust	Guide Inside Diameter	0.2756 - 0.2762 in. (7.000 - 7.015 mm)	0.2787 in. (7.08 mm)	
	Valve Stem Outside Diameter	0.2732 - 0.2738 in. (6.940 - 6.955 mm)	0.2717 in. (6.90 mm)	
	Valve Stem Bend	0.0018 - 0.0030 in. (0.045 - 0.075 mm)	0.0067 in. (0.17 mm)	
Valve Guide Installation Method		0.3819 - 0.3937 in. (9.70 - 10.00 mm)	-	See "Inspection of Cylinder Head" on page -114
		Cold-fitted		
Valve Guide Projection From Cylinder Head (4 Valves)		0.460 - 0.472 in. (11.7 - 12.0 mm)	-	See "Inspection of Cylinder Head" on page -114

Push Rod

Inspection Item	Standard	Limit	Reference Page
Push Rod Bend - All Models	Less than 0.0012 in. (0.03 mm)	0.0012 in. (0.03 mm)	See "Push Rod Bend" on page -113

Valve Spring

Inspection Item	Standard	Limit	Reference Page
Free Length	1.5630 in. (39.7 mm)	1.5433 in. (39.2 mm)	See "Inspection of Valve Springs" on page -116
Squareness	-	0.0551 in. (1.4 mm)	

Rocker Arm and Shaft

Inspection Item	Standard	Limit	Reference Page
Arm Shaft Hole Diameter	0.7283 - 0.7291 in. (18.500 - 18.520 mm)	0.7311 in. (18.57 mm)	See "Inspection of Rocker Arm Assembly" on page -113
Shaft Outside Diameter	0.7272 - 0.7280 in. (18.470 - 18.490 mm)	0.7260 in. (18.44 mm)	
Oil Clearance	0.0004 - 0.0020 in. (0.010 - 0.050 mm)	0.0051 in. (0.13 mm)	

Camshaft and Timing Gear Train Specifications

Camshaft

Inspection Item		Standard	Limit	Reference Page
End Play		0.0020 - 0.0079 in. (0.05 - 0.20 mm)	0.0118 in. (0.030 mm)	See "Removal of Camshaft" on page -134
Bend (1/2 the dial gauge reading)		0 - 0.0008 in. (0 - 0.02 mm)	0.0020 in. (0.05 mm)	See "Inspection of Camshaft" on page -146.
Cam Lobe Height		1.7087 - 1.7165 in. (43.400 - 43.600 mm)	1.6988 in. (50.650 mm)	
Shaft Outside Diameter/ Bearing Inside Diameter				
Gear End	Bushing Inside Diameter	1.9681 - 1.9707 in. (49.990 - 50.055 mm)	1.9736 in. (50.130 mm)	See "Inspection of Camshaft" on page -146
	Camshaft Outside Diameter	1.9655 - 1.9665 in. (49.925 - 49.950 mm)	1.7673 in. (49.890 mm)	
	Oil Clearance	0.0016 - 0.0051 in. (0.040 - 0.130 mm)	0.0094 in. (0.240 mm)	
Intermediate	Bore Inside Diameter	1.9685 - 1.9695 in. (50.000 - 50.025 mm)	1.9724 in. (50.100 mm)	
	Camshaft Outside Diameter	1.9650 - 1.9659 in. (49.910 - 49.935 mm)	1.9636 in. (49.875 mm)	
	Oil Clearance	0.0026 - 0.0045 in. (0.065 - 0.115 mm)	0.0089 in. (0.225 mm)	
Flywheel End	Bore Inside	1.9685 - 1.9695 in. (50.000 - 50.025 mm)	1.9724 in. (50.100 mm)	
	Camshaft Outside Diameter	1.9655 - 1.9665 in. (49.925 - 49.950 mm)	1.7673 in. (49.890 mm)	
	Oil Clearance	0.0020 - 0.0039 in. (0.050 - 0.100 mm)	0.0083 in. (0.210 mm)	

Idler Gear Shaft and Bushing

Inspection Item	Standard	Limit	Reference Page
Shaft Outside Diameter	1.8091 - 1.8100 in. (45.950 - 45.975 mm)	1.8071 in. (45.900 mm)	See "Inspection of Idler Gear and Shaft" on page -147
Bushing Inside Diameter	1.8110 - 4.8120 in. (46.000 - 46.025 mm)	1.8140 in. (46.075 mm)	
Oil Clearance	0.0010 - 0.0030 in. (0.025 - 0.075 mm)	0.0069 in. (0.175 mm)	

Timing Gear Backlash

Inspection Item	Standard	Limit	Reference Page
Crank Gear, Cam Gear, Idler Gear, Fuel Injection Pump Gear and PTO Gear	0.0031 - 0.0055 in (0.08 - 0.14 mm)	0.0063 in. (0.16 mm)	See "Checking Timing Gear Backlash" on page -131
Lubricating Oil Pump Gear	0.0035 - 0.0059 in. (0.09 - 0.15 mm)	0.0067 in. (0.17 mm)	
Balancer Drive Gear	0.0047 - 0.0071 in. (0.12 - 0.18 mm)	0.0079 in. (0.20 mm)	

Crankshaft and Piston Specifications

Crankshaft

NOTE: Check appropriate parts catalog for various sizes of replacement main bearing inserts.

Inspection Item		Standard	Limit	Reference Page
Bend (1/2 the dial gauge reading)		-	0.0008 in. (0.02 mm)	See "Inspection of Crankshaft" on page -145
Connecting Rod Journals	Journal Outside Diameter	2.2816 - 2.2820 in. (57.952 - 57.962 mm)	2.2796 in. (57.902 mm)	
	Bearing Inside Diameter	2.2835 - 2.2845 in. (58.000 - 58.026 mm)	-	
	Bearing Insert Thickness	0.0587 - 0.0591 in. (1.492 - 1.500 mm)	-	
	Oil Clearance	0.0015 - 0.0029 in. (0.038 - 0.074 mm)	0.0059 in. (0.150 mm)	
Main Bearing Journal	Journal Outside Diameter	2.5572 - 2.5576 in. (64.952 - 64.962 mm)	2.5552 in. (64.902 mm)	
	Bearing Inside Diameter	2.5590 - 2.5598 in. (65.000 - 65.020 mm)	-	
	Bearing Insert Thickness	0.0785 - 0.0791 in. (1.995 - 2.010 mm)	-	
	Oil Clearance	0.0015 - 0.0027 in. (0.038 - 0.068 mm)	0.0059 in. (0.150 mm)	

Thrust Bearing

Inspection Item	Standard	Limit	Reference Page
Crankshaft End Play - All Models	0.0051 - 0.0091 in. (0.13 - 0.23 mm)	0.0110 in. (0.28 mm)	See "Removal of Crankshaft" on page -138

Piston

Inspection Item		Standard	Limit	Reference Page
Piston Outside Diameter (Measure at 90° to the Piston Pin.)	4TNV98	3.8555 - 3.8567 in. (97.930 - 97.960 mm)	3.8541 in. (97.895 mm)	See "Inspection of Pistons, Piston Rings and Wrist Pin" on page -142
Piston Diameter Measure Location (Upward From the Bottom of the Piston.)	4TNV98	0.8661 in. (22 mm)	-	
Piston Pin	Hole Inside Diameter	1.1811 - 1.1815 in. (30.000 - 30.009 mm)	1.1826 in. (30.039 mm)	
	Pin Outside Diameter	1.1807 - 1.1811 in. (29.989 - 30.000 mm)	1.1795 in. (29.959 mm)	
	Oil Clearance	0.0000 - 0.0008 in. (0.000 - 0.020 mm)	0.0031 in. (0.080 mm)	

Piston Ring

Inspection Item		Standard	Limit	Reference Page
Top Ring	Ring Groove Width	0.0803 - 0.0811 in. (2.040 - 2.060 mm)	-	See "Inspection of Pistons, Piston Rings and Wrist Pin" on page -142
	Ring Width	0.0764 - 0.0772 in. (1.940 - 1.960 mm)	0.0756 in. (1.920 mm)	
	Side Clearance	0.0031 - 0.0047 in. (0.080 - 0.120 mm)	-	
	End Gap	0.0098 - 0.0177 in. (0.250 - 0.450 mm)	0.0213 in. (0.540 mm)	
Second Ring	Ring Groove Width	0.819 - 0.0825 in. (2.080 - 2.095 mm)	0.0864 in. (2.195 mm)	
	Ring Width	0.0776 - 0.0783 in. (1.970 - 1.990 mm)	0.0768 in. (1.950 mm)	
	Side clearance	0.0035 - 0.0049 in. (0.090 - 0.125 mm)	0.0096 in. (0.245 mm)	
	End Gap	0.017 - 0.0256 in. (0.450 - 0.650 mm)	0.0287 in. (0.730 mm)	
Oil Ring	Ring Groove Width	0.1187 - 0.1193 in. (3.015 - 3.030 mm)	0.1232 in. (3.130 mm)	
	Ring Width	0.1169 - 0.1177 in. (2.970 - 2.990 mm)	0.1161 in. (2.950 mm)	
	Side Clearance	0.0010 - 0.0024 in. (0.025 - 0.060 mm)	0.0071 in. (0.180 mm)	
	End Gap	0.0098 - 0.0177 in. (0.250 - 0.450 mm)	0.0217 in. (0.550 mm)	

Connecting Rod

Connecting Rod Small End

Inspection Item	Standard	Limit	Reference Page
Wrist Pin Bushing Inside Diameter	1.1821 - 1.1826 in. (30.025 - 30.038 mm)	1.1838 in. (30.068mm)	See "Inspection of Connecting Rod" on page -144
Wrist Pin Outside Diameter	1.1806 - 1.1811 in. (29.987 - 30.000 mm)	1.1795 in. (29.959 mm)	
Oil Clearance	0.0010 - 0.0020 in. (0.025 - 0.51 mm)	0.0043 in. (0.109 mm)	

Connecting Rod Big End

Inspection Item	Standard	Limit	Reference Page
Side Clearance - All Models	0.0079 - 0.0157 in. (0.20 - 0.40 mm)	-	See "Inspection of Connecting Rod" on page -144

Tappet

Inspection Item	Standard	Limit	Reference Page
Tappet Bore (Block) Inside Diameter	0.4724 - 0.4731 in. (12.000 - 12.018 mm)	0.4739 in. (12.038 mm)	See "Inspection of Tappets" on page -144
Tappet Stem Outside Diameter	0.4715 - 0.4720 in. (11.975 - 11.990 mm)	0.4707 in. (11.955 mm)	
Oil Clearance	0.004 - 0.0017 in. (0.010 - 0.043 mm)	0.0033 in. (0.083 mm)	

Cylinder Block Specifications

Cylinder Block

Model	Inspection Item	Standard	Limit	Reference Page
Cylinder Inside Diameter		3.8583 - 3.8594 in. (98.000 - 98.030 mm)	3.8634 in. (98.130 mm)	See "Inspection of Cylinder Block" on page -142
Cylinder Bore	Roundness	0.0004 in. (0.01 mm) or less	0.0012 in. (0.03 mm)	
	Taper			

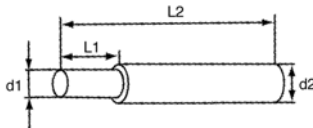
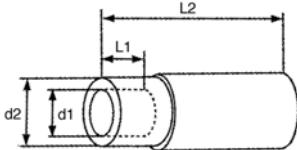
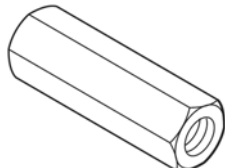
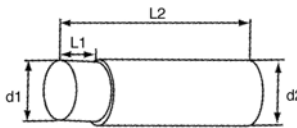
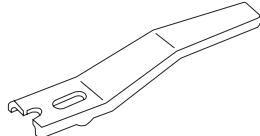
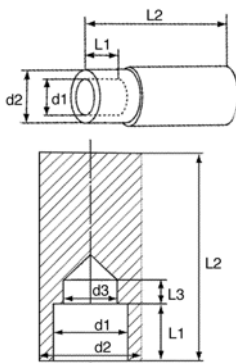
Special Torque Chart

Torque for Bolts and Nuts

Component	Thread Diameter and Pitch	Torque	Lubricating Oil Application (Thread Portion and Seat Surface)
Cylinder Head Bolt	M11 x 1.25 mm	76 - 83 ft•lb (103.1 - 112.9 N•m; 8.7 - 9.3 kgf•m)	Applied
Connecting Rod Bolt	M10 x 1.0 mm	40 - 43 ft•lb (53.9 - 58.8 N•m; 5.5 - 6.0 kgf•m)	Applied
Flywheel Bolt	M14 x 1.5 mm	137 - 152 ft•lb (186.2 - 205.8 N•m; 19 - 21 kgf•m)	Applied
Main Bearing Cap Bolt	M11 x 1.25 mm	80 - 87 ft•lb (108.1 - 117.9 N•m; 11.0 - 12.0 kgf•m)	Applied
Crankshaft Pulley Bolt	M14 x 1.5 mm	80 - 94 ft•lb (107.9 - 127.5 N•m; 11.0 - 13.0 kgf•m)	Applied
Fuel Injector Bolt	M8 x 1.25 mm	17 - 21 ft•lb (22.6 - 28.4 N•m; 2.3 - 2.9 kgf•m)	Not Applied
Fuel Pump Drive Gear Nut	M18 x 1.5 mm	83 - 90 ft•lb (113 - 123 N•m; 11.5 - 12.5 kgf•m)	Not Applied
High-Pressure Fuel Lines Bolt	M12 x 1.5 mm	174 - 217 ft•lb (19.6 - 24.5 N•m; 2.0 - 2.5 kgf•m)	Not Applied

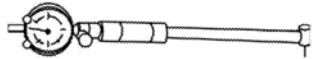
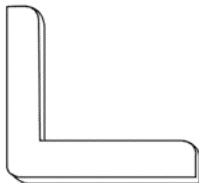
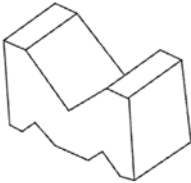
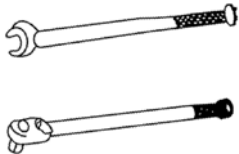
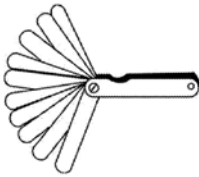
See "Tightening Torques for Standard Bolts and Nuts" on page -48

Special Service Tools

No.	Illustration	Tool name	Applicable model and tool size														
1	 FG008269	Valve Guide Tool (For Removing Valve Guide)	<table><tr><th>Model</th><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>4TNV98</td><td>0.787 in. (20 mm)</td><td>2.953 in. (75 mm)</td><td>0.256 in. (6.5 mm)</td><td>0.394 in. (10 mm)</td></tr></table> FG010215 *Locally manufactured	Model	L1	L2	d1	d2	4TNV98	0.787 in. (20 mm)	2.953 in. (75 mm)	0.256 in. (6.5 mm)	0.394 in. (10 mm)				
Model	L1	L2	d1	d2													
4TNV98	0.787 in. (20 mm)	2.953 in. (75 mm)	0.256 in. (6.5 mm)	0.394 in. (10 mm)													
2	 FG008270	Valve Guide Tool (For Installing Valve Guide)	<table><tr><th>Model</th><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>4TNV98</td><td>0.276 in. (7 mm)</td><td>2.362 in. (60 mm)</td><td>0.512 in. (13 mm)</td><td>0.630 in. (16 mm)</td></tr></table> FG010216	Model	L1	L2	d1	d2	4TNV98	0.276 in. (7 mm)	2.362 in. (60 mm)	0.512 in. (13 mm)	0.630 in. (16 mm)				
Model	L1	L2	d1	d2													
4TNV98	0.276 in. (7 mm)	2.362 in. (60 mm)	0.512 in. (13 mm)	0.630 in. (16 mm)													
3	 FG008871	Fuel Injector Removal Tool (2-Valve Head)	Part No. 129470-92305														
4	 FG008271	Connecting Rod Bushing Replacer (For Removal/ Installation of Connecting Rod Bushing)	<table><tr><th>Model</th><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>4TNV98</td><td>0.787 in. (20 mm)</td><td>3.937 in. (100 mm)</td><td>1.181 in. (30 mm)</td><td>1.299 in. (33 mm)</td></tr></table> FG010217	Model	L1	L2	d1	d2	4TNV98	0.787 in. (20 mm)	3.937 in. (100 mm)	1.181 in. (30 mm)	1.299 in. (33 mm)				
Model	L1	L2	d1	d2													
4TNV98	0.787 in. (20 mm)	3.937 in. (100 mm)	1.181 in. (30 mm)	1.299 in. (33 mm)													
5	 FG008872	Valve Spring Compressor (For Removal/ Installation of Valve Spring)	Part No. 129100-92630														
6	 FG008273	Installer (for Installing Valve Stem Seal)	<table><tr><th>Model</th><th>d1</th><th>d2</th><th>d3</th><th>L1</th><th>L2</th><th>L3</th></tr><tr><td>4TNV98</td><td>0.598 in. (15.2mm)</td><td>0.827 in. (21mm)</td><td>0.472 in. (12mm)</td><td>0.465 in. (11.8mm)</td><td>2.559 in. (65mm)</td><td>0.157 in. (4mm)</td></tr></table> FG010218 *Locally manufactured	Model	d1	d2	d3	L1	L2	L3	4TNV98	0.598 in. (15.2mm)	0.827 in. (21mm)	0.472 in. (12mm)	0.465 in. (11.8mm)	2.559 in. (65mm)	0.157 in. (4mm)
Model	d1	d2	d3	L1	L2	L3											
4TNV98	0.598 in. (15.2mm)	0.827 in. (21mm)	0.472 in. (12mm)	0.465 in. (11.8mm)	2.559 in. (65mm)	0.157 in. (4mm)											

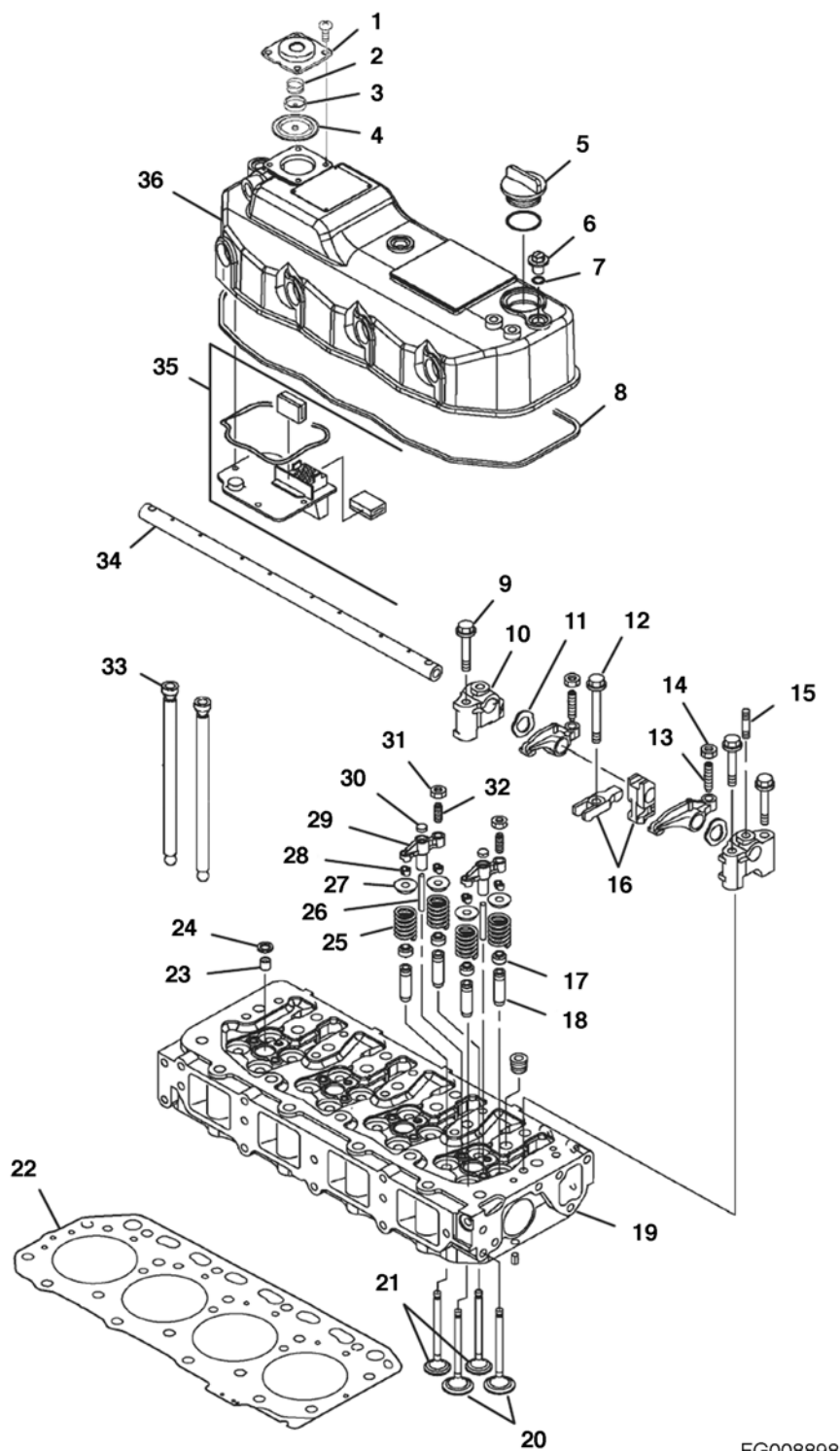
No.	Illustration	Tool name	Applicable model and tool size										
7	 FG008274	Filter Wrench (For Removal / Installation of Engine Oil Filter)	Available Locally										
8	 FG010220	Camshaft Bushing Tool (For Extracting Camshaft Bushing)	<table><tr><th>Model</th><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>4TNV98</td><td>0.709 in. (18 mm)</td><td>2.756 in. (70 mm)</td><td>1.968 in. (50 mm)</td><td>2.087 in. (53 mm)</td></tr></table> FG010228 *Locally manufactured	Model	L1	L2	d1	d2	4TNV98	0.709 in. (18 mm)	2.756 in. (70 mm)	1.968 in. (50 mm)	2.087 in. (53 mm)
Model	L1	L2	d1	d2									
4TNV98	0.709 in. (18 mm)	2.756 in. (70 mm)	1.968 in. (50 mm)	2.087 in. (53 mm)									
9	 FG008232	Flex-Hone (For Preparation of Cylinder Walls)	<table><tr><th>Model</th><th>Yanmar Part No.</th><th>Cylinder Bore</th></tr><tr><td>4TNV98</td><td>129400-92440</td><td>3.504 - 3.976 in. (89 - 101 mm)</td></tr></table> FG010229	Model	Yanmar Part No.	Cylinder Bore	4TNV98	129400-92440	3.504 - 3.976 in. (89 - 101 mm)				
Model	Yanmar Part No.	Cylinder Bore											
4TNV98	129400-92440	3.504 - 3.976 in. (89 - 101 mm)											
10	 FG008275	Piston Ring Compressor (For Installing Piston)	Part No. 95550-002476 The Piston Insertion Tool is Applicable for 2.362 - 4.921 in. (60 - 125 mm) Diameter Pistons										
11	 FG008276	Piston Ring Expander (For Removal / Installation of Piston Ring)	Available Locally										

No.	Illustration	Tool name		Applicable model and tool size
1	FG008277	Dial Indicator	Locally Available	Measure shaft bend and end play
2	FG008278	Test Indicator	Locally Available	Measurements of narrow or deep portions that cannot be measured by dial gauge
3	FG008279	Magnetic Stand	Locally Available	For holding the dial gauge when measuring
4	FG008280	Micrometer	Locally Available	For measuring the outside diameters of crankshaft, pistons, piston pins, etc.

No.	Illustration	Tool name		Applicable model and tool size
5	 FG008281	Cylinder Bore Gauge	Locally Available	For measuring the inside diameters of cylinder liners, bearing bores, etc.
6	 FG008282	Calipers	Locally Available	For measuring outside diameters, depth, thickness and width
7	 FG008283	Depth Micrometer	Locally Available	For measuring of valve recession
8	 FG008284	Square	Locally Available	For measuring valve spring inclination and straightness of parts
9	 FG008285	V-Block	Locally Available	For measuring shaft bend
10	 FG008286	Torque Wrench	Locally Available	For tightening nuts and bolts to the specified torque
11	 FG008287	Feeler Gauge	Locally Available	For measuring piston ring gaps, piston ring clearance, and valve adjustment clearance

4-valve Cylinder Head

4-Valve Cylinder Head Components



FG008898

Figure 121

Reference Number	Description
1	Crankcase Breather Cover
2	Diaphragm Spring
3	Diaphragm Cup
4	Crankcase Breather Diaphragm
5	Oil Fill Cap
6	Valve Cover Nut
7	Valve Cover Nut O-Ring
8	Valve Cover Gasket
9	Support Bolt
10	Rocker Arm Shaft Support
11	Wave Washer
12	Fuel Injector Retainer Bolt
13	Valve Adjusting Screw (Primary)
14	Valve Adjusting Screw Lock Nut (Primary)
15	Rocker Arm Shaft Aligning Stud
16	Fuel Injector Retainer
17	Valve Stem Seal
18	Valve Guide
19	Cylinder Head

Reference Number	Description
20	Intake Valve
21	Exhaust Valve
22	Cylinder Head Gasket
23	Fuel Injector Nozzle Protector
24	Fuel Injector Nozzle Seat
25	Valve Spring
26	Valve Bridge Guide
27	Spring Retainer
28	Valve Keepers
29	Valve Bridge
30	Valve Bridge Seat
31	Valve Adjusting Screw Lock Nut (Secondary)
32	Valve Adjusting Screw (Secondary)
33	Push Rod
34	Rocker Arm Shaft
35	Crankcase Breather Components
36	Valve Cover

Disassembly of 4-Valve Cylinder Head

Prepare a clean, flat working surface on a workbench large enough to accommodate the cylinder head assembly. Discard all gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of the cylinder head.

1. Drain the coolant from the engine into a suitable container. See "Adjust Intake / Exhaust Valve Clearance" on page -86



CAUTION

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

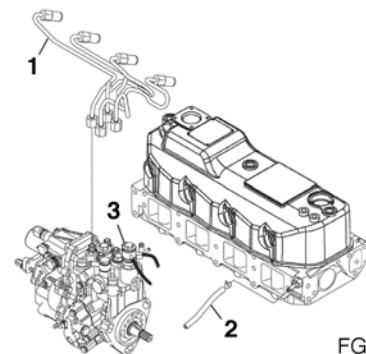
2. Remove the high pressure fuel injection lines (1, Figure 122). See "Removal of Fuel Injectors" on page -194



CAUTION

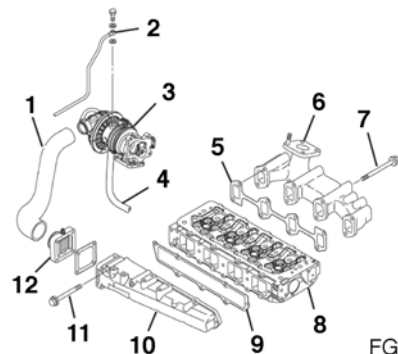
Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

3. Disconnect the fuel return hose (2, Figure 122) from the cylinder head.
4. Disconnect the hoses (3, Figure 122) from the cold start device on the fuel injection pump.
This cooling water pipe is not used in electronically controlled engines 4TNV98-E.
Instead, these engines use a solenoid valve and connecting coupler but, when removing the cylinder head only, it is not necessary to remove the connecting coupler.
5. Remove the turbocharger-to-intake manifold hose (1, Figure 123) (if equipped).
6. Disconnect the electrical wire from the intake air heater (12, Figure 123).
7. Remove the intake manifold bolts (11, Figure 123). Remove the intake manifold (10, Figure 123). Discard the intake manifold gasket (9, Figure 123).
8. Disconnect the turbocharger oil supply (2, Figure 123) and the return lines (4, Figure 123) (if equipped).
9. Remove the exhaust manifold bolts (7, Figure 123). Remove the exhaust manifold (6, Figure 123) with the turbocharger attached. Discard the exhaust manifold gasket. (5, Figure 123).



FG008899

Figure 122



FG008918

Figure 123

10. Remove the engine coolant pump. See "Disassembly of Engine Coolant Pump" on page -207

Removal of Valve Cover

NOTE: *The high pressure fuel injection lines and valve cover grommets must be removed prior to removing the valve cover. See "Removal of Fuel Injectors" on page -194*

1. Remove the high-pressure fuel lines.
2. Use a flat-blade screwdriver (Figure 124) to remove the fuel injection line grommets (1, Figure 125) from the valve cover (3, Figure 125) and fuel injectors (2, Figure 125). There is a notch at the 3 o'clock position in the valve cover opening to insert the screwdriver.
3. Remove the valve cover nuts (4, Figure 125).
4. Remove the O-ring (5, Figure 125) on each valve cover nut.
5. Remove the valve cover (3, Figure 125). Discard the valve cover gasket (6, Figure 125).
6. Inspect and clean the crankcase breather assembly. See "Inspect Crankcase Breather System" on page -88

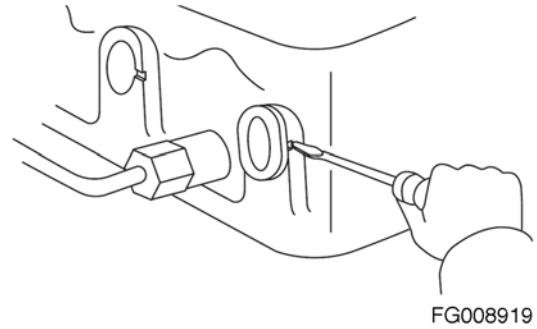


Figure 124

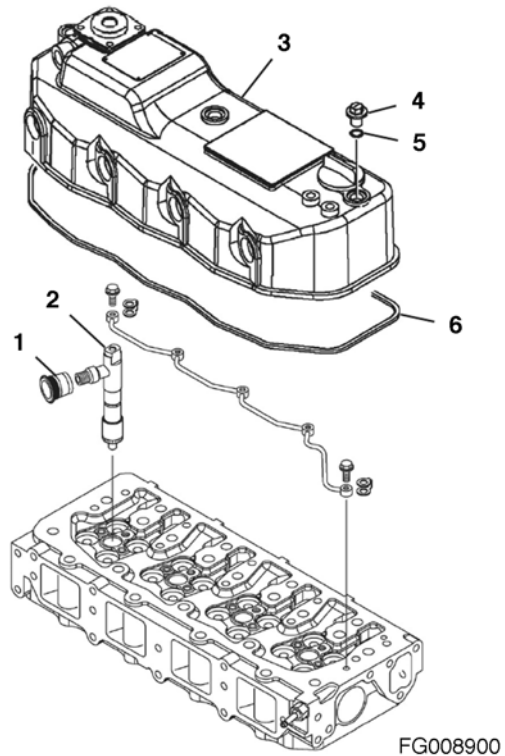


Figure 125

Removal of Rocker Arm Assembly

1. Remove the fuel injectors from the cylinder head. See "Removal of Fuel Injectors" on page -194
2. Remove the bolts (1, Figure 126) that retain the rocker arm shaft supports to the cylinder head.
3. Remove the rocker arm and shaft assembly from the cylinder head.

NOTE: *Identify the push rods and valve bridges so they can be installed in their original locations.*

4. Remove the push rods (2, Figure 126).
5. Remove the valve bridge assemblies (3, Figure 126). Remove the seat (4, Figure 126) from each valve bridge.
6. Identify all parts so that they will be reinstalled in their original locations.

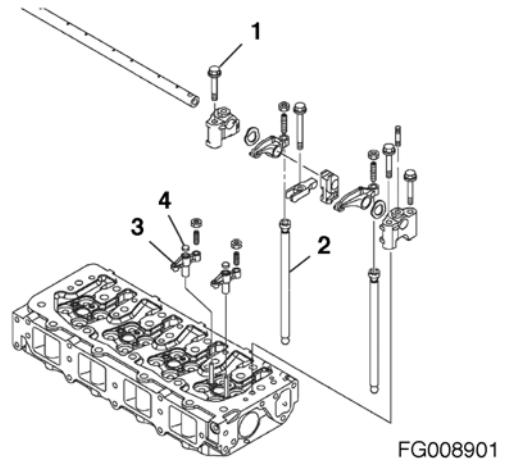


Figure 126

Disassembly of Rocker Arm Assembly

NOTE: *Identify the rock arm so they can be reinstalled with the original matching valve and pushrod.*

1. Remove the rocker arm shaft alignment studs (5, Figure 127) from the rocker arm shaft supports (6, Figure 127).
2. Slide the supports, wave washers (Figure 127, 7), rocker arms (8, Figure 127), and fuel injector retainers (4, Figure 127) off the rocker shaft (1, Figure 127), leaving these parts in order on the bench surface.

NOTE: *Figure 127 shows components for one cylinder. Components for all remaining cylinders are assembled in the same order.*

3. Remove the valve adjusting screw (2, Figure 127) and the lock nut (3, Figure 127) from the rocker arms.

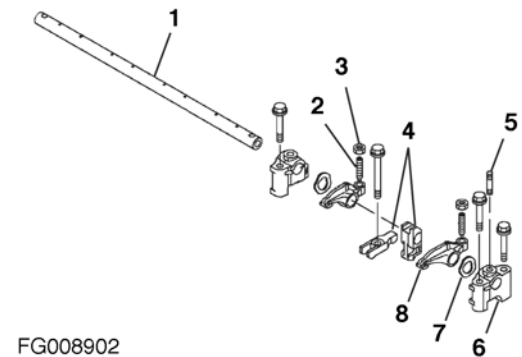


Figure 127

Removal of Cylinder Head

1. Loosen the cylinder head bolts following the sequence shown in Figure 128.

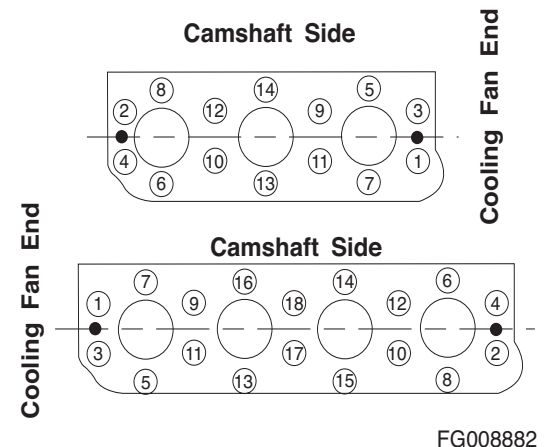
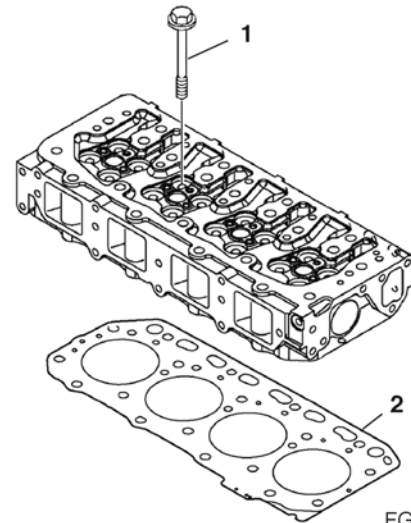


Figure 128

2. Remove the cylinder head bolts (1, Figure 129)
3. Lift the cylinder head away from the cylinder block. Discard the cylinder head gasket (2, Figure 129). Place the cylinder head on the work bench to prevent damage to the combustion surface.

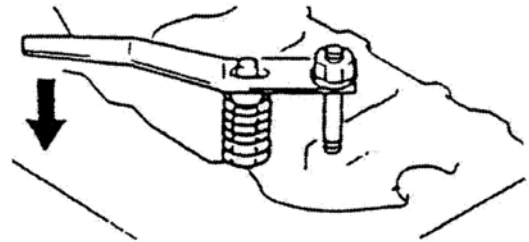


FG008904

Figure 129

Removal of Intake and Exhaust Valves

1. Place the cylinder head on the work bench with the combustion side down.
2. Using the valve spring compressor tool, compress one of the valve springs (Figure 130).



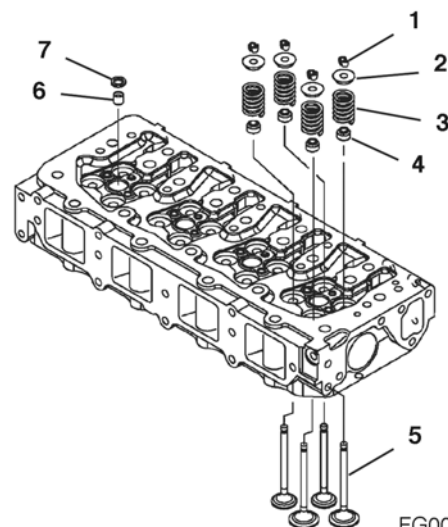
FG008306

Figure 130

3. Remove the valve keepers (1, Figure 131).
4. Slowly release the tension on the valve spring.
5. Remove the spring retainer (2, Figure 131), valve spring (3, Figure 131).
6. Repeat the procedure with all the remaining valves.

NOTE: *If the valves are to be reused, identify them so they can be installed in their original location.*

7. Remove the injector nozzle protectors (6, Figure 131) and the seats (7, Figure 131).
8. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves (5, Figure 131) from the cylinder head.
9. Remove the valve stem seals (4, Figure 131).



FG008905

Figure 131

Removal of Valve Guides

Note: Removal of the valve guides should be postponed until inspection and measurement procedures have been performed. See "Inspection of Valve Guides" on page -114

1. Using a drift pin and hammer, drive the valve guides (1, Figure 132) out of the cylinder head.

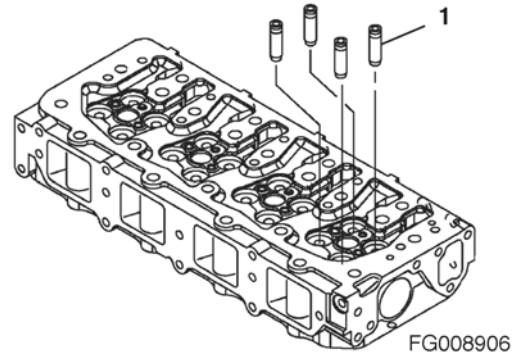


Figure 132

Cleaning of Cylinder Head Components



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

Thoroughly clean all components using a non-metallic brush and an appropriate solvent. Each part must be free of carbon, metal filings and other debris.



Figure 133

Inspection of Cylinder Head Components

Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted or otherwise damaged. Discard any parts that do not meet its specified limit.



CAUTION

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.



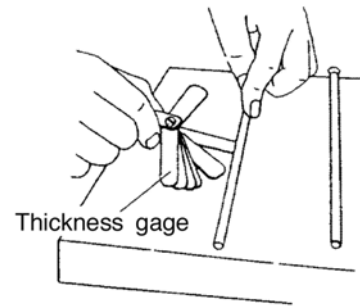
CAUTION

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

Inspection of Push Rods

Push Rod Bend

1. Place the push rods on a flat inspection block or layout bed.
2. Roll the push rods until a gap can be observed between a portion of the push rod and the surface of the block or layout bed.
3. Use a feeler gauge to measure the gap (Figure 134). See "Push Rod" on page -96 for the service limit.



FG008319

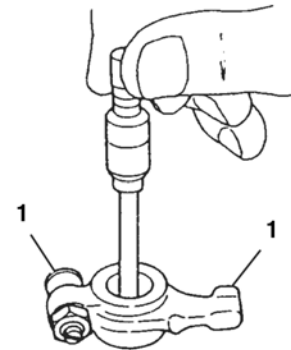
Figure 134

Inspection of Rocker Arm Assembly

Rocker Arm Shaft Hole Diameter

Use a telescoping gauge and micrometer to determine if the inside diameter of all the rocker arm support brackets and the rocker arms (Figure 135) are within the specified limits. See "Rocker Arm and Shaft" on page -96 for the service limit.

Inspect the contact areas (1, Figure 135) for excessive wear or damage.

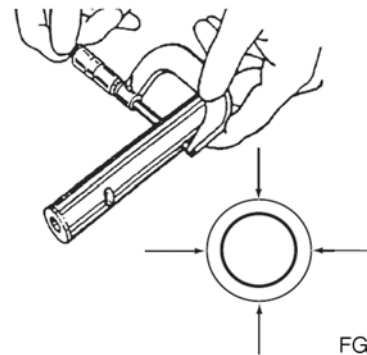


FG008886

Figure 135

Rocker Arm Shaft Outside Diameter

Use a micrometer to measure the rocker arm shaft diameter (Figure 136). Measure at each rocker arm location in two directions 90° apart (Figure 136). See "Rocker Arm and Shaft" on page -96 for the service limit.



FG008887

Figure 136

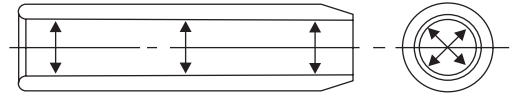
Inspection of Valve Guides

Valve Guide Inside Diameter

Visually inspect the valve guides for distortions, scoring or other damage.

NOTE: *Measure the valve guides while they are installed in cylinder head.*

Use a telescoping gauge and micrometer to measure the inside diameter at each end of the valve guide. Measure in three places and 90° apart (Figure 137). See "Intake / Exhaust Valve and Guide" on page -95 for the service limit. Replace the valve guides if not within specification.



FG008888

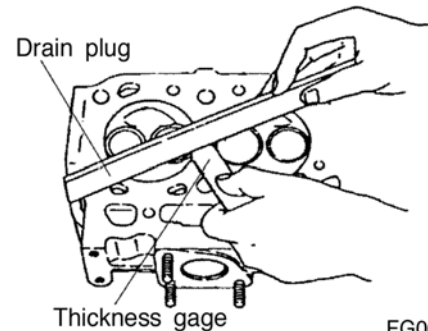
Figure 137

Inspection of Cylinder Head

Cylinder Head Distortion

Place the cylinder head flat and inverted (combustion side up) on the bench. Use a straight edge and feeler gauge to measure cylinder head distortion (Figure 138). Measure diagonally and along each side. See "Cylinder Head" on page -95 for the service limit.

If distortion exceeds the service limit, resurface or replace the cylinder head. Remove only enough material to make the cylinder head flat, but do not remove more than 0.008 in (0.20 mm).



FG008307

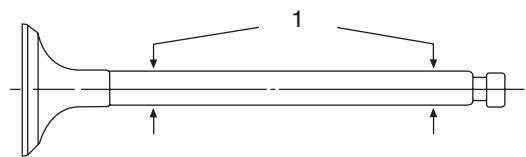
Figure 138

Inspection of Intake and Exhaust Valves

Visually inspect the intake and exhaust valves. Replace any valves that are obviously discolored, heavily pitted or otherwise damaged.

Valve Stem Diameter

Use a micrometer to measure the valve stem diameter. Measure the valve stem near the combustion end and near the opposite end (1, Figure 139). See "Intake / Exhaust Valve and Guide" on page -95 for the service limit.



FG008889

Figure 139

Valve Stem Bend

Place the valve stem on a flat inspection block or layout bed. Roll the valve until a gap can be observed between a portion of the valve stem and the surface of the block or bed. Use a feeler gauge to measure the gap (Figure 140). See "Intake / Exhaust Valve and Guide" on page -95 for the service limit.

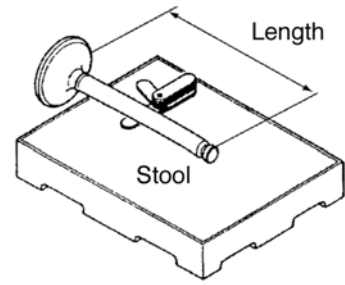


Figure 140

FG008314

Valve Recession

NOTE: *The valve guides must be installed to perform this check.*

Insert the valves into their original locations and press them down until they are fully seated. Use a depth micrometer (Figure 141) to measure the difference between the cylinder head gasket surface and the combustion surface of each exhaust and intake valve (Figure 142). See "Cylinder Head" on page -95 for the service limit.

NOTE: *2-Valve cylinder head is shown. 4-Valve cylinder head is similar.*

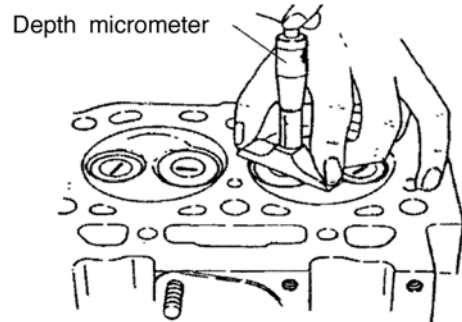


Figure 141

FG008308

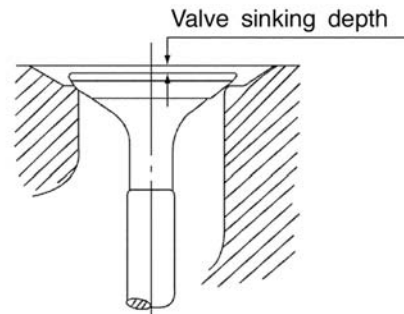


Figure 142

FG008309

Valve Face and Valve Seat

Always check the clearance between the valve and valve guide before grinding or lapping the valve seats. See "Intake / Exhaust Valve and Guide" on page -95 for the service limit. If the clearance exceeds the limit, replace the valve and/or valve guide to bring the clearance within the limit.

Roughness or burrs will cause poor seating of a valve. Visually inspect the seating surfaces of each valve and valve seat to determine if lapping or grinding is needed.

Visually inspect all valves faces and valve seats for pitting, distortion, cracking, or evidence of overheating. Usually the valves and valve seats can be lapped or ground to return them to serviceable condition. Severely worn or damaged components will require replacement.

Coat the valve seat with a thin coat of bluing compound. Install the valve and rotate to distribute bluing onto the valve face. The contact pattern should be approximately centered on the valve face (1, Figure 143) and even in width.

Also visually inspect the valve seat for even contact.

Light cutting can be performed by the use of a hand-operated cutter (Figure 144).

Valve seat diameter can be adjusted by top-grinding with a 150° stone to make the seat diameter smaller, and bottom-grinding using a 40° stone to make the seat diameter larger. Once the seat location has been corrected, grind and lap the seat angle (1, Figure 144) to specification. See "Cylinder Head" on page -95 for specifications.

Grind the valve face and/or valve seat as necessary to return them to serviceable condition. Grinding is needed if the valve and valve seat do not contact correctly. Check the valve margin and valve recession after grinding.

If the valve or seat require grinding, lap the valve after grinding. Lap the valve face to the valve seat using a mixture of valve lapping compound and engine oil.

Be sure to thoroughly wash all parts to remove all grinding powder or compound.

Inspection of Valve Springs

Inspect the valve springs. If damage or corrosion is seen, or if measurements exceed the specified limits, replace the springs.

Fractures

Check for fractures on the inside and outside portions of the springs. If the valve spring is fractured, replace the valve spring.

Corrosion

Check for corrosion of spring material caused by oxidation.

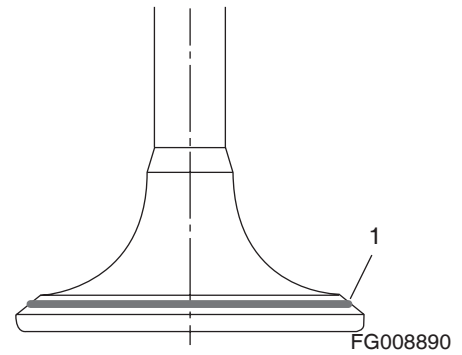


Figure 143

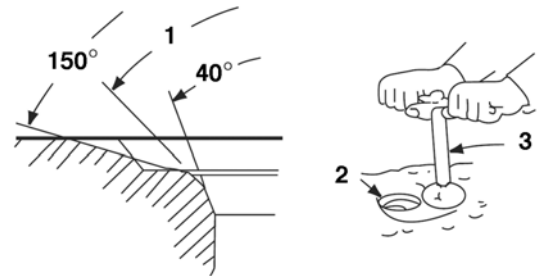
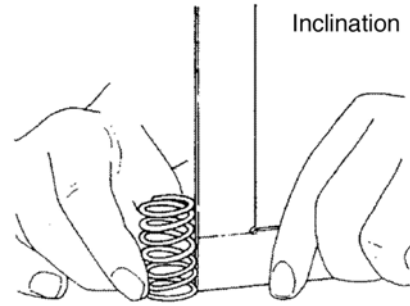


Figure 144

Squareness

Use a flat surface and a square to check each spring for squareness (Figure 145). See "Valve Spring" on page -96 for the service limit.

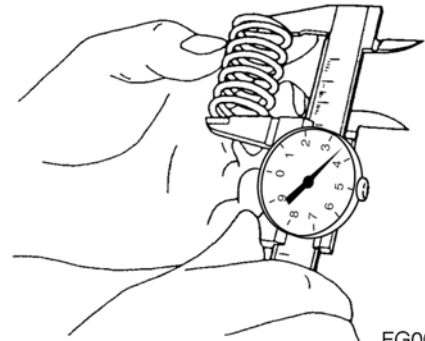


FG008316

Figure 145

Free Length

Use a caliper to measure the length of the spring (Figure 146). See "Valve Spring" on page -96 for the service limit.



FG008892

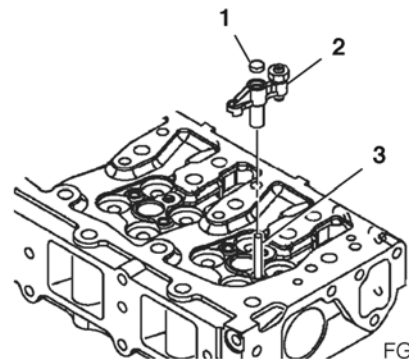
Figure 146

Inspection of Valve Bridges

Visually inspect the contact surface at both ends of the valve bridge (2, Figure 147) for excessive wear or mushrooming.

Remove and inspect the seat (1, Figure 147).

Measure the diameter of the valve bridge guide pin bore in the valve bridge and guide pin (3, Figure 147). See "Rocker Arm and Shaft" on page -96 for the service limit.



FG008907

Figure 147

Reassembly of Cylinder Head

Use new gaskets, O-rings, and seals on reassembly of the cylinder head.



IMPORTANT

Liberally oil all components during reassembly to prevent premature wear or damage.

Reassembly of Valve Guides

1. The valve guides are installed into the cylinder head with an extremely tight press fit. Before installing the valve guides, place the valve guides in a freezer for at least twenty minutes. This will cause the valve guides to contract, making it easier to install the valve guides into place.
2. Immediately after removing the valve guides from the freezer, insert the valve guides (1, Figure 148) in their proper positions.

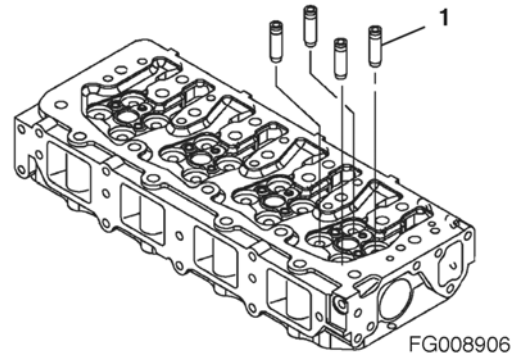


Figure 148

3. Finish installing the valve guides (1, Figure 149) into the cylinder head to the proper height (3, Figure 149) using the valve guide installation tool (2, Figure 149). See "Intake / Exhaust Valve and Guide" on page -95

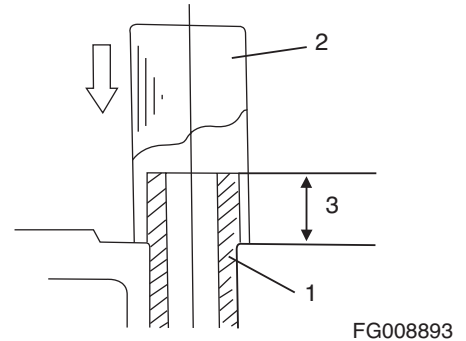


Figure 149

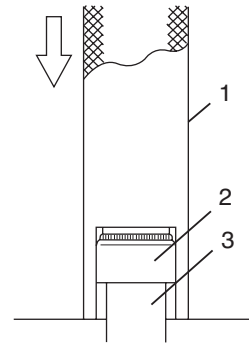
Reassembly of Intake and Exhaust Valves



IMPORTANT

Always install new valve stem seals. The exhaust valve seals can be identified by having yellow paint. Ensure they are installed in the correct locations.

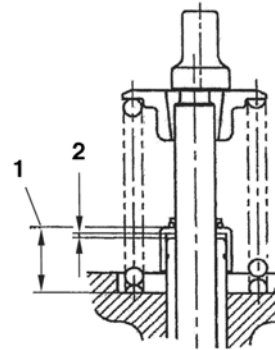
1. Oil the lip of the valve stem seal (2, Figure 150). Using the valve stem seal installation tool (1, Figure 150), install a new valve stem seal on each of the valve guides (3, Figure 150).



FG008894

Figure 150

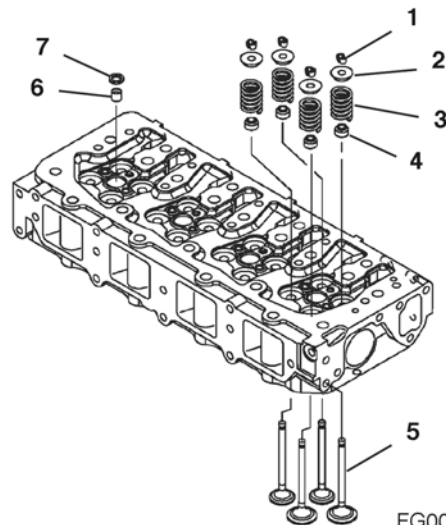
2. Measure the distance (1, Figure 151) from the cylinder head to the valve stem seal to ensure proper clearance (2, Figure 151) between the guide and seal. See "Intake / Exhaust Valve and Guide" on page -95
3. Place the cylinder head assembly on its exhaust port side.



FG008895

Figure 151

4. Place all the valves (5, Figure 152) in their proper location in the cylinder head.
5. Place the cylinder head on the workbench with the combustion side down. Install the valve spring (3, Figure 152) and spring retainer (2, Figure 152).
6. Using the valve spring compressor tool, compress the valve spring.
7. Insert the valve keepers (1, Figure 152) and slowly release the tension in the valve spring. Repeat the steps on all the remaining valves.



FG008905

Figure 152

Reassembly of Cylinder Head

1. Carefully clean both the combustion surface of the cylinder head and the top surface of the cylinder block. Then place a new cylinder head gasket (2, Figure 153) on the cylinder block.
2. Position the cylinder head on the on the cylinder head gasket.

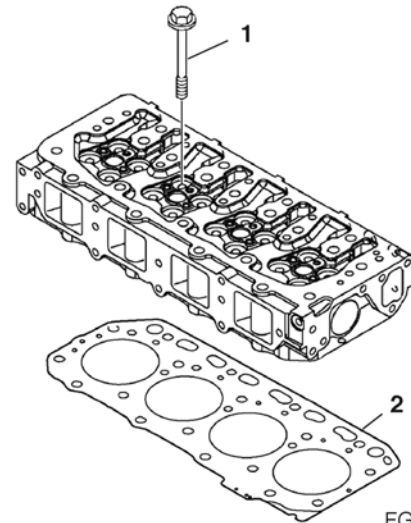


Figure 153

3. Lightly oil the threads of the cylinder head bolts (1, Figure 153). Tighten the bolts to the specified torque in two steps as shown in the chart below. Tighten in the sequence shown in (Figure 154). See "Special Torque Chart" on page -101 for specification.

First Step	1/2 of final torque
Second Step	Final torque

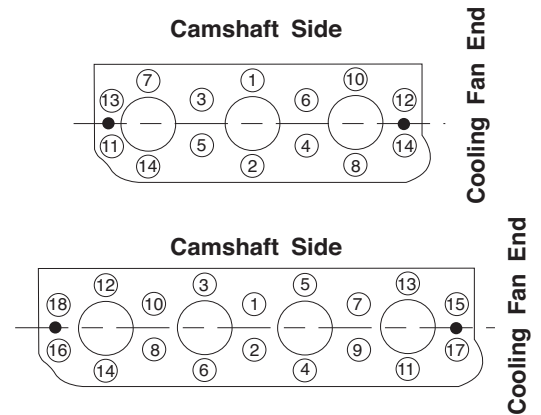


Figure 154

Reassembly of Rocker Arm Assembly

1. Reinstall the valve bridges (3, Figure 155) in their original locations and ensure each seat (4, Figure 155) is in place.
2. Insert the push rods (2, Figure 155) in their original locations.

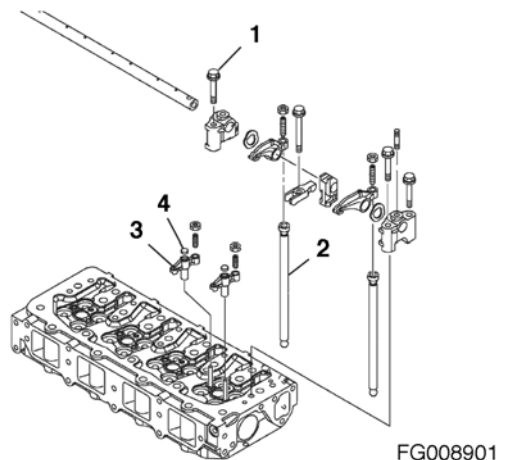


Figure 155



IMPORTANT

The wave washers (2, Figure 156) must be installed with the bow facing the rocker arms (1, Figure 156).

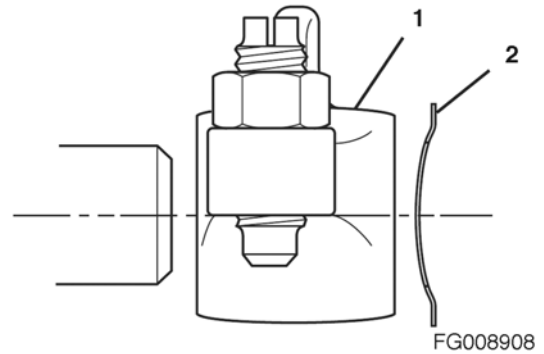


Figure 156



IMPORTANT

Ensure the lubrication holes (1, Figure 157) in the rocker arm shaft are oriented correctly with respect to the rocker arms (2, Figure 157).

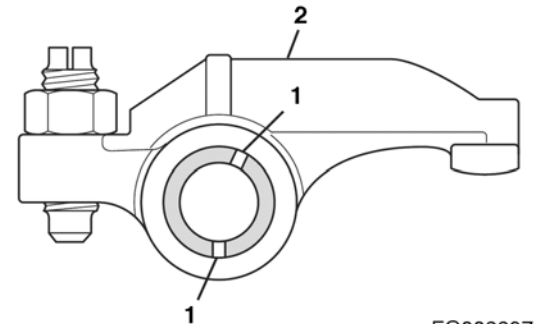


Figure 157

3. Lubricate the rocker arm shaft. Slide the rocker arm supports (6, Figure 158), wave washers (7, Figure 158), rocker arms (8, Figure 158), and fuel injector retainers (4, Figure 158) onto the shaft.

NOTE: *To properly align the rocker arm shaft with the rocker arm shaft supports, first reinstall one of the end rocker arm supports (6, Figure 158) with a hole for the shaft alignment stud (5, Figure 158). Align the hole in the rocker arm shaft and the hole in the rocker arm support bracket. Reinstall the alignment stud.*

NOTE: *Figure 158 shows components for one cylinder. Components for all remaining cylinders are assembled in the same order.*

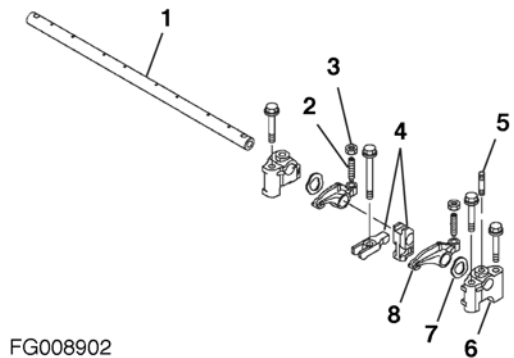


Figure 158

4. Position the rocker arm assembly on a flat surface. Reinstall the alignment studs (5, Figure 158).
5. Place the rocker arm shaft assembly onto the cylinder head.
6. If removed, reinstall the valve adjusting screws (2, Figure 158) and lock nuts (3, Figure 158).
7. Align the push rods with their respective rocker arms.
8. Reinstall and tighten the rocker arm shaft retaining bolts to the specified torque.
9. Tighten the rocker arm shaft alignment studs.
10. Adjust the valve clearance.
11. Reinstall the fuel injectors. See "Installation of the Fuel Injectors" on page -199

Reassembly of the Valve Cover

1. Lightly grease a new valve cover gasket (6, Figure 159). Place the gasket in the groove of the valve cover (3, Figure 159).
2. Place the valve cover on the cylinder head.
3. Be sure new O-rings (5, Figure 159) are installed on the valve cover nuts. Reinstall and tighten the valve cover nuts (4, Figure 159).
4. Reinstall the fuel injector grommets (1, Figure 159).
5. Reinstall the exhaust manifold using a new gasket. Tighten the bolts to specification.
6. Reinstall the intake manifold using a new gasket. Tighten the bolts to specification.
7. Reconnect the fuel injector return hose and fuel injection pump coolant hoses.
8. Reinstall the high-pressure fuel line grommets into the valve cover.
9. Reinstall the high pressure and fuel return lines. See "Installation of the Fuel Injectors" on page -199
10. Reinstall the coolant pump. Reassembly of Engine Coolant Pump.
11. Reinstall the alternator. See "Installation of Alternator" on page -251
12. Reconnect the turbocharger oil supply and drain lines.
13. Reconnect the air intake hose.

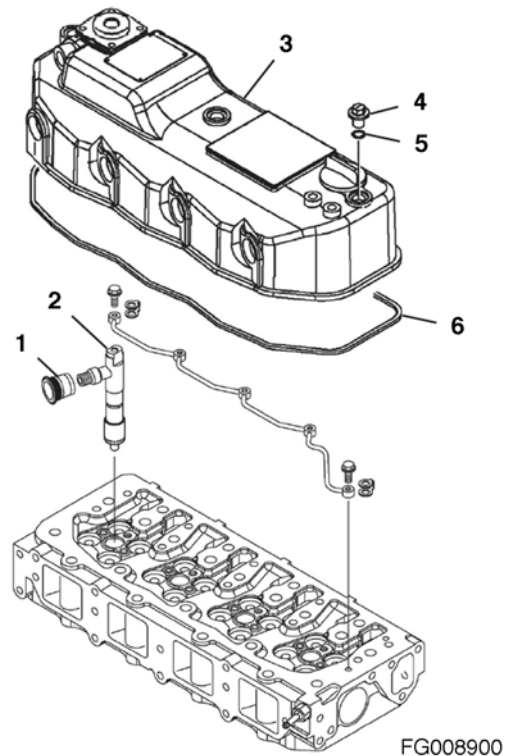


Figure 159

FG008900

Measuring and Adjusting Valve Clearance

Measure and adjust while the engine is cold.

NOTE: *The No. 1 piston position is on the flywheel end of the engine, opposite the radiator. The firing order is 1-3-2 for 3-cylinder engines and 1-3-4-2 for 4-cylinder engines.*

3-cylinder engines fire every 240° of crankshaft rotation.

4-cylinder engines fire every 180° of crankshaft rotation.

Valve clearance of both the intake and exhaust valves can be checked with the piston for that cylinder at top dead center (TDC) of the compression stroke. When a piston is at TDC of the compression stroke, both rocker arms will be loose and the cylinder TDC mark on the flywheel will be visible in the timing port of the flywheel housing.

If there is no valve clearance, and the cylinder is at TDC of the compression stroke, extreme wear, or damage to the cylinder head or valves may be possible.

If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the top deadcenter after turning. Make adjustment for the remaining cylinders in the order of firing by turning the crankshaft each time.

To decrease the number of rotations required to check all cylinders, other cylinders can also be checked as indicated in the chart below.

Example: On a 3-cylinder engine, with the No. 1 piston at TDC on the compression stroke (both valves closed), the valves indicated on the top line of the chart can be adjusted without rotating the crankshaft. To adjust the remaining two valves, rotate the crankshaft until the No. 1 piston is at TDC on the exhaust stroke (exhaust valve only open).

3-Cylinder Engines

Cylinder No.	1		2		3	
Valve	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
No. 1 Cylinder at TDC Compression	o	o	o			o
No. 1 Cylinder at TDC Exhaust				o	o	

4-Cylinder Engines

Cylinder No.	1		2		3		4	
Valve	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
No. 1 Cylinder at TDC Compression	o	o	o			o		
No. 4 Cylinder at TDC Compression				o	o		o	o

4-Valve Cylinder Heads

The 4-valve cylinder head operates two valves with a single rocker arm by employing a valve bridge (1, Figure 160) between the two valves (2, Figure 160). Clearance (4, Figure 160) between the valve bridge and valves must be set before adjusting the clearance (5, Figure 160) between the rocker arm (3, Figure 160) and valve bridge.

1. Remove the valve cover. See "Removal of Valve Cover" on page -109

NOTE: *If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the top dead center after turning, and make adjustment for other cylinders in the order of firing by turning the crankshaft 180° each time.*

2. Rotate the crankshaft clockwise as seen from the coolant pump end, to bring No. 1 piston to TDC on the compression stroke while watching the rocker arm motion and the timing grid on the flywheel. (Position where both the intake and exhaust valves are closed.)
3. Make sure there is clearance (5, Figure 160) between the valve bridge (1, Figure 160) and the rocker arm (3, Figure 160).

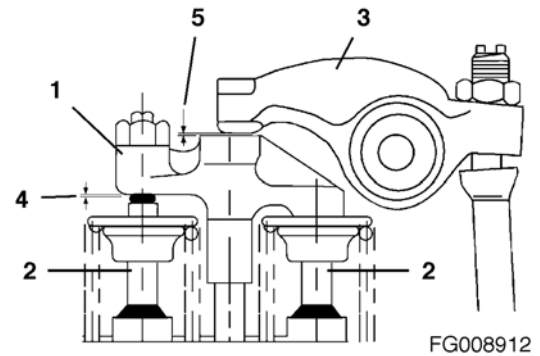


Figure 160



IMPORTANT

Do not loosen or tighten the valve adjusting screw lock nut without holding the valve bridge. Always hold the valve bridge using a wrench to prevent bending of the valve stems.

4. Loosen the valve bridge adjusting screw lock nut (1, Figure 161) while holding the bridge (3, Figure 161) with a wrench (2, Figure 161).

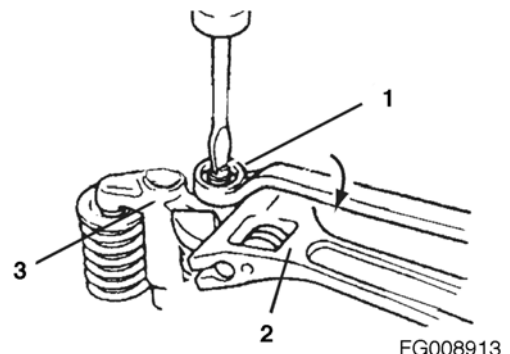


Figure 161

5. To assure the valve bridge contacts the rear valve, apply light, downward (4, Figure 162) finger pressure on the valve bridge (3, Figure 162), and loosen the valve bridge adjusting screw (1, Figure 162), until there is visible clearance (2, Figure 164) between the adjusting screw and the front valve.
6. To assure the valve bridge has equal contact with the front and rear valves, apply light downward (4, Figure 162) pressure on the valve bridge (3, Figure 162), adjust the valve bridge adjusting screw ((1, Figure 162), (1, Figure 164)) so there is zero "0" clearance (2, Figure 164) between the adjusting screw and the front valve.
7. Tighten the lock nut (1, Figure 163), while holding the valve bridge (3, Figure 163) with a wrench (2, Figure 163). Verify that the valve clearance (2, Figure 164) is zero "0".

NOTE: *Note: There is a tendency for the clearance to decrease slightly when the lock nut is tightened. It is suggested that you make the initial clearance adjustment is made slightly on the "loose" side before tightening the lock nut.*

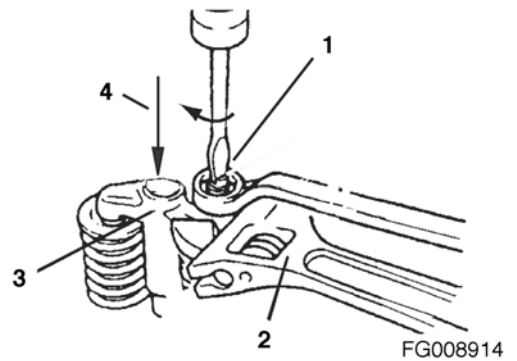


Figure 162

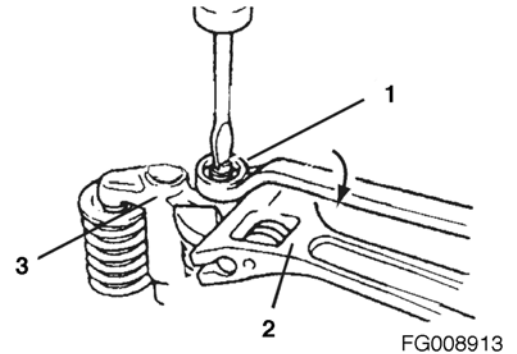


Figure 163

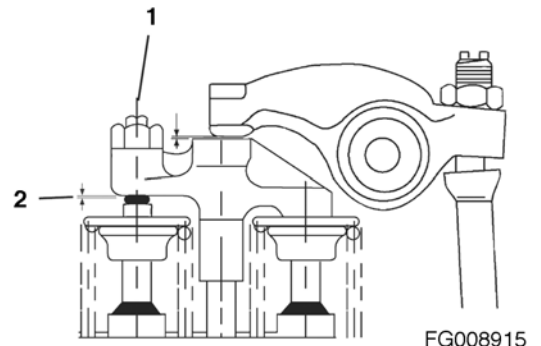


Figure 164

8. To adjust the actual valve clearance between the rocker arm and the valve bridge, insert a feeler gauge (1, Figure 165) of the correct thickness (See "Adjustment Specifications" on page -95) between the rocker arm (2, Figure 165) and valve bridge (3, Figure 165). Record the results and use this value as an indication of wear.
9. If adjustment is required, proceed to the next step.

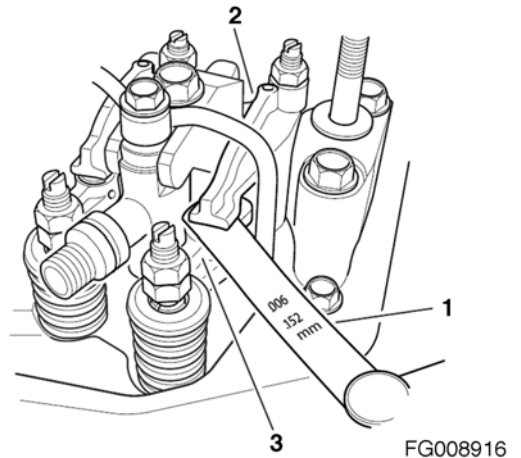


Figure 165

10. Loosen the valve adjusting screw lock nut (5, Figure 166) and valve adjusting screw (4, Figure 166) on the rocker arm (3, Figure 166) and check the clearance gap (2, Figure 166) for evidence of dirt or wear.

NOTE: *There is a tendency for the clearance to decrease slightly when the lock nut is tightened. It is suggested that you make the clearance adjustment is made slightly on the "loose" side before tightening the lock nut.*

11. Adjust the valve clearance (2, Figure 166) by turning the adjusting screw (4, Figure 166) until there is a slight "drag" on the feeler gauge when sliding it between the rocker arm and the valve bridge.
12. Hold the adjusting screw (4, Figure 166) while tightening the valve adjusting screw lock nut (5, Figure 166). Recheck the clearance.
13. Apply oil to the contact surface between the adjusting screw and push rod.
14. Rotate the crankshaft to measure and adjust the set of valves. Continue until all valves are measured and adjusted.

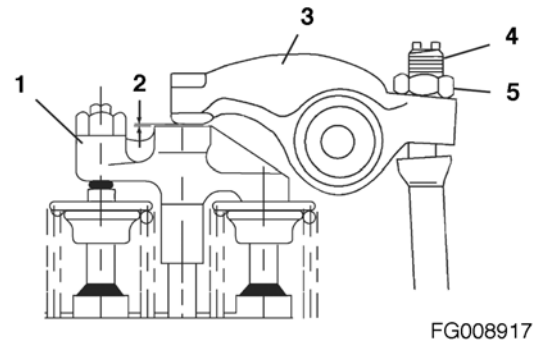
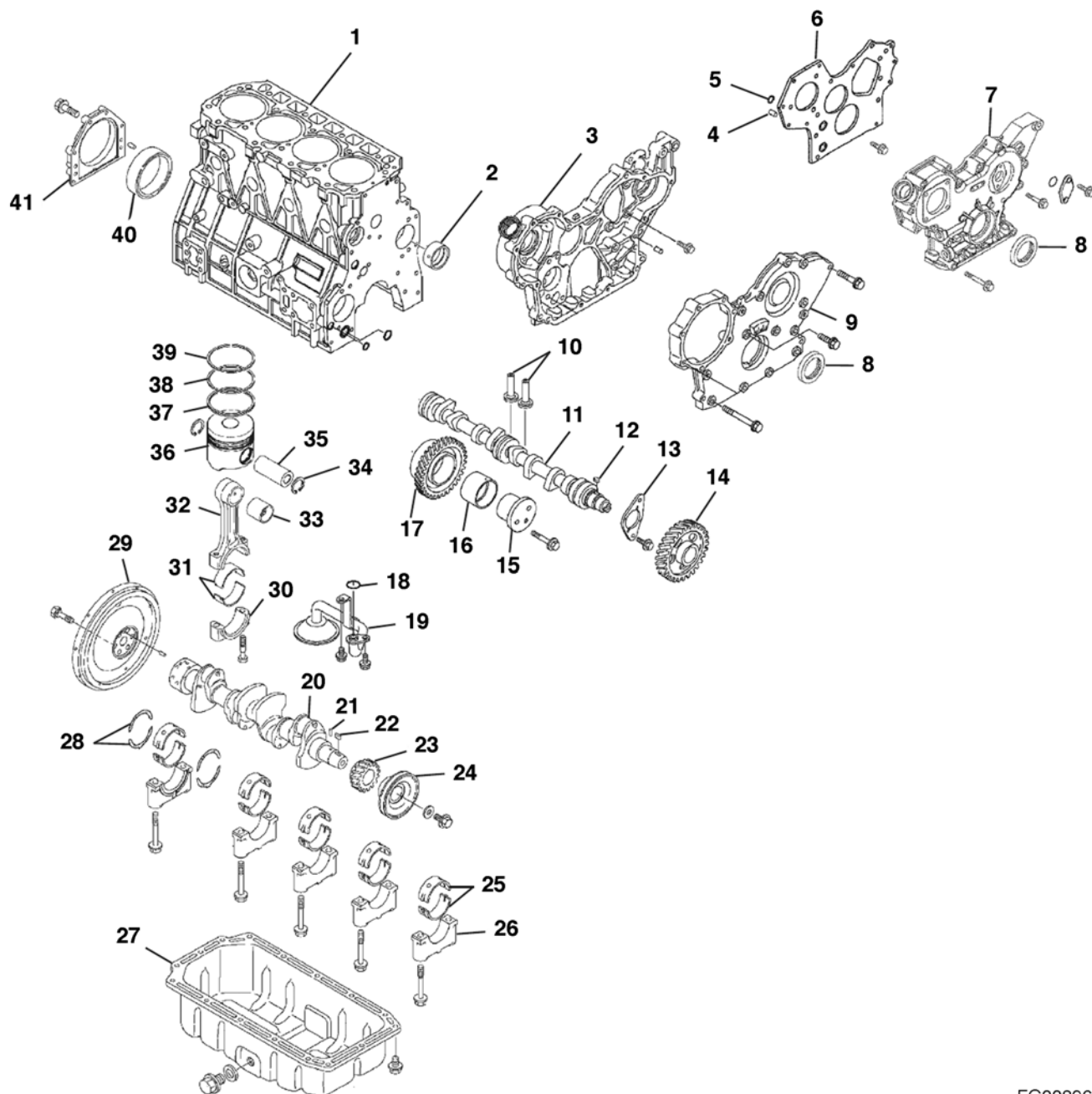


Figure 166

Crankshaft and Camshaft Components



FG008966

Figure 167

Reference Number	Description
1	Cylinder Block
2	Camshaft Bushing
3	Gear Case (4TNV98-E)
4	Dowel (2 used)
5	O-Ring
6	Front Plate (4TNV98-E)
7	Gear Case Cover (4TNV98-E)
8	Front Crankshaft Seal
9	Gear Case Cover (4TNV98-E)
10	Tappets
11	Camshaft
12	Camshaft Gear Key
13	Camshaft End Plate
14	Camshaft Gear
15	Idler Gear Shaft
16	Idler Gear Bushing
17	Idler Gear
18	Oil Pickup O-Ring
19	Oil Pickup
20	Crankshaft
21	Parallel Pin

Reference Number	Description
22	Crankshaft Gear Key
23	Crankshaft Gear
24	Crankshaft Pulley
25	Main Bearing Inserts
26	Main Bearing Cap
27	Oil Pan
28	Thrust Bearings
29	Flywheel
30	Connecting Rod Cap
31	Connecting Rod Bearing Inserts
32	Connecting Rod
33	Wrist Pin Bushing
34	Circlip
35	Wrist Pin
36	Piston
37	Oil Ring
38	Second Compression Ring
39	Top Compression Ring
40	Crankshaft Rear Seal
41	Crankshaft Rear Seal Housing

Disassembly of Engine

Prepare a clean, flat working surface on a workbench large enough to accommodate the engine components. Discard all used gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of engine.



CAUTION

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

If the engine will be completely disassembled, the following preliminary steps should be performed:

1. Disconnect the battery cables at the battery. Always disconnect the negative (-) cable first.
2. Remove the throttle cable, electrical connections, intake and exhaust system connections, and fuel supply lines from the engine.
3. Remove the alternator. See "Removal of Alternator" on page -246
4. Drain the engine coolant from the radiator and cylinder block. See "Adjust Intake / Exhaust Valve Clearance" on page -86 Remove the cooling system components from the engine.
5. Remove the engine from the machine. Mount the engine to a suitable engine repair stand having adequate weight capacity.



CAUTION

Be sure to secure the engine solidly to prevent injury or damage to parts due to the engine falling during work on the engine.

6. Clean the engine by washing with solvent, air or steam cleaning. Carefully operate so as to prevent any foreign matter or fluids from entering the engine or any fuel system or electrical components remaining on the engine.
7. Drain the engine oil into a suitable container. Remove the oil filter.
8. Remove the cylinder head. See page -106.
9. Remove the fuel injection pump from the gear case / front plate only if it must be sent out for repair, or will interfere with other procedures such as "hot tank" cleaning. If the fuel injection pump does not need to be repaired, leaving it mounted to the timing gear case or plate will eliminate the need to re-time it during reassembly. See "Fuel Injection Pump" on page -180
10. Remove the starter motor. See "Starter Motor" on page -223

Disassembly of Camshaft and Timing Components

Discard all gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of the camshaft and timing components.

Removal of Timing Gear Case Cover

1. Remove the bolt and washer retaining the crankshaft pulley.



IMPORTANT

Use care not to damage the threads in the end of the crankshaft when removing the crankshaft pulley.

2. Remove the crankshaft pulley using a gear puller.
3. Remove the bolts that retain the gear case cover to the cylinder block and oil pan.
4. Remove the gear case cover (1, Figure 168).

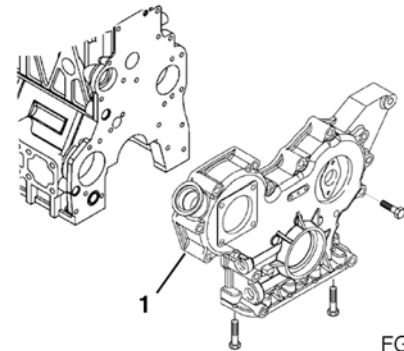


Figure 168

FG008911

Checking Timing Gear Backlash

Prior to removing the timing gears, measure the gear backlash and determine the gear wear.

Check the backlash between each pair of mating gears (Figure 169). If not within specification, replace both mating gears. See "Timing Gear Backlash" on page -97 for service limits.

NOTE: Do not allow the gear being checked to move axially as excess end play could cause a false reading.

Reference Number	Description
1	Fuel Injection Pump Drive Gear
2	Camshaft Drive Gear
3	Auxiliary Drive Gear (Optional)
4	Crankshaft Drive Gear
5	Direction of Rotation
6	Oil Pump Drive Gear
7	Idler Gear

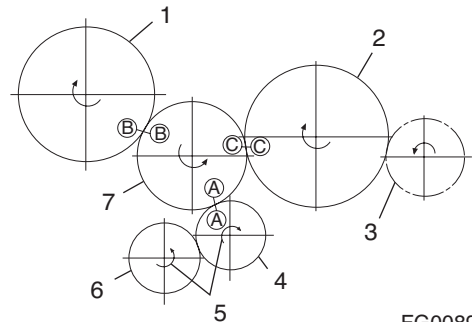


Figure 169

FG008920

Measuring Idler Gear-to-Crankshaft Gear Backlash

1. Install a dial indicator as shown in Figure 170.
2. Rotate the idler gear back and forth to check the idler gear-to-crankshaft gear backlash. The total indicator reading is the backlash. Record the measurement.

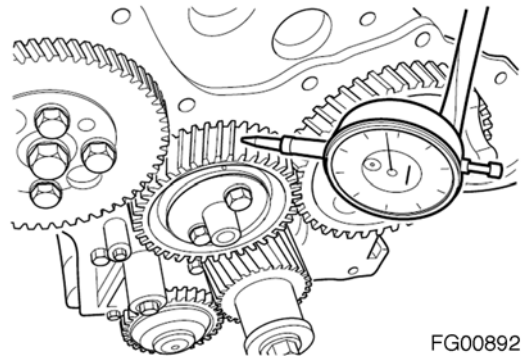


Figure 170

Measuring Idler Gear-to-Camshaft Gear Backlash

1. Drive a small wooden wedge between the crankshaft gear and idler gear to prevent the idler gear from rotating.
2. Install the dial indicator to read the camshaft gear backlash. Rotate the camshaft drive gear against the idler gear to measure the backlash. Record the measurement.
3. Check the idler gear-to-fuel injection pump drive gear backlash in the same manner as the camshaft drive gear. Record the measurement.

Removal of Timing Gears

1. Remove the bolts from the idler gear shaft (1, Figure 171). Remove the idler gear shaft, idler gear (2, Figure 171) and bushing (3, Figure 171).
2. Do not remove the crankshaft gear unless it is damaged and requires replacement. If the gear must be removed, remove it using a gear puller.
3. Removal of the camshaft gear requires the camshaft be removed and placed in a press. Do not remove the camshaft gear unless it or the camshaft is damaged and requires replacement. See "Removal of Camshaft" on page -134

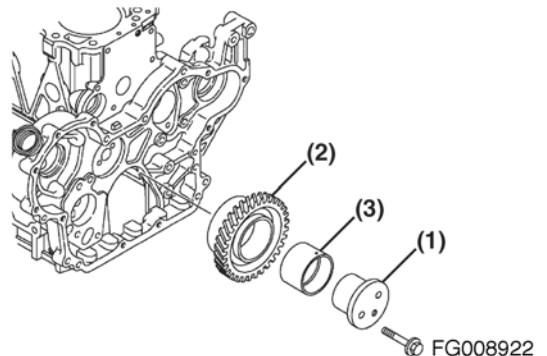


Figure 171



CAUTION

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub. Correct fuel injection timing will be very difficult or impossible to achieve.

4. Do not remove the fuel injection pump drive gear unless absolutely necessary to avoid damage to the gear or pump. Do not loosen or remove the four bolts (3, Figure 172) retaining the pump drive gear to the hub. Only remove the nut (1, Figure 172) and washer (2, Figure 172), leaving the hub attached to the gear. Remove the pump drive gear and hub as an assembly using a gear puller.

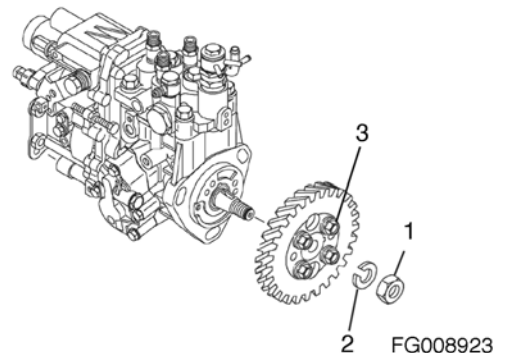
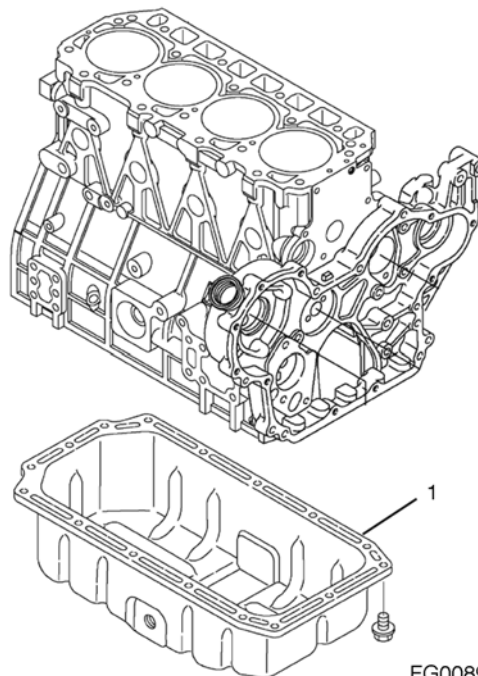


Figure 172

Removal of Oil Pan

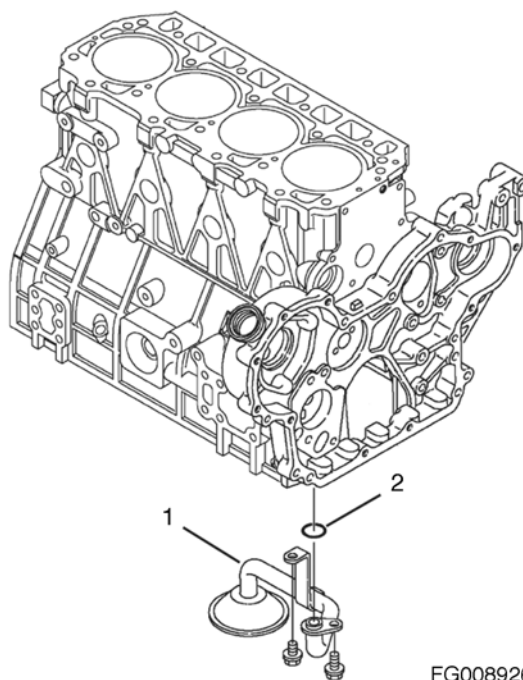
1. Invert the engine (oil pan up) on the engine stand.
2. Remove the oil pan (1, Figure 173).



FG008924

Figure 173

3. Remove the oil pickup tube (1, Figure 174) and O-ring (2, Figure 174).



FG008926

Figure 174

Removal of Camshaft

1. Before removing the camshaft, check the camshaft end play.

- Method A: Install a dial indicator (1, Figure 175) on the cylinder block. Move the camshaft (2, Figure 175) back and forth to measure the end play. Record the measurement. See "Camshaft" on page -97 for the service limit.

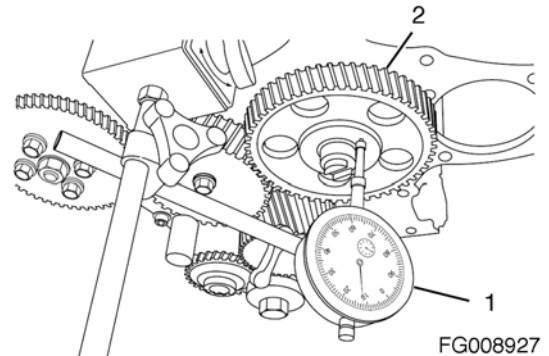


Figure 175

- Method B: Use a feeler gauge to measure the clearance between the thrust plate (1, Figure 176) and front camshaft bearing (2, Figure 176). See "Thrust Bearing" on page -98 for the service limit.

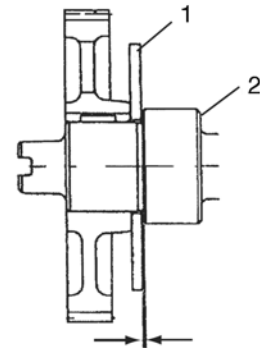


Figure 176

2. Remove the two bolts (3, Figure 177) retaining the camshaft thrust plate (1, Figure 177).
3. Rotate the engine in the engine stand so that gravity causes the tappets (5, Figure 177) to drop away from the camshaft lobes.

NOTE: Rotate the camshaft at least two turns to "bump" any sticking tappets away from the camshaft.

4. Slowly pull the camshaft (2, Figure 177) assembly out of the engine being careful not to damage the front camshaft bushing.

NOTE: If the engine is not installed on an engine repair fixture, stand the engine upright on the flywheel end mounting flange. Rotate the camshaft at least two turns to bump the tappets out of the way to prevent the tappets from interfering with the removal of the camshaft.

NOTE: The tappets are "mushroom" shaped and must be removed from inside the engine crankcase.

5. Remove the tappets. Mark the tappets so they can be reinstalled in the same location.
6. Remove the camshaft drive gear (4, Figure 177) only if the gear or camshaft require replacement. Use a knife-edge puller and a press to remove the gear. The gear is a shrink-fit and will need to be heated to 356° - 392°F (180° - 200°C) to remove.

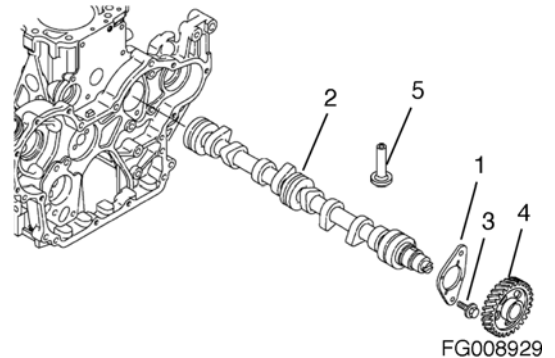


Figure 177

Removal of Gear Case or Front Plate

Note: The camshaft must be removed before the gear case / front plate can be removed. See "Inspection of Camshaft" on page -146

1. Remove the oil pump.

NOTE: *It is not necessary to remove the fuel injection pump from the gear case / front plate to remove the gear case / front plate. If the fuel injection pump does not need to be repaired, leaving it mounted to the timing gear case / front plate will eliminate the need to re-time it during assembly. See "Fuel Injection Pump" on page -180*

2. Remove the bolts (4, Figure 178).
3. Remove the gear case (1, Figure 178) or front plate from the cylinder block. Thoroughly clean all old sealant from the mating surfaces.
4. Inspect and measure the camshaft bushing. See "Camshaft" on page -97 for the service limit. If damaged or worn beyond service limits, remove the camshaft bushing (3, Figure 178).
5. Remove two O-rings (2, Figure 178).

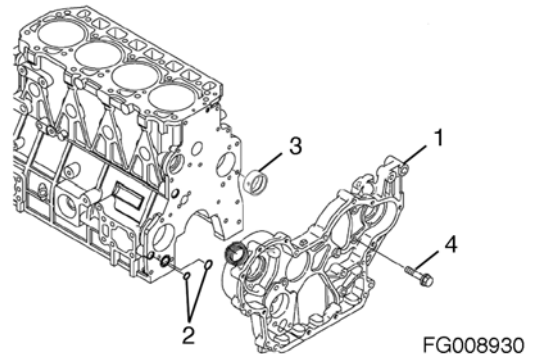


Figure 178

Disassembly of Crankshaft and Piston Components

Removal of Pistons



CAUTION

Keep the piston pin parts, piston assemblies, and connecting rod assemblies together to be returned to the same position during the reassembly process. Label the parts using an appropriate method.

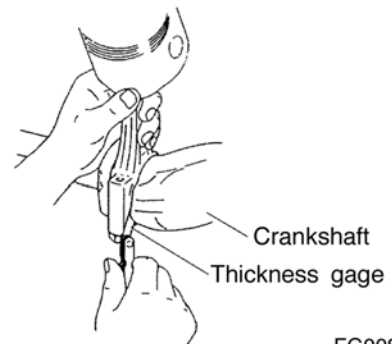


IMPORTANT

Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing the pistons.

NOTE: *Pistons can fall from cylinder block if the engine is inverted. Rotate the engine so the connecting rods are horizontal before removing the connecting rod caps.*

1. Using a feeler gauge, measure the connecting rod side clearance as shown (Figure 179). See "Connecting Rod Big End" on page -99 for the standard limit. If the measurement is out of specification, replace the crankshaft, connecting rod, or both.
2. Measure bearing oil clearance prior to removing the pistons and connecting rods to determine extent of wear. Record the measurements.



FG008336

Figure 179



IMPORTANT

Mark the connecting rod caps and connecting rods so the caps and connecting rods stay together.

- A. Remove the bearing cap. Do not remove the bearing inserts at this time.
- B. Wipe oil from the bearing insert and crankshaft journal surfaces.

- C. Place a piece of PLASTIGAGE (1, Figure 180) along the full width of the bearing insert.



IMPORTANT

Do not rotate the crankshaft when using PLASTIGAGE. A false reading may result.

- D. Reinstall bearing cap and tighten to specification. See "Torque for Bolts and Nuts" on page -101
- E. Remove bearing cap.
- F. Compare the width of the flattened PLASTIGAGE to the graduation marks on the package (Figure 181, 1). The mark that most closely matches the width of the flattened PLASTIGAGE will indicate the bearing oil clearance.
- G. Repeat with remaining connecting rods.



IMPORTANT

Do not allow the connecting rod to contact the crankshaft journal during piston removal. Damage to the bearing journal may result.

3. Use a wooden dowel against the connecting rod and tap the piston / connecting rod assembly out of the cylinder.
4. Mark the cylinder number on the piston and connecting rod.

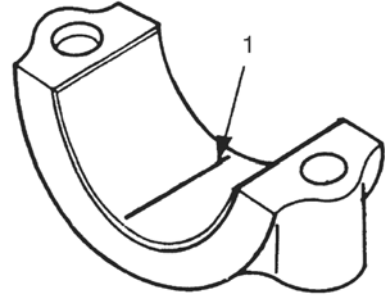


Figure 180

FG008932

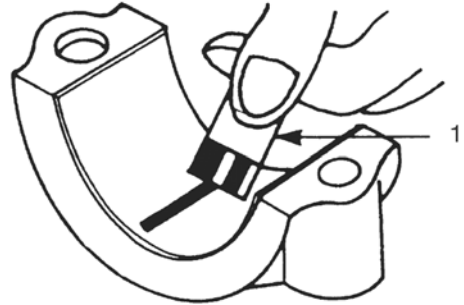
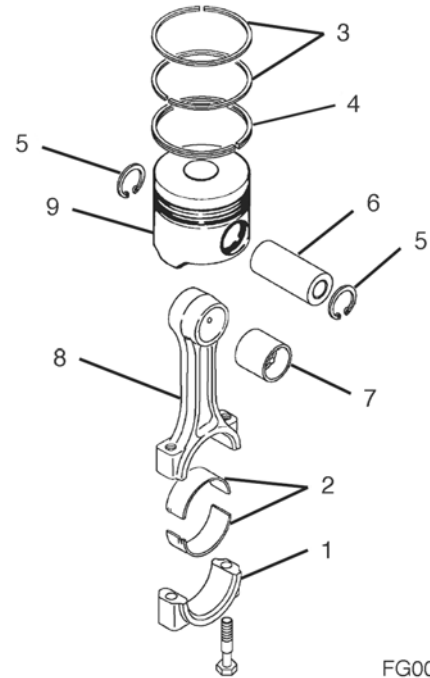


Figure 181

FG008933

5. Remove the bearing inserts (2, Figure 182).
6. Remove the compression rings (3, Figure 182) from the piston using a piston ring expander.
7. Remove the oil ring (4, Figure 182) from the piston using a piston ring expander.
8. Remove the circlips (5, Figure 182) from the wrist pin.
9. Remove the wrist pin (6, Figure 182) and connecting rod (8, Figure 182) from the piston (9, Figure 182).
10. Repeat the steps until all pistons are removed and disassembled.

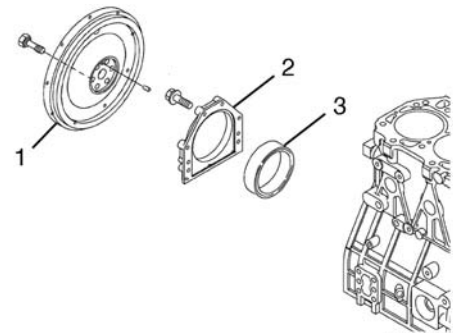


FG008934

Figure 182

Removal of Crankshaft

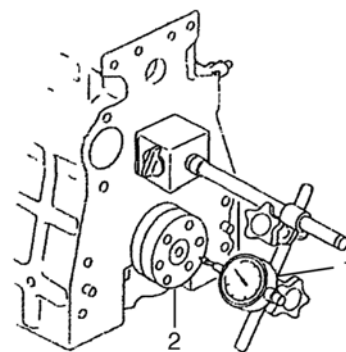
1. Remove the flywheel (1, Figure 183) from the crankshaft.
2. Remove the bolts from the rear oil seal assembly (2, 3, Figure 183). Remove the assembly from the engine.
3. Before removing the main bearing caps, measure the crankshaft end play. Use either of the following two methods.



FG008935

Figure 183

- Method A: Install a dial gauge (1, Figure 184) on the cylinder block. Move the crankshaft (2, Figure 184) in and out to measure the end play. Record the measurement.



FG008936

Figure 184

- Method B: Use a feeler gauge to measure the clearance (3, Figure 185) between the thrust bearing (1, Figure 185) and crankshaft (2, Figure 185). Record the measurement. See "Thrust Bearing" on page -98 for the service limit.

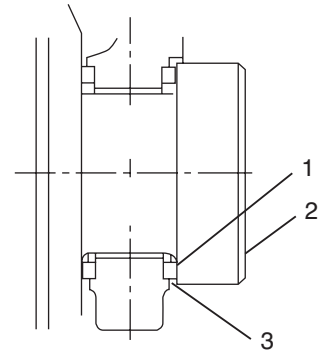


Figure 185

FG008937

4. Remove the main bearing caps (3, Figure 186). Be sure to note the markings on the main bearing caps, or mark them yourself, so they can be reinstalled in the same order as they were removed. Do not remove the bearing inserts at this time.

NOTE: The "arrows" on the main bearing caps point to the flywheel end of the engine.

5. Measure bearing oil clearance prior to removing the crankshaft to determine extent of wear. Record the measurements.
 - A. Wipe oil from the bearing insert and crankshaft journal surfaces.

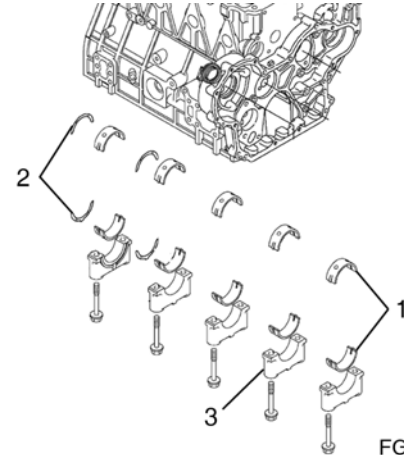


Figure 186

FG008938

- B. Place a piece of PLASTIGAGE (1, Figure 187) along the full width of each bearing insert.



IMPORTANT

Do not rotate the crankshaft when using PLASTIGAGE. A false reading may result.

- C. Reinstall bearing caps and tighten to specification. See "Special Torque Chart" on page -101
 - D. Remove bearing caps.
 - E. Compare the width of the flattened PLASTIGAGE to the graduation marks on the package (1, Figure 188). The mark that most closely matches the width of the flattened PLASTIGAGE will indicate the bearing oil clearance.
6. Remove the crankshaft from the engine.
 7. Remove the bearing inserts (1, Figure 186) and thrust bearings (2, Figure 186).

NOTE: Do not remove the crankshaft gear unless the gear or crankshaft are damaged and require replacement.

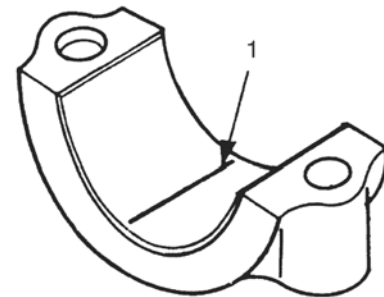


Figure 187

FG008932

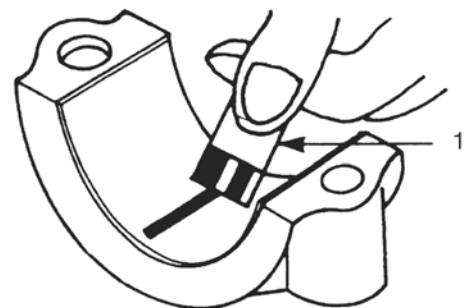
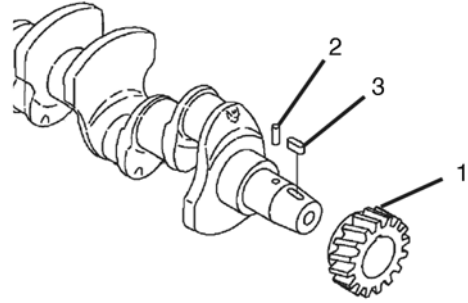


Figure 188

FG008933

8. If necessary, remove the crankshaft gear (1, Figure 189), parallel pin (2, Figure 189) and key (3, Figure 189). If using a gear puller, be careful not to damage the threads in the end of the crankshaft.



FG008939

Figure 189

Inspection of Crankshaft and Camshaft Components



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.

Thoroughly clean all components using a brush and appropriate solvent. Each part must be free of carbon, gasket material, metal filings and other debris.

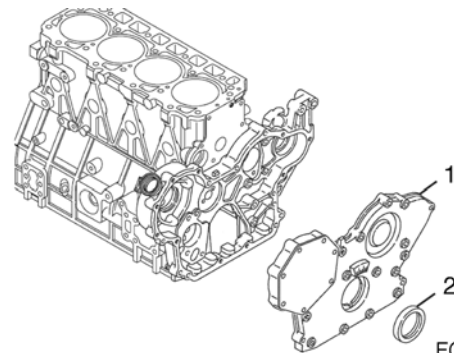


FG009153

Figure 190

Replacement of Crankshaft Oil Seals

1. Remove the seal (2, Figure 191) from the cover (1, Figure 191).
2. Apply a continuous bead of ThreeBond Liquid Gasket to the outside diameter of a new oil seal (2, Figure 191), and install in the gear case cover. Apply lithium grease to the lip of the seal.



FG008940

Figure 191

3. Remove the rear oil seal (3, Figure 192) from the seal housing (2, Figure 192).
4. Apply a continuous bead of ThreeBond Liquid Gasket to the outside diameter of a new oil seal (2, Figure 192), and install in the housing. Apply lithium grease to the lip of the seal.

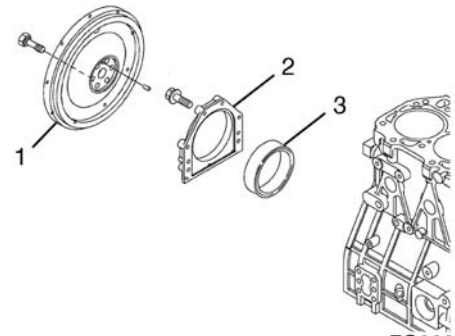


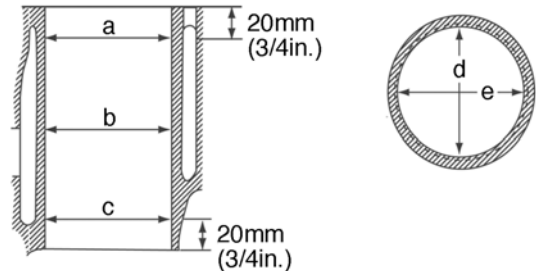
Figure 192

Measure Crankshaft Bearing Oil Clearance

Oil clearance should be checked during disassembly to determine the extent of wear, and during assembly to ensure long engine life. The same procedure is done for both connecting rods and main bearings.

Inspection of Cylinder Block

1. Ensure that oil passages are clear and unobstructed.
2. Check for discoloration or evidence of cracks. If a fracture is suspected, use the color check method or the Magnaflux method to determine if the cylinder block is fractured.
3. Inspect cylinders for roundness, taper, or evidence of scoring. Collect and record the measurements. Consider honing, reboring or replacing the cylinder block if the measurements are not within specification.
 - Take measurements at three places (Figure 193) (a, b, c), and in two directions (d and e) in each cylinder.



FG008941

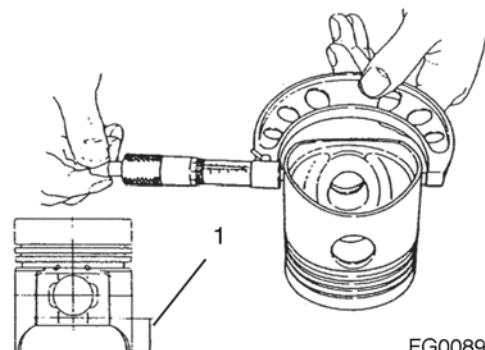
Figure 193

Inspection of Pistons, Piston Rings and Wrist Pin

NOTE: *On an engine with low hours, the pistons, piston rings may be reused if they are found to be within specifications. The pistons and piston rings must be reinstalled in the same cylinders from which they were originally removed.*

On an engine with high hours, the pistons rings should be replaced and the cylinder honed (See "Honing and Boring" on page -147) or replaced. The piston should be replaced as necessary.

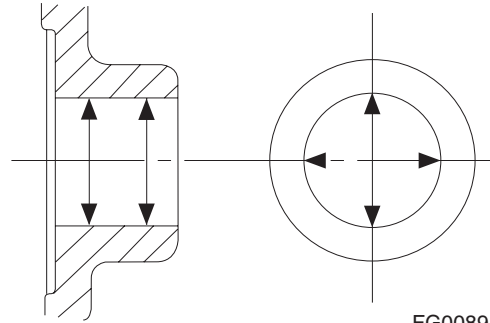
1. Clean piston ring grooves using a piston ring groove cleaning tool. Follow manufacturer's instructions for correct operation.
2. Wash the pistons in an appropriate solvent using a soft brush.
3. Visually inspect each piston for cracks. Pay particular attention to the ring lands between the piston ring grooves.
4. Measure the diameter of the piston skirt at 90° to the wrist pin bore as shown (Figure 194). Measurements must be taken at a specified distance (1, Figure 194) from the bottom of the piston, based on engine model. Record the measurements. See "Piston" on page -98 for specifications.
5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection (See "Inspection of Cylinder Block" on page -142) to obtain piston-to-cylinder clearance. Record the measurements. See "Piston" on page -98 for specifications.



FG008942

Figure 194

6. Measure the diameter of the wrist pin bore on both sides of the piston (Figure 195). See "Piston" on page -98 for specifications. Record the measurements.

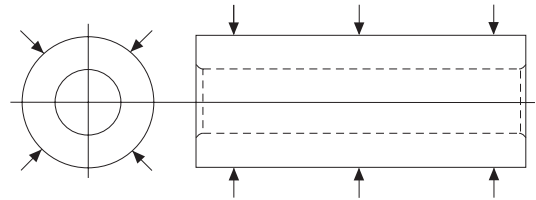


FG008944

Figure 195

7. Measure the outside diameter of the wrist pin in three places and at 90° (Figure 196). See "Piston" on page -98 for specifications. Record the measurements.
8. Using a micrometer, measure the thickness of each piston ring. See "Piston Ring" on page -99 for specifications. Record the measurements.

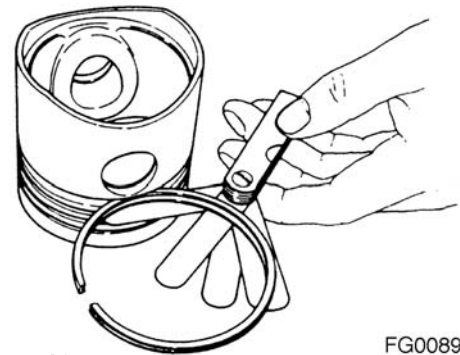
NOTE: *On an engine with low hours, the pistons, piston rings and cylinders may be reused if they are found to be within specifications.*
On an engine with high hours, the pistons rings should be replaced and the cylinder honed (See "Honing and Boring" on page -147) or replaced.
The piston should be replaced as necessary.



FG008945

Figure 196

9. Place each compression piston ring in the groove as shown (Figure 197). Use a feeler gauge to measure the clearance between the piston ring and the piston ring land. Record the measurements. See "Piston Ring" on page -99 for specifications. Replace the piston if not within specification.

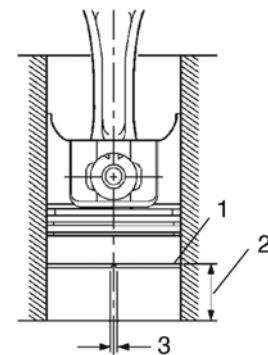


FG008946

Figure 197

10. To measure piston ring end gap, insert each compression piston ring (1, Figure 198), one at a time, into the cylinder. Use a piston with the piston rings removed to slide the ring into the cylinder bore until it is approximately 1.18 in. (30 mm) (2, Figure 198) from the bottom of the bore. Remove the piston. Measure the end gap (3, Figure 198) of each piston ring. Record the measurements. See "Piston Ring" on page -99 for specifications.

NOTE: *Always check the piston ring end gap when installing new piston rings. See "Piston Ring" on page -99 for specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.*



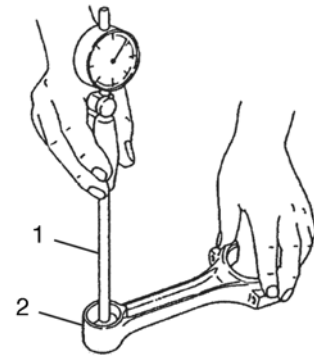
FG008947

Figure 198

11. Repeat the above steps for each cylinder and piston assembly.

Inspection of Connecting Rod

1. Measure the wrist pin bushing bore using a bore gauge (1, Figure 199). Replace the bushing if not within specifications. If the bushing has been removed, measure the inside diameter of the connecting rod small end (2, Figure 199). See "Connecting Rod" on page -99 for specifications.
2. Place the connecting rod bearing inserts into the connecting rod and connecting rod cap. Install the rod cap and tighten the bolts to the specified torque.
3. Measure the inside diameter. See "Crankshaft" on page -98 for specifications.

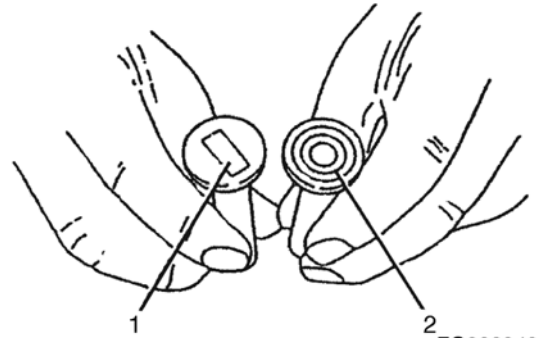


FG008948

Figure 199

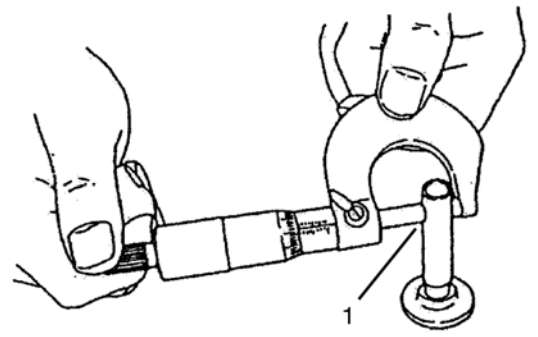
Inspection of Tappets

1. Inspect the tappet contact surfaces for abnormal wear (1, Figure 200). Normal wear will be even as shown in (2, Figure 200). Slight surface defects can be corrected using an oilstone.
2. Measure the outside diameter of the tappet stem (1, Figure 200). See "Tappet" on page -100 for the service limit.
3. Measure the tappet bores in the cylinder block. See "Tappet" on page -100 for the service limit.



FG008949

Figure 200



FG008950

Figure 201

Inspection of Crankshaft

1. Place the crankshaft end journals (4, Figure 202) on V-blocks.
2. Place a dial indicator (3, Figure 202) on a center main bearing surface.
3. Rotate the crankshaft and observe runout. See "Crankshaft" on page -98 for specifications.
4. Use the color check method or Magnaflux to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found.

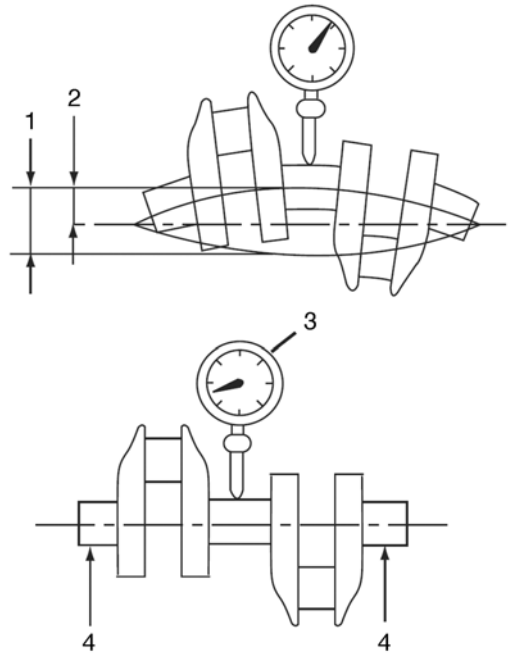


Figure 202

FG008951

5. Measure the outside diameter of each crankpin (2, Figure 203) and main bearing journal (1, Figure 203). See "Crankshaft" on page -98 for specifications. Take measurements at several places around each bearing surface. If not within specification, grind the journals and install undersize bearings, or replace the crankshaft.

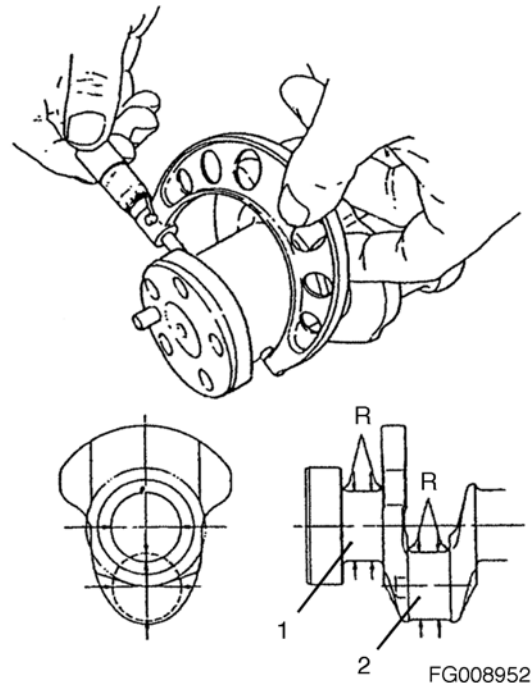
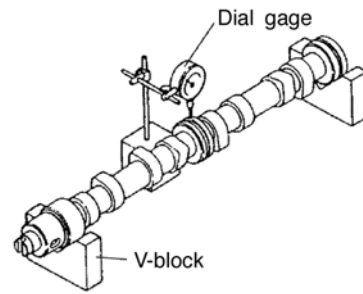


Figure 203

FG008952

Inspection of Camshaft

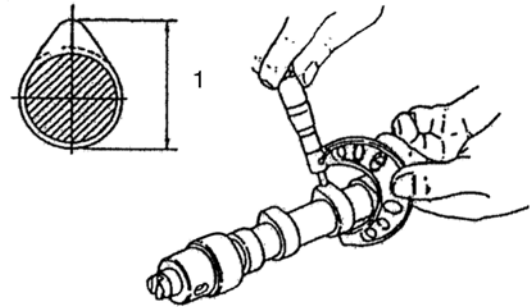
1. Use V-blocks and a dial indicator to check camshaft bend (Figure 204). Place the indicator on the center bearing journal.
2. Rotate the camshaft and observe the runout. See "Camshaft" on page -97 for specifications.



FG008332

Figure 204

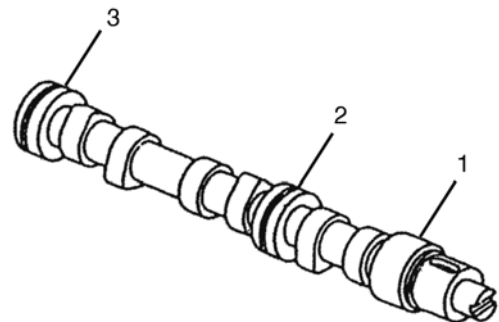
3. Measure the height of each lobe (1, Figure 205). See "Camshaft" on page -97 for specifications.



FG008953

Figure 205

4. Measure the diameter of the gear end (1, Figure 206), intermediate (2, Figure 206) and flywheel end (3, Figure 206) bearing journals. See "Camshaft" on page -97 for specifications.



FG008954

Figure 206

Inspection of Camshaft Bushing and Bores

1. Measure the I.D. of the front bushing and the remaining bores in the cylinder block. See "Camshaft" on page -97 for specifications.
2. If the camshaft bushing is not within specification, replace it using the appropriate service tool. If the remaining bores are not within specification, the cylinder block will require replacement as there are no bearing inserts used.

Inspection of Idler Gear and Shaft

1. Measure the outside diameter (1, Figure 207) of the idler gear shaft (2, Figure 207). See "Idler Gear Shaft and Bushing" on page -97 for specifications.
2. Measure the inside diameter (3, Figure 207) of the idler gear bushing (4, Figure 207) See "Idler Gear Shaft and Bushing" on page -97 for specifications.

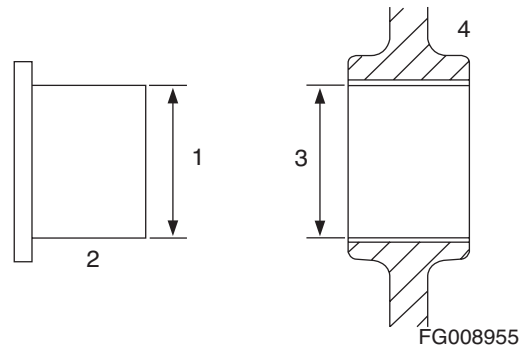


Figure 207

Honing and Boring

Pistons must move freely in the cylinders while maintaining adequate compression and oil sealing. If the cylinder walls are scuffed, scored, out-of-round, or tapered beyond specifications, rebore and hone to restore cylinders to usable condition. Slight imperfections can be corrected by honing alone.

1. Boring - Significant cylinder damage may be corrected by boring the cylinder to an oversize dimension. Refer to the appropriate parts catalog for available oversize pistons and piston rings.
 - Boring a cylinder should always be done in a properly equipped machine shop.
 - A bored cylinder should always be finished with a hone to properly prepare the cylinder surface so the new piston rings will seat properly.
 - After the cylinder has been bored and honed, install the appropriate oversize pistons and piston rings.
2. Honing - Minor cylinder imperfections may be corrected by using a rigid cylinder hone (1, Figure 208). Be sure not to exceed the maximum cylinder bore specification.
Deglazing - A used cylinder that did not require boring or honing, should always be deglazed with a ball hone (2, Figure 208) before installing new piston rings. This will properly prepare the cylinder surface to allow new piston rings to seat properly.

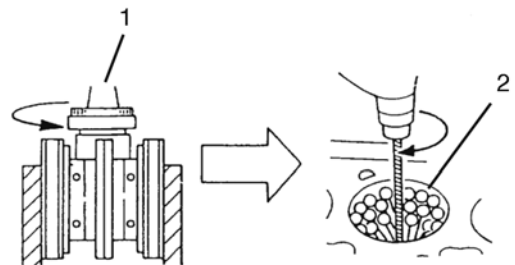


Figure 208

FG008957

NOTE: When honing a cylinder, with either a ridged hone or a ball hone (1, Figure 209), move the rotating hone up and down in the cylinder bore to accomplish a 30° to 40° crosshatch pattern (Figure 209). This will provide the ideal surface for the proper seating of new piston rings.



CAUTION

Do not allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

- Use a 50:50 mixture of diesel fuel and engine oil as a honing fluid.
- Use a 300-grit hone at 300-1200 rpm (Figure 208).



IMPORTANT

Solvents will not adequately remove honing residue, resulting in premature piston and ring wear. Always wash cylinders using hot, soapy water.

- When honing is completed, wash the cylinder block with hot water and soap. The cylinder wall is adequately cleaned when a white rag wiped in cylinder comes out clean. Use brushes to clean all passages and crevices. Rinse with hot water and dry with compressed air. Apply clean engine oil to all steel surfaces to prevent rusting.

Reassembly of Crankshaft and Piston Components

NOTE: Proceed slowly. Make no forced assemblies unless a pressing operation is called for. All parts must be perfectly clean and lightly lubricated when assembled.

Use new gaskets, seals and O-rings during assembly.

Liberal apply clean engine oil to all internal parts during assembly.

All fasteners should be tightened to a given torque. If a special torque is not provided in the Special Torque Chart on page 6-23, tighten to standard torque specifications. See "Tightening Torques for Standard Bolts and Nuts" on page -48

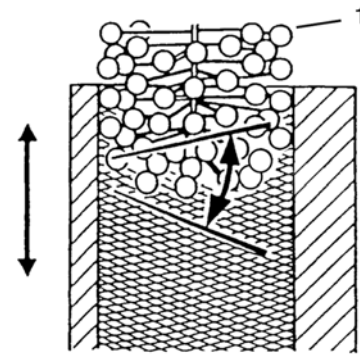


Figure 209

FG008956

Reassembly of Pistons

1. Select the parts needed to reassemble the piston and connecting rod for one cylinder.
2. If removed, install a new wrist pin bushing (7, Figure 210) using a press and the appropriate service tool. Be sure to align the oil holes.
3. Reinstall one circlip (5, Figure 210) into the piston. Ensure the circlip is securely seated in the groove.



IMPORTANT

The piston and connecting rod must be assembled together in the correct orientation. The orientation of the piston and connecting rod are different depending on engine model.

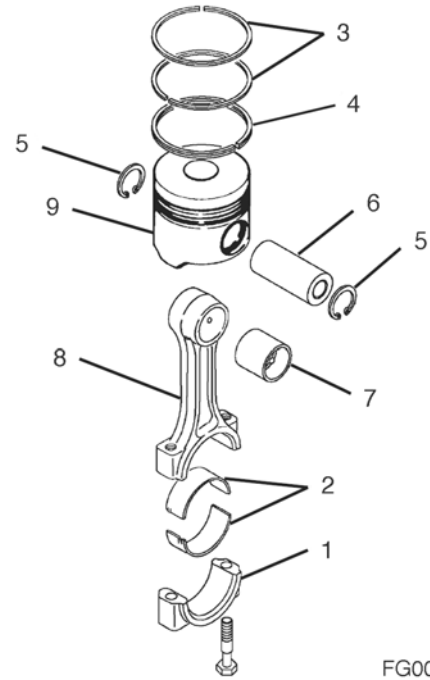
Piston to Connecting Rod Orientation - By Model

4TNV98-E

Orient the piston identification mark stamped on top of the piston on the same side as the rod and cap match marks stamped on the connecting rod.

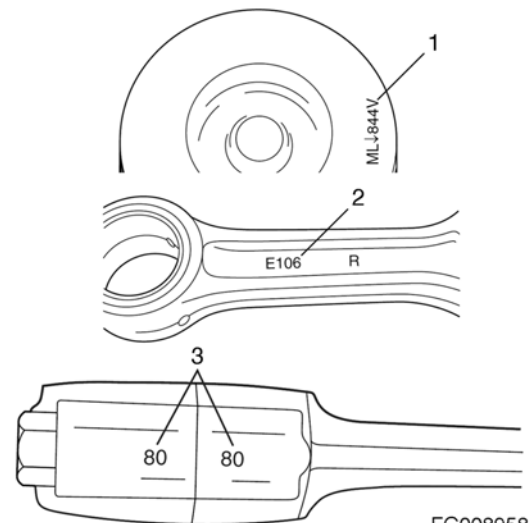
NOTE: *The actual appearance of the match marks will vary but they will always be in the same locations.*

Reference Number	Description
1	Piston Identification Mark
2	Embossed Mark on Connecting Rod
3	Rod and Cap Match Marks



FG008934

Figure 210



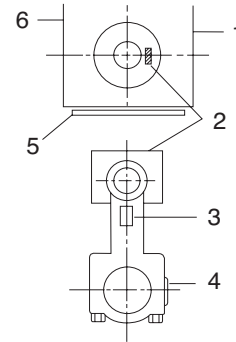
FG008958

Figure 211

Piston Assembly - 4TNV98-E

When correctly assembled, the piston identification mark (2, Figure 212) stamped into the top of the piston will be on the same side of the connecting rod as the match marks (4, Figure 212) stamped into the connecting rod and connecting rod cap.

When installed in the cylinder, the piston identification mark (2, Figure 212) stamped on the top of the piston must face the fuel injection pump side (1, Figure 212) of the engine and the embossed mark on the connecting rod (3, Figure 212) must face the flywheel end (5, Figure 212) of the engine.



FG008960

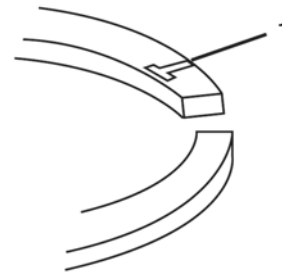
Figure 212

Reference Number	Description
1	Fuel Injection Pump Side of Engine
2	Piston Identification Mark
3	Embossed Mark on Connecting Rod
4	Rod and Cap Match Marks
5	Flywheel End of Engine
6	Camshaft Side of Engine

1. Lubricate and reinstall the wrist pin (3, Figure 210) through the piston and connecting rod.
2. Reinstall the second circlip (4, Figure 210) and ensure it is securely seated in the groove.

NOTE: If installing new piston rings the end gap must be checked and adjusted as necessary. (See page -142) for specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

NOTE: Reinstall the top and second piston rings with the stamped "makers mark" (1, Figure 213) facing the top of the piston. The "makers mark" may vary in appearance but will always be located on the top surface of the piston ring adjacent to the piston ring gap. The oil ring and oil ring expander can be installed either side up.



FG008961

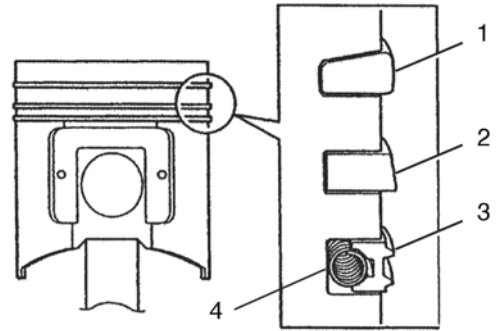
Figure 213



IMPORTANT

Always use a piston ring installation tool (expander) when installing piston rings. Never attempt to install piston rings by hand.

3. Reinstall the oil ring expander (4, Figure 214). Reinstall the oil ring (3, Figure 214) with the end gap at 180° from the expander end gap.
4. Reinstall the second compression ring (2, Figure 214). This ring is identified by its dark color and tapered face profile.
5. Reinstall the top compression ring (1, Figure 214). This ring is identified by its silver color and barrel-shaped face profile.



FG008962

Figure 214

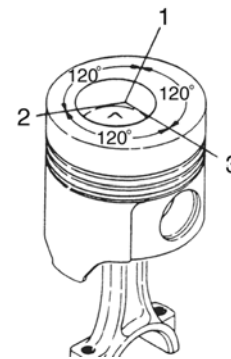


IMPORTANT

The oil ring expander (4, Figure 214) end gap must be located 180° from the oil ring (3, Figure 214) end gap.

6. Stagger the piston ring end gaps at 120° intervals (1, 2, 3, Figure 214)

Reference Number	Description
1	Top Compression Ring End Gap
2	Second Compression Ring End Gap
3	Oil Ring End Gap



FG008963

Figure 215

Installation of Crankshaft

1. If removed, reinstall the keys and timing gear on the crankshaft.
2. Reinstall new bearing inserts (1, Figure 216) and thrust bearing (2, Figure 216) in the cylinder block and main bearing caps. Apply a liberal coat of clean engine oil to the bearings and crankshaft journals.
3. Place the crankshaft into the engine.



IMPORTANT

The main bearing caps are numbered and have arrows for proper positioning. The No. 1 cap is at the flywheel end. The arrows point toward the flywheel end of the engine.

4. Reinstall the main bearing caps (3, Figure 216)
5. Apply a light coat of clean engine oil to the bearing cap bolts and tighten the bolts to the specified torque in two stages (1/2 then full torque). See "Special Torque Chart" on page -101 for specifications.
6. Rotate the crankshaft to assure it turns freely.
7. Apply threeBond Liquid Gasket to the mounting flange of the seal housing (2, Figure 217)
8. Align the seal housing with the two dowel pins.
9. Reinstall seal housing and seal assembly.
10. Reinstall the flywheel (1, Figure 217) and tighten the bolts to the specified torque. See "Special Torque Chart" on page -101 for specifications.

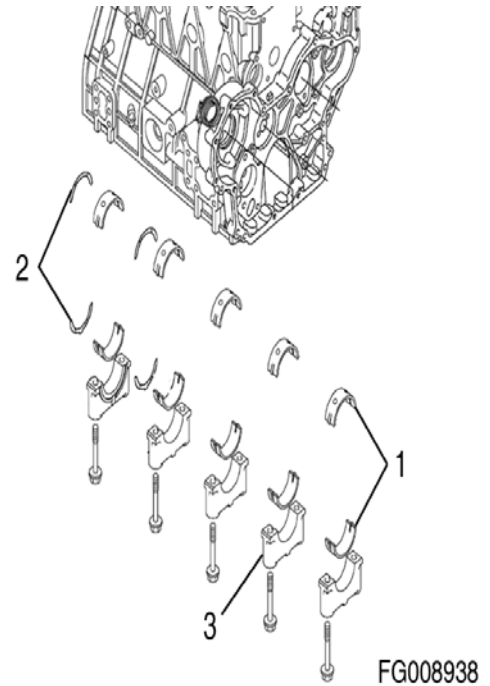


Figure 216

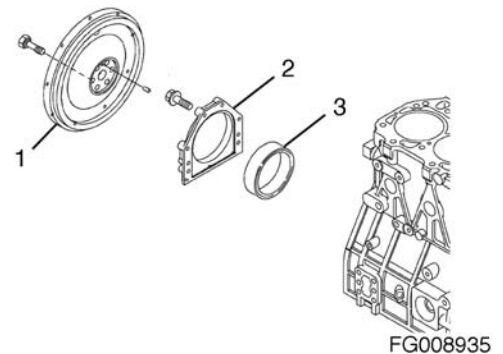


Figure 217

Installation of Pistons



IMPORTANT

Do not allow the connecting rod to contact the crankshaft journal during piston installation. Damage to the crankshaft bearing journal may result.

1. Lubricate the piston, piston rings, and cylinder with clean engine oil or assembly lubricant.

2. Rotate the crankshaft so the crankpin for the piston being installed is near bottom dead center.



IMPORTANT

Ensure the piston ring gaps are located correctly (Figure 218)

Reference Number	Description
1	Top Compression Ring End Gap
2	Second Compression Ring End Gap
3	Oil Ring End Gap

3. Using a piston ring compressor, compress the piston rings.



IMPORTANT

The piston and connecting rod must be installed in the correct orientation. The orientation of the piston to the cylinder is different depending on engine model.

Piston Orientation to Cylinder - By Model
4TNV98-E
Orient the piston identification mark stamped on top of the piston on the fuel injection pump side of the engine

Piston Installation - 4TNV98-E

When correctly assembled, the piston identification mark (2, Figure 219) stamped into the top of the piston will be on the same side of the connecting rod as the match marks (4, Figure 219) stamped into the connecting rod and connecting rod cap.

When installed in the cylinder, the piston identification mark (2, Figure 219) stamped on the top of the piston must face the fuel injection pump side (1, Figure 219) of the engine and the embossed mark on the connecting rod (3, Figure 219) must face the flywheel end (5, Figure 219) of the engine.

Reference Number	Description
1	Fuel Injection Pump Side of Engine
2	Piston Identification Mark
3	Embossed Mark on Connecting Rod
4	Rod and Cap Match Marks
5	Flywheel End of Engine
6	Camshaft Side of Engine

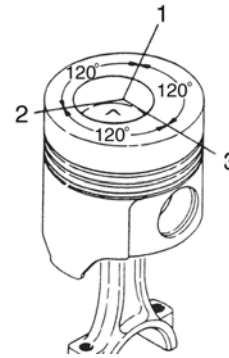


Figure 218

FG008963

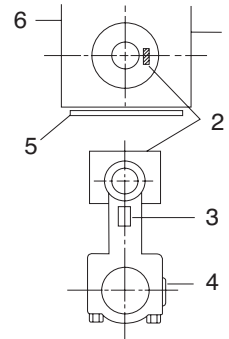


Figure 219

FG008960

4. Reinstall the bearing inserts (1, Figure 220) in the connecting rod and cap.
5. Apply a liberal coat of clean engine oil to the bearing inserts and crankshaft journal.
6. Apply a light coat of clean engine oil to the rod cap bolts. Reinstall the connecting rod cap (2, Figure 220). Tighten the connecting rod bolts to the specified torque in two stages (1/2 then full torque). See "Special Torque Chart" on page -101 for specifications.
7. Reinstall the remaining pistons in their respective cylinders.

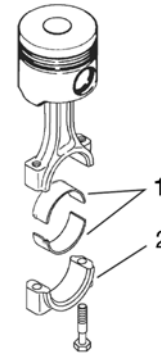


Figure 220

FG008964

Reassembly of Camshaft and Timing Components

Installation of Gear Case or Front Plate

1. If removed, install a new camshaft bushing (3, Figure 221) using the appropriate service tool.
2. Apply a continuous bead of threeBond Liquid Gasket to the mounting area of the gear case or front plate. Be sure to circle each bolt hole.
3. Install two new O-rings (2, Figure 221) in the cylinder block.
4. Reinstall the gear case (1, Figure 221). Tighten the bolts to the specified torque.

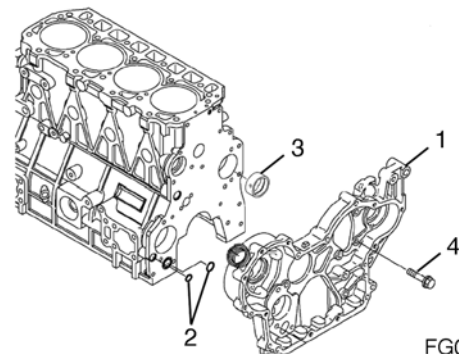


Figure 221

FG008930

Installation of Camshaft

NOTE: *The gear housing or front plate must be reinstalled prior to installing the camshaft. See "Installation of Gear Case or Front Plate" on page -154*

1. If removed, reinstall the camshaft end plate (1, Figure 222), key, and timing gear (4, Figure 222) onto the camshaft using a press.

NOTE: *Heat the gear to 356 - 392°F (180 -200°C) and press onto the end of the camshaft.*

2. Rotate the cylinder block so that gravity will keep the tappets (5, Figure 222) in place and out of the way of the camshaft lobes when the camshaft is being reinstalled.

NOTE: *If the engine is not installed on an engine repair fixture, stand the engine upright on the flywheel end mounting flange.*

NOTE: *The tappets are "mushroom" shaped and must be installed from inside the engine crankcase.*

3. Lubricate the tappets with clean oil or assembly lube. Reinstall the tappets in their respective locations in the cylinder block. Push the tappets fully into the tappet bores

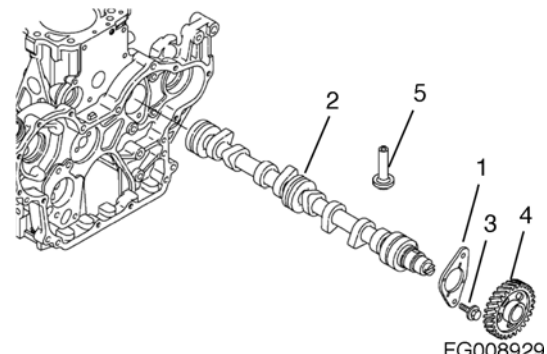


Figure 222

FG008929

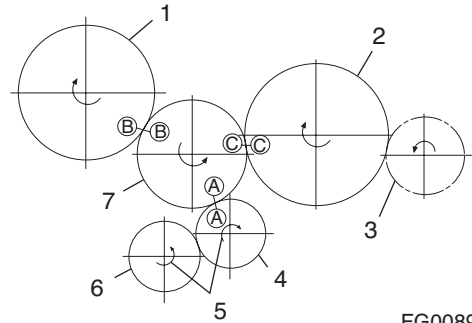
so they will not interfere with the installation of the camshaft.

4. Lubricate the camshaft (2, Figure 222) with clean engine oil or assembly lube. Slowly insert the camshaft through the front of the engine.
5. Reinstall and tighten the cap screws (3, Figure 222).
6. If removed, reinstall the fuel injection pump. Adjust the fuel injection timing the engine after installation. See "Adjusting Fuel Injection Timing" on page -193

Installation of Timing Gears

1. Set the No. 1 piston to top dead center.
2. Rotate the camshaft until the mark (C, Figure 223) is approximately at the 9 o'clock position.

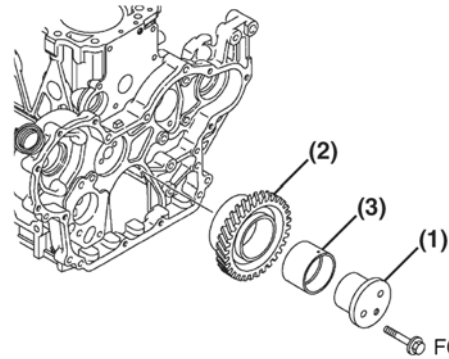
Reference Number	Description
1	Fuel Injection Pump Drive Gear
2	Camshaft Drive Gear
3	Auxiliary Drive Gear (Optional)
4	Crankshaft Drive Gear
5	Direction of Rotation
6	Oil Pump Drive Gear
7	Idler Gear



FG008920

Figure 223

3. Lubricate the idler gear (2, Figure 224), bushing (3, Figure 224) and idler gear shaft (1, Figure 224) with clean engine oil.
4. Align the timing gears as shown in (Figure 223).
5. Reinstall the idler gear and idler gear shaft. Be sure the oil hole in the bushing is facing toward the top of the engine.
6. Ensure all three timing marks (A, B, C, Figure 223) are aligned.
7. When all gears are properly aligned, tighten the idler gear retaining bolts to specified torque. See "Special Torque Chart" on page -101 for specifications.

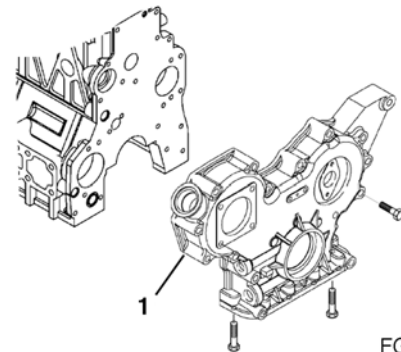


FG008922

Figure 224

Installation of Gear Case Cover

1. Apply a continuous bead of ThreeBond Liquid Gasket to the mounting area of the gear case cover (1, Figure 225). Be sure to circle the bolt holes.
2. Reinstall and tighten the gear case cover bolts.



FG008911

Figure 225

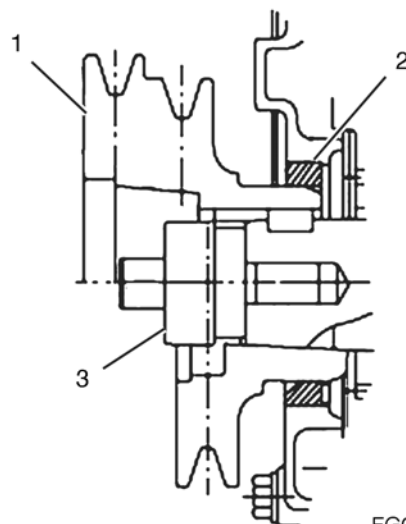
3. Reinstall the crankshaft pulley.



IMPORTANT

4TNV98-E: Use the crankshaft pulley installation tool (3, Figure 226) when reinstalling the pulley (1, Figure 226). The tool will guide the pulley hub and protect the front seal (2, Figure 226) from damage.v

4. Reinstall the washer and bolt. Tighten the bolt to the specified torque. See "Special Torque Chart" on page -101 for specifications.



FG008965

Figure 226

Installation of Oil Pan

1. Reinstall the oil pickup tube (1, Figure 227) using a new O-ring (2, Figure 227).

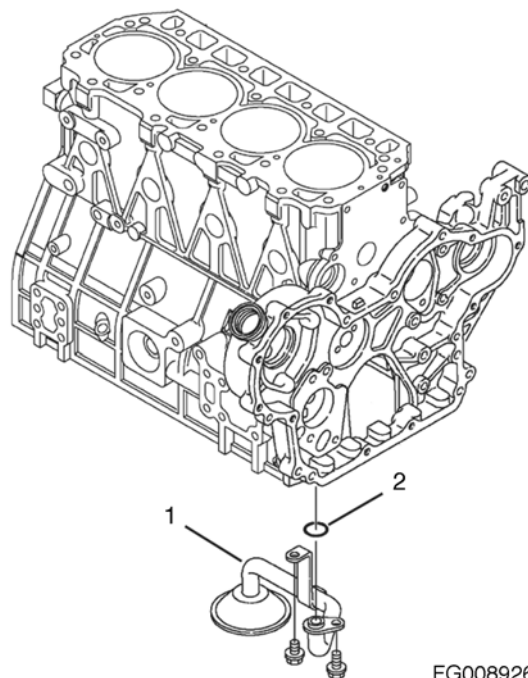


Figure 227

2. Apply a continuous bead of ThreeBond Liquid Gasket to the mounting surface of the oil pan (Figure 228, 1). Be sure to circle each bolt hole.
3. Reinstall the oil pan and tighten the bolts securely.

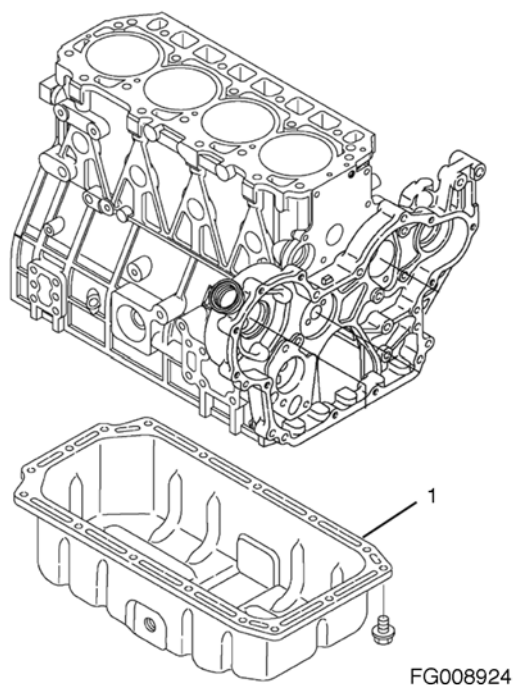


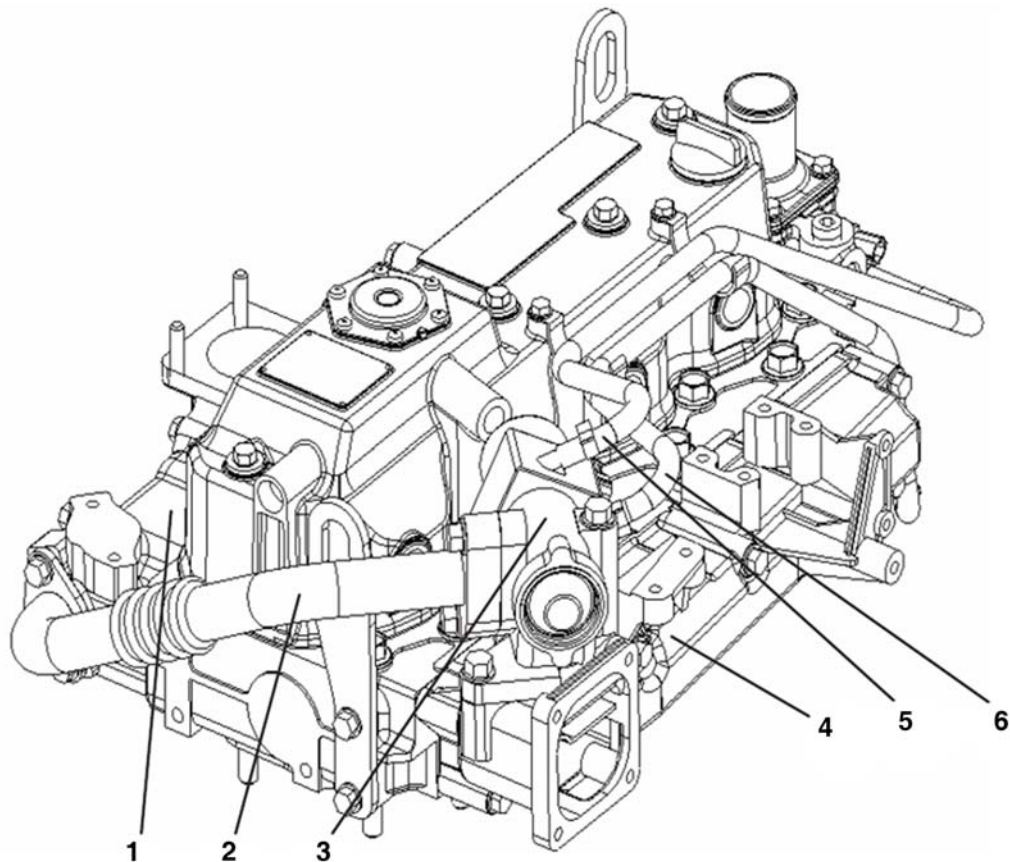
Figure 228

Final Reassembly of Engine

1. Reinstall the starter motor.
2. Reinstall the cylinder head. See "Reassembly of Cylinder Head" on page -120 for the 2-valve cylinder head or See "Reassembly of Cylinder Head" on page -120 for the 4-valve cylinder head.
3. Reinstall the engine in the machine.
4. Reconnect the fuel and coolant lines.
5. Reinstall the alternator.
6. Reconnect and adjust the throttle cable.
7. Reconnect all electrical connections.
8. Fill the engine with oil and coolant.
9. Reconnect the battery cables, negative (-) cable last.

EGR System

EGR System



FG012504

Figure 229

Reference Number	Description
1	Exhaust manifold
2	EGR pipe
3	EGR valve

Reference Number	Description
4	Intake manifold
5	Cooling water hose, EGR valve inlet
6	Cooling water hose, EGR valve outlet



DANGER

Scald Hazard!

Never Remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.

Always check the level of the engine coolant by observing the reserve tank.

Failure to comply will result in death or serious injury.



HAOA060L

Figure 230

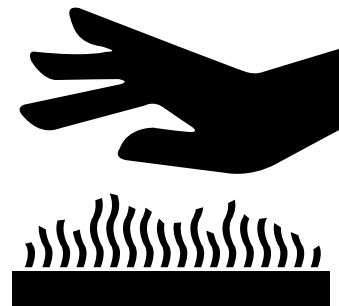


WARNING

Burn Hazard!

Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 231



WARNING

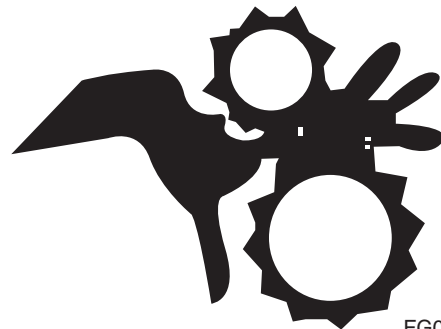
Entanglement Hazard!

Stop the engine before you begin to service it.

Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.

Failure to comply could result in death or serious injury.



FG009148

Figure 232



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.



Figure 233

FG009153



CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

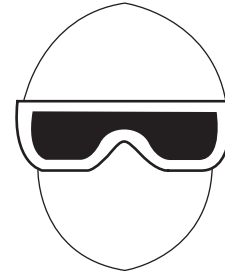


Figure 234

FG009152



CAUTION

Coolant Hazard!

Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

Failure to comply may result in minor or moderate injury.

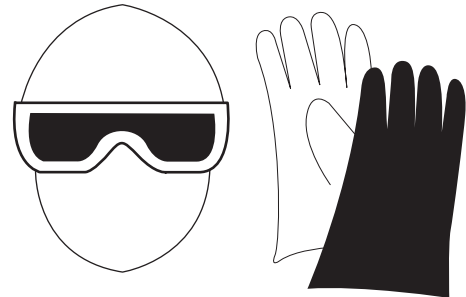


Figure 235

FG009154



CAUTION

When it is necessary to replace an EGR valve, be sure to replace the entire EGR valve assembly. Neither attempt to disassemble and repair the EGR valve, nor replace its individual components.



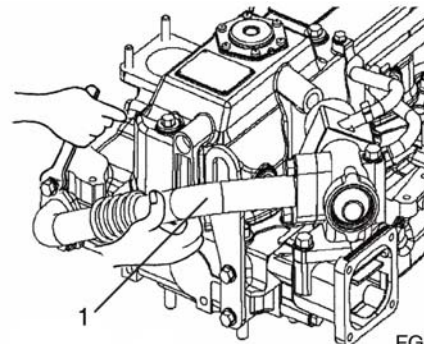
CAUTION

The EGR system uses steel gaskets at the joints between its components/parts. These steel gaskets are specific to the respective joints. When you remove the system's components/parts and reinstall them, replace the steel gaskets between them with new correct ones.

1. Drain the engine cooling water.
2. Remove the battery cable from the battery's minus (-) terminal.
3. min
4. If there is any additional equipment (such as an air cleaner) installed above the EGR valves, remove it in advance.
5. Remove the EGR valve connectors.
6. Disconnect the cooling water inlet and outlet hoses from each EGR valve by loosening the hose clips. When loosening the clips, put waste cloth or the like beneath the hose joints in case water leaks.

4TNV98-E

1. Loosen the nuts in the coupling flanges of the exhaust manifold and the EGR pipe.
2. Loosen the bolts in the coupling flanges of the EGR pipe and EGR valve, and remove the EGR pipe.
3. Remove the EGR valve.



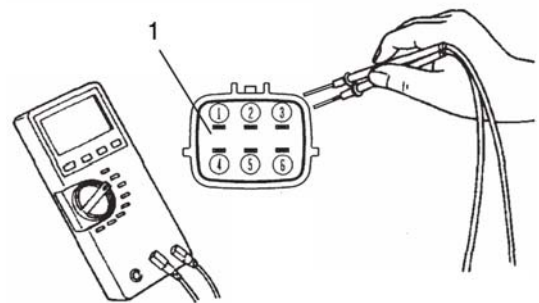
FG010626

Figure 236

Inspecting/Cleaning EGR Related Components

EGR Valve

Each EGR valve has four built-in coils. The power to each of the four coil is either ON or OFF at any given time. Depending on which coil is ON and which coil is OFF, the step motor rotates to determine the valve lift. The power to each coil is turned ON/OFF by the E-ECU based on the engine speed and fuel injection rate. The resistances of these coils should be as specified below when measured between each pair of pins shown. If any of the actually measured values is beyond the standard range, replace the entire EGR valve assembly.



FG010627

Figure 237 EGR valve connectors

Standard value	
Terminal	Resistance (Ω)
1 - 2	15 $\pm$ 2 at 20°C
2 - 3	
4 - 5	
5 - 6	

NOTE: *The higher the temperature, the higher the coil resistance. Therefore, wait for the EGR valve to return to normal state before measuring the resistances.*

EGR Valve Operation Checks

1. After removing each EGR valve from the engine, connect the valve with the connector.
2. Connect the valve to the battery's minus (-) terminal.
3. Turn on the key switch. (Note that turning on the key switch causes the E-ECU to check whether the valve functions properly by opening and shutting it.)
4. From the exhaust gas inlet, visually check whether the valve operates correctly.

NOTE: *If the EGR valve fails to smoothly operate, replace the entire valve assembly with new one.*

NOTE: *If the EGR valve does not respond at all, check whether there exists a voltage (EGR valve signal) between the connector pins. If the voltage is within the standard range, then replace the entire valve assembly with new one.*

IMPORTANT

Alternatively, you can remove the EGR pipe from the engine and check the valve operation through the gas inlet window, instead of removing the EGR valve from the engine.

Cleaning the EGR Valves



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.



Figure 238

FG009153



CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

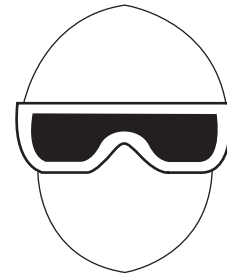


Figure 239

FG009152

The EGR valves must be periodically cleaned every 1500 hours because, as exhaust gas circulates through them for a prolonged time, carbon is deposited on their inner surfaces, possibly deteriorating the EGR ratio.

To remove deposited carbon, use compressed air (0.19MPa(2kg/cm²) or lower). If the valves are heavily fouled, use carbon cleaner, kerosene, or some other liquid capable of removing carbon as well as a soft brush to clean the valves, taking care not to damage their parts.

When cleaning the valves, take extreme care to prevent water, solvent, cleaner, and other liquid from entering into the motor and coupler terminals; otherwise, failure may result.



CAUTION

NEVER use high-pressure water or compressed air at greater than 28 psi (193 kPa; 19 686 mmAq) or a wire brush to clean the radiator fins. Radiator fins damage easily.

Precautions for Installation

1. The valve and stopper must be installed in their specific orientations. As shown in the figure above, install the valve and stopper so that they are located on the left-hand side of the lead valve.
2. Install the valve by tightening the machine screw while ensuring that it is evenly positioned inside the case window.
3. The machine screw must be tightened with torque of $1.37 \pm 0.2 \text{ N} \cdot \text{m}$ ($14 \pm 2 \text{ kgf} \cdot \text{cm}$).
4. After tightening the machine screw, mark it with a marker to indicate that it has already been tightened.

EGR Pipe and Other Connecting Elbows

The exhaust gas passage is subject to carbon deposition when used over time. To remove deposited carbon from the gas passage, use compressed air (0.19 MPa (2 kg/cm^2) or lower). If the exhaust gas passage is heavily fouled, clean it by dipping it in carbon cleaner, kerosene, or some other liquid capable of removing carbon.



CAUTION

Always be environmentally responsible.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

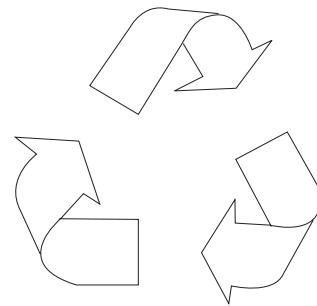
Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.

Failure to follow these procedures may seriously harm the environment.

Installing EGR Related Components/Parts

To install these components/parts, reverse the disassembly procedure described above: thus install the lead valve, spacer, EGR valve, EGR pipe, EGR cooler, elbow, cooler cooling water hose, and EGR cooling water hose exactly in this order.

The EGR system uses steel gaskets at the joints between its components/parts. When you remove the system's components/parts and reinstall them, replace the steel gaskets between them with new correct ones.



FG009156

Figure 240

FUEL SYSTEM

Before You Begin Servicing



WARNING

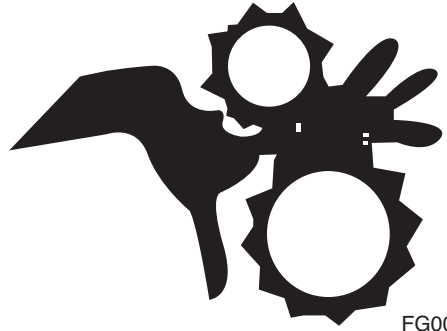
Entanglement Hazard!

Stop the engine before you begin to service it.

Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.

Failure to comply could result in death or serious injury.



FG009148

Figure 241



WARNING

Sudden Movement Hazard!

Engaging the transmission or PTO at an elevated engine speed could result in unexpected movement of the equipment.

Failure to comply could result in death or serious injury.



WARNING

Never inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.

Never inject fuel toward a fire source. Atomized fuel is highly flammable and may cause a fire or burn skin.



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.



FG009153

Figure 242

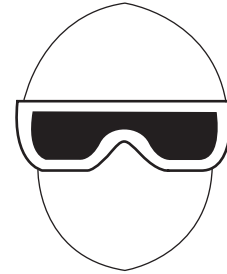


CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.



FG009152

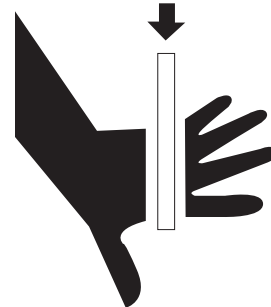
Figure 243



CAUTION

Pinch Hazard!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.



FG009155

Figure 244



CAUTION

Never remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

Never attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations and then replace the tamper-proof seals.



CAUTION

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.



CAUTION

Allow the engine to warm-up for at least five minutes and the idle speed of the engine to return to normal before engaging the transmission or any PTOs. Engaging the transmission or PTO at an elevated engine speed could result in an unexpected movement of the equipment.



CAUTION

Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.



CAUTION

After marking the position of the pump drive gear, do not rotate the engine crankshaft. Rotating the crankshaft will cause the fuel injection pump to become misaligned.



CAUTION

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub. Correct fuel injection timing will be very difficult or impossible to achieve.



CAUTION

Do not rotate the crankshaft with the injection pump removed.



CAUTION

Each pressure adjusting shim removed or added changes the pressure threshold by approximately 275 psi (1.9 MPa, 19 kgf/cm²). Adding adjusting shims increases the threshold pressure. Removing adjusting shims reduces the pressure threshold.

Introduction

This section of the Service Manual describes the procedures necessary to remove, install, and time the MP fuel injection pump and its associated system components. This fuel injection pump is representative of the fuel injection pumps used on other TNV DI model engines.

Fuel Injection Pump

NOTE: *If the MP fuel injection pump itself requires servicing, it must be taken to an authorized DOOSAN dealer or DOOSAN after sales service.*



CAUTION

Never remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

Never attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations and then replace the tamper-proof seals.

The following describes the features of the MP fuel injection pump, manufactured by DOOSAN.

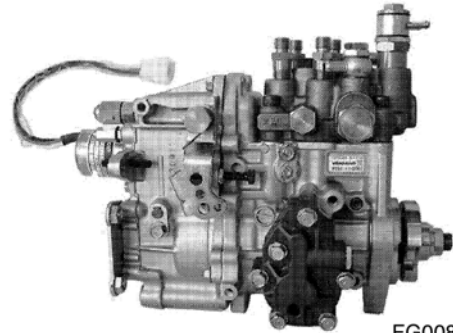
The fuel injection pump is a very important component of the engine. It is capable of making very precise fuel delivery adjustments according to the varied loads applied to the engine.

All of the fuel injection pump components are very precisely machined. It is extremely important to follow good service practices and maintain cleanliness when servicing the fuel injection pump.

The MP "Mono-Plunger" Fuel Injection Pump is a distributor type pump which consists of a single fuel supply plunger, a distributor shaft, a hydraulic head and a pump housing. The hydraulic head has a delivery valve for each cylinder. The fuel injection pump housing contains a governor and an internal camshaft.

The fuel is pressurized by the up and down motion of the camshaft-driven single plunger. It is then distributed to the proper fuel injector by the rotating distributor shaft.

There are two versions and sizes of the MP Fuel Injection Pump. The smaller of the two pumps, the MP2 pump, is used on the 3TNV88 model engines. The larger pump, the MP4 pump, which has a larger single plunger and a more aggressive cam profile, is used on the 4TNV94L -4TNV106T model engines.



FG008374

Figure 245

Stop Solenoid

The MP fuel injection pumps are equipped with a stop solenoid that controls the fuel flow inside the fuel injection pump.

With the starter switch in the OFF position, no current flows to the stop solenoid and the solenoid plunger is extended holding the fuel injection pump fuel rack in the "closed" position and not allowing fuel to flow through the injection pump and to the engine.

When the starter switch is turned to the start position, the "pull coil" (36.5 Amp draw / white wire) inside the solenoid is activated and pulls the solenoid plunger into the solenoid. This releases the fuel injection pump fuel rack, allowing fuel to flow through the injection pump and allowing the engine to start and run.

When the starter switch is returned to the ON or RUN position, the "pull coil" no longer receives current and the "hold coil" (0.5 Amp draw / red wire) inside the solenoid is activated. The "hold coil" holds the solenoid plunger in the RUN position, allowing fuel to continue flowing and the engine to continue running.

To stop the engine, the key switch is turned to the OFF position. Current no longer flows to the stop solenoid "hold coil", and the solenoid plunger extends and moves the injection pump fuel rack to the "closed" position, shutting off the fuel flow and stopping the engine.

Failure of the stop solenoid could result in the engine not starting, the engine stopping suddenly, the engine not continuing to run with the key switch returned to the ON or RUN position, or the engine failing to stop when the key switch is turned to the OFF position. Use a multimeter or continuity light to check for 12V at the stop solenoid connector in the correct sequence.

Electronically controlled engines 4TNV84T-Z, 4TNV98-Z, 4TNV98-E, and 4TNV98T-Z are designed so that, when the key is turned on or off, the corresponding signal is sent to the E-ECU.

Thus the E-ECU controls the rack actuator to provide a sufficient injection rate when the engine is started up (the key is turned on) or cut the fuel supply and stop the engine when the key is turned off. Therefore, this electronically controlled engine does not have a stop solenoid.

Cold Start Device

The TNV model engines are equipped with a cold start device (CSD).

The cold start device is located in the upper section of the fuel injection pump and is connected to the engine's cooling system.

- The cold start device improves engine starting at lower temperatures. At engine cooling system temperatures below 41°F (5°C), the cold start device advances the fuel injection timing and slightly increases the fuel injection volume.
- For approximately the first 5 minutes of operation, the idle speed of the engine will be slightly elevated.



CAUTION

Allow the engine to warm-up for at least five minutes and the idle speed of the engine to return to normal before engaging the transmission or any PTOs. Engaging the transmission or PTO at an elevated engine speed could result in an unexpected movement of the equipment.

- When the cold start device is activated, you may notice a slight increase in the exhaust smoke of the engine during engine warm-up. Electronically controlled engines 4TNV98-E use a cold start device (CSD) that consists of a fuel injection pump complete with a solenoid valve (1, Figure 246).
- When the engine is started with the cooling water sensor detecting a low water temperature of 10Ae or lower and the E-ECU receives the corresponding signal, then the E-ECU causes the CSD's solenoid valve to increase the injection rate and advance the injection timing.
- . Because of this, the engine speed increases by approximately 75 min-1 while the CSD is operating. When the water temperature becomes 10°C or higher, the CSD is turned off and the engine returns to the normal speed.

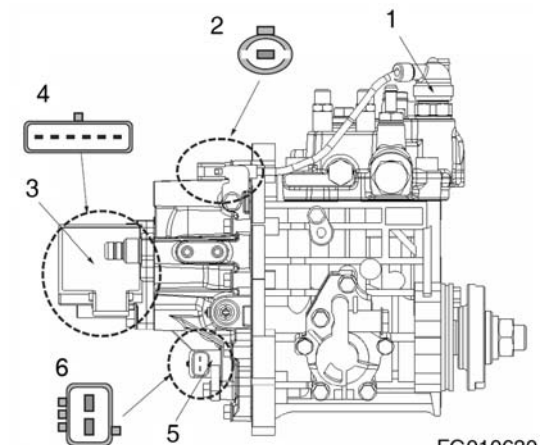


Figure 246

Trochoid Fuel Pump

NOTE: *The trochoid fuel pump located on the side of the MP fuel injection pump is not a "fuel supply" pump. The function of this pump is to raise the pressure of the fuel supplied by the electric fuel supply pump to the internal fuel pressure required by the MP fuel injection pump.*

The use of an electric fuel supply pump is required on all TNV model engines with the MP fuel injection pump.

Electronically Controlled Governor

Electronically controlled engines 4TNV98-E are quipped with an electronically controlled governor called "Eco Governor". Combined with the rack actuator (3, Figure 246), engine speed sensor (5, Figure 246), and other parts, the electronically controlled governor communicates with the engine controller (E-ECU), whereby the engine speed and fuel injection rate are controlled.

Fuel System Specifications

Special Torque Chart

Component	Tightening Torque	Lubricating Oil Application (Thread Portion and Seat Surface)
Fuel Injector Retainer Bolt	29 ft•lb (39.2 N•m; 4 kgf•m)	Not Applied
Fuel Pump Drive Gear Nut	83 - 91 ft•lb (113 - 123 N•m; 11.5 - 12.5 kgf•m)	Not Applied
High-Pressure Fuel Injection Line Nuts	22 - 25 ft•lb (29 - 34 N•m; 3.0 - 3.5 kgf•m)	Not Applied
Fuel Return Line Bolts	69 - 87 in•lb (7.8 - 9.8 N•m; 0.8 - 1.0 kgf•m)	Not Applied
Fuel Injection Pump Mounting Nuts	17 - 21 ft•lb (23 - 28 N•m; 2.3 - 2.9 kgf•m)	Not Applied
Fuel Injector Nozzle Case Nut	30 - 33 ft•lb (39.2 - 44.1 N•m; 4 - 4.5 kgf•m)	Not Applied
Fuel Injection Pump Plunger Plug	30 - 33 ft•lb (40 - 45 N•m; 4.1 - 4.6 kgf•m)	Not Applied

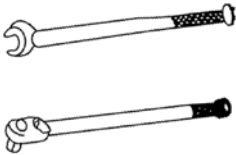
Test and Adjustment Specifications

Engine Class	Injector ID mark*	Fuel Injector Pressure	Fuel Injection Timing
CL VM	V	3133 - 3278 psi (21.6 - 22.6 MPa; 220 - 230 kgf/cm ²)	See "Checking and Adjusting Fuel Injection Timing" on page -189

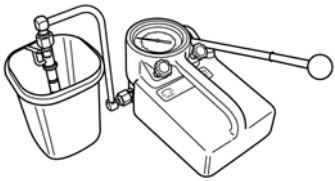
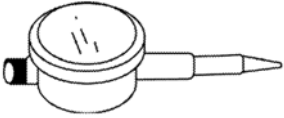
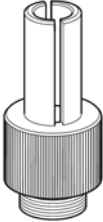
NOTE: Fuel injector pressures given are for used parts. New injectors (5 hours operation or less) will read approximately 725 psi (5 MPa; 51 kgf/cm²) higher.

* All DI injectors have 3 letters with the first letter starting with a V or W.

Special Service Tools

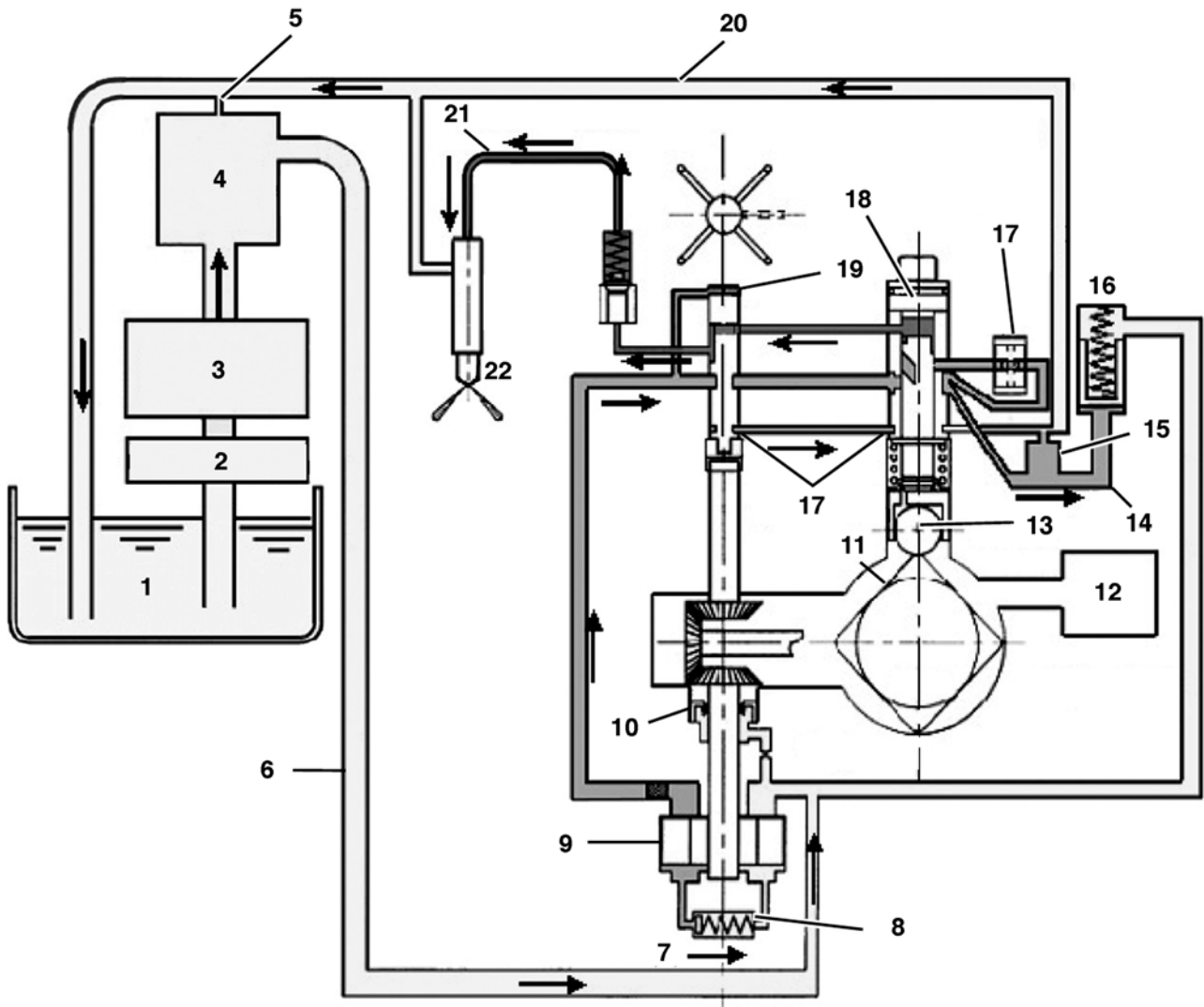
No.	Illustration	Tool name		Application
1	 FG008286	Torque Wrench	Locally Available	For tightening nuts and bolts to the specified torque

Measuring Instruments

No.	Illustration	Instrument Name		Application
1	 FG008971	Fuel Injector Tester	Locally Available	For observing injection spray pattern of fuel injection nozzle and measuring injection pressure
2	 FG008277	Dial Indicator*	Mituotoyo 2050SB - Locally Available	Check and adjust fuel injection timing
		Extension Rod*	Mituotoyo 303613 - Locally Available	
3	 FG008972	Fuel Injection Pump Plunger Adapter*	(M16) 4TNV98 - Z Part No. 158090-51841	Mount dial indicator to fuel injection pump
4	 FG008973	Plunger Adapter Clamp	DOOSAN Part No. 23000-013000	Clamps stem of dial indicator in plunger adapter.

* These special service tools may also be available as an "MP Fuel Injection Pump Special Tool Set". Contact your authorized DOOSAN dealer or distributor for details.

Fuel System Diagram



FG008974

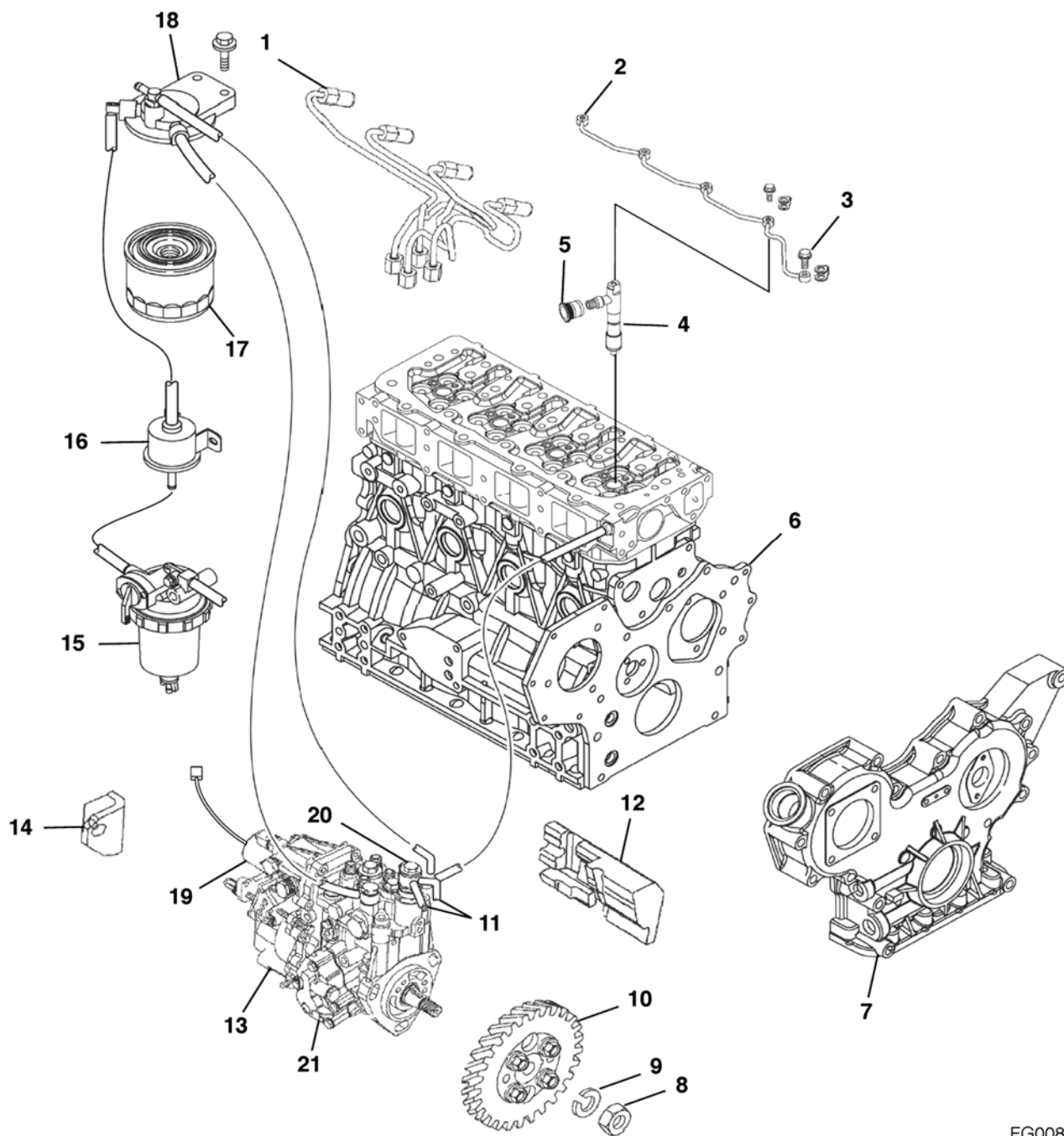
Figure 247

Reference Number	Description
1	Diesel Fuel Tank
2	Fuel Filter / Water Separator
3	Electric Fuel Pump
4	Fuel Filter
5	Air Bleed Orifice
6	Fuel Supply Line
7	Low Pressure Gallery
8	Pressure Control Valve
9	Trochoid Pump
10	Oil Seal
11	Fuel Injection Pump Cam
12	Engine Crankcase

Reference Number	Description
13	Tappet
14	High Pressure Gallery
15	Overflow Orifice
16	Accumulator
17	Timer Piston
18	Mono-Plunger
19	Distributor Shaft
20	Fuel Return Line
21	High-Pressure Fuel Injection Lines
22	Fuel Injector

Fuel System Components

4-Valve Cylinder Head



FG008976

Figure 248

Reference Number	Description
1	High-Pressure Fuel Injection Lines
2	Fuel Return Line
3	Return Line-to-Cylinder Head Bolt
4	Fuel Injector
5	Injection Line Grommet
6	Front Plate or Timing Gear Case
7	Gear Case Cover
8	Fuel Injection Pump Drive Gear Nut
9	Lock Washer
10	Fuel Injection Pump Drive Gear Assembly (DO NOT remove or loosen the four bolts that fasten the injection pump drive gear to the injection pump drive gear hub!)

Reference Number	Description
11	Coolant Lines for Cold Start Device*
12	Fuel Injection Pump Insulator
13	Diesel Fuel Injection Pump
14	Rear Fuel Injection Pump Support
15	Fuel Filter / Water Separator
16	Electric Fuel Supply Pump
17	Fuel Filter
18	Fuel Filter Housing
19	Stop Solenoid*
20	Cold Start Device (CSD)**
21	Trochoid Fuel Pump

* : Not used for electronically controlled engines.

** : Electronically controlled engines are equipped with a solenoid valve. As shown in the following figure, electronically controlled engines use an electronically controlled governor combined with a solenoid valve (CSD), rack actuator, engine speed sensor, and other parts.

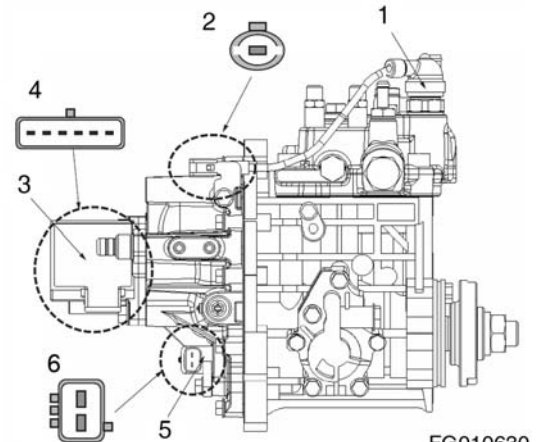


Figure 249

Fuel Injection Pump

Removal of Fuel Injection Pump

1. Loosen the cooling fan V-belt.
2. Remove the engine coolant fan guard (if equipped), engine coolant fan (2, Figure 250), spacer (3, Figure 250) if equipped, V-pulley (4, Figure 250) and cooling fan V-belt (1, Figure 250).
3. Close any fuel valves in the fuel supply line.
4. Place a drain pan under the fuel injection pump to catch any spillage.

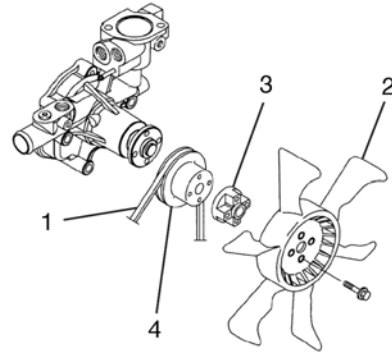


Figure 250

FG008977

5. Remove the high-pressure fuel injection lines as an assembly (1, Figure 251).

NOTE: To prevent "rounding" the fuel line nuts always use a "line" or "flare nut" wrench. When loosening the fuel line nuts, always hold the fuel injection pump delivery valves with a "back up" wrench to prevent loosening of the delivery valves.

6. First loosen the fuel line nuts at the fuel injectors and then at the fuel injection pump.

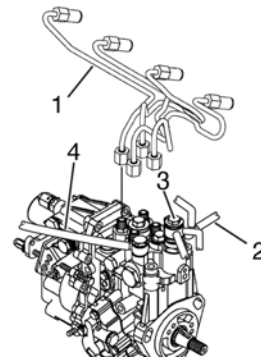


Figure 251

FG008978



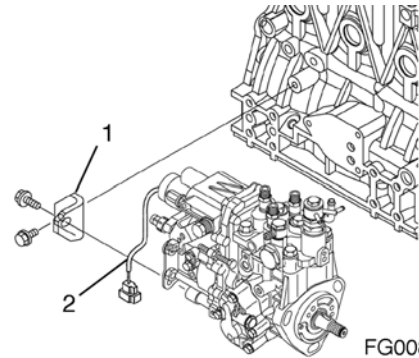
CAUTION

Remove or install the high - pressure fuel injection lines as an assembly whenever possible. Disassembling the high - pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

7. Finish loosening all the fuel line nuts and remove the high-pressure fuel lines as an assembly being careful not to bend any of the fuel lines. Be sure to protect the fuel system from contamination by covering all open connections.
8. Disconnect the coolant lines from the cold start device (3, Figure 251) on the fuel injection pump. Plug the open ends of the lines to minimize leakage and prevent contamination.
This cooling water pipe is not used in electronically controlled engines 4TNV98-E.
9. Disconnect the fuel return lines from the fuel return fitting (2, Figure 251). Plug the open ends of the lines to minimize leakage and prevent contamination.
10. Remove the fuel supply line (4, Figure 251). Plug the open end of the line to minimize leakage and prevent contamination.

11. Remove the throttle cable from the fuel injection pump.
12. Separate the stop solenoid wiring connector (2, Figure 252).
13. Remove the rear fuel injection pump bracket(s) (1, Figure 252) from the fuel injection pump.

NOTE: *Configuration of the fuel injection pump rear brackets may vary depending upon engine model.*



FG008979

Figure 252

14. Disconnect the lube oil line (1, Figure 253) and the clamp (2, Figure 253) from the pump.



IMPORTANT

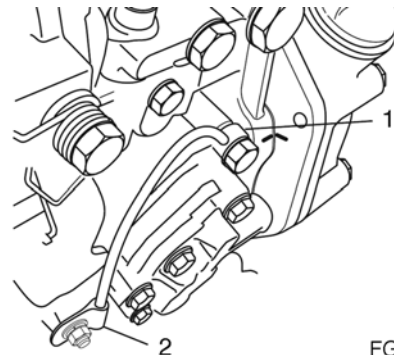
Take care to not damage or bend the oil line. In some applications, it may be preferable to remove the complete oil line assembly from the engine before proceeding.

NOTE: *On model 4TNV98-E, the cover is larger and retained by 7 bolts.*

15. Remove the fuel injection pump drive gear cover (1, Figure 254) from the gear case cover (2, Figure 254).

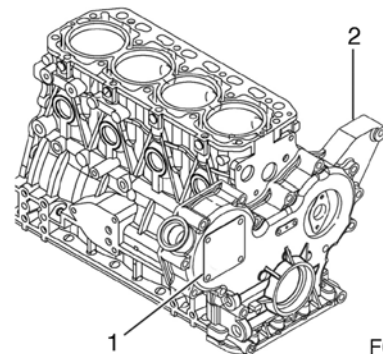
NOTE: *The fuel injection pump drive gear cover is secured with an adhesive sealant. Use a gasket scraper to separate the fuel injection pump cover from the gear case cover.*

16. To position the fuel injection pump for easier removal and installation, install a dial indicator (See "Checking and Adjusting Fuel Injection Timing" on page -189) into the injection pump plunger opening. Using a wrench on the crankshaft pulley bolt, rotate the crankshaft until the dial indicator shows that injection pump plunger is at the bottom of it's stroke.
17. To aid in reassembly, make reference marks on the fuel injection pump drive gear, and on either the gear case cover or idler gear.



FG008980

Figure 253



FG008981

Figure 254



CAUTION

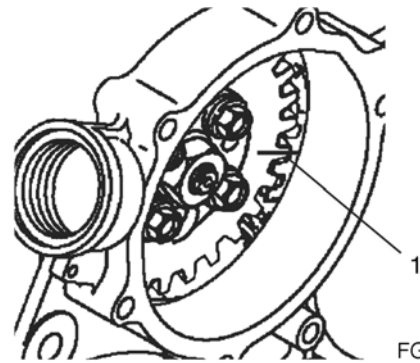
After marking the position of the pump drive gear, do not rotate the engine crankshaft. Rotating the crankshaft will cause the fuel injection pump to become misaligned.

- The idler gear is visible. Make a reference mark (1, Figure 255) across both the fuel injection pump drive gear and the idler gear.



CAUTION

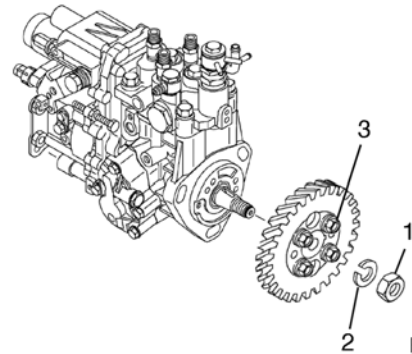
Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub. Correct fuel injection timing will be very difficult or impossible to achieve.



FG008983

Figure 255

18. Do not loosen or remove the four bolts (3, Figure 256) retaining the pump drive gear to the hub. Only remove the single drive gear nut (1, Figure 256) and washer (2, Figure 256), leaving the hub attached to the gear.
19. Hold the gear train using a large socket wrench on the crankshaft pulley nut. Loosen the fuel injection pump drive gear retaining nut (1, Figure 256) and turn it out to the end of the fuel injection pump shaft.



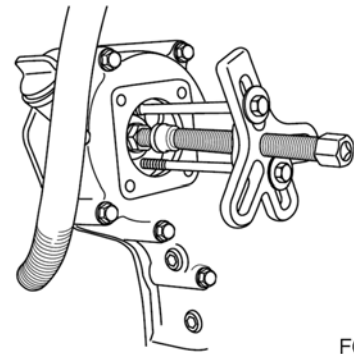
FG008984

Figure 256

20. Remove the pump drive gear and hub as an assembly using an appropriate two-bolt gear puller (Figure 257).

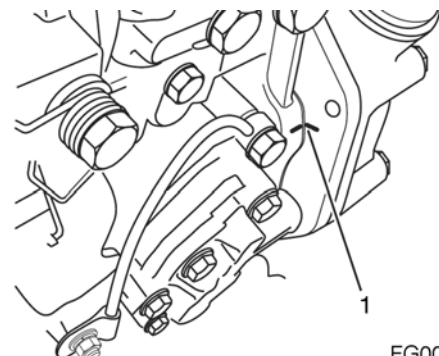
NOTE: *On TNV82 - 88 models the injection pump drive gear will remain "captured" in the gear case. On TNV94 - 106 models, the injection pump drive gear can be removed through the gear case cover opening.*

21. Once the fuel injection pump drive gear and hub assembly has "popped" loose from the tapered fuel injection pump drive shaft, carefully remove the drive gear nut (1, Figure 256) and lock washer (2, Figure 256).
22. Locate the mark stamped into the upper outside mounting boss of the fuel injection pump. Highlight this mark and make a corresponding mark on the gear case or front plate (1, Figure 258).



FG008985

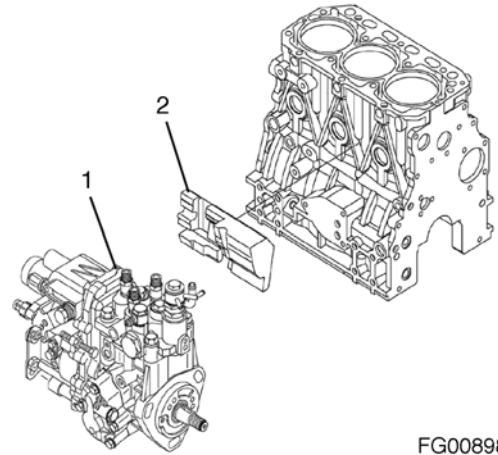
Figure 257



FG008986

Figure 258

NOTE: Some model engines may require the intake manifold and fuel injection pump insulator (2, Figure 259) be removed to access the inner fuel injection pump (1, Figure 259) retaining nuts.



FG008987

Figure 259

23. If required, remove the intake manifold and fuel pump insulator to access the fuel injection pump mounting nuts.

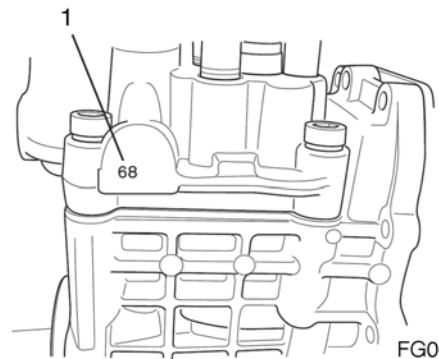
NOTE: The MP4 fuel injection pumps (TNV94 -Z model engines) are fastened to the gear case with four (4) studs and nuts.

24. Remove the fuel injection pump (1, Figure 260). For purposes of future injection timing purposes, record the fuel injection pump timing index number located on the boss on the engine side (back) of the of the fuel injection pump (1, Figure 260).



CAUTION

Do not rotate the crankshaft with the injection pump removed.



FG008988

Figure 260

25. If the fuel injection pump requires servicing, it must be sent to an authorized DOOSAN after sales service for repair and calibration, or replaced with a new fuel injection pump.



CAUTION

Never remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

Never attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations and then replace the tamper-proof seals.

Installation of Fuel Injection Pump

for electronically controlled engine



WARNING

Replacing the fuel injection pump involves rewriting the fuel injection data in the E-ECU.

Be sure to contact your local DOOSAN dealer before replacing the fuel injection pump.

Failure to rewrite the fuel injection data before replacing the fuel injection pump will void the engine warranty.

Improper use or misuse of the E-ECU may result in death or serious injury due to an abrupt and unexpected increase in engine speed.



IMPORTANT

If installing a new or recalibrated fuel injection pump, locate and record the timing index number located on the pump housing boss on the engine side of the new or recalibrated fuel injection pump (1, Figure 261). This number will be used to calculate and adjust the final fuel injection timing.

NOTE: If either or both of the fuel injection pumps do not have a timing index number, note the injection pump ID (example: XK42) on the injection pump ID label.

If additional assistance is needed in locating the engine timing index number and follow the instructions to locate an authorized DOOSAN industrial engine dealer or distributor for assistance.

NOTE: Treat the timing index number as if it has a decimal point (68 = 6.8).

1. Align the pump drive gear with the idler gear using the reference marks made earlier.

TNV82 -88 model engines (1, Figure 262).

TNV94 -106 model engines (1, Figure 263).

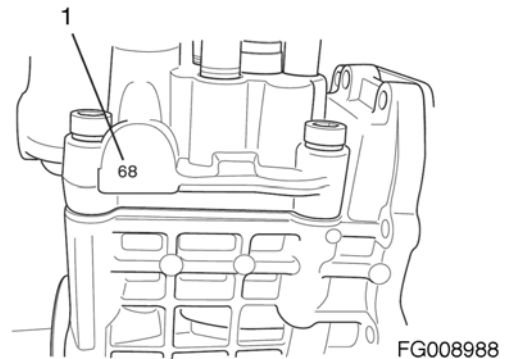


Figure 261

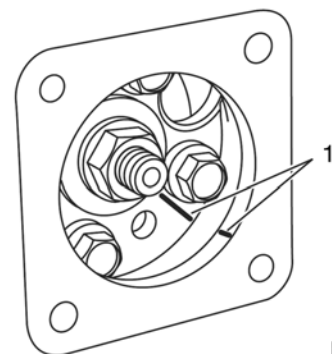


Figure 262

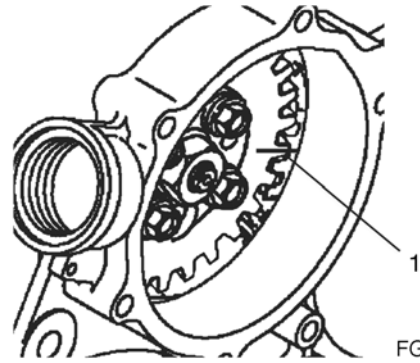


Figure 263

FG008983

2. If installing the fuel injection pump on an engine with the front gear case cover removed, the fuel injection pump drive gear can be aligned with the idler gear by aligning the stamped marks (A, B, C) on the fuel injection pump drive gear, idler gear, and crankshaft drive gear. Ensure all three timing marks (A, B, C, Figure 264) are aligned.

Reference Number	Description
1	Fuel Injection Pump Drive Gear
2	Camshaft Drive Gear
3	Auxiliary Drive Gear (Optional)
4	Crankshaft Drive Gear
5	Direction of Rotation
6	Oil Pump Drive Gear
7	Idler Gear

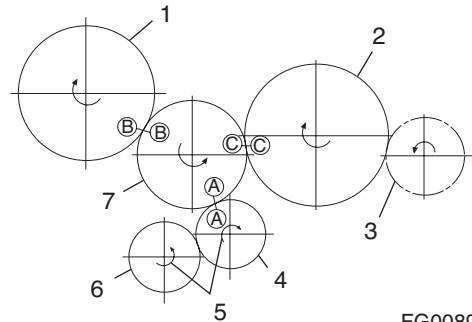


Figure 264

FG008920

3. Install a new O-ring on the pump mounting flange. Apply grease to the O-ring to hold it in place during installation of the injection pump.

NOTE: *Ensure the tapered surface of the fuel injection pump shaft is clean and dry.*

4. Align the key on the fuel injection pump shaft with the keyway in the fuel injection pump drive gear hub. Reinstall the fuel injection pump into the fuel injection pump drive gear and gear housing. Reinstall the pump retaining nuts finger tight.
5. Reinstall the fuel injection pump drive gear lock washer (2, Figure 265) and nut (1, Figure 265). Do not lubricate the threads of the nut or shaft. Hold the crankshaft pulley bolt with a socket wrench and tighten the drive gear nut to the specified torque. See "Special Torque Chart" on page -174

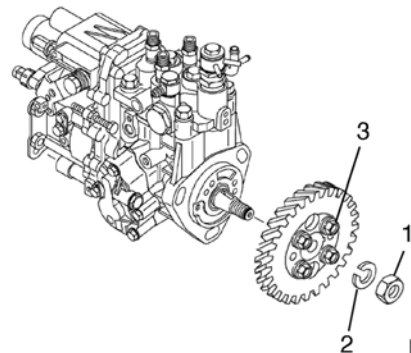
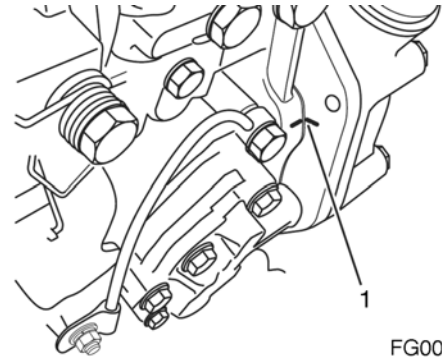


Figure 265

FG008984

If reinstalling the original fuel injection pump:

- Align the reference marks (1, Figure 266) previously made on both the fuel injection pump mounting flange and gear case or front plate.
- Tighten the fuel injection pump retaining nuts to specification. See "Special Torque Chart" on page -174

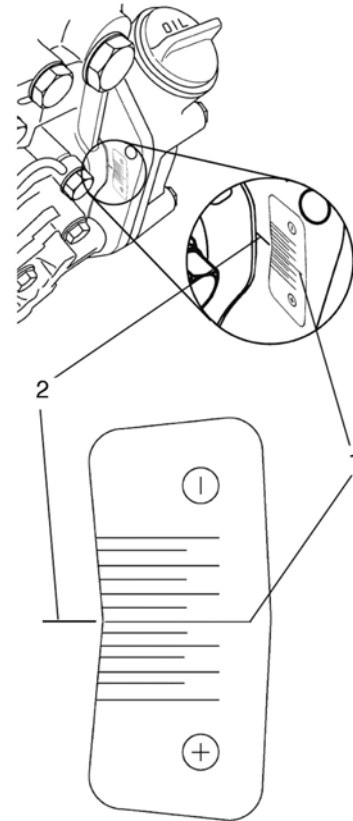


FG008986

Figure 266

If installing a new fuel injection pump:

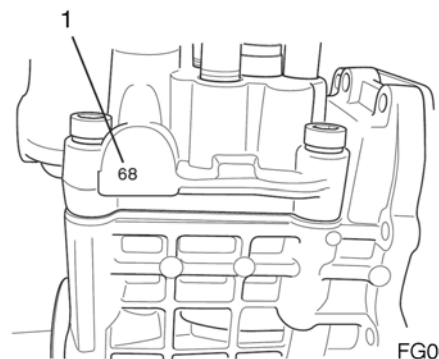
- Reinstall the timing grid sticker, provided with the new fuel injection pump, onto the back of the gear case / front plate (Figure 267). Align the "standard mark" (1, Figure 267) with the reference mark (2, Figure 267) made on the gear case during disassembly.



FG008990

Figure 267

- Calculate the difference between the timing index numbers (1, Figure 267) of the fuel injection pump that you removed and the replacement fuel injection pump. See Calculation Example below.



FG008988

Figure 268

Adjusting the fuel injection timing to compensate for the difference in pump timing index numbers:

Calculation Example

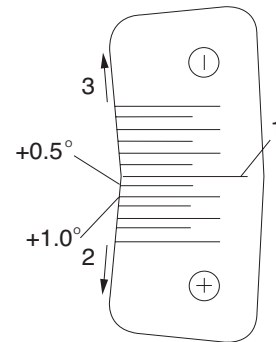
Timing Index Number	
Original injection pump=	6.8
Replacement injection pump=	7.3
Difference=	+0.5

- If the difference between the timing index numbers is a positive number, the fuel injection pump mounting position must be advanced (2, Figure 269) (rotated away from the engine) as compared to the "standard mark" (1, Figure 269) by the calculated positive amount, adjust the fuel injection pump to the calculated value.
- If the difference between the timing index numbers is a negative number, the replacement injection pump must be retarded (3, Figure 269) (rotated toward the engine) by the calculated negative amount.
- Each mark on the timing sticker represents 0.5° timing change.

The above calculated difference indicates that the replacement fuel injection pump is to be installed at +0.5° (advanced) from the "Standard Mark" (1, Figure 269) on the timing sticker.

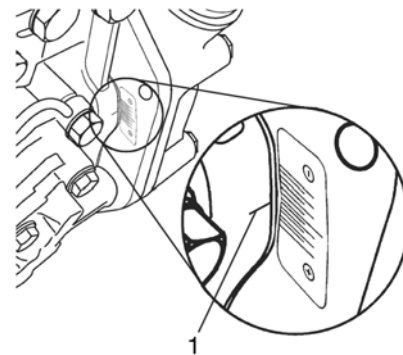
In this case, rotate the top of the fuel injection pump away from the cylinder block until the mark on the outside upper mounting boss (1, Figure 270) of the fuel injection pump aligns with the +0.5° mark on the timing sticker.

Tighten the fuel injection pump mounting nuts to specification. See "Special Torque Chart" on page -174



FG008991

Figure 269

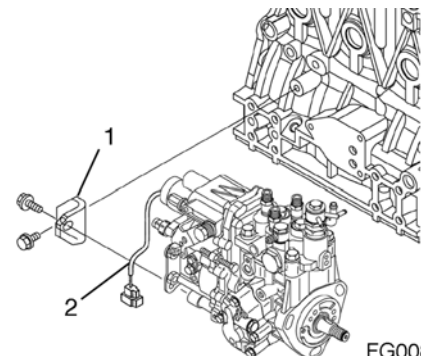


FG008992

Figure 270

- Reinstall the rear bracket(s) (1, Figure 271) to the fuel injection pump. Tighten the rear support bolts.

NOTE: Configuration of the fuel injection pump rear brackets may vary depending on the model.



FG008979

Figure 271

7. Reconnect the throttle linkage and the stop solenoid connector (2, Figure 272).
8. Reconnect the lube oil line (1, Figure 272) and clamp (2, Figure 272).
9. Apply ThreeBond Liquid Gasket or equivalent sealant to the sealing surface of the pump cover. Install the pump cover and tighten the cover bolts.
10. Reconnect the fuel return lines, fuel supply line and coolant lines to the fuel injection pump.
11. Reinstall the fuel injection high-pressure lines. Tighten the nuts to specification. See "Special Torque Chart" on page -174

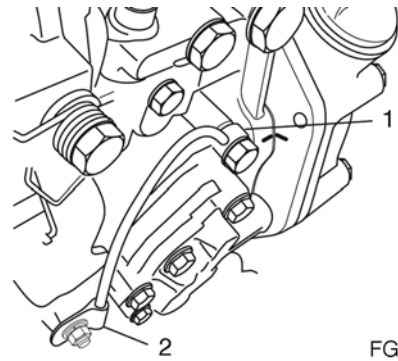


Figure 272

FG008980



IMPORTANT

When reinstalling a new or repaired fuel injection pump, it is important to add engine oil to the fuel injection pump to provide lubrication for initial start-up. Add 5-7 oz (150-200 cc) of clean engine oil to the fuel injection pump at the fill plug located in the upper outside section of the governor housing.

12. If equipped, verify the fuel injection pump insulator (2, Figure 273) is not damaged. Reinstall the insulator and intake manifold if previously removed.

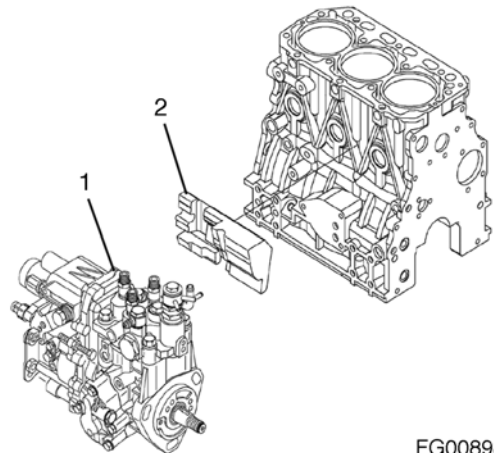


Figure 273

FG008987

13. Reinstall the coolant pump V-pulley (4, Figure 274), spacer (3, Figure 274) (if equipped) and engine coolant fan (2, Figure 274).
14. Reinstall the cooling fan V-belt (1, Figure 274). Adjust it as described in Check and adjust Cooling Fan V-belt on page 5-21.
15. Reinstall the cooling fan guard (if equipped).
16. Prime the fuel system. See "" on page -40
17. Operate the engine and check for fuel and coolant leaks.

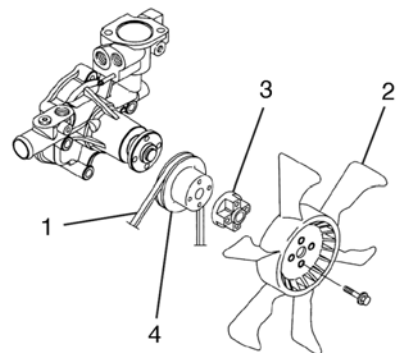


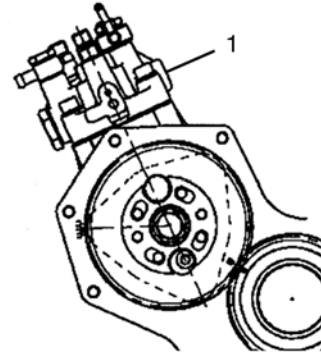
Figure 274

FG008977

Checking and Adjusting Fuel Injection Timing

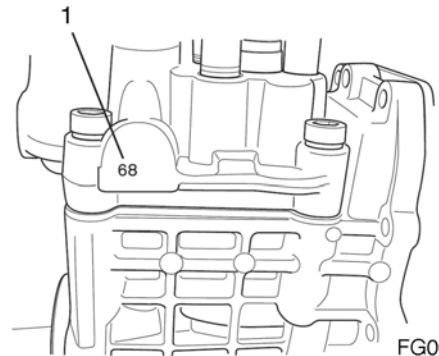
Determining the Fuel Injection Timing Specification

1. Locate and record the fuel injection pump timing index number (1, Figure 276) stamped into the boss on the engine side of the fuel injection pump housing (1, Figure 275). Treat this number as though there is a decimal point between the two digits. i.e. 68 = 6.8



FG008993

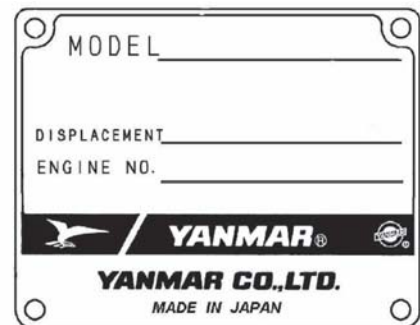
Figure 275



FG008988

Figure 276

2. The engine model number of this machine is 4TNV98 EPDBW
 - The FIR number for this engine is 4.
 - (Fuel Injection Pump Timing Index Number X 2) + FIR Number = FIT° (Fuel injection Timing in Degrees)
(6.8 X 2) = 13.6 + 4 = 17.6° Fuel injection Timing
 - Record the calculated fuel injection timing specification.



FG010659

Figure 277

Checking Fuel Injection Timing

NOTE: *Some fuel may drain from the fuel injection pump during this process. Make provisions to contain any such spillage.*

1. Turn off the fuel valve in the fuel supply hose and the fuel return hose.
2. Clamp shut the fuel injection pump fuel return hose leading to fuel filter (1, Figure 278).



IMPORTANT

Clean the top of the fuel injection pump to prevent any contamination when the fuel injection pump plunger plug (2, Figure 278) is removed.

3. Remove the forward fuel injection pump plunger plug (2, Figure 278) on the top of the fuel injection pump.
4. Install a dial indicator adapter and clamp into the pump plunger opening.

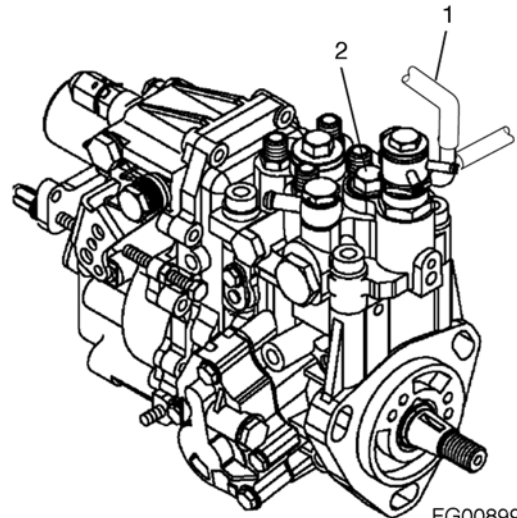


Figure 278

NOTE: *Use the M16 adapter used on the MP4 fuel injection pumps and plunger adapter clamp (1, Figure 279).*

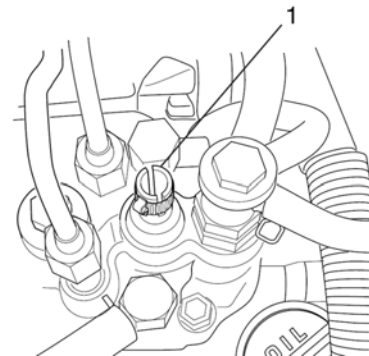


Figure 279

5. Install a dial indicator (1, Figure 280), Mitutoyo or equivalent, with a 30 mm extension, into the adapter. Secure with the plunger adapter clamp (1, Figure 279) at approximately the mid-point of its travel.

NOTE: *Note: The following references to the direction-of-rotation are facing the coolant pump end of the engine and are adjusted by turning the crankshaft pulley.*

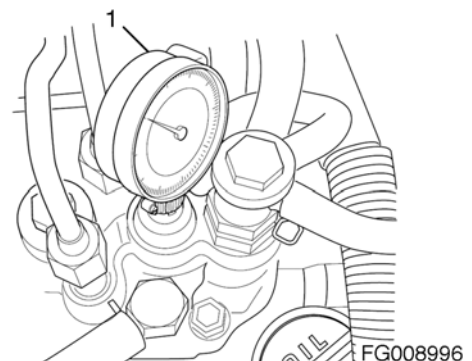


Figure 280

6. Using a wrench on the crankshaft pulley bolt, rotate the crankshaft in a clockwise direction while looking through the flywheel inspection port (1, Figure 281). Rotate the crankshaft until the injection timing marks on the flywheel are visible.

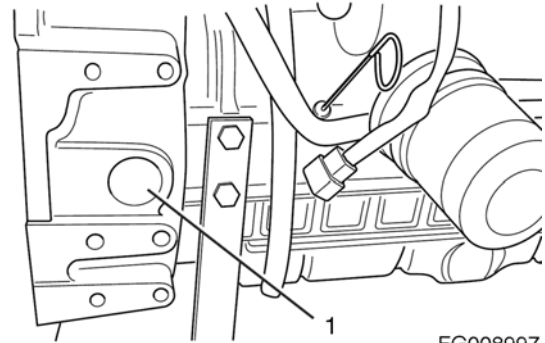


Figure 281

FG008997

7. Typical flywheel markings are as shown in (1, Figure 282).

NOTE: *A typical flywheel will have multiple timing grids depending on the number of cylinders. Any grid can be used to check the fuel injection timing.*

The flywheel shown in Figure 282 is for a "Standard Specification" DI engine. Flywheels used on some "OEM Specific" DI engines may be marked differently. You should contact that specific OEM for information on the identification of the timing marks.

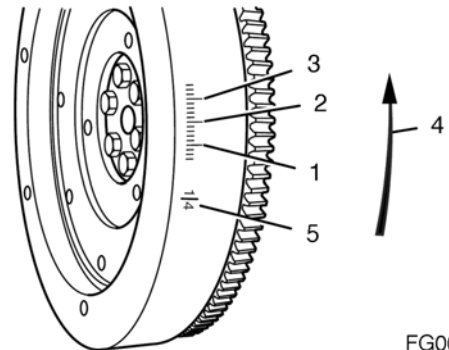


Figure 282

FG009010

Reference Number	Description
1	10° BTDC (Before Top Dead Center)
2	15° BTDC
3	20° BTDC
4	Direction of Rotation
5	TDC (Top Dead Center)

NOTE: *The TDC (Top Dead Center) mark can be identified by the cylinder numbers stamped near the TDC mark on the flywheel.*

If you are uncertain as to the timing degree designation of the timing marks on the flywheel timing grid, you can determine the timing degree designation by measuring the timing grid.

- First measure the distance between two of the "longer" marks on the timing grid. (They are 5° apart.) Then measure the distance from the TDC mark to the first "longer" mark on the timing grid. Divide that measurement by the distance between the two "longer" marks. The resulting answer will tell you how many degrees there are between the TDC mark and the first "longer" mark.

- **EXAMPLE:** If the distance between the two "longer" marks is approximately 2.0 cm and the distance from the TDC mark is approximately 4.0 cm, the answer is approximately 2. This indicates there is 10° (2 x 5°) between the TDC mark and the first "longer" mark on the timing grid. That means the first "longer" mark on the timing grid indicates 10° BTDC, the second "longer" mark indicates 15° BTDC and the third timing mark indicates 20° BTDC. If the answer is 3, that indicates there is 15° (3 x 5°) between the TDC mark and the first "longer" mark and that the first "longer" mark indicates 15° BTDC with the second and third "longer" marks indicating 20° BTDC and 25° BTDC respectively.

8. Highlight the timing reference mark (2, Figure 283) on the flywheel housing or engine back plate (2, Figure 284). Highlight the TDC (Top Dead Center) mark (1, Figure 283) on the flywheel.

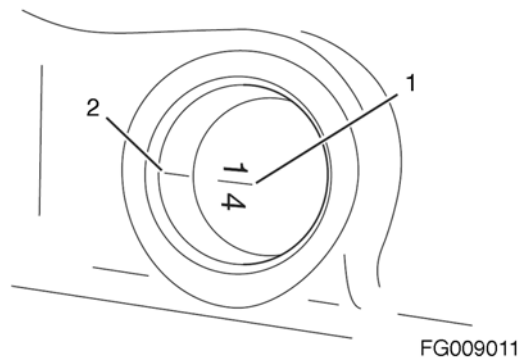


Figure 283

9. Highlight the target timing mark (1, Figure 284) on the flywheel as calculated in Determining the Fuel Injection Timing Specification on page 7-26.
10. Rotate the crankshaft counter-clockwise until the dial indicator shows that the injection pump plunger is at the bottom of its stroke. Rock the crankshaft back and forth slightly to confirm a point where the dial indicator shows no movement. Zero the dial indicator.
11. Slowly rotate the crankshaft clockwise until the dial indicator shows a pump plunger lift of 2.5 mm (0.098 in.).
12. Check the position of the flywheel target timing mark (1, Figure 284) in relation to the timing reference mark (2, Figure 284) on the flywheel housing or engine back plate. If the two marks are aligned, the fuel injection timing is correct. If the marks do not align, the fuel injection timing must be adjusted. See "Adjusting Fuel Injection Timing" on page -193
13. If the injection timing is correct, remove the dial indicator and adapter. Replace the pump plunger plug and its copper gasket and tighten to specifications. Replace the flywheel inspection port cover. Open the fuel supply valve and remove the clamp from the fuel supply hose and the fuel return hose.
14. Prime the fuel system. Operate the engine and check for leaks.

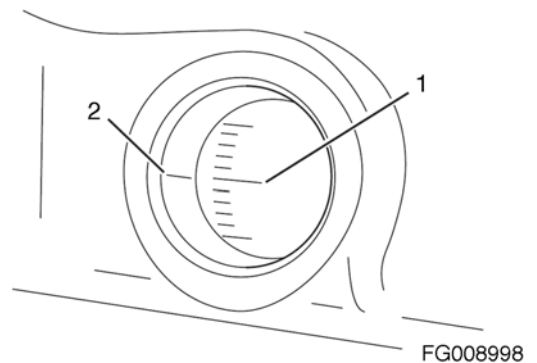
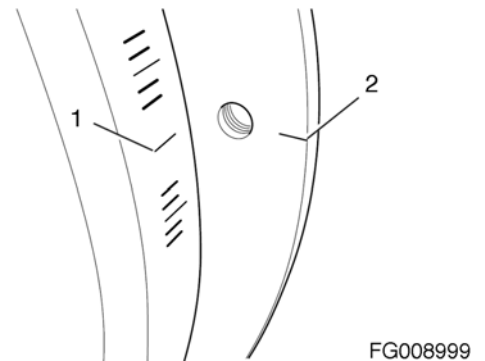


Figure 284



Adjusting Fuel Injection Timing

If the timing marks did not align when performing the Checking Fuel Injection Timing on page 7-27, the following steps must be performed to properly time the engine.

1. Leave the dial indicator installed in the fuel injection pump. Do not disturb the reading on the dial indicator.
2. Rotate the flywheel until the target timing mark (1, Figure 285) and the timing reference mark (2, Figure 285) on the flywheel housing or back plate are aligned.



IMPORTANT

Do not rotate the crankshaft during the remainder of this procedure.

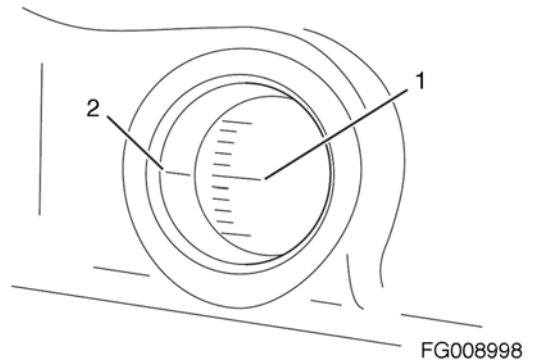


Figure 285

3. Note the reading on the dial indicator (1, Figure 286). If the reading is less than 2.5 mm (0.098 in.), the fuel injection timing is "retarded". If the dial indicator reading is greater and than 2.5 mm (0.098 in.), the fuel injection timing is "advanced".

NOTE: *Some model engines require the intake manifold and fuel injection pump insulator be removed to access the inner fuel injection pump retaining nuts.*

4. Loosen the nuts fastening the fuel injection pump to the gear case or front plate. Loosen the rear bracket(s) on the fuel injection pump.

NOTE: *Loosening the high-pressure injection line nuts on the fuel injection pump may make rotating the pump easier.*

5. Rotate the fuel injection pump until the dial indicator reads 2.5 mm (0.098 in.).
6. To "advance" the injection timing, rotate the top of the fuel injection pump away from the engine.
7. To "retard" the injection timing, rotate the top of the fuel injection pump toward the engine.
8. When the dial indicator reads 2.5 mm (0.098 in.) of pump plunger lift and the target timing mark on the flywheel aligns with the reference mark on the flywheel housing or engine back plate, the injection timing is correct.
9. Tighten the fuel injection pump mounting nuts and rear bracket(s).
10. Remove the dial indicator and adapter. Replace the plug in the pump plunger opening and tighten it to specification. If removed, install the intake manifold and pump insulator. Tighten the high-pressure injection line nuts to specification. Open the fuel supply valve, remove the clamp from the fuel return line and prime the fuel system. Operate the engine and check it for leaks.

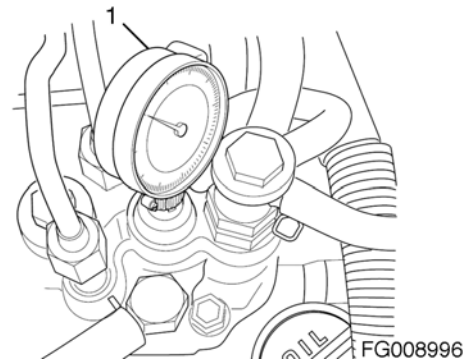


Figure 286

Fuel Injectors

Removal of Fuel Injectors

4-Valve Cylinder Head

1. Close any fuel valves in the fuel supply line.
2. Remove the valve cover.
3. Remove the injector return line (1, Figure 287). Be careful not to bend the line.
4. Remove the fuel injector mounting clamp bolts (2, Figure 287). Lift the injector mounting clamps (3, Figure 287) away from injector.
5. Remove the fuel injector (4, Figure 287) from the cylinder head.

NOTE: *The fuel injectors can be removed by manually pulling them out of the fuel injector wells.*

6. Remove the injector nozzle protector (5, Figure 287) and seat (6, Figure 287) from the cylinder head. Discard both items.
7. Repeat steps to remove the remaining fuel injectors.

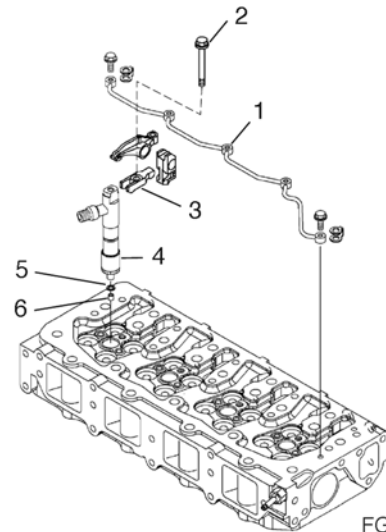


Figure 287

Testing of Fuel Injectors



CAUTION

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Thoroughly clean the fuel injector nozzle using clean diesel fuel and a brass wire brush.
2. Visually inspect the fuel injectors and nozzle protectors for deposits or damage. Clean, repair or replace as necessary.

NOTE: *Test the fuel injector using an injection nozzle tester. Operate the tester following the information provided by the tester manufacturer. Use clean, filtered fuel or FIE calibration fluid for the test.*

3. Using the correct adapter, connect a fuel injector to a nozzle tester. Aim the fuel injector into a suitable container to catch the fuel spray.



CAUTION

Never inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.

Never inject fuel toward a fire source. Atomized fuel is highly flammable and may cause a fire or burn skin.



CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

4. Pump the operating lever of the tester slowly, observing the pressure reading at the point where the fuel injector begins spraying fuel (Figure 289). Figure 294 for injector ID location. See "Fuel System Specifications" on page -174 for correct pressure readings.

NOTE: *The opening pressure of a new fuel injector will be approximately 725 psi (5 MPa; 51 kgf/cm²) higher than one that has been operated for five hours or longer.*

5. Pump the operating lever slowly to hold the pressure steady at a point just below the opening pressure and hold it for 5 seconds. Observe the injector to see that it is sealing properly and is not "dripping". If fuel leaks from the return line fitting, check that the nozzle case nut is tight. Service or replace the injector if fuel continues to leak from either the return line fitting or nozzle.
6. Pump the operating lever more rapidly to repeatedly "pop" the injector and observe the spray pattern. The pattern should be a very fine uniform spray (Figure 290). If a dripping or an uneven pattern is seen (Figure 291), service or replace the injector.

If the fuel injector fails any of these tests, it should be serviced or replaced as necessary. If the pressure is outside specified limits, adjust the pressure. See "Adjusting Fuel Injector Pressure" on page -198

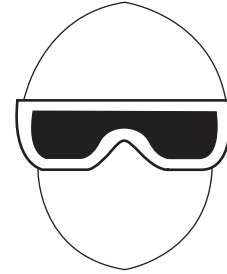


Figure 288

FG009152

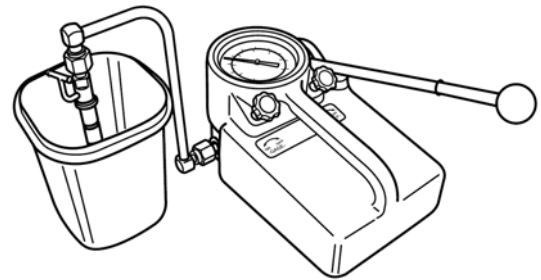


Figure 289

FG008971

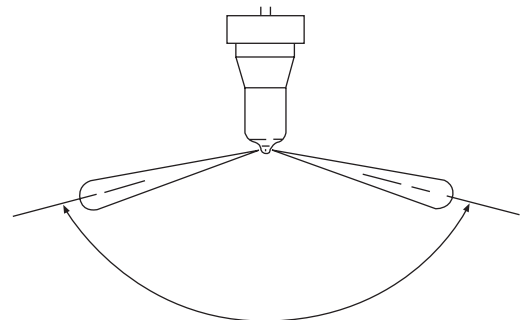


Figure 290

FG009004

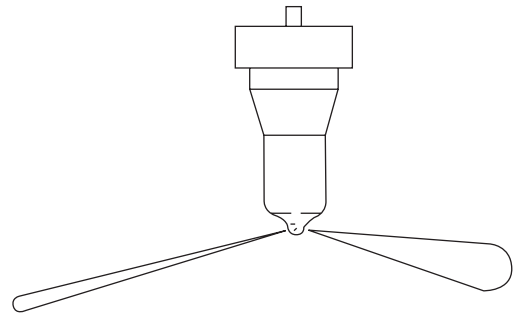


Figure 291

FG009005

Disassembly and Inspection of Fuel Injectors



CAUTION

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Clean carbon from used injectors using clean diesel fuel. Hardened deposits or varnish can be cleaned using a brass wire brush.
2. Place the fuel injector in a soft-jawed vise with the nozzle pointing up.
3. Remove the nozzle case nut.
4. Carefully remove the injector from the vise.
5. Turn the injector over and remove the nozzle body, nozzle valve, valve stop spacer, nozzle spring seat, nozzle spring, and shims.
6. Inspect the sealing surfaces (2, Figure 292) between the valve stop spacer and nozzle body for nicks or scratches. Check the contact area between the valve stop spacer and the nozzle valve (1, Figure 292) for scoring, or pitting. Use a magnifier glass to inspect the area.

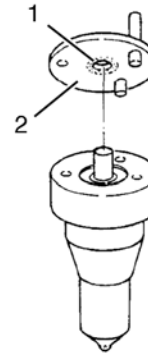


Figure 292

FG009007

7. Perform a nozzle valve slide test:
 - A. Wash nozzle body and valve in clean diesel fuel.
 - B. While holding the nozzle body vertical, pull the nozzle valve about 2/3 of the way out (Figure 293).
 - C. Release the valve. It should fall smoothly to its seat by it's own weight.
8. Replace the fuel injector assembly if it fails any inspection.

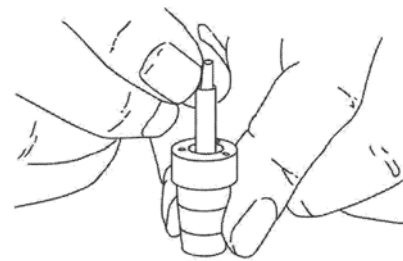


Figure 293

FG008244

Adjusting Fuel Injector Pressure

The fuel injectors open when pressure reaches a predetermined pressure threshold. They close when the pressure is reduced below that threshold. The pressure threshold can be adjusted by adding or removing shims (3, Figure 294).

Reference Number	Description
1	Fuel Return Passage
2	Injector ID Location
3	Injector Body
4	Pressure Adjusting Shims
5	Spring
6	Spring Seat
7	Valve Stop Spacer
8	Nozzle Valve
9	Nozzle Body
10	Nozzle Case Nut

The injection pressure will change by approximately 275 psi (1.9 MPa; 19 kgf/cm²) for every 0.1 mm (0.004 in.) in shim thickness.

See the parts catalog for available shims.

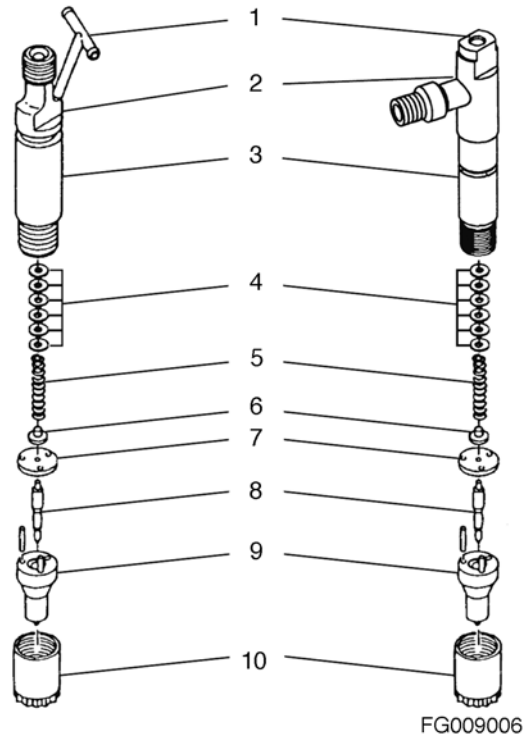


Figure 294



CAUTION

Each pressure adjusting shim removed or added changes the pressure threshold by approximately 275 psi (1.9 MPa, 19 kgf/cm²). Adding adjusting shims increases the threshold pressure. Removing adjusting shims reduces the pressure threshold.

1. Disassemble the fuel injector assembly. See "Disassembly and Inspection of Fuel Injectors" on page -197
2. Remove or add adjusting shims as needed.
3. Reassemble the fuel injector assembly. "Reassembly of Fuel Injectors" on page 1-199.
4. Retest the fuel injector. See "Testing of Fuel Injectors" on page -194. If the injector cannot be adjusted to the appropriate pressure, discard the fuel injector.

Reassembly of Fuel Injectors

1. Secure the injector in a soft-jawed vise with the nozzle end up.
2. Reinstall the shims, nozzle spring, nozzle spring seat, valve stop spacer, nozzle valve, and nozzle body.
3. Reinstall the nozzle case nut. Tighten it to specification. See "Special Torque Chart" on page -174

Installation of the Fuel Injectors

4-Valve Cylinder Head

1. Reinsert a new nozzle seat (6, Figure 295) and nozzle protector (5, Figure 295) in the cylinder head for each injector.
2. Reinstall a O-ring on to each injector body.
3. Reinsert each fuel injector (4, Figure 295) into the cylinder head.
4. Reinstall the fuel injector retainers (3, Figure 295) and torque the retaining bolts (2, Figure 295) to specification.
5. Reinstall the fuel injector return line assembly using new gaskets on each side of the injector line screws.
6. Reinstall the fuel high-pressure fuel lines to each injector and tighten the nuts using a "line" or "flare nut" wrench.
7. Prime the fuel system. See "Priming the Fuel System" on page -40
8. Operate the engine and check for fuel and coolant leaks.

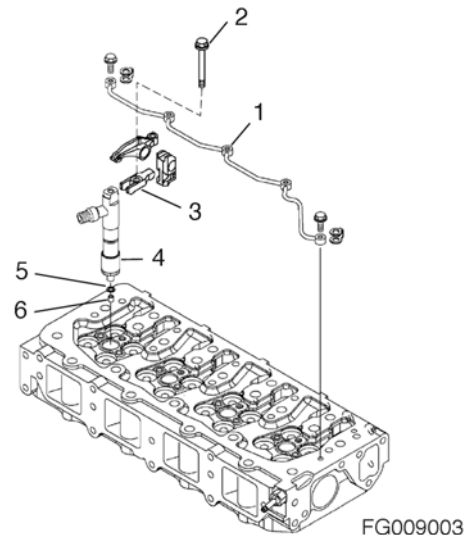
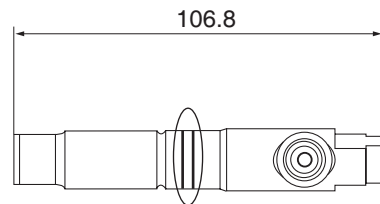


Figure 295

Fuel Injection System (for a Four-Valve Cylinder Head)

Fuel injection system (for a four-valve cylinder head) The fuel injection system for a four-valve cylinder head is different, not only in the nozzle valve specifications, but also in the nozzle holder specifications. Therefore, it is marked as follows; take care not to install a wrong part when replacing it with new one.

Identifying the fuel injector assembly



4TNV94-Z, -E Identification
groove : two

FG010631

Figure 296

COOLING SYSTEM

Before You Begin Servicing



DANGER

Scald Hazard!

Never Remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.

Always check the level of the engine coolant by observing the reserve tank.

Failure to comply will result in death or serious injury.



HAOA060L

Figure 297

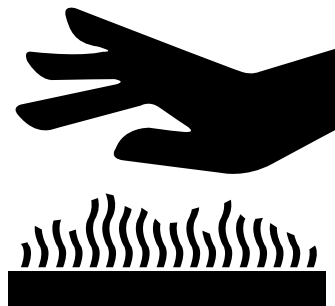


WARNING

Burn Hazard!

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 298



WARNING

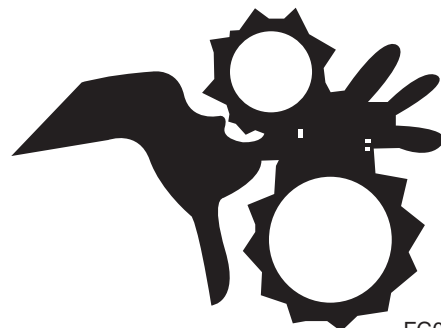
Entanglement Hazard!

Stop the engine before you begin to service it.

Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.

Failure to comply could result in death or serious injury.



FG009148

Figure 299



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.



FG009153

Figure 300



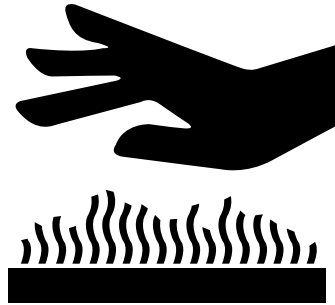
WARNING

Burn Hazard!

If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.

Always wear eye protection.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 301

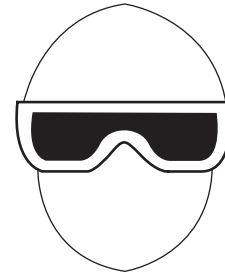


CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.



FG009152

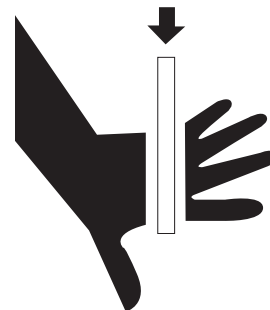
Figure 302



CAUTION

Pinch Hazard!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.



FG009155

Figure 303



CAUTION

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and / or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

NEVER mix different types of engine coolants. This may adversely affect the properties of the engine coolant.



CAUTION

If the engine coolant pump must be replaced, replace the engine coolant pump as an assembly only. Do not attempt to repair the engine coolant pump or replace individual components.



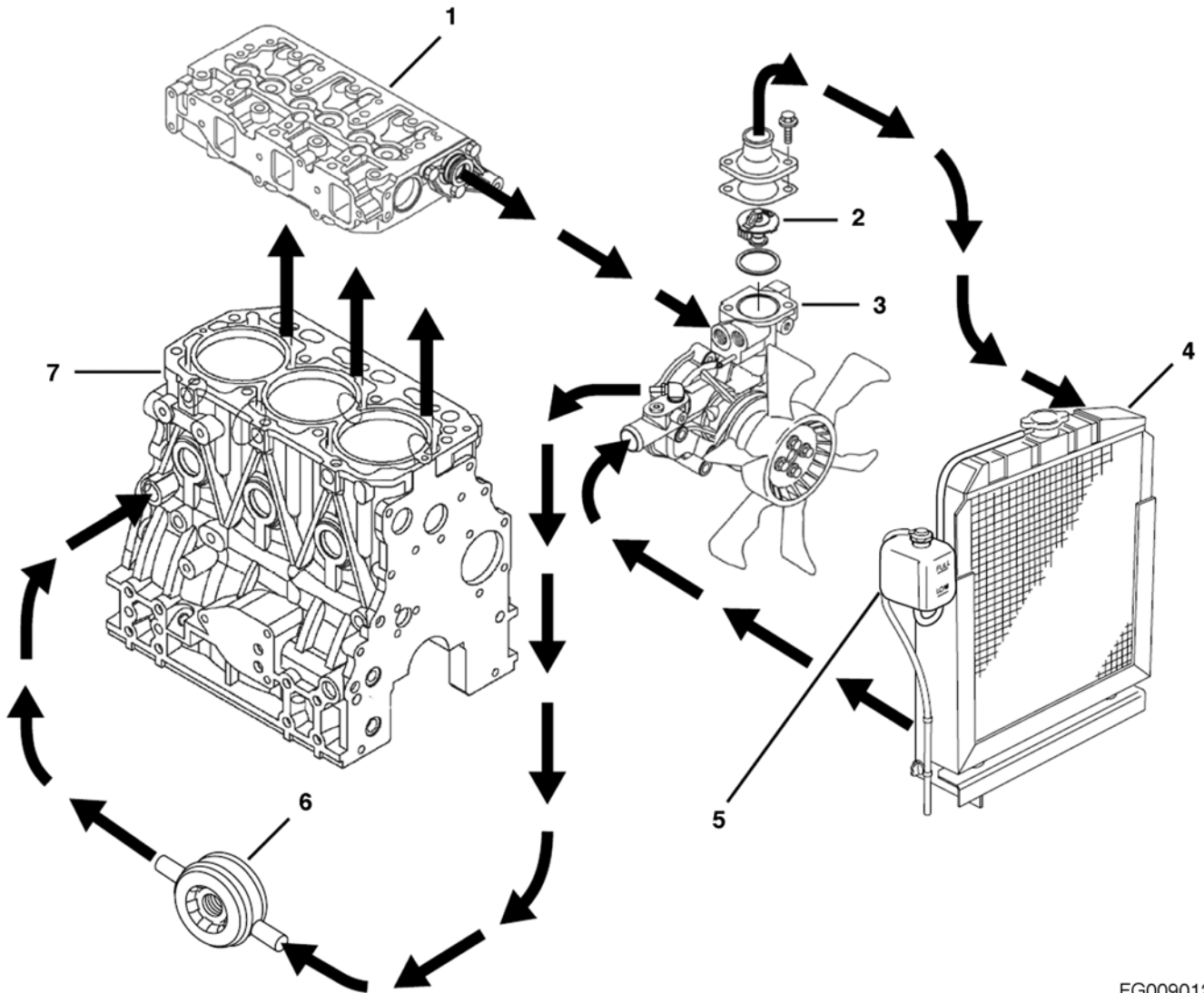
CAUTION

Use a new special O-ring between the engine coolant pump and the joint. Be sure to use the special O-ring for each engine model. Although the O-ring dimensions are the same as a commercially available O-ring, the material is different.

Introduction

This section of the Service Manual describes the procedures necessary to service the standard engine coolant pump. This engine coolant pump is representative of the coolant pumps used on other TNV model engines. For specific part detail, see the parts catalog for the engine you are working on.

Cooling System Diagram



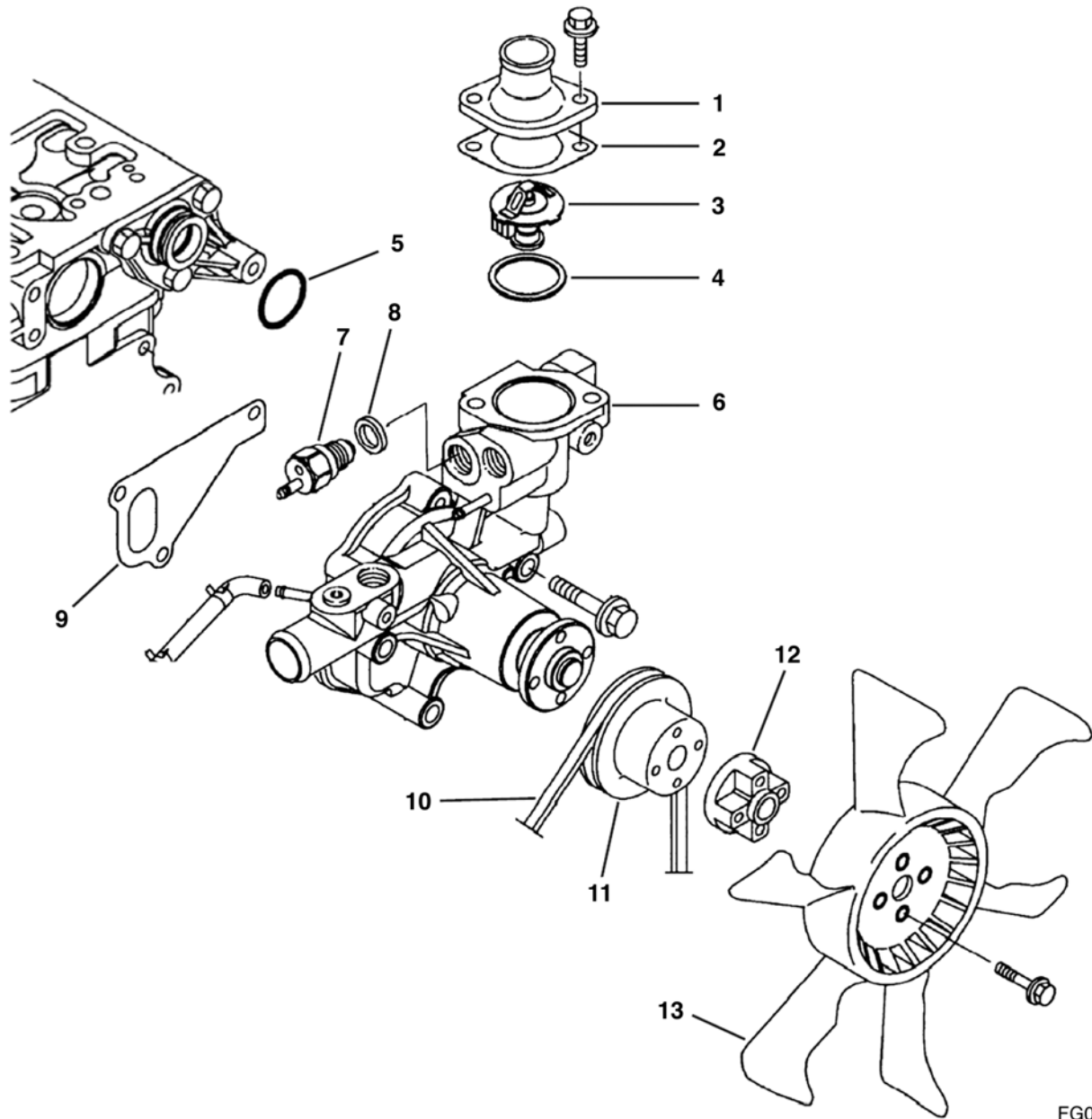
FG009012

Figure 304

Reference Number	Description
1	Cylinder Head
2	Thermostat
3	Engine Coolant Pump
4	Radiator

Reference Number	Description
5	Coolant Recovery Tank
6	Engine Oil Cooler*
7	Cylinder Block

Engine Coolant Pump Components



FG009013

Figure 305

Reference Number	Description
1	Thermostat Cover
2	Thermostat Cover Gasket
3	Thermostat
4	Thermostat O-Ring
5	Special O-Ring
6	Engine Coolant Pump
7	Temperature Switch

Reference Number	Description
8	Gasket
9	Engine Coolant Pump Gasket
10	V-Belt
11	Engine Coolant Pump V-Pulley
12	Spacer
13	Engine Coolant Fan

Engine Coolant System Check

Check the engine coolant system for leakage.

1. With the radiator properly filled, install a cooling system tester (1, Figure 306).
2. Apply 10.8 -14.8 psi (75 -105 kPa; 0.75 -1.05 kgf/cm²) to the cooling system. If the pressure reading drops, the engine coolant system is leaking. Identify the source of the leak and repair it.

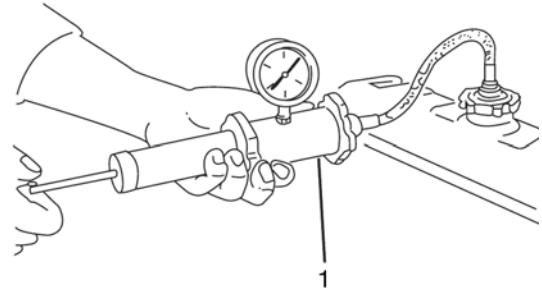


Figure 306

FG009021

Engine Coolant Pump

Removal of Engine Coolant Pump Verify the condition of the engine coolant pump before disassembling it from the engine. Check the engine coolant pump shaft bearing for abnormal noise, sticking, excessive play and water leakage. Replace the coolant pump if any of these conditions are present.



CAUTION

If the engine coolant pump must be replaced, replace the engine coolant pump as an assembly only. Do not attempt to repair the engine coolant pump or replace individual components.



IMPORTANT

Make sure the engine and engine coolant are not hot.

1. Before removing the engine coolant pump or thermostat, it will be necessary to drain the engine coolant. Drain the coolant into a clean container if the coolant is to be reused. Otherwise, properly dispose of the coolant.
2. Remove the radiator cap (1, Figure 307).
3. Remove the drain plug or open the drain cock (1, Figure 307) at the lower portion of the radiator and drain the coolant.

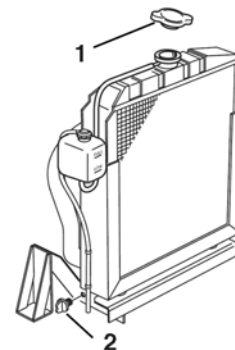


Figure 307

FG008869

4. Drain the coolant from the engine block.
 - On models equipped with an oil cooler, remove the coolant hose (1, Figure 308) at the oil cooler.
 - On models not equipped with an oil cooler, remove the coolant drain plug (1, Figure 309) from the engine block.

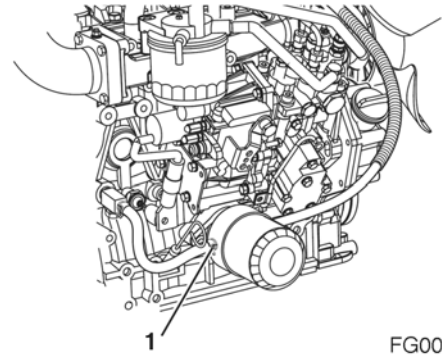


Figure 308

FG008853

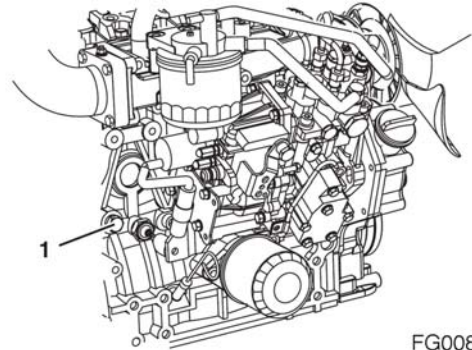


Figure 309

FG008852

5. Loosen the alternator mounting bolts. Loosen and remove the V-belt and rotate the alternator away from the engine and out of the way.



CAUTION

Pinch Hazard!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

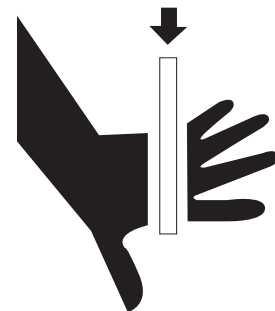


Figure 310

FG009155

6. Remove the engine coolant fan guard (if equipped), engine coolant fan (1, Figure 311), spacer (2, Figure 311) and engine coolant pump V-pulley (3, Figure 311).
7. Disconnect the coolant hoses and the temperature switch lead wire from the engine coolant pump.
8. Remove the engine coolant pump (4, Figure 311). Discard the gasket.

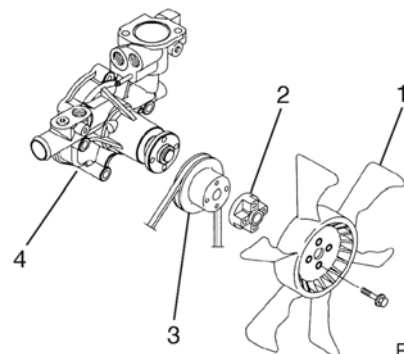


Figure 311

FG009022

Disassembly of Engine Coolant Pump

1. Remove the thermostat cover (1, Figure 312). Discard the gasket.
2. Remove the thermostat (2, Figure 312). Discard the O-ring. Remove the temperature switch (3, Figure 312) and gasket (4, Figure 312). Discard the gasket.

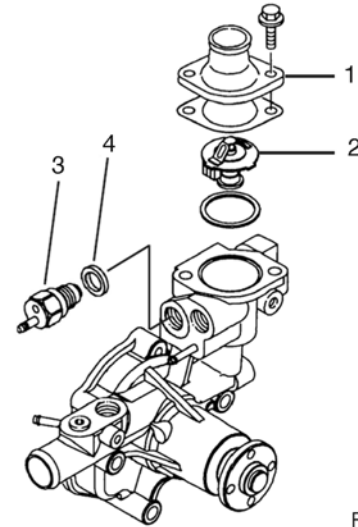


Figure 312

FG009023

Cleaning and Inspection

Temperature Switch

1. Check for proper operation of the temperature switch. Connect a continuity light or ohmmeter to the temperature switch. Connect one lead to the terminal of the switch (1, Figure 313) and the other lead to the metal portion of the switch (2, Figure 313).
2. Place the temperature switch and an accurate thermometer (3, Figure 313) in engine coolant.
3. Slowly increase temperature of the fluid using an external heat source.
4. The temperature switch is operating properly if the continuity light or ohmmeter indicates continuity when the fluid temperature reaches 225°F - 235°F (107°C - 113°C).

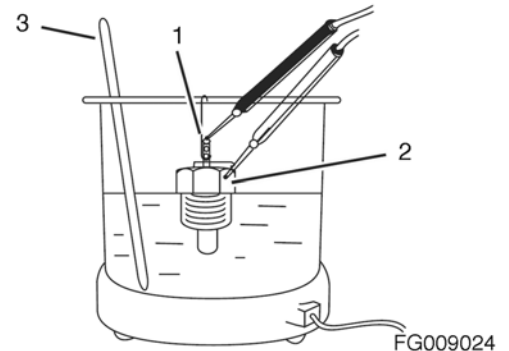


Figure 313

FG009024

Water Temperature Sensor

1. Inspect the water temperature sensor to make sure that it is properly operating. As shown in the following figure, connect an electric resistor to the coupler of the water temperature sensor (1, Figure 314).
2. Dip the water temperature sensor and an accurate thermometer (2, Figure 314) into the cooling water.
3. Measure the electric resistance value while slowly raising the cooling water temperature using an external heat source.
4. The resistance value at each of the following temperatures is within the permissible range specified, the water temperature sensor is correctly operating.

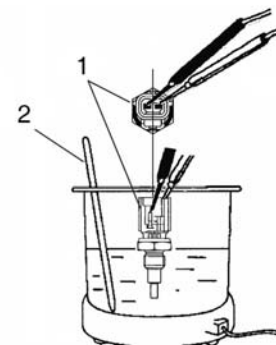


Figure 314

FG010632

Cooling water temperature (°C)	Resistance (kΩ)
20	$2.45^{+0.1}_4$
80	0.318 ± 0.008
0.008	(0.1836)

Thermostat

1. Check for proper operation of the thermostat. Place the thermostat (1, Figure 315) and an accurate thermometer (2, Figure 315) in warm water.
2. Slowly increase the temperature of the water using an external heat source.
3. The thermostat is operating properly if it starts to open at the temperature value stamped on the flange of the thermostat, and fully opens as the temperature of the water is increased.

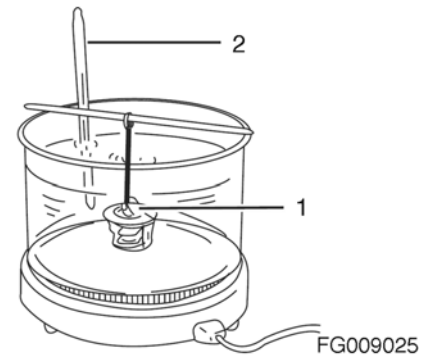


Figure 315

Radiator Cap

1. Check for proper operation of the radiator cap. Install the radiator cap (1, Figure 316) on a cooling system tester.
2. Apply 10.8 - 14.8 psi (75 - 105 kPa; 0.75 - 1.05 kgf/cm²) to the radiator cap. The radiator cap relief valve must open within the specified range.

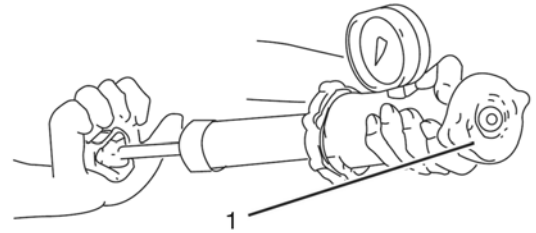


Figure 316

Reassembly of Engine Coolant Pump

1. Reinstall the thermostat (1, Figure 317) and a new O-ring.
2. Reinstall the thermostat cover (2, Figure 317) and a new gasket. Tighten the thermostat cover bolts.
3. Reinstall the temperature switch (3, Figure 317) and a new gasket (4, Figure 317)

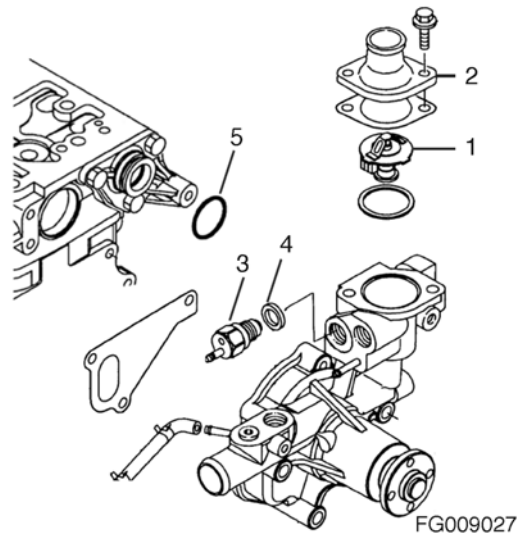


Figure 317

Installation of Engine Coolant Pump

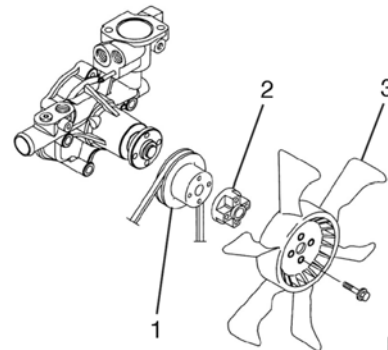
1. Position the engine coolant pump on the engine and install a new gasket. Install a new special O-ring (5, Figure 317) on assembly between the engine coolant pump and the joint.



CAUTION

Use a new special O-ring between the engine coolant pump and the joint. Be sure to use the special O-ring for each engine model. Although the O-ring dimensions are the same as a commercially available O-ring, the material is different.

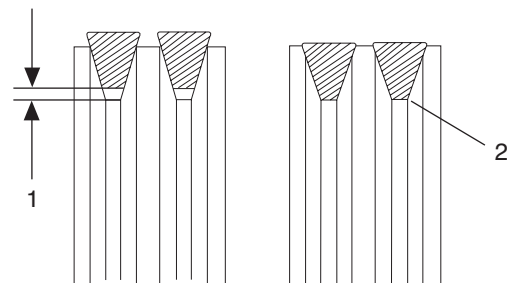
2. Reinstall the engine coolant pump bolts. Tighten the bolts.
3. Inspect and reinstall the coolant hoses and the temperature switch lead wire.
4. Reinstall the engine coolant pump V-pulley (1, Figure 318), spacer (2, Figure 318) engine coolant fan (3, Figure 318) and engine coolant fan guard (if equipped).



FG009028

Figure 318

5. Inspect the condition of the V-belt. There must be clearance (1, Figure 319) between the V-belt and the bottom of the pulley groove. If there is no clearance (2, Figure 319) between the V-belt and the bottom of the pulley groove, replace the V-belt.
6. Reinstall the V-belt. Tighten the V-belt to the proper tension. See "Check and Adjust Cooling Fan V-Belt" on page -80
7. Reinstall and tighten the drain plug or close the drain cock in the radiator. Reinstall and tighten the engine block drain plug or reconnect the coolant hose at the oil cooler.
8. Fill the radiator and engine with engine coolant. See "Adjust Intake / Exhaust Valve Clearance" on page -86



FG008859

Figure 319



CAUTION

Only use the engine coolant specified. Other engine coolant may affect warranty coverage, cause an internal buildup of rust and scale and / or shorten engine life.

Prevent dirt and debris from contaminating the engine coolants. Carefully clean the radiator cap and the surrounding area before you remove the cap.

Never mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

LUBRICATION SYSTEM

Before You Begin Servicing



WARNING

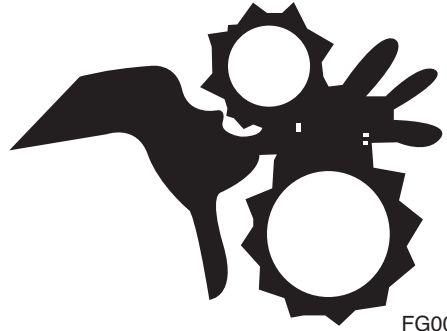
Entanglement Hazard!

Stop the engine before you begin to service it.

Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.

Failure to comply could result in death or serious injury.



FG009148

Figure 320

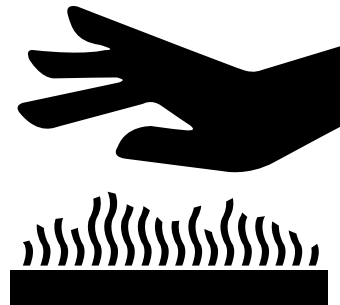


WARNING

Burn Hazard!

Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 321



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.



FG009153

Figure 322

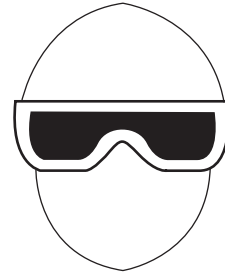


CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.



FG009152

Figure 323



CAUTION

If any oil pump component clearance exceeds its limit, the oil pump must be replaced as an assembly.



CAUTION

Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.

Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

Never overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.



CAUTION

If the oil pump must be replaced, replace it as an assembly only. Do not replace individual components.

Introduction

This section of the Service Manual describes the procedures necessary to service the 4TNV98-E Trochoid oil pumps.

See "Replace Engine Oil and Engine Oil Filter" on page -79 for engine oil and engine oil filter replacement procedures.

Oil Pump Service Information

Engine Oil Pressure

At Rated Engine RPM						At Low Idle Speed
1500 - 1800 min ⁻¹	2000 - 2500 min ⁻¹	2600 min ⁻¹	2700 min ⁻¹	2800 min ⁻¹	2900 - 3000 min ⁻¹	
0.29 - 0.39 MPa (3.0 - 4.0 kgf/cm ²)						0.06 MPa (0.6 kgf/cm ²) or greater

Outer Rotor Outside Clearance

Standard	Limit	Reference Page
0.0039 - 0.0061 in. (0.100 - 0.155 mm)	0.0098 in. (0.25 mm)	Check Outer Rotor Outside Clearance on page 9-14

Outer Rotor Side Clearance

Standard	Limit	Reference Page
0.0020 - 0.0039 in. (0.05 - 0.10 mm)	0.0059 in. (0.15 mm)	Check Outer Rotor Side Clearance on page 9-12

Outer Rotor to Inner Rotor Tip Clearance

Standard	Limit	Reference Page
-	0.0063 in. (0.16 mm)	Outer Rotor to Inner Rotor Tip Clearance on page 9-11

Inner Rotor and Gear Boss Clearance

Item	Parts	Standard Dimension	Standard Clearance	Standard Clearance Limit	Reference Page
Inside Clearance of Inner Rotor	Gear Boss Diameter	2.0886 - 2.0925 in. (53.05 - 53.15 mm)	0.012 - 0.020 in. (0.3 - 0.5 mm)	0.024 in. (0.6 mm)	“Check Rotor Shaft Clearance” on page 1-216
	Rotor Diameter	2.1043 - 2.1083 in. (53.45 - 53.55 mm)			
Inner Rotor Width Across Flat Clearance	Width Across Flat of Gear Boss	1.9468 - 1.9587 in. (49.45 - 49.75 mm)	0.008 - 0.020 in. (0.2 - 0.5 mm)	0.028 in. (0.7 mm)	
	Width Across Flat of Rotor	1.9665 - 1.9705 in. (49.95 - 50.05 mm)			

Rotor Shaft Clearance <Trochoid type>

Inspection Item	Standard	Limit	Reference Page
Gear Case bearing I.D	0.5110 - 0.5126 in. (12.980 - 13.020 mm)	0.5138 in. (13.050 mm)	"Check Rotor Shaft Clearance" on page 1-216
Rotor Shaft O.D.	0.5100 - 0.5104 in. (12.955 - 13.020 mm)	0.5096 in. (12.945 mm)	
Rotor Clearance	0.0006 - 0.0026 in. (0.015 - 0.065 mm)	0.0041 in. (0.105 mm)	

Lubrication System Diagram

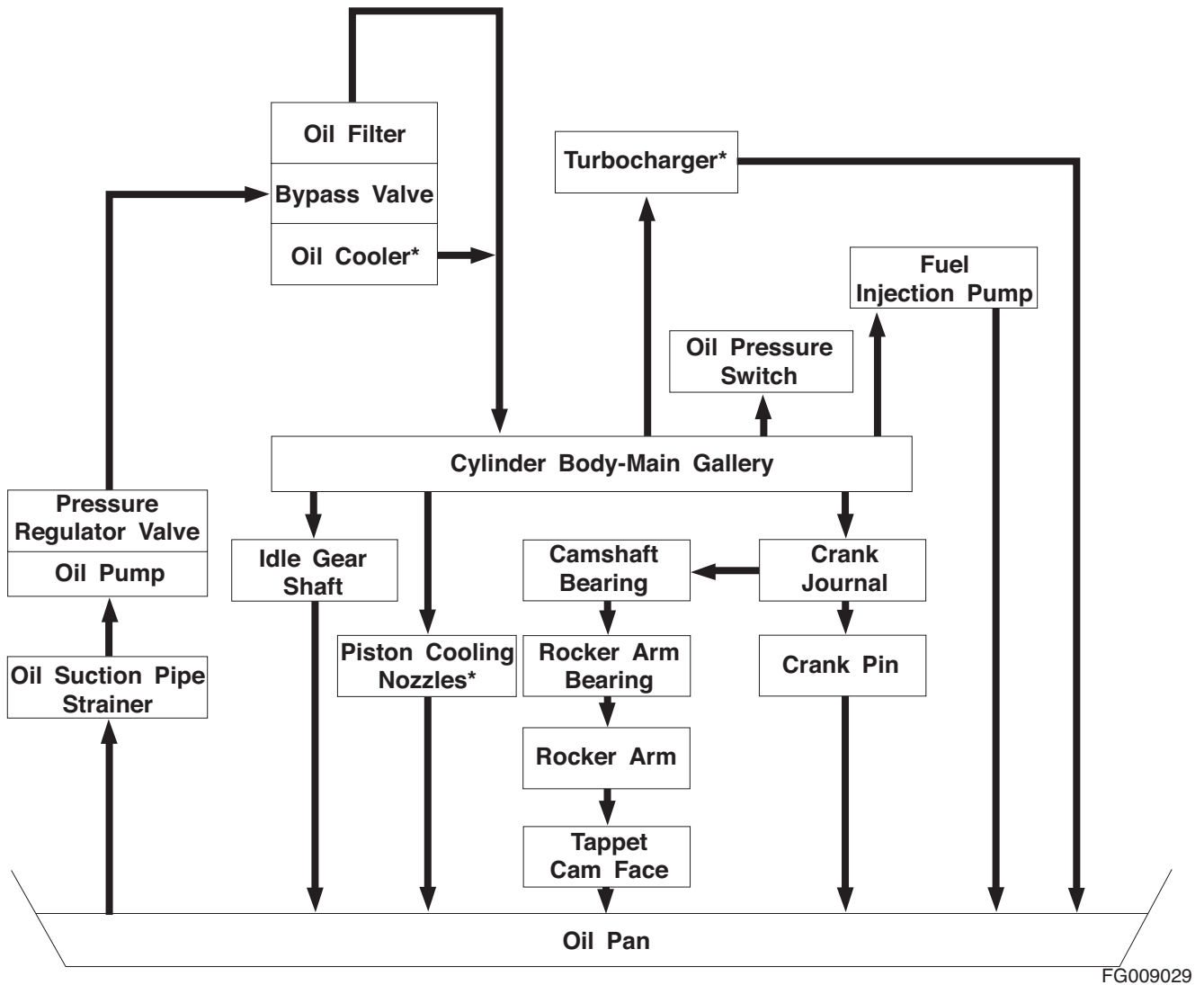


Figure 324

NOTE: Items marked * are not standard equipment on all models.

Checking Engine Oil Pressure

Perform an engine oil pressure check if there is any indication of low oil pressure such as the oil pressure indicator is on or the oil pressure gauge indicates low oil pressure. See "Oil Pump Service Information" on page -212

1. Disconnect the wire lead from the oil pressure switch or sending unit (1, Figure 325).
2. Remove the oil pressure switch.
3. Install a mechanical oil pressure gauge in the oil pressure switch port.
4. Start the engine:
 - If the mechanical oil pressure test gauge indicates good oil pressure, replace the faulty oil pressure switch or sending unit, or faulty machine oil pressure gauge in instrument panel.
 - If the mechanical oil pressure test gauge indicates low oil pressure, troubleshoot the lubrication system to locate the cause of the low oil pressure.

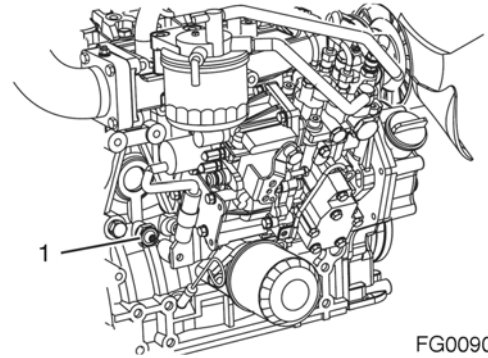


Figure 325

FG009030

Trochoid Oil Pump

4TNV98 Oil Pump Components

The oil pump on these model engines is located in the front gear case and is driven by the same gear train that drives the camshaft and fuel injection pump. You must remove the front gear case cover to gain access to the oil pump.

Reference Number	Description
1	Gear Case Housing
2	Outer Rotor
3	Inner Rotor
4	Cover Plate
5	Drive Gear

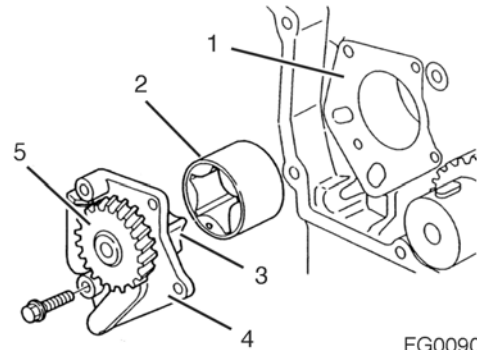


Figure 326

FG009040

Disassembly of Oil Pump

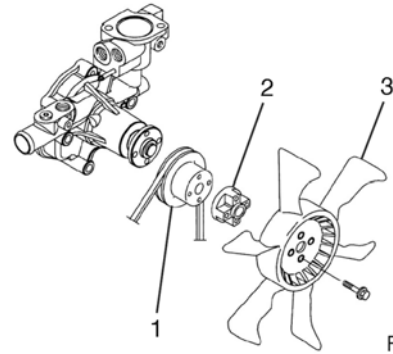


CAUTION

If the oil pump must be replaced, replace it as an assembly only. Do not replace individual components.

Remove the engine cooling fan guard (if equipped), engine cooling fan (3, Figure 327), spacer (2, Figure 327), engine coolant pump V-pulley (1, Figure 327) and V-belt.

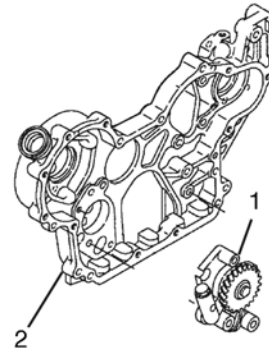
1. Remove the crankshaft pulley and the gear case cover.
See Removal of Timing Gear Case Cover on page 6-73.



FG009028

Figure 327

2. Remove the oil pump assembly bolts. Remove the oil pump assembly (1, Figure 328) from the gear case housing (2, Figure 328).



FG009041

Figure 328

Cleaning and Inspection

Wash the oil pump, oil pressure regulator and oil pump cavity. Inspect for wear or damage. Replace as necessary.



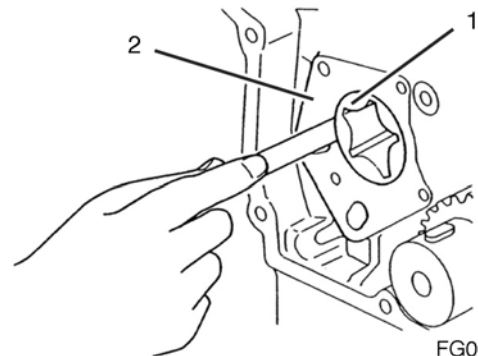
CAUTION

If any oil pump component clearance exceeds its limit, the oil pump must be replaced as an assembly.

Check Outer Rotor Outside Clearance

Determine the outside clearance of the outer rotor. Insert a feeler gauge between the outer rotor (1, Figure 329) and gear case oil pump cavity (2, Figure 329).

Record the measurement(s) and see Check Outer Rotor Outside Clearance on page 9-11 for the service limits.



FG009042

Figure 329

Outer Rotor to Inner Rotor Tip Clearance

Determine the outer rotor to inner rotor tip clearance. Insert a feeler gauge between the top of an inner rotor tooth (1, Figure 330) and the top of an outer rotor tooth (2, Figure 330) and measure the clearance.

Record the measurement(s) and see Outer Rotor to Inner Rotor Tip Clearance on page 9-11 for the service limits.

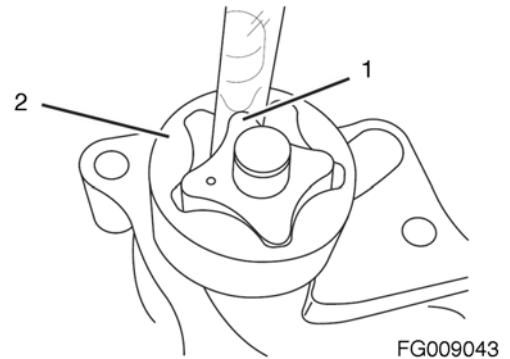


Figure 330

Check Outer Rotor Side Clearance

Determine the side clearance of the outer rotor across the pump cavity. Measure the depression using a depth micrometer (1, Figure 331).

Record the measurement(s) and see Check Outer Rotor Side Clearance on page 9-12 for the service limits.

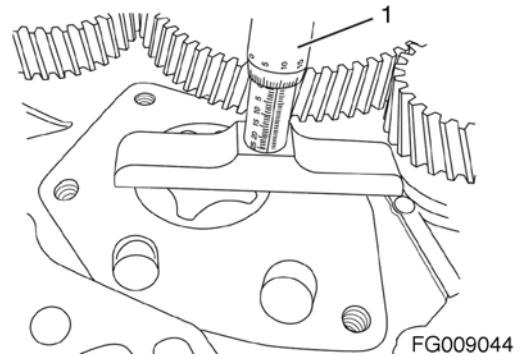


Figure 331

Check Rotor Shaft Clearance

Determine the rotor shaft clearance. Measure the outside diameter of the rotor shaft (1, Figure 332) and the bore diameter in the gear case housing (2, Figure 332).

Calculate the difference between the two measurements to determine the clearance.

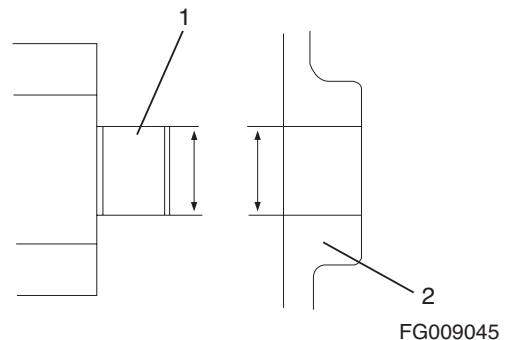
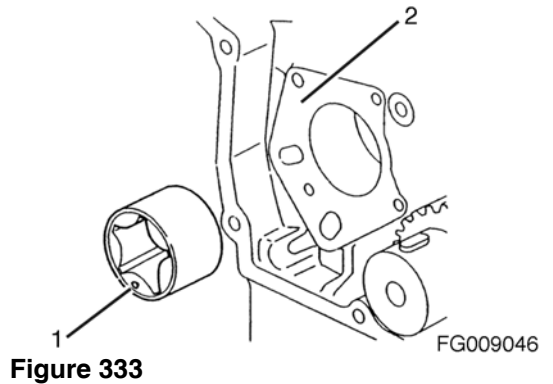


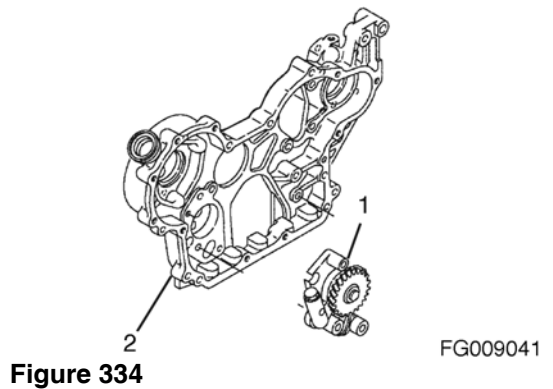
Figure 332

Reassembly of Oil Pump

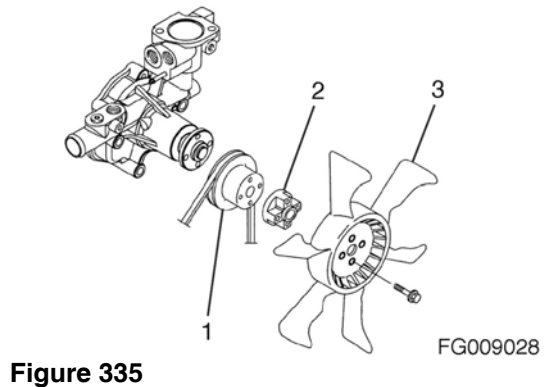
1. Lubricate the outer rotor and pump bore in the gear case with clean engine oil.
2. Reinstall the outer rotor in the gear case housing. The punch mark (1, Figure 333) on the end of the outer rotor must face away from the gear case housing (2, Figure 333).



3. Reinstall the oil pump assembly (1, Figure 334) into the gear case housing (2, Figure 334). Tighten the bolts to specified torque.
4. Reinstall the gear case cover and crankshaft pulley. See "Installation of Gear Case Cover" on page -156



5. Reinstall the engine coolant pump V-pulley (1, Figure 335), spacer (2, Figure 335), engine cooling fan (3, Figure 335) and engine cooling fan guard (if equipped).
6. Reinstall the V-belt. Tighten the V-belt to the proper tension as described in Check and Adjust Cooling Fan V-Belt on page 5-22.



STARTER MOTOR

Before You Begin Servicing



WARNING

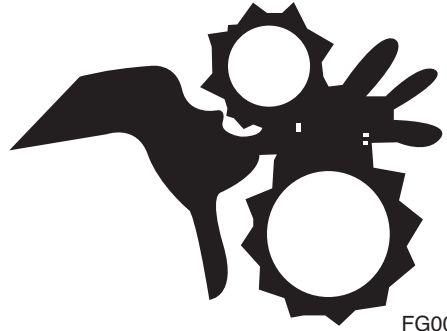
Entanglement Hazard!

Stop the engine before you begin to service it.

Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.

Failure to comply could result in death or serious injury.



FG009148

Figure 336



WARNING

Shock Hazard!

Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. Always keep the connectors and terminals clean.

Failure to comply could result in death or serious injury.



FG009151

Figure 337



WARNING

Fume / Burn Hazard!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.



FG009153

Figure 338

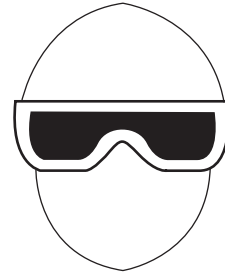


CAUTION

FLYING OBJECT HAZARD!

Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.



FG009152

Figure 339



CAUTION

The starter motor can be damaged if operated continuously longer than 10 seconds while performing the no-load test.



CAUTION

Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated on the wiring diagram. The starter motor will malfunction or break down if the resistance is higher than the specified value.



CAUTION

The starter motor is water-proofed according to JIS D 0203, R2 which protects the motor from rain or general cleaning. Do not use high-pressure wash or submerge the starter motor in water.



CAUTION

Use a specialized battery charger to recharge a battery with a voltage of 8 volts or less. Booster starting a battery with a voltage of 8 volts or less will generate an abnormally high voltage and destroy electrical equipment.

Introduction

This section of the Service Manual covers the servicing of the starter motor. Standard equipment on TNV model engine is used in this section to show the service procedures for a representative start motor and it may be different from actual equipment.

Starter Motor Specifications

Nominal Output			3.0 hp (2.3 kW)
Weight			12.1 lb (5.5 kg)
Revolution Direction (As Viewed From Pinion)			Clockwise
Engagement System			Magnetic Shift
No-load	Terminal Voltage / Current		11 V / 140 A max
	Revolution		4100 rpm (min ⁻¹)
	Terminal Voltage / Current		2.5 V / 1050 A max
	Torque		18 ft-lb (24.5 N•m; 2.5 kgf/m) minimum
Clutch System			Overrunning
Pinion Projection Voltage at 212°F (100 °C)			8.6 V max
Pinion DP or Module / Number of Teeth			M3/9
Difference (O-ring, Oil Seal)			Dry (none)
Application			Standard
Brush	Spring Force		7.868 lbf (35 N; 3.6 kgf)
	Height	Standard	0.591 in. (15 mm)
		Limit	0.354 in. (9 mm)
Magnetic Switch	Series Coil Resistance		0.27 W at 68°F (20°C)
	Shunt Coil Resistance		0.60 W at 68°F (20°C)
Commutator	Outside Diameter	Standard	1.437 in. (36.5 mm)
		Limit	1.398 in. (35 mm)
	Run-Out	Standard	0.001 in. (0.03 mm)
		Limit	0.008 in. (0.2 mm)
	Insulation Depth	Standard	0.020 - 0.031 in. (0.5 - 0.8 mm)
		Limit	0.008 in. (0.2 mm)
Armature	Run-Out	Standard	0.001 in. (0.03 mm)
		Limit	0.008 in. (0.02 mm)
Bearing Type	Armature Front	Nominal Number	6903DDU
	Armature Rear		608DDU
	Pinion Front		60004DDU
	Pinion Rear		6904DDU
Pinion Projection Length (Length L)			0.012 - 0.059 in. (0.3 - 1.5 mm)

Starter Motor Troubleshooting

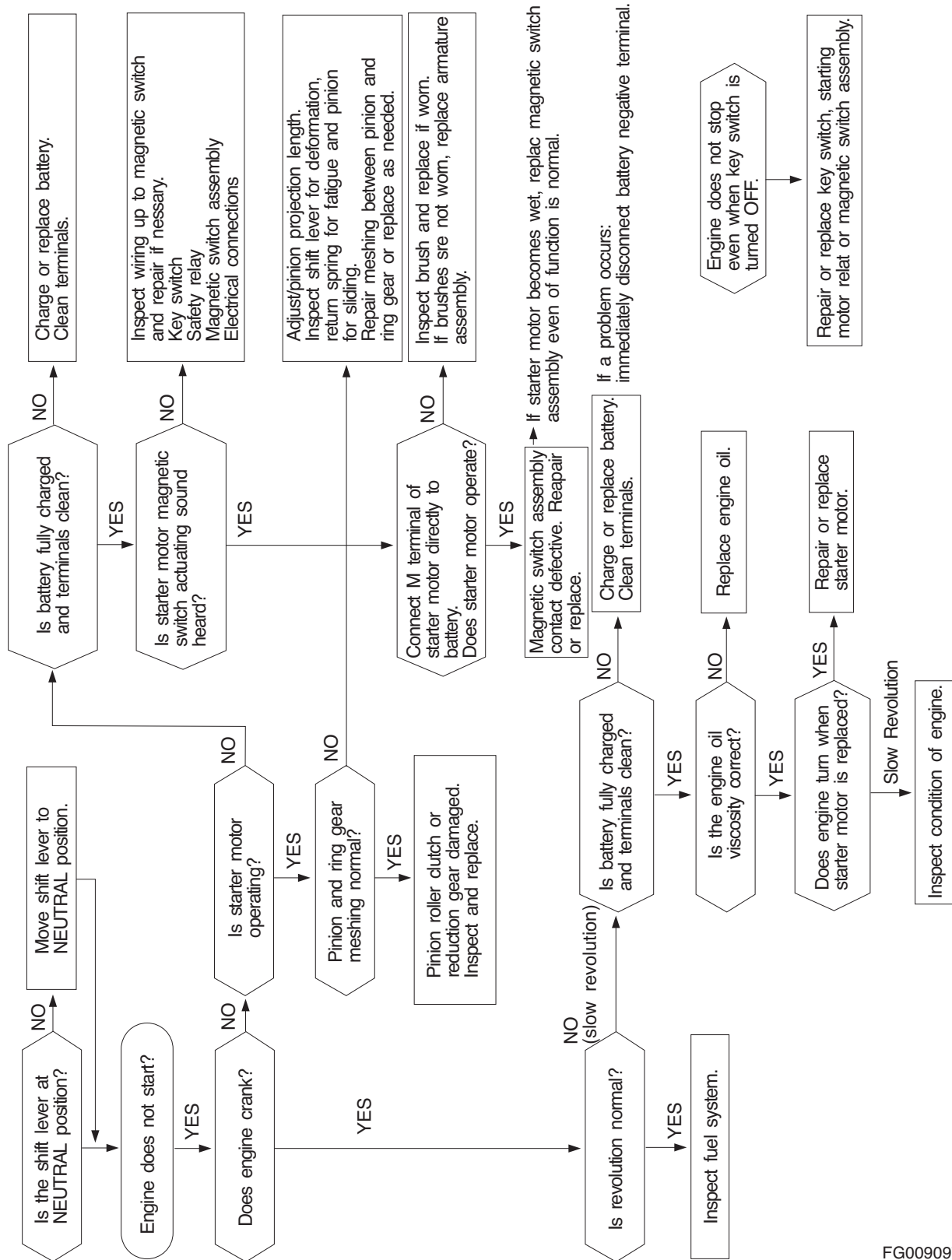
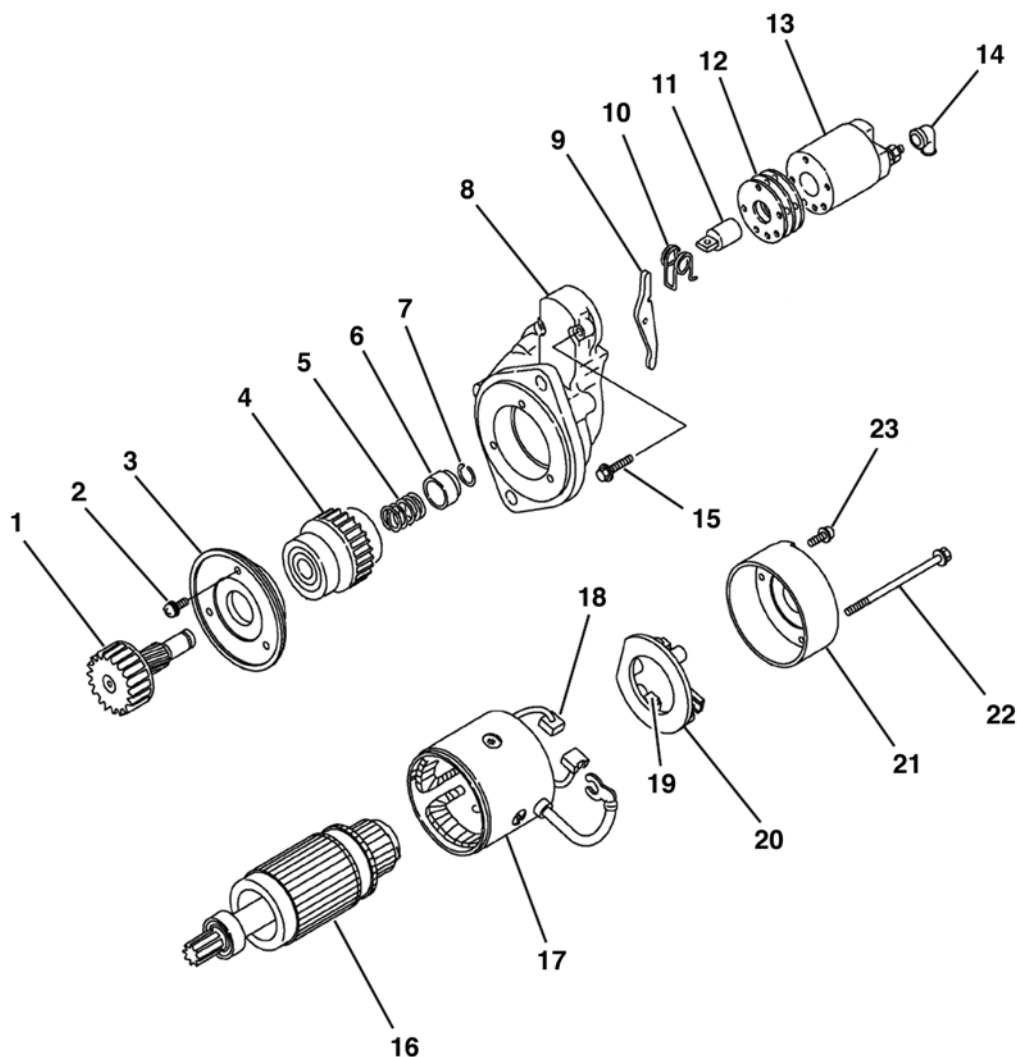


Figure 340

FG009097

Starter Motor Components



FG009061

Figure 341

Reference Number	Description
1	Pinion Shaft
2	M4 Bolts (3 used)
3	Bearing Retainer
4	Pinion Clutch Assembly
5	Return Spring
6	Pinion Stop
7	Retaining Ring
8	Gear Housing
9	Shift Lever
10	Torsion Spring
11	Plunger
12	Dust Covers (Shims)

Reference Number	Description
13	Magnetic Switch Assembly (Solenoid)
14	Cover
15	M6 Bolts (2 used)
16	Armature Assembly
17	Field Coil Assembly
18	Positive (+) Brushes
19	Negative (-) Brushes
20	Brush Holder Assembly
21	Rear Cover
22	M5 Through Bolts (2 used)
23	M4 Bolts (2 used)

Starter Motor



WARNING

Shock Hazard!

Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. Always keep the connectors and terminals clean.

Failure to comply could result in death or serious injury.

NOTE: While starter motor design varies between models, the basic repair procedures are the same. The following procedures are typical and may differ from the stater being serviced.

Removal of Starter Motor

1. Disconnect the battery cables at the battery, negative (-) cable first.
2. Remove the electrical wires from the magnetic switch assembly.
3. Remove the starter mounting bolts (1, Figure 343). Remove the starter motor from the flywheel housing.

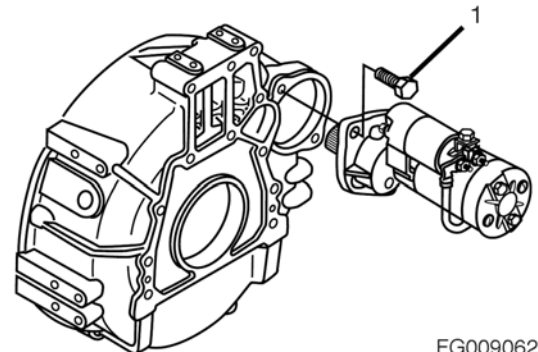


Figure 343

FG009062

Disassembly of Starter Motor

1. Loosen the M8 nut from the magnetic switch (solenoid) assembly (Figure 344). Disconnect the wire from the magnetic switch.

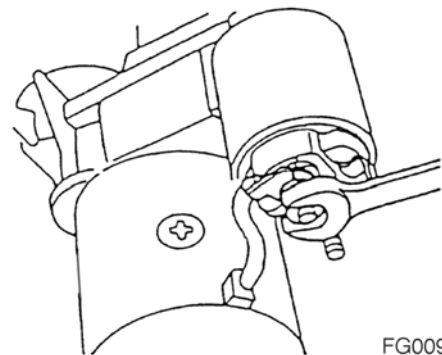


Figure 344

FG009063



Figure 342

FG009151

2. Remove the two M4 bolts (1, Figure 345) securing the rear cover (2, Figure 345) to the brush holder assembly (3, Figure 345).
3. Remove the two M5 through bolts (4, Figure 345). Separate the rear cover (2, Figure 345), field coil assembly (5, Figure 345) with the armature assembly (6, Figure 345) from the gear housing (7, Figure 345).

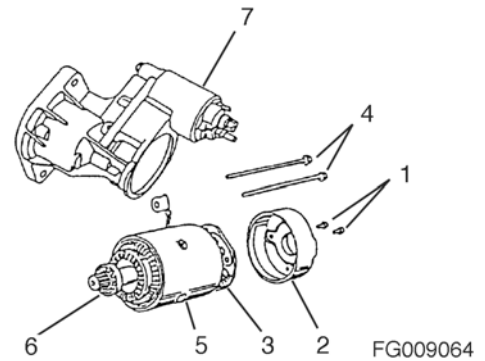


Figure 345

4. Pull the brush springs up using a brush spring puller. On the negative (-) side, bring the brush spring into contact with the side of the brush for lifting from the commutator surface. On the positive (+) side, remove the brush from the brush holder assembly (1, Figure 346).

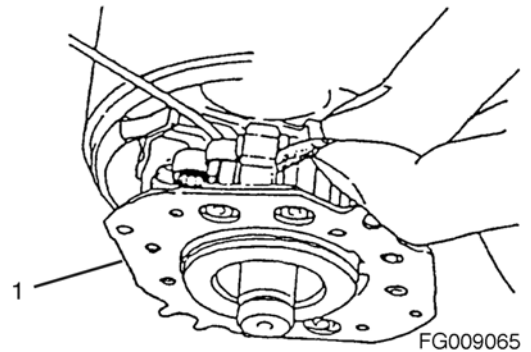


Figure 346

5. Remove the brush holder assembly (1, Figure 347) from the armature assembly (3, Figure 347).
6. Pull the armature assembly (3, Figure 347) out from the field coil assembly (2, Figure 347).

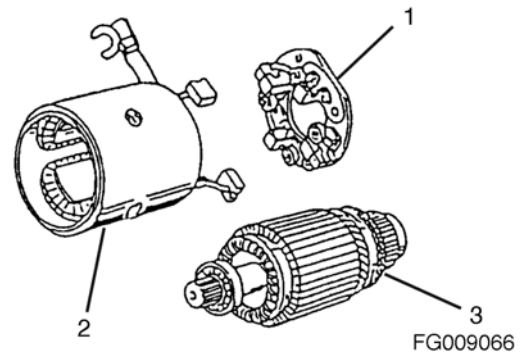


Figure 347

7. Remove the two M6 bolts (1, Figure 348) retaining the magnetic switch assembly (2, Figure 348) to the gear housing. Remove the magnetic switch assembly, dust cover(s) (3, Figure 348) and torsion spring (4, Figure 348) from the gear housing.

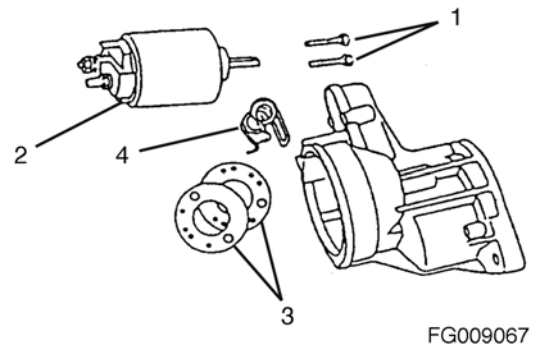


Figure 348

8. Disassemble the dust cover (3, Figure 349) and shift the lever (4, Figure 349) from the gear housing.

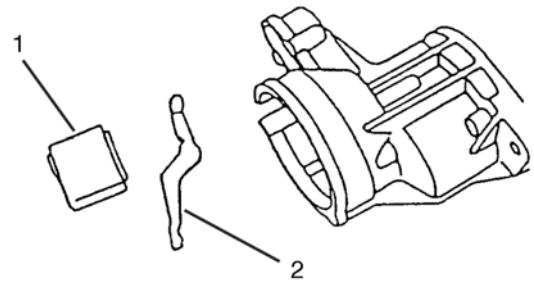


Figure 349

FG009068

9. Remove the three M4 bolts (1, Figure 350) securing the bearing retainer assembly (2, Figure 350) to the gear housing. Remove the bearing retainer assembly from the gear housing.
10. Remove the pinion clutch assembly (3, Figure 350) from the bearing retainer assembly.

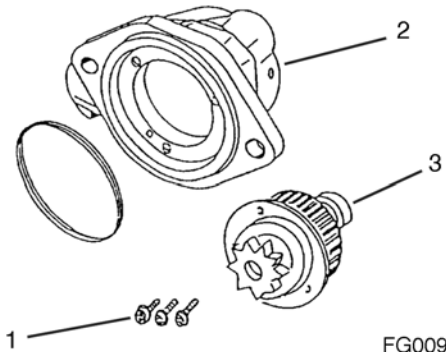


Figure 350

FG009069

11. Using a flat-blade screwdriver, remove the retaining ring (1, Figure 351) from the shaft of the pinion.

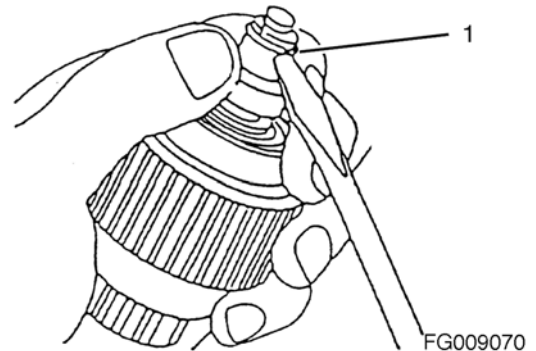


Figure 351

FG009070

12. Disassemble the pinion stop (3, Figure 352), return spring (4, Figure 352), pinion clutch assembly (1, Figure 352), and pinion shaft (5, Figure 352).

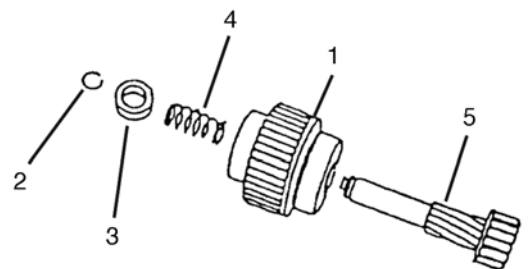


Figure 352

FG009071

Cleaning and Inspection

Armature

Commutator Surface Inspection

if the commutator is rough, polish the surface with a #500 to #600 emery cloth (Figure 353).

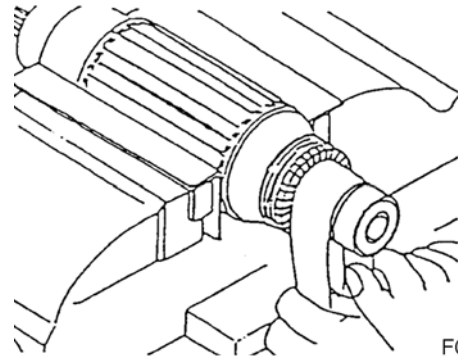


Figure 353

FG009072

Measure Commutator Outside diameter

Measure Commutator Outside diameter (Figure 354). Replace the armature if the measurement is less than the limit.

See "Starter Motor Specifications" on page -220 for the service limit.

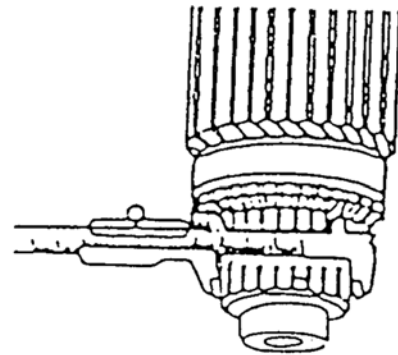


Figure 354

FG009073

Measure Commutator Insulation Depth

Measure the depth of the insulating material (1, Figure 355) between commutator segments (2, Figure 355). If the depth measures less than the limit, use a hacksaw blade (3, Figure 355) to remove the insulating material until the depth is within the limit.

A normal commutator condition is indicated in (4, Figure 355). An abnormal commutator condition is indicated in (5, Figure 355).

See "Starter Motor Specifications" on page -220 for the service limit.

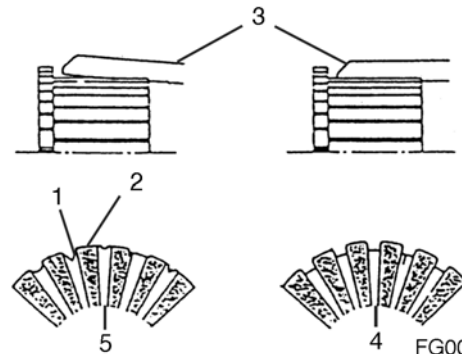


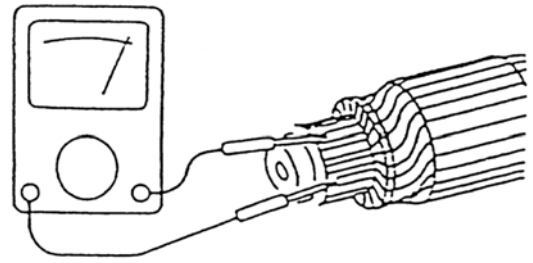
Figure 355

FG009074

Armature Coil Continuity Test

Check for continuity between the commutator segments using a multimeter (Figure 356). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the armature.



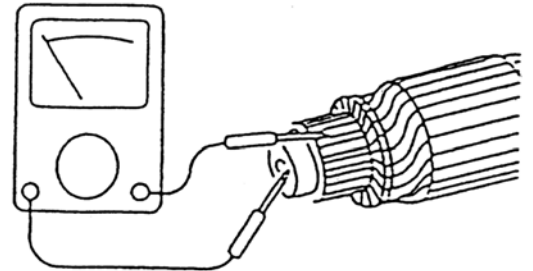
FG009075

Figure 356

Armature Coil Insulation Test

Check for continuity between a commutator segment and the shaft or armature using a multimeter (Figure 357). The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the armature.



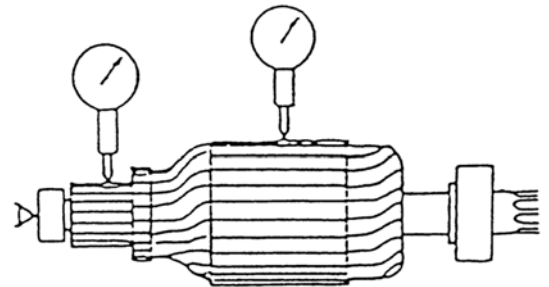
FG009076

Figure 357

Measure Armature and Commutator Run-Outs

Measure the armature core run-out and the commutator run-out using a dial indicator (Figure 358). Replace the armature if either of the measurements is less than the limit.

See "Starter Motor Specifications" on page -220 for the service limit.



FG009077

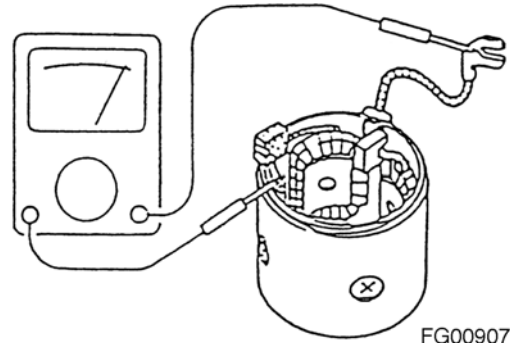
Figure 358

Field Coil

Field Coil Continuity Test

Check for continuity between the field coil terminals using a multimeter (Figure 359). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the field coil assembly.



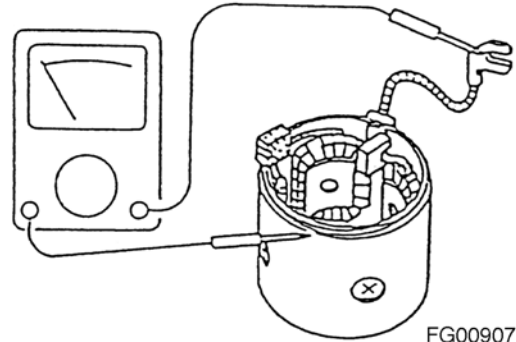
FG009078

Figure 359

Field Coil Insulation Test

Check for continuity between the field coil terminal and the yoke using a multimeter (Figure 360). The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the field coil assembly.



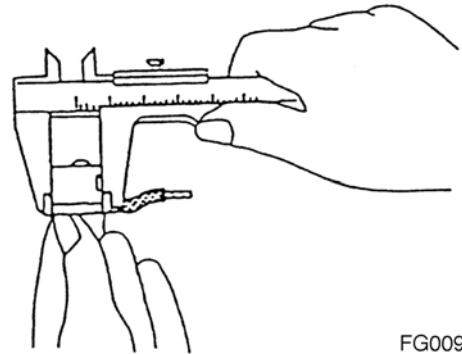
FG009079

Figure 360

Measure Brush Length

Measure the length of the brush (Figure 361). Replace the brush if the length is less than the limit.

See "Starter Motor Specifications" on page -220 for the service limit.



FG009080

Figure 361

Magnetic Switch

If the starter motor becomes wet, replace the magnetic switch even if the magnetic switch assembly function is normal.

Shunt Coil Continuity Test

Check for continuity between the "S" terminal and the switch body using a multimeter (Figure 362). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the magnetic switch.

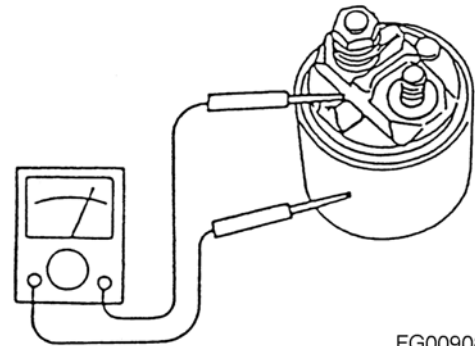


Figure 362

FG009081

Series Coil Continuity Test

Check for continuity between the "S" and "M" terminals using a multimeter (Figure 363). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the magnetic switch.

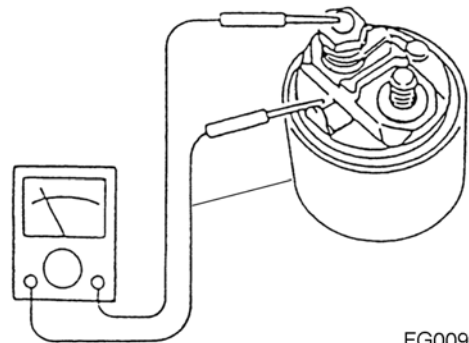


Figure 363

FG009082

Coil Resistance Test

See "Starter Motor Specifications" on page -220 for the service limit.

Contact Continuity Test

Depress the plunger at the bottom of the magnetic switch. Check for continuity between the "B" and "M" terminals using a multimeter (Figure 364). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the magnetic switch.

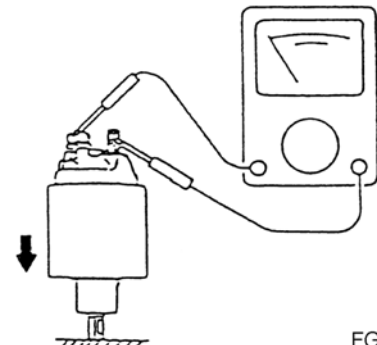


Figure 364

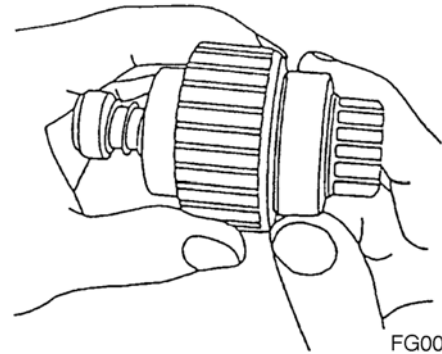
FG009083

Pinion Clutch Assembly

Pinion Clutch Assembly Inspection

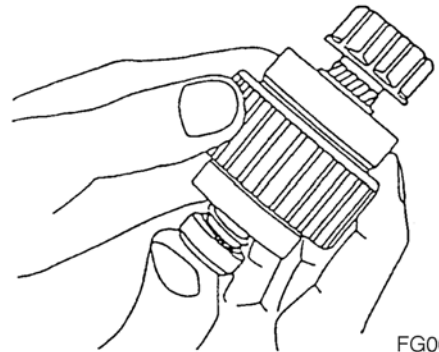
Manually rotate the pinion clutch assembly in the drive direction (Figure 365). It should rotate freely in the drive direction and is locked by turning it in the opposite direction. Replace the pinion clutch assembly if the results are different.

Slide the pinion clutch assembly on the shaft. It should slide smoothly on the shaft (Figure 366). Rust, too much grease or damage could prevent the pinion clutch from sliding smoothly. If the pinion clutch assembly does not slide smoothly, clean the shaft and pinion clutch assembly or replace the damaged component.



FG009084

Figure 365

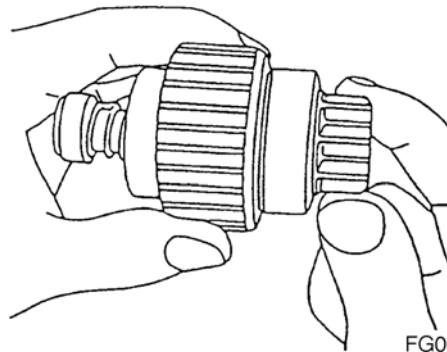


FG009085

Figure 366

Ball Bearing Inspection

Rotate each ball bearing while holding the pinion clutch assembly (Figure 367). Replace the ball bearing if it does not rotate smoothly or has excessive play.

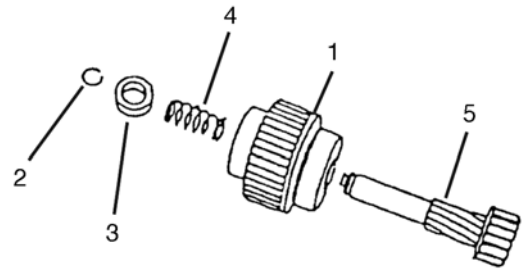


FG009086

Figure 367

Reassembly of Starter Motor

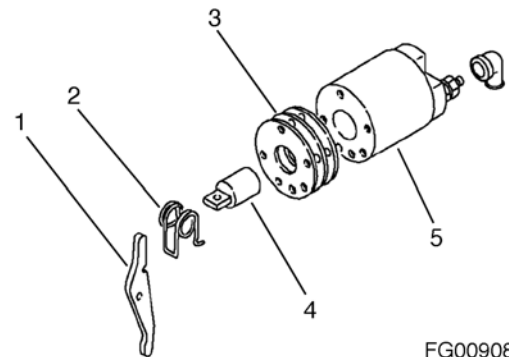
1. Apply appropriate starter bendix grease (obtain locally) to the pinion shaft. Reassemble the pinion shaft (5, Figure 368), pinion clutch assembly (1, Figure 368), return spring (4, Figure 368) and pinion stop (3, Figure 368). Reinstall the retaining ring (2, Figure 368) in the groove in the pinion shaft. Slide the piston stop over the retaining ring.
2. Reinstall the pinion clutch assembly into the bearing retainer assembly.
3. Reinstall the bearing retainer assembly and pinion assembly to the gear housing. Reinstall and tighten the three M4 bolts.



FG009071

Figure 368

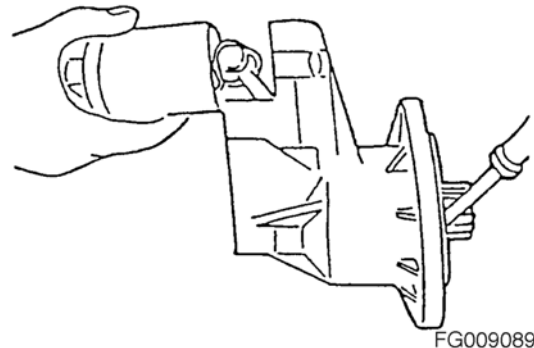
4. Apply a small amount of high temperature lithium grease (obtain locally) to the sliding portions of the shift lever (1, Figure 369). Reassemble the torsion spring (2, Figure 369), shift lever and dust cover(s) (3, Figure 369), plunger (4, Figure 369) and magnetic switch assembly (5, Figure 369).



FG009087

Figure 369

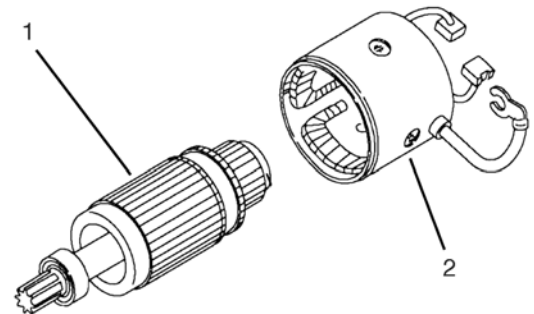
5. Reassemble the magnetic switch assembly to the gear housing. Pry the pinion away from the gear housing to allow installation of the magnetic switch assembly (Figure 370).
6. Secure the magnetic switch assembly to the gear housing using the two M6 bolts.



FG009089

Figure 370

7. Carefully install the armature assembly (1, Figure 371) into the field coil assembly (2, Figure 371).



FG009090

Figure 371

8. Position the brush springs in brush holders (Figure 372). Reinstall the brushes in the brush holders. Reversing the brushes will cause the starter motor to turn backwards.
9. Carefully install the brush holder assembly to the armature assembly.
10. Reinstall the field coil assembly with the armature assembly to the gear housing.
11. Reinstall the rear cover to the brush holder assembly. Securely tighten the two bolts.

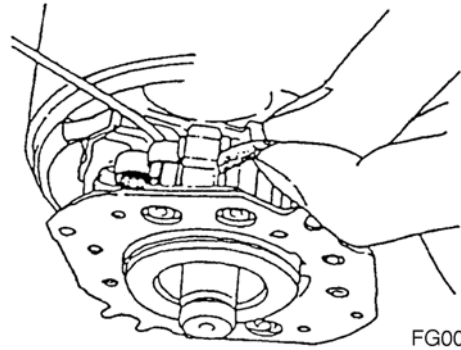


Figure 372

12. Reinstall the two M4 through bolts (Figure 373). Securely tighten the through bolts. Reconnect the wire to the magnetic switch assembly. Tighten the M8 nut. Reinstall the cover over the connection.

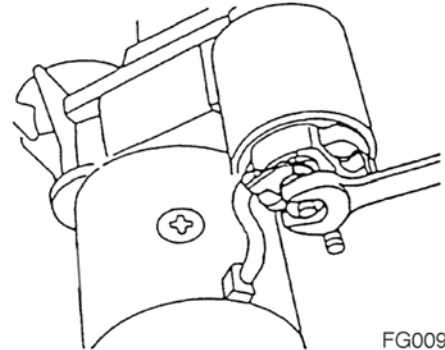
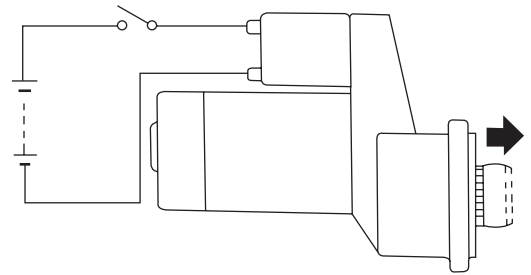


Figure 373

Check Pinion Projection Length

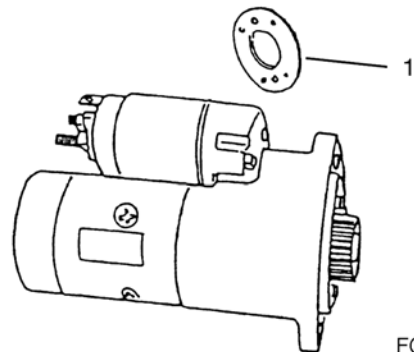
1. Connect the positive (+) lead from a battery to the "S" terminal.
2. Connect the negative (-) lead to the "M" terminal.
3. Lightly pull the pinion away from the gear housing.
4. Turn the switch ON and measure the pinion moving distance L in the thrust direction (Figure 374). Perform this test within 10 seconds. See "Starter Motor Specifications" on page -220 for the service limit.



FG009092

Figure 374

5. If the measured L dimension is outside the standard range, adjust the dust covers to obtain the standard range. Dust cover (1, Figure 375) are available in 0.020 in (0.5 mm) and 0.031 in (0.8 mm) thicknesses.



FG009093

Figure 375

No-Load Test

Test the characteristics of the starter motor by performing a no-load test.



CAUTION

The starter motor can be damaged if operated continuously longer than 10 seconds while performing the no-load test.

1. Secure the starting motor in a vise or other suitable fixture.
2. Connect an ammeter (1, Figure 376) in series between the battery positive (+) terminal (2, Figure 376) and the main positive (+) terminal (3, Figure 376) on the starter motor.

NOTE: *The ammeter and all wire leads used in this test must have a capacity equal to or greater than the amperage draw specification for the starter motor being tested.*

3. Connect a wire lead between the mounting base of the starter motor (4, Figure 376) and the battery negative terminal (5, Figure 376).
4. Connect a voltmeter (7, Figure 376) to the battery negative (-) terminal (5, Figure 376) and the main positive (+) battery terminal (3, Figure 376) on the starter motor.
5. Install a switch (6, Figure 376) in a circuit between the battery positive (+) terminal (2, Figure 376) and the starter magnetic switch (solenoid) terminal (8, Figure 376) on the starter motor.
6. Use a suitable tachometer to monitor the rpm of the starter.
7. Turn the switch to the ON position. Monitor the rpm, amperage draw and voltage. For test specifications, for the appropriate starter motor.

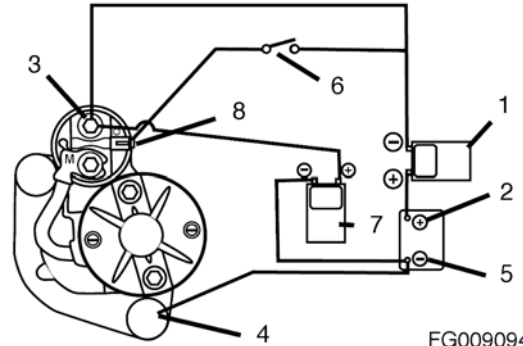


Figure 376

FG009094

Installation of Starter Motor

1. Reinstall the starter motor to the flywheel housing.
2. Reinstall the starter mounting bolts (1, Figure 377). Tighten the bolts to specification. See "Tightening Torques for Standard Bolts and Nuts" on page -48
3. Reconnect the electrical wires to the magnetic switch assembly (solenoid). Be sure to place the cover over the battery positive (+) cable connection.
4. Reconnect the battery cables at the battery.

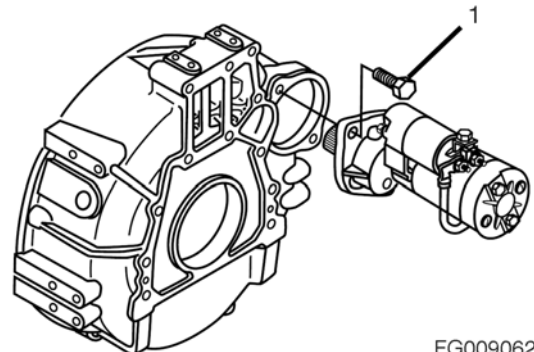


Figure 377

FG009062

ALTERNATOR

Before You Begin Servicing



WARNING

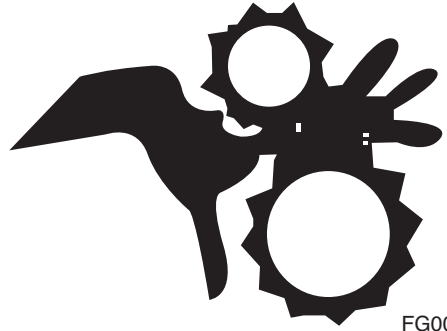
ENTANGLEMENT HAZARD!

Stop the engine before you begin to service it.

NEVER leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.

If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.

Failure to comply could result in death or serious injury.



FG009148

Figure 378



WARNING

SHOCK HAZARD!

Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.

Failure to comply could result in death or serious injury.



FG009151

Figure 379

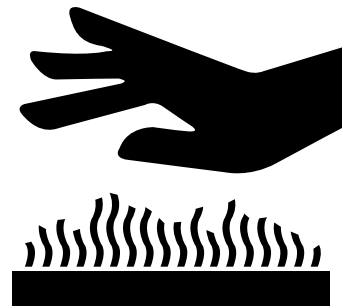


WARNING

BURN HAZARD!

Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.

Failure to comply could result in death or serious injury.



HAOA050L

Figure 380



WARNING

FUME / BURN HAZARD!

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Failure to comply could result in death or serious injury.



Figure 381

FG009153



CAUTION

FLYING OBJECT HAZARD!

ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Failure to comply may result in minor or moderate injury.

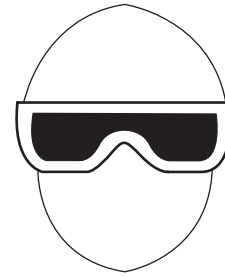


Figure 382

FG009152



CAUTION

PINCH HAZARD!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

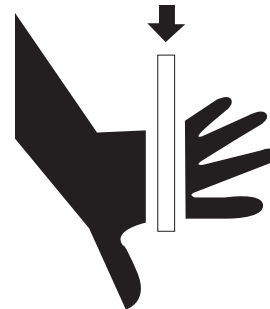


Figure 383

FG009155



CAUTION

NEVER permit anyone to operate the engine or driven machine without proper training.

Read and understand this Operation Manual before you operate or service the machine to ensure that you follow safe operating practices and maintenance procedures.

Machine safety signs and labels are additional reminders for safe operating and maintenance techniques.

See your authorized DOOSAN dealer or distributor for additional training.



CAUTION

Do not short-circuit the charging system between alternator terminals IG and L. Damage to the alternator will result.



CAUTION

Do not connect a load between alternator terminals L and E. Damage to the alternator will result.



CAUTION

Do not remove the positive (+) battery cable from alternator terminal B while the engine is operating. Damage to the alternator will result.



CAUTION

Do not turn the battery switch OFF while the engine is operating. Damage to the alternator will result.



CAUTION

Do not operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.



CAUTION

Do not reverse the positive (+) and negative (-) ends of the battery cable. The alternator diode and stator coil will be damaged.



CAUTION

When the battery indicator goes out, it should not come on again. The battery indicator only comes on during operation if the alternator fails or if the V-belt breaks. However, if an LED is used in the battery indicator, the LED will shine faintly during normal operation.



CAUTION

Using a non-specified V-belt will cause inadequate charging and shorten the belt life. Use the specified belt.



CAUTION

Agricultural or other chemicals, especially those with a high sulfur content, can adhere to the IC regulator. This will corrode the conductor and result in battery over-charging (boiling) and charging malfunctions. Consult DOOSAN dealer before using the equipment in such an environment or the warranty is voided.



CAUTION

Do not use a high-pressure wash directly on the alternator. Water will damage the alternator and result in inadequate charging.

Introduction

This section of the Service Manual describes the servicing of the dynamos and alternators. Standard equipment on TNV model engine is used in this section to show the service procedures for a representative dynamos and alternators and it may be different from actual equipment.

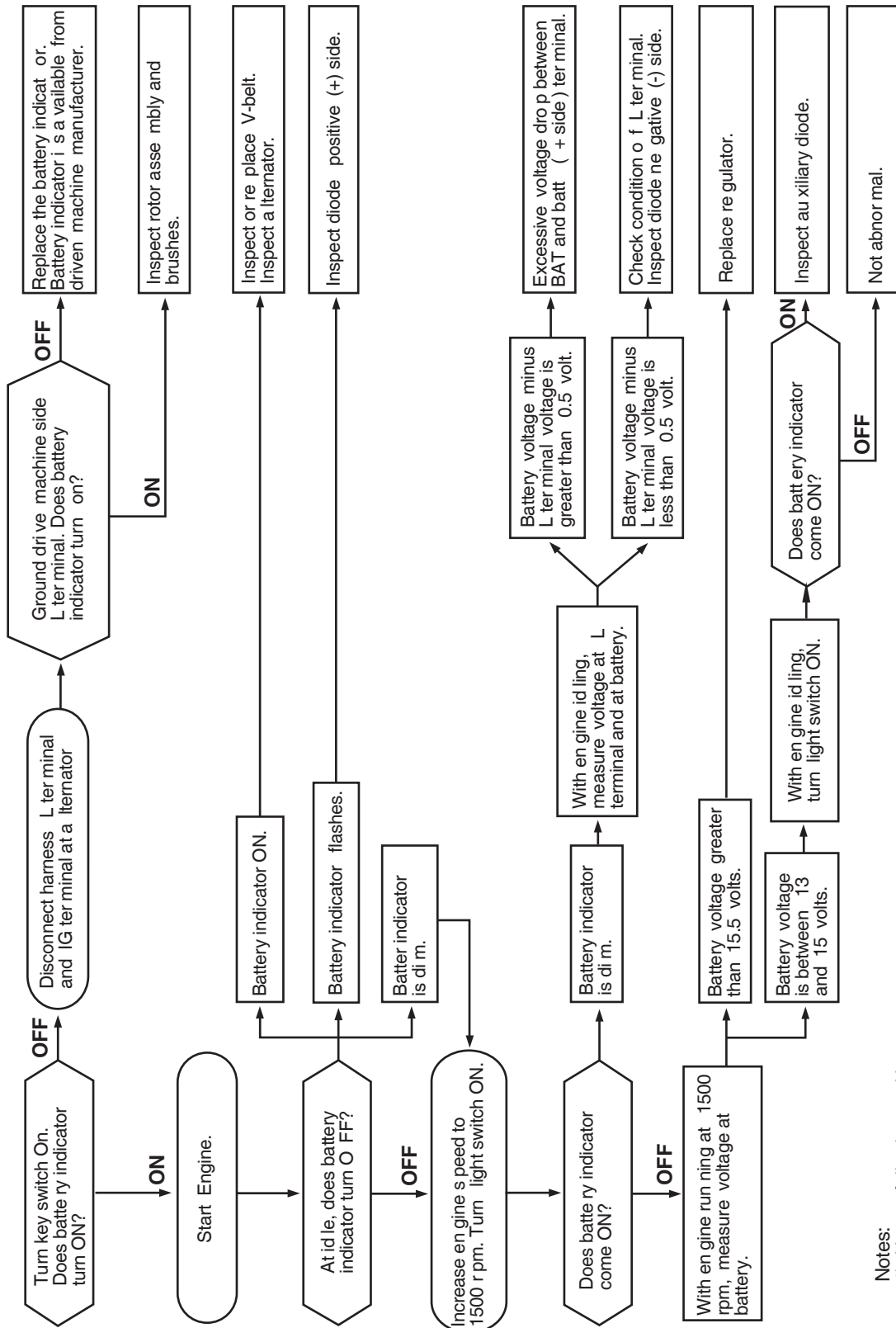
Alternator Specifications

Nominal Output (13.5 Volts Heat)	40 Amps
Weight	6.17 lb (2.8 kg)
Revolution Direction (As Viewed From Pulley)	Clockwise
Rating	Continuous
Battery Voltage	12 Volts
Rated Revolution	5,000 rpm (min ⁻¹)
Operating Range	1,350 - 18,000 rpm (min ⁻¹)
Grounding Characteristics	Negative (-) Side of Circuit
Integrated Regulator	IC Regulator
Outside Diameter of Pulley	2.724 in. (69.2 mm)
Belt Shape	Type A

Dynamo Specifications

Nominal Output (13.5 Volts Heat)		20 Amps
Weight		3.97 lb (1.8 kg)
Revolution Direction (As Viewed From Pulley)		Clockwise
Rating		Continuous
Battery Voltage		12 Volts
Rated Revolution		3,500 rpm
Operating Range		1,400 - 6,600 rpm
Grounding Characteristics		Negative (-) Side of Circuit
Integrated Regulator		IC Regulator
Outside Diameter of Pulley	A-Belt	2.56 in. (65 mm)
	Special M-Belt	2.28 in. (58 mm)
Belt Shape		Type A or Type Special M

Alternator Troubleshooting



Notes:

- 1) Use a fully charged battery
- 2) DC voltmeter: 0 to 30 V, 0.5 class
- 3) The check method is also applicable to the bench test

FG009100

Alternator Components

Part No. 129423-77200 alternator is used in this section to show the service procedures for the representative alternator. For specific part detail, see the Parts Catalog for the engine you are working on.

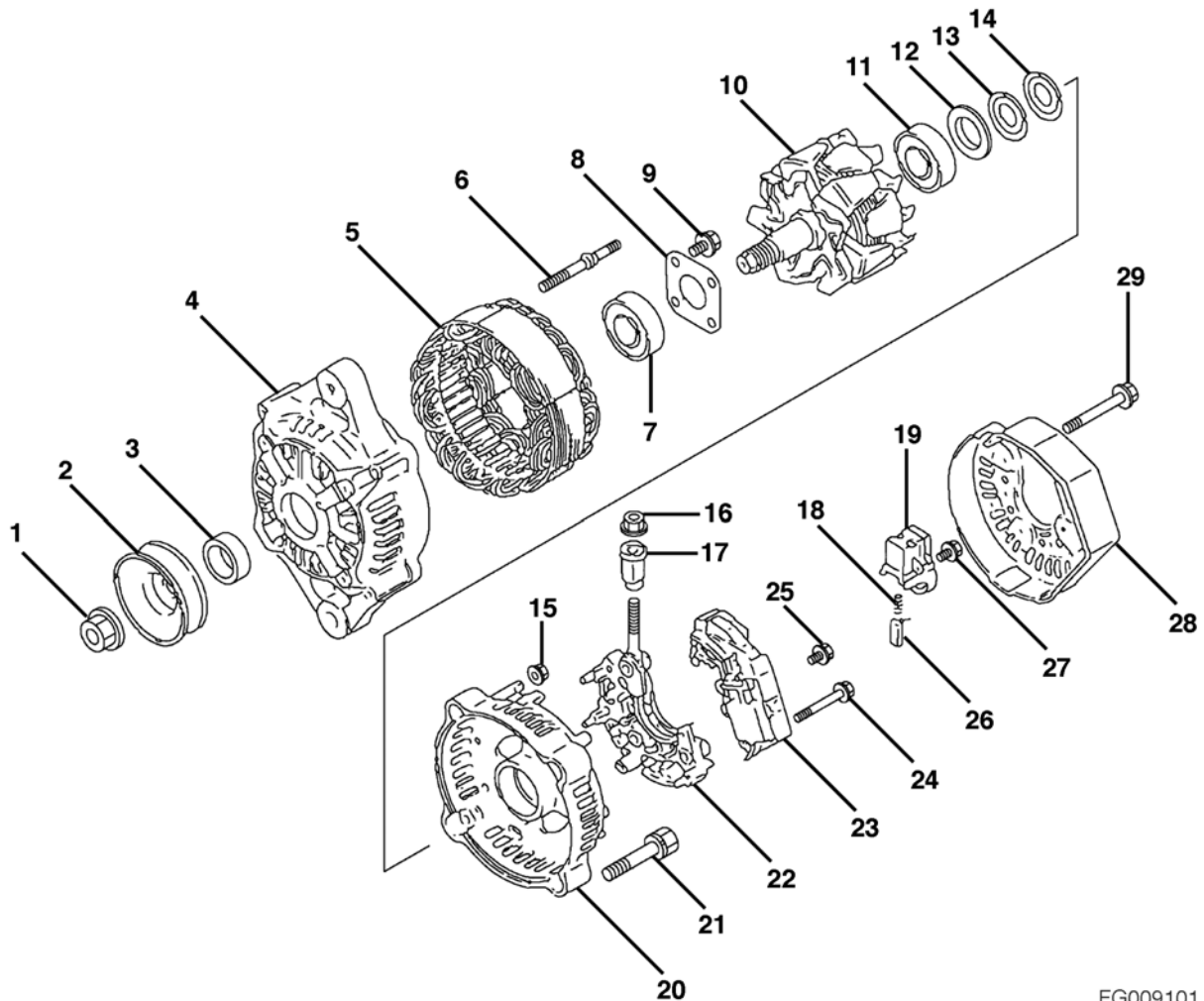


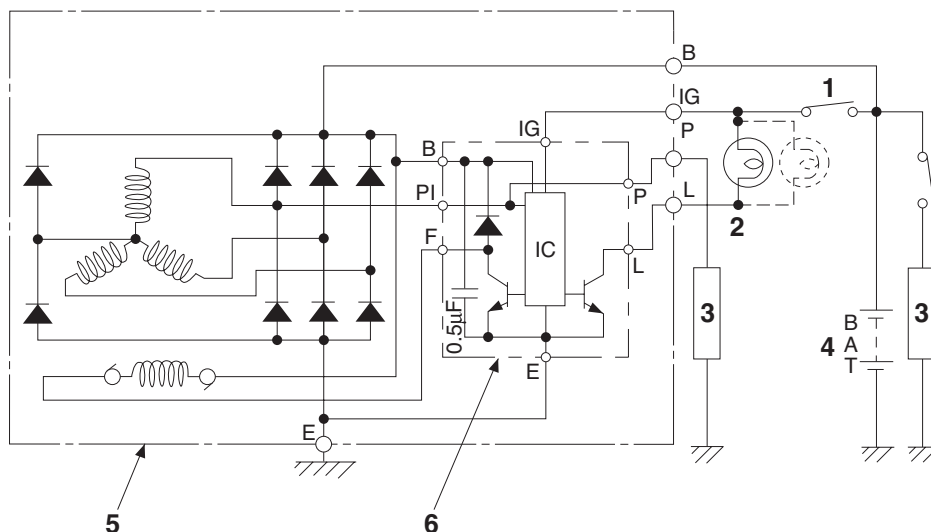
Figure 385

FG009101

Reference Number	Description
1	Nut
2	Pulley
3	Collar
4	Front Frame Housing
5	Stator Assembly
6	Stud (2 used)
7	Front Frame Housing Bearing
8	Bearing Cover
9	Bearing Cover Bolt (4 used)
10	Rotor Assembly
11	Rear Frame Housing Bearing
12	Bearing Cover
13	Thrust Washer
14	Thrust Washer
15	Nut (2 used)

Reference Number	Description
16	Nut
17	Insulation Bushing
18	Spring (2 used)
19	Brush Holder
20	Rear Frame Housing
21	Bolt (2 used)
22	Holder
23	IC Regulator Assembly
24	Bolt (2 used)
25	Bolt
26	Brush (2 used)
27	Bolt
28	Rear Cover
29	Bolt (3 used)

Alternator Wiring Diagram



FG009102

Figure 386

Reference Number	Description
1	Key Switch
2	Charge Lamp (3.4 Watts Max.)
3	Load

Reference Number	Description
4	Battery
5	Alternator Assembly
6	IC Regulator Assembly



CAUTION

Do not short-circuit the charging system between alternator terminals IG and L. Damage to the alternator will result.



CAUTION

Do not connect a load between alternator terminals L and E. Damage to the alternator will result.



CAUTION

Do not remove the positive (+) battery cable from alternator terminal B while the engine is operating. Damage to the alternator will result.

Alternator Standard Output

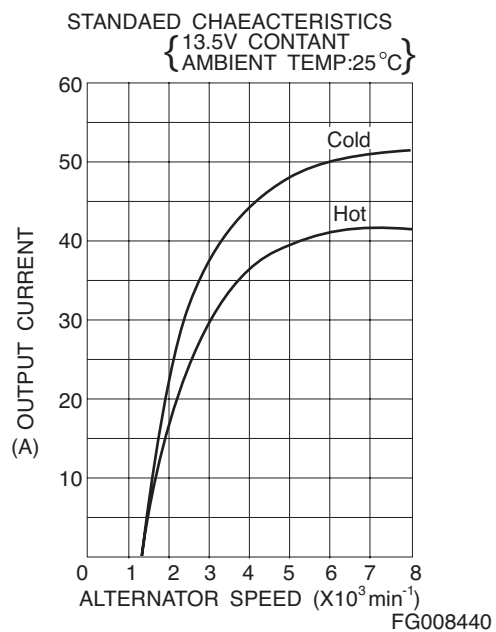


Figure 387

Alternator



WARNING

SHOCK HAZARD!

Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.

Failure to comply could result in death or serious injury.



FG009151

Figure 388

Removal of Alternator

1. Disconnect the electrical wires from the alternator.
2. Loosen the V-belt.

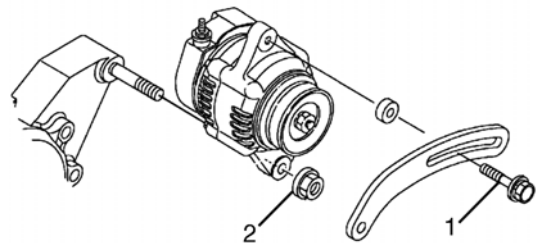


CAUTION

PINCH HAZARD!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

3. Remove the V-belt adjuster from the alternator bolt (1, Figure 389).
4. Remove the nut (2, Figure 389) from the gear case stud. Remove the alternator.



FG009103

Figure 389

Disassembly of Alternator

1. Remove the nut (1, Figure 390) from the shaft of the rotor assembly. Remove the pulley (2, Figure 390).

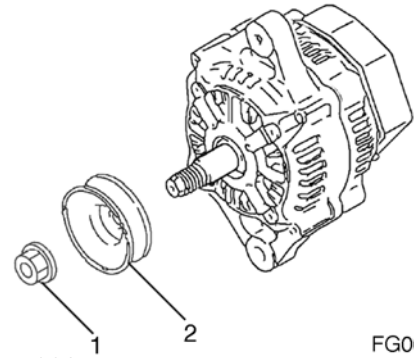


Figure 390

FG009104

2. Remove the three bolts (1, Figure 391) retaining the rear cover (2, Figure 391) to the rear frame assembly.
3. Remove the brush holder (3, Figure 391). Remove the brush springs (4, Figure 391) and brushes (5, Figure 391).

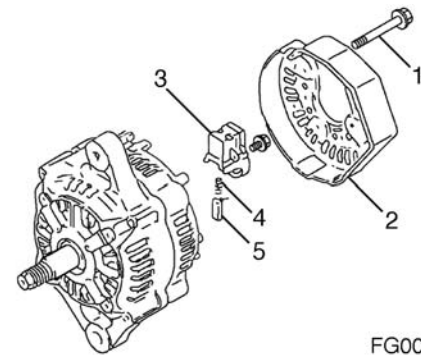


Figure 391

FG009105

4. Remove the bolt retaining the regulator assembly (1, Figure 392) to the holder (2, Figure 392).
5. Remove the bolts retaining the holder (2, Figure 392) to the rear frame housing. Remove the holder.
6. Remove the nut (3, Figure 392) retaining the insulation bushing (4, Figure 392). Remove the insulation bushing.

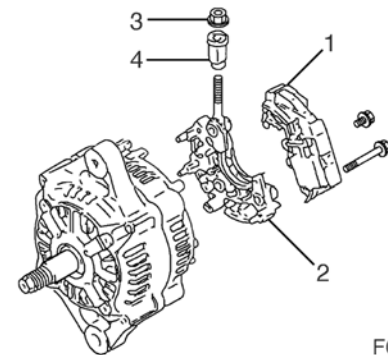


Figure 392

FG009106

7. Remove the two bolts (1, Figure 393) and two nuts (2, Figure 393) securing the rear frame housing to the front frame housing.

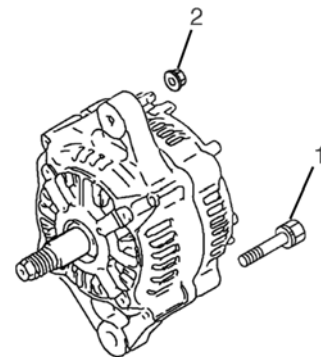


Figure 393

FG009107

8. Using a press, remove the rotor assembly (1, Figure 394) from the front frame housing (2, Figure 394) and rear frame housing (1, Figure 394).

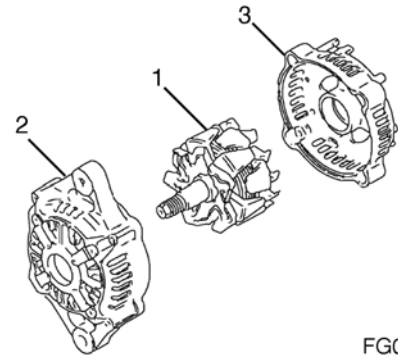


Figure 394

FG009108

9. Remove the stator assembly (1, Figure 395) from the front frame housing.
10. If it is necessary to replace the bearing (2, Figure 395) in the front frame housing, remove the four bolts (3, Figure 395) securing the plate (4, Figure 395) to the front frame housing. Remove the plate. Use a puller to remove the bearing. Discard the bearing.

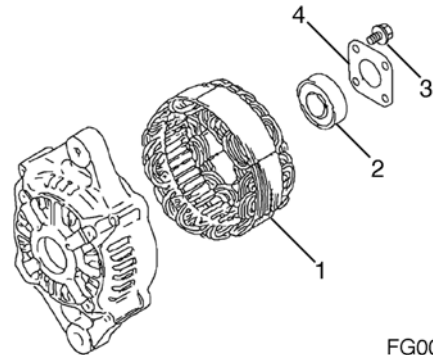


Figure 395

FG009109

11. If it is necessary to replace the bearing (1, Figure 396) in the rear frame housing, use a puller to remove. Discard the bearing. Remove the bearing cover (2, Figure 396) and two thrust washers (3, Figure 396).

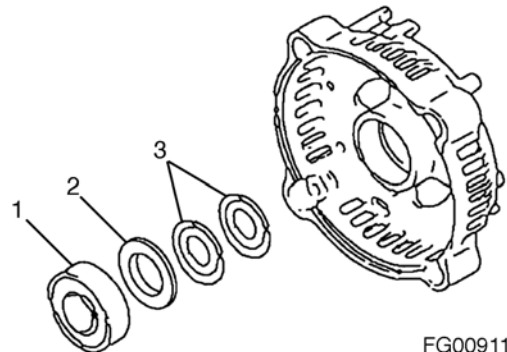
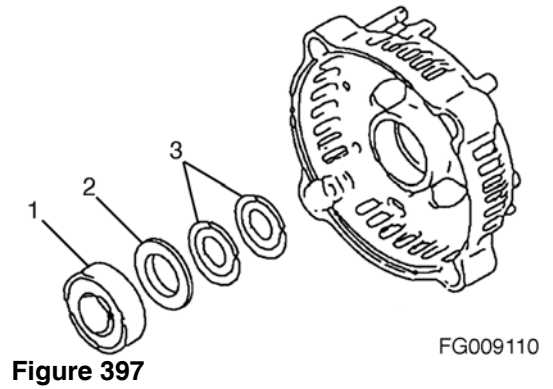


Figure 396

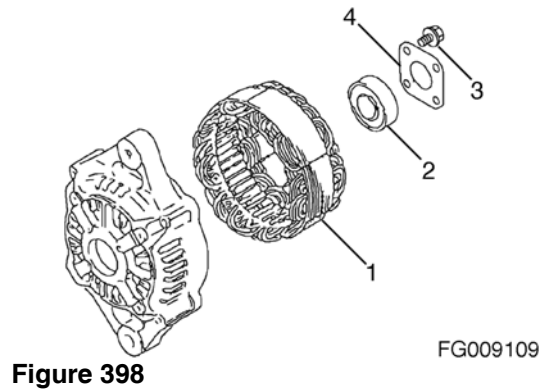
FG009110

Reassembly of Alternator

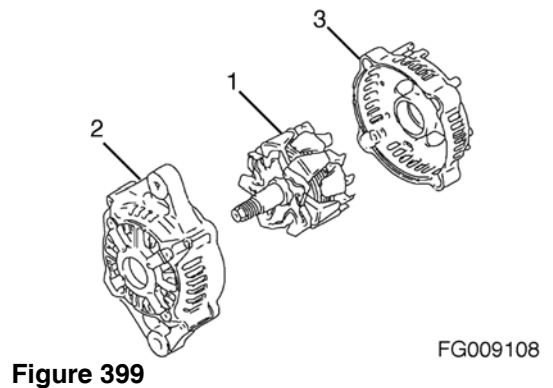
1. If removed, reinstall the two trust washers (3, Figure 397) and bearing cover (2, Figure 397) in the rear frame housing. Lubricate the outside diameter of a new bearing (1, Figure 397). Press the bearing into the rear frame housing.



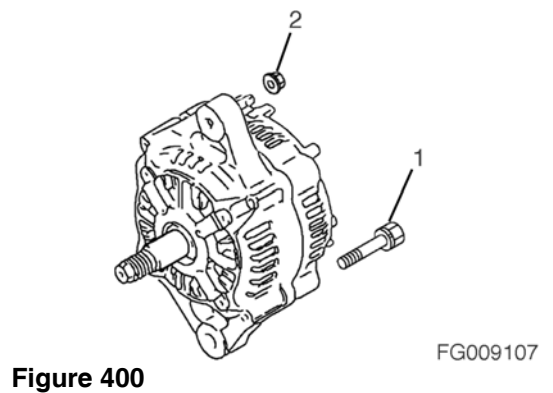
2. If removed, lubricate the outside diameter of a new front frame housing bearing. Press the bearing (2, Figure 398) into the front frame housing. Reinstall the plate (4, Figure 398) to the front housing. Tighten the four bolts (3, Figure 398).
3. Position the stator assembly (1, Figure 398) on the front frame housing studs.



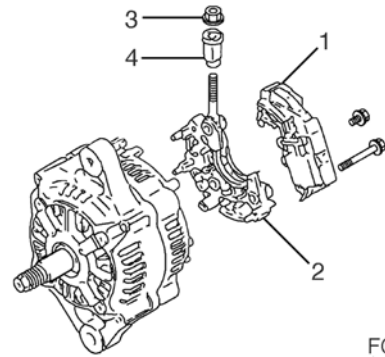
4. Lubricate the shaft of the rotor assembly (1, Figure 399). Press the rotor assembly into the front frame housing (2, Figure 399) and rear frame housing (3, Figure 399).



5. Align the front frame housing with the rear frame housing. Reinstall the two bolts (1, Figure 400) and two nuts (2, Figure 400).



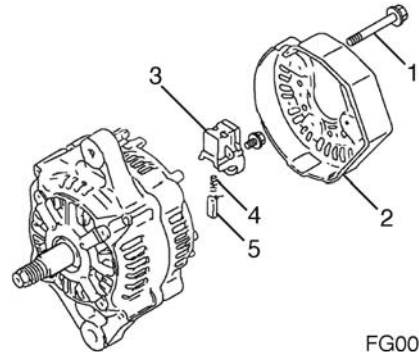
6. Reinstall the insulation bushing (4, Figure 401) and nut (3, Figure 401).
7. Reassemble the regulator assembly (1, Figure 401) to the holder (2, Figure 401).



FG009106

Figure 401

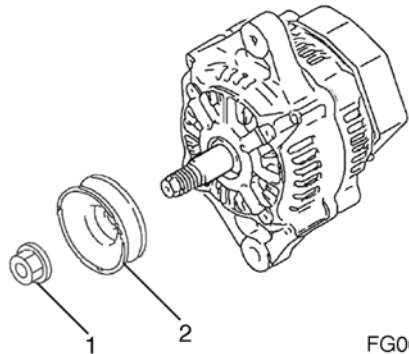
8. Reinstall the brush holder (3, Figure 402), springs (4, Figure 402) and brushes (5, Figure 402).
9. Reattach the regulator assembly and holder to the rear frame housing.
10. Reinstall the rear cover (2, Figure 402) to the rear frame housing with three bolts (1, Figure 402).



FG009105

Figure 402

11. Reassemble the pulley (2, Figure 403) and nut (1, Figure 403) to the shaft of the rotor assembly. Tighten the nut.

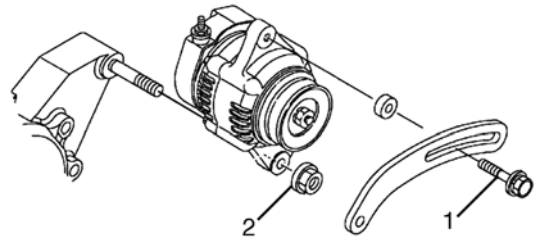


FG009104

Figure 403

Installation of Alternator

1. Position the alternator on the gear case. Loosely reinstall the nut (2, Figure 404) on the gear case stud and the V-belt adjuster bolt (1, Figure 404).
2. Reconnect the electrical wires to the alternator. Tighten the nuts to 15 - 20 in.-lb (1.7 -2.3 N•m ; 17-23 kgf•m).
3. Reinstall the V-belt. Tighten the V-belt to the proper tension as described in See “” on page -70.
4. Start the engine. Listen for any unusual sounds from the alternator.



FG009103

Figure 404



CAUTION

Do not operate the engine if the alternator is producing unusual sounds.

Damage to the alternator will result.

5. Verify that the charge indicator is ON while the engine is operating. If the charge indicator is not ON, repair the problem before operating the engine.

Dynamo Component Location

Standard dynamo is used in this section to show the service procedures for the representative dynamo. For specific part detail, see the Parts Catalog for the engine you are working on.

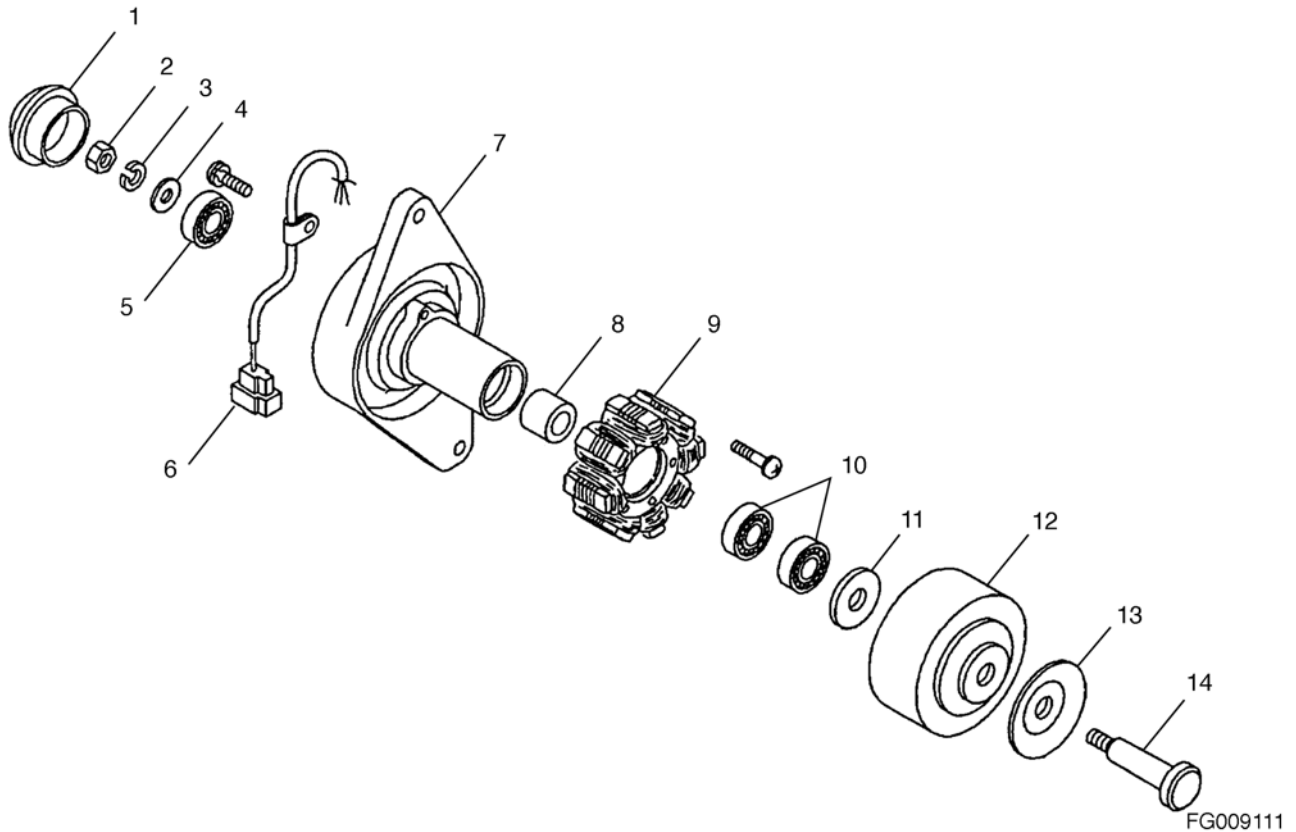


Figure 405

Reference Number	Description
1	Rear Cover
2	Nut
3	Lock Washer
4	Flat Washer
5	Rear Bearing
6	Output Wire and Connector
7	Plate

Reference Number	Description
8	Spacer
9	Stator Assembly
10	Front Bearing (2 used)
11	Flat Washer
12	Flywheel Assembly
13	Pulley Half
14	Through Bolt

Dynamo Wiring Diagram

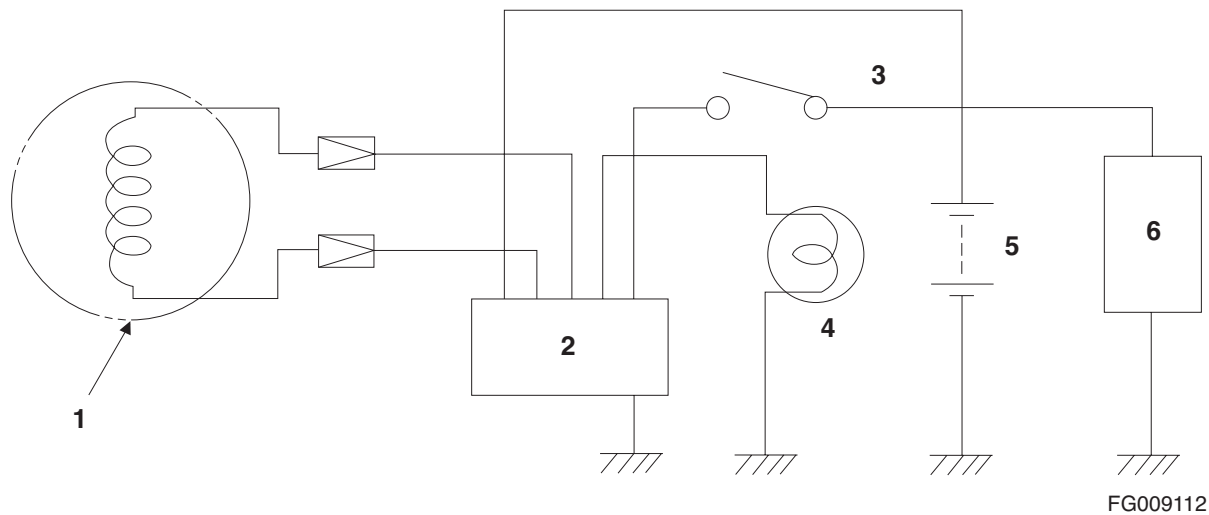


Figure 406

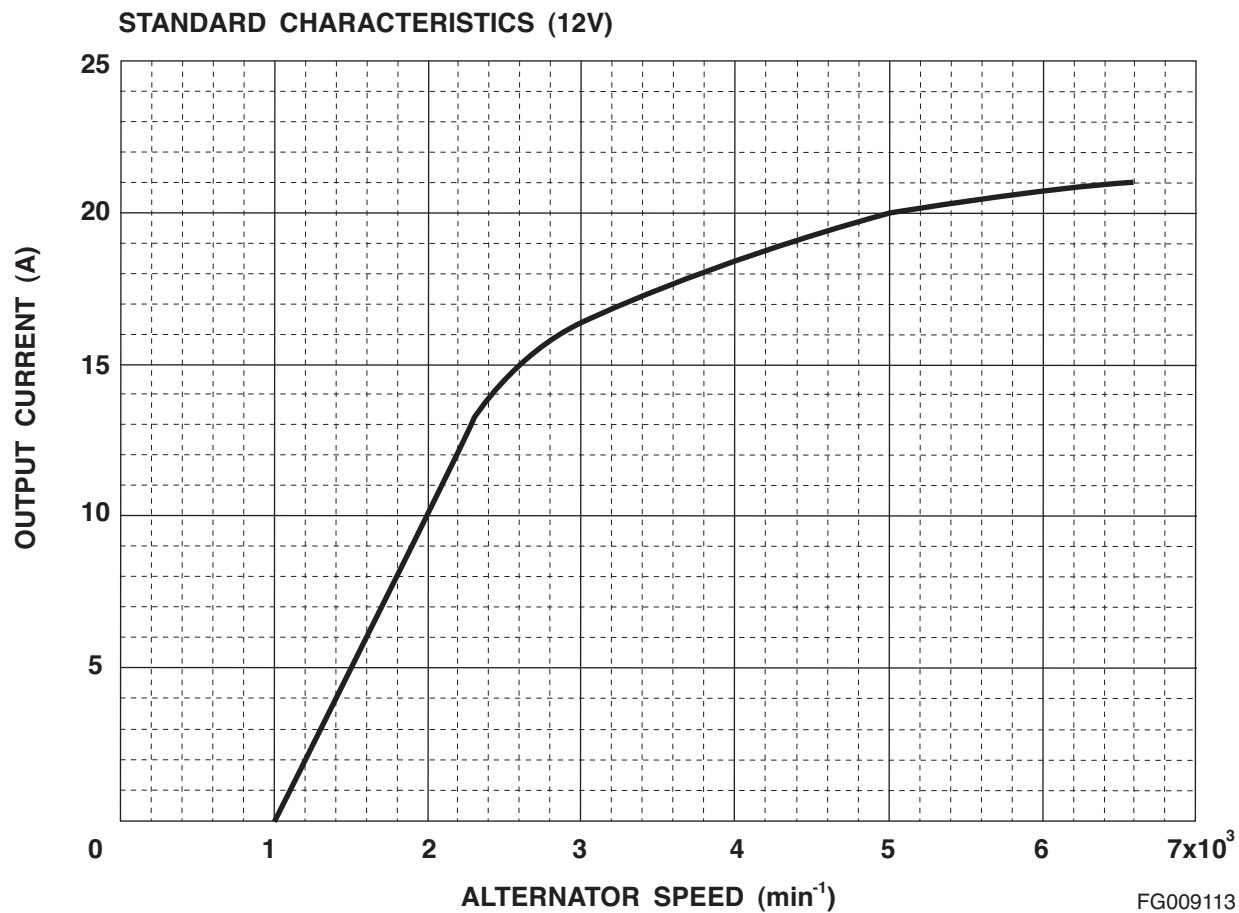
Reference Number	Description
1	Dynamo
2	IC Regulator Assembly
3	Key Switch

Reference Number	Description
4	Charge Lamp (3.4 Watts Max.)
5	Battery
6	Load

Operation of Dynamo

The dynamo consists of a series of permanent magnets that rotate around a stationary stator coil. The magnets are attached to the flywheel which is rotated via the engine cooling fan drive belt. The resultant output is an AC (alternating current) signal. The AC is converted to DC (direct current) in the IC Regulator. The IC Regulator outputs charging DC current to the battery.

Dynamo Standard Output



Testing of Dynamo

Use a circuit tester or multimeter to perform the following tests.

Testing Stator Coil Continuity

1. Disconnect the dynamo output wire connector.
2. Connect one meter lead to each of the stator wire terminals and read the meter.

NOTE: *The meter reading should indicate continuity. If continuity is not indicated, the windings are open and the stator must be replaced.*

Testing Stator Coil Short-to-Ground

1. Disconnect the dynamo output wire connector.
2. Test continuity between each stator wire terminal and engine ground.

NOTE: *The meter reading should infinity. If the meter reading indicates continuity, the windings are shorted to ground and the stator must be replaced.*

Testing Dynamo Regulated Output

1. Test and record the battery voltage with the engine not running.
2. Start the engine and operate it at normal operating rpm.
3. Again, check the battery voltage with the engine running.

NOTE: *The meter reading with the engine running must be higher than with the engine not running.*

- If results are not correct, test the stator for continuity and shorts to the ground.
- Check the charging system wiring.
- If no problems are found in previous checks, replace the IC regulator.

Dynamo

Removal of Dynamo

1. Disconnect the output wire connector from the dynamo.
2. Loosen the V-belt.

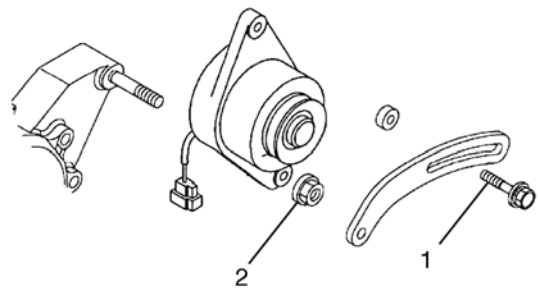


CAUTION

PINCH HAZARD!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

3. Remove the V-belt adjuster from the dynamo bolt (1, Figure 408).
4. Remove the nut (2, Figure 408) from the gear case stud. Remove the dynamo.

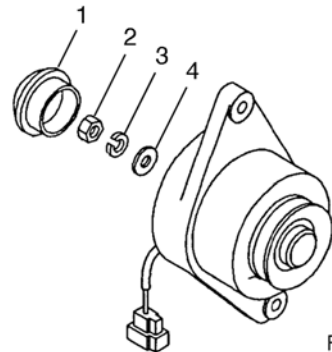


FG009114

Figure 408

Disassembly of Dynamo

1. Remove the rear cover (1, Figure 409).
2. Remove the nut (2, Figure 409), lock washer (3, Figure 409), and flat washer (4, Figure 409).



FG009115

Figure 409

3. Remove the through bolt (1, Figure 410), pulley half (2, Figure 410), flywheel (3, Figure 410), flat washer (4, Figure 410), bearings (5, Figure 410), and spacer (6, Figure 410).

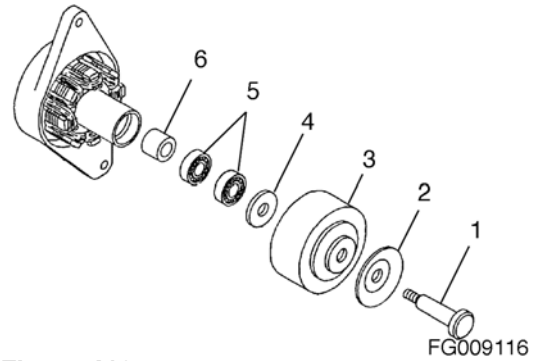


Figure 410

4. Remove the screws (1, Figure 411) and the stator assembly (2, Figure 411).
5. Remove the rear bearing (3, Figure 411).

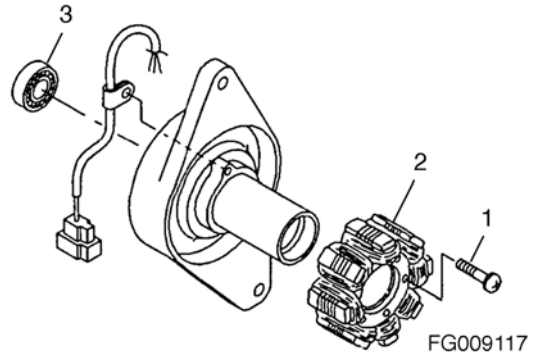


Figure 411

Reassembly of Dynamo

1. Reinstall the rear bearing (3, Figure 412).
2. Reinstall the stator (2, Figure 412) and screws.

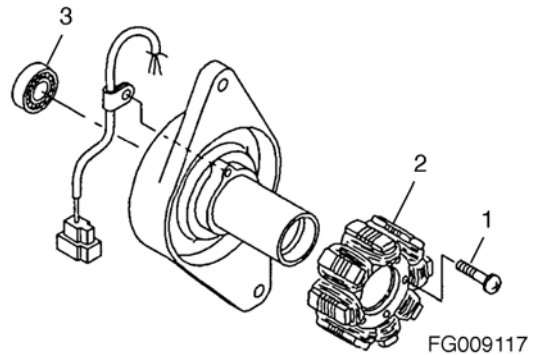


Figure 412

3. Reinstall the front bearings (5, Figure 413) and spacer (6, Figure 413).
4. Reinstall the flat washer (4, Figure 413), flywheel (3, Figure 413), pulley half (2, Figure 413) and through bolt (1, Figure 413).

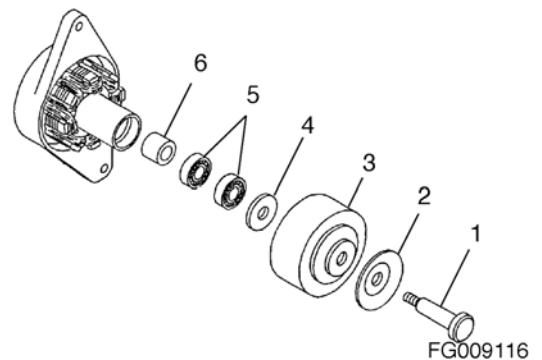
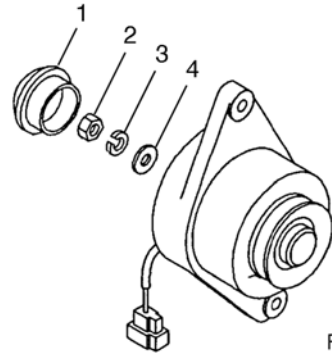


Figure 413

5. Reinstall the flat washer (4, Figure 414), lock washer (3, Figure 414), and nut (2, Figure 414). Tighten the nut to the specified torque.
6. Reinstall the rear cap (1, Figure 414).

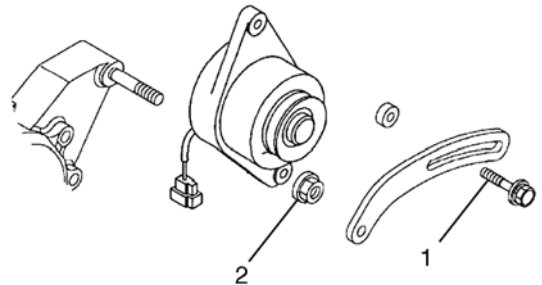


FG009115

Figure 414

Installation of Dynamo

1. Position the dynamo on the gear case. Loosely reinstall the nut (2, Figure 415) on the gear case stud and the V-belt adjuster bolt (1, Figure 415).
2. Reconnect the dynamo output wire connector.
3. Reinstall the V-belt. Tighten the V-belt to the proper tension as described in See “” on page -70.
4. Start the engine. Listen for any unusual sounds from the alternator.



FG009114

Figure 415



CAUTION

Do not operate the engine if the alternator is producing unusual sounds.

Damage to the alternator will result.

5. Verify that the charge indicator is ON while the engine is operating. If the charge indicator is not ON, repair the problem before operating the engine.

ELECTRIC WIRING

Electric Wiring Precautions

Failure to follow these precautions may result in the failure of an electrical component and the loss of warranty coverage on that item as well as related items. Make sure that all users read and understand these precautions.



CAUTION

Do not reverse the positive (+) and negative (-) ends of the battery cable. The alternator diode and stator coil will be damaged.



CAUTION

When the battery indicator goes out, it should not come on again. The battery indicator only comes on during operation if the alternator fails or if the V-belt breaks. However, if an LED is used in the battery indicator, the LED will shine faintly during normal operation.



CAUTION

Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated in the Battery Cable Resistance chart in the Electric Wiring Section of this manual. The starter motor will malfunction and fail if the resistance is higher than the specified value.



CAUTION

Removing the battery cables or the battery while the engine is operating may cause damage to the current limiter depending on the electrical equipment being used. This situation could cause loss of control of output voltage. The continuous high voltage of 23-24 volts (for 5000 rpm dynamo) will damage the current limiter and other electrical equipment.



CAUTION

Reversing the battery cable connections at the battery or on the engine will destroy the SCR diode in the current limiter. This will cause the charging system to malfunction and may cause damage to the electrical harnesses.

Electrical Wire Resistance

AWG	Metric Nominal mm ²	Ohms / Foot Resistance
20	0.5	0.009967
18	0.8	0.006340
16	1.25	0.004359
14	2	0.002685
12	3	0.001704
10	5	0.001073
8	8	0.000707
6	15	0.000421
4	20	0.000270
2	30	0.000158
1	40	0.000130
0 (1/0)	50	0.000130
00 (2/0)	60	0.000087
000 (3/0)	85	0.000066
0000 (4/0)	100	0.000051

Wiring voltage drop should not exceed 5% $[0.05] \times 12 \text{ Volts} = 0.6 \text{ Volts}$.

Voltage Drop = Current [Amps] x Length of Wire [Feet] x Resistance per Foot Ω

Example:

Current draw of 100 Amps x 3 feet of 4 AWG wire $100 \text{ Amps} \times 3 \text{ Feet} \times 0.000270 = 0.08 \text{ Volts [Voltage Drop]}$

Battery Cable Resistance

AWG	mm ²	Maximum Total Battery Cable Length (Positive Cable + Negative Cable + a*) 12V Starter Motor Output			
		Less Than 2.68 HP (2 kW)		Greater Than 2.68 HP (2 kW)	
		m	ft	m	ft
6	15	1.5	4.75	N/A	N/A
4	20	2.3	7.4	N/A	N/A
2	30	3.8	12.6	2.3	7.5
1	40	4.6	15.3	2.8	9.2
0 (1/0)	50	5.9	19.5	3.5	11.6
00 (2/0)	60	7.0	22.8	4.2	13.7
000 (3/0)	85	9.3	30.5	5.6	18.3
0000 (4/0)	100	11.9	39	7.1	23.4
00000 (5/0)	125	N/A	N/A	8.3	27.3
000000 (6/0)	150	N/A	N/A	10.1	33.3

NOTE: Total allowable resistance of the complete battery cable circuit (positive cable + negative cable + a*) (a*: Resistance (Ω) of a battery switch or other electrical equipment having high resistance).

NOTE: For starter motors of less than 2.68 HP (2 kW): the total resistance must be less than 0.002 Ω . For starter motors of greater than 2.68 HP (2 kW): the total resistance must be less than 0.0012 Ω .

Electrical Wire Sizes - Voltage Drop

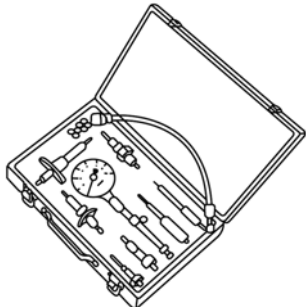
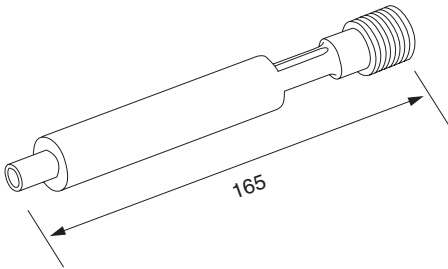
Total current on circuit in amps	Length of conductor from source of current to device and back to source (in feet)																		
	10	15	20	25	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
12 Volts	Wire Size (AWG)																		
5	18	16	14	12	12	12	10	10	8	8	8	6	6	6	6	6	6	6	6
10	14	12	10	10	10	8	6	6	6	6	4	4	4	4	2	2	2	2	2
15	12	10	10	8	8	6	6	6	4	4	2	2	2	2	2	1	1	1	1
20	10	10	8	6	6	6	4	4	2	2	2	2	1	1	1	0	0	0	2/0
25	10	8	6	6	6	4	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	3/0
30	10	8	6	6	4	4	2	2	1	1	0	0	0	2/0	2/0	3/0	3/0	3/0	3/0
40	8	6	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	3/0	4/0	4/0	4/0	4/0
50	6	6	4	4	2	2	1	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0				
60	6	4	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0	4/0						
70	6	4	2	2	1	0	2/0	3/0	4/0	4/0									
80	6	4	2	2	1	0	3/0	3/0	4/0	4/0									
90	4	2	2	1	0	2/0	3/0	4/0	4/0										
100	4	2	2	1	0	2/0	3/0	4/0											
24 Volts																			
5	18	18	18	16	16	14	12	12	12	10	10	10	10	10	8	8	8	8	8
10	18	16	14	12	12	10	10	10	8	8	8	6	6	6	6	6	6	6	6
15	16	14	12	12	10	10	8	8	6	6	6	6	6	4	4	4	4	4	2
20	14	12	10	10	10	8	6	6	6	6	4	4	4	4	2	2	2	2	2
25	12	12	10	10	8	6	6	6	4	4	4	4	2	2	2	2	2	2	1
30	12	10	10	8	8	6	6	4	4	4	2	2	2	2	2	1	1	1	1
40	10	10	8	6	6	6	4	4	2	2	2	2	1	1	1	0	0	0	2/0
50	10	8	6	6	6	4	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	3/0
60	10	8	6	6	4	4	2	2	1	1	0	0	0	2/0	2/0	3/0	3/0	3/0	3/0
70	8	6	6	4	4	2	2	1	1	0	0	2/0	2/0	3/0	3/0	3/0	3/0	4/0	4/0
80	8	6	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	3/0	4/0	4/0	4/0	4/0
90	8	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0	4/0	4/0	
100	6	6	4	4	2	2	1	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0				

Conversion of Awg to European Standards

Conductor Size (AWG)	Conductor Diameter (mm)	Conductor Cross-sectional Area (mm ²)
25	0.455	0.163
24	0.511	0.205
23	0.573	0.259
22	0.644	0.325
21	0.723	0.412
20	0.812	0.519
19	0.992	0.653
18	1.024	0.823
17	1.15	1.04
16	1.29	1.31
15	1.45	1.65
14	1.63	2.08
13	1.83	2.63
12	2.05	3.31
11	2.30	4.15
10	2.59	5.27
9	2.91	6.62
8	3.26	8.35
7	3.67	10.6
6	4.11	13.3
5	4.62	16.8
4	5.19	21.2
3	5.83	26.7
2	6.54	33.6
1	7.35	42.4
0 (1/0)	8.25	53.4
00 (2/0)	9.27	67.5
000 (3/0)	10.40	85.0
0000 (4/0)	11.68	107.2
00000 (5/0)	13.12	135.1
000000 (6/0)	14.73	170.3
1.1 circular mil (CM) @ 0.0005067 mm ²		

TROUBLESHOOTING

Special Service Tools

Compression Gauge Kit	For measuring compression pressure Gauge Set	 FG009118
	Adapter for direct injection 4-valve cylinder head for 4TNV98 - Z	 FG009120

Troubleshooting by Measuring Compression Pressure

Compression pressure drop is one of the major causes of increasing blow-by gas (engine oil contamination or increased engine oil consumption as a resultant phenomenon) or starting failure. The compression pressure is affected by the following factors:

1. Degree of clearance between the piston and cylinder
2. Degree of clearance at the intake / exhaust valve seat
3. Gas leak from the nozzle gasket or cylinder head gasket

The pressure will drop due to increased parts wear. Pressure drop reduces the durability of the engine.

A pressure drop may also be caused by a scratched cylinder or piston, dust entrance from the dirty air cleaner element or a worn or broken piston ring. Measure the compression pressure to determine the condition of the engine.

Compression Pressure Measurement Method

1. Warm up the engine.
2. Stop the engine. Remove the high-pressure fuel injection lines as an assembly from the engine. Remove the fuel injector from the cylinder to be measured. See "Removal of Fuel Injectors" on page -194
3. Remove the valve cover assembly. See "Removal of Valve Cover" on page -109 Remove the fuel injector from the cylinder to be tested. See "Removal of Fuel Injectors" on page -194
4. Turn off the fuel supply valve in the fuel supply line. Disconnect the fuel injection pump stop solenoid at the connector. This prevents the fuel injection pump from injecting fuel during compression testing.
5. Before installing the compression gauge (1, Figure 416) 2 valve engine, (1, Figure 417) 4 valve engine) adapter, crank the engine with the stop solenoid disconnected for a few seconds to clear the cylinder of any residual fuel.
6. Install a nozzle seat at the tip end of the compression gauge adapter. Install the compression gauge and the compression gauge adapter at the cylinder to be measured.
7. Crank the engine until the compression gauge reading is stabilized.

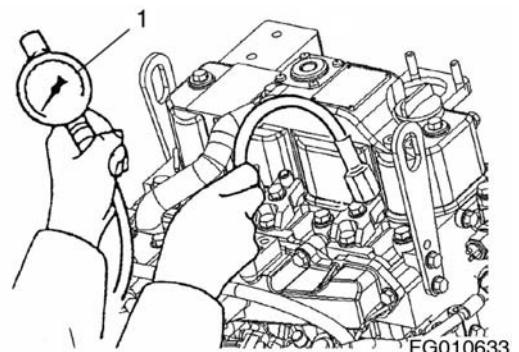


Figure 416

FG010633

8. After performing the compression check remove the compression gauge and compression gauge adapter from the cylinder.
9. Install the fuel valves. See See "Installation of the Fuel Injectors" on page -199 See "Inspection of Valve Guides" on page -114 Then install the valve covers and injection high pressure lines. .
Then connect the stop solenoid..
10. Turn on the fuel supply valve and reconnect the injection pump stop solenoid.
11. Prime the fuel system. Check for leaks. Test the engine.

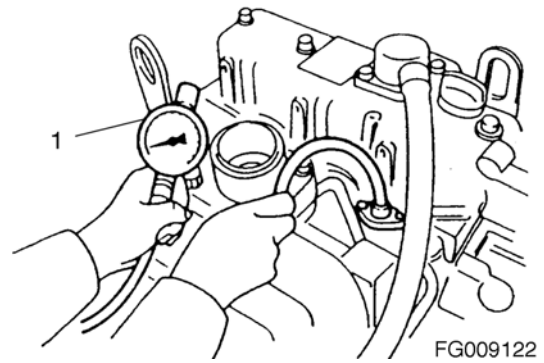


Figure 417

FG009122

Standard Compression Pressure (Reference Value)

Engine Model	Compression Pressure at 250 rpm (250 min ⁻¹)		Deviation Between Cylinders
	Standard	Limit	
4TNV98-E	483 - 513 psi (3.33 - 3.53 MPa; 34 - 36 kgf/cm ²)	384 - 414 psi (2.65 - 2.85 MPa; 27 - 29 kgf/cm ²)	29 - 43 psi (0.2 - 0.3 MPa; 2 - 3 kgf/cm ²)

Engine Speed and Compression Pressure (Use for Reference)

Engine Speed and Compression Pressure (Use for Reference)

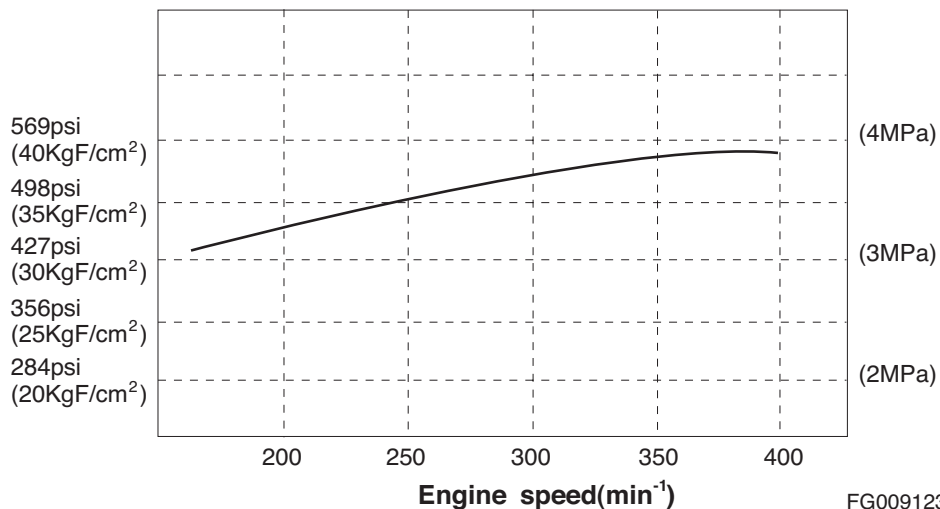


Figure 418

FG009123

Measured Value and Troubleshooting

When the measured compression pressure is below the limit value, inspect each part by referring to the table below.

No.	Item	Cause	Corrective Action
1	Air Cleaner Element	Clogged element	Clean the element.
		Broken element	Replace the element.
		Defect at element seal portion	
2	Valve Clearance	Excessive or no clearance	Adjust the valve clearance.
3	Valve Timing	Incorrect valve clearance	Adjust the valve clearance.
4	Cylinder Head Gasket	Gas leak from gasket	Replace the gasket.
			Retighten the cylinder head bolts to the specified torque.
5	Intake / Exhaust Valve	Sticking valve	Replace the intake / exhaust valve.
	Valve Seat	Gas leak due to worn valve seat or foreign matter trapped in valve	Lap the valve seat.
6	Piston	Gas leak due to scratching or wear	Perform honing and use an oversized part.
	Piston		
	Cylinder		

Quick Reference Table for Troubleshooting

The following table summarizes the general trouble symptoms and their causes. If any trouble symptom occurs, take corrective action before it becomes a serious problem so as not to shorten the engine service life.

Engine SP001434
Page 269

[illegible]

Symptoms and conditions of failure		Starting failure		Engine stall after start up		Speed control error				Engine output low		Noise and vibration		Lubricating oil		Cooling water	Intake air	Exhaust gas		Fuel		Electrical parts				Corrective Action	Referenced page number																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
		Starter does not rotates		Starter rotates		Smoke		Revolution speed cannot be changed with accelerator (stays at a constant speed)	No load		Work load	Smoke color								Work load																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										

Electrical wiring

NOTE: The following wiring diagram is “representative” of a common installation using a TNV engine. The actual installation may be equipped with a variety of electrical components and wiring harnesses. Contact the machine manufacturer for specific information.

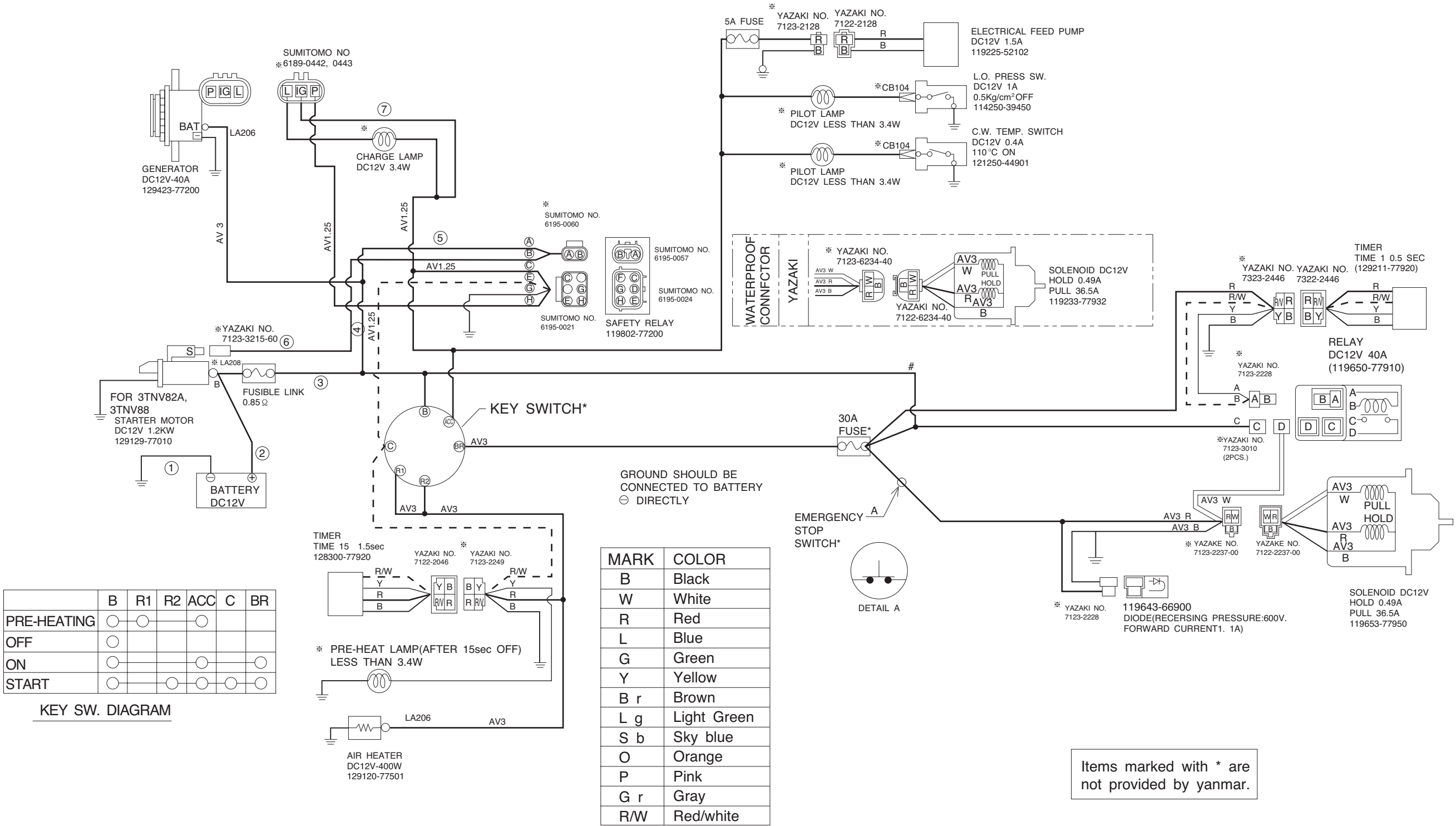


Figure 1

FG009221

Drive Coupling (Main Pump)

Edition 1

MEMO

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Drive Coupling (Main Pump)

Safety Precautions.....	5
Applicable Models	5
Drive Coupling.....	6
Installation of Drive Coupling	7
Installation Procedure	7

MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

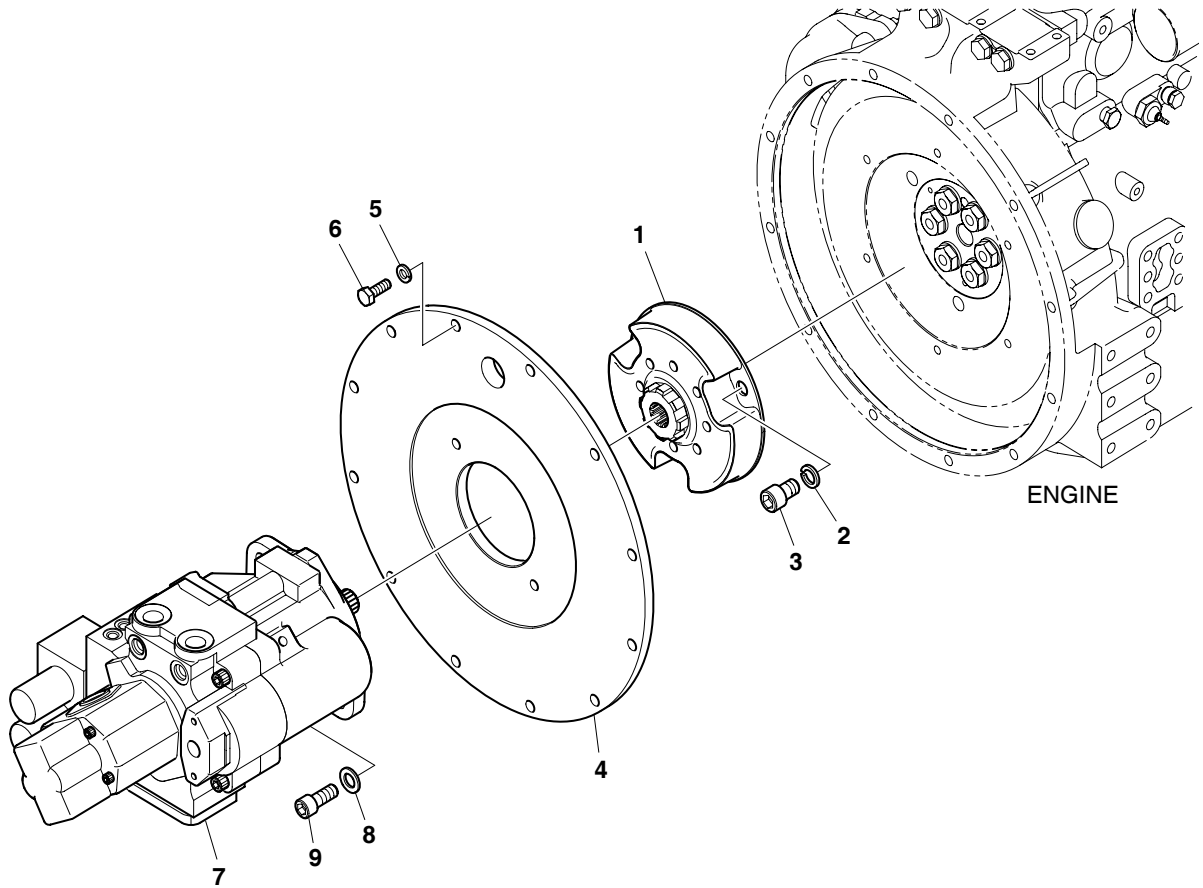
APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

DRIVE COUPLING

Figure 1, show typical drive coupling installations.



FG013229

Figure 1

Reference Number	Description
1	Coupling
2	Washer
3	Bolt
4	Pump Cover
5	Washer

Reference Number	Description
6	Bolt
7	Pump
8	Washer
9	Bolt

INSTALLATION OF DRIVE COUPLING

Always follow the following installation procedure when installing the drive coupling in the main pump.

NOTE: *Noncompliance with the procedure may cause noise or shortening of life of the drive coupling or the main pump.*

Installation Procedure

1. Assemble the coupling (1, Figure 1) in the engine flywheel with spring washers (2, Figure 1) and bolts (3, Figure 1).

NOTE: *Apply lock tight to bolts.*

NOTE: *Tightening torque = 13.8 kg•m*

2. Assemble the pump cover (4, Figure 1) to the fly wheel housing with spring washers (5, Figure 1) and bolts (6, Figure 1).

NOTE: *Check the distance between the coupling and the pump cover to be 9 mm*

NOTE: *Tightening torque = 6.5 kg•m*

3. Assemble the pump (7, Figure 1) to the pump cover with, spring washers (8, Figure 1) and bolts (10, Figure 1).

NOTE: *Apply lock tight to bolts.*

NOTE: *Tightening torque = 9kg•m*

Hydraulics

Accumulator

Edition 1

MEMO

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Accumulator

Safety Precautions.....	5
Applicable Models	5
General Description	6
Specifications.....	8

MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own personal responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX27Z	5001 and Up
DX35Z	5001 and Up
DX55	50001 and Up
DX60R	50001 and Up
DX80R	50001 and Up
DX180LC	5001 and Up
DX225LC	5001 and Up
DX225NLC	5001 and Up
DX255LC	5001 and Up
DX300LC	5001 and Up
DX300LL	5001 and Up
DX340LC	5001 and Up
DX420LC	5001 and Up
DX480LC	5001 and Up
DX520LC	5001 and Up

GENERAL DESCRIPTION

The accumulator is a gas-charged storage device designed to hold a reserved quantity of hydraulic fluid under pressure. Accumulators are used in hydraulic circuits in as much the same way as condensers (or capacitors) are used to collect, store and maintain electrical charge in a circuit.

In a hydraulic circuit, minor variations or lags in pump output that might cause unsteady or irregular operation are made up from the supply of pressurized oil in the accumulator.

Reference Number	Description
1	Screw Plug
2	Steel Pressure Vessel
3	Diaphragm
4	Fluid Valve

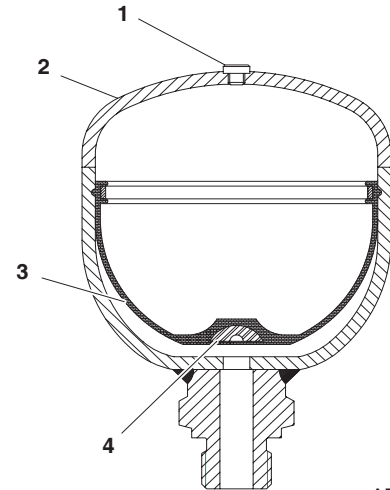


Figure 1

Accumulators are solidly constructed to resist high operating pressures of the fluids they contain. There are only three main moving parts: a plug at the top allows precharging or expelling gas from the compressible, precharged upper chamber; a valve assembly at the bottom of the accumulator for passing hydraulic fluid in and out, and an elastic diaphragm to separate the two chambers. The flexible diaphragm changes shape to conform to the changing pressures and volumes of the two fluids in the upper and lower chambers.

The drawings in Figure 2 display the six possible states the diaphragm can be in, they are as follows:

1. With no gas charge in the upper chamber 0 bar (0 psi, empty) and no oil in the bottom 0 bar (0 psi, dry) the elastic diaphragm hangs loosely.
2. When the prepressure charge of gas (usually nitrogen) is introduced through the port at the top of the accumulator, the diaphragm expands to maximum size. The valve button in the center of the diaphragm pushes into the fluid opening in the bottom chamber, sealing off the lower valve. If the pressure of the gas charge exceeds system oil pressure, no fluid enters the accumulator. The button also keeps the diaphragm from protruding into the lower valve opening.

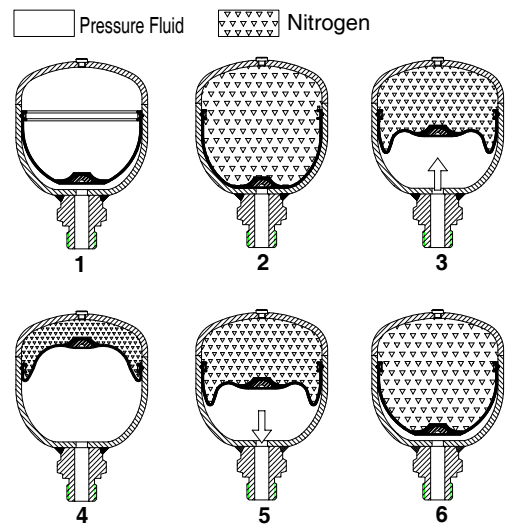


Figure 2

NOTE: Precharge pressure is referred to as the "P1" pressure. The accumulator manufacturer's "P1" rated pressure should be stamped or marked on the accumulator's rating plate. Annual checks of actual precharge pressure should be made by tapping a hydraulic pressure gauge (and 3-way adapter coupling) into the valve on the bottom of the accumulator. When hydraulic fluid is pushed out the lower valve opening by the pressure of the gas charge on the other side of the diaphragm - and there is no counterpressure from system oil - the valve

button on the bottom of the diaphragm eventually seals off the lower oil passage. Just after the needle on the gauge reaches its highest point (when there is 0 bar (0 psi) resistance from hydraulic system pressure) pressure on the gauge will drop sharply to zero, as the accumulator is completely emptied of oil and the diaphragm button closes.

Record the highest gauge reading and compare to the "P1" rated precharge pressure on the accumulator manufacturer's data label. Repeat this test at least once a year to verify proper functioning of the accumulator.

3. As hydraulic system pressure overcomes accumulator precharge pressure, the flexible diaphragm begins to retract upward.
4. When system oil is at highest working pressure and the accumulator fills to maximum reserve capacity, the flexible diaphragm is pushed up into the top of the upper chamber.

The highest working pressure is sometimes referred to as the "P3" pressure and can also be referenced on the manufacturer's data label on the exterior of the accumulator.

5. If system oil pressure begins to fall off or is momentarily checked or interrupted, the energy stored on the other side of the diaphragm, in the form of compressed gas, pushes oil back out of the lower chamber, maintaining oil pressure of the circuit.
6. With minimal system pressure, an equilibrium point may be reached in which accumulator precharge pressure and hydraulic system oil pressure achieve a rough balance. In this state a minimal amount of oil is stored in the accumulator.

Specifications

Model	Serial Number	System	Charge Pressure	Volume
DX27Z	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX35Z	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX55	S/N 50001 and Up	Pilot	10 kg/cm ² (142 psi)	320 cc (19.53 in ³)
DX60R	S/N 50001 and Up	Pilot	10 kg/cm ² (142 psi)	320 cc (19.53 in ³)
DX80R	S/N 50001 and Up	Pilot	10 kg/cm ² (142 psi)	320 cc (19.53 in ³)
DX180LC	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX225LC	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX225NLC	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX255LC	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX300LC	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX340LC	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX420LC	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX480LC	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)
DX520LC	S/N 5001 and Up	Pilot	10 kg•cm ² (140 psi)	320 cc (19.53 in ³)

Center Joint (Swivel)

Edition 1

MEMO

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Center Joint (Swivel)

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

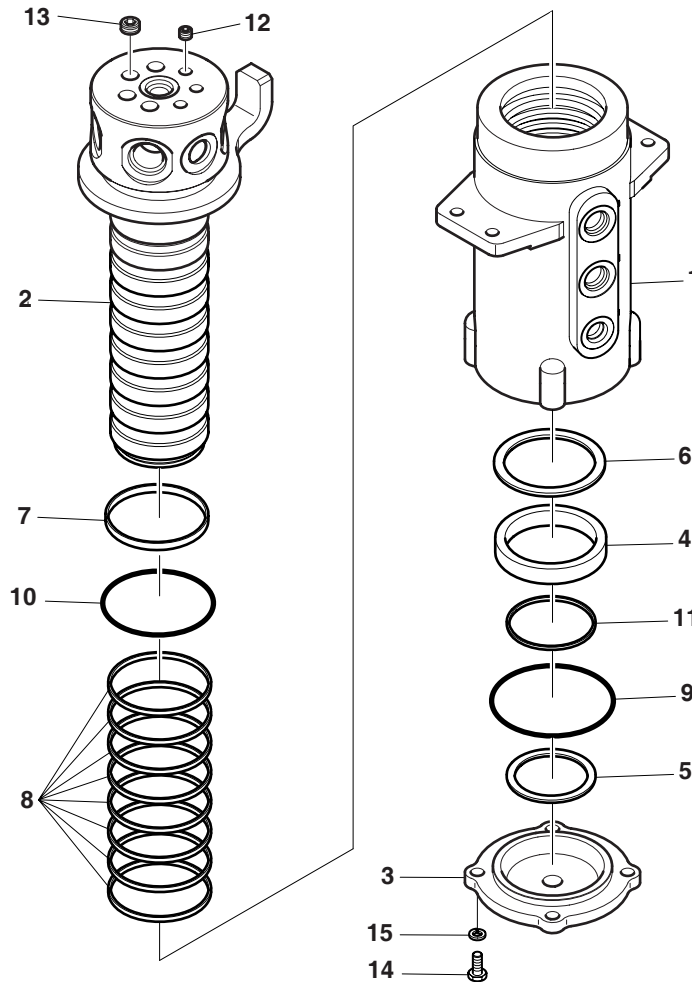
MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up
DX80R	50001 and Up

GENERAL DESCRIPTION

The center joint (swivel) is designed to allow hydraulic oil from the upper structure to flow to components in the lower structure.

It is capable of allowing continuous 360° rotation of the upper structure in relationship to the lower structure.

Disassembly Diagram



FG013233

Figure 1

Reference Number	Description
1	Hub
2	Shaft Assembly
3	Cover
4	Spacer
5	Shim
6	Shim
7	Seal Dust
8	Sliper Seal

Reference Number	Description
9	O-ring
10	O-ring
11	Retaining Ring
12	Plug
13	Plug
14	HEX-Bolt
15	Spring Washer

DISASSEMBLY



CAUTION

It is recommended to use a hoist or a similar device for it is heavy.



CAUTION

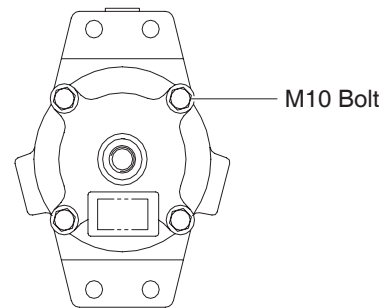
Remove active oil and wash it out before starting disassembly.



CAUTION

It should be disassembled after it's active oil is cool enough after it is removed from the system for it's active oil is very hot.

1. Remove active oil remaining on each port with air.
2. Use a 17 mm spanner to loosen cover bolts and remove the cover and O-rings (1AG95).
3. Use a pliers to remove the retaining ring and disassemble the spacer at the back of the retaining ring.



FG013234

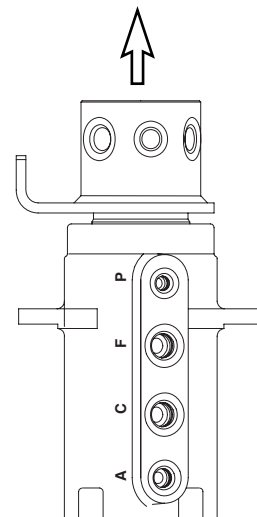
Figure 2



CAUTION

Care should be taken not to make a flaw on the surface of the shaft when disassembling the hub of the shaft assembly.

4. Disassemble the hub from the shaft assembly.
It can be disassembled easily by fixing the Shaft assembly, tightening at least 2 ~ 10 mm eye bolts on the Hub, and lifting it with a hoist slowly.



FG013235

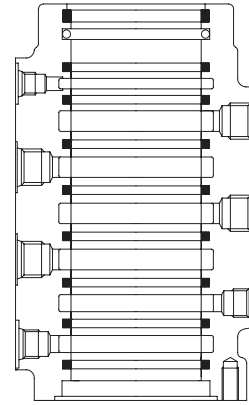
Figure 3

5. Separate the Hub into 8 sliper seals, 1 O-ring (1BP80), and 1 Dust seal (LBH80).



CAUTION

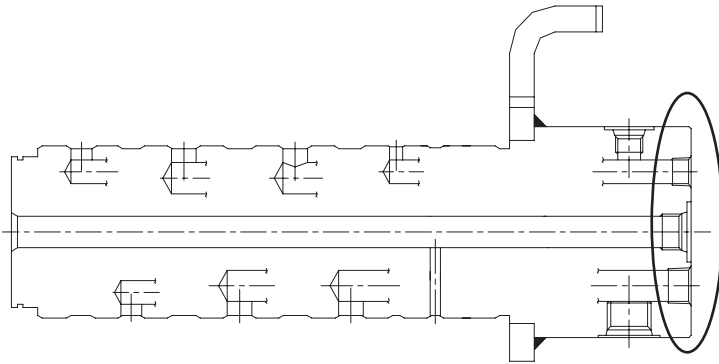
Care should be taken not to damage the inside of the Hub because is likely to be damaged when disassembling the slipper seal. It may be disassembled more easily with a driver whose tip is bent as shown in the figure below.



FG013236

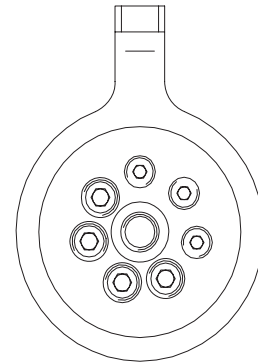
Figure 4

6. Remove the PT plugs sealing the shaft.



* PT 1/4 : 6 mm wrench

* PT 3/8 : 8 mm wrench



FG013238

Figure 5

7. Remove foreign substance at every pieces disassembled and wash them out.
8. Replace disassembled O-rings and slipper seals with new ones, for they cannot be reused.



CAUTION

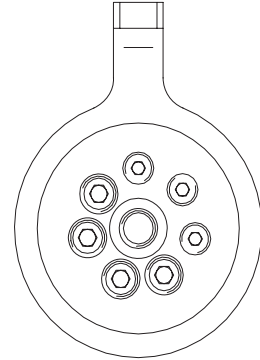
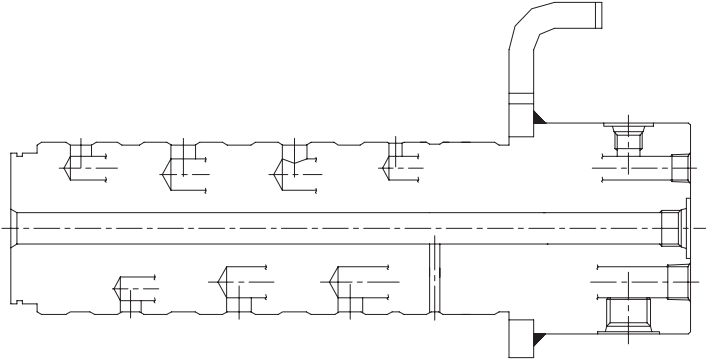
The inside of the Hub should be air washed and rust-proof treated after washing it, as its material is subject to rust.

REASSEMBLY



CAUTION

Apply active oil to every functional (moving) part before assembly to reduce any assembly friction as much as possible.



FG013239

Figure 6

1. Wrap the teflon tape around the PT plug about 6 ~ 10 times.
2. Assemble the PT plug into the washed shaft.

PT 1/4: 6 mm wrench	PT 3/8: 8 mm wrench
Engagement torque: 3 ~ 4 kg•m	Engagement torque: 6 ~ 7 kg•m

3. Assemble the sliper seal and the O-ring into the Hub.
4. Assemble the dust seal (LBH80) into the Hub.



CAUTION

Apply active oil to every functional (moving) part before assembly to reduce any assembly friction as much as possible.



CAUTION

For any sliper seal which is protruded, press it with finger to seat it in its position. Care should be taken when using a driver or a metal tool, which may cause damage to it.



CAUTION

Applying active oil to the surface of the shaft enables the assembly without any damage to the sliper seal.

5. Fix the position of the shaft and press the hub carefully into shaft with both being parallel each other.
6. Use a plastic (or urbber) hammer to tap the hub until it is inserted completely.



CAUTION

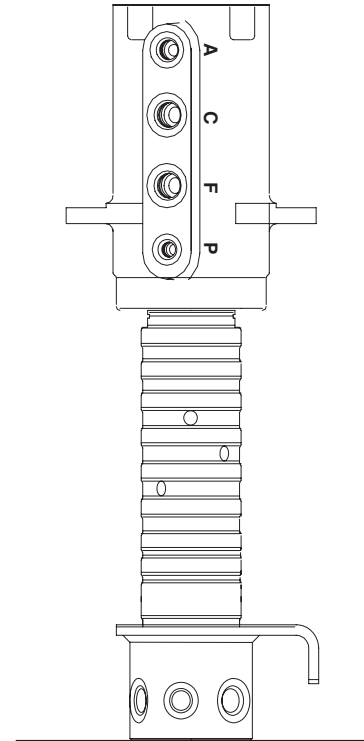
Tap the Hub in a zigzag pattern that it does not tilt to one side.

7. Assemble the shim, spacer and install the retaining ring.
8. Set the O-ring (1AG95) in its place and assemble the cover in the direction as shown in the figure.
9. Engage the cover bolt (M10) at torque of 5 ~ 6 kg•m.



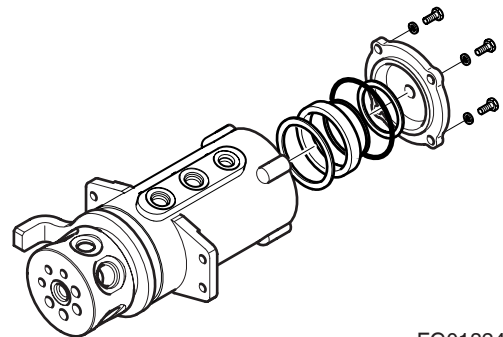
CAUTION

After the completion of the assembly, a start-up and a rotation torque tests should be performed for the sliper seal to seat in its place properly.



FG013241

Figure 7



FG013242

Figure 8

CENTER JOINT ASSEMBLY

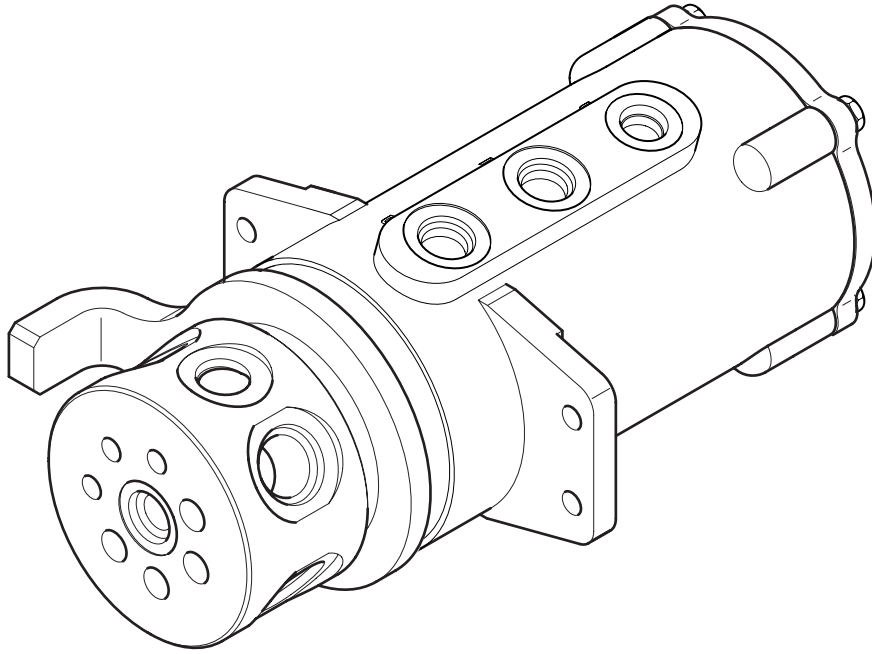


Figure 9

FG013245

Cylinders

Edition 1

MEMO

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Cylinders

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

GENERAL DESCRIPTION

Two essentially similar types of hydraulic cylinders are used on the excavator. The cylinder that is used to operate the excavator boom or bucket is equipped with a rod stopper, which acts as a cushion only when the cylinder rod is fully retracted (and the bucket is pulled close to the arm). This type of cylinder is shown in the lower drawing.

Arm cylinders have a cushion or stopper for operation in both directions. This type of cylinder is shown in the upper drawing.

Theory of Operation

Reference Number	Description
1	Piston
2	Oil Path A
3	Oil Path B

Cylinder piston rods are extended or retracted by oil flow to the back side of the cylinder (shown as "oil path A") or to the front of the cylinder ("oil path B").

The cylinder rod is extended as oil flow is pumped through the circuit to the back side of the piston. The force (F1) of the piston stroke can be expressed by the formula below, where P = circuit oil pressure and the inside diameter of the cylinder is expressed by B (Figure 1).

$$F_1 = P \times \frac{\pi B^2}{4}$$

(P: Pressure, p = 3.14, B: Cylinder Inside Diameter)

Reference Number	Description
1	Cylinder Inside Diameter - B
2	Oil Path A
3	Oil Path B
4	Rod Diameter

When the cylinder rod is retracted, oil flow through the circuit from the pump to the front side of the cylinder generates a force (F2) that can be expressed by the formula in which the diameter of the piston rod is expressed by R, and the other two terms are the same as in the preceding expression.

$$F_2 = P \times \frac{\pi(B^2 - R^2)}{4}$$

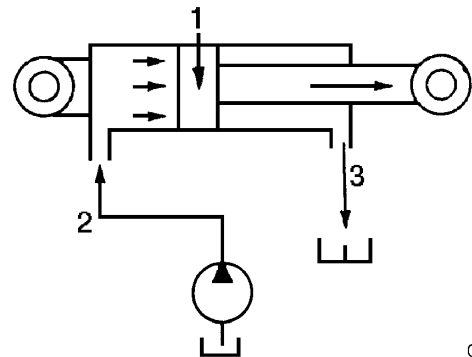


Figure 1

0330

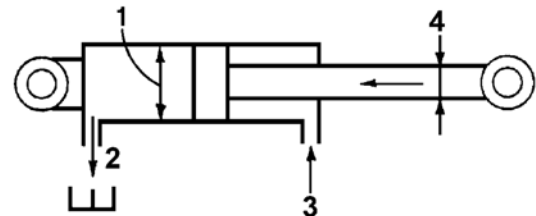


Figure 2

0331

Because the volume of oil needed to lengthen the cylinder rod (Q1) is greater than the volume of oil required to retract the cylinder rod, it takes more time to decrease cylinder stroke length than it does to lengthen it.

$$Q_1 = S \times \frac{\pi(B^2)}{4}$$

$$Q_2 = S \times \frac{\pi(B^2 - R^2)}{4}$$

$$Q_1 > Q_2$$

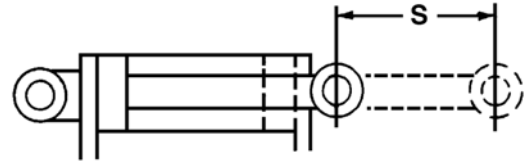


Figure 3

FG011246

Parts List

The following parts list is a partial listing only; for full and complete parts list information, refer to the Hydraulic Equipment Component Parts List

Cross section in Figure 4 shows an arm cylinder.

Cross section in Figure 5 shows a boom cylinder.

The bucket and boom cylinders are identical and differ only in the attached pipes.

Boom Cylinder

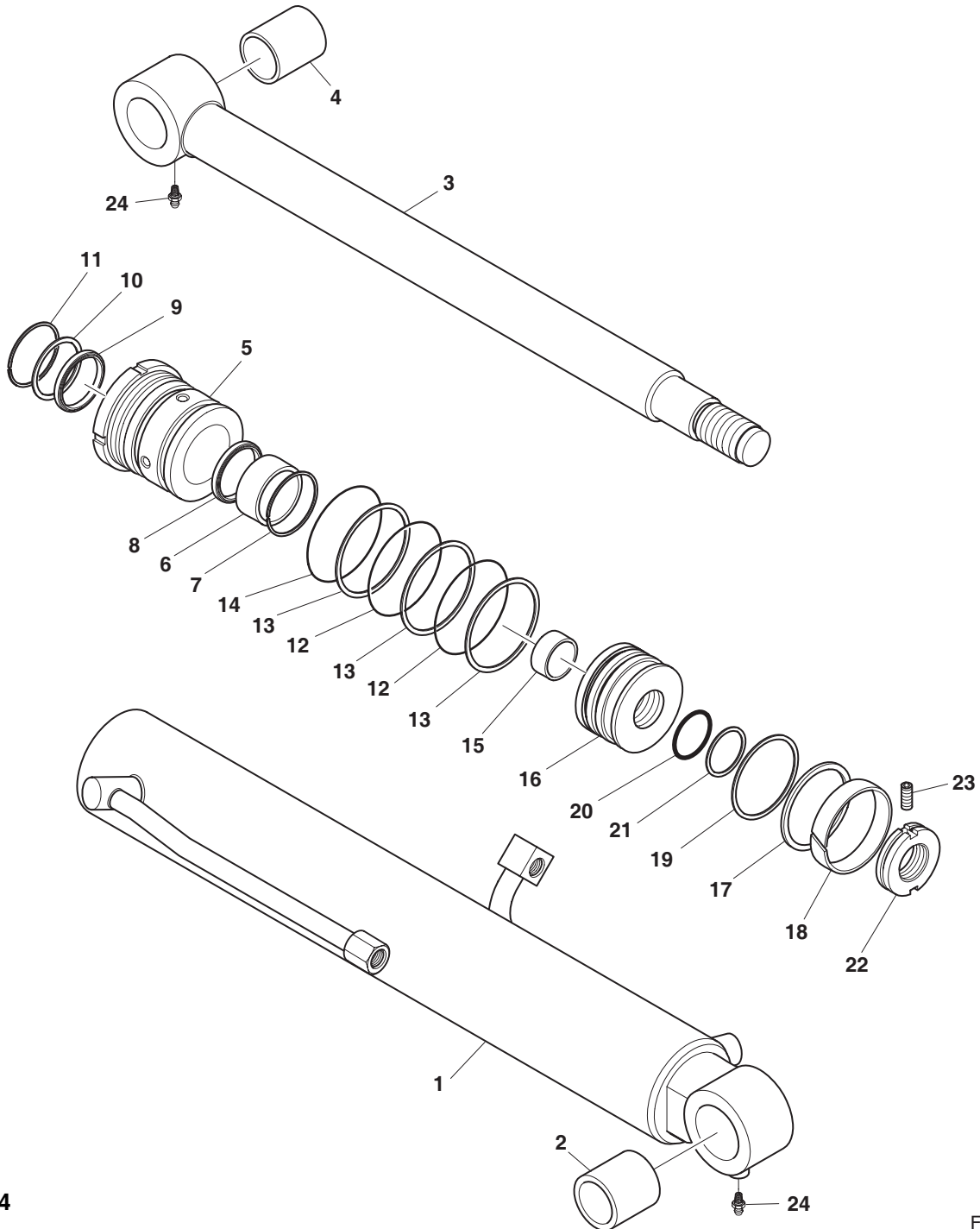


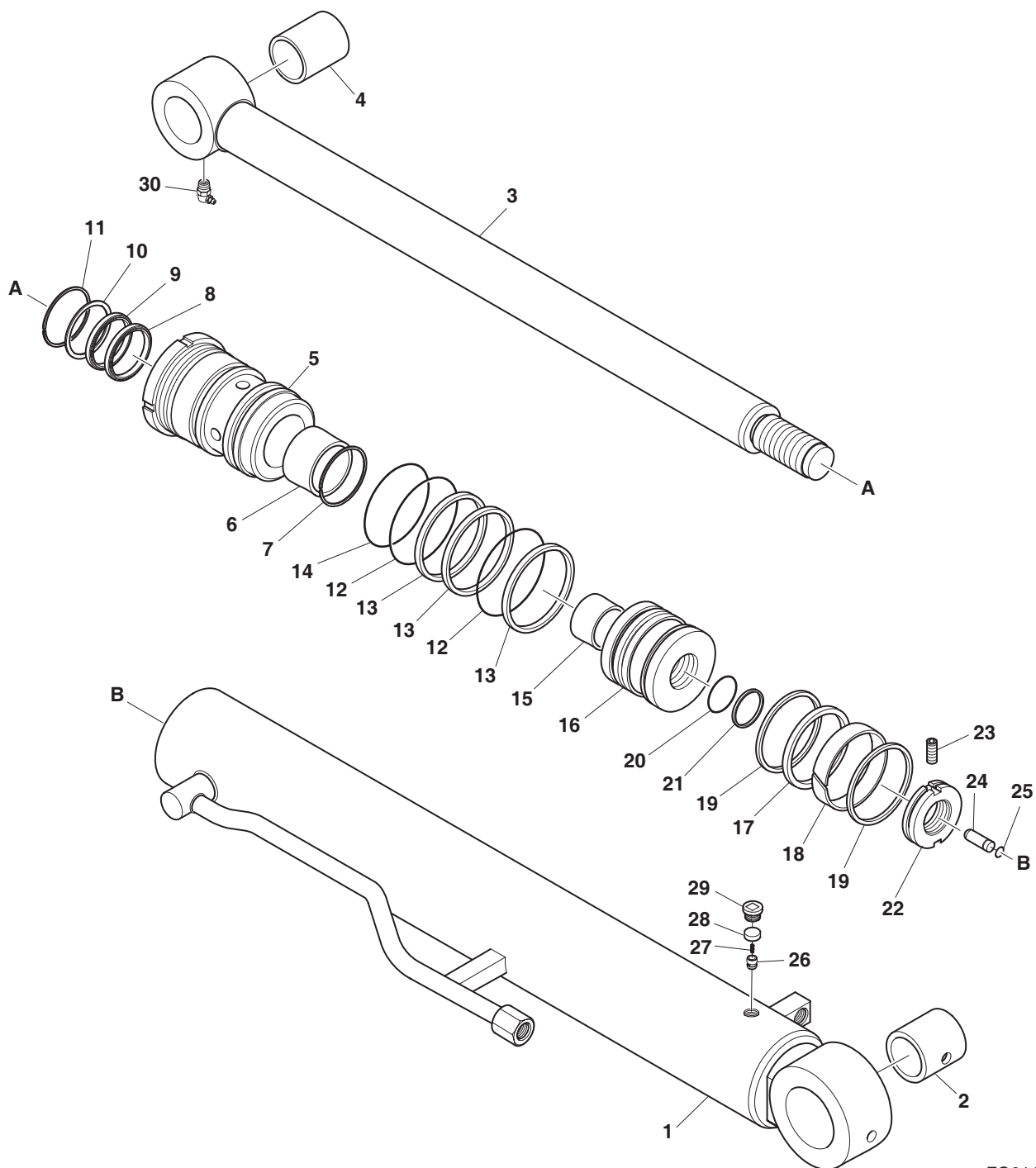
Figure 4

FG011071

Reference Number	Description
1	Tube Assembly
2	Bush
3	Rod Assembly
4	Bush
5	Rod Cover
6	DD-bush
7	Ring, Retaining
8	Seal, Buffer
9	U-packing
10	Wiper, Dust
11	Ring, Retaining
12	O-ring

Reference Number	Description
13	Ring, Back Up
14	O-ring
15	Ring, Cushion
16	Piston
17	Ring, Glyd
18	Ring, Wear
19	Ring, Dust
20	O-ring
21	Ring, Back Up
22	Nut, Piston
23	Screw, Set
24	Nipple, Grease

Arm Cylinder



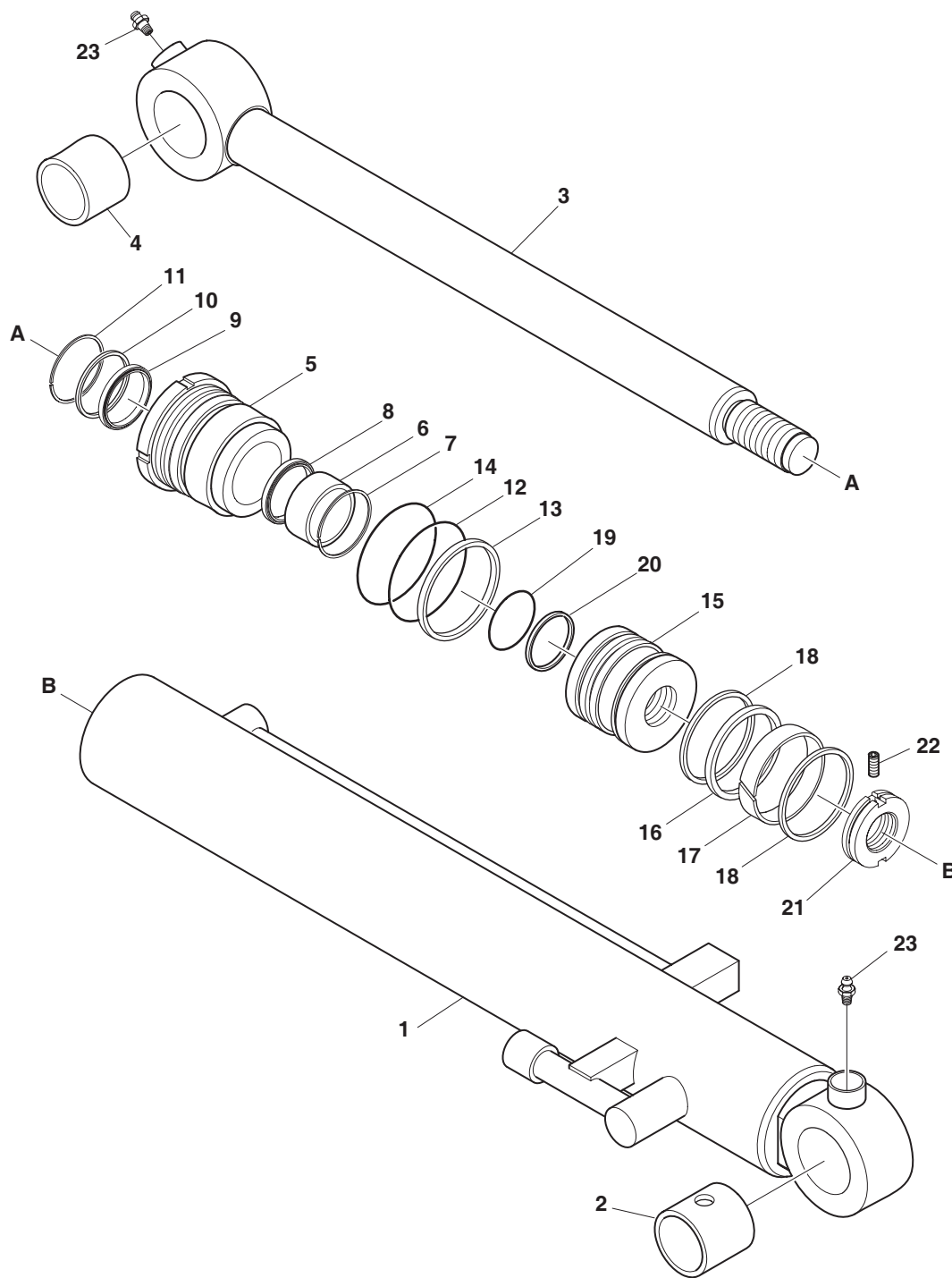
FG011072

Figure 5

Reference Number	Description
1	Tube Assembly
2	Bush
3	Rod Assembly
4	Bush
5	Rod Cover
6	DD-bush
7	Ring, Retaining
8	Seal, Buffer
9	U-packing
10	Wiper, Dust
11	Ring, Retaining
12	O-ring
13	Ring, Back Up
14	O-ring
15	Ring, Cushion

Reference Number	Description
16	Piston
17	Ring, Glyd
18	Ring, Wear
19	Ring, Dust
20	O-ring
21	Ring, Back Up
22	Nut, Piston
23	Screw, Set
24	Plunger, Cushion
25	Ring, Stop
26	Valve, Check
27	Spring
28	Support, Spring
29	Plug, Hex Socket
30	Nipple, Grease

Bucket Cylinder



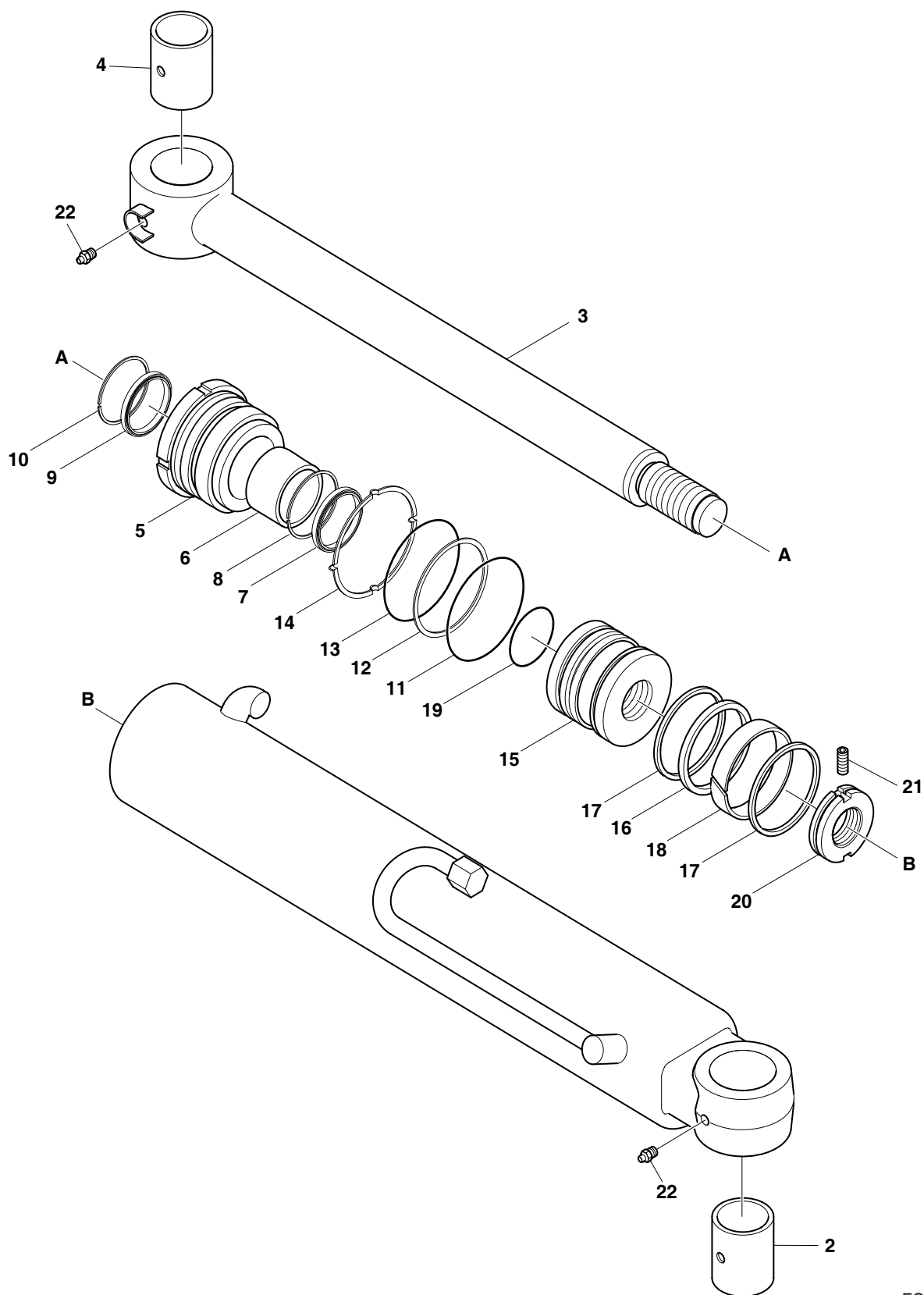
FG011073

Figure 6

Reference Number	Description
1	Tube Assembly
2	Bush
3	Rod Assembly
4	Bush
5	Rod Cover
6	DD-bush
7	Ring, Retaining
8	Seal, Buffer
9	U-packing
10	Wiper, Dust
11	Ring, Retaining
12	O-ring

Reference Number	Description
13	Ring, Back Up
14	O-ring
15	Piston
16	Ring, Glyd
17	Ring, Wear
18	Ring, Dust
19	O-ring
20	Ring, Back Up
21	Nut, Piston
22	Screw, Set
23	Nipple, Grease

Boom Swing Cylinder



FG013247

Figure 7

Reference Number	Description
1	Tube Assembly
2	Bush
3	Rod Assembly
4	Bush
5	Rod Cover
6	DU-bush
7	U-packing
8	Ring, Back Up
9	Wiper, Dust
10	Ring, Retaining
11	O-ring

Reference Number	Description
12	Ring, Back Up
13	O-ring
14	Washer
15	Piston
16	Ring, Glyd
17	Ring, Dust
18	Ring, Wear
19	O-ring
20	Nut, Piston
21	Screw, Set
22	Nipple, Grease

SPECIAL TOOLS AND MATERIALS

Piston Nut

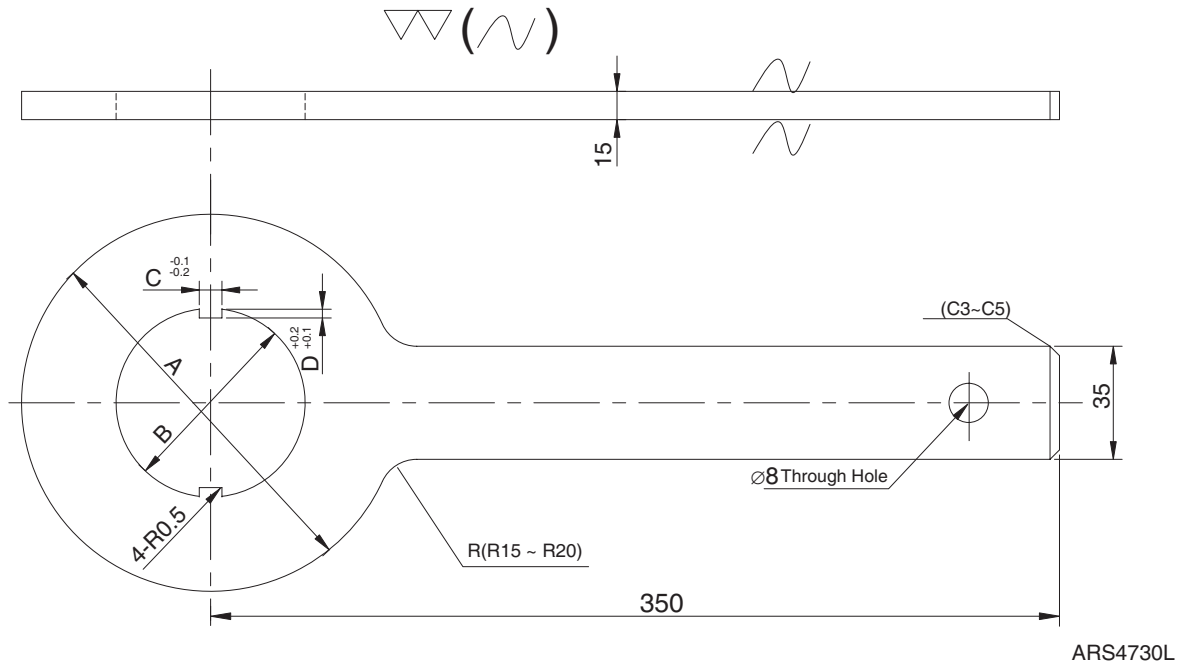


Figure 8

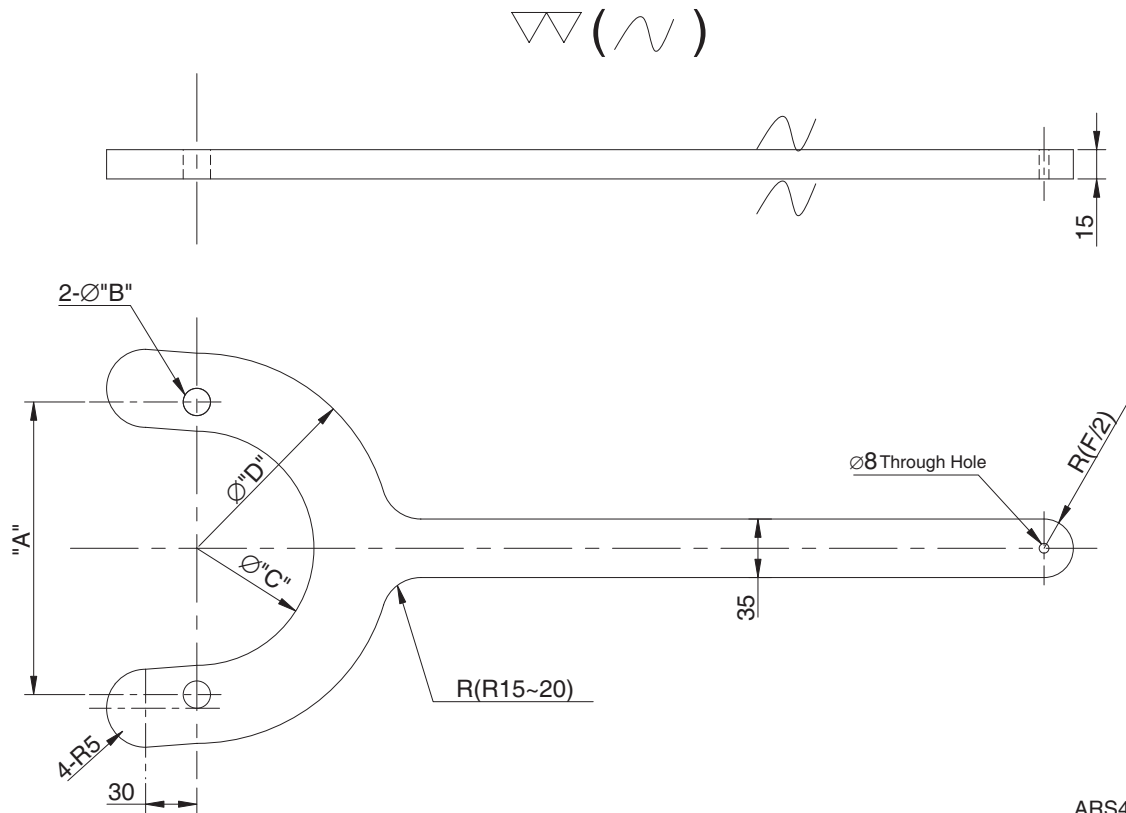
Material SM45C (AISI 1045)

Rockwell Harden from 22 - 27

Oil Quench

Model	Cylinder	øA (mm)	øB (mm)	C (mm)	D (mm)
DX60R	ARM	106.0	66.0	11.0	4.5
	BOOM	112.0	72.0	11.0	4.5
	BUCKET	106.0	66.0	11.0	4.5
	SWING	109.0	69.0	11.0	4.5
DX80R	ARM	114.0	74.0	11.0	4.5
	BOOM	119.0	79.0	11.0	4.5
	BUCKET	109.0	69.0	11.0	4.5
	SWING	112.0	72.0	11.0	4.5

Piston Jig



ARS4740L

Figure 9

Material SM45C (AISI 1045)

Rockwell Harden from 22 - 27

Oil Quench

Model	Cylinder	øA (mm)	øB (mm)	C (mm)	D (mm)
DX60R	ARM	65.0	12.0	22.0	52.0
	BOOM	80.0	12.0	25.0	55.0
	BUCKET	65.0	12.0	22.0	52.0
	SWING	80.0	12.0	25.0	55.0
DX80R	ARM	75.0	12.0	27.0	60.0
	BOOM	75.0	12.0	27.0	60.0
	BUCKET	60.0	12.0	22.0	52.0
	SWING	80.0	12.0	25.0	55.0
	DOZER	70.0	12.0	25.0	55.0



Place: Finally work to used DNMG Tip <Nose R0.4>

Model	Cylinder		øA (mm)	øB (mm)	E (mm)	F (mm)
DX60R	ARM		50.0	58.0	20.0	5.0
	BOOM		50.0	58.0	20.0	5.0
	BUCKET		50.0	58.0	20.0	5.0
	SWING		50.0	0.0	20.0	0.0
	DOZER		65.0	70.0	30.0	0.0
DX80R	ARM		65.0	78.0	20.0	6.0
	BOOM		65.0	78.0	20.0	6.0
	BUCKET	H/C	50.0	58.0	20.0	5.0
		K/L	55.0	66.0	20.0	5.5
	SWING		65.0	78.0	20.0	6.0
	DOZER		50.0	0.0	20.0	0.0

Dust Wiper Jig

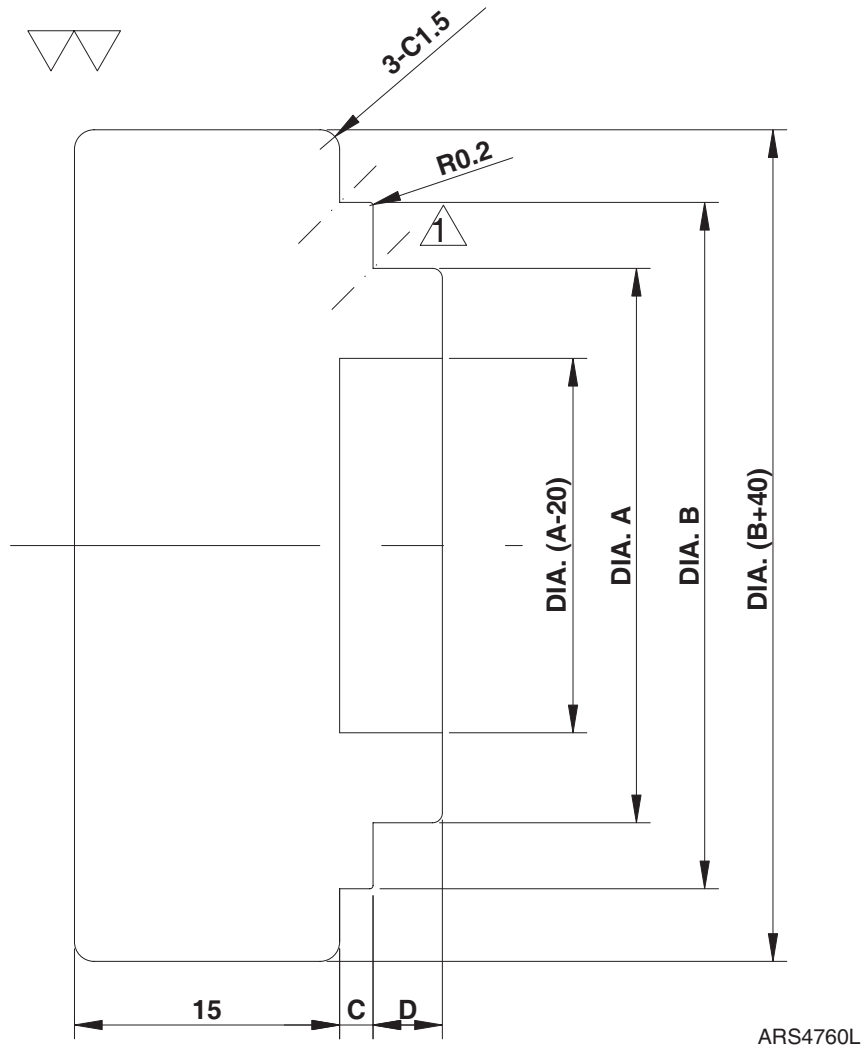


Figure 11

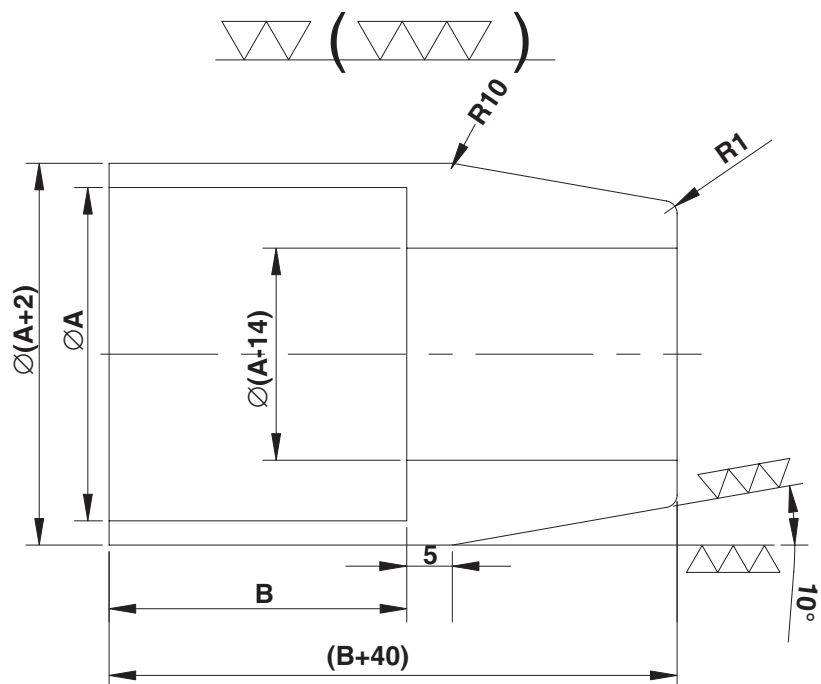
Material: SM45C which is done thermal refining <QT> Hrc 22 - 28

Undefined Chamfer C/R = 0.5 Max.

Place: Finally work to used DNMG Tip <Nose R0.4>

Model	Cylinder	øA (mm)	øB (mm)	C (mm)	D (mm)
DX60R	ARM	53.0	69.0	4.0	7.0
	BOOM	58.0	74.0	4.5	7.0
	BUCKET	55.0	62.0	4.5	7.0
	DOZER	80.0	74.0	4.5	7.0
DX80R	ARM	63.0	79.0	5.0	7.0
	BOOM	68.0	84.0	4.5	7.0
	BUCKET	53.0	69.0	4.5	7.0
	SWING	58.0	74.0	4.5	7.0
	DOZER	58.0	74.0	4.5	7.0

Slipper Seal Jig

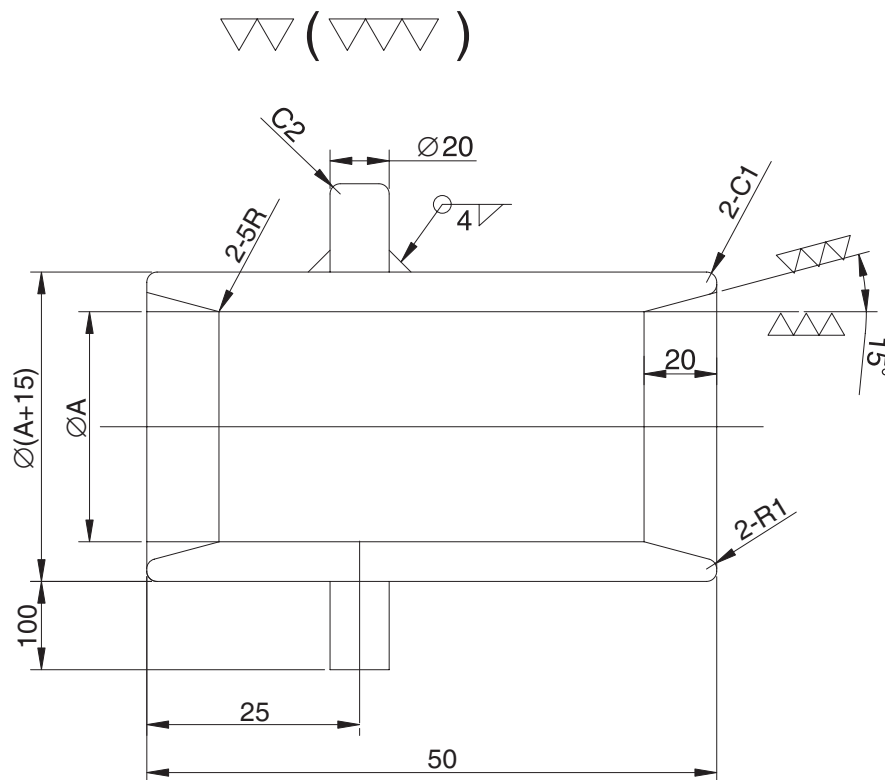


ARS4770L

Figure 12

Model	Cylinder	øA (mm)	øB (mm)
DX60R	ARM	79.5	11.5
	BOOM	104.5	21.5
	BUCKET	79.5	15
	SWING	109.5	20.5
	DOZER	109.5	10
DX80R	ARM	99.6	28
	BOOM	114.6	26
	BUCKET	84.5	28.5
	SWING	109.5	21
	DOZER	99.6	19.5

Slipper Seal Straightening Jig



ARS4780L

Figure 13

Model	Cylinder	øA (mm)
DX60R	ARM	85.7
	BOOM	105.7
	BUCKET	80.7
	DOZER	110.7
DX80R	ARM	100.7
	BOOM	115.7
	BUCKET	85.7
	SWING	110.7
	DOZER	100.7

DISASSEMBLY



CAUTION

Vent air from the hydraulic system before disconnecting cylinder piping connections. Use the lever on the reservoir, while the engine is running. Discharge the hydraulic accumulator and vent residual tank pressure after the engine is shut off. Pour clean replacement fluid back into the system if excessive fluid is lost.

1. Following removal of cylinder from excavator attachment, support cylinder on some type of sturdy work platform and drain all oil. Rotate cylinder so that piping ports are on top, to allow trapped air to vent.

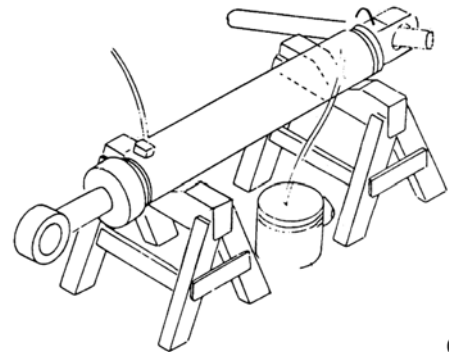


Figure 14

0333

2. Position piston rod so that it is extended approximately one half meter (20").

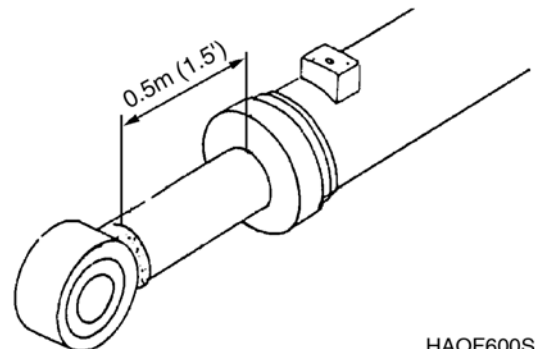


Figure 15

HAOF600S

3. Remove bolts (7) on the end of cylinder.

NOTE: Wrap a cloth or other protective material around piston rod, to avoid possibility of accidentally scratching or scoring rod surface while fasteners are being loosened and removed. Component parts (numbered in parentheses) are keyed to Figure 4.

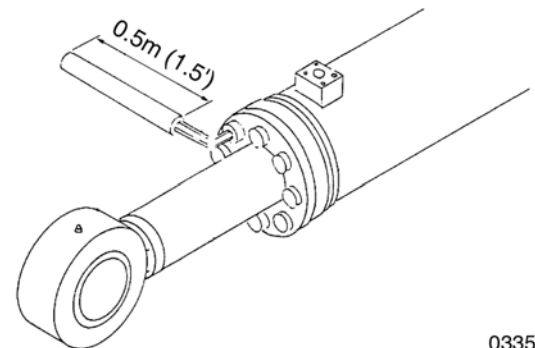
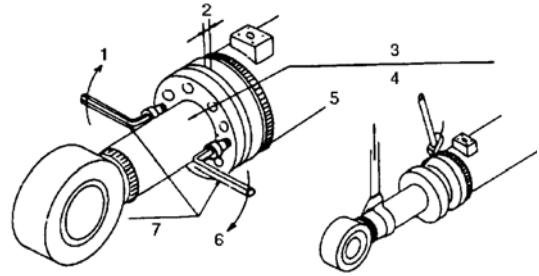


Figure 16

0335

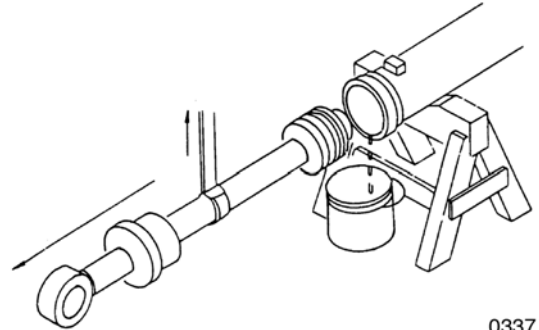
4. Tap two bolts into cover of cylinder head, 180° apart. Tighten them in a staggered, even sequence, to back off piston rod end cover from edge of cylinder wall. Look for adequate clearance between cover and end of cylinder wall before using a plastic or other soft-faced hammer for final disassembly.



HAOF610S

Figure 17

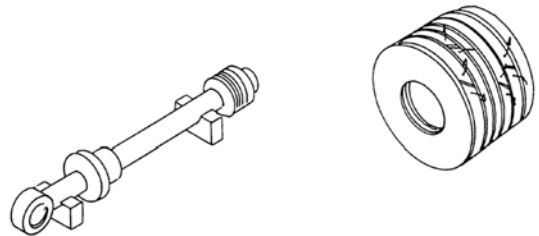
5. Begin withdrawing piston rod assembly, away from cylinder. Attach a lifting support when final 1/3 of rod is still inside barrel of cylinder. Prepare support blocks for piston rod before it has been completely withdrawn.



0337

Figure 18

6. Lower piston rod to support blocks and detach wear ring (outer surface) (18) from end of rod.



HAOF620S

Figure 19

7. Immobilize piston rod by inserting a wooden or other nonscoring, nonmetallic support through end of rod.

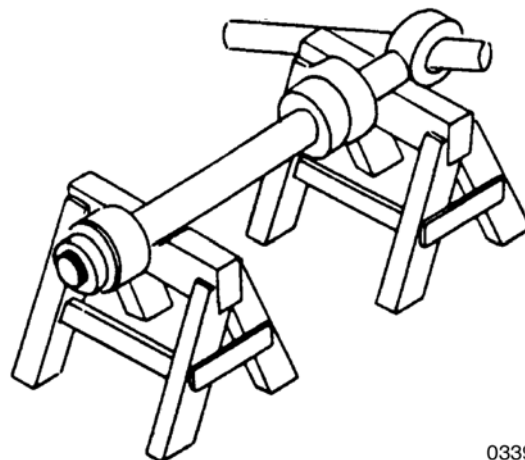


Figure 20

0339

8. Remove set screw by using a socket wrench.

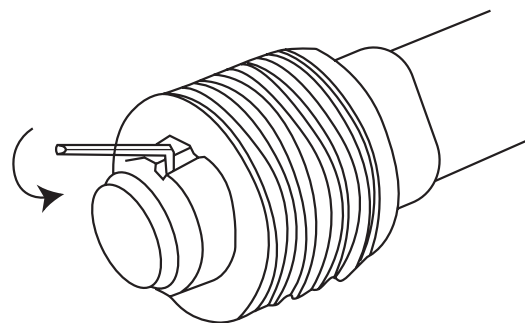


Figure 21

HAOF340L

9. Fabricate or purchase a piston nut removal wrench. (Dimensions are called off at beginning of this procedure. This tool may also be ordered through your local DOOSAN Parts distributor). Remove nut from end of piston.

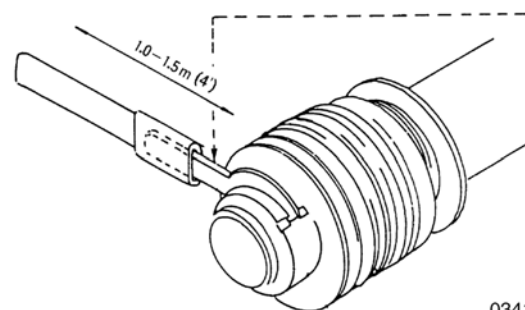


Figure 22

0341

10. Use second piston tool described at beginning of this procedure to separate piston. Detach cushion ring (15), taking care not to damage cushion ring.

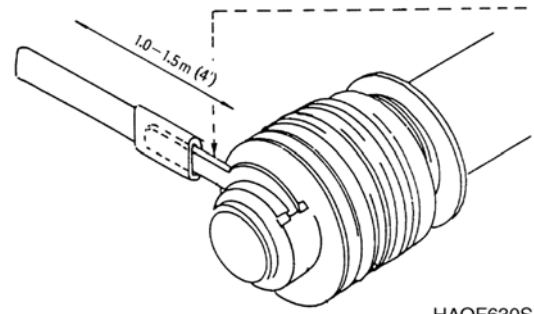


Figure 23

11. Use a plastic hammer to evenly pull off rod cover (9) from end of piston rod. Be careful not to damage rod bushing (6) and dust wiper, U-packing and other seals.

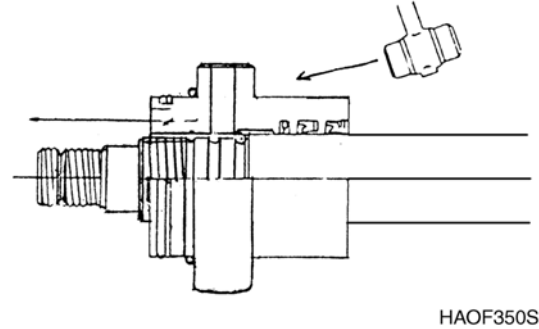


Figure 24

12. Use a dull, rounded-tip tool to pry off O-ring (11) and backup ring (12).

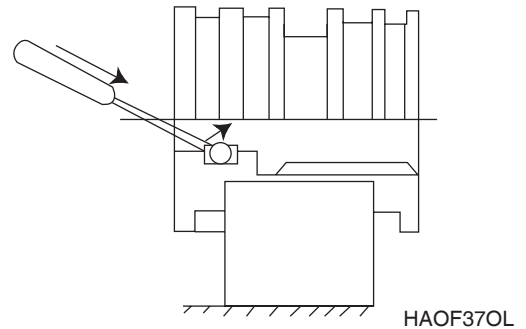


Figure 25

13. Find a screwdriver with an appropriate width tip to facilitate removal of slipper seal (19), wear ring (18) and slide ring (17) from piston (16).

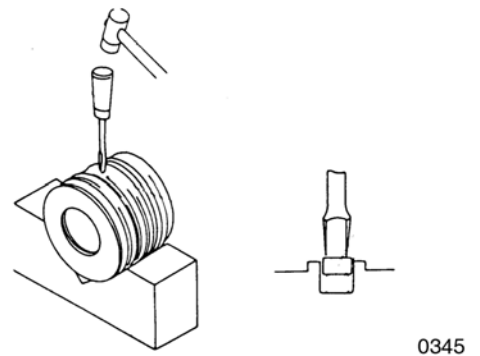


Figure 26

14. Pull off O-ring (20) and backup ring (21) from cylinder head.

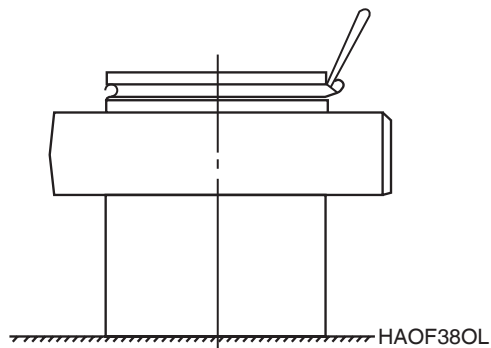


Figure 27

15. During disassembly of cylinder head, be careful not to damage buffer seal (5) and U-packing (4).

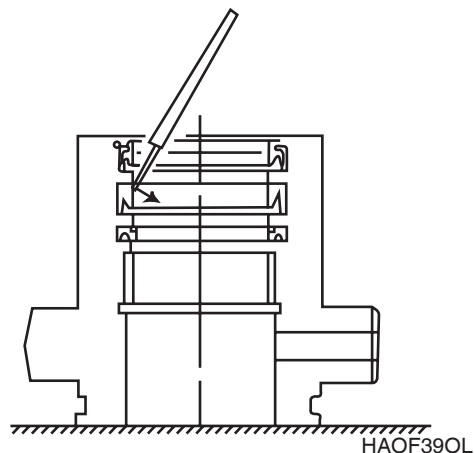


Figure 28

16. Disassemble retaining ring (3) and dust wiper (2). Separate retaining ring (8) and rod bushing (6).

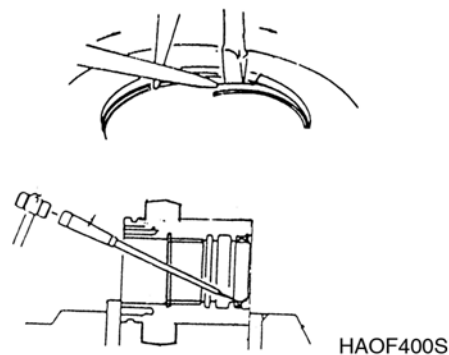


Figure 29

17. Force out pin bushing (1) from body of cylinder.

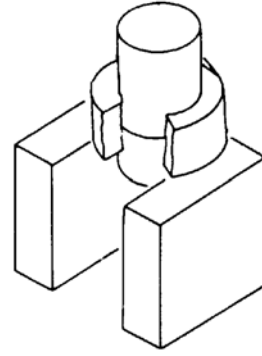


Figure 30

0349

ASSEMBLY

IMPORTANT

Replace any part that shows evidence of damage or excessive wear. Replacement of all O-rings and flexible seals is strongly recommended. Before starting the cylinder assembly procedure, all parts should be thoroughly cleaned and dried, and/or prelubricated with clean hydraulic fluid. Prepare the work area beforehand to maintain cleanliness during the assembly procedure.

NOTE: Assemble subassemblies of cylinder in the following order:

1. Cylinder body
 2. Piston rod
 3. Piston assembly
 4. Cylinder head assembly
1. Assemble pin bushing (1) to piston rod (13) and body of cylinder (14).
 2. Following the assembly of rod cover components, install dust wiper (2) and rod bushing (6) to rod cover (9). Insert retaining rings (3 and 8).

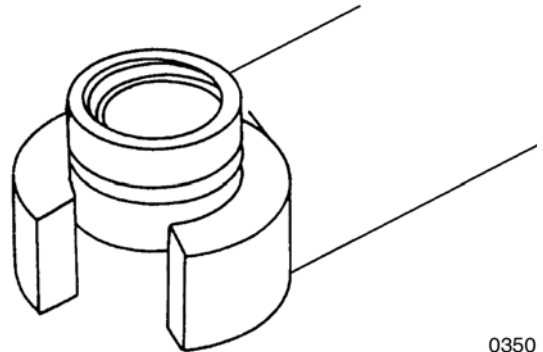


Figure 31

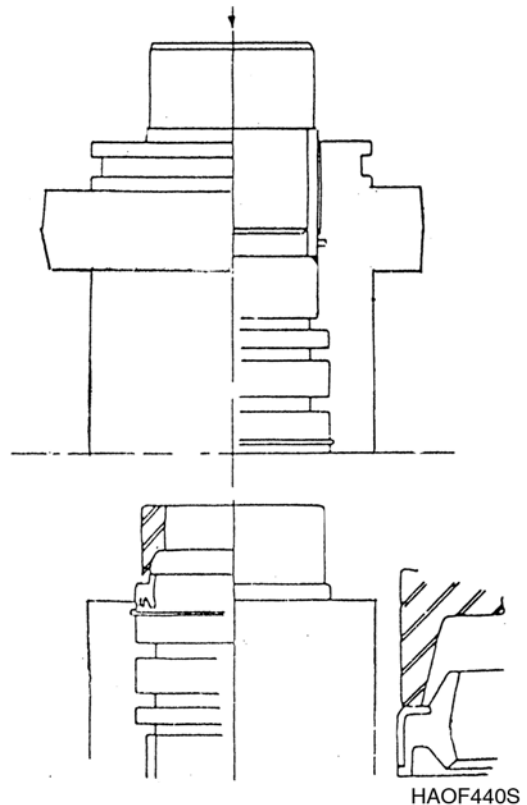


Figure 32

3. Prelubricate O-rings and seals before assembly (Figure 33).

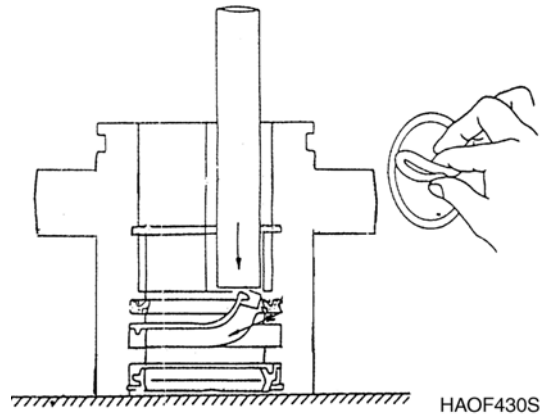


Figure 33

4. Before starting to rebuild piston assembly, heat slipper seal for 5 minutes in an oil bath warmed to 150°-180°C (302°-356°F). Use special slipper seal jig (third item in list of specialized tools at the beginning of this procedure) to attach seal. Cool seal by pushing a retracting jig against seal for several minutes. Apply a strip of clean, see-through sealing tape around slipper seal to keep it free of dust.

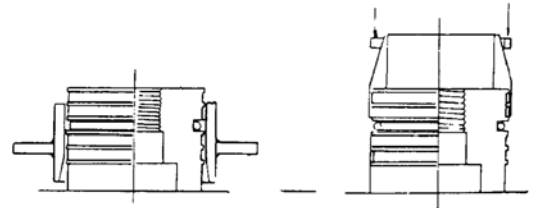


Figure 34

5. Immobilize piston rod on solid support blocks. Assemble O-ring (20) and backup ring (21). Prepare to attach rod cover assembly to piston rod. Push rod cover by tightening piston nut (22).

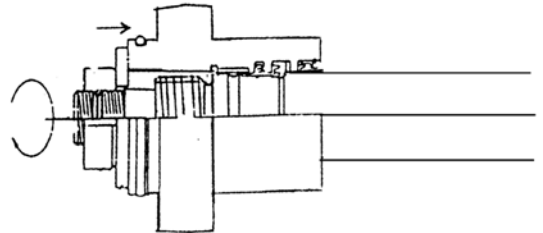


Figure 35

6. Assemble cushion ring (15) and attach piston assembly to piston rod.

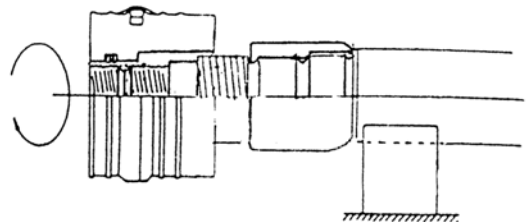


Figure 36

7. Use specially fabricate or factory sourced tool to tighten piston nut (22).

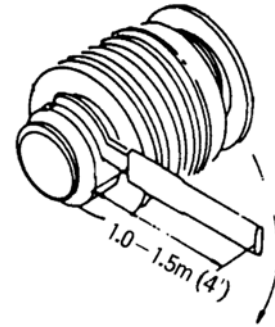


Figure 37

0356

8. Assemble wear ring (18), slide ring (17) and set screw (23) to piston assembly.

Reference Number	Description
1	Set Screw

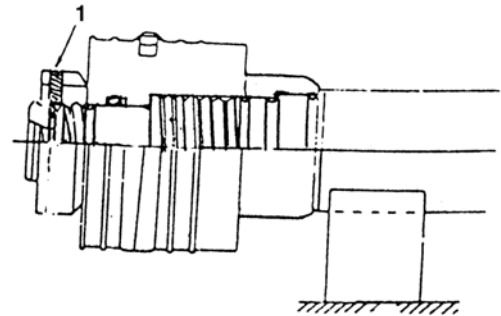


Figure 38

HAOF470S

9. Immobilize body of cylinder before assembly.

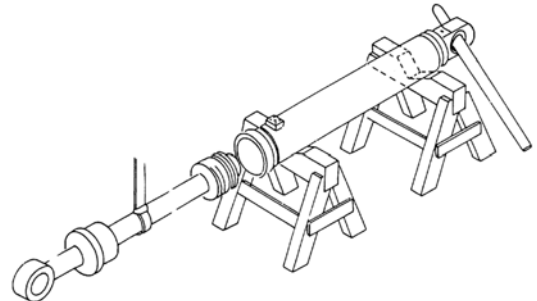


Figure 39

0358

10. Preapply fastener locking compound (Loctite #242 or #243 or an alternate manufacturer's equivalent product) to all end cover retaining bolts. Wrap a protective cushion around end of rod while tightening fasteners, to prevent possible damage to polished surface of rod, should a wrench slip during retightening.

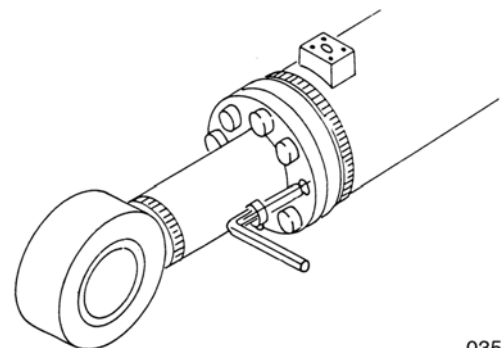


Figure 40

0359

Swing Motor

Edition 1

MEMO

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

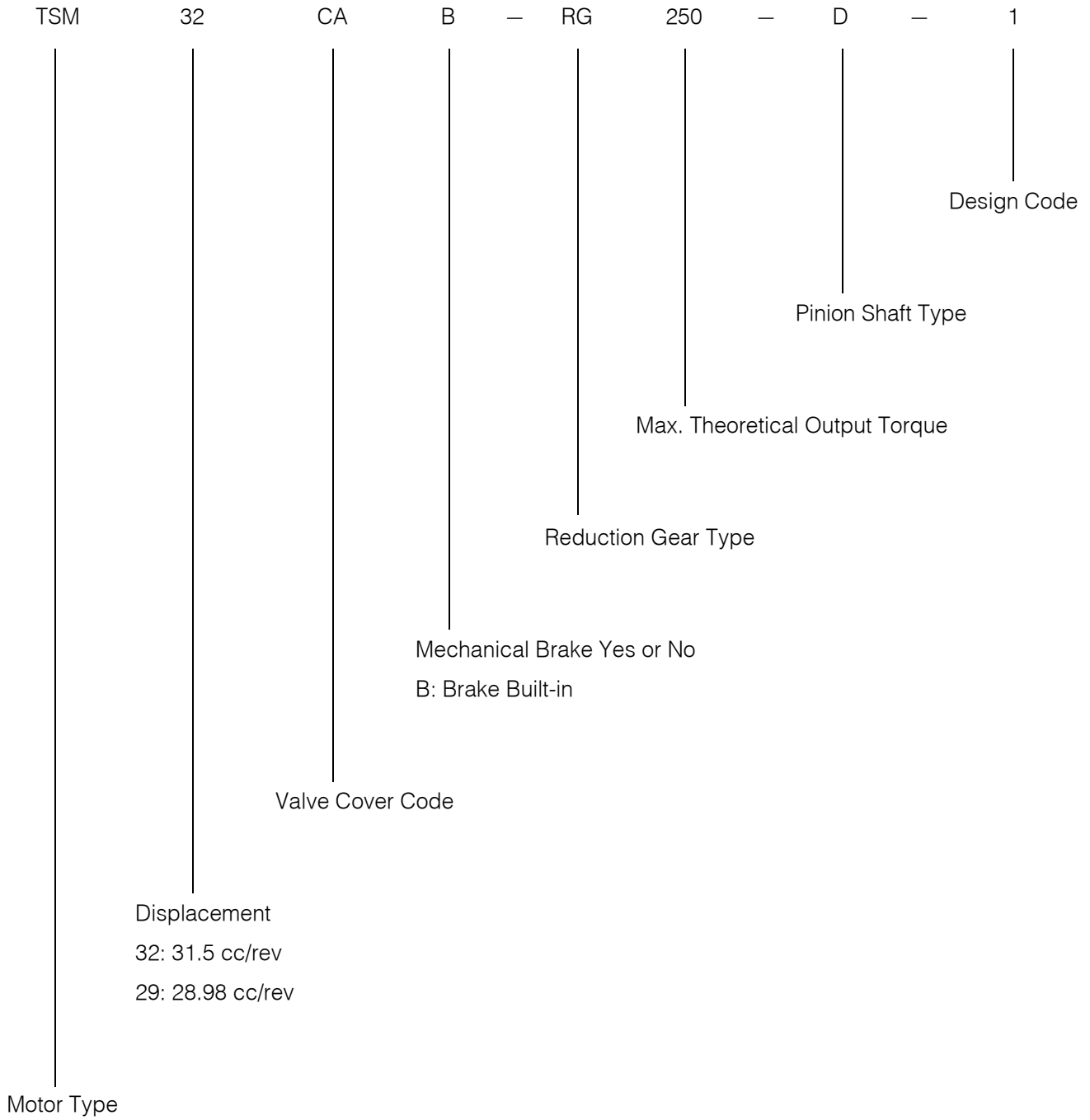
Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

INDICATION OF TYPE



SPECIFICATIONS

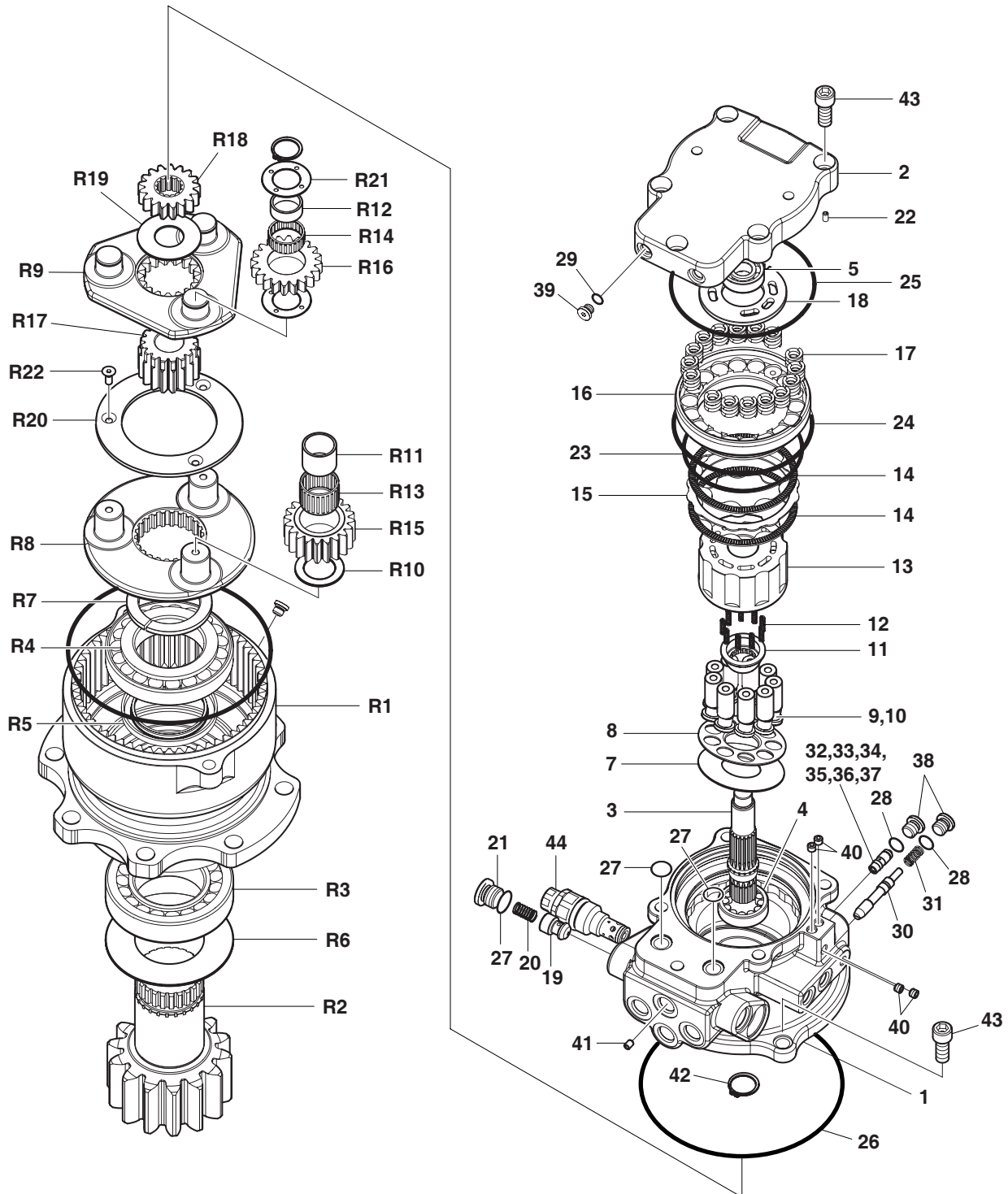
MODEL	TSM32 (S)CAB-RG250D
Displacement	31.5 cc/rev
Set Pressure of Relief Valve	220 kgf/cm ²
Theoretical Output Torque (Motor)	10.5 kg•m
Rated Flow Rate	38.5 lpm
Brake Torque	14.5 kgf•m
Brake Release Pressure	10 ~ 20 kgf/cm ²
Theoretical Output Torque	205 kgf•m
Gear Ratio	19.464
Weight	49.7 kgf

NOTE: *The theoretical value at the rated pressure, not including mechanical efficiency.*

TSM32 series can be applied from 28.98 cc/rev to 31.5 cc/rev by the change of displacement.

CONSTRUCTION AND PRINCIPLES OF WORKING

Construction



FG013250

Figure 1

Reference Number	Description
1	Casing
2	Valve Casing
3	Drive Shaft
4	Roller Bearing
5	Ball Bearing
7	Shoe Plate
8	Retainer Plate
9	Piston assembly
10	Piston assembly
11	Spherical Bush
12	Cylinder Spring
13	Cylinder Block
14	Friction Plate
15	Separation Plate
16	Brake Piston
17	Brake Spring
18	Valve Plate
19	Plunger
20	Check Spring
21	Plug
22	Spring Pin
23	O-ring
24	O-ring
25	O-ring
26	O-ring
27	O-ring
28	O-ring
29	O-ring
30	Spool
31	Spring
32	Plunger A
33	Filter
34	Bush

Reference Number	Description
35	Spacer
36	Throttle Plate
37	Spring
38	RO Plug
39	RO Plug
40	Plug
41	Orifice
42	Snap Ring
43	Socket Bolt
44	Relief Valve
R1	Gear Casing
R2	Pinion Shaft
R3	Taper Roller Bearing
R4	Taper Roller Bearing
R5	Oil Seal
R6	Bearing Cover
R7	Half Collar
R8	Carrier No.2
R9	Carrier No.1
R10	Thrust Washer No.3
R11	Inner Ring No.2
R12	Inner Ring No.1
R13	Needle Bearing
R14	Needle Bearing
R15	Planet Gear No.2
R16	Planet Gear No.1
R17	Sun Gear No.2
R18	Sun Gear No.1
R19	Thrust Washer No.1
R20	Thrust Plate
R21	Thrust Washer No.2
R22	Screw

Principles of Working

Motor Part

High pressure oil from the control valve is routed through valve casing and valve plate to pistons. When the oil enters the cylinder bores through port, it forces the pistons against the fixed inclined swash plate (F1, F2). The force (F2) causes the piston shoes to slide on the swash plate forcing the rotating group to turn, thereby rotating the output shaft.

During the second half of the motor's revolution, low pressure oil is discharged as the pistons ride toward a higher position on the shoe plate.

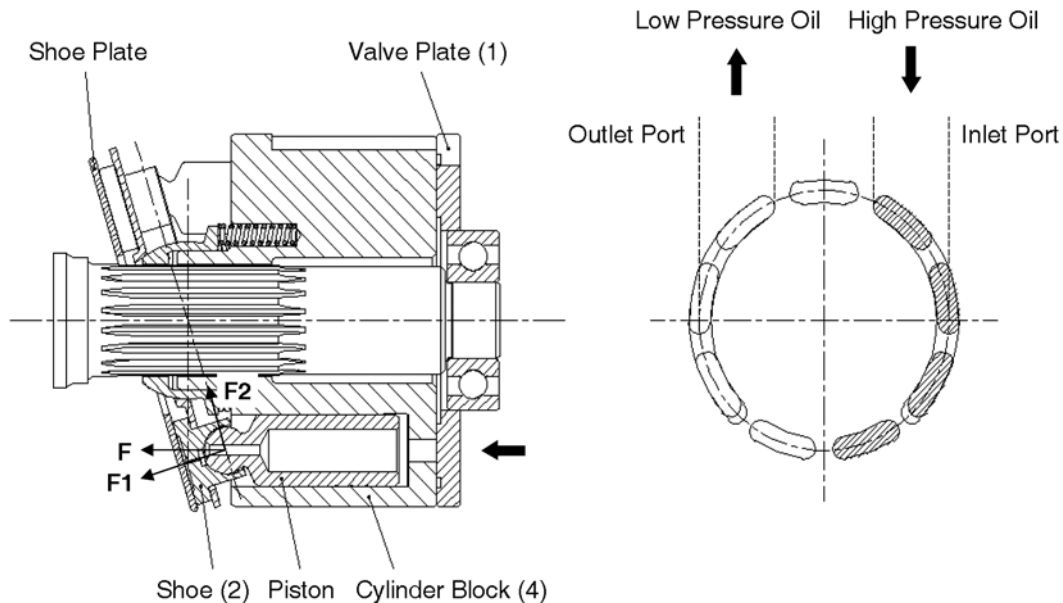
A small amount of supply oil flows through the center of each piston to lubricate the piston ball joint and the piston shoe face. The motor is internally lubricated from leakage inside the motor.

To reverse rotation, system oil flow is changed from inlet port to outlet port and vice versa. Theoretical output torque is as follow formula.

$$T = \frac{p \times q}{2 \times \pi}$$

P: EFFECTIVE PRESSURE (kgf/cm²)

q: DISPLACEMENT (cc/rev)



FG013319

Figure 2 Diagram Showing the Working Explanation

Valve Casing Part

1. Anticavitation Check Valve

The motor can be rotated faster than supplied oil flow because there is no counter-balancing valve to prevent over speed ; in order to prevent cavitation of the motor, oil compensation insufficient flow is drawn through the anti-cavitation check valve.

2. Relief Valve: TSR25A (Figure 3)

We consider that port P is applied pressure by tank pressure.

Port P, R are affected by tank pressure at first, as shown (1, Figure 3). The relief valve starts operating when the force that is determined by multiply the pressure area (A1) of plunger (301) by pressure P1 is equal to the sum spring (321) force (Fsp) and the force that is determined by multiply the pressure area (A2) by pressure Pg of room 'g' in the plunger (301).

Here, Pg is the pressure of room 'g' applied pressure by passing oil through orifice m. If Pg arrives at the pressure which is determined by spring (321) pushing the piston (302), the piston move to left side. when piston (302) move left side, room 'h' operates as damping room which is designed at the side of adjustment plug (401) and piston (302).

Because of this mechanism, the pressure of room 'g' increases smoothly while the piston (302) reaches end of adjustment plug (401) (2, Figure 3).

$$P_1 \times A_1 = F_{sp} + P_g \times A_2$$

$$P_1 = \frac{F_{sp} + P_g \times A_2}{A_1}$$

If the piston (302) reaches end of adjustment plug (401), it doesn't move left side anymore. So, the pressure of room 'g' is Ps and spring (321) force is Fsp (3, Figure 3).

Therefore, the pressure P changes as shown (4, Figure 3). The pressure (Ps) of last state is following equation.

$$P_s \times A_1 = F_{sp'} + P_s \times A_2$$

$$P_s = \frac{F_{sp'}}{A_1 - A_2}$$

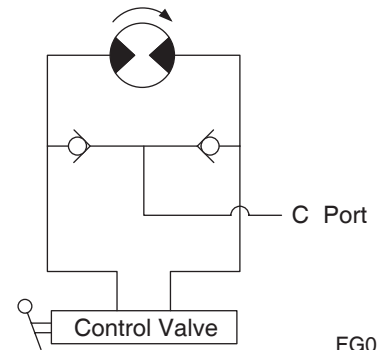
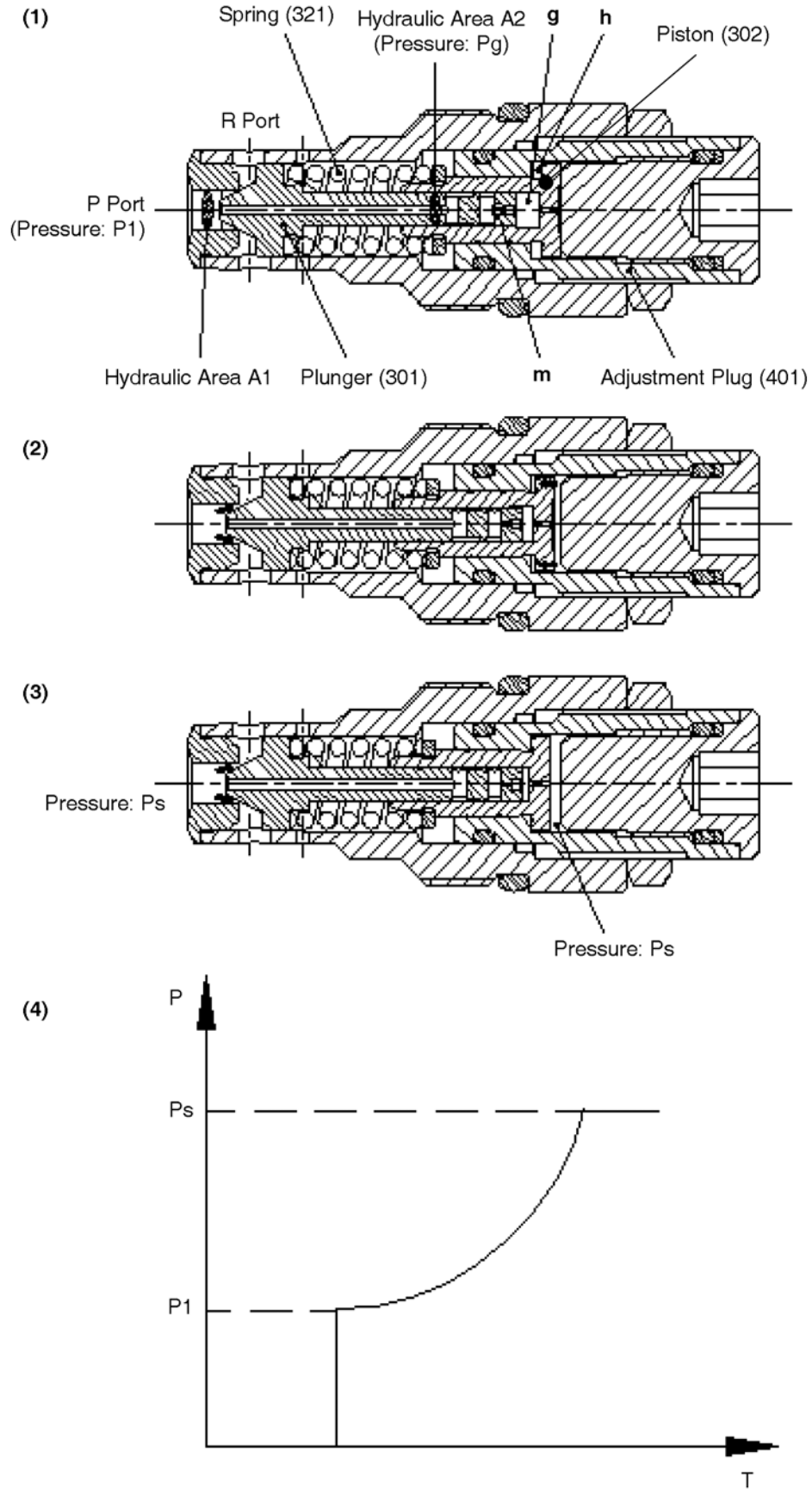


Figure 3

FG013320



FG013322

Figure 4 Relief Valve: TSR25A Working Description

Brake Part

The swing brake is spring applied and hydraulically released. Friction plate (15) are splined to and rotate with cylinder block. separation plates (15) are splined to the motor casing (1).

When the swing controller blocks pilot pressure at port (SH), the brake springs (17) force on brake piston (16) squeeze the separation and friction plates together to prevent the upper structure from swinging.

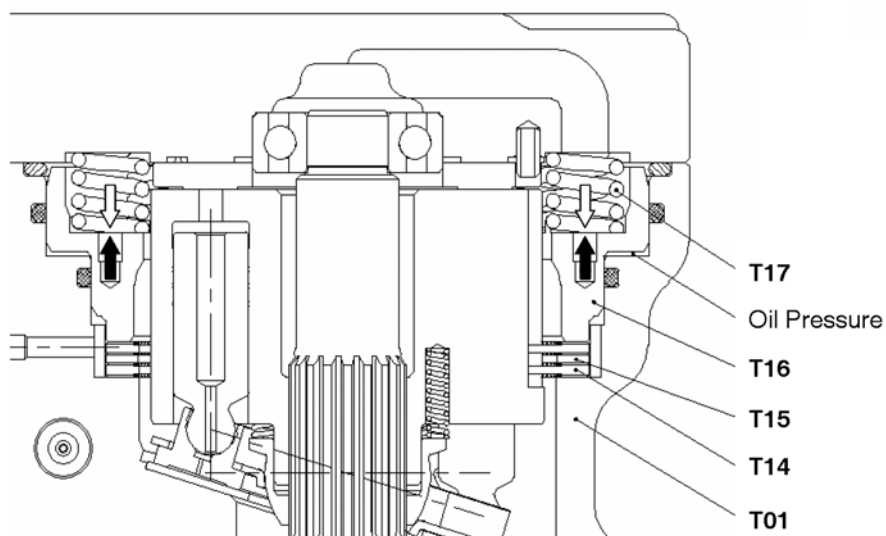


Figure 5 Brake Working Description

FG013324

PRECAUTION IN USE

Inspection

Prior to installation of a new motor, inspect the following items.

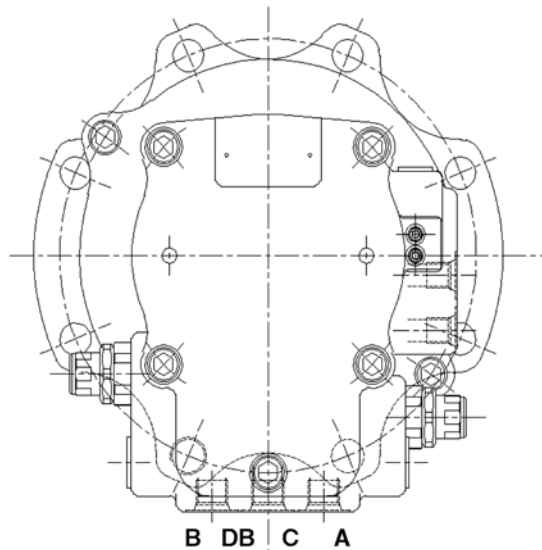
1. Inspect whether or not there is any damage during transit, or if any parts are lost missing.
2. Inspect each tightened part is loosened or not.
3. Check whether or not covers for flange surface and drain port are perfect, and the inside of the motor is dirty with intruded dust.

Rotation Direction

The relation between the oil flow and the revolutionary direction of the shaft is self-explanatory as shown in Figure 6.

The revolutionary direction of a motor vary according to the slope surface of casing.

Pay attention to discriminate between geometry of casing and the direction of flange as the direction of tilting angle.



FG013325

Figure 6

Direction	Inlet Port	Outlet Port	Revolutionary Direction of Shaft Facing the Shaft Side
Counterclockwise	B	A	Right-handed
Clockwise	A	B	Left-handed

External Load of Shaft

Pay attention to the shaft of motor in order not to apply radial and thrust load.

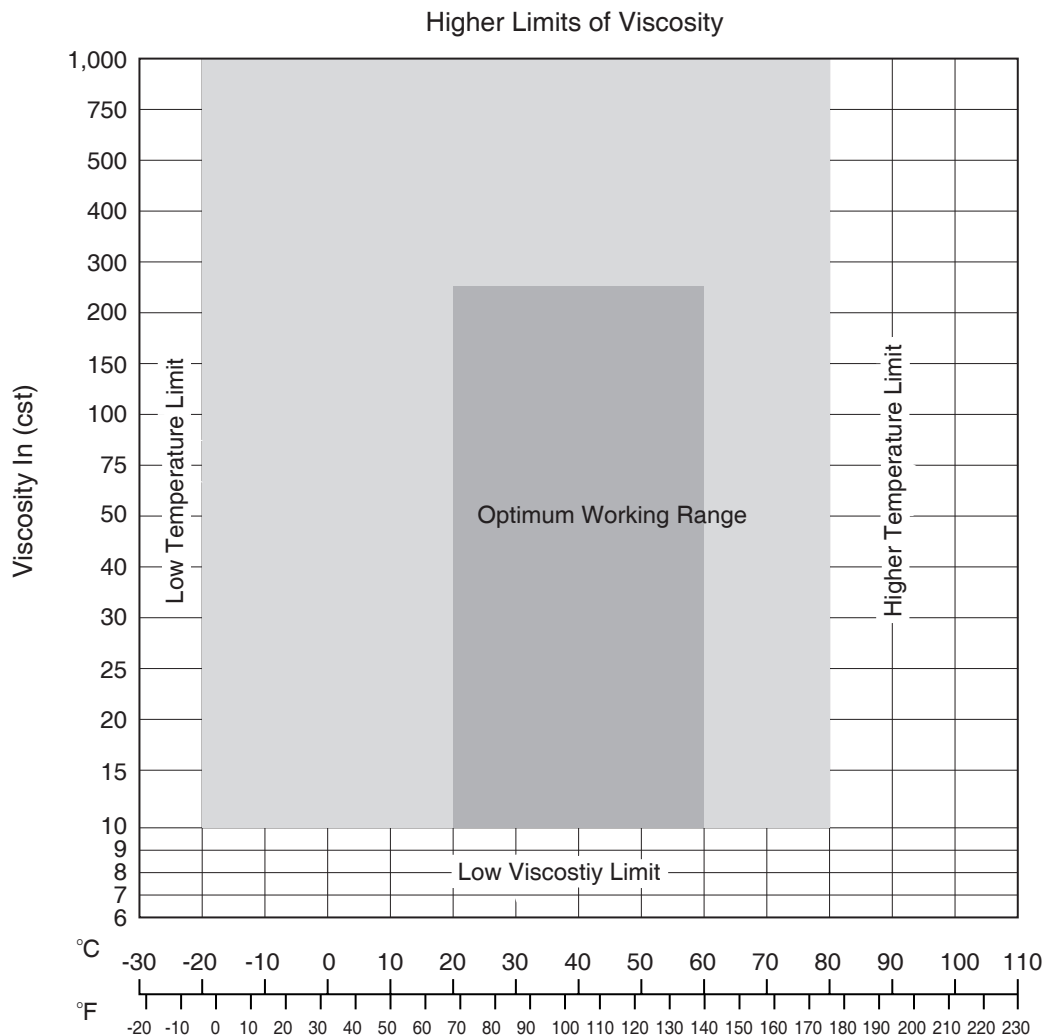
Hydraulic Fluids and Range of Temperature

1. Mineral Oil

Please use a highly viscosity index working fluid which has additions of anti-foam agent, oxidation inhibitors, corrosion inhibitors, viscosity index improvers, oiliness agent and the oil with a high viscosity.

2. Optimum viscosity and temperature (Figure 7)

In order to obtain the highest performance of the motor, oil which has a viscosity in a range of 10 to 200 cst is most suitable. But, it can be used a viscosity in a range of 10 to 1,000 cst. The range of working temperature is limits to -25 °C ~ -100 °C because of the oil seal, O-ring. Further, the deterioration of the working fluid becomes excessive beyond 65 °C ; therefore, it is desirable not to exceed 60 °C.



FG013328

Figure 7 The proper range of viscosity and temperature

3. Except mineral oil

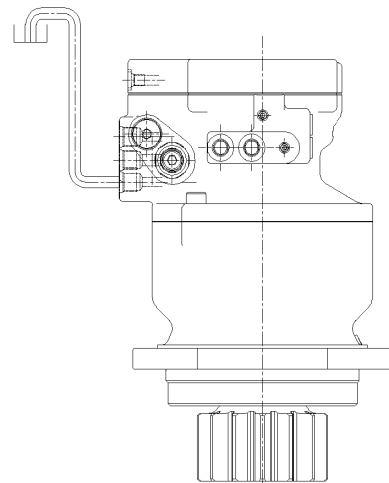
Incase if using special fluid (phosphate ester compounds, water-glycol, fluid fatty acid ester compound, etc.), please consult us for instruction prior to use.

Filter

If fine particles of dirt and metal are mixed with oil, they enter into sliding surfaces and accelerate wear in each part, and in the worst case seizure will be likely to occur. It is recommended, therefore, that the customer not only will take necessary measures to prevent oil from contamination with such fine particles but also to provide an oil filter in the circuit without fail. For satisfactory service life of these motors in application, the operating fluid should be continuously filtered to the minimum cleanliness level of class 8 of NAS. Also, install a 10μ filter in the hydraulic circuit and MILLIPORE FILTER pollution level recommends below 2 ~ 4 mg / 100 cc.

Installation and Piping

1. When the motor is installed that its shaft turns downside.
2. The motor should be installed that it is concentricity below 0.05 mm.
3. The tightening torque of bolts for fixing the motor to the bracket is shown in assembly drawing the customer's reference.
4. Since the casing inside is always kept filled with oil, the drain must be returned to the tank through the return pipe which is once raised higher tank that of the motor itself as shown in Figure 8.
5. Motors will tolerate in the casing pressure up to maximum 3 kgf/cm^2 , but for common pressure, 2 kgf/cm^2 below should be kept.
6. Piping should be cleaned and flashing well.
7. Be care to as the installation to piping.
8. Use the drain pipe bigger than the port size and form shortly as possible as.



FG013331

Figure 8

Oil Filling

1. Fill in the casing with oil using the drain port before the operating.

In the motor, there are many kinds of high-speed sliding surface like bearing, piston, shoe, spherical bush, and etc. So If there isn't enough oil, can make some problem like sticking or breaking in those parts.

2. All the air in the motor and circuit must be removed, otherwise, it will be likely to be causes of imperfect working or a damage of the motor.

Precaution in Starting Operations

1. If the direction of revolution is correct or not.
2. Whether or not there is any leakage of oil from the motor.
3. If the equipment vibrates abnormally or not during operation or when the revolution direction is changed.
4. If the oil temperature rises rapidly in spite of running for a short period of time.
5. Whether the pressure varies to a great extent as compared with the established one.
6. If the piping is fully connected or not.

TROUBLESHOOTING

General Cautions

Here, counter-measures to be taken when troubles have happened while the motor is in operation are described.

As for general precaution.

1. Consider a cause of the trouble before repairing
Before setting to work, think whether the same thing has happened before or not. Also, think again whether it is the motor that is in trouble.
2. Be careful of dust
It is not too much to say that most troubles are ascribed to dust so that measures for dust prevention is taken into consideration with utmost care in the case of partial disassembling.
3. Handling part
Pay attention to the handling of parts not to injure them, especially to moving parts such as pistons, bearing and valves etc.
4. Pay attention to work the handling of O-ring, gasket
Once seals have been disassembled, they should be replaced even if damage is not observed.

Investigation Manner of the Motor Body

It is extremely difficult to trace trouble in the hydraulic circuits. Inspect the following items and investigation whether or not the fault is caused by the motor.

1. Inspection the oil in casing
Remove the drain plug and inspect the hydraulic oil in the casing. If a large amount of metallic particles come out with the oil, you should suspect a failure of internal parts.
2. Presence of abnormal noise
Check whether the motor emits an abnormal noise.
3. Pressure measurement of various points.
Measure pressures at various points and check for faults, instead of disassembling parts at random.
4. Measurement of drain quantity
 - A. In the case of locking the swing and adding the pressure oil to motor, it's normal the drain rate would be about under 10 l/min.
 - B. In normal swing mode, the drain rate would be under 1 l/min.

Condition and Countermeasures of Troubles

Motor does not rotation

Condition	Cause	Remedy
The pressure of the circuit is not increasing	1. Setting pressure of relief valve is incorrect. 2. Working defectiveness of relief valve. 1) Plunger stick. 2) Close up an orifice hole of plunger. 3. Seat defectiveness of plunger.	1. Reset the pressure to correct value. 2. 1) Revise or exchange of stick face. 2) Disassembly or cleaning. 3. Replace for damaged seat part.
The pressure of the circuit is increasing	1. Overload. 2. Stick of motion portion. 3. The brake dose not release. 4. Stick of brake piston. 5. Stick of friction plate.	1. Load removes. 2. Do repair or inspect the piston/shoe, cylinder block, valve plate etc. 3. 1) Do repair or inspect circuit 2) Check for the break valve. 3) Assembly and inspection. 4) Assembly and inspection. Replace for the stick parts.

The revolutionary direction is reverse

Condition	Cause	Remedy
The revolutionary direction is reverse.	1. The revolutionary direction of motor is reverse. 2. The inlet and outlet in piping is reversely connected.	1. Reassemble them after disassembling. 2. Correct piping.

The number of revolution does not reach the established value

Condition	Cause	Remedy
The number of revolution does not reach the established value.	1. The volume of flowing is not sufficient. 2. The temperature is too high and too much oil is leaking. 3. Valves / pistons / rings etc. are worn away and broken.	1. Check discharge volume of pump and circuit up to the motor. 2. Reduce the oil temperature. 3. Replace it.

Brake torque is not sufficient.

Condition	Cause	Remedy
Brake torque is not sufficient	1. Friction plates are worn. 2. Brake piston is becoming stick. 3. Brake releasing pressure is not working. 4. Spline of friction plates are damaged.	1. Disassembly or inspection. When it is worn better than standard, replace it. 2. Disassembly or inspection 3. 1) Check for the circuit. 2) Check for the brake valve 4. Disassembly or inspection. 1) Replace for damaged parts.

Motor is much slip

Investigates the DRAIN quantity for motor.

Normal: app. 200 cc/min

Condition	Cause	Remedy
Motor is much slip	1. Working defectiveness of relief valve is the same item 1). 2. Seat defectiveness of plunger.	1. It is the same item 1). 2. Replace it.

Oil leak

1. Oil leak from the oil seal

Condition	Cause	Remedy
Oil leak from the oil seal	1. The lip is dirty or damaged. 2. The shaft may be damaged or worn out. 3. The lib is damaged too high pressure in the casing. 4. The shaft is rusty.	1. Replace the oil seal. 2. Replace the driving shaft or defective centering of the driving shaft. 3. It repairs the drain piping which is closed up. 4. Disassemble, repair, and replace the oil seal.

2. Oil leak from the blind and union

Condition	Cause	Remedy
Oil leak from the blind and union	1. O-ring is not in. 2. O-ring is broken. 3. Seal face is defective. 4. The bolt is loose or not tightened.	1. Insert O-ring. 2. Replace it. 3. Disassemble or repair. 4. Tighten adequately or replace it.

DISASSEMBLING AND ASSEMBLING

Tightening Torque of Bolts

It is shown tightening torque of bolts used in motor. In case of reassembling, tighten accurately each bolt in accordance.

Bolt Size	Name	Tightening Torque (kgf•cm)	Part NO.
M12	Hexagon bolt	1, 040 ± 160	43
M20	RO Plug	900 ± 100	21
PF 1/8	Plug	100 ± 20	39
PF 1/4	Plug	370 ± 20	38
M30	Relief Valve	1, 600 ± 100	44

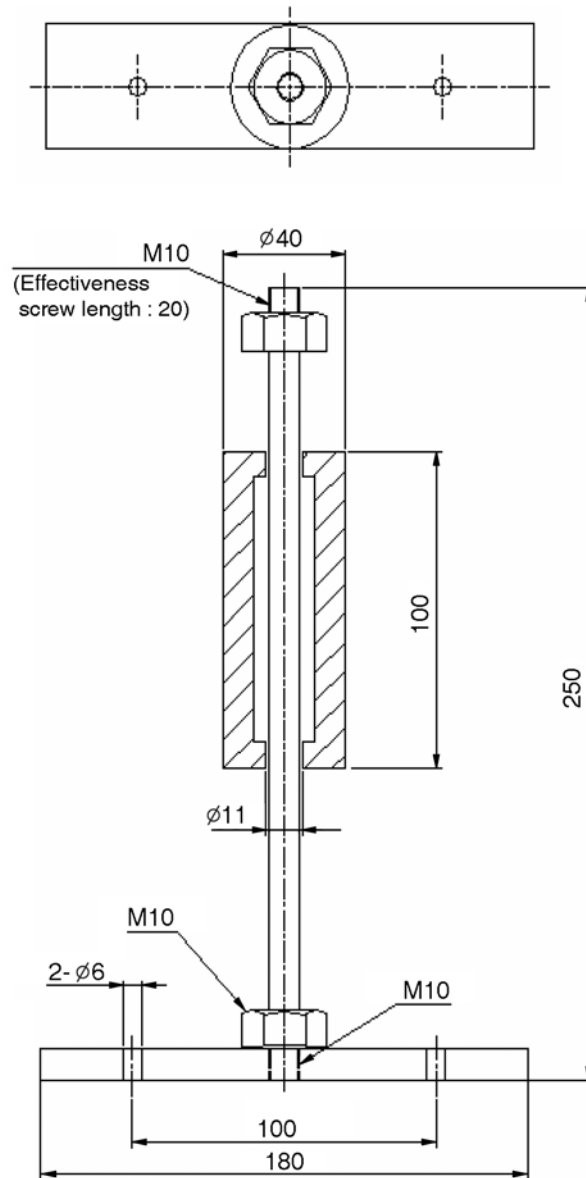
* Refer to page 9/46 for Part NO.

Necessary Tools

Shown necessary tools for disassembling and reassembling.

Name	Size	2-face width	Application Part	Tool
Hexagon Bolt	M12	10	Valve Casing	Hexagon spanner socket wrench
Plug	M20	10	RO Plug	Hexagon spanner socket wrench
Plug	PF 1/8	4	RO Plug	Hexagon spanner socket wrench
Plug	PF 1/4	6	RO Plug	Hexagon spanner socket wrench
Relief Valve	M30	30	Relief Valve	Hexagon spanner socket wrench

Tool	Specifications	Dimensions
Plier (For lock ring)		For ø25 axis
Driver		(-) Type: 2EA
Steel rod		About 10 × 8 × 200: 1EA
Hammer		One each of plastic hammer and metal hammer
Torque wrench		Torque range - For 100 ~ 450 kgf•cm - For 400 ~ 1, 800 kgf•cm - For 1, 200 ~ 4, 800 kgf•cm
Slide Hammer bearing plier		-
Special tool for removing the brake piston		Next page reference



FG013338

Figure 9 Special tool for removing the brake piston

Disassembly of Motor

Please use the following procedures for the inspection and repair of the motor.

Numerals given in parentheses following the parts names indicate the parts number shown by the drawing in the instruction and maintenance manual.

1. Completely remove dirt and dust adhering to the outside.

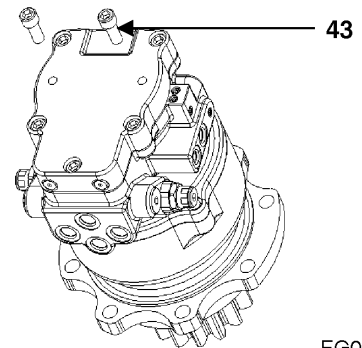
Discharge all hydraulic fluid in the motor casing and the port oil passage. Use a clean, dust-free work area.

Handle parts with care to prevent dirt and dust from adhering.

Do not over-disassemble.

2. Separating the motor and the reduction gear.

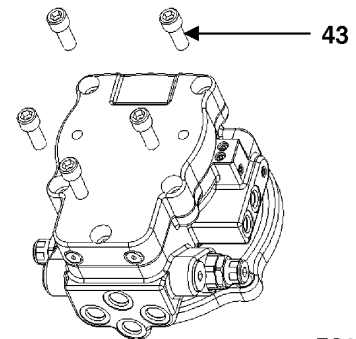
Secure the swing device in a vice and remove the socket head bolt (43).



FG013339

Figure 10

3. Secure the motor assembly in a vice and remove the socket head bolt (43).



FG013342

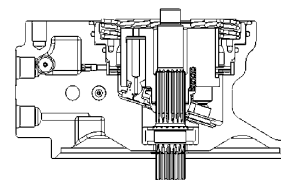
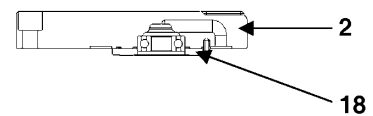
Figure 11

4. Separate the valve casing (2) from the motor.



CAUTION

When separating the valve casing (2), be careful not to drop the valve plate (18).



FG013343

Figure 12

5. Remove the valve plate (18).

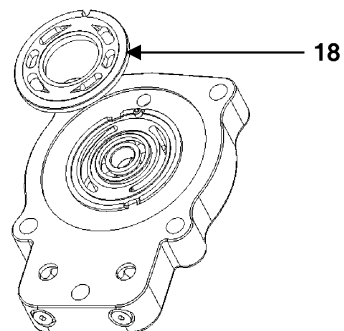


Figure 13

FG013344

6. Remove the bearing (5) and the pin (22).

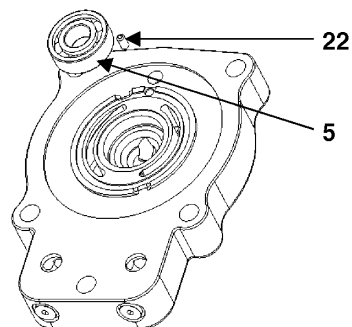


Figure 14

FG013346

7. Remove brake springs (17).

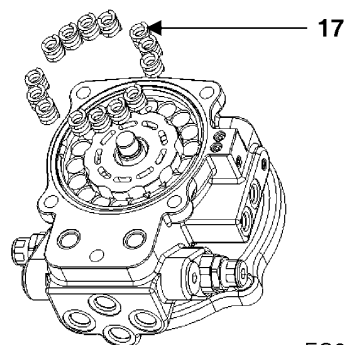


Figure 15

FG013347

8. Remove the O-ring (26, 27).

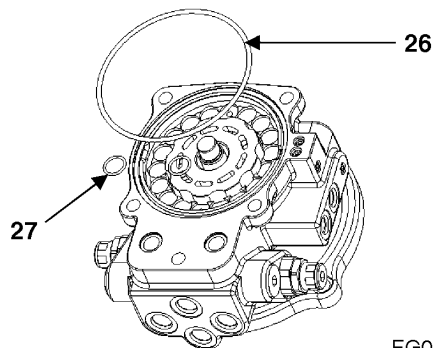


Figure 16

FG013348

9. Remove brake piston (16) from the casing (1) by using the special tool for removing the brake piston.

Lift it up straight by using the bolt hole in the brake piston.

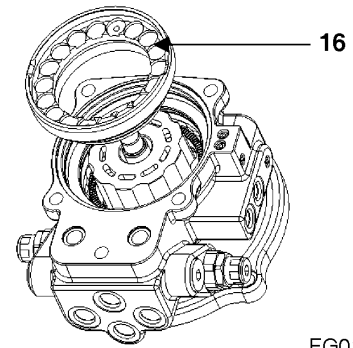


Figure 17

FG013360

10. Pull out friction plate (14, 2EA) and separation plate (15, 1EA) from the casing (1).

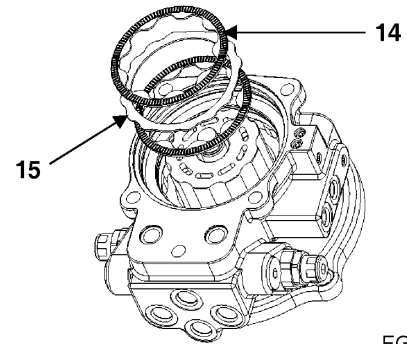


Figure 18

FG013361

11. After placing the motor horizontally, remove the cylinder block (13) and other associated parts.

Reference Number	Description
8	Retainer plate
9	Piston assembly
10	Piston assembly
11	Spherical bush
12	Cylinder spring
13	Cylinder block

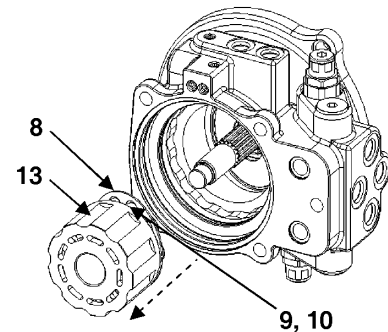


Figure 19

FG013362

When taking out the cylinder block, be careful not to pull out spring (12).

Be careful not to damage the sliding parts of the cylinder block, spherical bush and shoe.

12. Remove the retainer plate (8), and the piston assembly (9, 10).

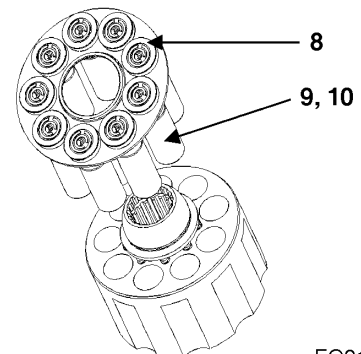
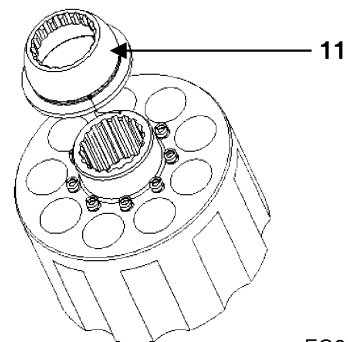


Figure 20

FG013363

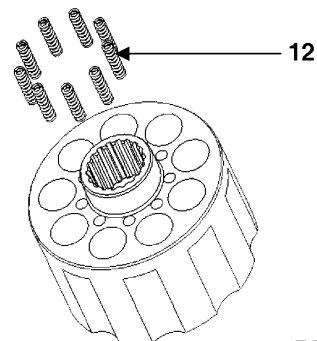
13. Remove the spherical bush (11).



FG013364

Figure 21

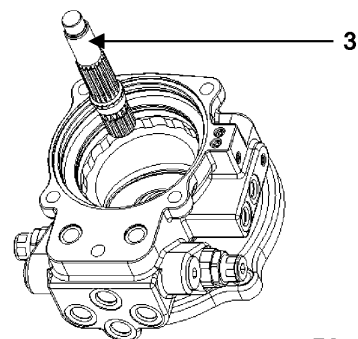
14. Remove the cylinder spring (12).



FG013365

Figure 22

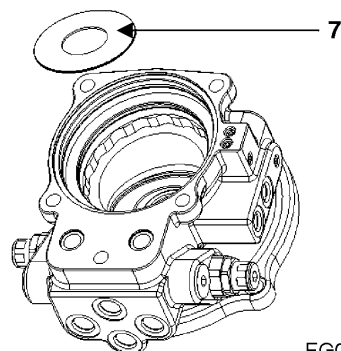
15. Remove the drive shaft (3).



FG013366

Figure 23

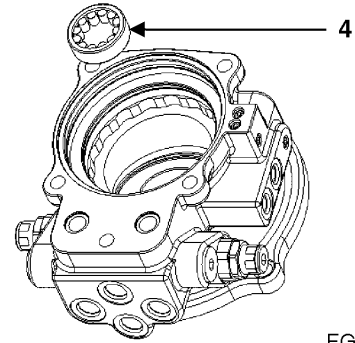
16. Remove the shoe plate (7).



FG013367

Figure 24

17. Remove the bearing (4).



FG013368

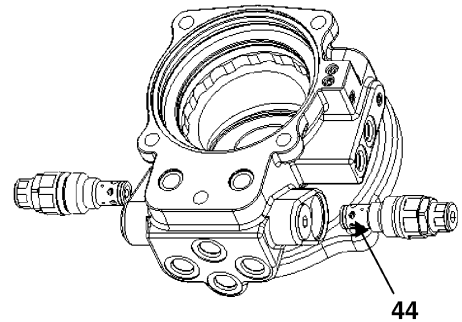
Figure 25

18. Remove the relief valve (44).



CAUTION

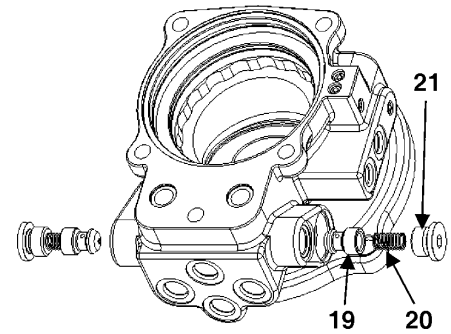
Do not disassemble the relief valve assembly because it is a functional component.



FG013369

Figure 26

19. Remove the plug (21), the spring (20) and the plunger (19).

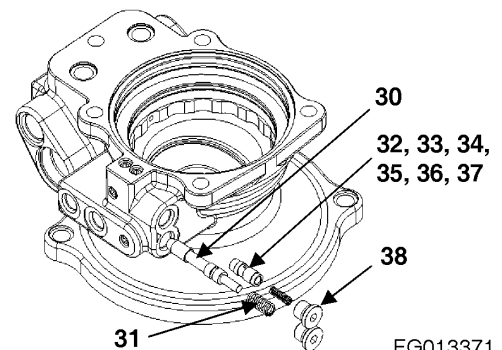


FG013370

Figure 27

20. Remove the spool (30) and other associated parts.

Reference Number	Description
30	Spool
31	Spring
32	Plunger A assembly
33	Plunger A assembly
34	Plunger A assembly
35	Plunger A assembly
36	Plunger A assembly
37	Plunger A assembly
38	Plug



FG013371

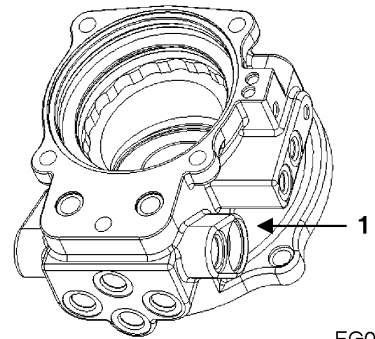
Figure 28

Disassembling is finished, check each component thoroughly.

Assembly of Motor

Following are caution to be specially borne in mind.

- A. Rework damaged parts and before assembling, prepare all parts to be replaced.
 - B. Clean all parts and dry with compressed air.
 - C. Coat the sliding parts and bearing with clean hydraulic oil.
 - D. Replace O-ring, oil seal.
 - E. For the mounting of bolts to install the various parts, please use a torque wrench, etc. and tighten the bolts with the torque shown.
1. Place casing (1) on the work table with the valve casing side downward.

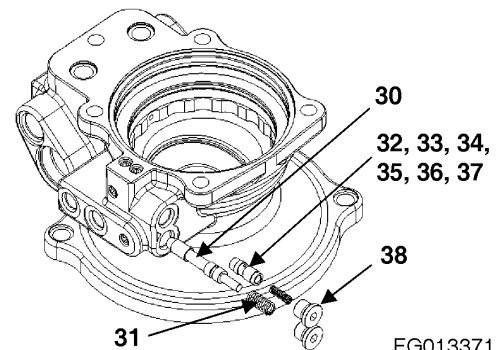


FG013372

Figure 29

2. Assemble the spool (30) and other associated parts.

Reference Number	Description
30	Spool
31	Spring
32	Plunger A assembly
33	Plunger A assembly
34	Plunger A assembly
35	Plunger A assembly
36	Plunger A assembly
37	Plunger A assembly
38	Plug

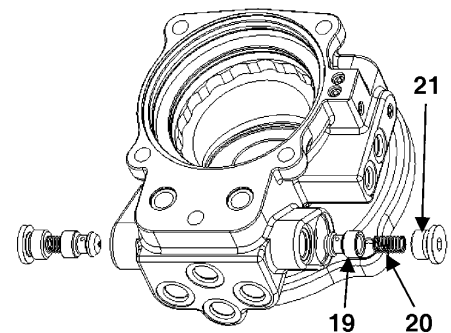


FG013371

Figure 30

3. Assemble plunger (19) and spring (20) to casing (1) and tighten RO plug (21) with O-ring.

Confirm the smooth movement of the plunger before installing the plug.



FG013370

Figure 31

4. Assemble the relief valve (44).

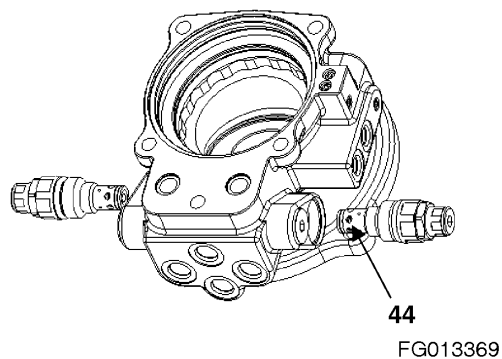


Figure 32

5. Assemble roller bearing (4) in the casing (1) with a using of tool.

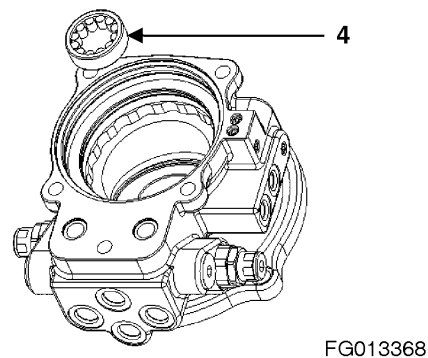


Figure 33

6. Apply grease to the back side of the shoe plate (7) and assembly it.

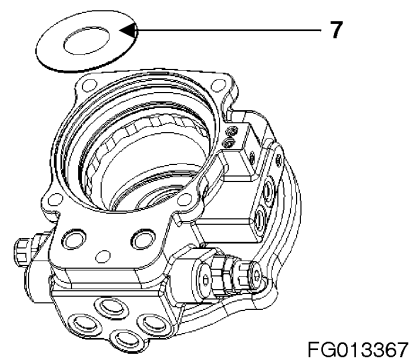


Figure 34

7. Assemble the drive shaft (3) in the casing (1).

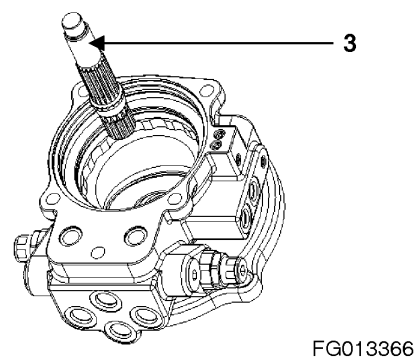


Figure 35

8. Apply grease to the O-ring (23, 24) and assemble it.

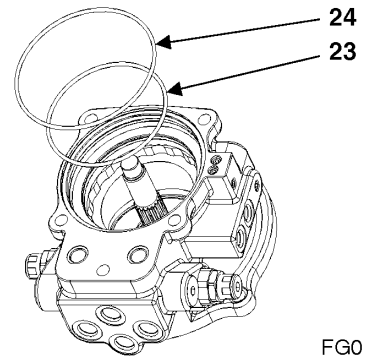


Figure 36

FG013373

9. Assemble the cylinder spring (12).

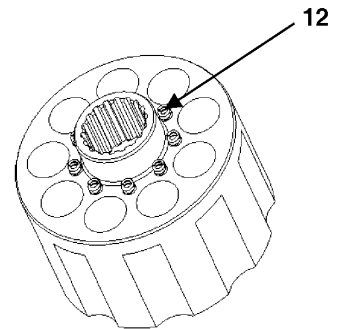


Figure 37

FG013374

10. Assemble the spherical bush (11).

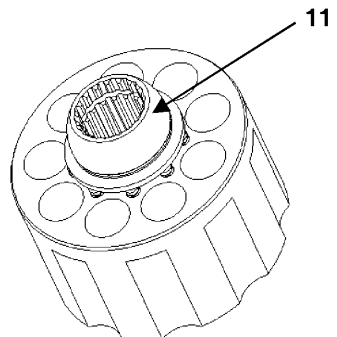


Figure 38

FG013375

11. Set the piston assembly (9, 10) on the retainer plate (8) and assembly it in the cylinder block (13).



CAUTION

Apply an ample amount of hydraulic fluid to the sliding part before assembly.

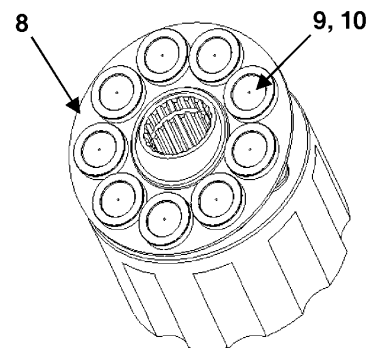


Figure 39

FG013376

12. Assemble the cylinder block (13) and other associated parts.

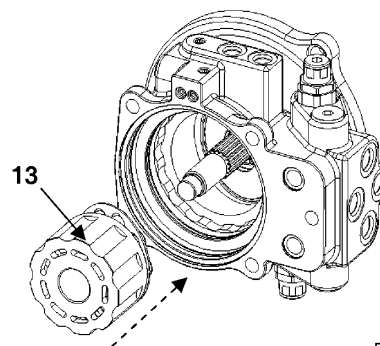


Figure 40

FG013391

13. Assemble the friction plate (14, 2EA) and separation plate (15, 1EA).

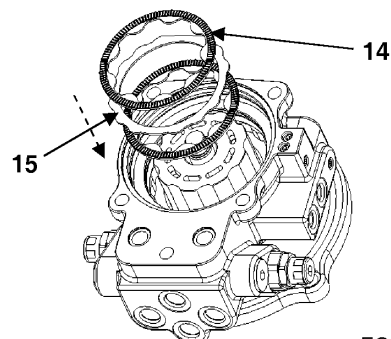


Figure 41

FG013392

14. Assemble the brake piston (16).

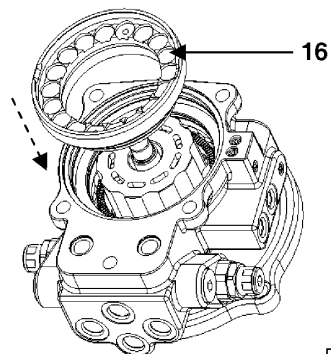


Figure 42

FG013393

15. Assemble the brake spring (17).
Confirm the springs are fitted to the brake piston completely.

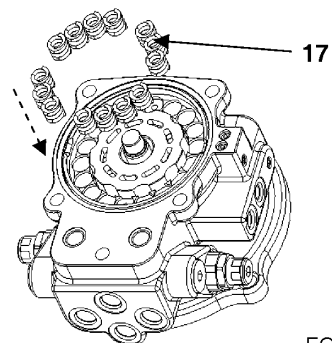


Figure 43

FG013394

16. Assemble the O-ring (26, 27).

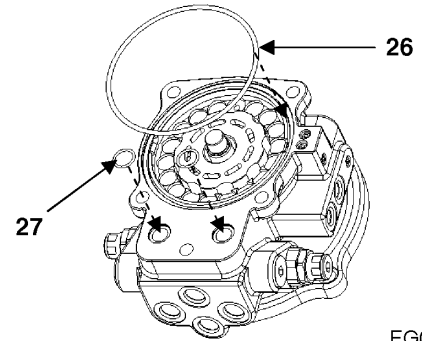


Figure 44

17. Press-fit the ball bearing (5).
Assemble the pin (22).

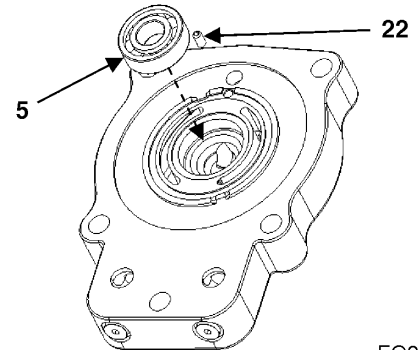


Figure 45

18. Assemble the valve plate (18).
Be careful to note the direction of the valve plate.
Mount the valve plate with its round part toward the opposite side of the flange.
Coat lightly with grease.

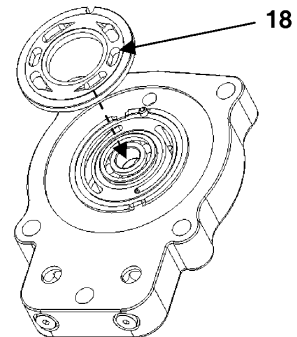


Figure 46

19. Assemble the valve casing (2).



CAUTION

When separating the valve casing (2), be careful not to drop the valve plate (18) or let the brake springs pop out.

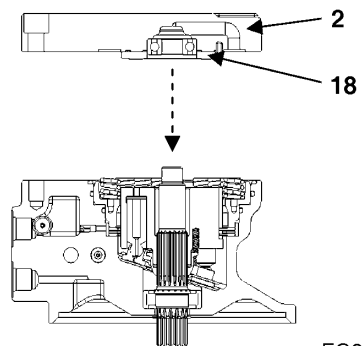


Figure 47

20. Mount valve casing (2) to casing (1) and tighten hex socket bolts (43) to specification.

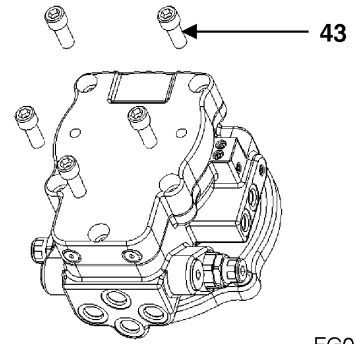


Figure 48

FG013342

The assembly is completed.

Disassembly of Reduction Gear

Please use the following procedures for the inspection and repair of the reduction gear.

Numerals given in parentheses following the parts names indicate the parts number shown by the drawing in the instruction and maintenance manual.

1. Wind the wire rope at reduction gear outside, lift up the reduction gear, and clean the reduction gear with cleaning oil. After cleaning, dry with compressed air.
2. Remove the sun gear No.1 (R18).

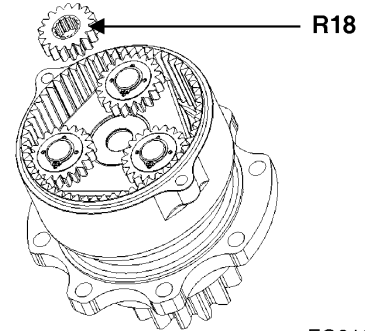


Figure 49

FG013411

3. Remove the carrier No.1 sub-assembly (R9).

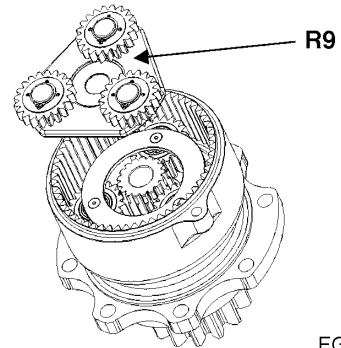


Figure 50

FG013412

4. Remove the sun gear No.2 (R17).

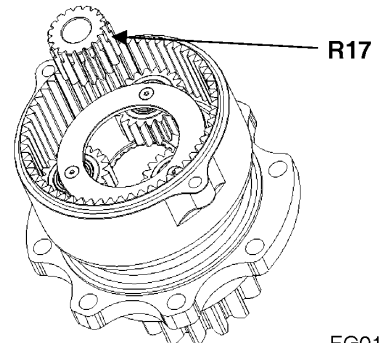
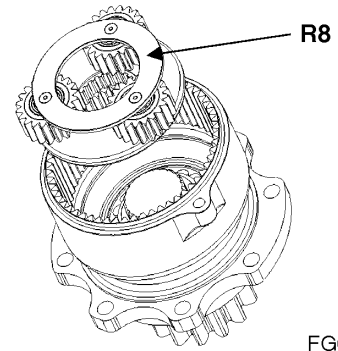


Figure 51

FG013413

5. Remove the carrier No.2 sub-assembly (R8).

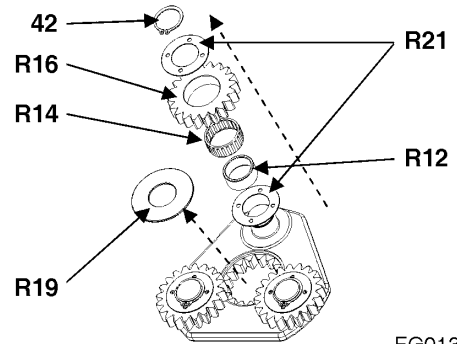


FG013414

Figure 52

6. Remove the following parts.

Reference Number	Description
42	Snap ring
R12	Inner ring No.1
R14	Needle bearing
R16	Planet gear No.1
R19	Thrust washer No.1
R21	Thrust washer No.2

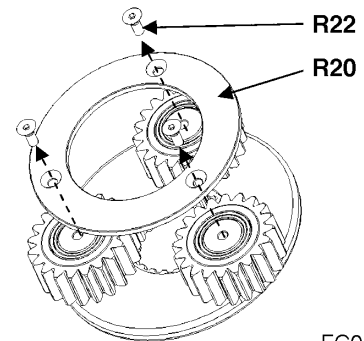


FG013415

Figure 53

7. Secure the carrier No.2 in a vice and loosen the screw (R22) to remove the thrust plate (R20).

NOTE: The screw is hard to remove because loctite was used during assembly. To facilitate the removal of the screw, warm the screw with a drier.

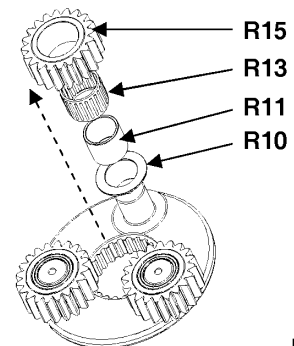


FG013416

Figure 54

8. Remove the following parts.

Reference Number	Description
R10	Thrust washer No.3
R11	Inner ring No.2
R13	Needle bearing
R15	Planet gear No.2



FG013417

Figure 55

9. Remove the half collar (R7).

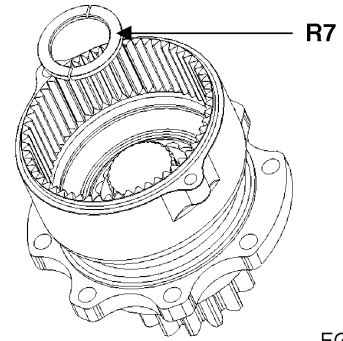


Figure 56

FG013418

10. Remove the pinion shaft (R2).



CAUTION

When removing the pinion shaft, be careful not to drop it. If it is hard to remove, lightly strike it with a plastic hammer.

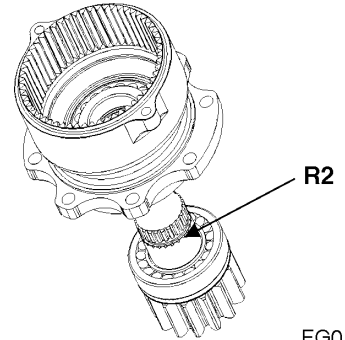


Figure 57

FG013419

11. Remove the taper roller bearing (R4).

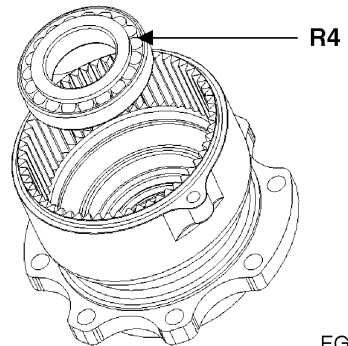


Figure 58

FG013420

12. Remove the oil seal (R5).



CAUTION

The removed oil seal must not be used again.

When removing it, exercise care to prevent damage to the outer races of the taper roller bearings.

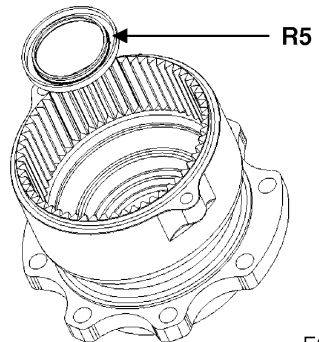


Figure 59

FG013421

Disassembling is finished, check each component thoroughly.

Assembly of Reduction Gear

Following are caution to be specially borne in mind.

- A. Rework damaged parts and before assembling, prepare all parts to be replaced.
 - B. Clean all parts and dry with compressed air.
 - C. Coat the sliding parts and bearing with clean hydraulic oil.
 - D. Replace oil seal.
1. Place the gear casing (R1) on the work table.

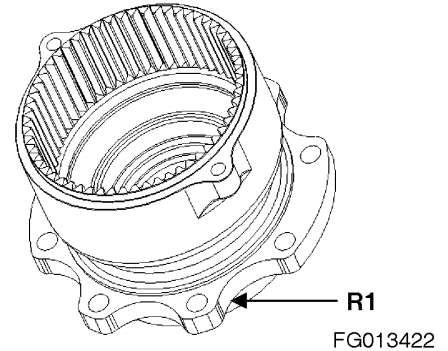


Figure 60

2. Press to insert oil seal (R5) by using pressing jig after spreading grease oil around the outside ring of the oil seal.

Coat grease oil slightly on the lip surface to prevent any scratch when installing.

Be sure to check by eye that the oil seal is seated completely after being inserted.

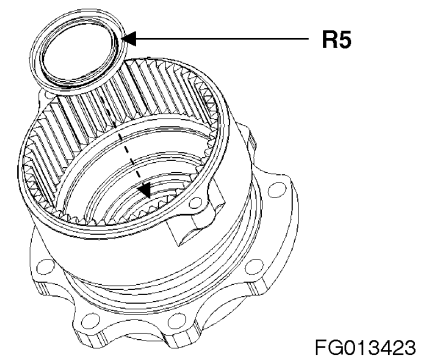


Figure 61

3. Install the bearing cover (R6) and the taper roller bearing (R3) on the pinion shaft (R2).

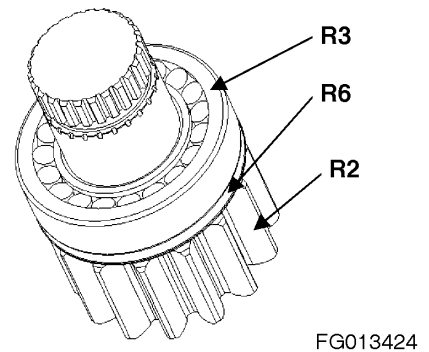


Figure 62

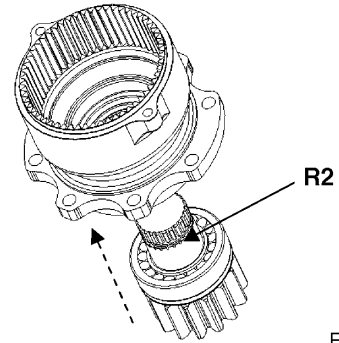
4. Install the pinion shaft (R2) and other associated parts.



CAUTION

Prior to assembling the pinion shaft, etc.

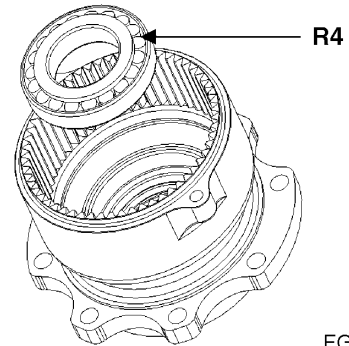
Apply grease slightly on the lip surface to prevent any scratch when installing.



FG013425

Figure 63

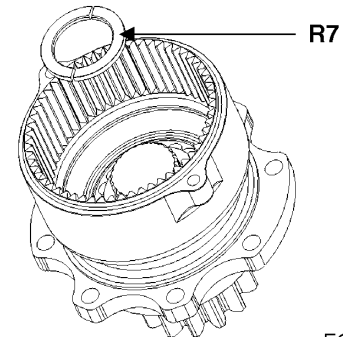
5. Install the taper roller bearing (R4) with a using of tool.



FG013420

Figure 64

6. Install the half collar (R7) with a using of tool.

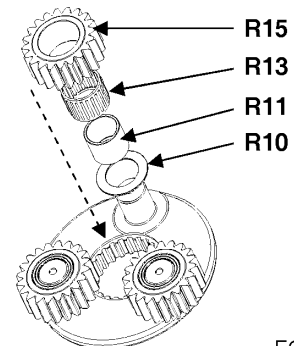


FG013418

Figure 65

7. Install the following parts.

Reference Number	Description
R10	Thrust washer No.3
R11	Inner ring No.2
R13	Needle bearing
R15	Planet gear No.2



FG013426

Figure 66

8. Install the following parts.

Reference Number	Description
R20	Thrust plate
R22	Screw



CAUTION

Apply loctite to the screw prior to tightening it.

9. Install the carrier No.2 sub-assembly (R8).

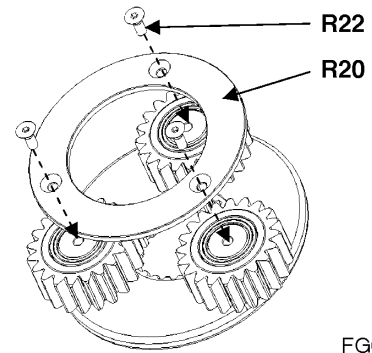


Figure 67

FG013427

10. Install the sun gear No.2 (R17).

Be sure to check the direction of sun gear when assembling.

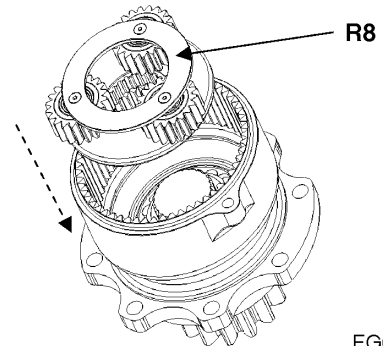


Figure 68

FG013428

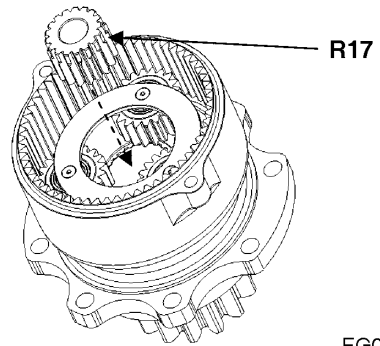


Figure 69

FG013429

11. Install the following parts.

Reference Number	Description
42	Snap ring
R12	Inner ring No.1
R14	Needle bearing
R16	Planet gear No.1
R19	Thrust washer No.1
R21	Thrust washer No.2

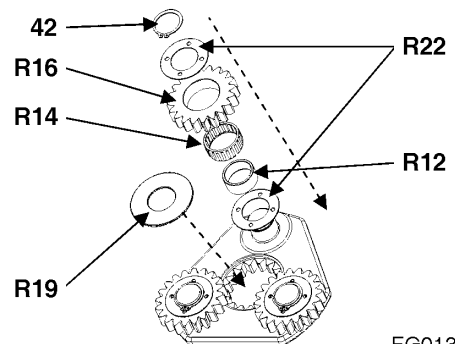
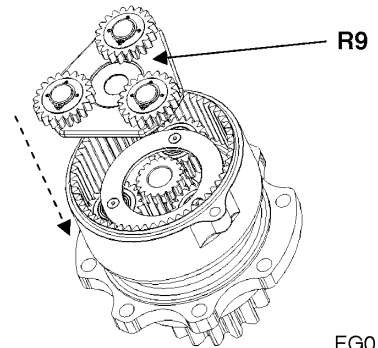


Figure 70

FG013430

12. Install the carrier No.1 sub-assembly (R9).

Turn the carrier slowly by hand to adjust the matching holes when assembling.

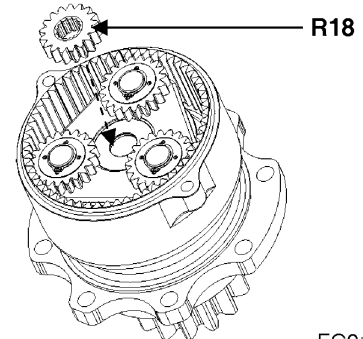


FG013431

Figure 71

13. Install the sun gear No.1 (R18).

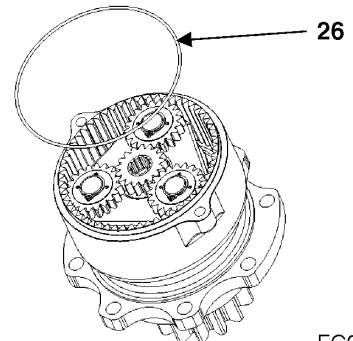
Be sure to check the direction of sun gear when assembling.



FG013432

Figure 72

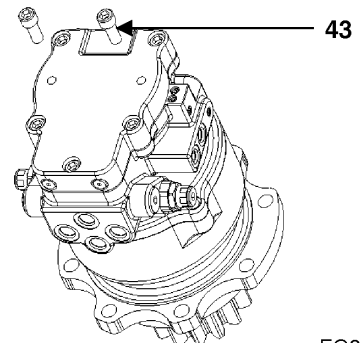
14. Install the O-ring (26).



FG013433

Figure 73

15. Place the motor assembly on the reduction gear assembly and loosely tighten the socket bolt (43), then tighten it the specified torque.



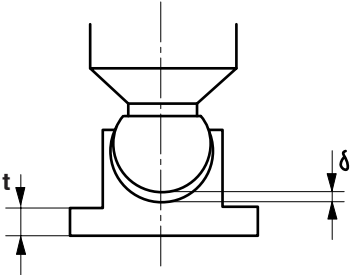
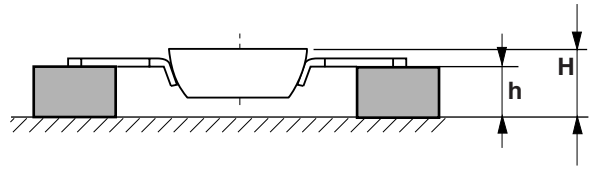
FG013339

Figure 74

MAINTENANCE STANDARDS

Part Replacement Standards for Hydraulic Motor

If the various parts of the motor have been worn out beyond the following standard values, please replace them. But this shall apply only to those cases when is no remarkable outside damage.

Item	Standard Dimension (mm)	Recommended Value for Replacement (mm)	Remedy
Clearance between piston and cylinder bore	0.034	0.044	Replace piston or cylinder block.
Gap between piston and caulked part of shoe (δ)	0.1	0.3	Replace piston or shoe.
Thickness of shoe (t)	3.8	3.6	Replace piston or shoe.
Assembled height of retainer plate (H-h)	13.2	12.7	Replace spherical bush and retainer as a pair.
Thickness of friction plate	2.8	2.4	Replace it.
 Gap between piston and caulked part of shoe (δ), Thickness of shoe (t)		 Assembled height of retainer (H-h)	

Part Replacement Standards for Reduction Gear

Item	Standard Dimension (mm)	Recommended Value for Replacement (mm)	Remedy
Pitting or crack of gear	-	Pitting area rate: 10%	Replace if pitting or crack is found.
Motor driving shaft external spline	Overpin: 28.194 (ø3.048)	27.594	(Z=15)
No.1 Sun gear internal spline	Overpin: 19.767 (ø2.743)	20.367	Replace (Z=15)
No.1 Sun gear	Displacement: 23.269 (3 teeth)	22.969	Replace (Z=17)
No.1 Planet gear	Displacement: 31.876 (4 teeth)	31.576	Replace (Z=20)
No.1 Carrier internal gear	Overpin: 42.171 (ø6)	42.771	Replace (Z=17)
No.2 Sun gear	Displacement: 23.269 (3 teeth)	22.969	Replace (Z=17)
No.2 Planet gear	Displacement: 31.876 (4 teeth)	31.576	Replace (Z=20)
No.2 Carrier internal spline	Overpin: 55.255 (ø5)	55.855	Replace (Z=24)
Pinion shaft external spline	Overpin: 69.343 (ø4.5)	68.743	Replace (Z=24)
Pinion shaft gear	Displacement: 55.251 (3 teeth)	54.951	Replace (Z=13)
Ring gear internal gear	Overpin: 168.144 (ø5)	168.744	Replace (Z=58)
Crack & flaking of bearing inner/outer race & roller	-	-	Replacement if crack or flaking is found
Crack & flaking of gear & spline contact part	-	-	Replacement if crack or flaking is found

NOTE: Z means number of teeth.

Standard for Correcting Sliding Surfaces

If the surface roughness of the sliding surface of a part exceeds the following standards, correct it or replace the part.

Item	Surface Roughness	Roughness Requiring Correction
Shoe	0.8 - Z (Ra=0.2) (LAPPING)	3 - Z (Ra=0.8)
Shoe Plate	0.4 - Z (Ra=0.1) (LAPPING)	3 - Z (Ra=0.8)
Cylinder Block	1.6 - Z (Ra=0.4) (LAPPING)	12.5 - Z (Ra=3.2)
Valve Plate	0.8 - Z (Ra=0.2) (LAPPING)	6.3 - Z (Ra=1.6)

NOTE: *Lap each sliding surface to a standard roughness level or finer.*

If the sliding surface of the cylinder block, valve plate, retainer plate or spherical bush is roughness, replace parts as sub-assemblies.

Travel Motor

Edition 1

MEMO

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Travel Motor

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

GENERAL

CONFIGURATION

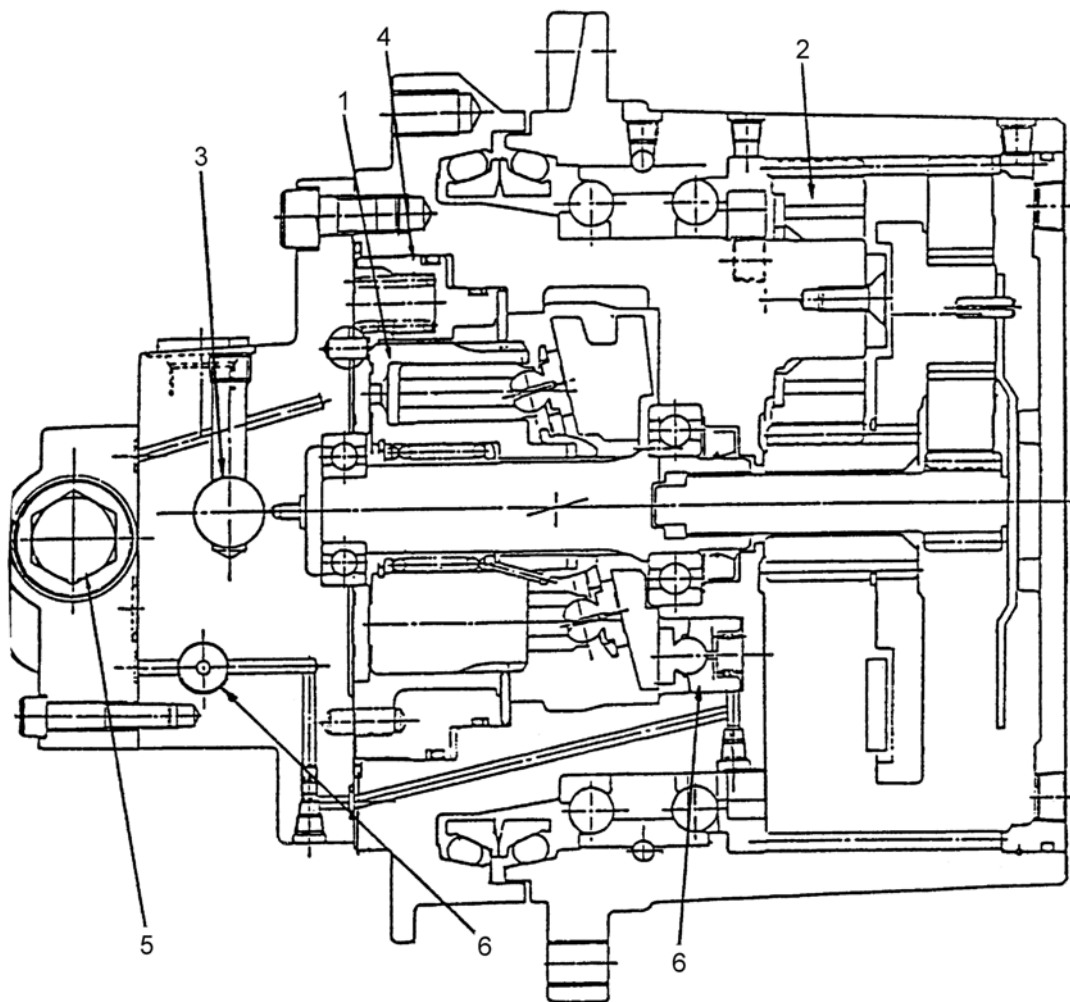
The travel motor is a decelerator contained tilting axial piston motor and has 6 built-in functions, which are; tilting axial piston motor, counter adjusting valve, crossover relief valve, 2-speed changeover device, packing brake, and decelerator. The motor converts the energy of the pressurized oil discharged from the pump into mechanical energy and also transfers high-speed torque power to the decelerator.

Features

- Small size and light weight due to integration of motor and decelerator into one unit.
- The internal counter adjuster permits adjustment of the quantity of oil supplied and prevents reverse rotation.
- The brake circuit includes both counter adjusting valve and relief valve.

The relief valve has a cushioning function, allowing smooth starting and stopping possible.

Structural Diagram of the Travelling System



HASC290S

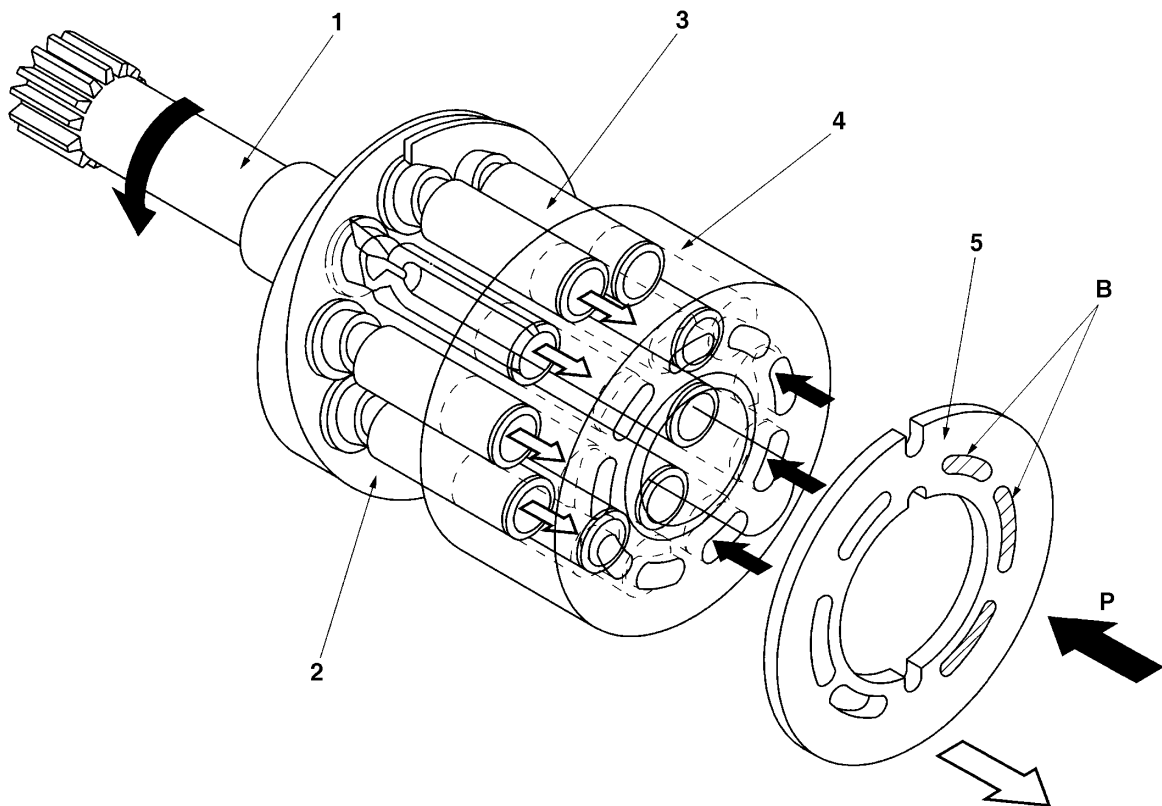
Figure 1

Reference Number	Description
1	Axial Piston Motor
2	Decelerator
3	Counter Adjusting Valve
4	Parking Brake

Reference Number	Description
5	Crossover Relief Valve
6	2-speed Travel Changeover Device

Structural Diagram of the Axial Piston Motor

The Cylinder Block contains 9 pistons and the valve plate is connected to the base of the cylinder block. When high-pressure oil (P) flows through port B, pistons push the swash plate with force $F = P.A$ (where A is the surface area of the piston bore) and the pushing force is translated into rotational movement by the Swash Plate and the shaft is rotated.



FG013892

Figure 2

Reference Number	Description
1	Shaft
2	Valve Plate
3	Piston Assembly

Reference Number	Description
4	Swash Plate
5	Retainer Plate

OPERATING PRINCIPLE

When Travelling

When the control valve is in the state as shown in figure below, pressurized oil from the hydraulic pump will flow into P1 port of the brake valve. The pressurized oil flowing through P1 port will push to open the check valve contained in the plunger, and then flow through M1 port and attempt to rotate the hydraulic motor. At this time the hydraulic oil returning to the hydraulic pump through M2 port can not flow past the check valve causing the discharge pressure of the pump to rise.

The hydraulic oil whose pressure has increased passing through P1 port will act on the end of the plunger and push the plunger to the right. When the pressure at P1 port overcomes the set spring pressure, the plunger will move to the right and the fluid returning from M2 port will flow through the notch at the plunger edge, through P2 port past the control valve and return to the tank, starting the rotation of the hydraulic motor. When the P1 port pressure increases the plunger will be completely changed over and the cross over path will be completely opened resulting in no back pressure.

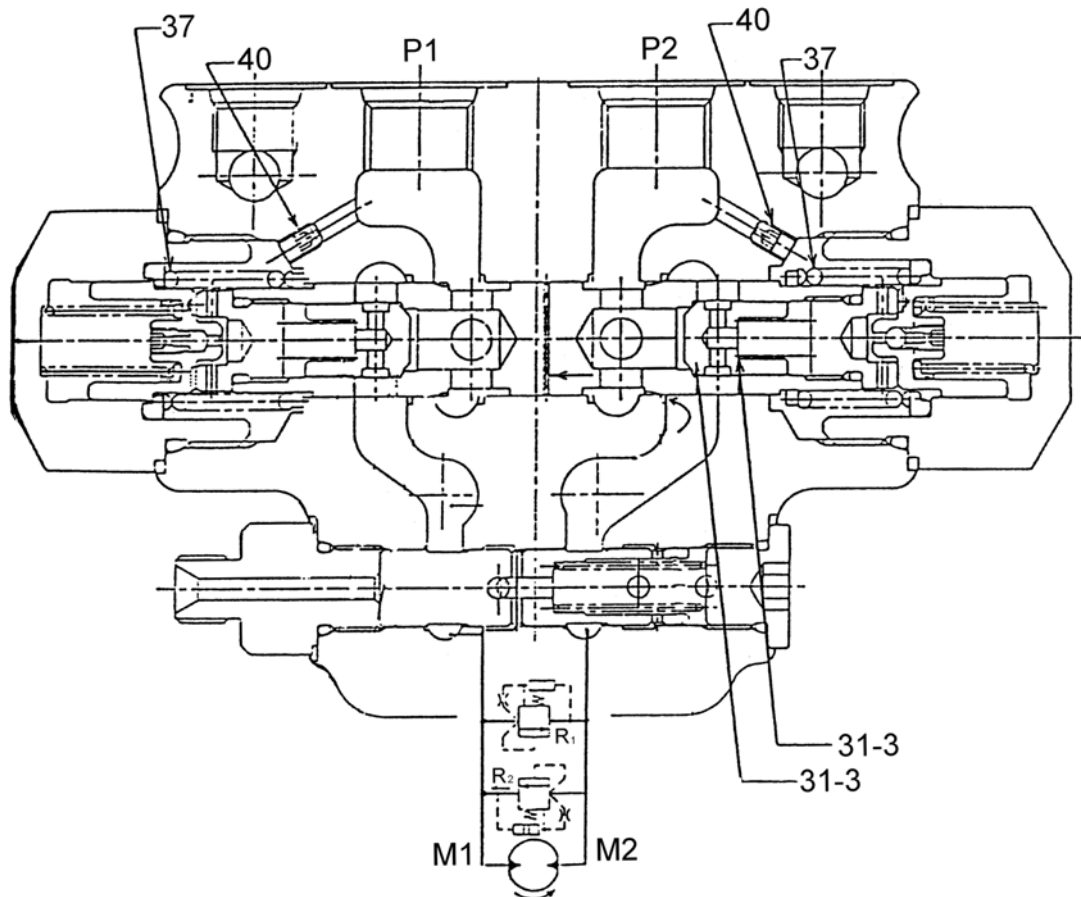


Figure 3

HASC310S

When Counterbalance Operates

When the rotation speed of the hydraulic motor is excessively high, the quantity of the hydraulic oil being discharged from M2 port is more than the quantity of oil being input through M1 port. The P1 port pressure will decrease and the set spring pressure will overcome the pressure being applied to the end of the plunger. As a result, the plunger will move to the left and the groove around the plunger will be restricted building back pressure and delaying the action of the hydraulic motor

When revolution of the hydraulic motor is delayed the pressure of port P1 will increase, thus allowing hydraulic oil flowing through the control valve to drive the hydraulic motor. At this time, the plunger will move to the right side due the increase in pressure of port P1 and the notch on the outer pillar of the plunger will open wide, thus resulting in the decrease of pressure of port M2 and allowing no negative pressure. In other words, this will generate mixed pressure toward notch on the outer pillar of the plunger, and have the hydraulic motor revolve at a revolution speed matching the quantity of hydraulic oil flowing into the hydraulic motor.

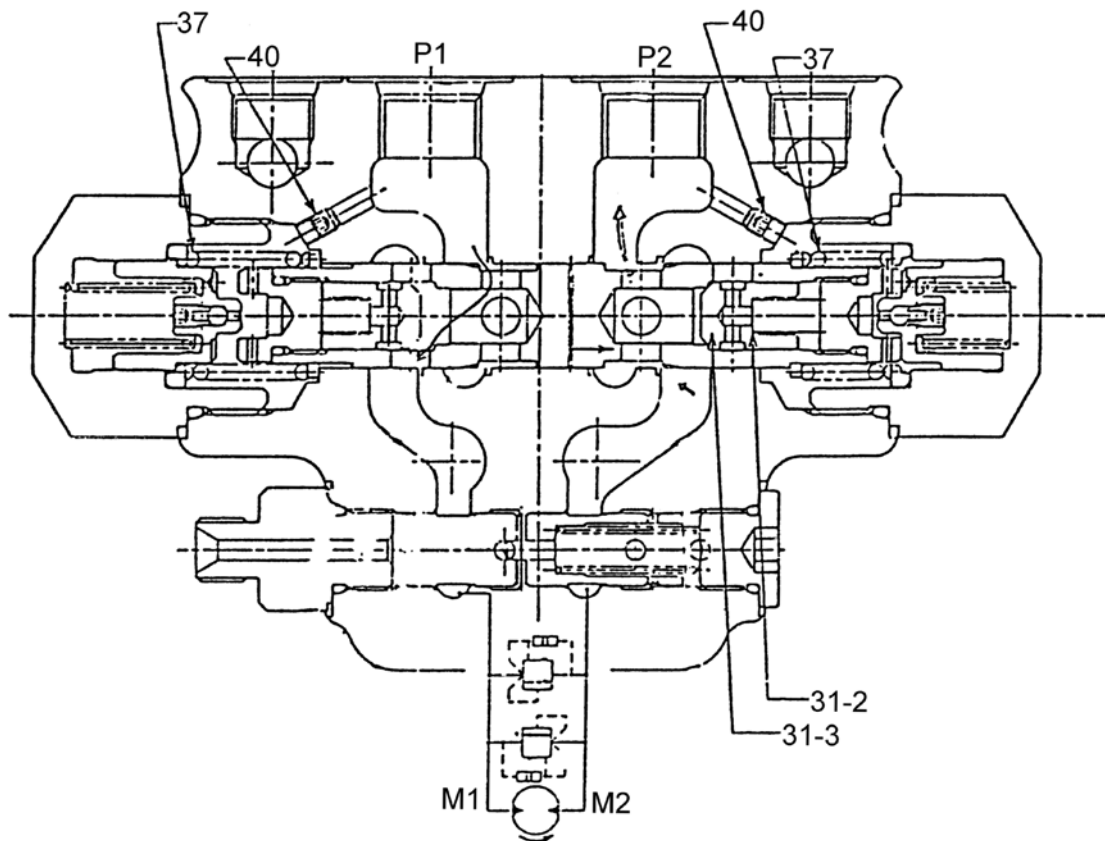


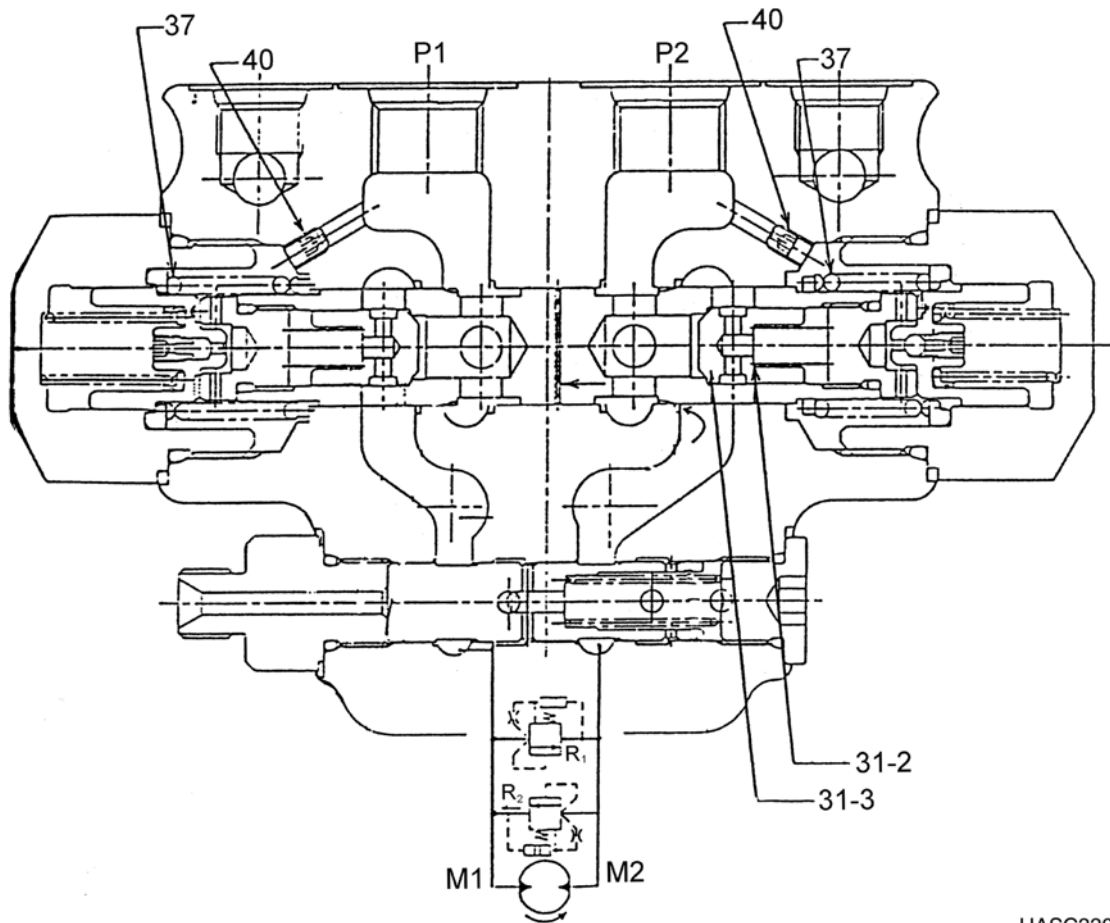
Figure 4

HASC360S

When Brake Functions

When control valve is in the neutral position, then there will be no hydraulic oil discharged from the hydraulic pump. This will result in equalizing both pressure of ports P1 and P2 and in having the plunger return to the neutral position due to spring force, thus shutting notch on the outer pillar of the plunger.

Nevertheless, because the hydraulic motor tends to continue to revolve due to inertia force, it will continue pumping operation, thus causing pressure of port M2 to increase. This increased pressure will operate the relief valve, thus discharging hydraulic oil to port M1. This will result in absorbing shock pressure arising from inertia force of port M2, while at the same time preventing port M1 from forming cavitation.

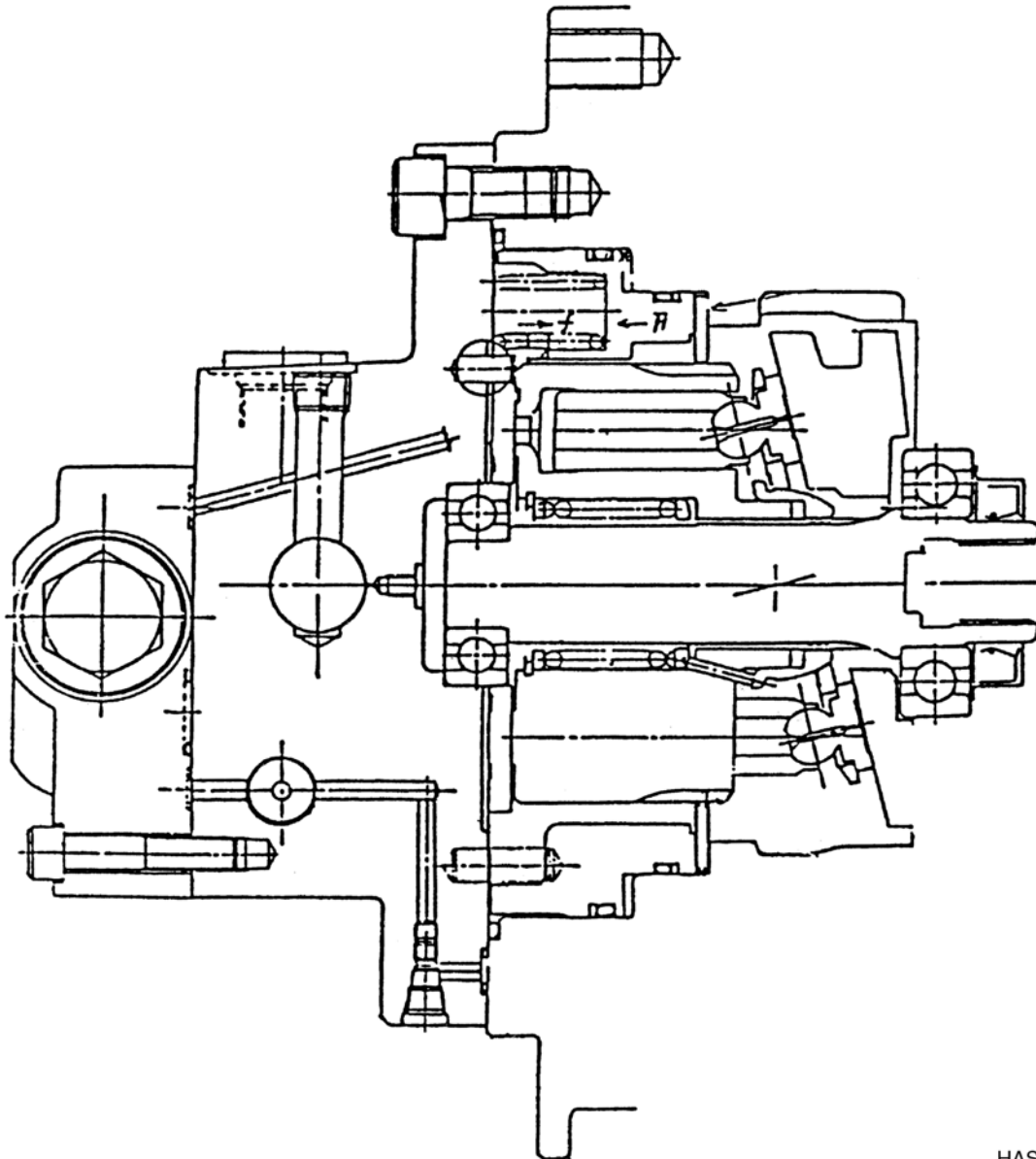


HASC330S

Figure 5

Operating Principle of Parking Brake

Parking brake consists of friction board, piston, and spring. Cylinder block and friction board are interconnected through a spool line. Friction board produces friction force by means of spring. Pressurized oil that entered the motor will open the release port of the parking brake and push the spring that presses the friction board, thus releasing the brake. When stopping, the release port of the parking brake will be closed, and pressurized oil inside the brake chamber will drain into the casing, causing spring force to have the brake operate.



HASC340S

Figure 6

2 Speed Limiting Function

1. At Low Speed

As shown on the following figure, tilting plate is braced at three sides (a, b and c), and is machined so as to enable rotation by means of 2 scale balls.

In case of low speed, spools are driven by spring to stand at the position as shown on the figure, and pistons Pi1 and Pi2 controlling the tilting swash plate are connected with the tank, thus not allowing the force (F_p) that presses the swash plate to influence those pistons. At that time ΣF a sum of forces ($F + F_{s1}$), that, centering on the rotational axis influences the tilting plate, will exceed ΣF a sum of forces ($F_{pi} + F_{s2}$), that influences those pistons, thus having the motor operate at low speed.

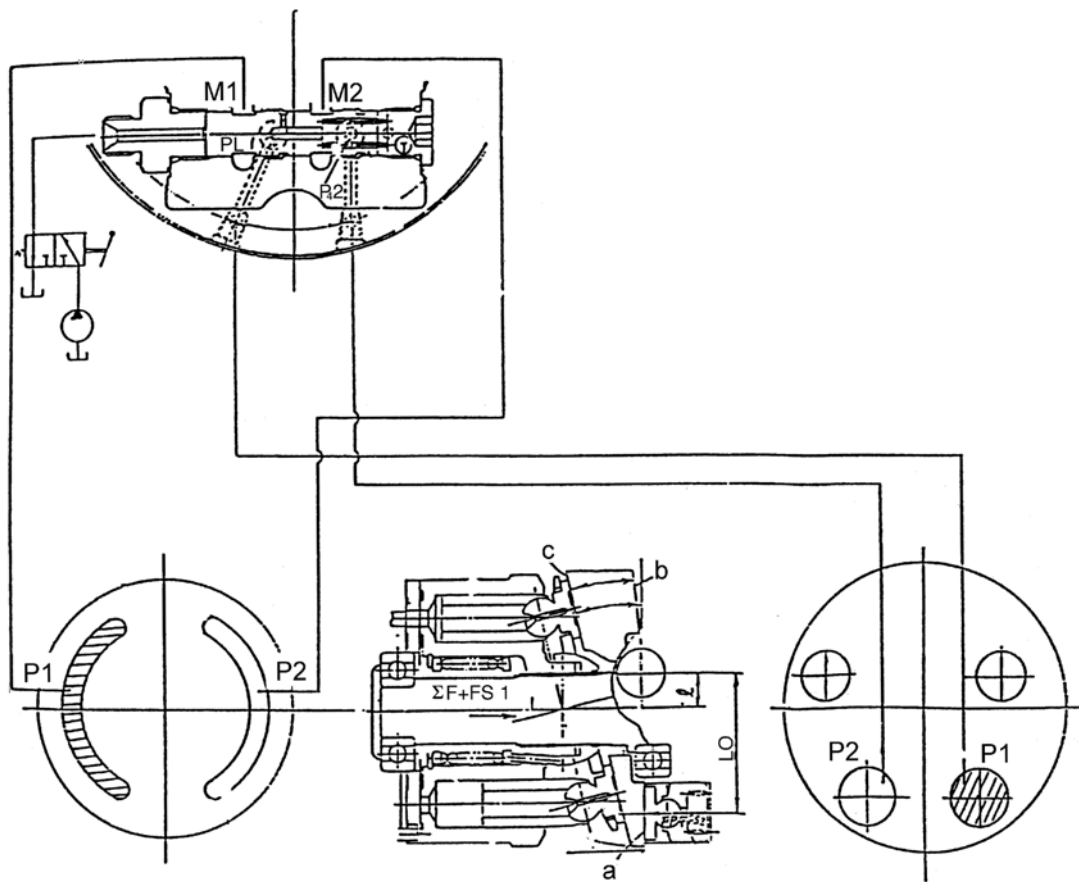


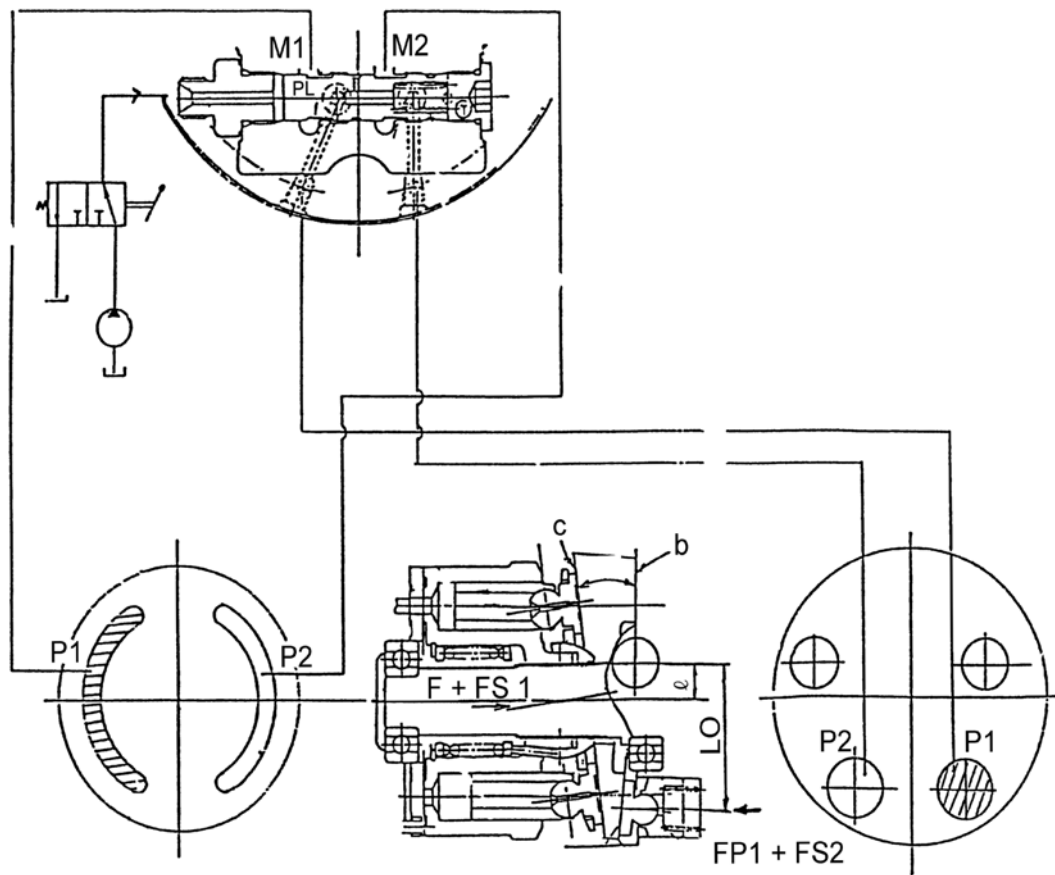
Figure 7

HASC350S

2. At High Speed

When you turn on the travel 2-speed switch, this will actuate pilot pressure, which will move spools as shown on the following figure. Then, pressurized oil will flow into ports M1, M2, Pi1 and Pi2, having motor driving forces ($P1$: high-pressure, $P2$: low-pressure) transfer to respective pistons controlling tilting plates. Consequently, forces ($F_{p1} = A_{p1} \cdot p_1$, $F_{p2} = A_{p2} \cdot p_2$) which press tilting plates will be created on the pistons controlling the tilting plates.

At this time, F_1 , the sum of forces ($F + F_{s1}$), that, centering on the rotational axis, influences the tilting plate, will be less than F_2 , the sum of forces ($F_{p1} + F_{s2}$), that influences those pistons, thus making the swash plate angle widest and having the motor operate at high speed.



HASC320S

Figure 8

PARTS LIST

Hydraulic Motor

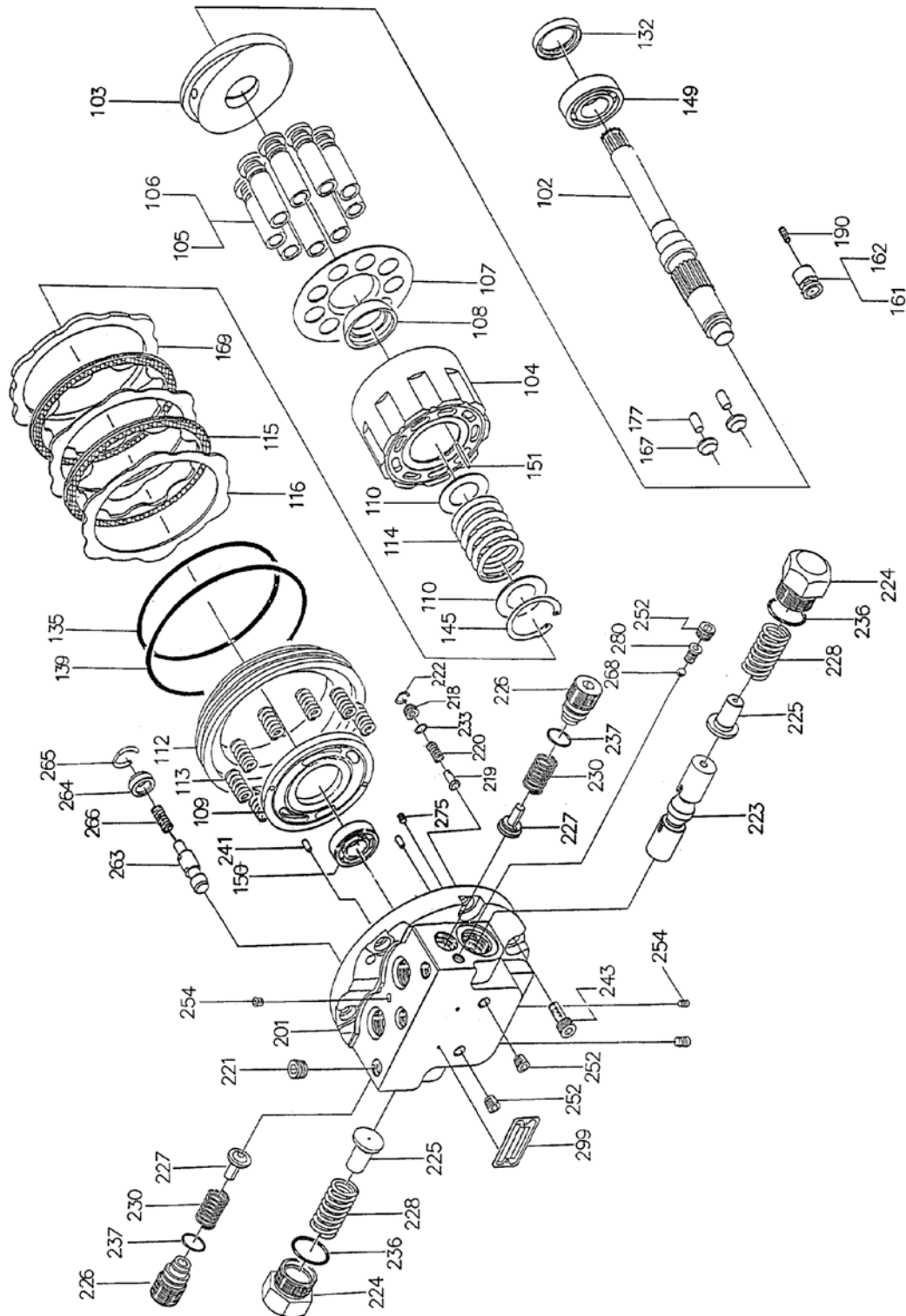


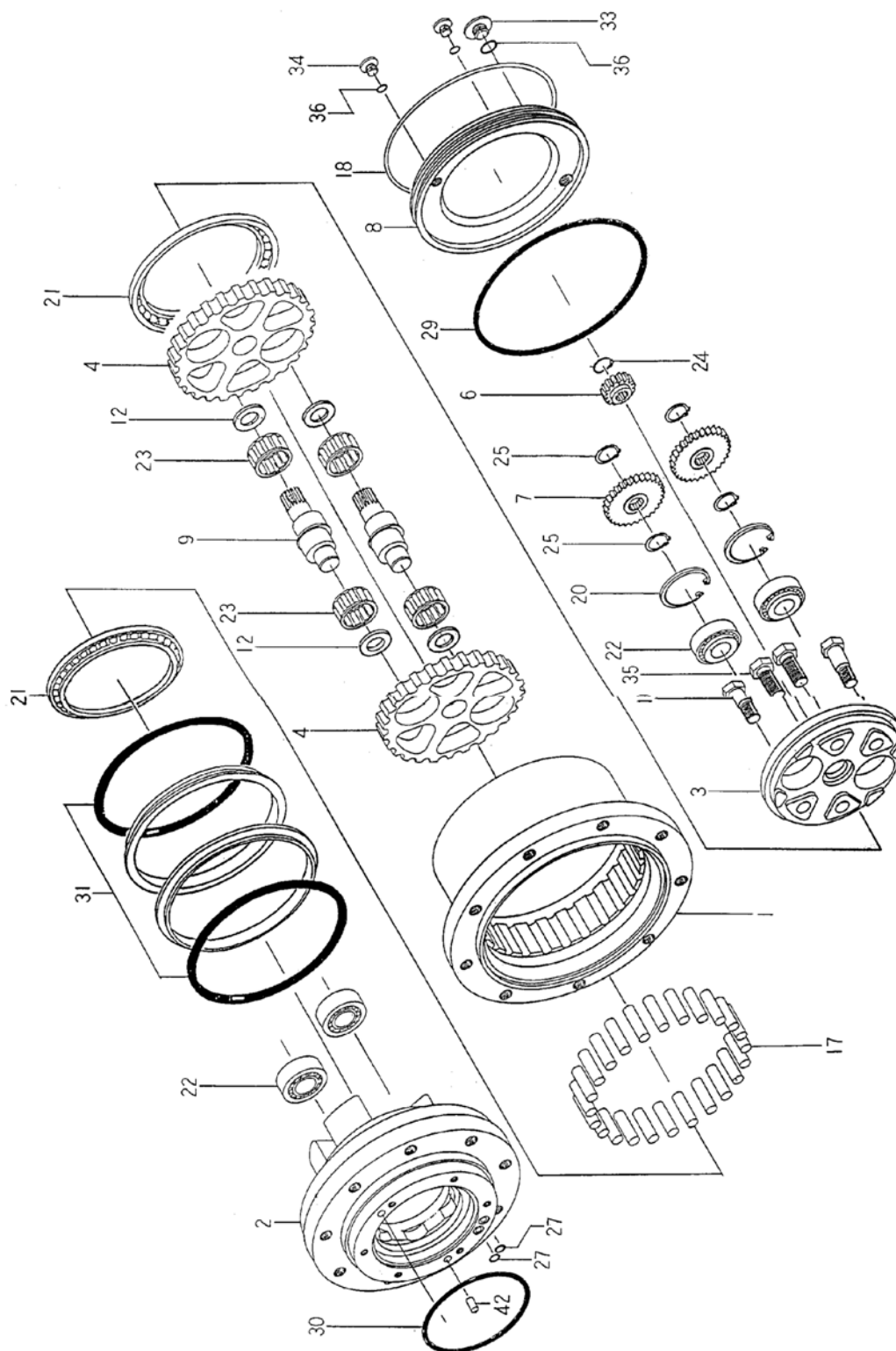
Figure 9

AXS0470S

Reference Number	Description
Hydraulic Motor	
102	Shaft
103	Swash Plate
104	Cylinder Block
105	Piston
106	Shoe
107	Retainer Plate
108	Thrust Ball
109	Timing Plate
110	Washer
112	Piston
113	Spring
114	Spring
115	Friction Plate
116	Mating Plate
132	Oil Seal
135	O-ring
139	O-ring
145	Retaining Ring
149	Ball Bearing
150	Ball Bearing
151	Roller
161	Piston
162	Shoe
167	Pivot
169	Mating Plate
177	Parallel Pin
190	Spring
Valve	

Reference Number	Description
201	Rear Flange
218	Valve Seat
219	Valve
220	Spring
221	Plug
222	Ring
223	Spool
224	Plug
225	Stopper
226	Plug
227	Valve
228	Spring
230	Spring
233	O-ring
236	O-ring
237	O-ring
241	Parallel Pin
243	Hex. Socket Head Bolt
252	Hex. Socket Head Plug
254	Hex. Socket Head Plug
263	Plug
264	Stopper
265	Ring
266	Spring
268	Steel Ball
273	O-ring
275	Orifice
280	Plug
299	Name Plate

Reduction Gear



AXS0480S

Figure 10

Reference Number	Description
1	Hub
2	Spindle
3	Hold Flange
4	RV Gear
6	Input Gear
7	Spur Gear
8	Cover
9	Crank Shaft
12	Spacer
17	Pin
18	Ring
19	Reamer Bolt
20	Retaining Ring

Reference Number	Description
21	Ball Bearing
22	Tapered Roller Bearing
23	Needle Roller Bearing
24	Retaining Ring for Shaft
25	Retaining Ring for Shaft
27	O-ring
29	O-ring
30	O-ring
31	Floating Seal
33	Plug
35	Hex Head Bolt
36	O-ring
42	Parallel Pin

SPECIAL TOOLS AND MATERIALS

Standard Tools

Name	Description	Applicable Parts
Torque Wrench	Dial Type, Approx. 180N	33, 221, 226, 243, 280, 252, 254, 224, 34
	Dial Type, Approx. 560N	19, 35
Hexagon Wrench	Nominal 4 mm	254
	Nominal 5 mm	252
	Nominal 6 mm	243
	Nominal 8 mm	33, 34, 226
Hexagon Socket Insert Angle 12.7 mm	Nominal 1/4 mm	221
	Nominal 4 mm	254
	Nominal 5 mm	252
	Nominal 6 mm	243
	Nominal 8 mm	33, 34, 226
Socket Insert Angle 12.7 mm	Nominal 24 mm	19, 35
	Nominal 30 mm	224
Extension bar	Insert Angle 12.7 mm	19, 35
Spanner	Nominal 30 mm	224
Hand Hammer	Nominal 12 mm	1, 21
Plastic Hammer	ABT. 300 mm	8, 102
Retaining Ring Pliers	For shafts	24, 25
	For Holes	20, 145
Center Punch	ø9.5 x 100	1
Pin Punch	ø3 x 150	21
Washing Brush		For Washing
Wire Washing Brush		For Washing
Paint Maker	Paint Maker: White	Match Marking
Receptacles	Volume: W450 x D300 x H120	For oil draining and holding balls
Metal Net Basket		17
Leather Gloves		149
Vinyl Sheets	500 x 500 x 1.0	21
Oil Pot With Handle		For Oil Filling

Equipment and Materials

Name	Description	Applicable Parts
General Work Stand		For Disassembling and Assembling Works
Washing Tank		For Washing Motor and Parts
Press	Press Capacity: 1960 N (200 kg•m) (1,446 ft lb)	104, 149
Heating Tank	Volume: 20 x 20 x 20 in (500 x 500 x 500 mm) Heating Capacity: Over 100°C (212°F)	149
Electric Drill	Portable Drill Diameter: 10 mm (0.394 in)	1
Drill	Diameter: 2 mm (0.079 in)	1
Crane		GM Motor, 1, 2
Lathe		3
Grinder		
Compressed Air Supply	Pressure: 0.29 - 0.49 MPa (3 - 5 kg/cm ²) (42 - 71 psi)	For Drying Washed Parts

Measuring Devices

Name	Description	Applicable Parts
Thickness Gauge	Measurement: 0.04 - 0.3 mm (0.0016 - 0.0118 in)	For Adjusting Thickness of Retaining Ring (20)
External Micrometer	Measurement Range: 0 - 0.25 mm (0 - 0.0098 in) Min. Graduation: 0.01 mm (0.0004 in)	
Depth Micrometer	Measurement: 0.04 - 0.3 mm (0.0016 - 0.0118 in) Measurement Range: 0 - 0.25 mm (0 - 0.0098 in) Min. Graduation: 0.01 mm (0.0004 in)	For Preload Adjustment of Ball Bearing (21)

Manufacturing Tools

Travel Motor Workbench

Workbench for easily and safely disassembling and assembling the travel motor.

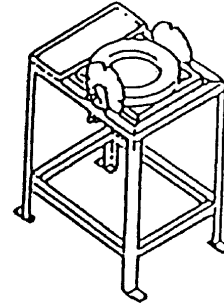


Figure 11

AXS0300S

Fixture

For connecting spindle (2) and hub (1).

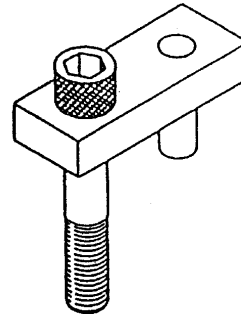


Figure 12

AXS0310S

Holder (I)

For inserting spring (114), washer (110) and retaining ring (145) into cylinder block (104).

For removing spring (114) from cylinder block (104).

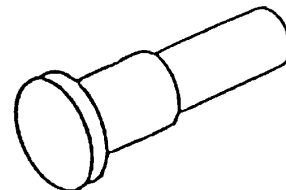


Figure 13

AXS0320S

Holder (II)

For removing ball bearing (149) from or inserting it onto shaft (102).

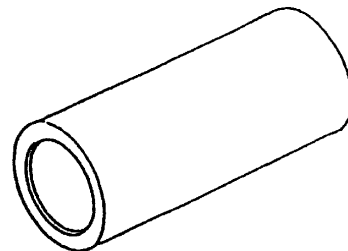


Figure 14

AXS0330S

Holder (III)

For press fitting oil seal (132) into the oil seal hole the spindle (2).

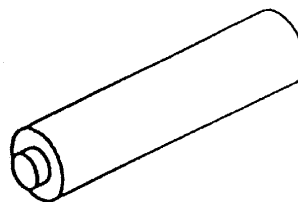


Figure 15

AXS0340S

Holder (IV)

For installing the RV gear assembly on spindle (2).

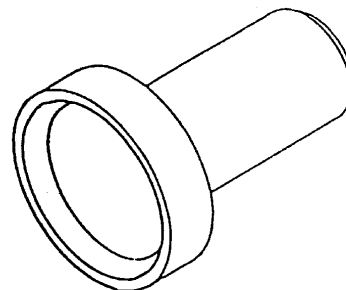


Figure 16

AXS0350S

Steel Rod

For removing ring (18) from hub (1).

For removing ring (265) from rear flange (201).



Figure 17

AXS0360S

Bearing Preload Adjuster

For adjusting the preload of ball bearing (21).

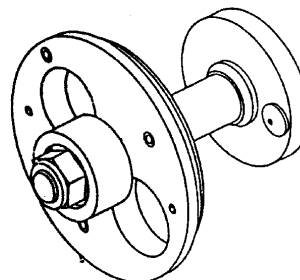


Figure 18

AXS0370S

Aluminum Rod

For disassembling oil seal (132) from spindle (2).

For removing ball bearing (21) and pin (17) from hub (1).

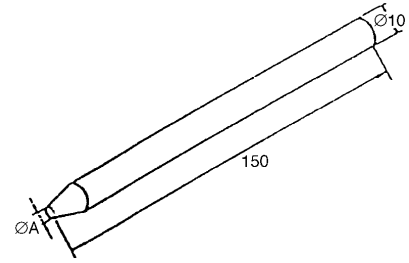


Figure 19

AXS0380S

PF Eye Bolt

For lifting cover (8).

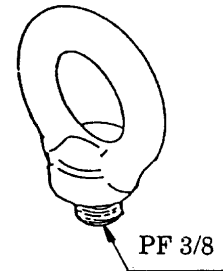


Figure 20

AXS0390S

Eye Bolt

For lifting the GM motor, hub (1) and spindle (2).

	"A"
Hub	M14
Spindle	M14
GM Motor	M14



Figure 21

AXS0400S

F/S Installation Tool (I)

For installing floating seal (31) to hub (1).

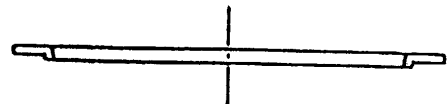
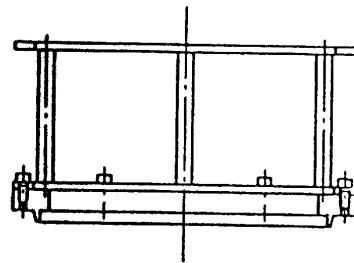


Figure 22

AXS0410S

F/S Installation Tool (II)

For installing floating seal (31) to hub (1) and spindle (2).

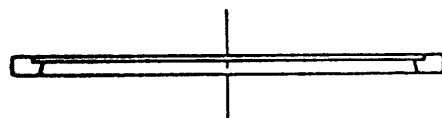


AXS0420S

Figure 23

F/S Installation Tool (III)

For installing floating seal (31) to spindle (2).

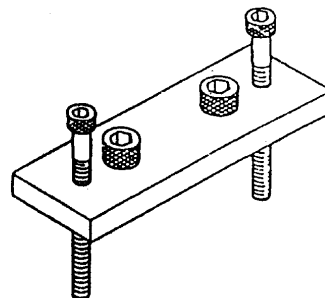


AXS0430S

Figure 24

Cover Removable Tool

For removing cover (8) from hub (1).

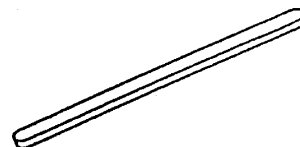


AXS0440S

Figure 25

Slice

For removing timing plate (109) from rear flange (201).



AXS0450S

Figure 26

Tightening Torque

Part No.	Name	Screw Dimension	Width Across Flat	Qty	Tightening Torque
19	Reamer Bolt	M16 (P2.0)	24 mm	2	25.7 ±4.0 kg•m (252 ±39.2 Nm) (186 ±29 ft lb)
33	Plug	PF 3/8	8 mm	1	6.0 ±1.0 kg•m (58.8 ±9.8 Nm) (43 ±7 ft lb)
34	Hexagon Socket Plug	PF 3/8	8 mm	2	6.0 ±1.0 kg•m (58.8 ±9.8 Nm) (43 ±7 ft lb)
35	Hexagon Socket Bolt	M16 (P2.0)	24 mm	2	25.7 ±4.0 kg•m (252 ±39.2 Nm) (186 ±29 ft lb)
221	Plug	9/16-18 UNF	1/4 "	1	3.0 ±0.5 kg•m (29.4 ±4.9 Nm) (22 ±4 ft lb)
224	Plug	M25 (P1.5)	30 mm	2	20 ±1.5 kg•m (196 ±14.7 Nm) (145 ±11 ft lb)
226	Plug	M20 (P1.5)	8 mm	3	8.0 ±1.0 kg•m (78.5 ±9.8 Nm) (58 ±7 ft lb)
243	Hexagon Socket Bolt	M8 (P1.25)	6 mm	6	3.0 ±0.5 kg•m (29.4 ±4.9 Nm) (22 ±4 ft lb)
252	Hexagon Socket Plug	PT 1/8	5 mm	3	1.25 ±0.25 kg•m (12.3 ±2.45 Nm) (9 ±2 ft lb)
254	Hexagon Socket Plug	NPTF 1/16	4 mm	4	1.0 ±0.2 kg•m (9.81 ±1.96 Nm) (7 ±1 ft lb)
280	Plug	M6 (P1.0)		1	1.0 ^{+1.96} ₀ kg•m (9.81 ^{+0.2} ₀ Nm) (7 ⁺¹ ₀ ft lb)

Weight Table

Applicable Parts	Component	Weight
GM Motor	Travel Motor Assembly	Approx. 57 kg (559 N) (126 lb)
1	Hub	Approx. 11 kg (108 N) (24 lb)
2	Spindle	Approx. 20 kg (196 N) (44 lb)
201	Rear Flange Assembly	Approx. 6.15 kg (60.3 N) (14 lb)

TRAVEL MOTOR TROUBLESHOOTING

Travel Motor

Applicable Parts	Component	Weight
Motor Does Not Turn	Defective of motor, counter balance valve, decelerator, etc.	Check suction pressure
	Major components of motor broken	Replace abnormally abraded parts. Remove surface scratches, burrs and reinstall. Replace damaged parts
Motor Rotates Slow	Insufficient oil pressure or quantity	Check oil level in tank
	Poor pump performance	Check for any abnormal signs of moisture icing damage after disassembling parts. Repair or replace parts.
Motor Rotates With Varying Speed	Leakage of pressurize oil towards the drain port due to ice abrasion.	Check pressure at input port of the motor.
	Abraded bearings	Replace all worn parts
Oil Leakage	Broken oil seal and O-rings	Replace broken oil seal and O-rings. Coat O-rings with small quantity of grease when replacing.

Counterbalance Valve

Applicable Parts	Component	Weight
Slow or No Rotation	Plungers will not change over. Hydraulic oil will not circulate. Foreign objects between the plunger and the base plate. Clogged orifice.	Check if hydraulic line is damaged. Replace or repair damaged parts and install after cleaning. Assemble after cleaning.
Slow Stopping or Will Not Stop	Plunger will not return. Foreign objects between the plunger and the base plate. Spring defect or damage Clogged orifice.	Install after cleaning. Replace or repair damaged parts. Install new spring and replace damaged parts.
Large Shock When Stopping	Plunger changeover speed is too fast Defective spring seat.	Install spring seat on a correct position.
Abnormal noise	Plunger does not return. Foreign objects lodged between plunger and base plate. Damaged spring. Clogged orifice.	Install after cleaning. Repair or replace damaged parts Replace spring.

Relief Valve

Applicable Parts	Component	Weight
No or Slow Rotation	Defective relief valves seats. Foreign objects in relief valve. Broken spring.	Remove foreign objects. Replace spring.
	Pressure too low to over come relief valve set pressure. Loose spring. Clogged orifice.	Replace relief valve. Remove foreign objects.
Slow Stopping or Will Not Stop	Defective relief valve seat. Foreign objects in relief valve. Broken spring.	Remove foreign objects. Replace spring.
	Pressure too low to over come relief valve set pressure. Loose spring. Clogged orifice.	Replace relief valves. Clogged orifice.
Large Shock When Stopping	Shock absorbing function not operating. Foreign objects in pistons.	Remove foreign objects.
	Relief valve set pressure is too high.	Readjust pressure.

2-Speed Change Over

Applicable Parts	Component	Weight
Wandering	Spools will not change over. Foreign objects in spools and valve body. Damaged springs. Broken spring.	Remove foreign objects. Reinstall springs. Replace springs.
	Oil leak in 2-speed control piston due to abnormal abrasion.	Repair or replace damaged parts.
	Abnormal abrasion of scale ball.	Repair or replace damaged parts.

Parking Brake

Applicable Parts	Component	Weight
Insufficient Brake Force	Abraded disc. Transmuted disc surface. Loose spring.	Replace disc. Repair disc by abrading or replace disc. Replace springs.
	Abnormal Heating	Replace O-rings. Remove foreign objects.
	Brake will not release. Oil leak due to damaged O-rings. Clogged orifice.	

DISASSEMBLY

Preparations

Perform the following preparations before disassembling.

Workbench Preparations

Provide a travel motor workbench.

Provide a sturdy workbench with which the internal parts of the travel motor can be disassembled or assembled, is wide enough to place parts so they do not move or fall off the bench while working.

Spread a rubber or vinyl sheet on the workbench.

Preparation of Tools and Materials

Provide the tools and materials listed in "Special Tools and Materials" on page 1-20.

General Suggestions When Working



CAUTION

Internal parts are coated with hydraulic fluid during disassembly and are slippery. If a part slips out of your hand and falls, it could result in bodily injury or could damage the part. Be very careful when handling.



CAUTION

Combustibles such as white kerosene are used for washing parts. These combustibles are easily ignited, and could result in fire or injury. Be very careful when handling.

1. Before disassembling, perform inspections and clearly determine the nature of any abnormalities which might occur, and work according to the disassembly procedure.
2. Each part is manufactured to extreme precision. Handle with care and be sure not to hit the parts together or drop them.
3. When working, do not attempt to beat forcefully or wrench tightly fitting parts. Doing so could produce burrs or damage the parts so they can't be mounted or may reduce their performance. You should exercise patience when working.

4. If you leave parts disassembled or partially disassembled, rust could develop on the parts due to moisture or dirt. If you have to interrupt work before completion, be careful to take measures to protect against rust or dust.
5. Place a counter mark on mating faces of parts when disassembling.
6. Arrange removed parts neatly when disassembling so as not to damage or lose the parts while working.
7. As a rule, once any type of seal is disassembled it should be replaced with a new one even if it shows no signs of damage. You should have a new ready when disassembling.
8. The photographs and drawings contained in the manual are of representative models. Disassembly procedure is however not affected even if the product you are using differs in part.

Disassembly Procedure

Washing GM motor.

1. Fasten the eyebolts to spindle (2).

NOTE: *Fasten the 2 eyebolts in the screw holes for mounting the spindle so they are positioned symmetrically.*

2. Hook the wire in the eyebolts, hoist the GM motor with a crane and carry to the washing tank.



Figure 27

3. Wash each part of the GM motor with a brush.

NOTE: *Earth and sand get in the clearance between hub (1) and spindle (2) (floating seal mounting section). Be sure to wash this part with special care.*



Figure 28

GM Motor Installation

1. Set the GM motor on a workbench.

NOTE: While matching the screw holes of hub (1) and screw holes of the workbench, carefully place the travel motor in the mounting holes of the workbench.

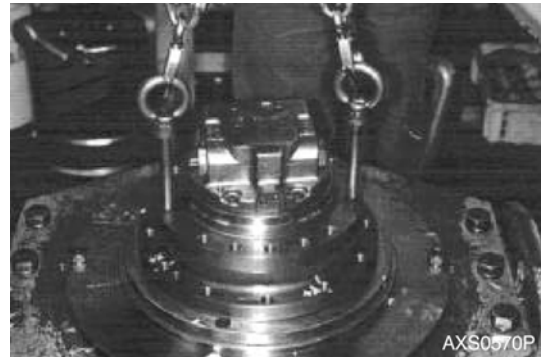


Figure 29

2. Mount the GM motor on workbench so that the 2 hex socket head bolts are positioned symmetrically.



CAUTION

Tighten the hex socket head bolts securely. Failure to do so could result in injury caused by GM motor falling when it is inverted.



Figure 30

Lubricating Oil Extraction

NOTE: If disassembling the rear flange only, proceed to below item (7).

1. Invert the GM motor.
2. Loosen and remove plugs (33), hex socket plug (34).

NOTE: When extracting lubricating oil, place a container below the workbench.

3. Dispose of drained fluids according to local regulations.



Figure 31

4. Slowly invert the GM motor and extract the lubricating oil.
5. Remove O-ring (36) from plug (33), and hex. socket plugs (2 plugs).

NOTE: Do not reuse O-ring (36) which has been removed.



Figure 32

Cover Removal

1. Turn the work bench so cover (8) is on top.
2. Paint match marks on cover (8) and hub (1).
3. Look into the seem to locate the gap of ring (18). Remove ring (18) using a steel rod.



CAUTION

Be careful when removing the ring. You could become injured if the tip of the pliers comes out of the hole of the retaining ring, and the retaining ring jumps out.

4. In case of difficulty to remove the ring following the above method, try the following method.
 - A. Look into the seem to locate the gap of ring (18). Make a punch mark on hub (1) at a point about 20 mm (0.79 in) from the ring end in circular direction and 5 mm (0.1969 in) from the end face of the hub.
 - B. Using an electric drill, make a 2 mm (0.079 in) diameter hole at a punch mark.

NOTE: *Be sure to center the drill on the punch mark, and keep drilling until the ring starts rising. After drilling clear through the wall of the hub, be sure to wipe off the chips completely.*

- C. Insert the steel rod into the drilled hole and push the ring out.



CAUTION

Be careful when removing the ring. You could become injured if the tip of the pliers comes out of the hole of ring, and the ring jumps out.

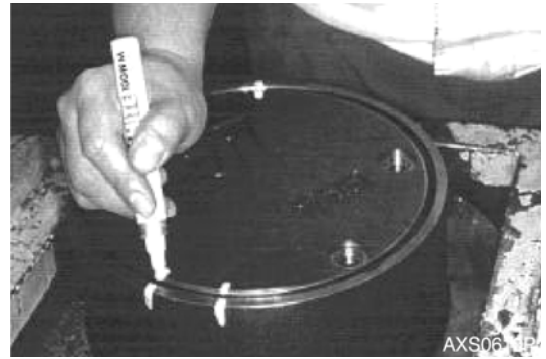


Figure 33



Figure 34



Figure 35

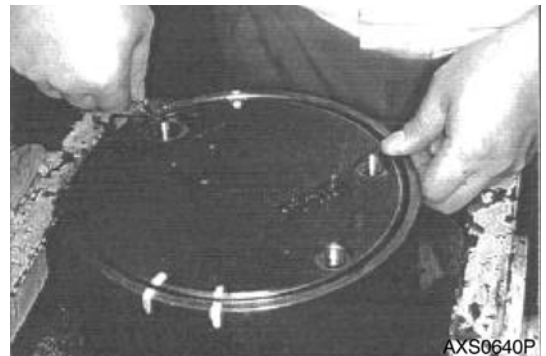


Figure 36

- D. Pick the end portion of the ring and pull it out to remove the ring off the groove.



Figure 37

5. Remove cover (8) from hub (1) making use of the cover removable tool.
6. Remove O-ring (29) from cover (8).

NOTE: *O-ring (29) might prevent the cover from sliding out. If it is difficult to lift the cover off, shake the cover loose by tapping on it with a plastic hammer, so that the cover will slide out without cocking.*

NOTE: *Do not reuse O-ring (29) which has been removed.*



Figure 38

Input Gear Removal

1. Remove retaining ring (24) from shaft (102).



CAUTION

Be careful when removing the retaining ring. You could become injured if tip of the pliers comes out of the retaining ring hole, and the retaining ring jumps out.

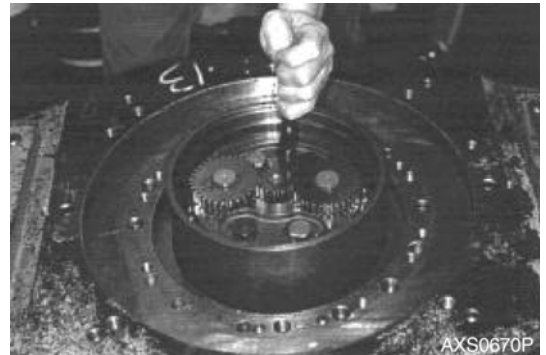


Figure 39

2. Draw out input gear (6) from shaft (102).



Figure 40

Spur Gear Removal

1. Take out two retaining rings (25) from crank shaft (9).



CAUTION

Be careful when removing the retaining ring. You could become injured if tip of the pliers comes out of the retaining ring hole, and the retaining ring jumps out.



Figure 41

2. Draw out two spur gears (7) from crank shaft (9).



Figure 42

Rear Flange Removal

1. Turn the work bench so rear flange (201) is on top.
2. Loosen plugs (224) (2 plugs).

NOTE: *Temporarily loosen the plugs to make work easier later.*



Figure 43

3. Loosen plugs (226) (2 plugs).

NOTE: *Temporarily loosen the plugs to make work easier later.*

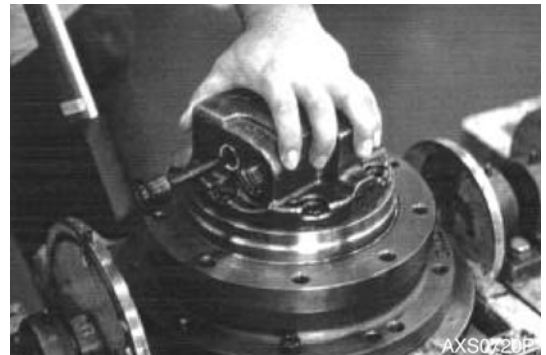


Figure 44

4. Remove hex. socket bolts (243) (6 bolts) from spindle (2).

NOTE: *Be sure loosen the last two bolts slowly.*



Figure 45

5. Remove rear flange (201) from spindle (2).

NOTE: *Hold the rear flange with both hand, and gently lift it straight up; be careful not to cock it while lifting. Remember, timing plate (109) will come out with the rear flange.*



Figure 46

6. Pull out parallel pins (42) (2 pins) from spindle (2).

7. Remove O-rings (30, 27) from spindle (2).

NOTE: *The removed O-rings should be replaced with new ones even if they are free from damage.*



Figure 47

Disassembly of Plugs Inside Rear Flange

1. Remove two plugs (224) from rear flange (201).

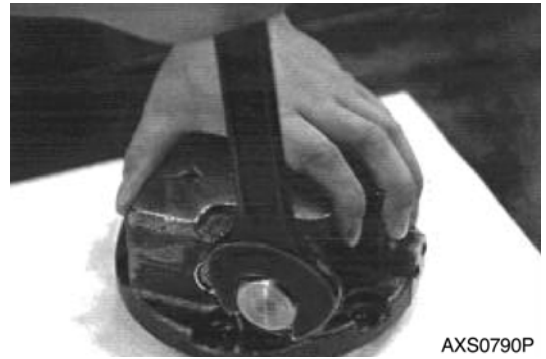


Figure 51

2. From each of the two holes, take out spring (228) and stopper (225).
3. Remove spool (223) from rear flange (201).

NOTE: To remove, tilt rear flange to let the spool slide down, catch the spool and slowly pull it out.

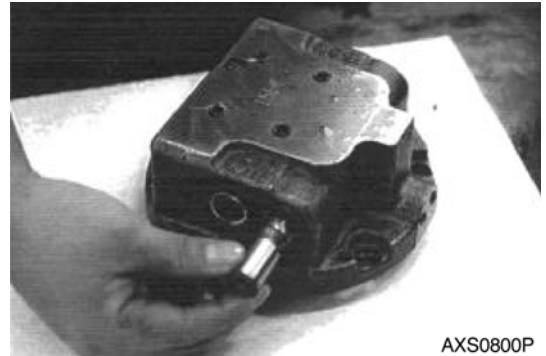


Figure 52

4. Remove two plugs (226) from rear flange (201).



Figure 53

5. Remove two springs (230) and two valves (227) from rear flange (201).

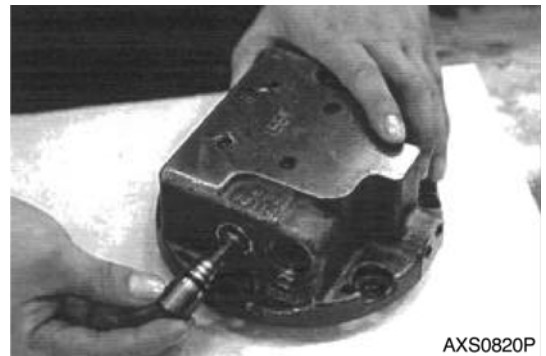


Figure 54

6. Remove O-ring (236) from plug (224).

NOTE: *Do not reuse O-ring which has been removed.*

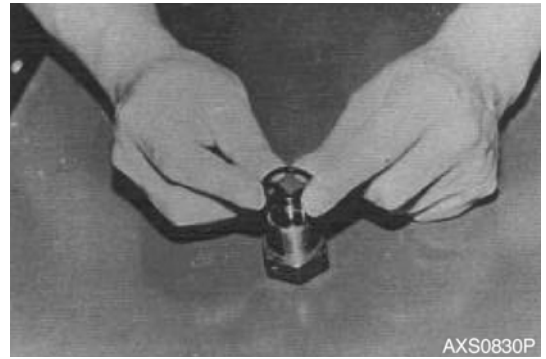


Figure 55

7. Remove O-ring (237) from plug (226).

NOTE: *Do not reuse O-ring which has been removed.*

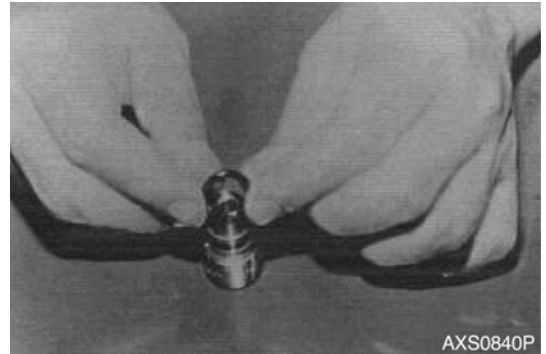


Figure 56

Disassembling Valve (For 2-Speed Control)

1. Press and hold down stopper (264) using a steel bar, and in that state, as shown in the diagram, press the notch in ring (265) using a sharp pointed steel bar. This deforms ring (265), disengaging it from the ring groove in rear flange (201). Ring (265) can now be removed from rear flange (201).

NOTE: *Do not reuse O-ring which has been removed.*

2. Insert the rear flange so that ring hole from which the ring was removed comes down, and lift rear flange (201) to remove stopper (264), spring (266) and valve (263).

NOTE: *When removing the ring from its hole, it may be scratched. Correct any scratched hole surface. Do not reuse the disassembled ring.*



CAUTION

If inverting the rear flange, it does not cause stopper, spring, and valve to come out, carefully apply compressed air from the pilot port to remove them.

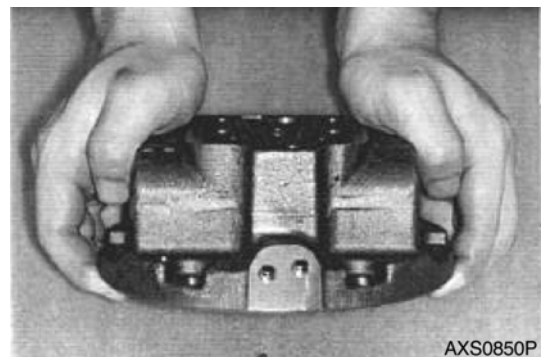


Figure 57

Remove Hexagon Socket Plug

1. You may remove plug (252) but may not disassemble it unless absolute necessary. If the plug is blocked by dirt or any other foreign material, remove it and clean the oil gate. Be careful not to drop steel ball (268).

Disassembling Valve for Parking Brake

1. Press and hold down valve seat (218) using a steel bar, and in that state, as shown in the diagram, press the notch in ring (222) using a sharp pointed steel bar. This deforms the ring, disengaging it from ring groove in the rear flange. Ring can not be remove from the rear flange.

NOTE: *When removing the ring from its hole, it may be scratched. Correct any scratched hole surface. Do not reuse the disassembled ring. Removed O-rings should be replaced with new ones even if they are free from damage.*

2. Block port for valve seat (218), and apply compressed air into access hole in the rear flange.



CAUTION

The abrupt injection of compressed air could cause the valve seat to pop up. To ensure your safety, carefully apply compressed air.

3. Holding rear flange with the hole down, carefully shake the rear flange vertically to let valve (219) and spring (220) come out.

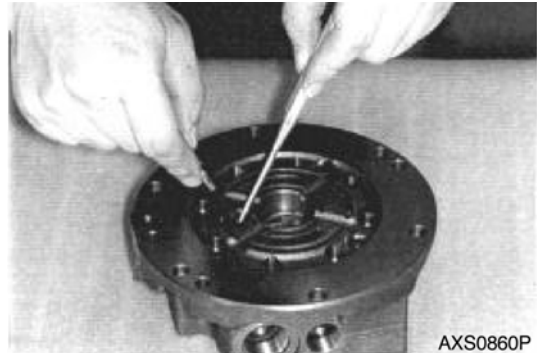


Figure 58



Figure 59

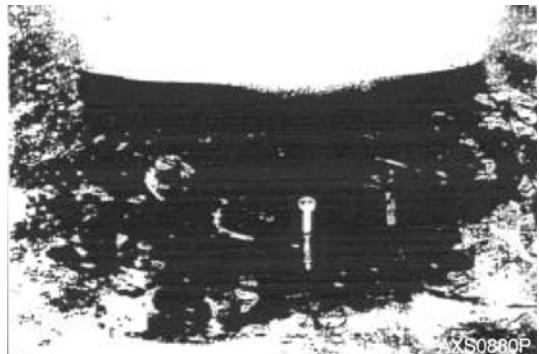


Figure 60

Disassembling Parking Brake

1. Remove piston (212) by injecting compressed air into the access hole in the spindle.



CAUTION

The abrupt injection of compressed air could cause the piston to pop up. To ensure your safety, hold a protective cover over the piston.

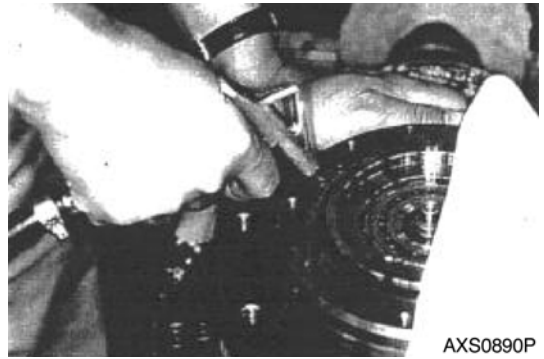


Figure 61

2. Take out O-rings (235, 239) from the piston.

NOTE: *Removed O-rings should be replaced with new ones even if they are free from damage.*



Figure 62

Disassembling Hydraulic Motor

1. Turn GM motor 90° and drain hydraulic oil from the motor.

NOTE: *Place an oil receptacle just below the motor to catch oil.*

2. Take out friction plate (215), and mating plates (216, 269).
3. Hold cylinder block (104) by hand, turn alternately 2 - 3 times, and cut away shoe (106) bonded to swash plate (103).

NOTE: *If the cylinder block has been removed as is, shoe remains bonded to the swash plate, and the parts (piston, shoe and etc.) mounted on the cylinder block and fall into the spindle.*

4. Draw out cylinder block (104) from shaft (102).

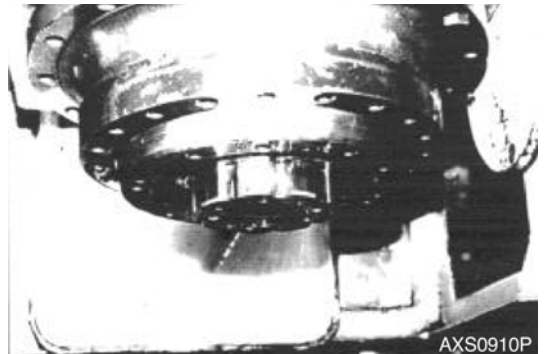


Figure 63

5. Remove the piston assembly (piston (105), shoe (106)) from cylinder block (104).

NOTE: *When removing, grip retainer plate (107) with both hands and remove together with the retainer plate. The piston assembly is a minimum unit. If replacement is necessary, replace the piston assembly as one unit.*

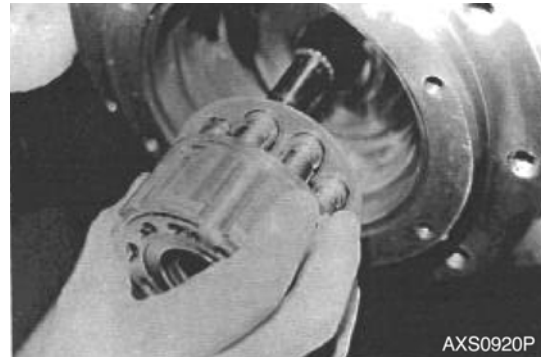


Figure 64

6. Remove the piston assembly from retainer plate (107).

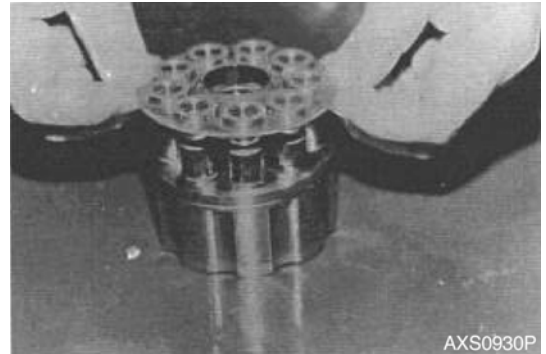


Figure 65

7. Remove thrust ball (108) from cylinder block (104).



Figure 66

8. Draw out three needle rollers (151) from cylinder block (104).



Figure 67

Removal of Spring Inside Cylinder Block

1. Place cylinder block (104) on the press bench.

NOTE: *The spring is removed only when replacing. The spring is removed by lining up the shaft centers of holder (1) and washer in order to prevent damage to the cylinder block through contact. Cover cylinder block with a vinyl sheet to prevent sliding surfaces of the cylinder block from being damaged.*

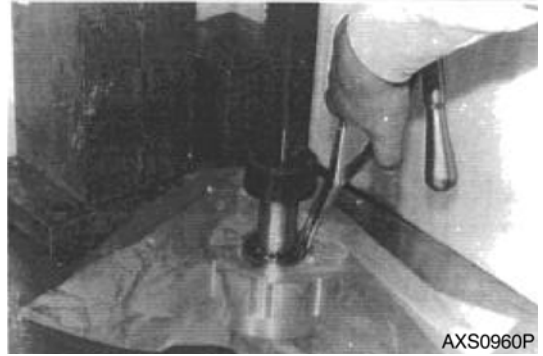


Figure 68

2. Place holder (1) on washer (110), and while clamping holder with the press, remove retaining ring (145) with a retaining ring pliers.



CAUTION

If press is loosened suddenly, the spring could jump out resulting in injury. Loosen the press slowly.

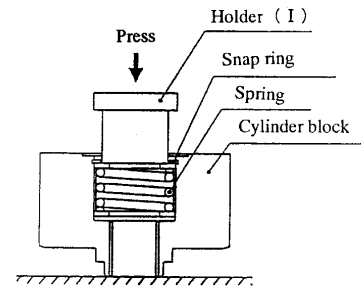


Figure 69

3. Remove spring (114) and washer (110) from cylinder block (104).



Figure 70

Removal of Swash Plate

1. Take out swash plate (103) from the shaft.
2. Remove shaft (102) and ball bearing (149) on it as well, from spindle (2).
3. Remove pivots (167) and pins (177) from spindle (2).

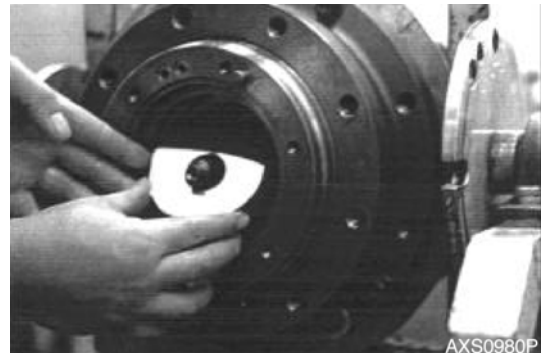


Figure 71

- Remove piston assembly (161,162) by injecting compressed air into the access hole in spindle (2).



CAUTION

Be careful that the abrupt injection of compressed air could cause the piston assembly to pop out. To ensure your safety, hold a protective cover over the piston assembly.



Figure 72

Removing Ball Bearing From Shaft

- Place retainer (II) on the work bench. Insert shaft (102) into the retainer.
- Remove ball bearing (149) from shaft (102) by pressing on the shaft end with a press.

NOTE: *Do not remove ball bearing if it is not be replaced. Do not reuse removed ball bearing.*

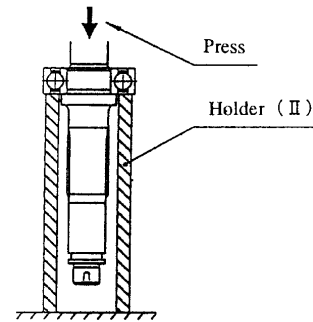


Figure 73

Removing Hold Flange

- Turn the workbench so the spindle is on top.
- Fasten the fixture jig to the hub & spindle.

NOTE: *This clamping is necessary because the hub is sandwiched between the spindle and hold flange. Cramp the spindle and hub securely before removing the hold flange so that the spindle will not fall from the workbench.*



Figure 74

- Turn the workbench upside down.
- Remove retaining rings (20) (2 rings) from hold flange (3).



Figure 75

5. Paint match mark between retaining rings (20) and hold flange (3).

NOTE: *The match marks are intended to ensure that hold flange and retaining rings are in their correct positions when assembled.*



Figure 76

6. Turn the work bench 90 degrees.
7. Loosen reamer bolts (19).

NOTE: *Loctite (638) is used on screw threads of the reamer bolts. For these reason, they might behave as if they were seized in place. When loosening them, turn the torque wrench back and forth to break the loctite and repeat this process until each bolt becomes loose enough to be run out by bare hand. The torque specification for these bolts is 25.7 kgf·m (252Nm) (186 ft lb) but much greater torque of up to 25.7 kgf·m (252Nm) (186 ft lb) may be needed to loosen them because of the loctite.*



Figure 77

8. Loosen hex. head bolt (35).

NOTE: *Loctite (638) is used on screw threads of the hex. head bolts. For these reason, they might behave as if they were seized in place. When loosening them, turn the torque wrench back and forth to break the loctite and repeat this process until each bolt becomes loose enough to be run out by bare hand. The torque specification for these bolts is 25.7 kgf·m (252Nm) (186 ft lb) but much greater torque of up to 25.7 kgf·m (252Nm) (186 ft lb) may be needed to loosen them because of the loctite.*



Figure 78

9. Return the work bench 90 degrees.
10. Remove hold flange (3) from spindle (2).



Figure 79

11. Paint mach marks across hold flange (3) and spindle (2).

NOTE: *The match marks are intended to ensure that the hold flange and spindle are in their correct positions when assembled. The four holes for the reamer bolts and hex. head bolts in the spindle are machined with the holed flange attached to the spindle. Therefore, if one of them must be replaced, replace both as a set at the same time. (A set of the spindle and hold flange is called the spindle assembly).*

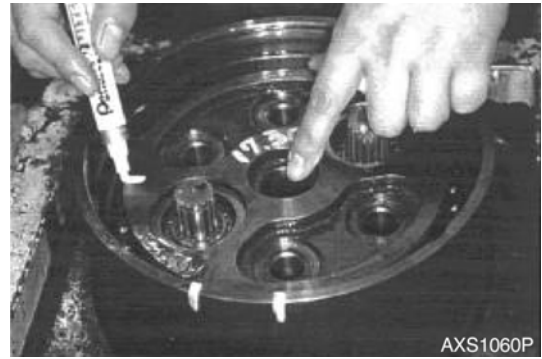


Figure 80

Fixture Removal

1. Invert the GM motor.
2. Remove the fixture (2 fixtures).



Figure 81

Removing Spindle

1. Fasten eyebolts (2 bolts) in the mounting holes of spindle (2) so they are symmetrically positioned.
2. Hook on the eyebolt, gently and slowly hoist with a crane and remove spindle (7) from hub (1). At this time, floating seal (31), outer ring of tapered roller bearing (22), and oil seal (132) come off together.

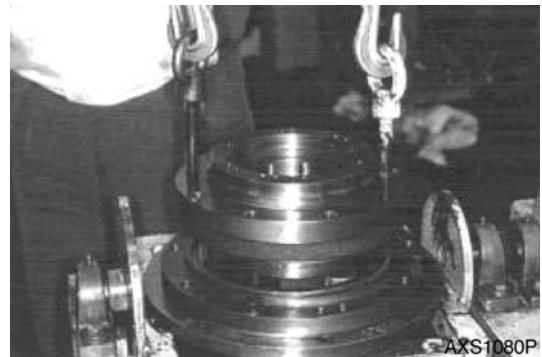


Figure 82

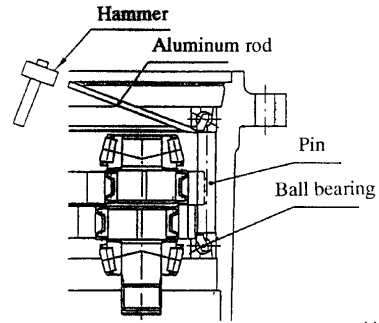
Removal of Ball Bearing, RV Gear Assembly, and Pin

1. Remove floating seal (31) from hub (1).

NOTE: When removing ball bearing (21), tap end face of the pins equally in 3 - 4 places around the circumference a little at a time so as not to wrench ball bearing (21). When mating part of the outer ring of ball bearing (21) is removed from hub (1), ball bearing (21), RV gear assembly and pin (17) will fall from hub (1). In order to keep the parts from being damaged, place a container underneath the workbench, and place a rubber mat over it.

2. Strike the end face of pin (17) with a pin punch and a hammer, and remove ball bearing (21) from hub (1). At this time, the RV gear assembly (RV gear (4), crank shaft (9), tapered roller bearing (22), needle roller bearing with retainer (23), spacer (12)) and pin (17) can be taken out together.
3. Remove ball bearing (21), RV gear assembly and pin (17) which have fallen.

NOTE: Tapered roller bearing (22), needle roller bearing (23), and spacer (12) are not removed from crank shaft (9) except when replacing.



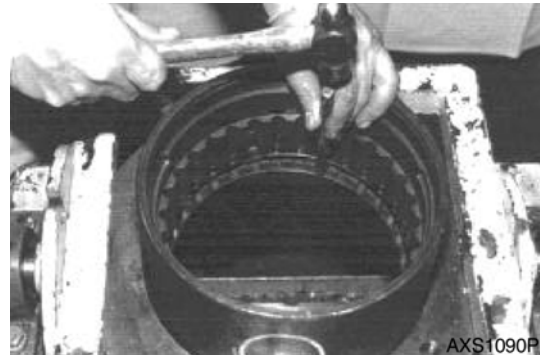
AXS0510S

Figure 83

Ball Bearing Removal

NOTE: When removing, ball bearing (21) falls from hub (1). Place a rubber mat the underneath workbench to keep the part from being damaged.

1. From cover (8) side of hub (1), strike the end face of pin (17) with a pin punch and hammer, and remove ball bearing (21) from hub (1).



AXS1090P

Figure 84

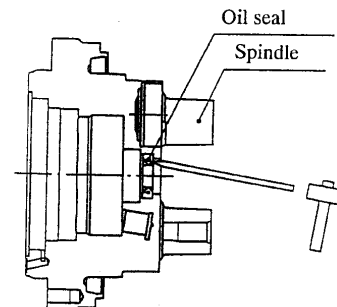
Disassembling Spindle Fittings

1. Remove oil seal (132) from spindle (2).

NOTE: Absolutely do not reuse oil seal (132). Which has been removed.

2. Remove floating seal (31) from spindle (2).

NOTE: The removed floating seal should be replaced with new ones even if it's free from damage.



AXS0520S

Figure 85

3. Pull out the outer rings of tapered roller bearings (22) from spindle (2).

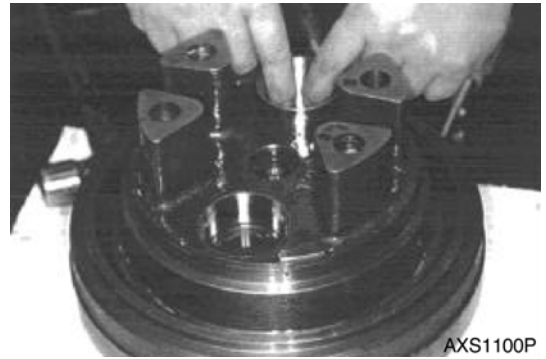


Figure 86

Disassembling Hold Flange

1. Remove the outer rings of tapered roller bearings (22).

NOTE: *Remove the outer ring only when the ball bearing is to be replaced.*



Figure 87

Washing

1. Separate hub (1), spindle (2), cover (8), and rear flange (101) from other parts (hereafter called the built-in parts).
2. Wash the built-in parts in a washing bath.

NOTE: *Carefully wash to remove any darts from external surfaces. Wash all parts carefully with kerosene.*



CAUTION

Wash all parts carefully with kerosene. Take notice of a possibility of due to combustibility.

3. Full a primary washing vessel with kerosene. Put the built-in parts in it and wash them.

NOTE: *To prevent the built-in parts from being marred by dirt during washing, immerse the parts in kerosene long enough for any dirt or oil to become loose and surface before washing them.*



Figure 88

Finish Washing

1. Rinse the washed parts in a rinsing sink filled with clean kerosene by gently shaking each part in the kerosene.

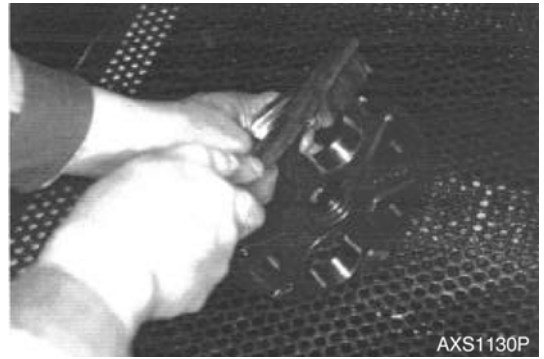


Figure 89

2. Using clean, lint free cloth, wipe each rinsed part to remove dripping kerosene.

NOTE: Dry hub (1), spindle (2) and hold flange (3) by spraying with compressed air until they are dry and clean. Let other parts dry naturally until they are dry and clean. After drying, coat every part with oil. Take notice that all pins and ball / roller for the bearings are carefully separated and surfaces protected from any damage to prevent flaws to the pins and ball / rollers.



Figure 90

SERVICE PREPARATIONS

Follow these standards when disassembling and inspecting the GM motor. Handle the various parts carefully. Be especially careful not to damage the moving and sliding parts.

Seals

Once disassembled, all seals (O-rings, oil seals, floating seals) should be replaced with new ones even if no damage is observed.

Service Standards for Parts Subject to Wear

1. Replace all parts which show striking damage.
2. Replace if various parts have the following problems (phenomenon).

Part No.	Part Name	Phenomenon	Standard	Service Limit
2 3 19 35	<u>Spindle Kit</u> Spindle Hold Flange Reamer Bolt Hex. Socket Bolt	• Serious damage in appearance. • Abnormal wear such as scuffing.		
4 9 22 23 12	<u>RV gear assembly</u> RV gear Crankshaft Tapered roller bearing Needle roller bearing Spacer	• RV gear teeth surface are worn unequally. • Movement of various parts not smooth when crankshaft (9) is tuned		
20	Retaining ring	• Circumferential end face has abnormal wear		
21	Ball bearing	• Has indentation. • Exhibits flaking phenomenon. • Worm unequally.		
201 223	Rear Flange Kit Rear Flange Spool	• Flaw in moving part with spool (223). • Clearance with spool is too large. • Flaw on working face with valve (227). • Depth to working face with valve (227) is too large. • Flaw on circumference. • Circumference worn unequally.	Diameter clearance 7μ ~ 13μ	Diameter clearance 33μ
102	Shaft	• Working face with oil seal (132) is worn. • Spline is worn.		
103	Swash plate	• Has burning phenomenon,		

Part No.	Part Name	Phenomenon	Standard	Service Limit
104	Cylinder block	- Spline section is worn. - Inner surface of bore is worn too much. - Flaw and unequal wear on sliding plate surface with timing plate (109).		
105 106	Piston assembly Piston Shoe	- There is clearance in shaft direction of the piston (105) and shoe (106). - Shoe is abnormally worn. - Shoe is unequally worn.	Clearance 0.050 mm (0.0020 in)	Clearance 0.150 mm (0.0059 in)
107	Retainer plate	Circumference and face is unequally worn.		
108	Thrust ball	Ball surface has burning phenomenon and equal wear.		
227	Valve	Flaw in sheet surface.		
149 150	Ball bearing	- Has indentation. - Exhibits flaking phenomenon. - Worn unequally.		
263	Valve	Flaw on circumference		

ASSEMBLY

Assembly, as a rule, assembly is carried out by performing the procedure for disassembly in reverse.

Preparation

Provide a workbench, tools, and materials in the same way as for "Disassembly" on page 1-29.

General Suggestions When Working

1. Pay the same attention as for general suggestions for "Disassembly" on page 1-29.
2. When assembling, remove all foreign objects or metal fragments from parts, and make sure there are no burrs or dents, etc., on parts. If there are burrs or dents, remove with an oil stone.
3. Replace O-rings, oil seals and floating seals with new ones.
4. Replace reamer bolt (19) with new ones.
5. Bonding agent is applied to the screw section of reamer bolt (19), hex socket bolt (35) and screw holes of reamer bolt (19), hex socket bolt (35) of spindle (2) when assembling. Degrease in order to remove grease.
6. Be careful not to damage O-rings, oil seals and floating seals when mounting. (Apply a small amount of grease to make them slippery.)
7. Be sure to coat the moving and sliding parts of the hydraulic motor section and valve section with clean hydraulic fluid (NAS standard class 9 or less) and assemble.
8. Do not use cloth gloves for assembly. (To prevent fiber pieces from causing faulty operation.)
9. Bolts and plugs should be tightened by the torque value given in 1 - 2. Tightening Torque Table.
10. When assembly is complete, plug all ports to prevent dirt from entering.
11. The photographs and drawing contained in the manual are of representative models. Disassembly procedure is however not affected even if the product you are using differs in part.

Assembly Procedure

NOTE: *If assembling after replacing parts, preload adjustment of the ball bearing and shaft direction clearance adjustment of the taper roller bearing are necessary. Before assembling, therefore, make sure the following parts have been replaced.*

1. Renewal parts required for preload adjustment of the ball bearing: Hub (1), spindle kit, ball bearing (21).
2. Renewal parts required for shaft direction clearance adjustment of the taper roller bearing: Spindle kit, RV gear assembly.

NOTE: *If assembling after replacing the parts listed above, be sure to assemble using parts which have been adjusted. If you assemble with parts that have not been adjusted, it will cause the travel motor to operate poorly or break down prematurely.*

Hub Section Assembly

1. Fasten 2 eyebolts in the screw holes of hub (1) so they are symmetrically positioned.
2. Hook the wire in the eyebolts, hoist the hub (1) with a crane, and set hub (1) on the workbench.

NOTE: *While matching the screw holes of the hub (1) and mounting holes of the workbench, place the hub gently in the mounting holes of the workbench.*

3. Fasten hub (1) to the workbench so that the hex. socket bolt are symmetrically positioned.



CAUTION

Tighten the hex socket bolts securely. Failure to do so could result in injury if the travel motor is inverted and falls.

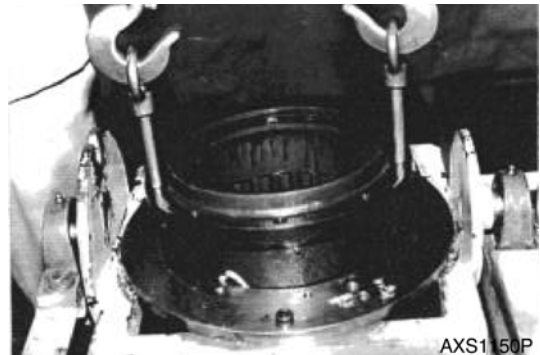


Figure 91



Figure 92

4. Press fit the ball bearing (21) in the hub (1) with an aluminum rod and hammer.

NOTE: *Be sure to keep it true and square by shining the aluminum rod around and pushing it in just a little at each spot.*



Figure 93

5. Apply oil thinly on the outside circumference of the O-ring of the floating seal (31), and mount the floating seal in the floating seal groove of the hub (1).

NOTE: *To mount the floating seal, piece the F/S installation tool (I), floating seal and F/S installation tool (II) in that order, and press in until F/S installation tool (II) reaches F/S installation tool (I). Remove the installation tools, and check the inclination of the floating seal surface to make sure it is within 1 mm (0.0394 in).*

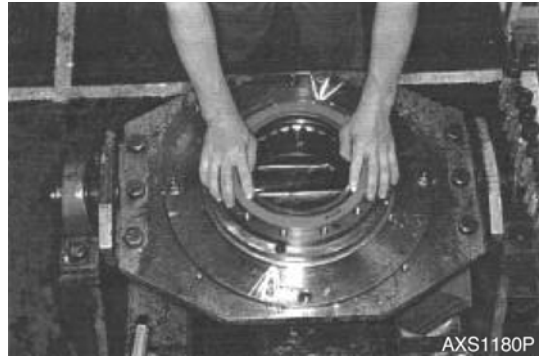


Figure 94

Spindle Assembly

1. Apply oil thinly on the outside circumference of the O-ring of floating seal (31) and mount the floating seal in the floating seal groove of the spindle (2).

NOTE: *To mount the floating seal, place the F/S installation tool (III), floating seal and F/S installation tool (III) in that orders, and press in until F/S installation tool (II) reaches F/S installation tool (III). Remove the installation tools, and, check the inclination or the surface of the floating seal to make sure it is within 1 mm (0.0394 in).*



Figure 95

2. Fit the outer ring of tapered roller bearing (22) into the spindle (2).

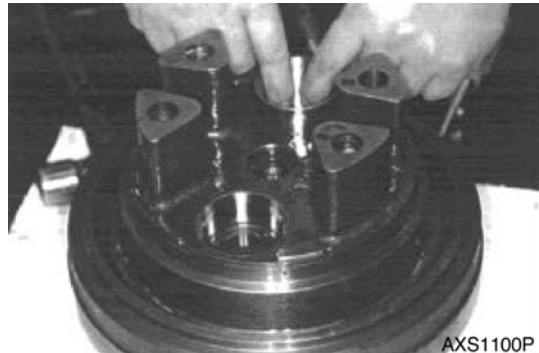


Figure 96

3. Install eyebolts to the spindle (2).
4. Lift the spindle (2) with crane, and gently it into the hub (1).

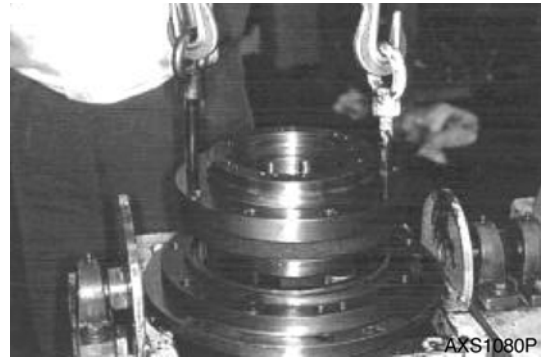


Figure 97

5. Fasten the fixture jig to the hub (1) and the spindle (2), and tighten them slowly and equally.
6. Turn the workbench upside down.



Figure 98

Mount RV Gear Assembly

1. Install RV gear (4) In the hub (1).



Figure 99

2. Install the crank shaft (9) (2 shafts) in the hub (1).

NOTE: *Match the inner race of the tapered roller bearing (22) of the crank shaft (9) with the outer race hole of the tapered roller bearing (22) fit in the spindle (2).*

3. Install RV gear (4) in the hub (1).



Figure 100

4. After applying lubricating oil to the pins (17) (24 pins) insert between the pin groove of hub (1) and gear teeth groove.



Figure 101

5. Insert the ball bearing (21) in the hub (1).

NOTE: *The fit of the ball bearing (21) outer diameter and hub (1) inner diameter is press fit. Press fit gradually and uniformly by tapping the pin punch. At this time, place the ball bearing (21) securely in the hub (1).*

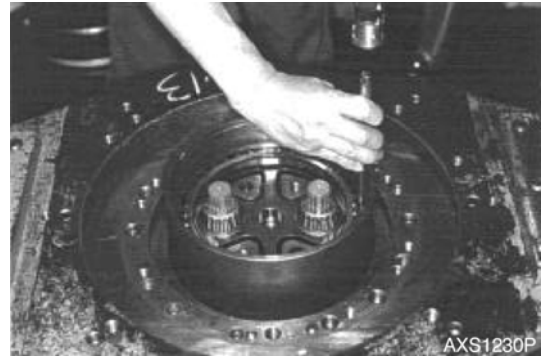


Figure 102

Hold Flange Mounting

1. Check if the hub (1), spindle kit, ball bearing (21) (2 bearings) parts have been replaced with new ones.

NOTE: *If there are no renewal parts, proceed to the next step. If there is even 1 renewal part, proceed to the next step after carrying out "Preload Adjustment of Ball Bearing" on page 1-69.*

2. Install the hold flange (3) on the spindle (2). Make sure the match mark is in the same position as when it was disassembled.

NOTE: *If it is hard to place the hold flange (3) in the inner ring or the ball bearing (21), insert into the ball bearing (21) by tapping the hold flange (3) uniformly with a plastic hammer.*



Figure 103

Tightening Reamer Bolts and Hex. Socket Bolts

1. Apply antiseize lubricant to the shank, and the adhesive to the reamer bolt (19).

NOTE: *If the reamer bolt is smeared with oil or grease, degrease it with a degreasing agent, clean it with solvent, and let it stand and get dry for ten minutes before applying adhesive to it.*

2. Fasten the reamer bolts (19) (2 bolts) with specified torque.

NOTE: *Tightening torque: $25.7 \pm 4.0 \text{ kgf}\cdot\text{m}$ ($252 \pm 39.2 \text{ Nm}$) (186 ft lb)*

NOTE: *Fasten the reamer bolts slowly and evenly to position the hold flange.*

3. Apply bonding agent to screw section of hex.socket bolts (35) (2 bolts).

NOTE: *If the hex.socket bolt is smeared with oil or grease, degrease it with a degreasing agent, clean it with solvent, and let it stand and get dry for ten minutes before applying adhesive to it.*

4. Fasten the hex.socket bolts (35) (2 bolts) with specified torque.

NOTE: *Tightening torque: $25.7 \pm 4.0 \text{ kgf}\cdot\text{m}$ ($252 \pm 39.2 \text{ Nm}$) (186 ft lb)*

NOTE: *Fasten the hex.socket bolts slowly and evenly to position the hold flange.*

5. Install the outer ring of the tapered roller bearing (22) to the hold flange (3).
6. Invert the GM motor.
7. Remove the fixtures (2 fixtures).
8. Invert the GM motor.

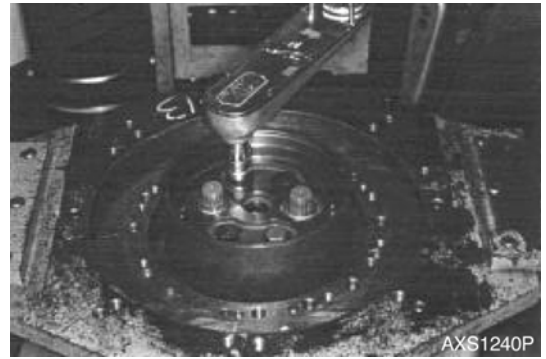


Figure 104

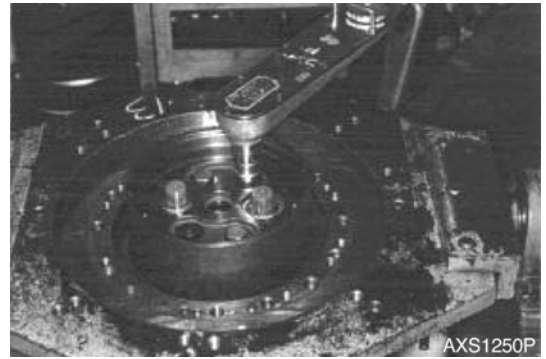


Figure 105



Figure 106

Install Retaining Rings

1. Check if any spindle (2), hold flange (3), RV gear assembly, and the spacer (12) a newly replaced parts.

NOTE: *If none of them is a newly replaced part, go to the next step. If any of them is a newly replaced part, adjust the axial clearance of tapered roller bearing (22) before doing to the next step. If only retaining rings (20) is to be replaced with a new one a retaining ring (20) that is identical with or equivalent to the replaced retaining ring must be selected from 15 available types.*

2. Install retaining rings (20) into the retaining ring grooves in the hold flange (30).

NOTE: *Install the two retaining rings in the same position as before disassembly, as indicated by the match marks on the hold flange. if new retaining ring is used, select this retaining ring having an appropriate thickness (see after item) and install it into the retaining ring grooves in the hold flange.*

3. Install two retaining rings (25) into the retaining ring grooves in the crank shaft (9).



Figure 107



Figure 108

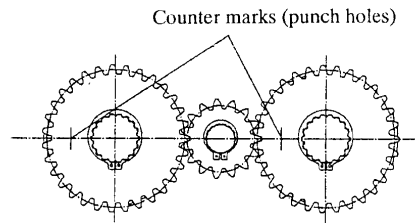
Spur Gear Assembly

1. Match the counter marks (Figure 111) of the spur gears (7) (2 gears) and mount on the crank shaft (9).

NOTE: Insert the spur gears (7) (2 gears) on the crank shaft (9) by matching the counter marks (punch holes) (Figure 111) as shown in the Figure 111.



Figure 109



AXS0460S

Figure 110

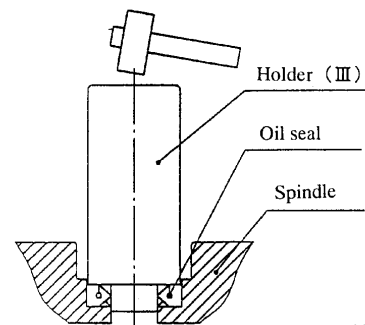
2. Install retaining rings (25) into the retaining ring grooves in the crank shafts (9).



Figure 111

Mounting Oil Seal

1. Turn the workbench upside down.
2. Apply lithium grease to the lip section of the oil seal and press fit the oil seal (132) into spindle (2) with the holder (III) and hammer.



AXS0530S

Figure 112

Shaft Assembly

1. Install ball bearing (149) by shrink fitting. To install, heat the ball bearing by keeping it immersed in heating equipment at $100^{\circ}\text{C} \pm 10^{\circ}\text{C}$ ($212^{\circ}\text{F} \pm 50^{\circ}\text{F}$) for about ten minutes.

NOTE: *Wear thick leather gloves in handling the heated ball bearing. Be sure to push the bearing all the way down until its inner race seats on the shoulder.*

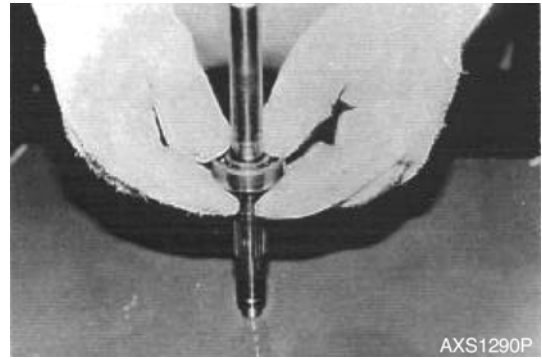


Figure 113

2. Apply lithium grease to the outer ring of the ball bearing (149).
3. Install piston assembly (161, 162) and the spring (190) into the spindle (2).

NOTE: *Before install the piston assembly, apply hydraulic oil to the piston assembly.*

4. Insert the parallel pins (177) (2 pins) into the pin holes of the spindle (2).
5. Apply lithium grease to the hemispherical surface of the pivots (167), and fit into the parallel pins (142) of the spindle (2).
6. Turn the work bench 90 degrees.
7. Fit the motor shaft (102) slowly into the spindle (2).

NOTE: *Take care not to scratch or cut the lip portion of the oil seal in place with the splined foremost end of the shaft.*



Figure 114

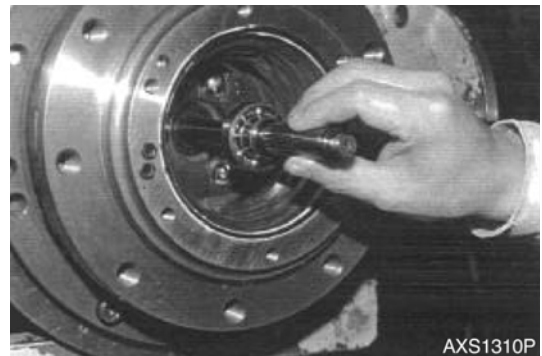


Figure 115

8. Install the swash plate (103) to the spindle (2).

NOTE: *Apply lithium grease to the swash plate on matching surface of the spindle. Make sure that the locating the pivot of the spindle enters the pivots hole of the swash plate.*

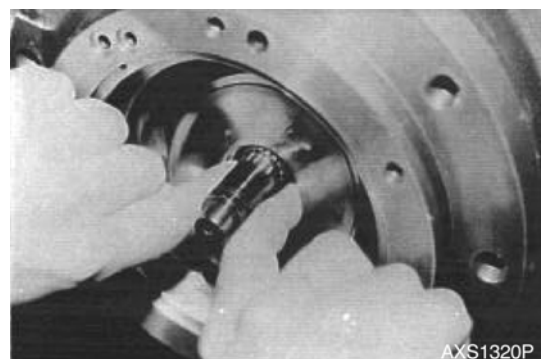


Figure 116

Assembly of Cylinder Block Interior

1. Insert washer (110), spring (114), washer (110) and retaining ring (145) in that order, into cylinder block (104).
2. Place the cylinder block (104) on the press bench.



CAUTION

When mounting the retaining ring, if the tip of the pliers slips out of the hole or the retaining ring, the retaining ring could jump out.

NOTE: *Press force of spring (114) is 60 kgf (588 N or more). Protect by covering cylinder block (104) with a vinyl sheet so the contact surface with the timing plate of cylinder block (104) does not become damaged.*

3. Place holder (I) on the washer (110), and while clamping with the press, fit the retaining ring (145) in the retaining ring groove of the cylinder block (104) with a retaining ring pliers.

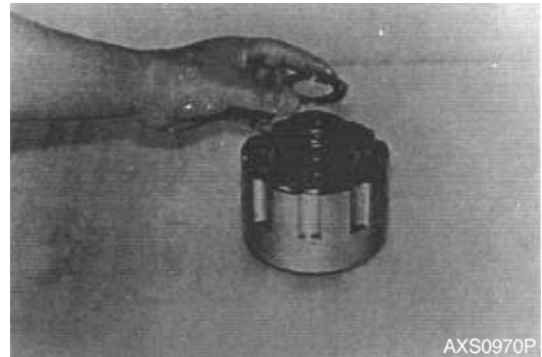


Figure 117

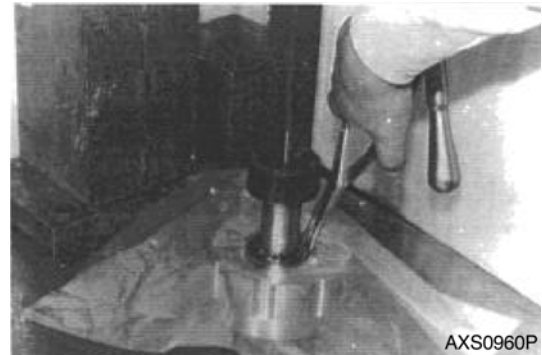


Figure 118

Assembly of Hydraulic Motor Parts

1. Place the needle rollers (151) (3 rollers) cylinder block (104) and place the thrust ball (108) on top.

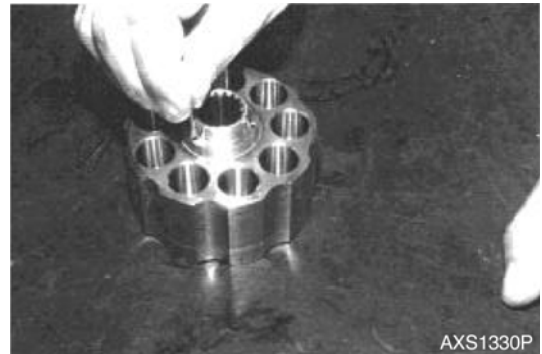


Figure 119

2. Install the nine piston assembly (105, 106) into retainer plate (107).

NOTE: *After assembling, dip the whole thing in hydraulic fluid.*

3. Fit retainer plate (107) and 9 piston assembly into cylinder block (104).

NOTE: *Match round surface sections of retainer plate and thrust ball.*

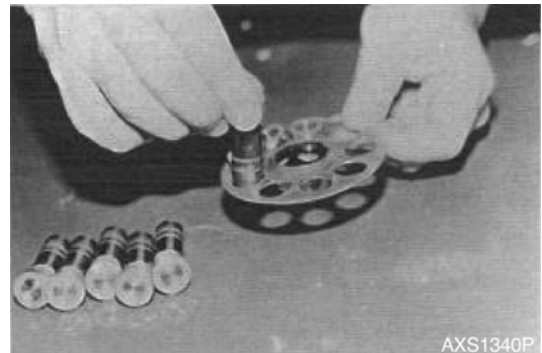


Figure 120

4. Install the cylinder block (104) to the shaft (102).
5. Turn cylinder block (104) with your hands and make sure there is no looseness.



Figure 121

Assembly of Parking Brake Section

1. Turn the workbench 90 degrees.
2. Install mating plate (269), friction plate (215) and mating plate (216) in that order in the inner circumference groove of the spindle (2) and the section in cylinder block (204).

NOTE: *Install the friction plate after applying the hydraulic fluid.*



Figure 122

3. Fit O-rings (235, 239) to piston (212). At this time, apply a thin coat of grease to the O-rings.
4. Install piston (212) in spindle (2).

NOTE: *If the piston doesn't fit into the spindle because of the resistance of the O-rings, tap the edge of the piston lightly and equally with a plastic hammer. Be careful not to damage the O-rings at this time.*



Figure 123

Assembly of Brake Valve Parts in Rear Flange

1. Fit O-rings (237) to the each plugs (226).

NOTE: *Apply grease to the O-rings (237).*

2. Install the valve (227) and the spring (230) on the plugs (226) (2 plugs). At this time, apply grease and connect the valve, spring and plug by cohesion of the grease.
3. Install the valve (227) and the spring (230) and the plug (226) in the rear flange (201) and temporarily tighten.

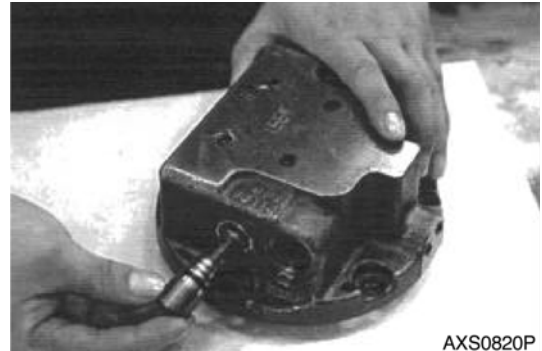


Figure 124

4. Insert the spool (223) into the rear flange (201).

NOTE: *Apply hydraulic liquid to the spool and insert the spool into the rear flange. Insert the spool straight into the bore, taking care not to damage the sliding surfaces of the spool and the bore, so that there will be no internal leakage of oil along the spool. Bear in mind that such.*

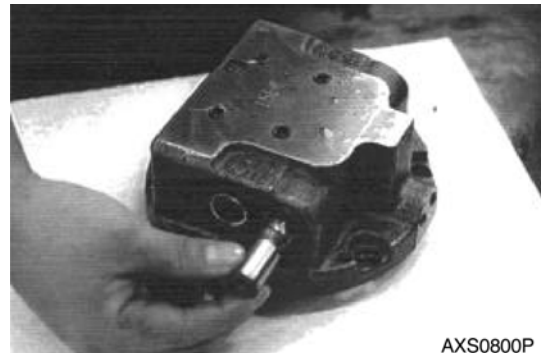


Figure 125

5. Fit the O-ring (236) to the plug (224) (2 plugs).

NOTE: *Apply grease to the O-ring (236).*

6. Install the stopper (225) and the spring (228), to the plug (224) (2 plugs).
7. Fasten the plugs (224) into the rear flange (201).

NOTE: *When fasten the plugs into the rear flange, insert carefully so as not to deform the spring.*

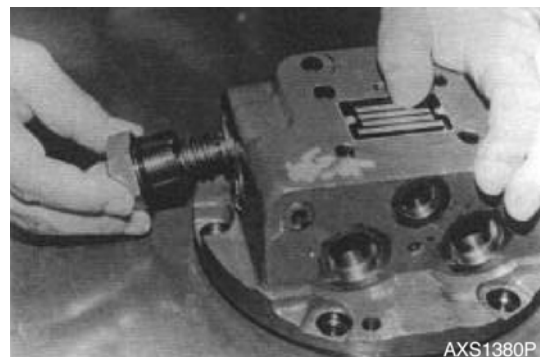


Figure 126

8. Temporarily tighten the plugs (224).

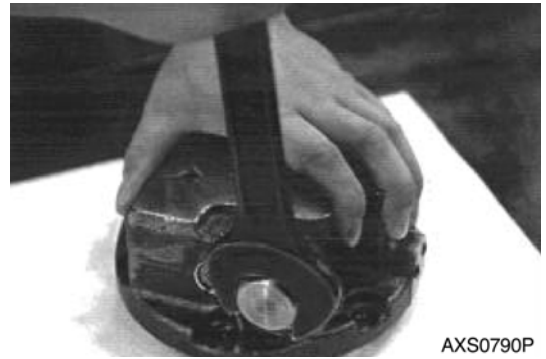


Figure 127

AXS0790P

Assembly of Rear Flange Mounted Parts

1. Put rear flange (201) on the workbench, with its inner face up.
2. Insert valve (263) into rear flange (201).



Figure 128

AXS1390P

3. Install the spring (266) into the valve (263), and insert the stopper (264) on it.

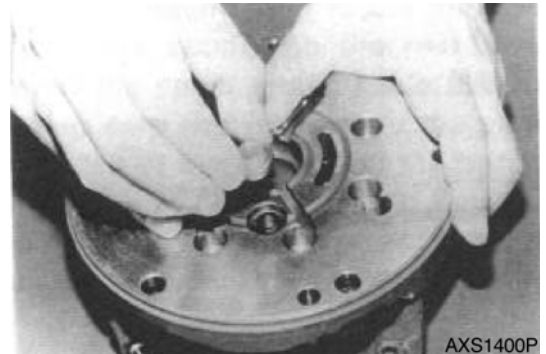


Figure 129

AXS1400P

4. Slightly bend a new ring (265) and insert it into the rear flange (201) from the top of stopper (264). Then fit the new ring (265) into the groove of the rear flange (201).

NOTE: *The ring used must be fitted snugly into the ring groove of the rear flange. Improper insertion of the ring into the ring groove may cause unstable of the valve, thus disassembling high/low speed selection. The ring must be a new one.*



Figure 130

AXS1410P

5. Apply hydraulic fluid to the ball bearing (150), and fit the ball bearing into the rear flange (201).

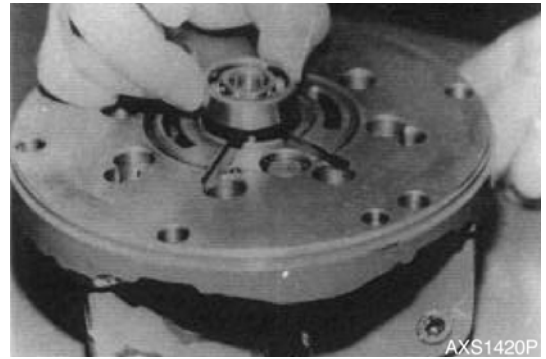


Figure 131

6. Insert the parallel pins (241) (2 pins) in the pin holes of the rear flange (201).

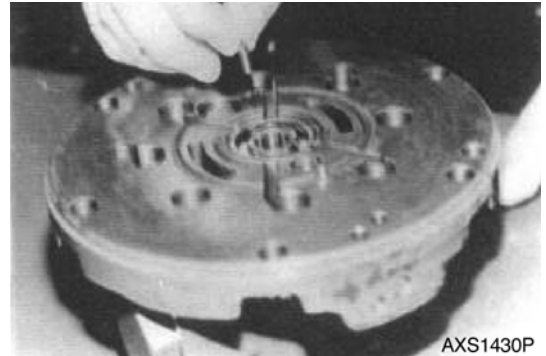


Figure 132

7. Apply grease to the mating face with the rear flange (201) of the timing plate (109).

NOTE: *Fitting of timing plate (109) is carried out until the timing plate adheres to the rear flange (201). Adhesion prevents the timing plate from falling from the rear flange when mounting the rear flange on spindle (2).*

8. Fit the timing plate (109) on the rear flange (201) using the parallel pin (241) as a guide.



Figure 133

Connection of Rear Flange with Spindle

1. Fit the O-rings (30, 27) in the O-ring groove of the spindle (2).

NOTE: *Fit the O-ring (30, 27) without applying grease. If assembled with grease applied, the grease may bleed from the mating face of the rear flange and the spindle when the travel motor is running. This may be mistaken as an oil leak, so do not apply grease.*



Figure 134

2. Insert the parallel pins (142) (2 pins) into the spindle (2).
3. Put 0.3 liters of hydraulic fluid in the spindle (2).



Figure 135

4. Install the rear flange (201) onto the spindle (2) so that two parallel pins (142) on the spindle enter the pinholes in the rear flange (201).



Figure 136

5. Tighten hex. socket bolts (243) (6 bolts) equally and evenly with specified torque.

NOTE: *Tightening torque: $3.0 \pm 0.5 \text{ kgf}\cdot\text{m}$ ($29.4 \pm 4.9 \text{ Nm}$) ($22 \pm 4 \text{ ft lb}$)*



Figure 137

6. Tighten plugs (224) with specified torque.

NOTE: *Tightening torque: $20 \pm 1.5 \text{ kgf}\cdot\text{m}$ ($196 \pm 14.7 \text{ Nm}$) ($145 \pm 11 \text{ ft lb}$)*



Figure 138

7. Tighten plugs (226) with specified torque.

NOTE: *Tightening torque: $8 \pm 1 \text{ kgf}\cdot\text{m}$ ($78.5 \pm 9.8 \text{ Nm}$) ($8.0 \text{ kg}\cdot\text{m}$) ($58 \pm 7 \text{ ft lb}$)*



Figure 139

Input Gear Assembly

1. Turn the workbench upside down.
2. Install the input gear (6) to the shaft (102).

NOTE: *The teeth of the input gear should mesh smoothly with the two spur gears.*



Figure 140

3. Fit the retaining ring (24) to the shaft (102).

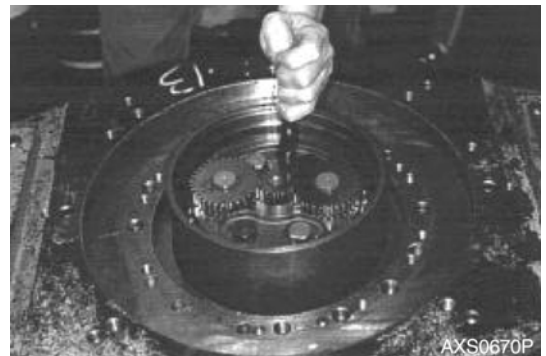


Figure 141

Cover Assembly

1. Fill the reduction gear with the specified quantity of lubrication oil.

NOTE: *Lubricating oil: 1 liter (0.26 U.S. gal.)*

2. Fit the O-ring (29) to the cover (8).

NOTE: *Apply grease to the O-ring (29).*

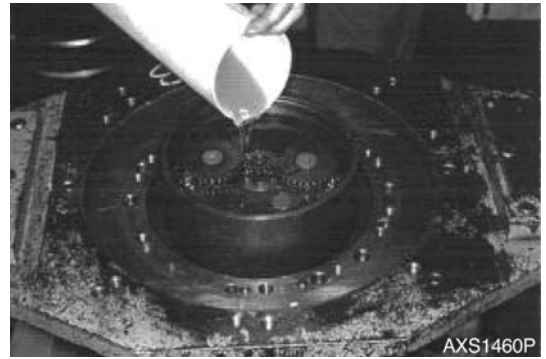


Figure 142

3. Place the cover (8) on the hub (1), make sure the match mark is in the same position as it was disassembled. After positioning the cover, force it into the hub by lightly hammering with a plastic hammer on and around its rim.



Figure 143

4. Install the ring (18) into the hub (1).



Figure 144

5. Fit the O-ring (36) to the plugs (33). Tighten plugs (33) with the specified torque to the cover (8).

NOTE: *Tightening torque: $6 \pm 1 \text{ kgf}\cdot\text{m}$ ($58.8 \pm 9.8 \text{ Nm}$) ($43 \pm 7 \text{ ft lb}$)*



Figure 145

Remove Assembled GM Motor from Workbench

1. Turn the workbench upside down.
2. Remove the hex.socket bolts (2 bolts) securing the GM motor to the workbench.



Figure 146

3. Fasten the eyebolts (2 bolts) to the spindle (2).

NOTE: *Be sure that the two eyebolts are opposite to each other.*

4. Hook the hook and wire on the eyebolts and remove the GM motor from the work bench with a crane.



Figure 147

Preload Adjustment of Ball Bearing

NOTE: *In order to ensure the proper life for the ball bearing (21), it is necessary to provide a certain preload. Therefore, if replacing a part that influences the amount of preload, temporarily assemble in accordance with the following procedure, and check the amount of preload. If You assemble without checking, it could cause the GM motor to operate poorly or break down prematurely.*

- Parts which influence amount of preload of the ball bearing: Hub (1), spindle kit, ball bearing (21).
- If not replacing the parts listed above, skip this process and proceed to process No. 3 of "Mount RV Gear Assembly" on page 1-54.
- Preload check and preload adjustment instructions are as follows.

1. Ball bearing (21) preload adjustment procedure.

- A. Mount the main bearing preload adjustment jig on the spindle (2), tighten the special nut, and apply preload to the ball bearing (21). Special nut tightening torque: 5 kgf•m (49 Nm) (36 ft lb)

NOTE: *The hold flange and spindle have been machined as a pair and are therefore configured as an assembly. The hold flange alone therefore cannot be replaced. At this time, the spindle must be replaced together with it. This assembly is referred to as the "spindle assembly". If replacing by spindle assembly, perform disassembly and assembly again.*

2. Remove the main bearing preload adjustment jig from the spindle (2).
3. After completing hold flange adjustment by the adjustments of items I, II and III, proceed to the process No. 3 of "Mount RV Gear Assembly" on page 1-54.



Figure 148

Adjusting Axial Clearance on Tapered Roller Bearing

NOTE: *If the following parts have been replaced, readjust the axial clearance on tapered roller bearing (22) selecting retaining rings (20) having a suitable thickness: Hub (1), Spindle (2), Hold flange (3), RV gear assembly, and snap rings (20). If you assemble without checking, it could cause the can motor to operate poorly or break down prematurely.*

- If not replacing the parts listed above, retaining ring adjustment is unnecessary, and main assembly is carried out from "Install Retaining Rings" on page 1-57 as is.
 - Shaft direction clearance adjustment method of the tapered roller bearing is as follows.
1. Apply holder (IV) to the outer ring of the tapered roller bearing (22) on the crank shaft (9), and lightly hammer the holder.

NOTE: *Hammering makes insertion of the RV gear assembly into spindle (2) easier.*

2. Fit the least thick the retaining rings (20) in the retaining ring grooves in the spindle (2).



Figure 149



Figure 150

3. Lightly hammer the retaining ring (20) with a hammer and holder (IV).

NOTE: *Check whether the retaining ring has been reliably fitted in the spindle.*



Figure 151

4. Measure the clearance between retaining ring (20) and the outer ring of roller bearing (22) with a thickness gauge.
5. Determine whether the thickness of the retaining ring is suitable.

Max = Thickness of thickness gauge + Thickness of currently mounted ring

Min. = Thickness of thickness gauge + Thickness of currently mounted ring - 0.05 mm (0.002 in)



Figure 152

6. After deciding thickness of the retaining ring, select another retaining ring from 12 available types fit it into the hold flange.
7. After fitting the retaining ring of the set thickness, "Install Retaining Rings" on page 1-57.



Figure 153

PERFORMANCE CONFIRMATION TEST

- After servicing the GM motor, perform the following performance tests by the following procedure.

Required Measuring Devices

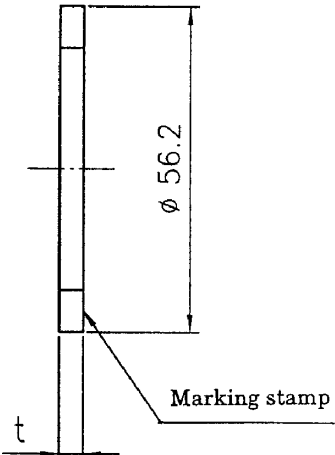
Pressure gauge for 35 kgf/cm ² (3.43 MPa) (498 psi)	2 pieces
Graduated cylinder (for 5 liter)	1 pieces
Stopwatch	1 pieces

Test Procedure

GM motor mounting/piping	Mount the GM motor to body (frame section) and connect pipping. The track shoe must not be attached here at this time. (This is because for conducting the performance test (no-load operation) of the GM motor.) NOTE: <i>When connecting piping, connect so that the pressure gauge (main circuit) can be mounted and drain volume of the hydraulic motor can be measured.</i> NOTE: <i>When mounting the GM motor, do not strike with a hammer, etc., but rather mount gently using the bolt holes.</i>				
Break-in operation of the GM motor	Speed ranges	GM motor rpm	Pressure	Rotation direction	Running time
	Low speed	10 rpm	No-load	Left / Right	Min. 1 minute each
	High speed	20 rpm			
GM motor performance confirmation test Good -> Attach the track shoe Not Good -> Disassemble and adjust again	1. Pretest preparatory operation. Perform preparatory operation until approximately thee following temperatures. • Hydraulic fluid temperature: 45 - 55°C (113 - 131°F) • Speed reducer hub external temperature: 40 - 80°C 40°C (104 - 176°F) 2. Confirmation test: Measure the following pressure items to decide with the motor passes or fails the test. <u>Passing criteria</u> • GM motor device pressure: Max. 16 kgf/cm ² (1.56 MPa) (226 psi) @10 rpm • Hydraulic motor drain volume: Max. 0.5 liter/min. (0.13 U.S. gal.) @10 rpm				

CLEARANCE ADJUSTMENT

PART DIMENSIONS

Part Name	Dimensions	
Retaining ring (20)  AXS0540S NOTE: 56.2 mm (2.21 in)	Classification symbol	Dimension (T)
	A	1.75 mm < T ≤ 1.80 mm (0.07 in < T ≤ 0.0709 in)
	B	1.80 mm < T ≤ 1.85 mm (0.0709 in < T ≤ 0.0728 in)
	C	1.85 mm < T ≤ 1.90 mm (0.0728 in < T ≤ 0.0748 in)
	D	1.90 mm < T ≤ 1.95 mm (0.0748 in < T ≤ 0.0768 in)
	E	1.95 mm < T ≤ 2.00 mm (0.0768 in < T ≤ 0.0787 in)
	F	2.00 mm < T ≤ 2.05 mm (0.0787 in < T ≤ 0.0807 in)
	G	2.05 mm < T ≤ 2.10 mm (0.0807 in < T ≤ 0.0827 in)
	H	2.10 mm < T ≤ 2.15 mm (0.0827 in < T ≤ 0.0846 in)
	I	2.15 mm < T ≤ 2.20 mm (0.0846 in < T ≤ 0.0866 in)
	J	2.20 mm < T ≤ 2.25 mm (0.0866 in < T ≤ 0.0886 in)
	K	2.25 mm < T ≤ 2.30 mm (0.0886 in < T ≤ 0.0906 in)
	L	2.30 mm < T ≤ 2.35 mm (0.0906 in < T ≤ 0.0925 in)
	M	2.35 mm < T ≤ 2.40 mm (0.0925 in < T ≤ 0.0945 in)
	N	2.40 mm < T ≤ 2.45 mm (0.0945 in < T ≤ 0.0965 in)
	O	2.45 mm < T ≤ 2.50 mm (0.0965 in < T ≤ 0.0984 in)

Main Control Valve

Edition 1

MEMO

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SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

COMPOSITION, FUNCTION AND OPERATION

The control valve is located between pump, cylinder and motor on the oil pressure circuit. Each component within the main control valve operates and controls oil flowing from the main pump. Such control changes operation direction and speed of both cylinder and motor.

Control Valve Consists of Following Sections:

1. Arm2 Section (Figure 28)
2. Bucket Section (Figure 29)
3. Boom1 Section (Figure 30)
4. Run to Right Section(Figure 31)
5. Inlet Section (Figure 32)
6. Run to Left Section(Figure 33)
7. Arm1 Section (Figure 34)
8. Boom2/Aux Section (Figure 35)
9. Dozer Section (Figure 36)
10. Boom Swing Section (Figure 37)
11. Swing Section (Figure 38)
12. Straight Travel Section (Figure 39)

Function of Control Valve

1. Control for neutral
Oil discharges from the return port through the center bypass passage within the main control valve.
2. Operation of control valve
Such control changes flow direction of oil in order to change operation, stop or to change, operation direction of both cylinder and motor. Pump oil is supplied to each section from the enter bypass passage and the parallel passage. Oil returned from each control valve is discharged from the return port through return passage.
3. Drop prevention of operation of cylinder and motor using load check valve
4. Restriction of circuit pressure by relief valve
5. Straight run function
Running moves forward even though operating each working machine of boom, arm, bucket and preliminary during running.
6. Arm reproduction function
Supplies some of returning oil to the cylinder bottom part in Crowd (speedup of cylinder).

7. Arm 2 function
If operating the arm cylinder, working oil from the P1 pump side (No.1 section) and the P2 pump side (No.6 section) are mixed by the outside pipe.
8. Boom2 function
When performing Lift Up operation on the Boom, working oil in the Boom2 section of the P2 pump group is mixed with Boom1 section through the inside passage of the control valve.
9. Anti-drift valve
An anti-drift plate is installed to reduce natural drop volume in the bottom part of Boom cylinder.
10. Boom right rotation circuit
Poppet with the throttle valve adhered is installed in the parallel passage so that Boom operates in simultaneous operation of Lift Up on boom + Bucket Crowd.
Same as for simultaneous operation of Boom + Arm2.

Operation of Main Section

Arm2

1. For neutral (Figure 11)
Working oil discharging from the pump is returned to the tank through neutral passage. Working oil of both A1 and B1 cylinder port is closed.
2. Crowd operation (Figure 12)
If converting the spool by pressurizing the Pa1 port, flow of the neutral passage is closed and working oil in the neutral passage pushes up the load check valve at both places and flow through "A1".
Working oil of the cylinder port "B" returns to the tank from the Arm1 section.
3. Crowd operation in simultaneous operation with boom (Figure 13)
Working oil pushes up the load check valve (parallel) with throttle valve and flows through the cylinder port "A".
4. Dump operation (Figure 14)
Like Crowd operation, return working oil returns to the tank from the cylinder port "A".

Boom1

1. For neutral (Figure 15)
An anti-drift plate is installed to reduce natural drop volume in the bottom part of cylinder.
2. Move up operation (Figure 16)
Working oil pushes up the poppet of the anti-drift plate as well as load check valve and flows through the cylinder port "B3". Return working oil returns to the tank from the cylinder port "A".

3. Lower down operation (Figure 17)
"Pa3" and "Pi1" port are connected and Lower Down pilot pressure applies to the "Pi1" port.
Operation of the anti-drift plate enables to connect the spring room side of the poppet to the "DR1" port and make poppet opening status, and returning passage is obtained.

Right Run

Method of flowing working oil for Neutral (Figure 18) and Operation (Figure 19) is as for Arm2.

Boom2/Aux

For Neutral (Figure 20) and Operation (Figure 21), working oil is supplied to Boom1 through inside passage of the control valve (Lift Up Mix).

Arm1

For Neutral (Figure 22), Crowd Operation (Figure 23) and Dump Operation (Figure 24), some of working oil returned from the cylinder port "B6" returns to the tank and the other oil pushes up poppet for recovery and supplies oil to "A6" (recovery circuit).

Straight Travel (Figure 25)

For Neutral (Figure 25), Operation (Figure 26), simultaneous operation of Running and Boom (or Bucket, Arm, Preliminary) enables to operate the Straight Travel.

Working oil of the P1 pump is supplied to Right Run, P2 pump to Left Run, and P3 pump to the Boom.

DISASSEMBLY

Following care should be taken in disassembly:

Make pressure of the actuator not fulfilled and stop engine. If disassembling with pressure fulfilled, it is dangerous as H/P oil may be discharged or parts may be taken out.

1. Take out air pressure within the tank. If there is pressure within a tank, it is dangerous as oil may be discharged in disassembly.
2. Properly clean around the part disassemble so that foreign material should not enter in the valve.
3. Keep disassembled parts with tags so that position of reassembly can be known.
4. Disassembles seal types (O-ring, backup ring, wiper) should be replaced with new parts.

Disassembly of Accessory

Take off relief valve assembly, Combination No. (15), (16), (17) of Figure 27.

Disassembly of Arm2, Bucket, Right Run, Left Run, Arm1, Dozer, Swing, Boom Swing Section

Take off the cap of Combination No. (3) of Figure 28, Figure 29, Figure 31, Figure 32, Figure 33, Figure 36, Figure 37, Figure 38 by loosening a (13) socket head bolt (hexagonal hole subtense 5mm). Remove (4) spring seat, (6) spring (5) spring seat and (12) O-ring. Then take out the (2) spool from the (1) valve housing. In this manner, also take out the opposite (8) cap. And Combination No. of the running socket head bolt becomes (10), while O-ring becomes (9).



CAUTION

When taking out the spool, straightly take out it so that stroke trace, scratched flaw, etc should not occur. If they occur, there is concern that flaw may occur in the body hole and that spool may enter in assembly. Entering of spool may result in poor operation. Tags, etc should be adhered for identification so that wrong identification of the actuator should not occur.

Disassembly of Boom1 Section (Figure 30)

Take off the cap of Combination No. (3) of Figure 30 by loosening a (13) socket head bolt (hexagonal hole subtense 5mm). Remove (4) spring seat, (6) spring (5) spring seat and (13) O-ring. Then take out the anti-drift valve Assy by loosening a (20) socket head bolt (hexagonal hole subtense 5mm). And take (4) spring seat, (6) spring (5) spring seat and (13) O-ring.

And to take off the (15) poppet, take out the (17) spacer with M4X0.7 screw. After taking out the (17) spacer, take off the (15) poppet, (16) spring.

Disassembly of Inlet Section (Figure 32)

Take off the cap (5) of Combination No. (3) of Figure 32 by loosening a (13) socket head bolt (hexagonal hole subtense 5mm). Remove (4) O-ring. Then take out the (2) spool from the (1) valve housing. In this manner, also take out the opposite (3) cap.

Disassembly of Boom2/Aux Section (Figure 35)

Take out the cap of Combination No. (3) of Figure 35 (3) by loosening a (13) socket head bolt (hexagonal subtense 5mm). Remove (4) spring seat, (6) spring, (5) spring seat and (12) O-ring. Then take out the (2) spool from the (1) valve housing. In this manner, take out the opposite (16) cap by loosening a (13) socket head bolt (hexagonal subtense 5mm). Remove (12) O-ring.

Disassembly of Straight Travel Section (Figure 39)

Take off the cap of Combination No. (3) of Figure 39 (3) by loosening a (13) socket head bolt (hexagonal hole subtense 5mm). Remove (4) spring seat, (6) spring and (5) O-ring. Then take out the (2) spool from the (1) valve housing. In this manner, also take out the opposite (8) cap.



CAUTION

Do not disassemble the (14) filter as it is firmly fixed. If disassembling or reassembling it, there is concern to result in poor operation of each working part that the filter may drop or damage and its scraps moves through the oil path.

Take Off of Load Check Poppet Type

By removing a tie-rod, take off load check and plug type before disassembling the valve housing. Types of poppet or plug are as follow:

Arm2 (Figure 28)	: (10) Plug×2, (9) spring×2, (7) poppet, (8) poppet
Bucket (Figure 29)	: (10) Plug×2, (9) spring×2, (7) poppet, (8) poppet
Boom1 (Figure 30)	: (21) Plug assembly×2, (10) Plug×2, (9) spring×2, (8) poppet×2
Right Run (Figure 31)	: (7) Plug
Inlet (Figure 32)	: (7) Plug assembly
Left Run (Figure 33)	: (7) Plug
Arm1 (Figure 34)	: (10) Plug, (9) spring, (7) poppet, (18) Plug, (16) spring, (15) poppet
Boom2/Aux (Figure 35)	: (15) Plug assembly×2, (10) Plug, (9) spring, (7) poppet
Dozer (Figure 36)	: (10) Plug, (9) spring, (7) poppet
Boom Swing (Figure 37)	: (10) Plug, (9) spring, (7) poppet
Swing (Figure 38)	: (10) Plug, (9) spring, (7) poppet
Straight Travel (Figure 39)	: (11) Plug

Disassembly of Valve Housing

Take off the (2) tie-rod by loosening a nut (hexagonal subtese8mm), Combination No. (1) of Figure 27. Orderly disassemble the valve housing of each section.

Disassemble parts on the matching surface of each section.

Arm2 (Figure 28)	: No parts
Bucket (Figure 29)	: (14) O-ring
Boom1 (Figure 30)	: (12) O-ring
Right Run (Figure 31)	: (12) poppet, (13) spring, (11) O-ring
Inlet (Figure 32)	: (6) O-ring×2
Left Run (Figure 33)	: (12) poppet, (13) spring, (11) O-ring
Arm1 (Figure 34)	: (14) O-ring, (19) O-ring, (21) O-ring
Boom2/Aux (Figure 35)	: (14) O-ring
Dozer (Figure 36)	: (14) O-ring
Boom Swing (Figure 37)	: (14) O-ring
Swing (Figure 38)	: (14) O-ring
Straight Travel (Figure 39)	: (15) O-ring

Identify each part disassembled by section so that position to squeeze and insert can be known for reassembly.

CLEANING

Completely clean all parts disassembled with a mineral oil. Place each part on a clean paper or cloth for drying and inspecting with compressed air.

INSPECTION

Inspect for any protruded part, scratched flaw, dented flaw and other defects on the whole surface.

1. Check that the actual groove surface of the valve housing is smooth and that there are scraps, dented point and rust, etc.
2. If there is dented point or defect on the check sheet surface of the valve housing, get away it by wrapping. Be cautious so that wrapping agents not remain within the valve.
3. All the interface and relief parts must lightly move. There should no dirt on all the grooves or passages.
4. When spring is damaged or deformed, replace it.
5. When operation of the relief valve is not good, replace assembly.
6. Replace all seals, wipers and O-rings.

ASSEMBLY

Be cautious of followings when handling O-rings (or seals) for assembly:

1. There should not be defect in forming or groove occurred when handling O-ring.
2. Sufficiently apply grease or working oil, etc to the system part of O-ring and O-ring.
3. The O-ring should not be stretched so that warping does not occur.
4. Be careful not to roll the O-ring while squeezing it for insertion. A twisted O-ring can cause an oil leak as it is difficult to return to the original shape after system mounting.

Assembly of Valve Housing

Insert below poppet, spring into the housing:

Right Run : (12) poppet, (13) spring
(Figure 31)
Left Run : (12) poppet, (13) spring
(Figure 33)

Mount O-ring in the matching surface as below on each section:

Arm2 : No O-ring
(Figure 28)
Bucket : (14) O-ring
(Figure 29)
Boom1 : (12) O-ring
(Figure 30)
Right Run : (11) O-ring
(Figure 31)
Inlet : (6) O-ring×2
(Figure 32)
Left Run : (11) O-ring
(Figure 33)
Arm1 : (14) O-ring, (19) O-ring, (21) O-ring
(Figure 34)
Boom2/Aux : (14) O-ring
(Figure 35)
Dozer : (14) O-ring
(Figure 36)
Boom Swing : (14) O-ring
(Figure 37)
Swing : (14) O-ring
(Figure 38)
Straight Travel : (15) O-ring
(Figure 39)

Then, orderly adhere Inlet housing and valve housing of each section to the tie-rod of Figure 27 Combination No. (1). And firmly tightening (2) nut (hexagonal subtense 8mm) to (1) tie-rod.
Tightening torque: 26.5 ~ 29.4 N•m

Assembly of Arm2, Bucket, Right Run, Left Run, Arm1, Dozer, Swing, Boom2/Aux, Boom Swing

Insert (6) spring between Combination No. (4), (5) spring seat of Figure 28, Figure 29, Figure 30, Figure 33, Figure 35, Figure 36, Figure 37, Figure 38, and insert the spool into the (1) valve housing with same position and direction as before-disassembly, and then mount the (3) cap with the O-ring mounted with a (13) socket head bolt (hexagonal hole subtense 5mm). In this manner, also mount the cap in the opposite side. Tightening torque: 8.8 ~ 10.8 N•m

Assembly of Boom1 Section (Figure 30)

Insert (6) spring between Combination No. (5), (4) spring seat of Figure 30, and insert the spool into (1) valve housing with same position and direction as before-disassembly, and then mount (3) cap with (13) O-ring mounted with a (14) socket head bolt (hexagonal hole subtense 5mm). For the anti-drift side, insert the (15) poppet, (16) spring and then insert the spacer mounting the (18) O-ring, (19) Back-up ring (be cautious of the mounting position of O-ring and backup). Then insert the (6) spring between Combination No. (5), (4) spring seat and insert the spool into the (1) valve housing with same position and direction as before-disassembly, and then mount the (7) anti-drift valve assembly equipped with the (13) O-ring with a (20) socket head bolt (hexagonal hole subtense 5mm). Tightening torque: 8.8 ~ 10.8 N•m

Assembly of Inlet Section (Figure 32)

Insert the (2) spool (right & left symmetry) of Figure 32 into (1) valve housing and mount the (3) cap equipped with the (4) O-ring with a (5) socket head bolt (hexagonal hole subtense 5mm). Also mount in this manner in the opposite cap. Tightening torque: 8.8 ~ 10.8 N•m

Assembly of Boom2/Aux Section (Figure 35)

Insert (6) spring between Combination No. (4), (5) spring seat of Figure 35, and insert the spool into (1) valve housing with same position and direction as before-disassembly, and then mount (3) cap equipped with (12) O-ring mounted with a (13) socket head bolt (hexagonal hole subtense 5mm). Then mount the (16) cap equipped with the (12) O-ring with a (20) socket head bolt (hexagonal hole subtense 5mm). Tightening torque: 8.8 ~ 10.8 N•m

Assembly of Straight Travel (Figure 39)

Insert (6) spring between Combination No. (4), (5) spring seat of Figure 39, and insert the (2) spool into (1) valve housing with same position and direction as before-disassembly, and then mount (3) cap equipped with (17) O-ring mounted with a (13) socket head bolt (hexagonal hole subtense 5mm). Tightening torque: 8.8 ~ 10.8 N•m

Then mount the (8) cap with the (14) filter-A inserted with a (20) socket head bolt (hexagonal hole subtense 5mm) as below.

Inserting of Load Check

Insert following load check, spring, plug (equipped with O-ring).

Arm2 (Figure 28)	: (10) Plug×2, (9) spring×2, (7) poppet, (8) poppet Plug Tightening torque: 30.4~32.4N•m (hexagonal subtense 14mm)
Bucket (Figure 29)	: (10) Plug×2, (9) spring×2, (7) poppet, (8) poppet Plug Tightening torque: 30.4~32.4N•m (hexagonal subtense 14mm)
Boom1 (Figure 30)	: (21) Plug assembly×2 Plug Tightening torque: 49~53N•m (hexagonal hole subtense 8mm) (10) Plug×2, (9) spring×2, (8) poppet×2 Plug Tightening torque: 30.4~32.4N•m (hexagonal subtense 14mm)
Right Run (Figure 31)	: (7) Plug Plug Tightening torque : 30.4~32.4N•m (hexagonal hole subtense 6mm)
Inlet (Figure 32)	: (7) Plug assembly Plug Tightening torque : 14~16 N•m (hexagonal hole subtense 5mm)
Left Run (Figure 33)	: (7) Plug assembly Plug Tightening torque : 30.4~32.4N•m (hexagonal hole subtense 6mm)
Arm1 (Figure 34)	: (10) Plug, (9) spring, (7) poppet Plug Tightening torque: 30.4~32.4N•m (hexagonal subtense 14mm) (18) Plug, (16) spring, (15) poppet Plug Tightening torque: 28.4~30.4N•m (hexagonal hole subtense 6mm)
Boom2/Aux (Figure 35)	: (15) Plug assembly Plug Tightening torque : 37.2~41.2N•m (hexagonal hole subtense 8mm) (10) Plug, (9) spring, (7) poppet Plug Tightening torque : 30.4~32.4N•m (hexagonal subtense 14mm)
Dozer (Figure 36)	: (10) Plug, (9) spring, (7) poppet Plug Tightening torque: 30.4~32.4N•m (hexagonal subtense 14mm)
Boom Swing (Figure 37)	(10) Plug, (9) spring, (7) poppet Plug Tightening torque: 30.4~32.4N•m (hexagonal subtense 14mm)
Swing (Figure 38)	: (10) Plug, (9) spring, (7) poppet Plug Tightening torque: 30.4~32.4N•m (hexagonal subtense 14mm)
Straight Travel (Figure 39)	: (11) Plug Plug Tightening torque: 30.4~32.4N•m(hexagonal hole subtense 6mm)

Accessory Adherence

Adhere (15), (16), (17) Relief valve assembly according to Combination No. of Figure 27.

Tightening torque: 69 ~ 78 N•m



CAUTION

Slowly insert the spool straightly to the hole. Poor operation of the spool may occur if inserting the spool when there is non-smooth or irregular feeling by operating the spool manually after inserting the spool.



CAUTION

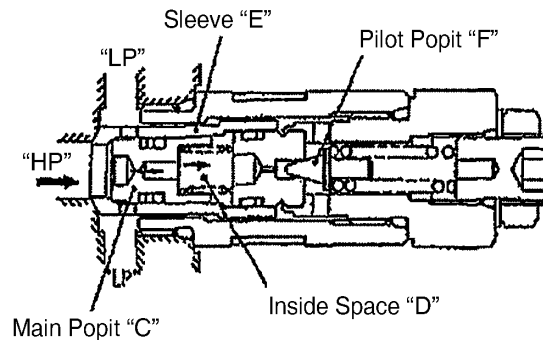
Recheck that there are possibly not-assembled or not-tightened parts disassembled after completing assembly. If not firmly tightening, oil may leak due to loose parts. Tightening torque as instructed in this manual shows value of wet status (adherence status of working oil).

RELIEF VALVE

Main Relief Valve (P1, P2, P3)

Operation

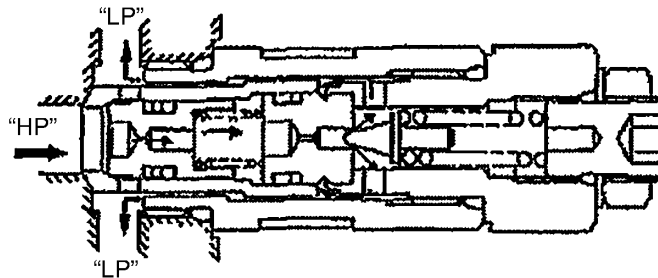
The main relief valve is laid between neutral passage "HP" and low pressure passage "LP" and operates as follow:



FG011263

Figure 1

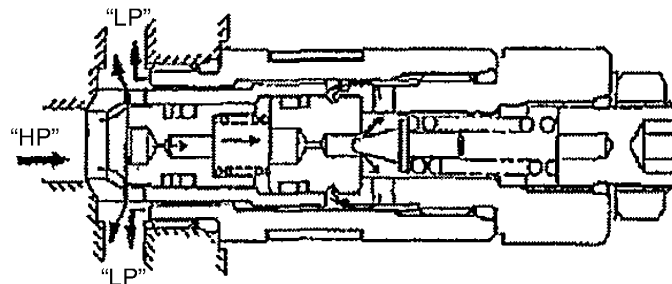
1. Oil fills the inside space "D" room through the throttle hole of the main poppet "C" and the main poppet "C" and sleeve "E" are firmly seated due to difference of the area.



FG010410

Figure 2

2. If pressure of the "HP" reaching to force of the pilot spring to be set, the Pilot poppet (F) is open. Oil flows around poppet and is delivered to the low pressure passage "LP" through a hole.

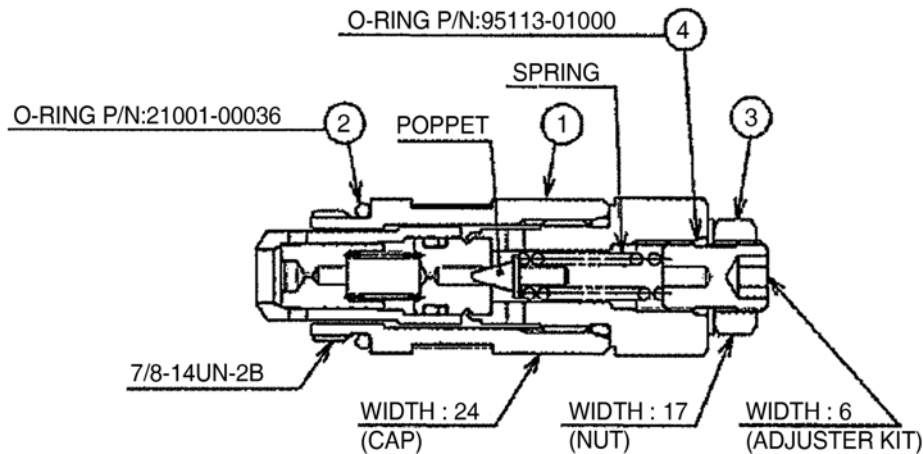


FG011264

Figure 3

3. The Pilot poppet "F" opens and so oil flows from "HP" to "D" room through the throttle hole of the main poppet "C". By this, pressure difference generates between "HP" and "D" room, and so the main poppet "C" opens and oil of the "HP" directly flows into "LP".

Hint for Disassembly and Assembly of Main Relief Valve



FG011265

Figure 4

1. Disassembly

For the original product, replace assembly.

When replacing, loosen the cap (1: hexagonal sub-tense 24) with a spanner, etc and take off the O-ring (2, Figure 4).

If oil leaks from the adjuster part (3, Figure 4), loosen the adjuster part and replace the O-ring (4, Figure 4).



CAUTION

In disassembling disassembly the adjuster kits, be cautious so that poppet may not be lost by which parts are popped up by spring.

2. Assembly

Properly check that there are no scraps, primer pieces, etc around cap (1, Figure 4) screw part. and insert a new O-ring (2, Figure 4).

After properly cleaning the relief mounting part of the valve housing, mount the relief valve and then tighten cam (1, Figure 4) <1: hexagon sub-tense 24> to tightening torque of 69~78N•m. If disassembling the adjuster kits, properly clean around the screw part and adjust pressure according to "Hint for Disassembly and Assembly of Overload Relief Valve" on page 1-21).



CAUTION

All tightening torques as directed above are wet status (working oil adherence status).

Overload Relief Valve

Overload Relief Valve

1. This relief valve is inserted between the cylinder port "HP" and the low pressure passage "LP". Oil fulfills the inside space (G) through a hole of the piston (C). the sleeve (K) and the main port (D) are firmly seated by which it applies to other area of (A), (B).

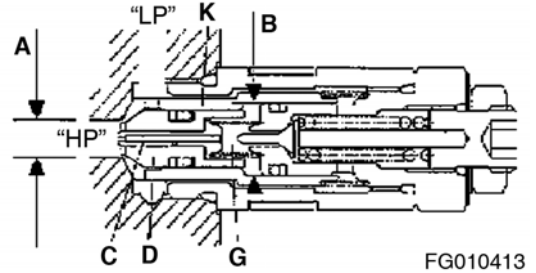
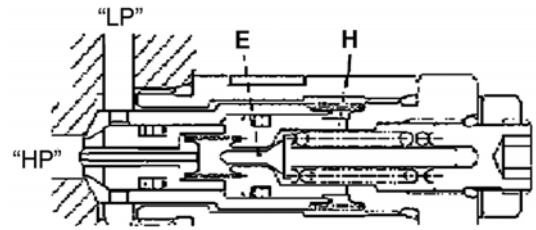


Figure 5

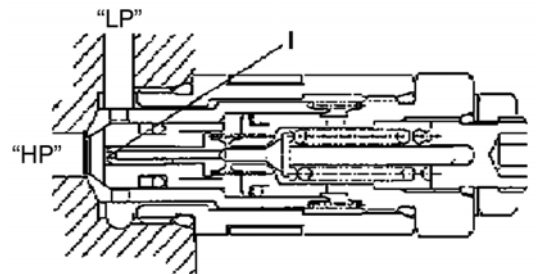
2. If pressure of the "HP", a cylinder port reaches to force of the pilot spring to be set, the Pilot poppet (E) is open. Oil flows around poppet and is delivered to the low pressure passage "LP" through a hole (H).



FG010414

Figure 6

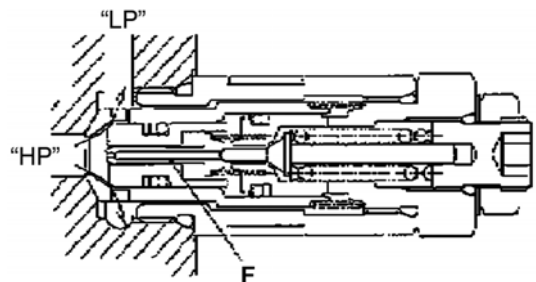
3. If the poppet (E) opens, oil flows through the throttle hole (I) of the piston (c) and so pressure difference generates at the rear of the passage, "HP" and the piston (c). The poppet (E) is seated due to movement of the piston (c).



FG010415

Figure 7

4. Oil flows from the passage "HP" to the rear side of the poppet (D) only between circular pole of both poppet (D) and piston (C) only by tightening (F) and so pressure difference becomes large. Accordingly poppet(D) opens and so oil flows to the direct passage "LP".



FG010416

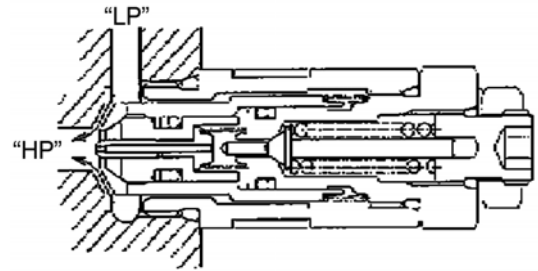
Figure 8

Suction Operation

The anti-void unit is equipped with In the cylinder port "HP", which supplies oil when cavitation occurs.

When pressure of the cylinder port "HP" is lower than "LP" in the low pressure side, the sleeve (K) opens by difference in the area between <A> and .

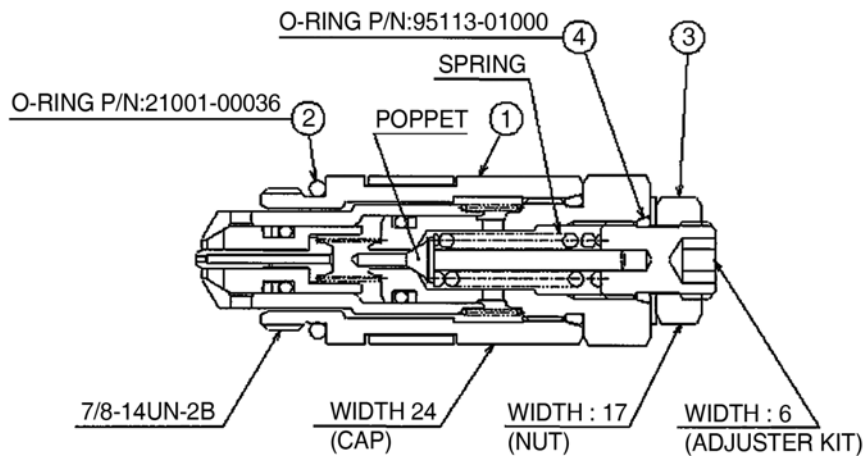
Oil flows from than "LP" in the low pressure side to the cylinder port "HP" and prevents cavitation.



FG010417

Figure 9

Hint for Disassembly and Assembly of Overload Relief Valve



FG011266

Figure 10

1. Disassembly

For the original product, replace assembly.

When replacing, loosen the cap (1: hexagonal subtense24) with a spanner, etc and take off the O-ring (2, Figure 10).

If oil leaks from the adjuster part (3, Figure 10), loosen the adjuster part and replace the O-ring (4, Figure 10).



CAUTION

In disassembling disassembly the adjuster kits, be cautious so that Poppet may not be lost by which parts are popped up by spring.

2. Assembly

Properly check that there are no scraps, primer pieces, etc around cam (1) screw part, and insert a new O-ring (2).

After properly clean the relief mounting part of the valve housing, mount the relief valve and then tighten cam (1: hexagon subtese 23) to tightening torque of 69 ~ 78N•m.

If disassembling the adjuster kits, assemble the screw part according to "Hint for Disassembly and Assembly of Overload Relief Valve" on page 1-21).



CAUTION

All tightening torques as directed above are wet status (working oil adherence status).

Pressure Adjustment of Relief Valve

Main Relief Valve (P1, P2 Rise Type)

1. Adhere a correct pressure gauge to the inlet circuit.
2. Operate the pump in the rated rotation number.
3. Convert the spool of the control valve and then reads value of the pressure gauge in the end of the cylinder stroke.



CAUTION

An actuator spool, whose set pressure of the overload relief valve is higher than the set pressure of the main relief valve, must be replaced.

4. H/P set (Step 1)
 - Tighten and insert the Plug (2) until the piston will touch with the section of Plug (4) (* subsidiary). In this case, the tightening torque of Plug (2) should be less than 19.6 N•m. However, when tightening and inserting the Plug (2), be cautious so that Plug (4) should not rotate together (P.12, ss:A, Length more than 4 mm).
 - Tighten and pressurize the Plug (4). (Slowly tighten Plug (4) while seeing the pressure gauge: 28.4MPa/rotation of plug.)
 - After setting pressure, lock with a hex nut (6).
5. L/P set (Step 2)
 - Loosely adjust the Plug (2) in the H/P set. If loosening the Plug (2), the piston moves to the right and so weight of the spring is reduced: 21.3 MPa/ rotation of plug rises.
 - After setting pressure, lock with a hex nut (3).
6. Increase pressure again and then check that it becomes specified pressure.

Main Relief Valve (P1, P2, P3)

1. Read value of the pressure gauge in the end of the cylinder stroke by replacing the spool of the control valve as 1).
2. Turn adjuster clockwise until required pressure will be obtained.
17.7MPa/rotation of adjuster rises.
3. When reaching to the specified pressure, press the adjuster so that it should not rotate and tighten the lock nut.
Tightening torque: 27.5 ~ 31.4 N•m
4. Increase pressure again and then check that it becomes specified pressure.

Overload Relief Valve



CAUTION

If set pressure is higher than main relief valve, do not adjust the overload relief valve but replace both relief valve and assembly whose setting is completed.

1. Read value of the pressure gauge in the end of the cylinder stroke by replacing the spool of the control valve as 1).
2. Turn adjuster clockwise until required pressure will be obtained.
28.4MPa/rotation of adjuster rises.
3. When reaching to the specified pressure, press the adjuster so that it should not rotate and tighten the lock nut.
Tightening torque: 27.5 ~ 31.4 N•m
4. Increase pressure again and then check that it becomes specified pressure.

MOUNTING

1. Be careful so that force will not be unnecessarily applied to pipe.
2. Tighten all mounting bolts to the same torque.
3. Take care as welding work near the valve may cause seal, etc by excessive heat or sputter,
4. Always perform handling to prevent damage of each part until piping for prevention of scraps ingress.

OPERATION

1. Check that the oil pressure circuit or working oil is clean and that there is no outside leakage by slowly increasing pressure (manually operate a working machine in the low idle).
2. Use oil whose aniline point is $82 \sim 113^{\circ}\text{C}$ as pneumatic working oil.
3. Do increase pressure of the relief valve over the specified set pressure.
4. Maintain the set pressure difference of both main relief valve and overload relief valve is over 3.0Mpa.
5. After fully performing preheat operation (warming-up), perform actual work. Especially for starting to operate the machine when working oil temperature or valve temperature is low, care should be taken of following points for preventing a stick of heat shock:
 - A. Evenly increase temperature of each part by operation so that working oil circulates within each actuator without consecutively and suddenly operating the main relief valve or the overload relief valve.
 - B. Do not suddenly perform mistake operation or complex operation when temperature is low as they may result in heat generation.

SPEC OF CONTROL VALVE

1. Rated flow: 70 L/min
2. Max pressure: 24.5 MPa
3. Allowable discharge pressure: Surge pressure: 1.5 MPa or less
Normal pressure: 0.34 MPa
4. Scope of usable fluid temperature : $-20 \sim 80^{\circ}\text{C}$
Spontaneous temperature 100°C
5. Adjustable scope of relief valve pressure
Main relief valve (P1, P2, P3): 3.9~24.5MPa
Overload relief valve: 20.6~30MPa

FAILURE AND TROUBLESHOOTING

Overall Control Valve

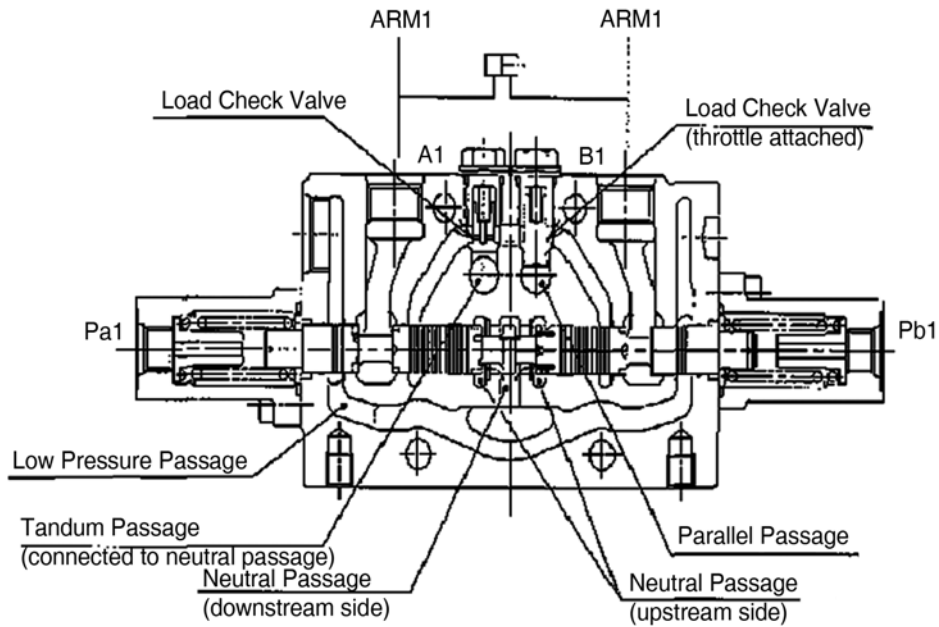
Failure	Possible Cause	Troubleshooting
Spool not subject to stroke	1. Fluid temperature abnormally rises	Remove the part that disturbs oil flow in the pipe.
	2. Working oil dirty	Change working oil and wash circuits.
	3. Pipe port joint too loose	Check torque.
	4. Valve housing is twisted by mounting	Check after loosening mounting bolt.
	5. Pressure too high	Adhere the pressure gauge to the pump port and the cylinder port.
	6. Spool bent	Replace with valve assembly.
	7. Damage of return spring	Replace damaged parts.
	8. Spring or cap turns aside	Loosen cap and take off the core and then tighten.
	9. Temperature distribution within valve not equal	Warm up the whole circuit.
	10. Scraps clogged within valve	Remove scraps (flashing).
	11. Pilot pressure insufficient	Check Pilot valve and Pilot relief pressure
Failing to maintain load	1. Oil leak from cylinder	Check the cylinder room part.
	2. Oil bypassed in the spool	Check possible spool damage.
	3. Oil leak from overload relief valve	Clean some of valve housing seat or relief valve seat
	4. Oil leak from anti-relief valve	Disassemble the anti-relief valve and clean the seat part of each part. When the seat part is damaged, replace Poppet or wrap around Poppet and the seat part. As both spool and sleeve are parts for relief, replace them at the same time.
Load dropped when changing position of spool from Neutral to Lift Up	1. Scraps are laid in the load check part.	Disassemble and clean the check valve.
	2. poppet or seat part of the check valve damaged	Replace poppet or wrap around poppet and the seat part.

Relief Valve

Failure	Possible Cause	Troubleshooting
Pressure not rise	1. Main poppet sleeve or pilot poppet stuck open, or scraps are laid between valve seat parts	Replace relief valve
Instable relief pressure	1. Pilot poppet seat damaged	
	2. Piston or main poppet is stuck	
Abnormal relief pressure	1. Seat part worn by scraps	Set pressure again and then tighten lock nut to specified torque
	2. Lock nut and adjuster loosened	
Oil leak	1. Damage of relief valve part	Replace relief valve
	2. Each part stuck by scraps	Replace O-ring on the adjuster or the mounting part.
	3. O-ring worn	

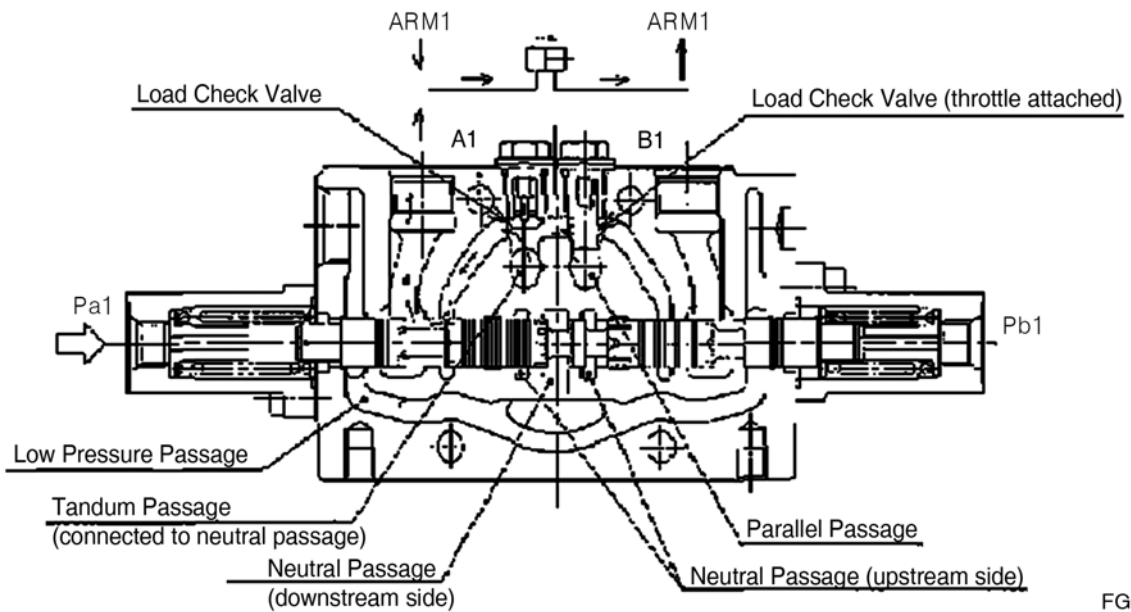
Overall Pneumatic System

Failure	Possible Cause	Troubleshooting
Pneumatic system fails or not operate	1. Failure of pump	Check pressure or replace pump
	2. Failure of relief valve	Replace relief valve
	3. Failure of cylinder, etc	Repair or replace
	4. Pump load pressure too large	Check circuit pressure
	5. Valve torn	Replace with valve assembly
	6. Spool not subject to stroke	Check movement of spool
	7. Oil surface of tank tool low	Supply working oil
	8. Filter clogged among circuit	Clean or replace filter
	9. Circuit pipe tightened	Check pipe



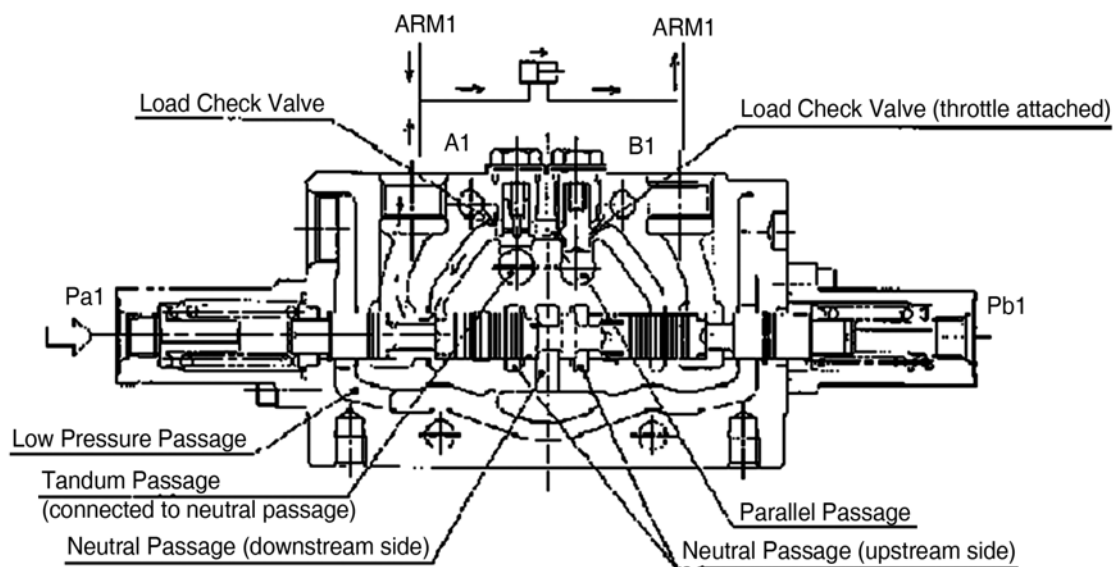
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Figure 11 Arm2 Neutral



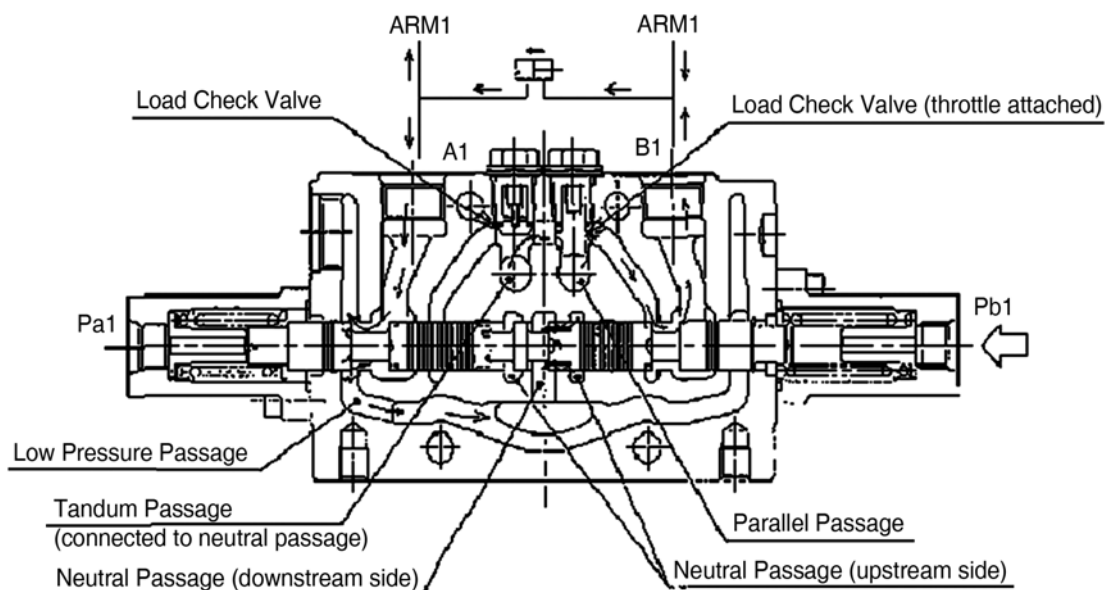
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Figure 12 Arm2 Crowd



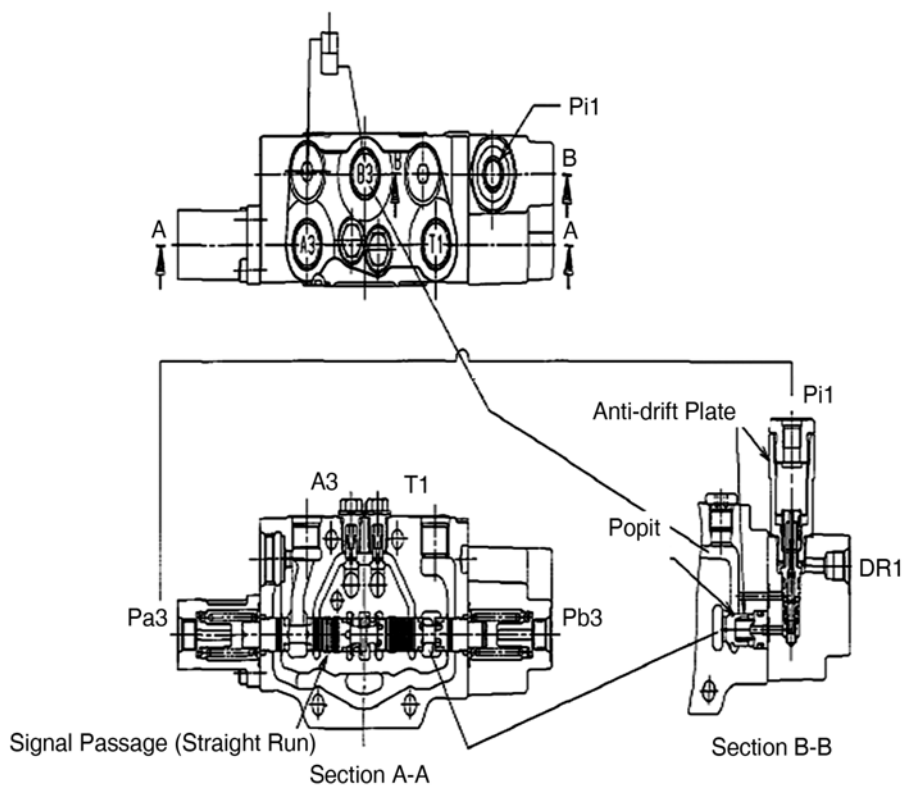
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Figure 13 Arm2 Crowd (simultaneous Operation with BOOM)



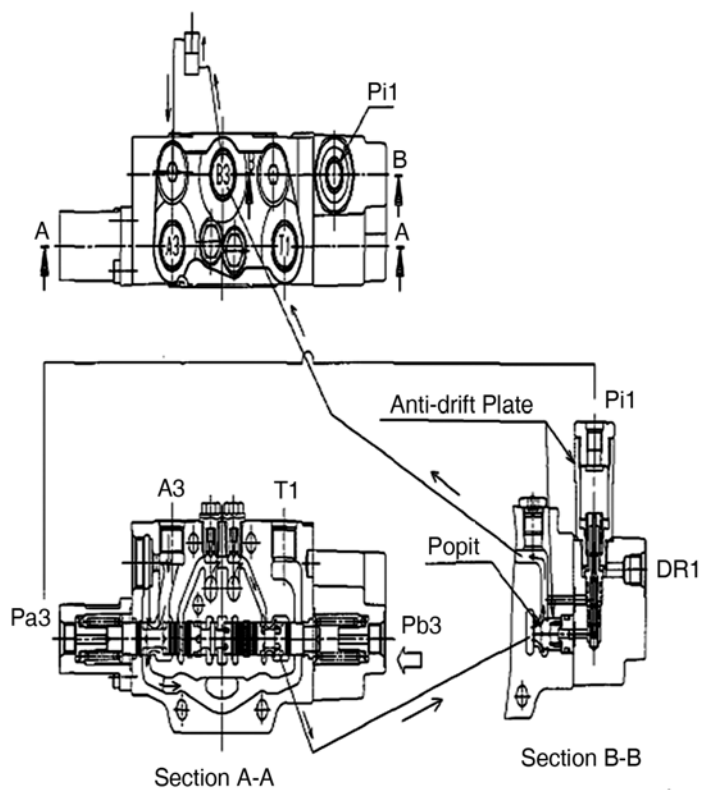
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Figure 14 Arm2 Dump



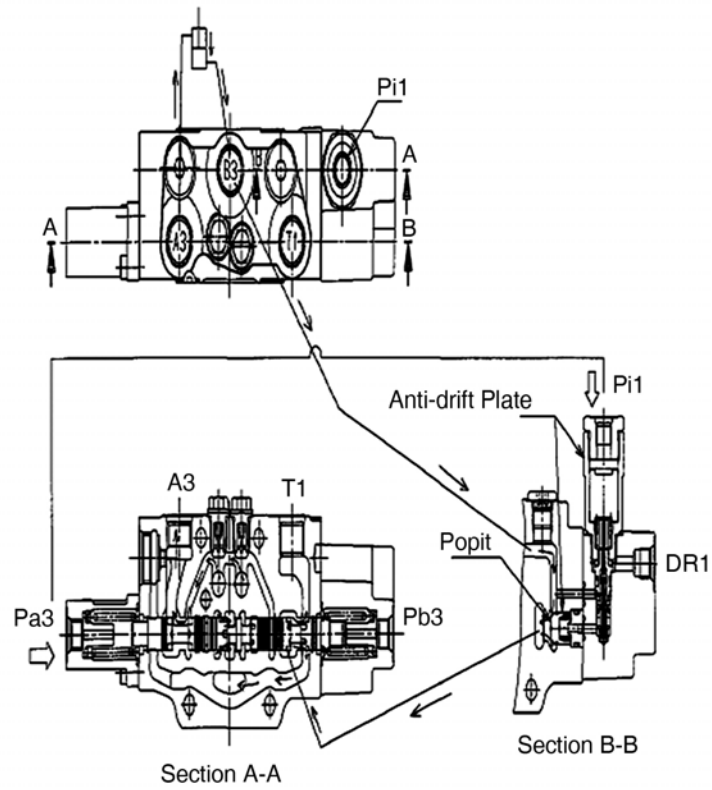
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Figure 15 Boom1 Neutral



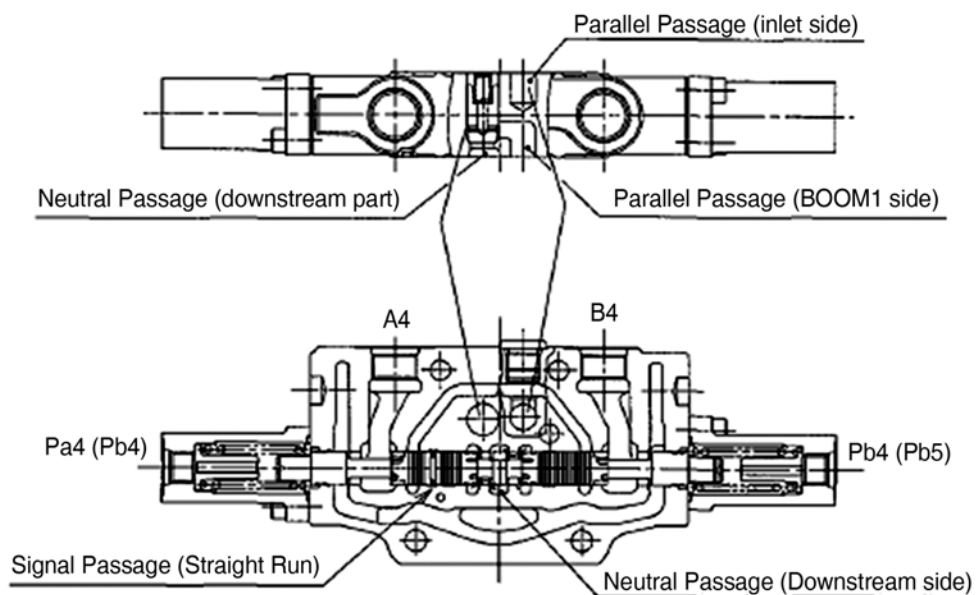
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Figure 16 Boom1 Lift Up



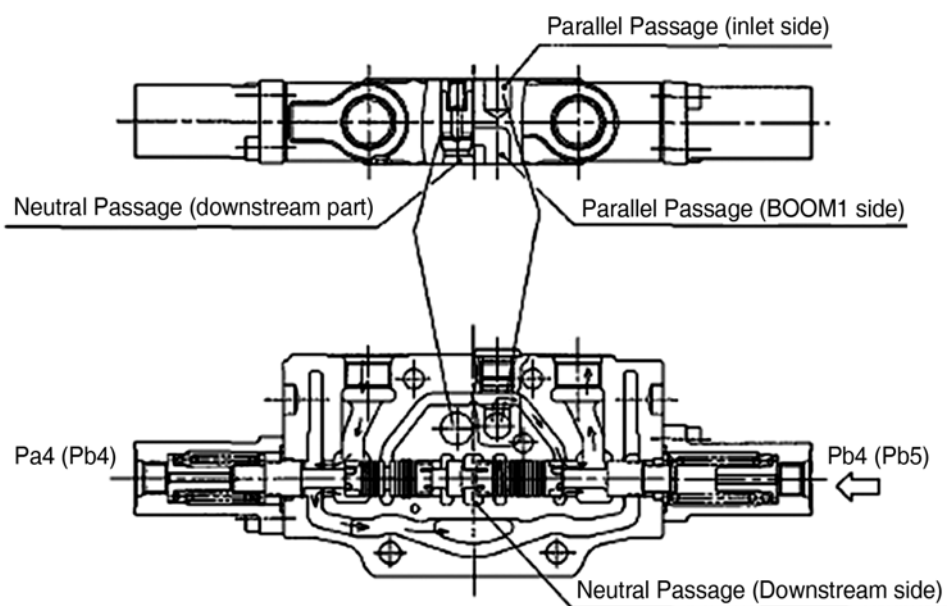
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Figure 17 Boom1 Lower Down



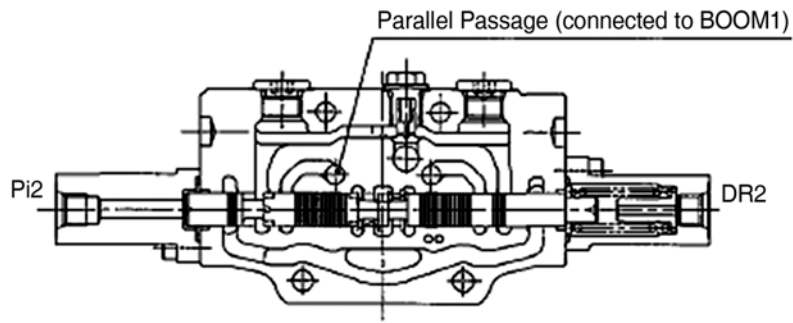
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Figure 18 Travel - R Neutral



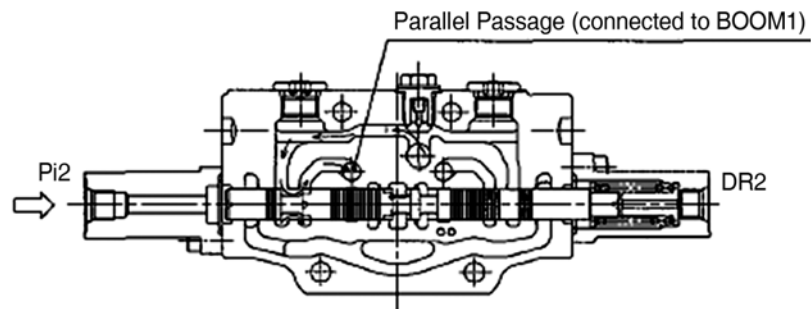
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Figure 19 Travel - R Pb4



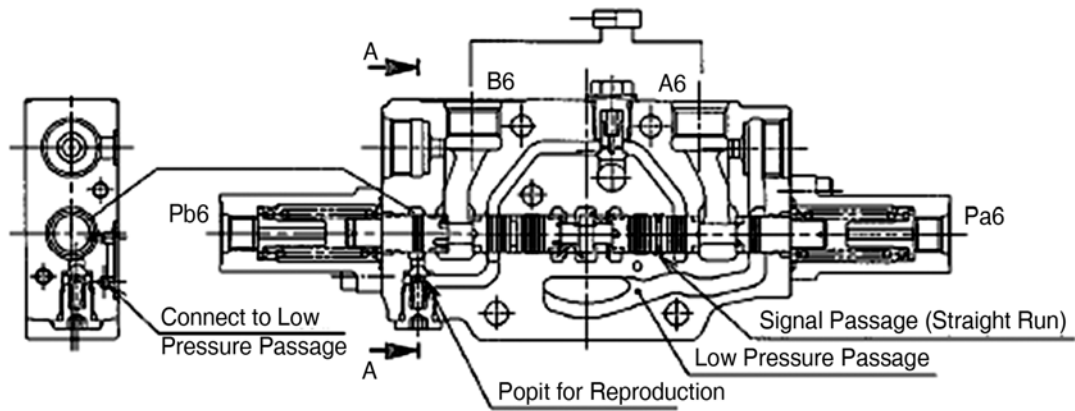
FG011276

Figure 20 Boom2 Neutral



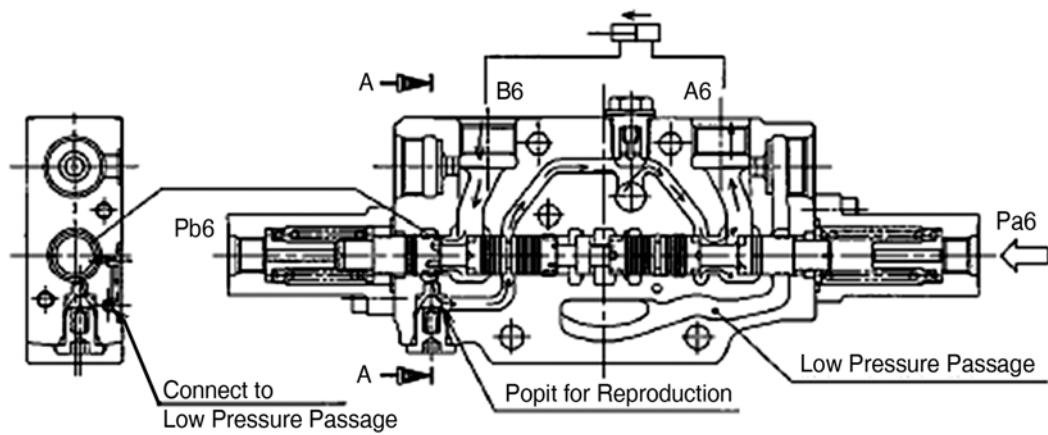
FG011277

Figure 21 Boom2 Lift Up Joint



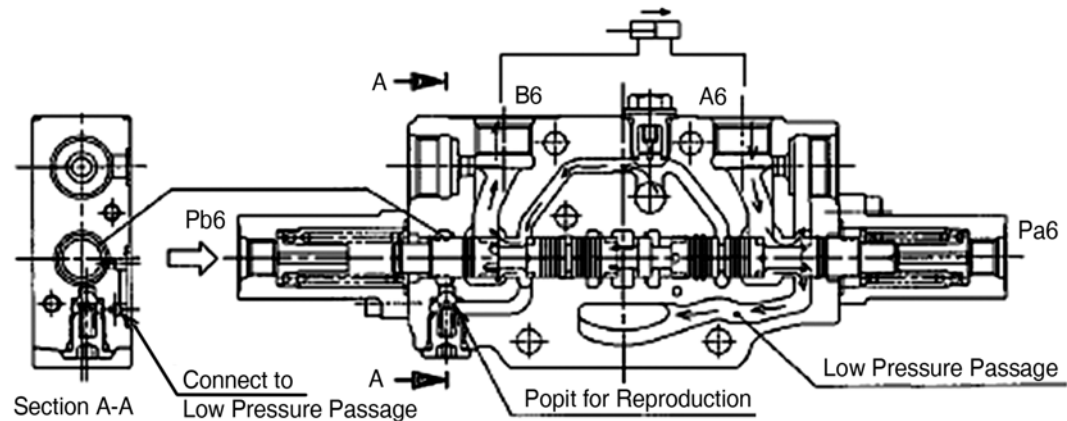
FG011278

Figure 22 Arm1 (Reproduction Circuit)



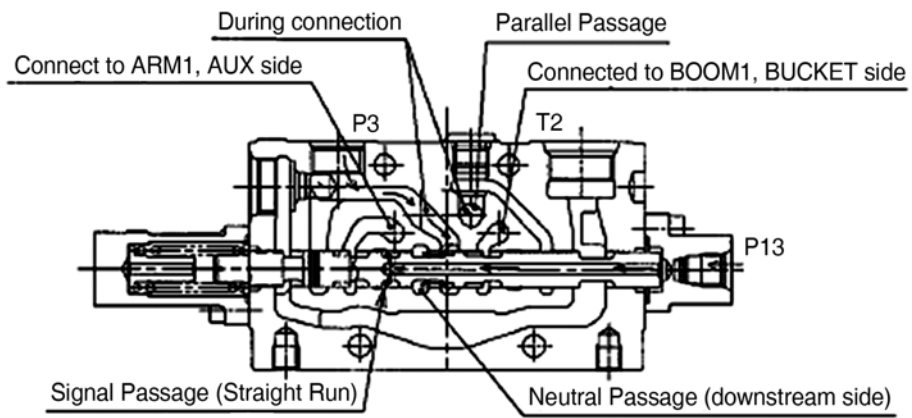
FG011279

Figure 23 Arm1 (reproduction Circuit)



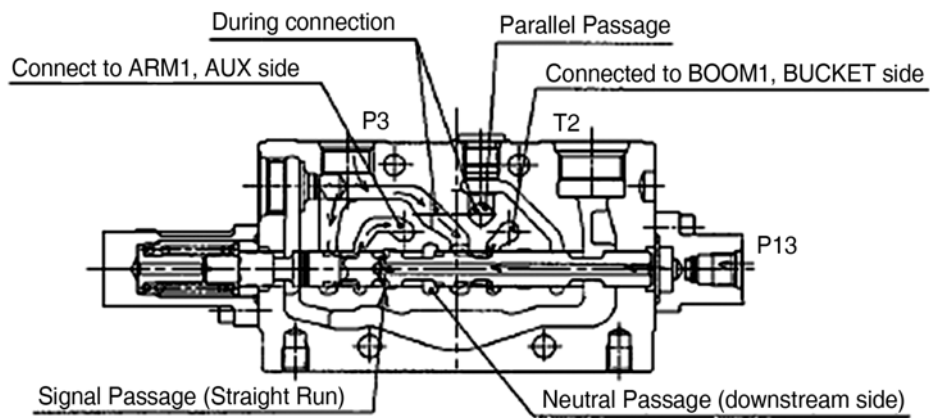
FG011280

Figure 24 Arm1 (reproduction Circuit) dump



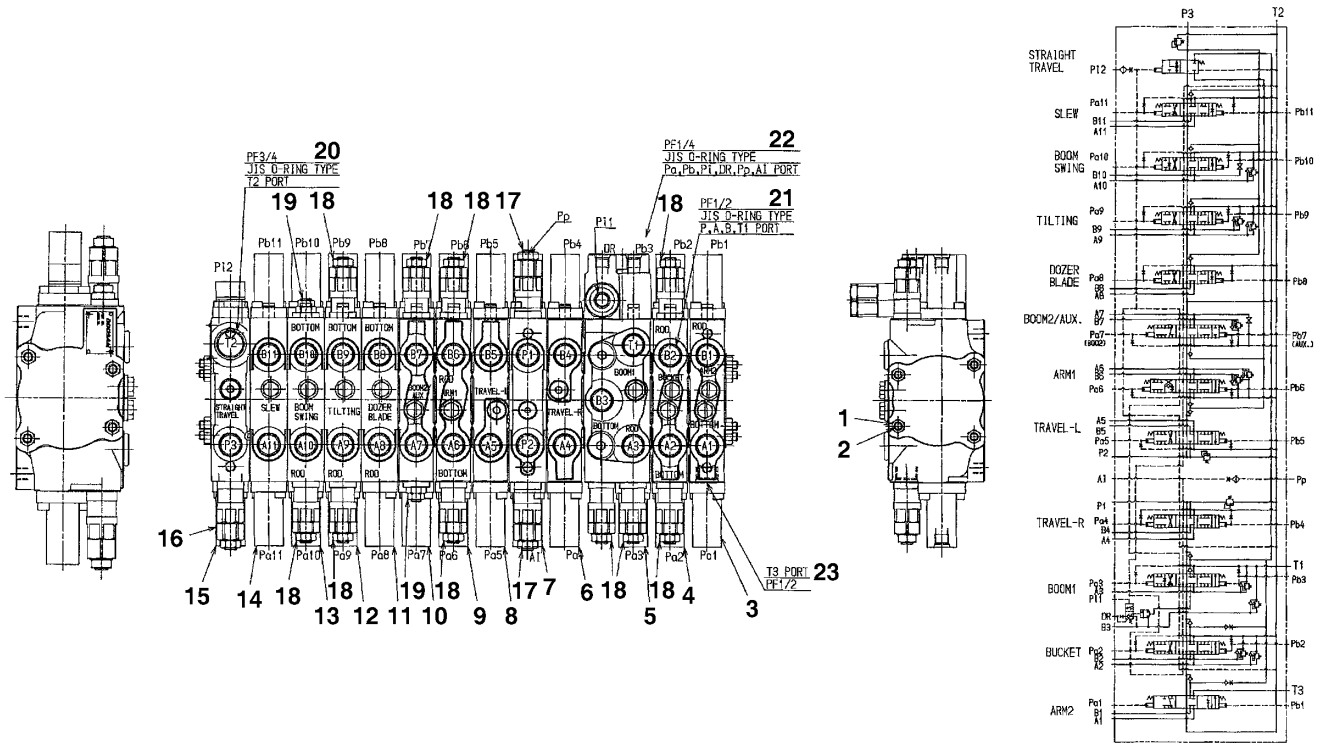
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Figure 25 Straight Travel Neutral



FG011282

Figure 26 Straight Travel Operation

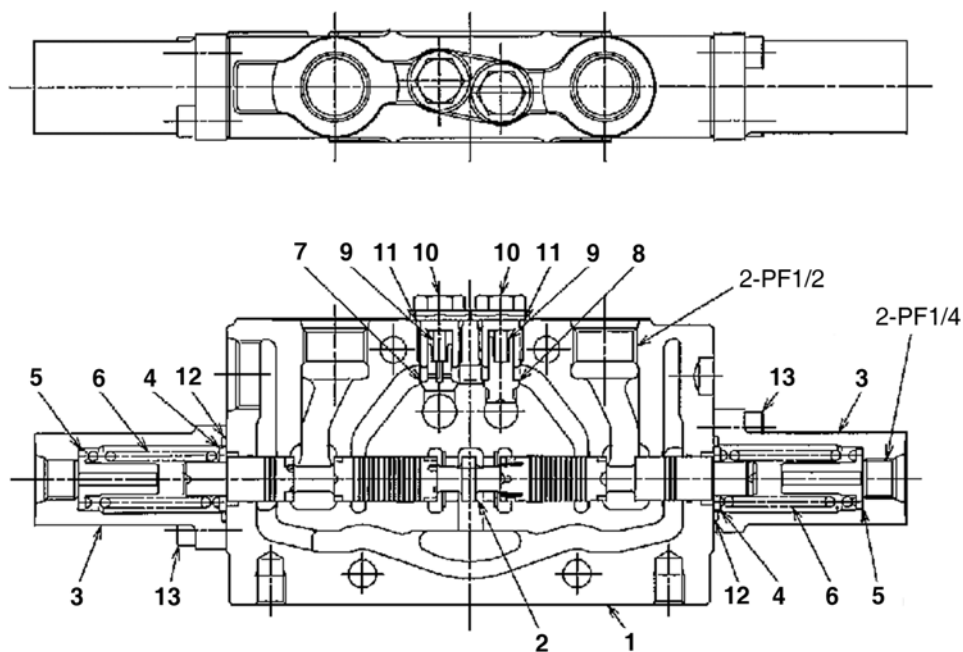


FG013806

Figure 27

Reference Number	Description
1	Nut
2	Tie-Roo
3	Spool Section Assembly
4	Spool Section Assembly
5	Spool Section Assembly
6	Spool Section Assembly
7	Spacer Section Assembly
8	Spool Section Assembly
9	Spool Section Assembly
10	Spool Section Assembly
11	Spool Section Assembly
12	Spool Section Assembly
13	Spool Section Assembly

Reference Number	Description
14	Spool Section Assembly
15	Spool Section Assembly
16	Relief Valve Assembly
17	Relief Valve Assembly
18	Relief Valve Assembly
19	Shutoff Valve Assembly
20	Shipping Plug
21	Shipping Plug
22	Shipping Plug
23	Shipping Plug

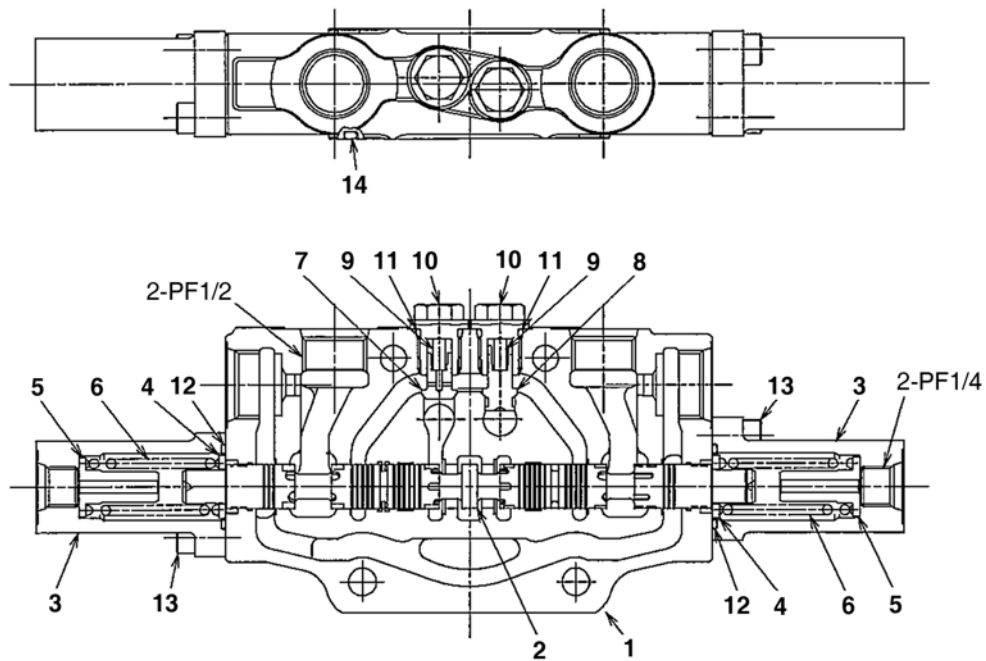


FG010477

Figure 28 Arm2

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Poppet

Reference Number	Description
8	Poppet
9	Spring
10	Plug
11	O-ring
12	O-ring
13	Socket Head Bolt

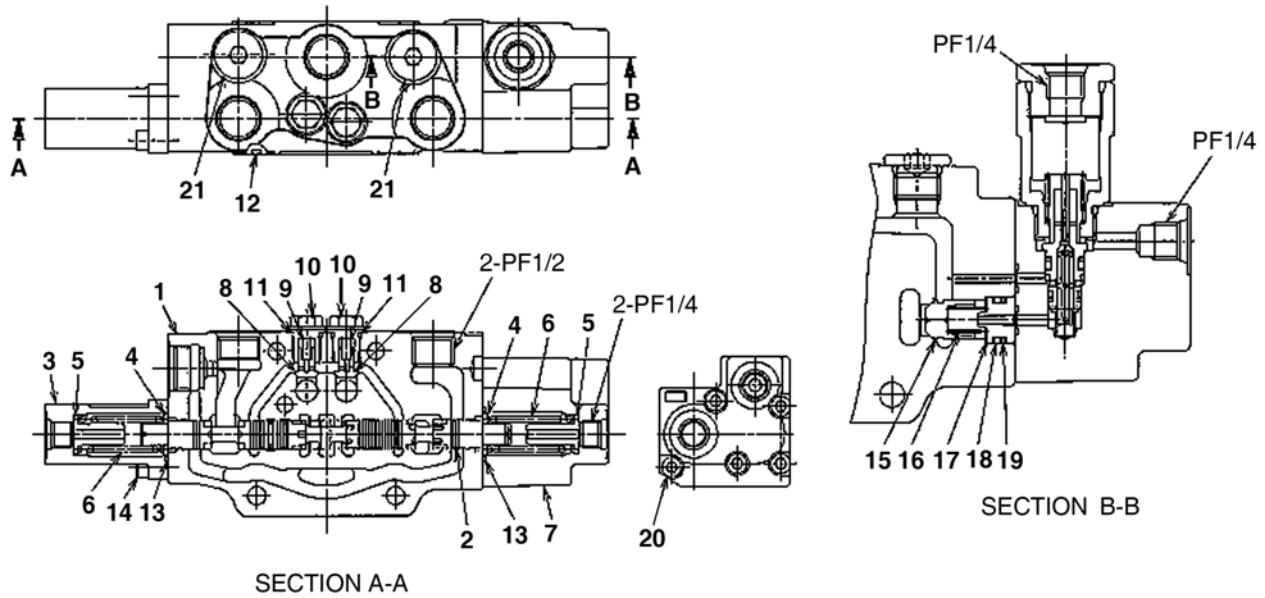


FG010478

Figure 29 BKT

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Poppet

Reference Number	Description
8	Poppet
9	Spring
10	Plug
11	O-ring
12	O-ring
13	Socket Head Bolt
14	O-ring

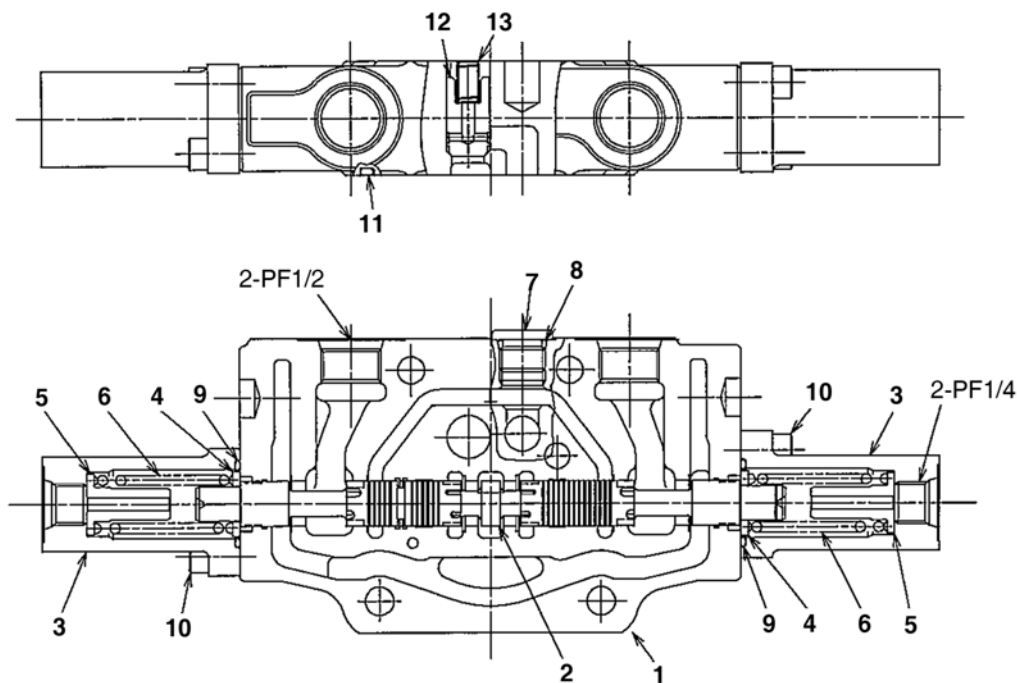


FG011283

Figure 30 Boom1

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Anti-Drift Valve Assembly
8	Poppet
9	Spring
10	Plug
11	O-ring

Reference Number	Description
12	O-ring
13	O-ring
14	Socket Head Bolt
15	Poppet
16	Spring
17	Spacer
18	O-ring
19	Backup Ring
20	Socket Head Bolt
21	Plug Assembly

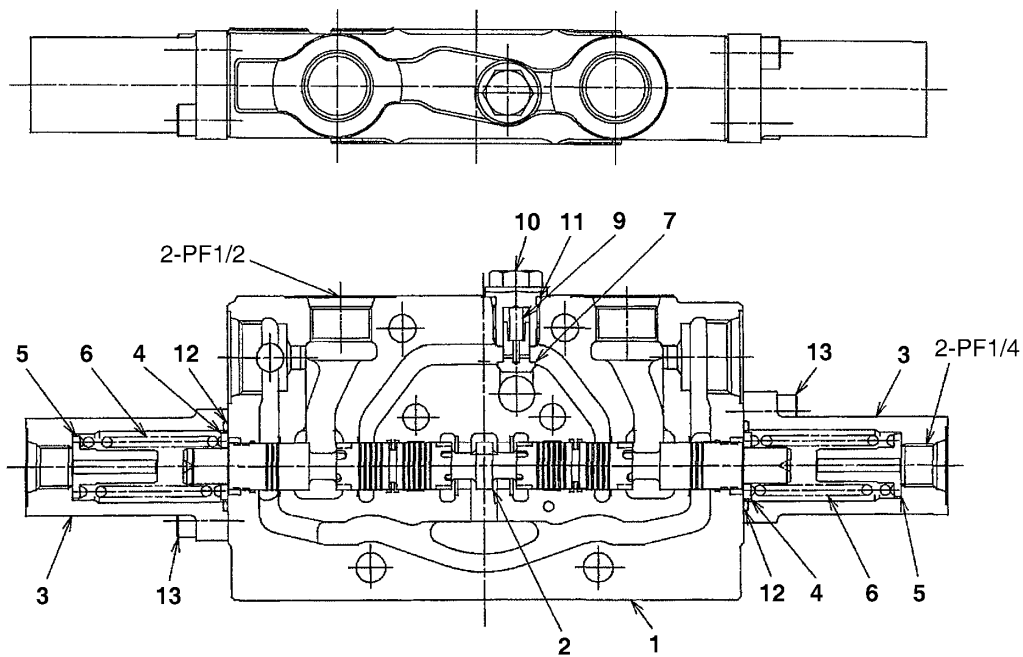


FG010480

Figure 31 T-R

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Plug

Reference Number	Description
8	O-ring
9	O-ring
10	Socket Head Bolt
11	O-ring
12	Poppet
13	Spring

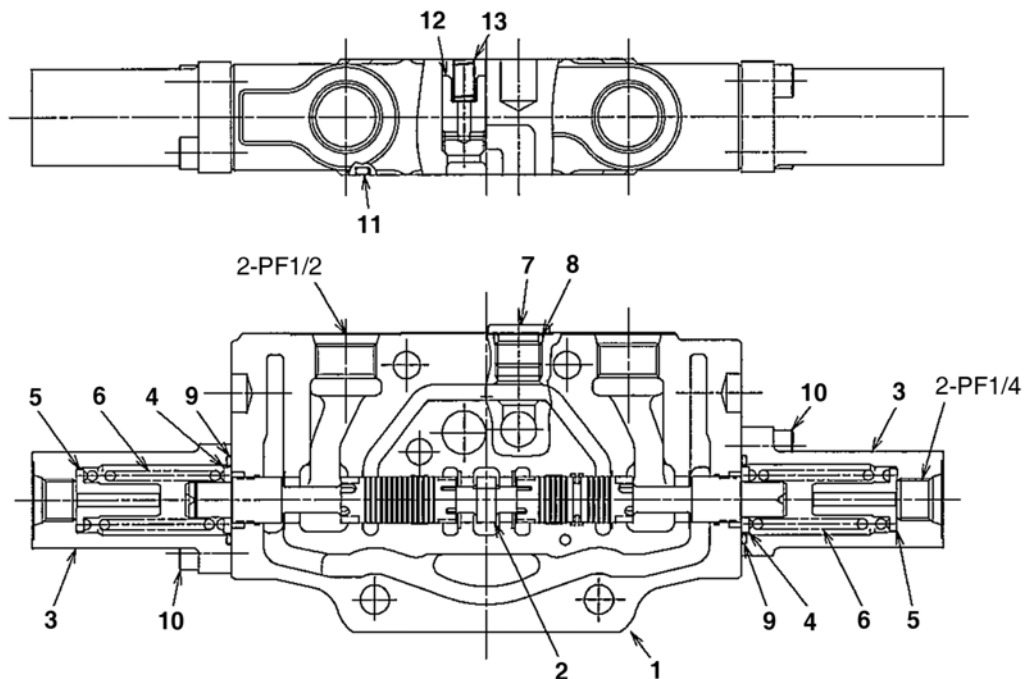


FG013809

Figure 32 Inlet

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Poppet

Reference Number	Description
8	-
9	Spring
10	Plug
11	O-ring
12	O-ring
13	Socket Head Bolt

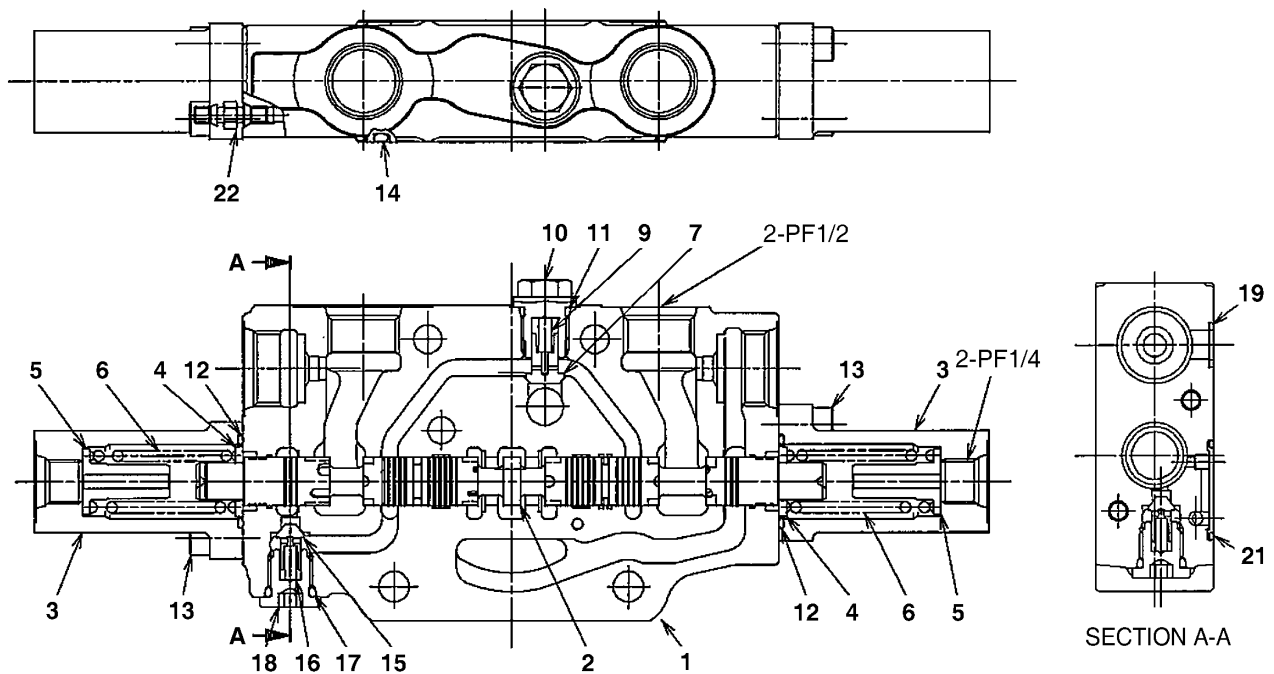


FG010482

Figure 33 T-L

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Plug

Reference Number	Description
8	O-ring
9	O-ring
10	Socket Head Bolt
11	O-ring
12	Poppet
13	Spring

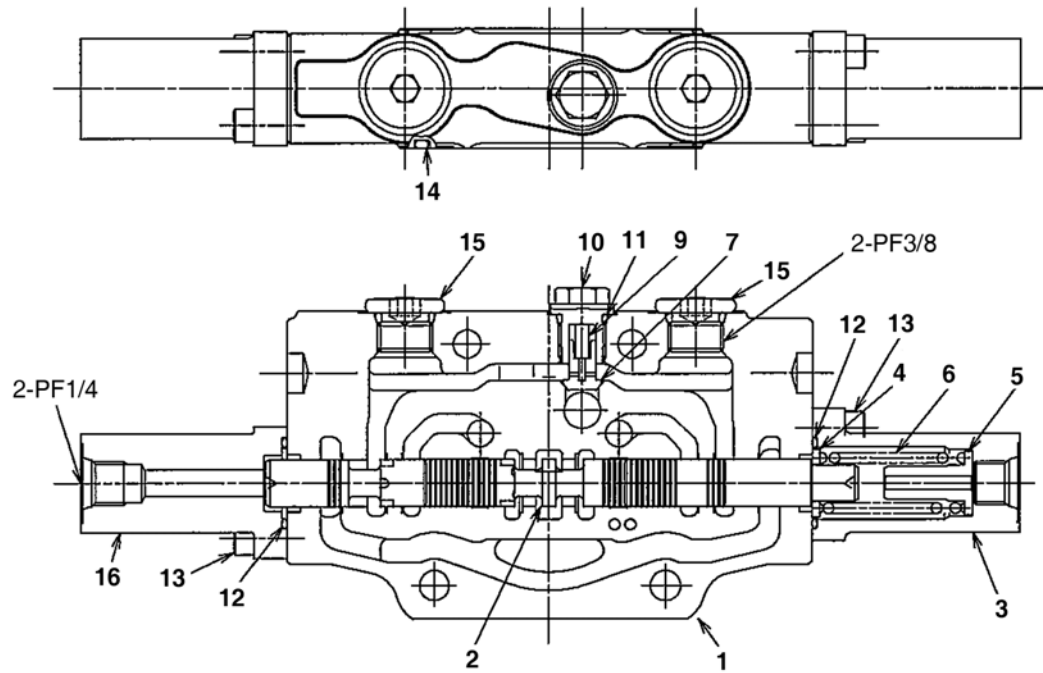


FG011284

Figure 34 Arm1

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Poppet
8	-
9	Spring
10	Plug
11	O-ring

Reference Number	Description
12	O-ring
13	Socket Head Bolt
14	O-ring
15	Poppet
16	Spring
17	O-ring
18	Plug
19	O-ring
20	-
21	O-ring
22	Plug

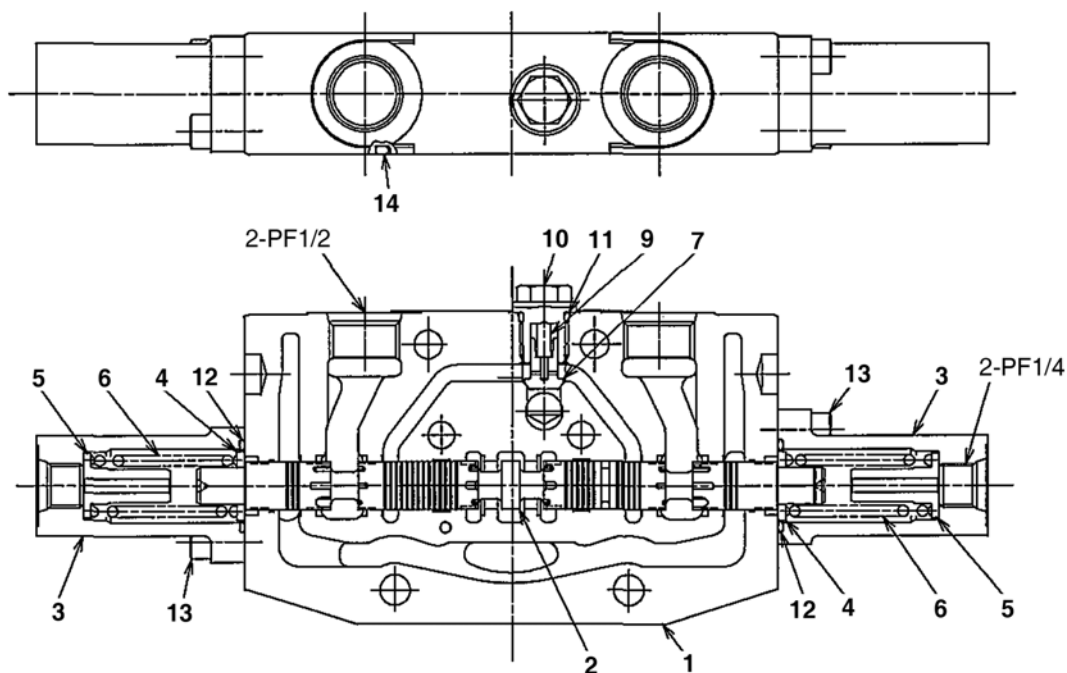


FG010483

Figure 35 Boom2/Aux

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Poppet
8	-

Reference Number	Description
9	Spring
10	Plug
11	O-ring
12	O-ring
13	Socket Head Bolt
14	O-ring
15	Plug Assembly
16	Cap

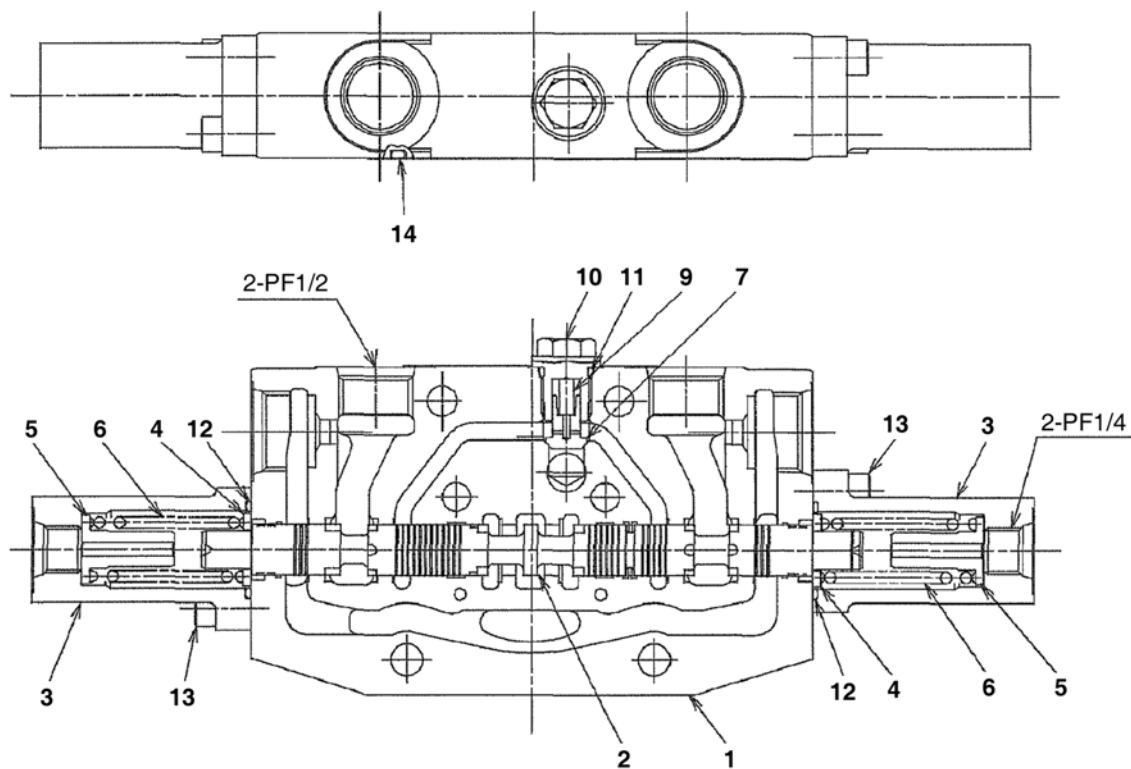


FG010487

Figure 36 Dozer

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Poppet

Reference Number	Description
8	-
9	Spring
10	Plug
11	O-ring
12	O-ring
13	Socket Head Bolt
14	O-ring

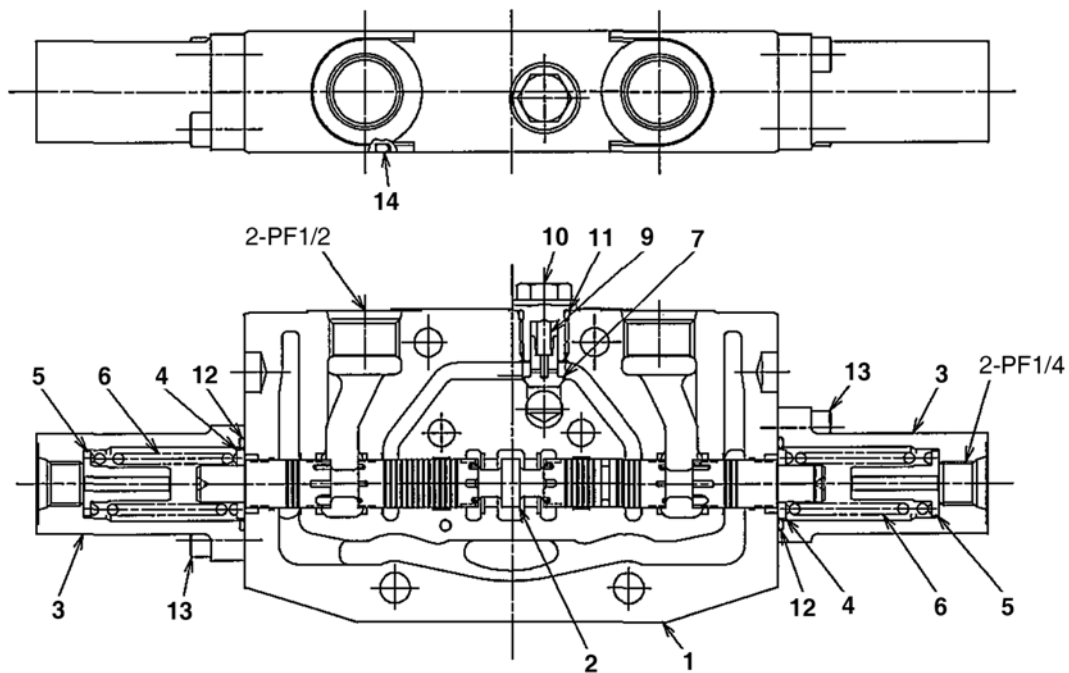


FG013318

Figure 37 Boom Swing

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Poppet

Reference Number	Description
8	-
9	Spring
10	Plug
11	O-ring
12	O-ring
13	Socket Head Bolt
14	O-ring

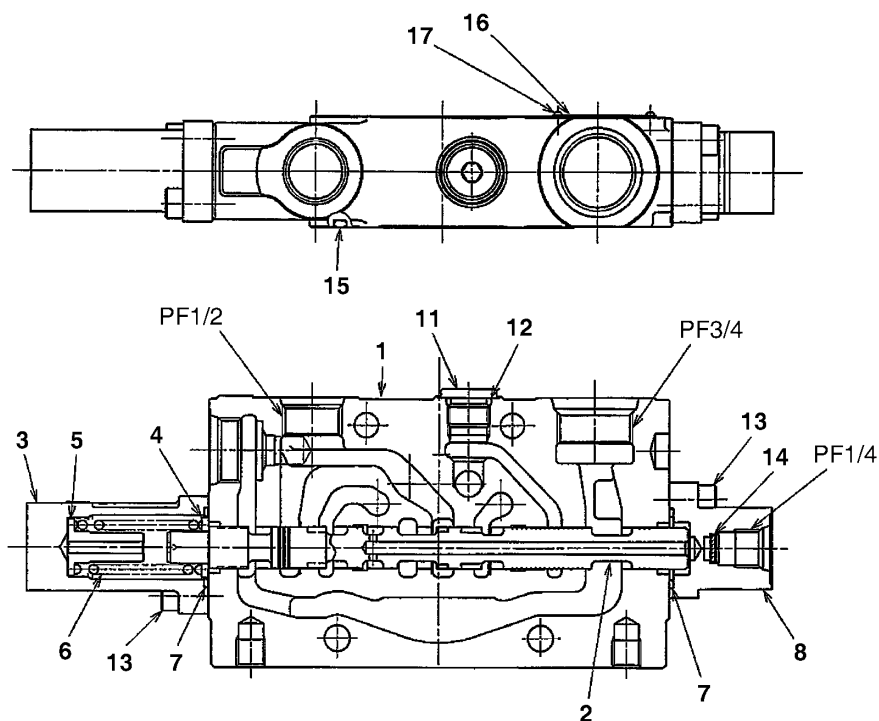


FG010487

Figure 38 Swing

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	Poppet

Reference Number	Description
8	-
9	Spring
10	Plug
11	O-ring
12	O-ring
13	Socket Head Bolt
14	O-ring



FG013815

Figure 39 Straight Travel

Reference Number	Description
1	Valve Housing
2	Spool
3	Cap
4	Spring Seat
5	Spring Seat
6	Spring
7	O-ring
8	Cap
9	-

Reference Number	Description
10	-
11	Plug
12	O-ring
13	Socket Head Bolt
14	Filter-A
15	O-ring
16	Name-Plate
17	Screw

Main Pump

Edition 1

MEMO

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Main Pump

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

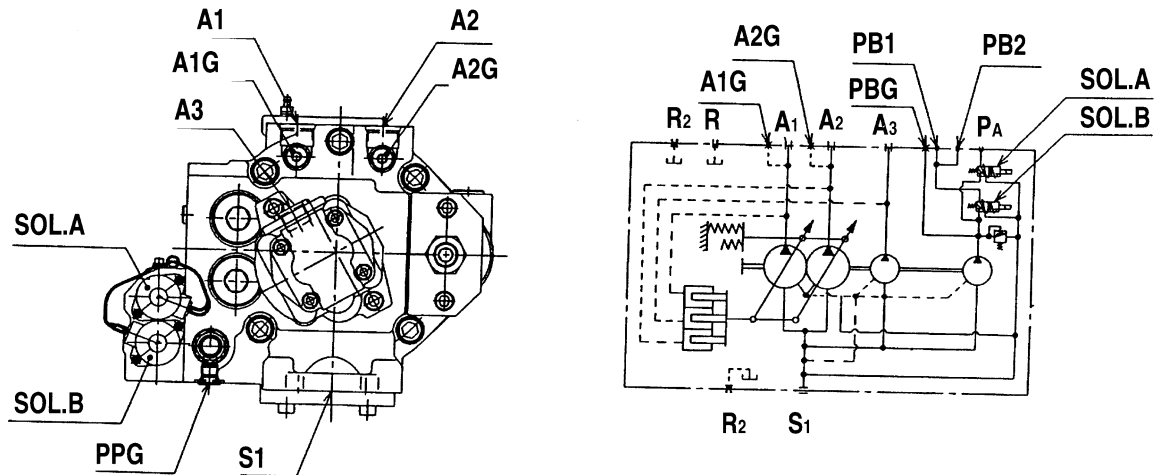
APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX55	50001 and Up
DX60R	50001 and Up

GENERAL DESCRIPTION

This is a capacity adjusting piston where two ports discharge oil to a single cylinder block. Although this is a double pump, it has a simple structure like a single pump. This pump is of a swash plate type and its tilt angle is like that of two pumps. The tilt angle of the pump changes the total pressure, $P_1 + P_2$. That is, as the output is controlled by a constant value, the relation between discharge pressure and flow rate, Q remains constant ($(P_1 + P_2) \times Q$). Pump No. 3 and the pilot pump are connected on the same axle using a coupling.



HASB010S

Figure 1

Description of Ports

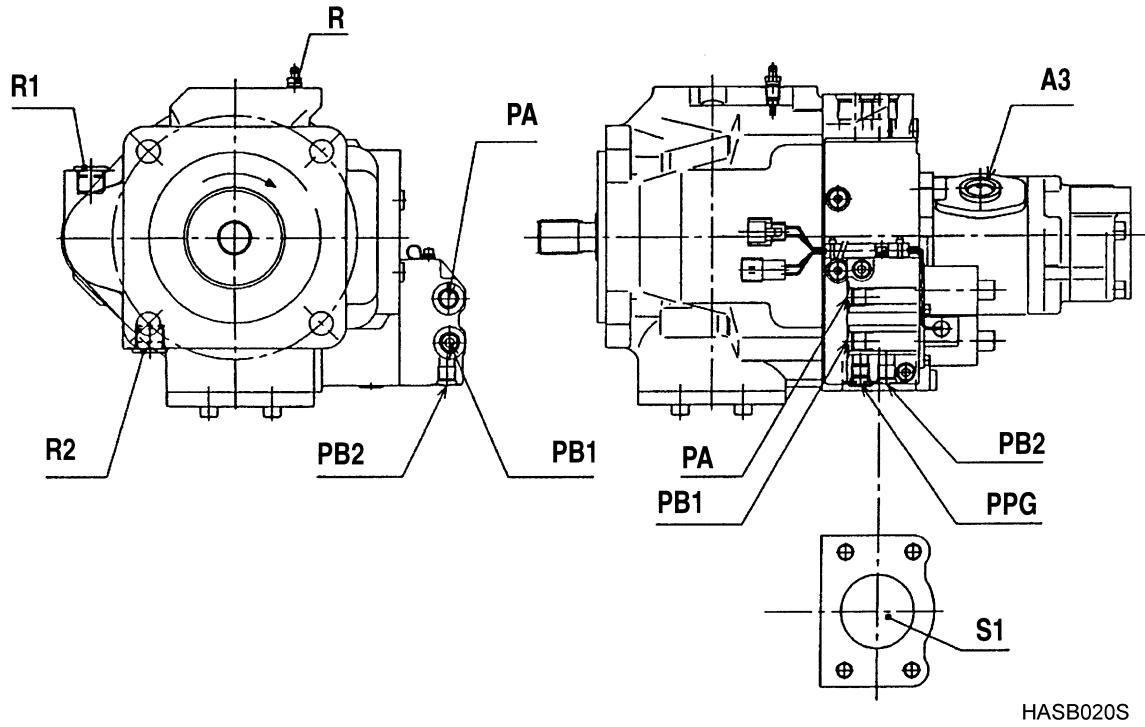


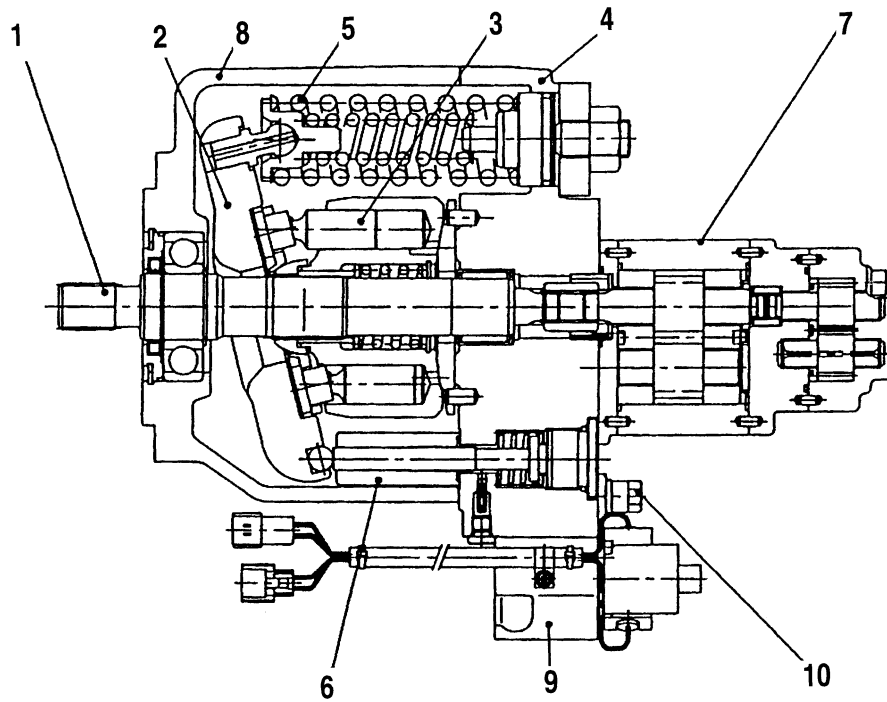
Figure 2

Port	Names	Size/Standard
S1	Intake Port	SAE 2 1/2 (Standard)
A1, A2	Discharge Port	G 3/4 (JIS B2351 O-TYPE)
A3	Discharge Port	G 1/2 (JIS B2351 O-TYPE)
A1G, A2G	Gauge Port	G 1/4 (JIS B2351 O-TYPE)
PA	Pilot Port	G 1/4 (JIS B2351 O-TYPE)
PB1, PB2	Pilot Port	G 1/4 (JIS B2351 O-TYPE)
PPG	Gauge Port	G 1/4 (JIS B2351 O-TYPE)
R	Air Discharge Port	M10 x 1 (With Bleeder Valve)
R1, R2	Drain Port	G 1/2 (JIS B2351 O-TYPE)

OPERATION PRINCIPLE AND FUNCTION OF COMPONENTS

Components of the Pump

- This is a capacity adjusting double piston pump which discharges oil into two ports from a single cylinder block. This being a single rotary group, it has a single intake port. Actuation oil is divided into two points by the control plate on the cover, where it is discharged into two discharge ports.
- Discharge pressure is determined by the control valve and the tilting plate by restoration strength of the spring. The quantity of discharged flow may vary because piston strokes are changed according to the tilt angle.
- At the same time, a method is adopted to control a constant output of the tilt angle.
- Pump No. 3 and the pilot pump are connected on the same axle using a coupling.



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Figure 3

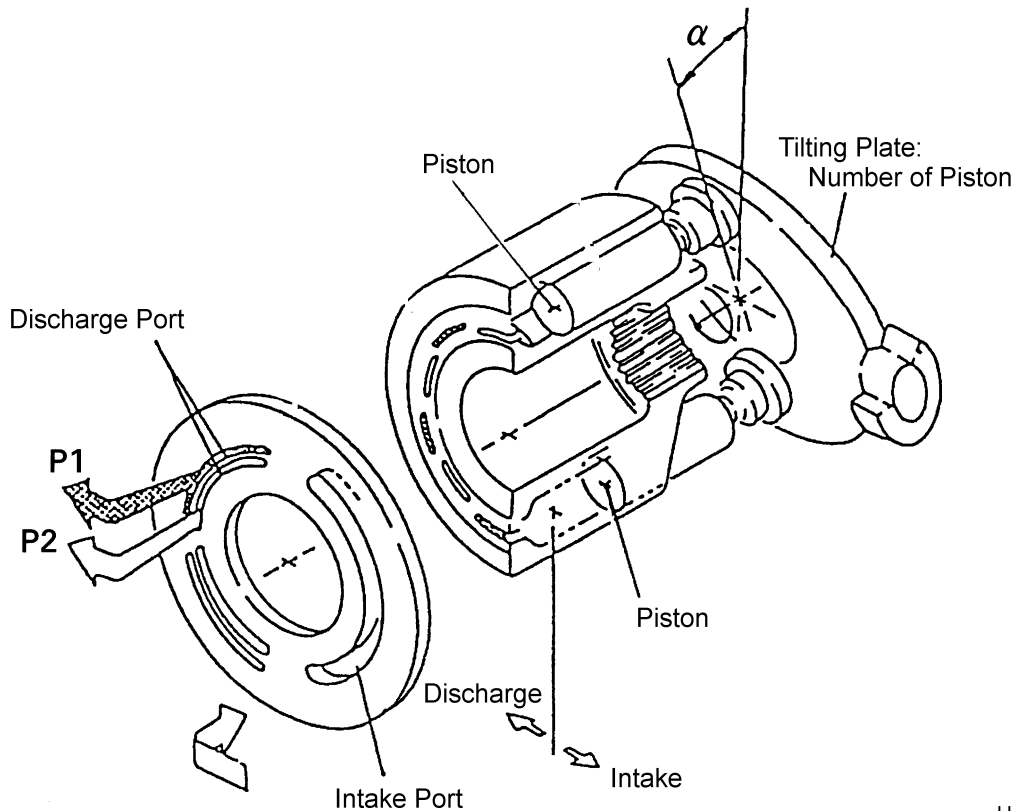
NO.	Name
1	Driving Axle
2	Tilting Plate
3	Rotary Group
4	Cover
5	Control Spring

NO.	Name
6	Control Piston
7	Gear Pump
8	Housing
9	Solenoid Valve
10	Relief Valve

Operation Principle

1. Function of Pump

- The cylinder block is joined together by a key groove and rotates along with driving axle.
- The piston is assembled inside cylinder which operates in a reciprocal action along with surface of tilting plate.
- The piston moves towards direction in which quantity of discharged oil increases, from lower tilting point toward upper tilting point (suction process).
- While piston strokes are going on from upper tilting point toward lower tilting point, piston moves towards direction in which quantity of discharged oil decreases. The actuator oil is discharged into discharge port (discharge process).
- The quantity of discharged oil changes according to change in tilt angle of tilting plate (tilting plate).
- Actuator oil that came into ports of cylinder block is discharged into discharge port of valve plate.
- The actuator oil that came into outer ports of cylinder block is discharged into discharge port of outer side of valve plate.

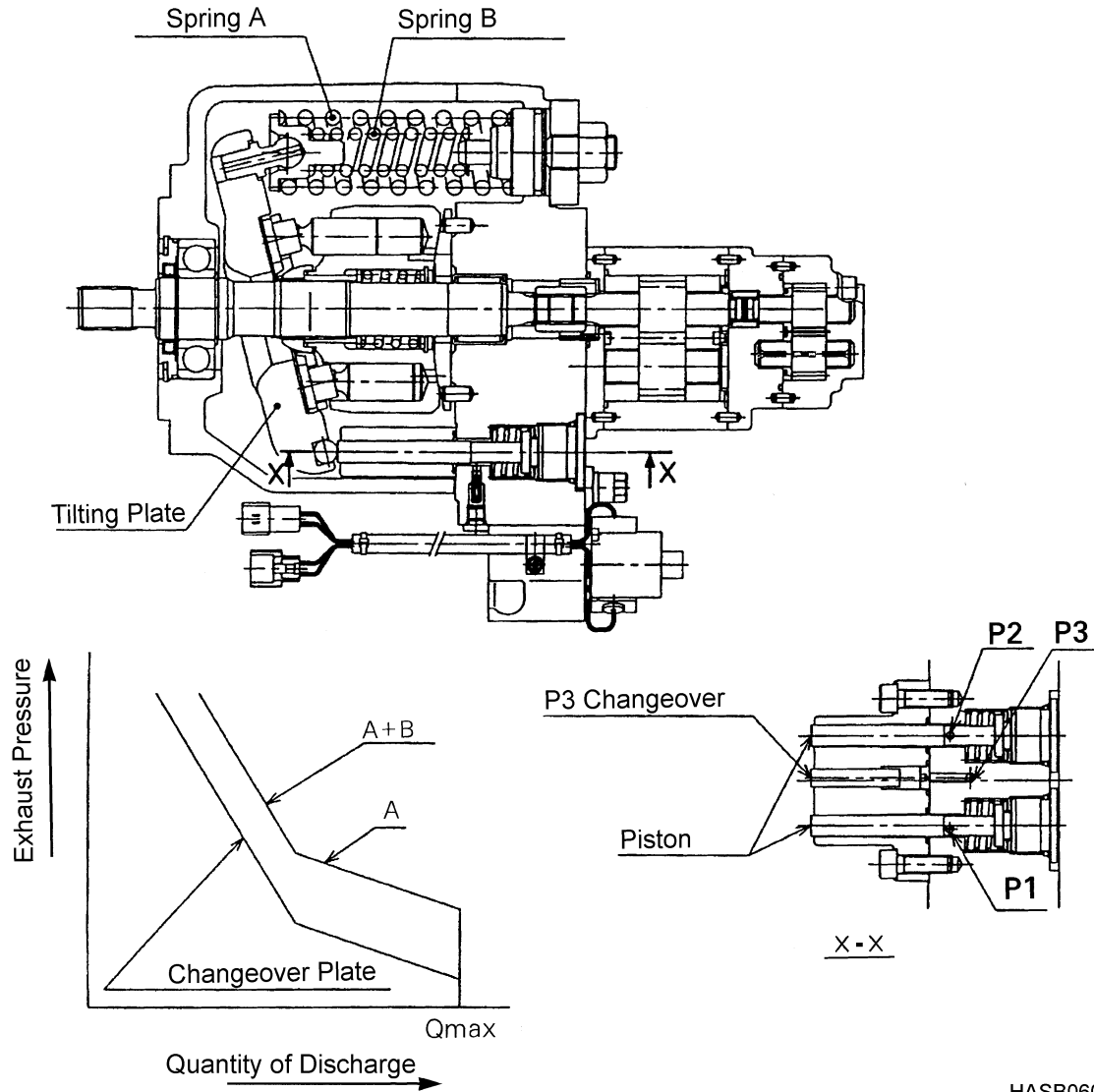


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Figure 5

2. Control Function

- Exhaust pressure P1 and P2 are determined by movement of tilting plate and piston.
- Spring works in direction against discharge pressure.
- The set load of spring A (outer spring) decreases and tilting plate becomes fixed at maximum tilt position, when hydraulic pressure is applied to piston.
- The tilting plate begins to incline when hydraulic pressure is applied to piston and spring A exceeds its set load, and keeps its tilting face at point where hydraulic pressure is in equilibrium with strength of spring. (Refer to "A" in middle part of Figure 6).
- Tilt angle begins to decrease when hydraulic pressure is applied to piston, and then spring B that so far has not worked begins to operate.
- The two springs become to revive their spring tension when hydraulic pressure reaches highest lower tilting point. (Refer to (A + B) domain in middle part of Figure 6).
- The control changeover curve begins to change when hydraulic pressure P3 that presses piston is applied.

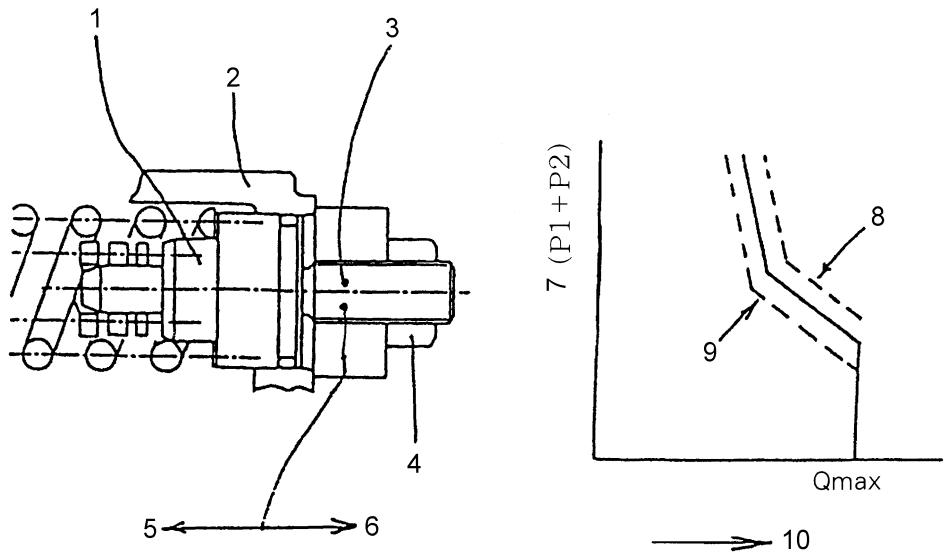


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Figure 6

3. Control / Adjustment Procedure

- A. Loosen hex nuts.
- B. Tighten or release adjusting nuts for adjustment of the power changing curve.



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Figure 7

Reference Number	Description
1	Spring Seat
2	Cover
3	Adjusting Nut
4	Hex Nut
5	Tighten

Reference Number	Description
6	Release
7	Total Pressure
8	Tighten
9	Release
10	Quantity of Oil

ADJUSTMENT

Fine adjustment of the hydraulic pump is made possible by the input power and control. Readjustment of any and all adjusting parts may result in depriving them of control function and placing the pump off the certified specifications. Do not adjust adjusting nuts at your disposal.

INSTALLATION

1. Install pump and place input axle horizontally.
2. Install pump lower than lowest level of actuator oil to ensure that actuator oil will continue to flow into tank.
3. Use a flexible hose after installation of pump on diesel engine. Install an intake pipe, be careful not to allow air to flow into pump.
4. Use a high-pressure flexible hose for discharge ports P1 and P2.
5. Fully charge pump with hydraulic oil following its installation.

DRIVING

1. Use a flexible coupling when you connect it to the motor.
2. Insert couplings near input axle. **Do not** give strong impact to couplings while inserting.
3. While viewing axle from end, rotate input axle clockwise.

HYDRAULIC OIL

1. Make sure that hydraulic oil is either general kerosene based hydraulic oil or anticorrosive actuator oil (ISO 3448, VG32 - 56 or equivalent)
2. The range of an optimum viscosity shall be:
 - Maximum allowable viscosity: 1000 β $\pm$ /s.
 - Minimum allowable viscosity: 10 β $\pm$ /s.
 - The range of recommended viscosity: 15 - 150 β $\pm$ /s.

PROCEDURES FOR TEST OPERATION

Make sure that the following shall be done before operating the engine:

1. Check whether or not actuator oil tank is clean.
2. Check whether or not pipe lines are well arranged and pump is installed to prevent tension.
3. Check whether or not pipe lines are tightly secured, according to pipe line diagram.
4. Check whether or not connecting parts and flanges are secured.
5. Check whether or not connecting parts between pump and motor are securely installed.
6. Check whether or not revolutionary direction of motor coincides with that of pump.
7. Check whether or not refined hydraulic oil is supplied from filter, and hydraulic oil is refilled up to gauge measuring point.
8. Check whether or not filter is capable of fine filtering (10 m or below).
9. Check whether or not filter is correctly installed in same direction as that of the oil road.
10. Check whether or not pump case is filled with hydraulic oil.
11. Check whether or not control valve is adjusted to location of bypass.
12. Operate the motor. Drive it at a warm temperature at a low speed.
13. Check whether or not system remains on "no load" condition when actuator gallery operates it correctly.
14. Check operating condition of actuator gallery while load is applied, when motor reaches an operation speed.
15. Check by use of monitors or built-in measuring devices.
16. Check noise level.
17. Check oil level of actuator oil tank. Refill if necessary.
18. Apply load to actuator gallery and set control valve pressure.
19. Check whether or not there are any parts having a oil leak.
20. Stop operating the motor.
21. Tighten again all bolts and plugs where oil leakage took place. (Make sure that all remaining pressure of circuit is removed before retightening.)
22. Check oil level of actuator oil tank.

23. Check whether or not pump and actuator gallery are operating properly.
24. Any irregular operation of actuator gallery indicates that air is still contained in the circuit. When all air is removed from circuit, then all parts will operate smoothly without any irregular motion and no foam will arise in actuator oil tank any longer.
25. Check temperature of actuator oil.
26. Stop operating the motor.
27. Check filter to insure that element is freed from any contamination.
28. Clean circuit if element is contaminated.



CAUTION

Be careful not to cause any damage to pump. Keep in mind the following while pump is in operation after air has come into pipe line and actuator gallery (If necessary, repair or replace actuator gallery or hydraulic oil).

1. **Fill pump housing with hydraulic oil after supplying actuator oil.**
 2. **Operate pump at a speed of 1,000 rpm or below. Make sure that oil quantity shall not fall below specified level.**
 3. **Maintain motor speed at 1,000 rpm or below when air is discharged from hydraulic circuit. Otherwise, operate actuator galleries at a cycle exceeding that, and then operate motor at idle for 5 minutes or more.**
-

MAINTENANCE AND PROTECTION

Need for maintenance of a hydraulic pump is limited to case where the actuator oil tank, especially actuator oil is replaced. Maintenance intervals may vary according to the operation hours and operation condition, and needs special interest of the operator.

CHECKING FILTERS

1. Check filters every day during the initial time of operation.
2. Check them once a week until operation has become stabilized.
3. Check them once a month after operation time exceeds 100 hours.



CAUTION

Check at the time of beginning operating whether or not filters are new after any part of the hydraulic system has been changed (for instance, additional part have been installed or pipelines have been replaced or repaired).

FILTER REPLACEMENT

1. Replace after beginning operating.
2. Replace after a lapse of 500 hours of operation.
3. Afterwards, hydraulic oil will change its property or quality hour by hour, largely on every 500 hours of operation. Check for any unusual contamination of the filter every day until the first filter has been replaced after beginning operation.



CAUTION

If the filter is a paper element replace complete assembly, as paper material cannot be washed.

REPLACEMENT OF HYDRAULIC OIL

1. After 2,000 hours of operation.
2. The replacement time period of every 2,000 hours or at other regular intervals may be shorten according to the degree of contamination and temperatures depending on the load condition of hydraulic oil.

When hydraulic oil level is low or needs replacement, keep in mind the following:

- Be sure to note the lowest and the highest operating temperature ratings of the hydraulic fluids when the equipment is being operated in the summer and winter seasons.
- Replace all hydraulic fluid.
- Be careful not to allow any foreign objects to enter the hydraulic system.
- Keep the inside of the actuator oil tank clean.
- Refill oil through the filter.

HYDRAULIC FLUID LEAKAGE CHECK

1. Check every day after starting operation.
2. When the viscosity is over the operating range, due to the low hydraulic fluid temperature, warm up the motor by operating the motor at approximately half the maximum engine speed. After that, operate the actuators at no load for a short period of time. When the oil temperature is lower than the outside temperature, the hydraulic oil tank must be preheated before operating the motor.
3. Be careful not to allow the hydraulic oil temperature to exceed 90° C.

DIAGNOSIS OF TROUBLES AND ACTIONS TO BE TAKEN

When a malfunction occurs, refer to the following table for the symptoms and perform the suggested actions to resolve the problem.

Diagnosis of Troubles with the Pump

Symptoms	Causes	Check	Remedies
Abnormal Noises	Air seeping into system due to low fluid level	Hydraulic oil level	Refill hydraulic fluid
	Loss of intake pressure due to increases in filter resistance	Check filters	Clean / replace filter
	Loss of intake pressure due to increase in oil viscosity at low temperatures	Check temperature and condition of hydraulic oil	Increase oil temperature or change to suitable oil.
	Input axle rpm is higher than the specified limit	Check input axle rpm. • Check pressure in overload condition • Check for contaminants • Check for water in hydraulic fluid	Adjust rotation speed
	Mechanical damage (bearing, etc.)	Check all major components	Replace damaged parts or replace pump • Adjust rpm. • Clean circuit • Replace oil
Insufficient Outflow Rate	Input axle rpm is low	Check input axle rpm.	Adjust rotation speed
	Abnormally high hydraulic oil temperature	Check oil temperature	Stop operation and check after oil temperature has cooled
	Increasing oil leakage in control valve and actuator gallery	Carefully examine control valve and actuator	Replace control valve and actuator
	Below optimum pump level	Carefully examine pump for problems	Replace pump
	Output control valve loose	Check lock nuts	Adjust and tighten
	Air seeping into system due to low fluid level	Check hydraulic oil level	Refill hydraulic fluid
	Loss of intake pressure due to clogged filter	Check filter	Wash or replace
	viscosity is increased and suction pressure is reduced due to low temperature	check temperature and condition of oil	raise oil temperature or replace oil

Symptoms	Causes	Check	Remedies
Pressure Does Not Increase	The relief valve set pressure is low	Check circuit oil pressure	Adjust relief valve
	Oil Leaking from control valve and actuator	Check the function of the actuators and return line pipes for overheating	Replace control valve and actuator
	Poor pump efficiency	Examine if problem originates from the pump	Replace pump
Overload At Normal Load	Increase in pump output adjustment	Check motor sound and speed	Compare and verify sound of motor and adjust output
	Control system Failure	Check movement of control system and presence of foreign objects	Repair or replace damaged parts
	Mechanical damage (bearing etc.)	Check bearing for cause of abnormal heat and noise	Repair or replace damaged parts
Decreased Revolution Speed At Varying Load	Maximum pressure in relief valve circuit	Check circuit for cause of abnormal vibration - Check pilot line for foreign objects - Check slipping of the control valve due to foreign objects	Replace relief valve. - Remove foreign objects - Repair or replace damaged parts
	Poor control valve performance		
Abnormally High Heat	Increasing pump leakage	Measure the actuator speed	Replace pump
	Mechanical damage (bearing etc.)	Check the source of noise and heat	Replace damaged parts
	Damaged rubbing surfaces	Check the source of abnormal heat	Replace damaged parts
Oil Leakage	Damaged O-rings and packings	Check area around leak and for abnormal pressure	Replace seal
	Damaged oil seals	Check for damage caused by foreign objects and for abnormal pressure	Replace seal
	Worn input axle seal		Replace input axle, seal and pump
	Loose plug	Check area around leak	Tighten and replace seal

Solenoid Valve and Relief Valve

Symptoms	Causes	Check	Remedies
Does Not Operate	Relief valve set pressure is low	Measure circuit pressure	Adjust relief valve
	Damaged or worn spool	Check for damage due to foreign objects	Replace valve
	Foreign objects in spool	Check for presence of foreign objects	Replace valve

Symptoms	Causes	Check	Remedies
Oil Leakage	Seal surface, packing or O-ring damage	Check area around leak and for abnormal pressure	Replace seal

DISASSEMBLING AND REASSEMBLING HYDRAULIC PUMP

Necessary Tools and Jigs

Disassembling and reassembling hydraulic pump needs the following tools and jigs as shown below:

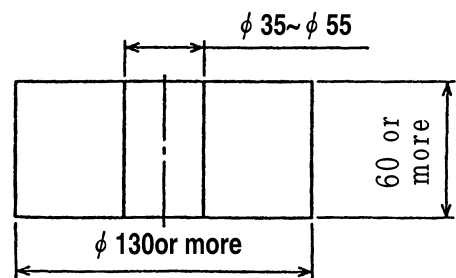
Tools

Names of Tools	Quantity	Size
Hex Wrench	1 Each	3, 6, 8, 12, 6, L=20
Spanner	1	17, 22
Plastic Hammer	1	Medium Size
Retaining Ring Pliers	1	Internal
Retaining Ring Pliers	1	External
Screw Driver	2	Medium Size
Torque Wrench	-	-
Grease	As Needed	-
Adhesive Compound	As Needed	Loctite #270

Jigs

Stand for disassembling and assembling is a plate on which the pump can be placed to face downward.

Rectangular blocks may be used in place of jig as long as end of axle does not touch the work bench.



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Figure 8

Reminders for Disassembly and Assembly

Reminders for Disassembly

1. Do not remove adjusting screws or nuts unless it is absolutely necessary. Unnecessary adjustments will affect operation and performance of equipment.
2. Be careful not to strike or drop any parts during disassembly.

Reminders for Assembly

1. Thoroughly clean all parts.
2. Be very careful not to damage any parts or allow any foreign objects to come into the parts being assembled.
3. As a rule, do not reuse O-ring and oil seal, DOOSAN recommends to use new O-rings and oil seals.
4. During assembly, always use a torque wrench to tighten all bolts and nuts to specified limits.

Disassembling Procedure

Solenoid Valve Disassembly

1. Remove hex socket head bolts (M8 x 30, 2 Each) by using a 6 mm Allen wrench.

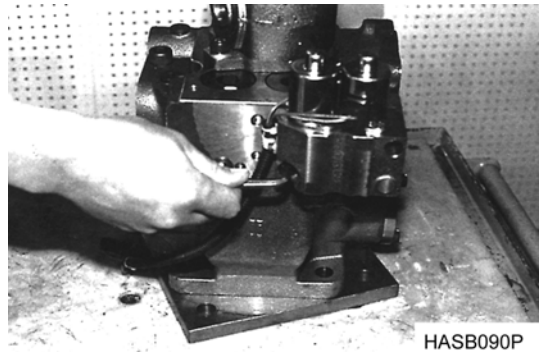


Figure 9

Gear Pump Disassembly

1. Remove hex socket bolts (M10 x 25, 2 each) by using a 8 mm allen key.

NOTE: *Be careful not to damage O-rings on the gear pump.*

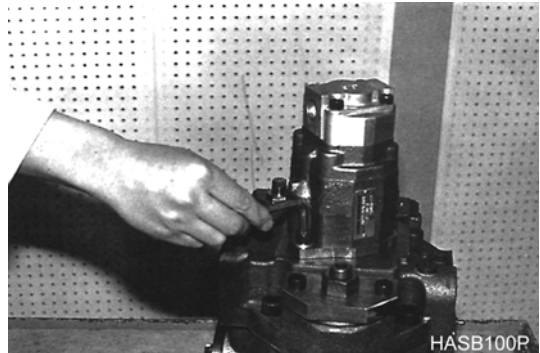


Figure 10

2. Remove couplings.

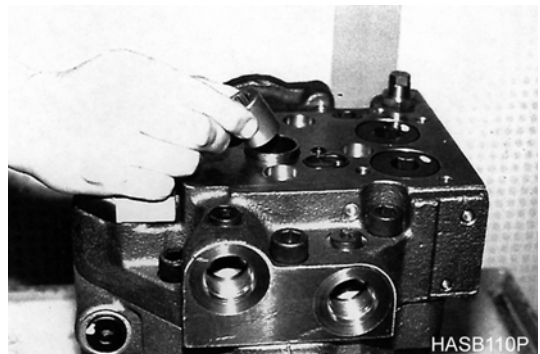


Figure 11

3. Remove bushing.

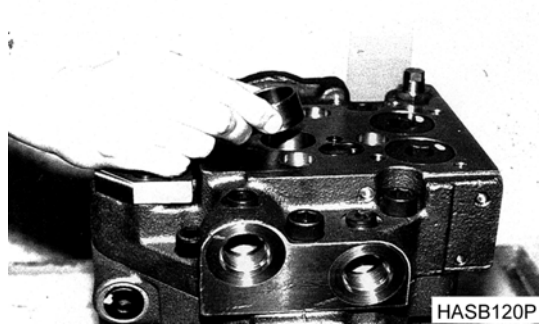


Figure 12

Main Pump Disassembly

1. Remove cover.
2. Remove Allen head bolts: (M14 x 40, 2 Each), (M14 x 65, 2 Each) and (M14 x 75, 2 Each).

NOTE: Use Allen wrench (12 mm)

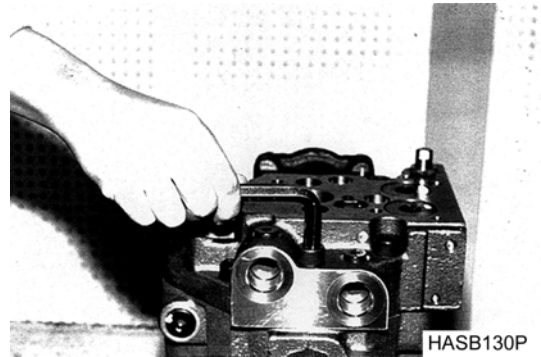


Figure 13

3. Remove cover while keeping horizontal balance. There may be some resistance, while removing cover, so lightly tap cover with a plastic hammer.

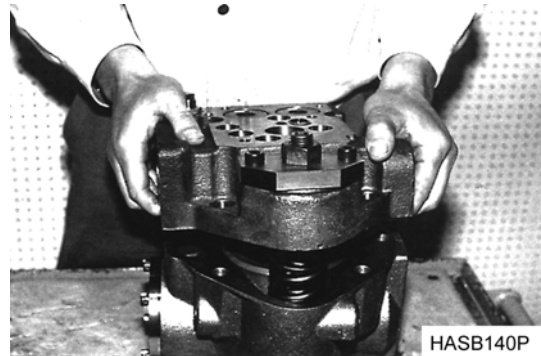


Figure 14

4. Remove gasket.

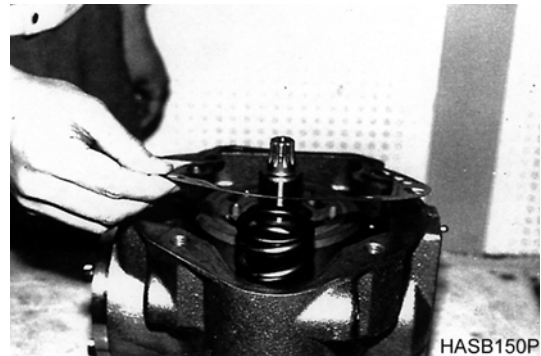


Figure 15

5. Remove components from housing.
6. Remove two springs and spring seats.
7. Remove parallel piston from housing.

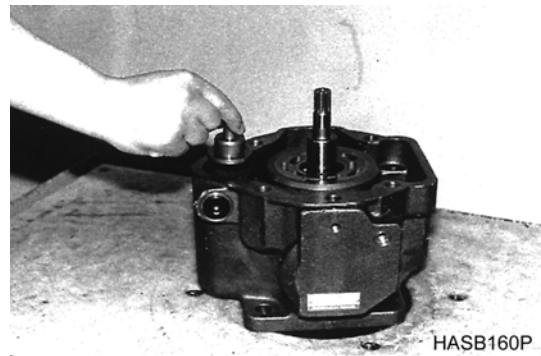


Figure 16

Rotary Group Removal

1. Lay pump on its side, and remove rotary group from the axle.

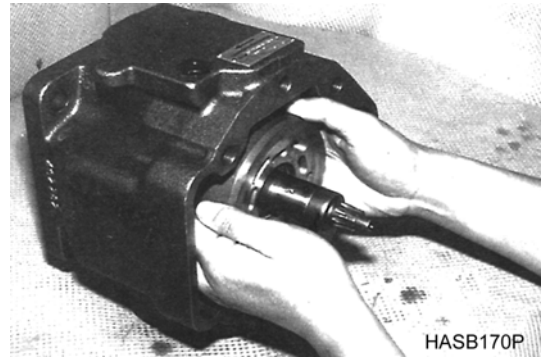


Figure 17

Axle Removal

1. Remove retaining ring (C-type) (80) using an internal retaining ring pliers.



Figure 18

2. Remove oil seal case and O-ring by using two screw drivers.

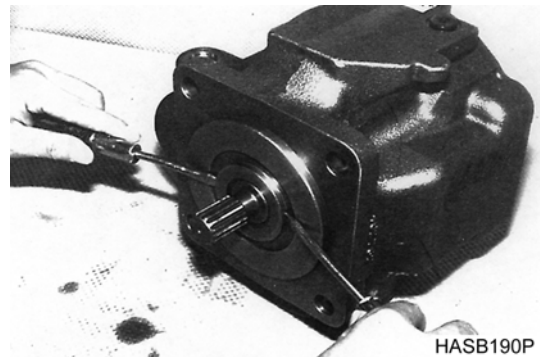


Figure 19

3. Tilting plate disassembly
4. Using an Allen wrench (6 mm), remove hex socket bolts (M8 x 22, 4 Each) and plate.

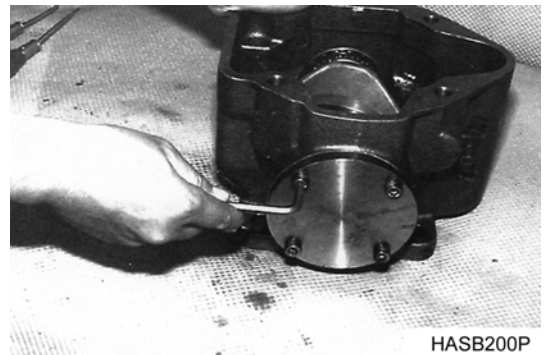


Figure 20

5. Remove O-ring, seal, and bearing (outside wheel).



Figure 21

6. Bearing (inside wheel) disassembly.
Use a brass drift (10) and tap the underside of the bearing and remove.



Figure 22

7. Remove tilting plate.

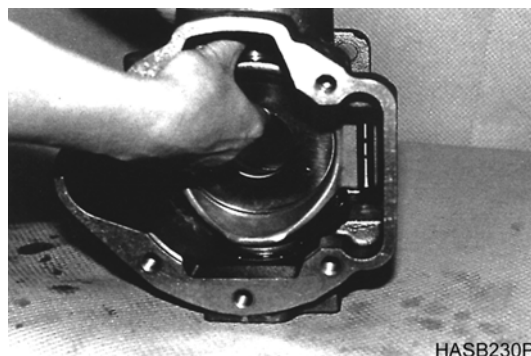


Figure 23

8. Bearing (outside ring) disassembly.
NOTE: *Perform this disassembly only when necessary.*

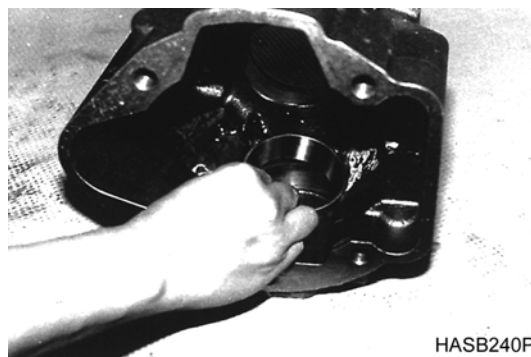


Figure 24

Cover Disassembly

1. Disassemble and remove control plate.

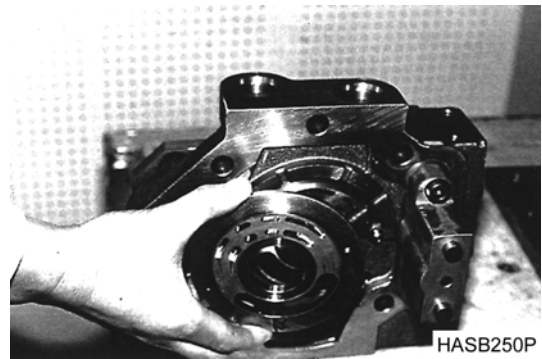


Figure 25

2. Remove two plugs (GIA).

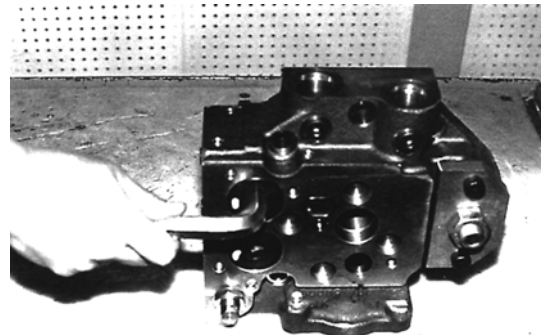


Figure 26

3. Control piston disassembly
4. Remove two spring seats, two springs and two parallel pins.
5. Two conic plate spring and spring are between the two slotted taps and the piston. Mark the right and the left for differentiation, and place them on the right side.

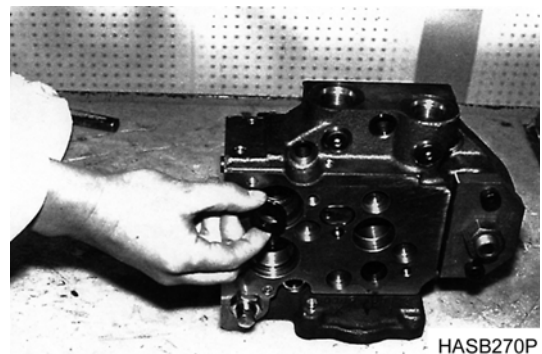


Figure 27

6. Disassembling the two pistons.
7. Mark the right and the left for differentiation.

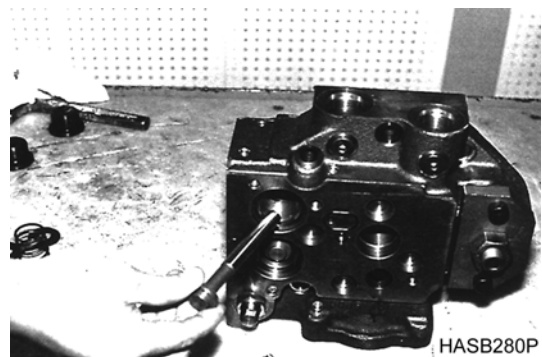


Figure 28

Disassembling Cylinder

1. Using an Allen wrench (8 mm), remove Allen head bolts (M10 x 30, 2 Each).

NOTE: Bolts are coated with Loctite #270. Disassemble them only when necessary.

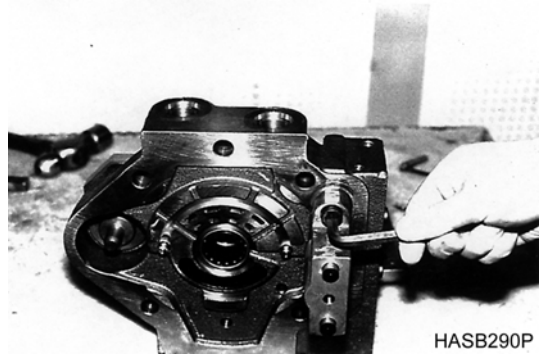


Figure 29

2. Disassemble the control spring.

NOTE: Disassemble hex nuts only when necessary. Disengage hexagon bolts (M10 x 30, 2 Each) and remove cover by using an Allen wrench (8 mm).



Figure 30

3. Disassemble spring seat.



Figure 31

4. Disassemble relief valve. Remove hex nuts.

NOTE: Disassemble this part only when necessary.

NOTE: Use wrench (24 mm)

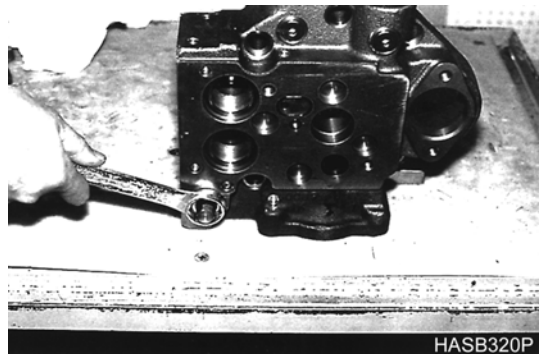


Figure 32

5. Remove adjusting screws.

NOTE: *Be careful not to lose the shim.*

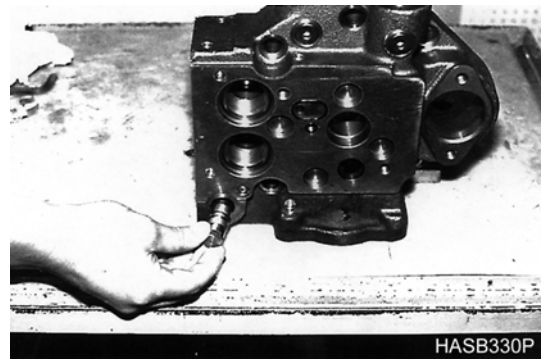


Figure 33

6. Remove springs.

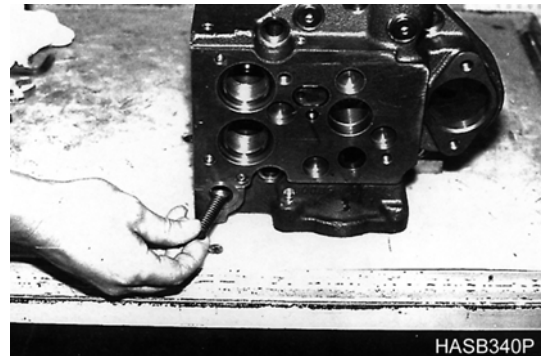


Figure 34

7. Remove spools.

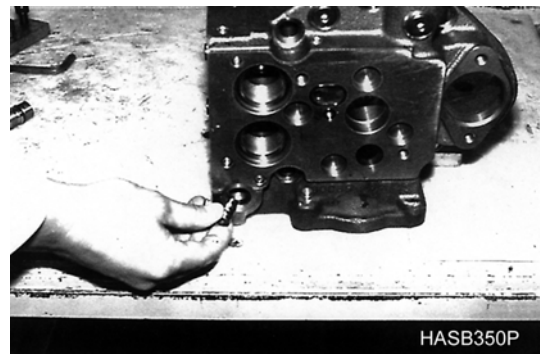


Figure 35

Gear Pump Disassembly

1. Using an Allen wrench (6 mm), remove Allen head bolts (M8 x 45, 4 each).



Figure 36

2. Remove side plate, backup ring, oblong cylindrical ring and gear.

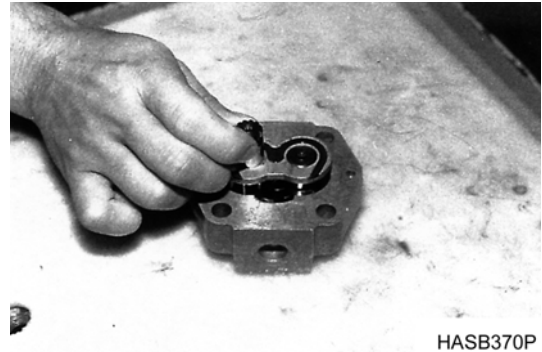


Figure 37

3. Remove idle gear.

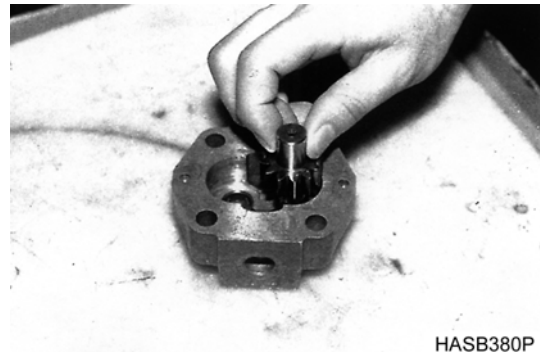


Figure 38

4. Gear pump (GSP2) disassembly
5. Using a wrench (6 mm), remove hex socket bolts (M10 x 90, 4 each).
6. Remove O-rings and filters assembled into the gear pump housing.

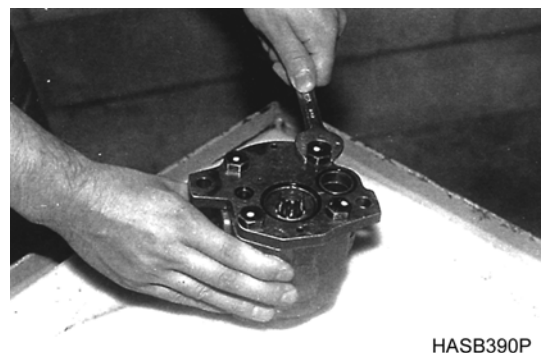


Figure 39

7. Remove front cover.

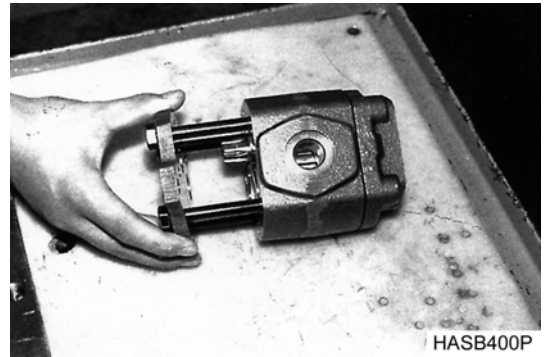


Figure 40

8. Disassemble the middle body.



Figure 41

9. Remove molded O-rings.



Figure 42

10. Disassemble plate, guide and O-ring.



Figure 43

11. Remove plate.

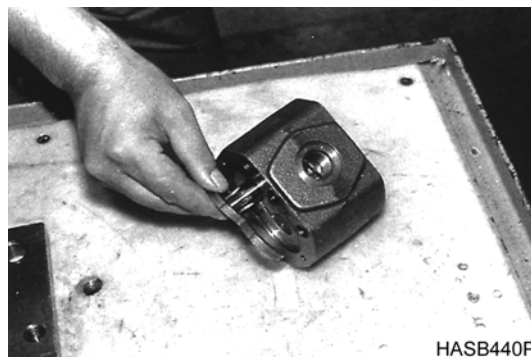


Figure 44

12. Disassemble drive gear, idle gear and side plate.

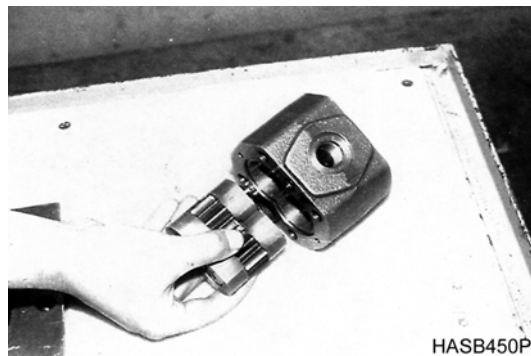


Figure 45

Disassemble Solenoid Valves

1. Using an Allen wrench (8 mm), remove Allen head bolts (M4 x 10, 4 each).

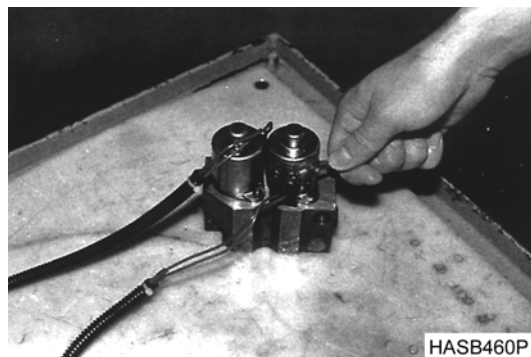


Figure 46

2. Remove solenoids.

NOTE: Be careful not to drop the push rod.

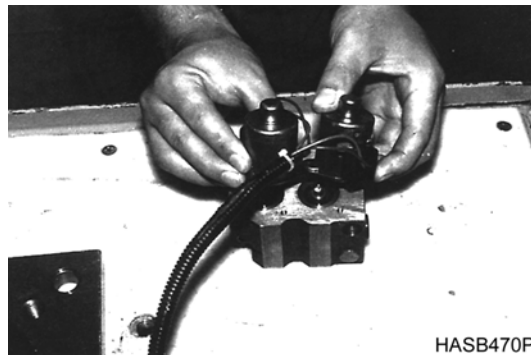


Figure 47

3. Remove spools.

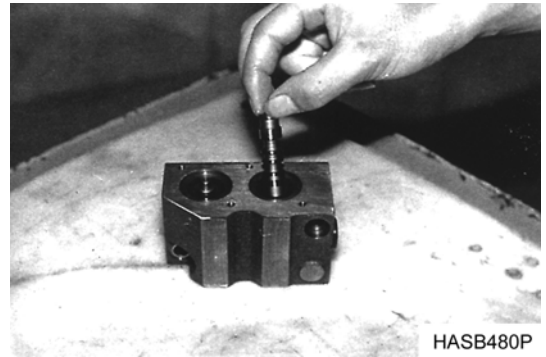


Figure 48

4. Remove O-rings.

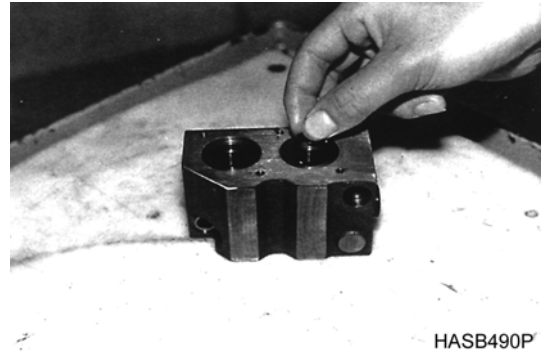


Figure 49

5. Remove springs.

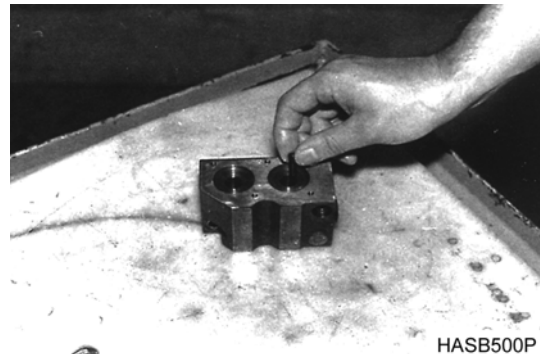


Figure 50

Standard Values for Maintenance

Wash and dry all parts thoroughly before inspection. Inspect the critical parts carefully and replace those which are found to have abnormal abrasion or damaged by impact beyond their tolerance with new ones. Replace seals, if they are found to have noticeable deformation or damage.

1. Piston Assembly and Cylinder Block

- Inspect their appearance to insure that they have no damage (particularly to the moving areas), corrosion and abnormal abrasions.
- Measure the gap between the outside diameter of the piston and the inside diameter of the cylinder block and verify that they are within acceptable limits.

Gap Limit: $D - d = 0.050 \text{ mm (0.0197")}$

Reference Number	Description
1	Piston Assembly
2	Cylinder Block

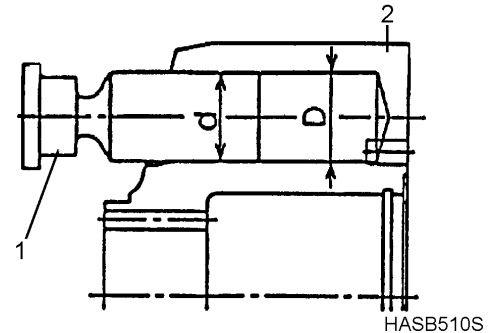


Figure 51

2. Piston Shoe and Piston

- Check gap between the piston and the piston shoe axle.

Gap Limit: $E = 0.2 \text{ mm (0.0079")}$

Reference Number	Description
1	Shoe
2	Piston

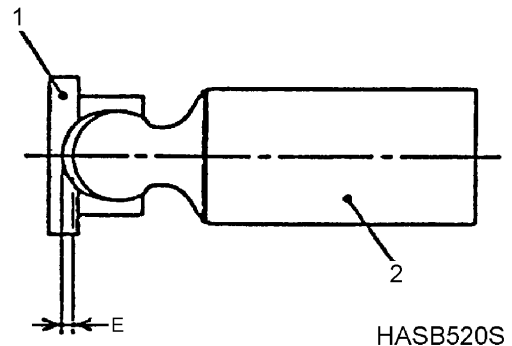


Figure 52

3. Axle

- Check surface condition of the mating area of the oil seal to the axle shaft.

Wear Limit: $A = 0.025 \text{ mm (0.0010")}$

Reference Number	Description
1	Oil Seal Seat Area

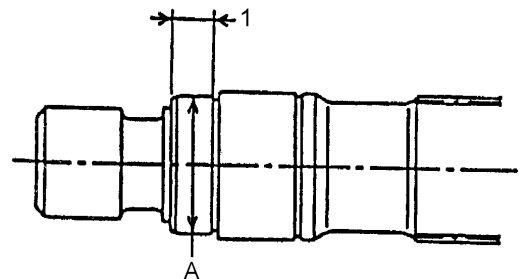
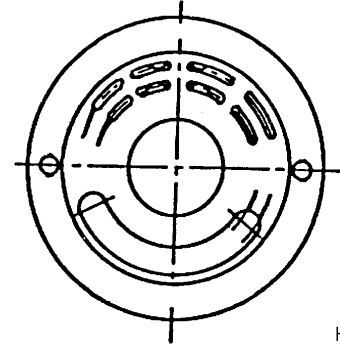


Figure 53

HASB530S

4. Control Plate

- Check for any surface damage and replace if necessary



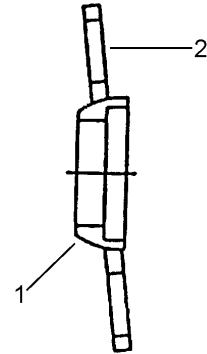
HASB540S

Figure 54

5. Guide and Retainer

- Check for any corrosion or uneven wear. If unsure, replace both guide and retainer as a set.
- Minor corrosion or damage can be removed by lapping. Wash the surface after lapping.

Reference Number	Description
1	Shoe
2	Piston



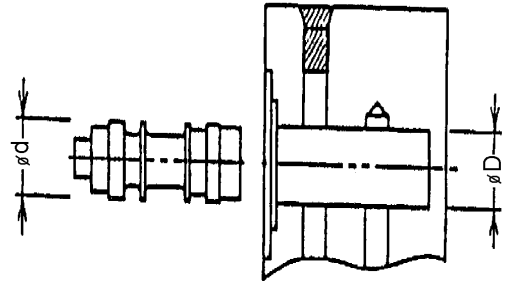
HASB550S

Figure 55

6. Solenoid Valves, A and B

Check the clearance between inside diameter of the block and the outside diameter of the spool.

Clearance: $D - d = 0.015 \text{ mm (0.0006")}$



HASB560S

Figure 56

7. Relief Valve

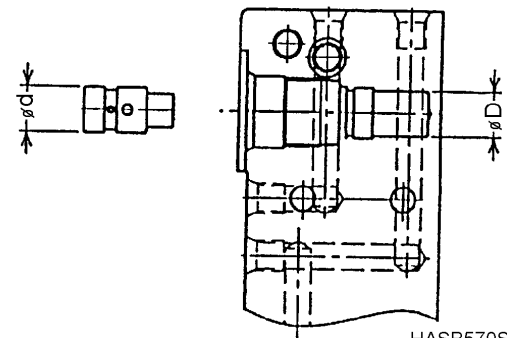
Check the clearance between the inside diameter of the cover and the outside diameter of the spool.

Clearance: $D - d = 0.015 \text{ mm (0.0006")}$

8. Relief Valve

Check the set pressure.

Set pressure: $30 \pm 0.2 \text{ kg/cm}^2 @ 6.5 \text{ l/min @ 100 rpm (427 psi @ 1.72 gpm @ 100 rpm)}$



HASB570S

Figure 57

Reassembly Procedure

Assembling Tilting Plate

1. Install bearings (outside wheel) into housing.

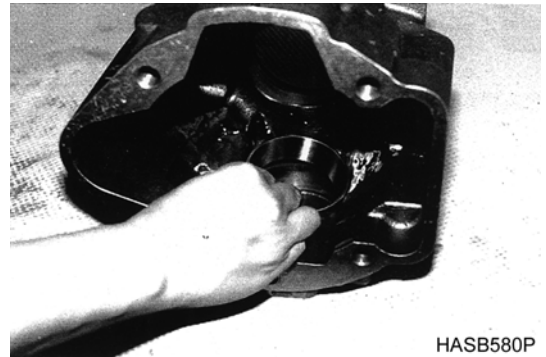


Figure 58

2. Coat backside of the plate with grease, and install tilting plate.

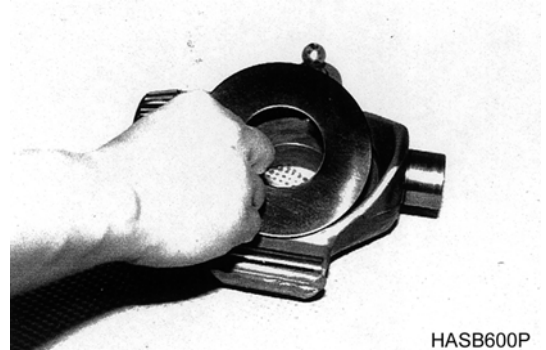


Figure 59

Reference Number	Description
1	Shiny Surface
2	Front Face
3	Rear Face

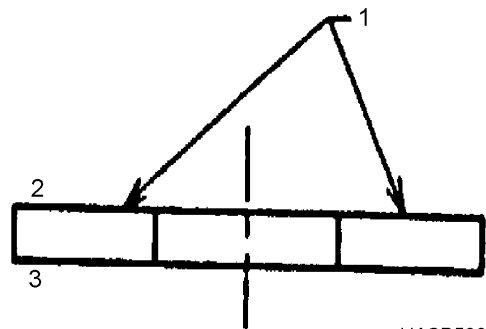


Figure 60

3. Install tilting plate into housing.

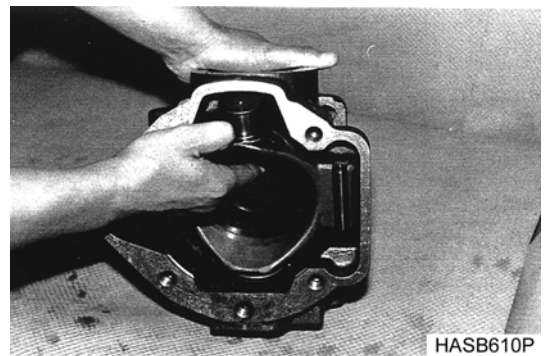


Figure 61

4. Install bearings (both inside and outside wheels).



Figure 62

5. Install seal and O-rings.



Figure 63

6. Using an Allen wrench (8 mm), install Allen head socket bolts (M8 x 22, 4 each) to mount the plate.

NOTE: *Tightening Torque 28 - 35 Nm (2.9 - 3.6 kg•m)
(21 - 26 ft lb)*



Figure 64

Assembling the Drive Axle

1. Install axle into housing. Use a plastic hammer and tap key groove to position the bearing near the end of the housing.

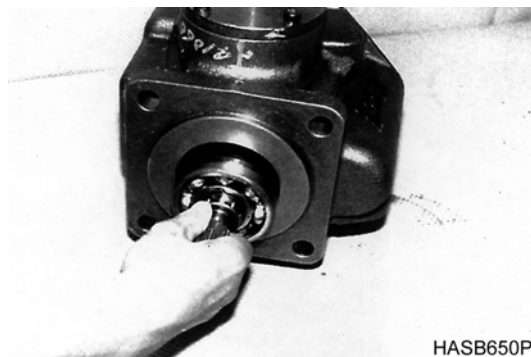


Figure 65

2. Lightly coat the O-rings with grease and install into housing.

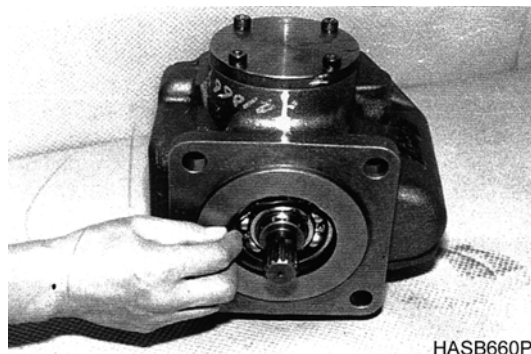


Figure 66

3. Place oil seal flat to the housing surface. Prepare oil seal by coating with grease in advance.

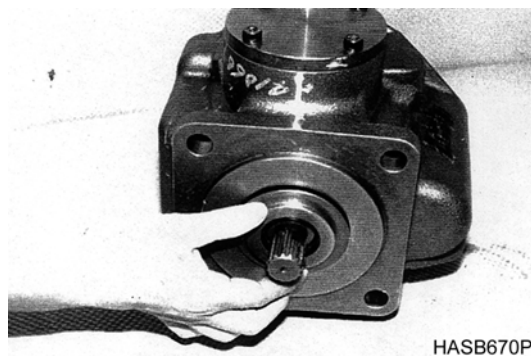


Figure 67

4. Install retaining rings to hold axle in place.

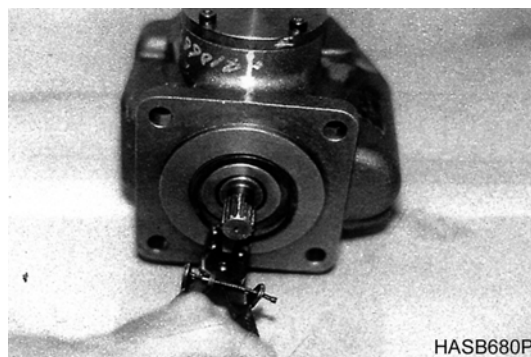


Figure 68

5. Coat three parallel pins with grease and insert them into cylinder block.

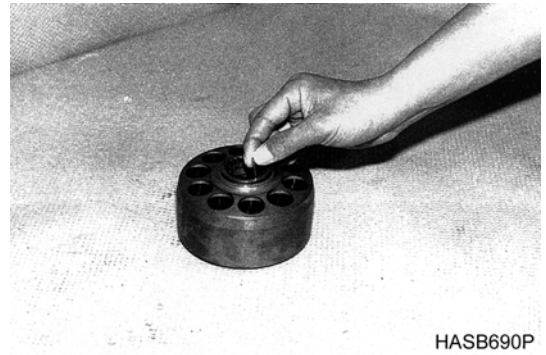


Figure 69

6. Assembling Rotary Group
7. Install ten pistons into retainer.



Figure 70

8. Coat inside of the guides with grease.
9. Install guides between retainer and cylinder block and then insert pistons into cylinder block.



Figure 71

10. Install rotary group assembly into spool axle.

NOTE: While assembling, coat the slipping face of the piston shoe and the contact points of the control plate cylinder block with grease.

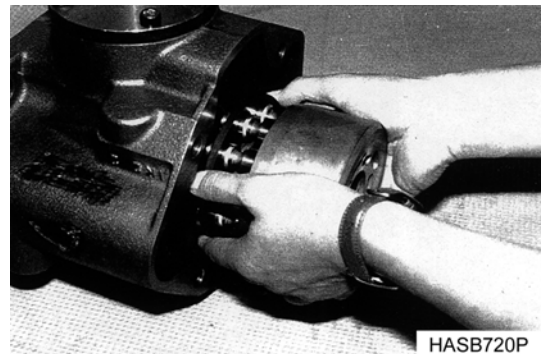


Figure 72

Assembling Control Spring

1. Coat control spring bores with grease before assembling.

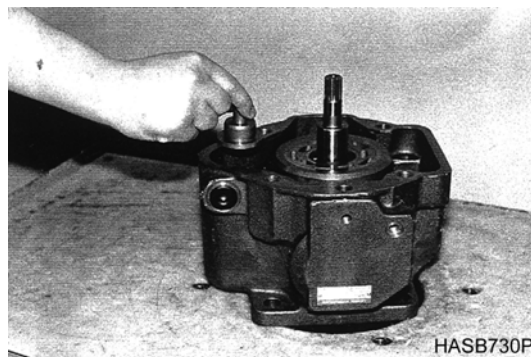


Figure 73

2. Install two springs (both internal and external).



Figure 74

3. Install spring seat and insert control spring.



Figure 75

4. Install cover with Allen head bolts.

NOTE: *Tightening Torque 55 - 69 Nm (5.6 - 7.0 kg•m)
40.5 - 50.5 ft lb)*

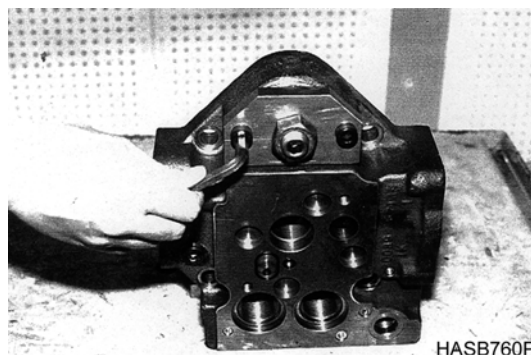


Figure 76

5. Install Allen head bolts (M10 x 30, 2 each) to mount cylinder.

NOTE: Coat bolts with Loctite #270 before tightening.

NOTE: Tightening Torque 55 - 69 Nm (5.6 - 7.0 kg•m)
40.5 - 50.5 ft lb)

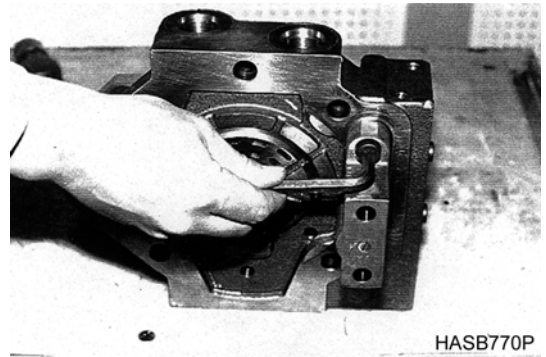


Figure 77

6. Install pistons.

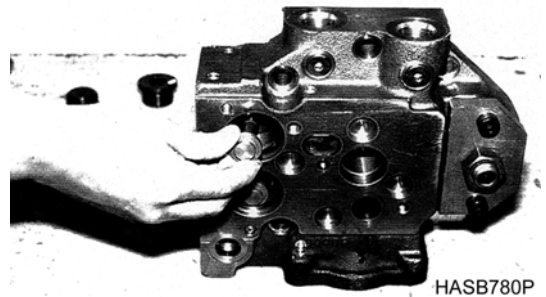


Figure 78

7. Engage a spring and a cone type plate spring (2 units).

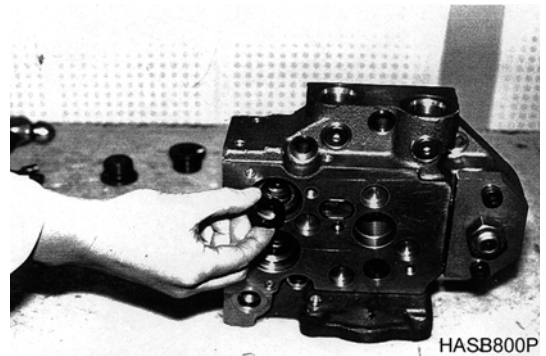


Figure 79

Reference Number	Description
1	Assembling Direction
2	Cone Type Plate Spring

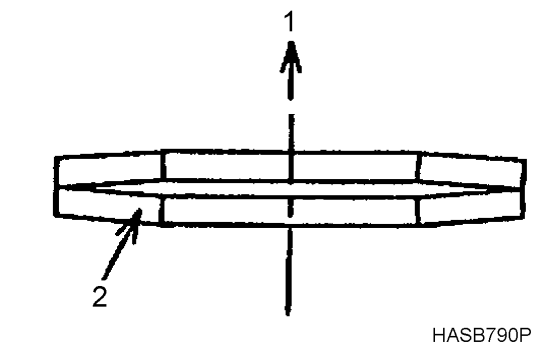


Figure 80

8. Install two plugs (GIA).

NOTE: *Tightening Torque 350 - 470 Nm (36 - 48 kg•m)
(260 - 347 ft lb)*

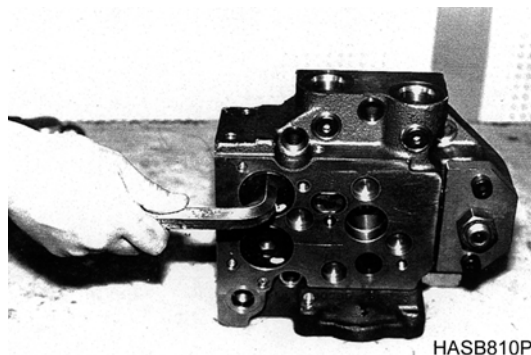


Figure 81

9. Coat parallel pins with grease and insert into cylinder.

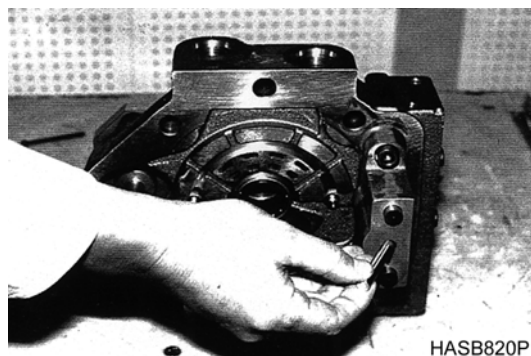


Figure 82

10. Coat rear side of control plate with grease and align plate with key groove in cover and install onto block.

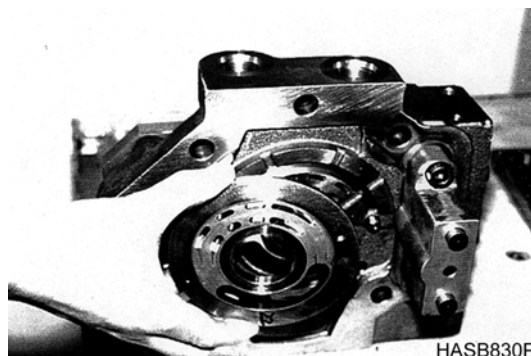


Figure 83

Assembling Relief Valve

1. Install spools.

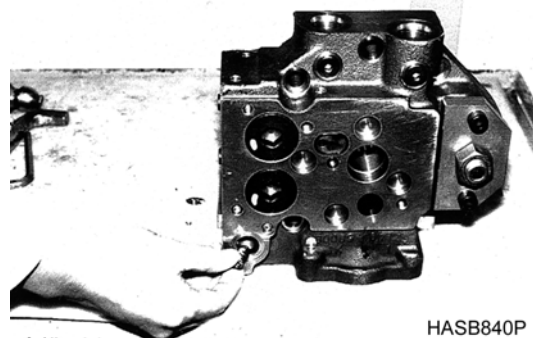


Figure 84

HASB840P

2. Insert springs into spool bore.

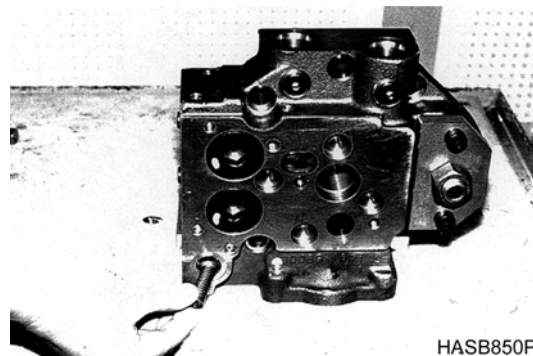


Figure 85

HASB850P

3. Insert shim(s) into adjusting bolt.



Figure 86

HASB860P

4. Insert adjusting bolt.

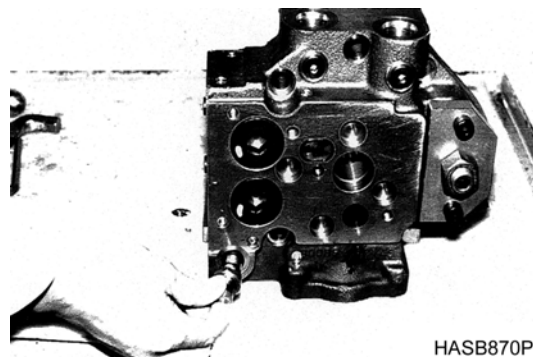


Figure 87

HASB870P

5. Tighten adjusting bolt.

NOTE: *After completing all assembly procedures tighten down adjusting bolt to torque of 9.8 Nm.*

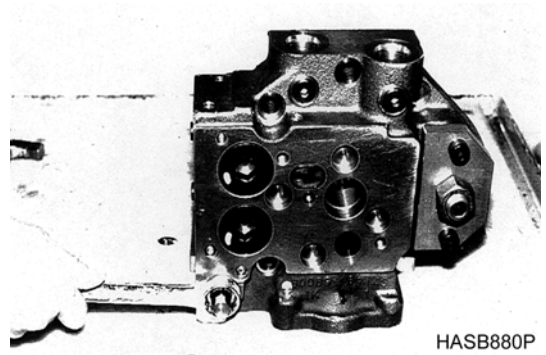


Figure 88

6. Assembling of pickings.
7. Place gasket on the housing surface and assemble the upper and lower halves of the pump together.

NOTE: *Be careful not to let aligning pins drop while assembling.*

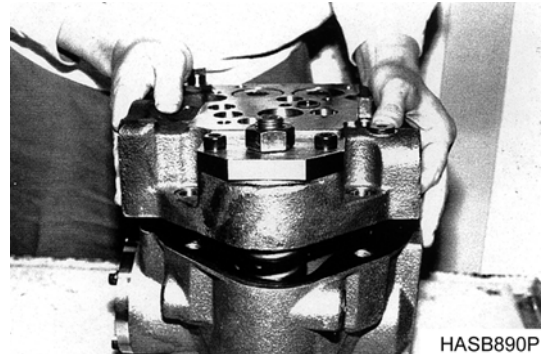


Figure 89

8. Install cover.
(M14 x 40, 2 each) (M14 x 75, 1 each)

NOTE: *Torque 150 - 180 Nm (15 - 18 kg•m) 108.50 - 130 ft lb).*

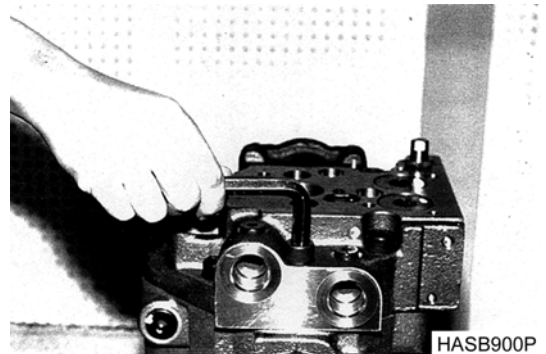


Figure 90

9. Install O-rings in cover.

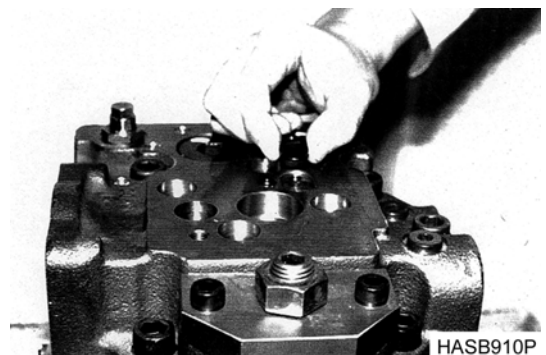


Figure 91

10. Install bushings.



Figure 92

11. Install couplings at the end of the main pump axle.

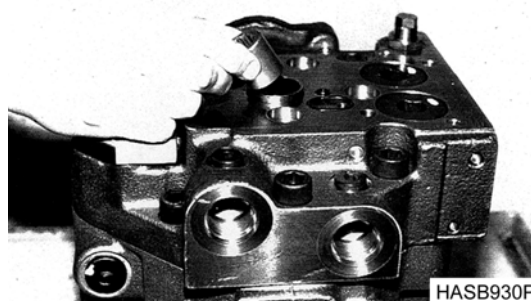


Figure 93

12. Assemble main pump and gear pump.

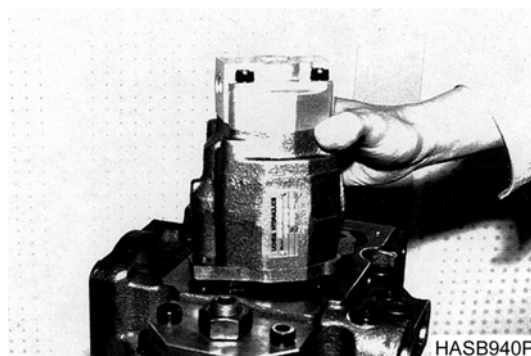


Figure 94

13. Using an Allen wrench, install hexagon bolts to hold the gear pump.

NOTE: Torque 55 - 69 Nm (5.6 - 7.0 kg•m) (40.50 - 50.63 ft lb)

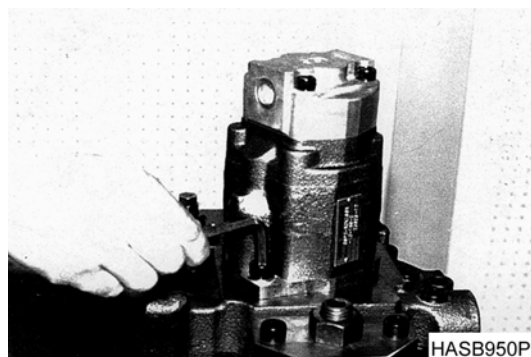


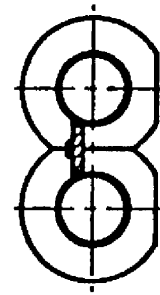
Figure 95

Assembling of the Gear Pump

1. Gear pump (GSP2)

Install square rings on the side.

Reference Number	Description
1	Intake Side
2	Discharge Side
3	Direction of Inserting Square Rings



HASB960P

Figure 96

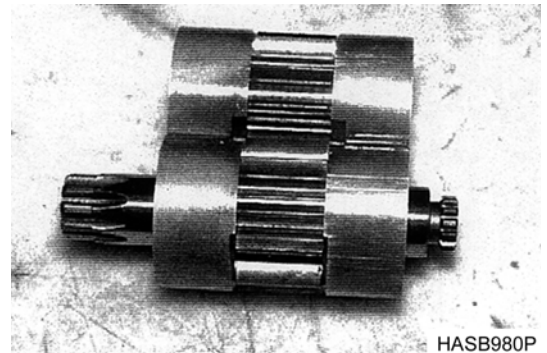
NOTE: *Be careful not to reverse the directions of intake and exhaust sides.*



HASB970P

Figure 97

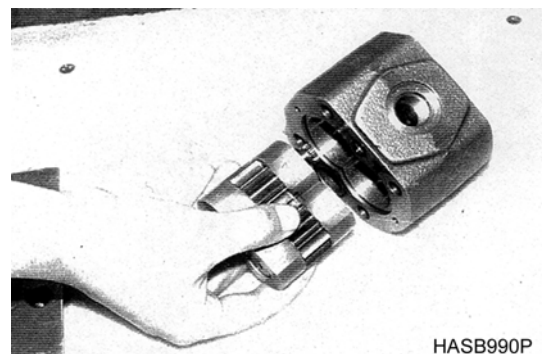
2. Install drive axle and idle gear on the side plate.



HASB980P

Figure 98

3. Install drive axle, idle gear and side plate.



HASB990P

Figure 99

4. Engage O-ring in guide, and then insert them into plate.

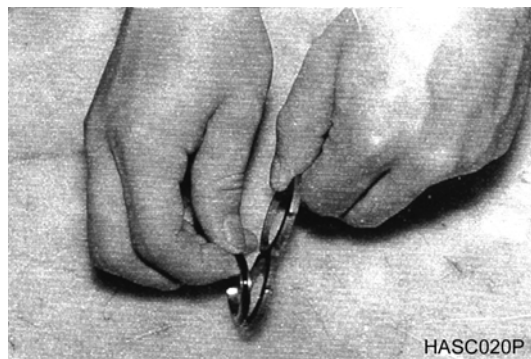


Figure 100

Reference Number	Description
1	Face With Large Radius
2	Guide

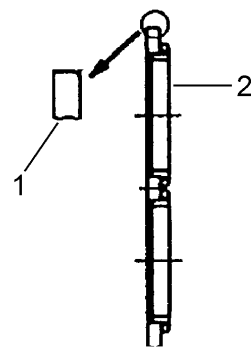


Figure 101

5. Assemble plate, guide and O-ring.

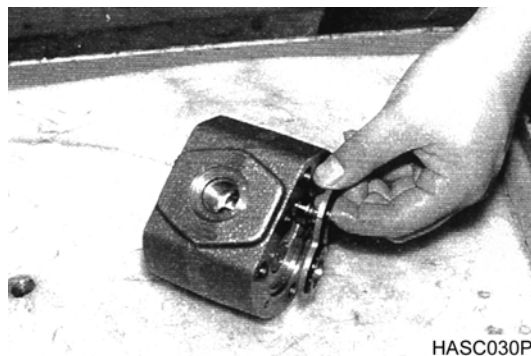


Figure 102

6. Assemble two plates. Be careful not to reverse the directions of the intake and exhaust sides.

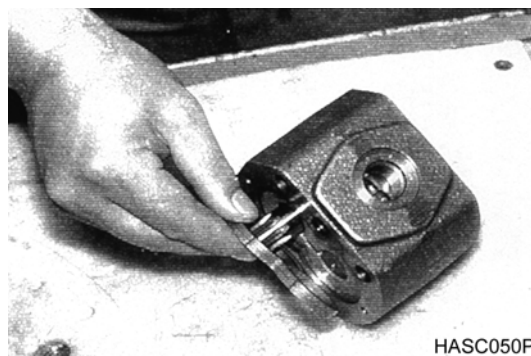
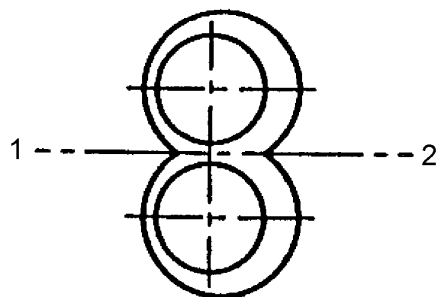


Figure 103

Reference Number	Description
1	Intake Side
2	Discharge Side



HASC040S

Figure 104

7. Install square ring.



HASC060P

Figure 105

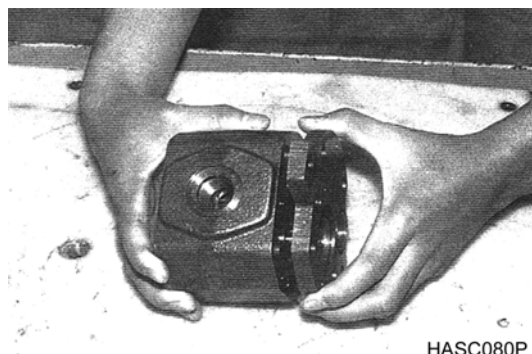
8. Insert two alignment pins into front cover.



HASC070P

Figure 106

9. Install front cover.

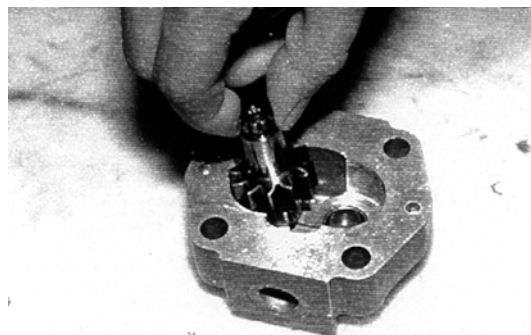


HASC080P

Figure 107

Assembling Gear Pump (G1)

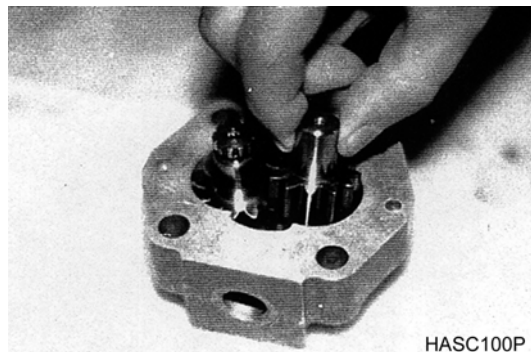
1. Insert drive gear into housing.



HASC090P

Figure 108

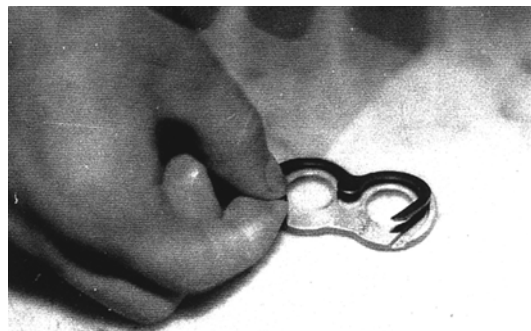
2. Insert idle gear.



HASC100P

Figure 109

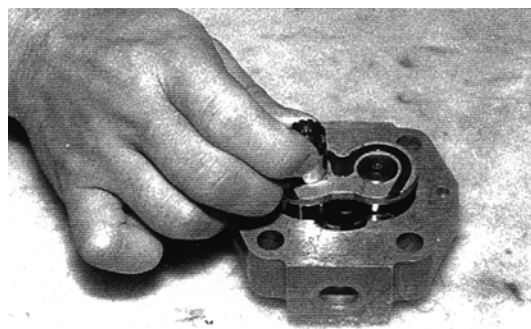
3. Coat square rings with grease. Assemble making certain the backup ring is in place.



HASC110P

Figure 110

4. Install side plate (assembled in step 12), into housing.



HASC120P

Figure 111

5. Install two aligning pins in the middle housing.

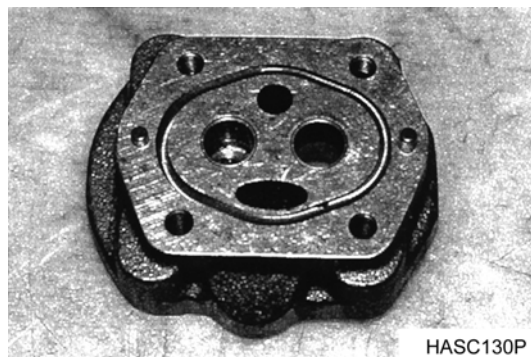


Figure 112

6. Install O-ring into middle housing.

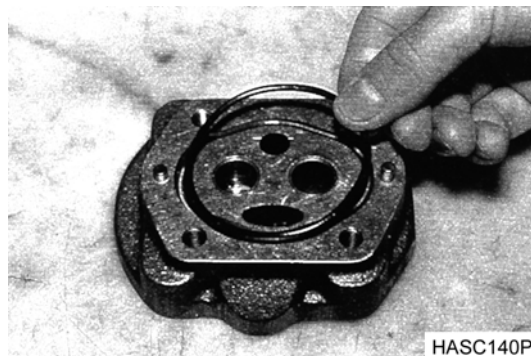


Figure 113

7. Assemble the two middle housings.

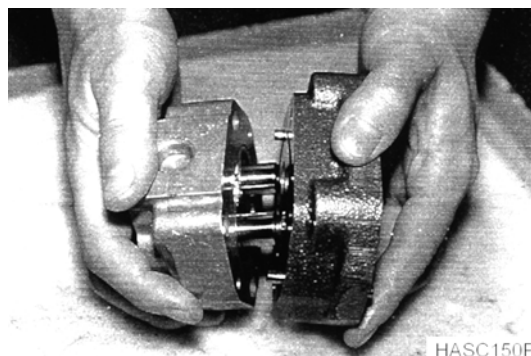


Figure 114

8. Install socket head bolts to secure housing.

NOTE: Tightening Torque 29 Nm (3 kg•m) (21.70 ft lb).



Figure 115

9. Insert aligning pins into the middle housing.



Figure 116

10. Place the Gear Pump (GSP2) on its side and install coupling to the end of axle.

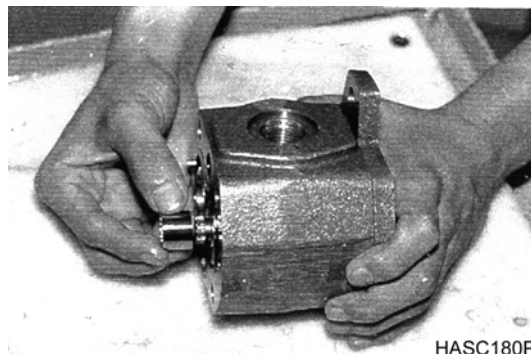


Figure 117

11. Assemble two Gear Pumps (GSP2 and G1).

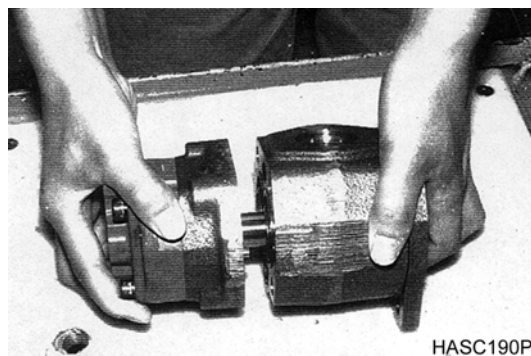


Figure 118

12. Install Allen head bolts to secure the two gear pumps (GSP2 and G1).

NOTE: *Tightening Torque 59 Nm (6 kg•m) (43.40 ft lb)*

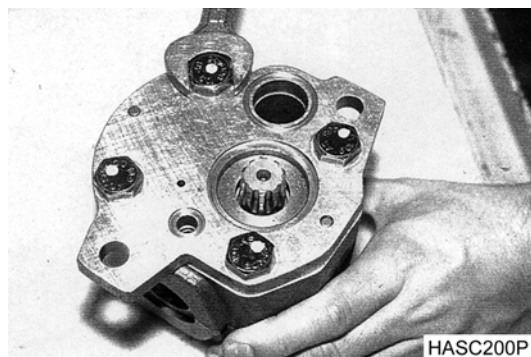


Figure 119

13. Install O-ring and filter in the front housing.



Figure 120

HASC210P

Assembling Solenoid Valves

1. Insert springs.

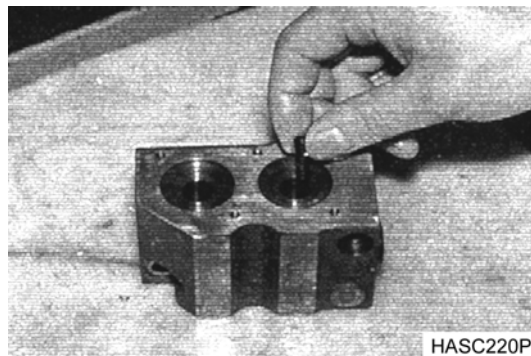


Figure 121

HASC220P

2. Insert spools.

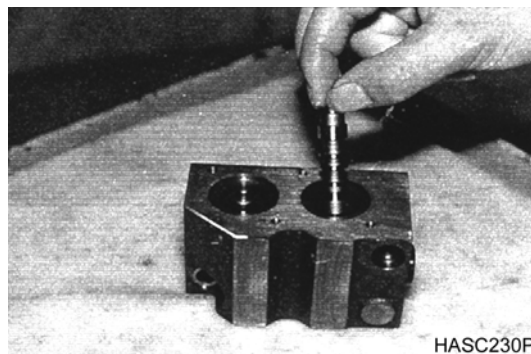


Figure 122

HASC230P

3. Install O-rings.

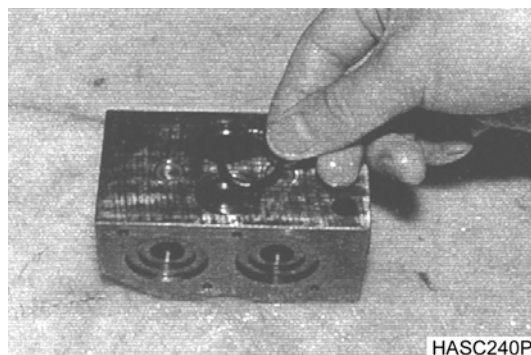


Figure 123

HASC240P

4. Install solenoids.

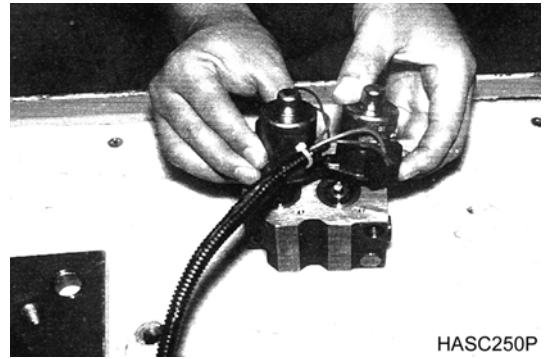


Figure 124

5. Install socket head bolts to secure solenoid in place.(M4 x 10, 4 each)

NOTE: *Tightening Torque 3 - 4 Nm (0.35 - 0.45 kg•m)
(2.53 - 3.25 ft lb).*

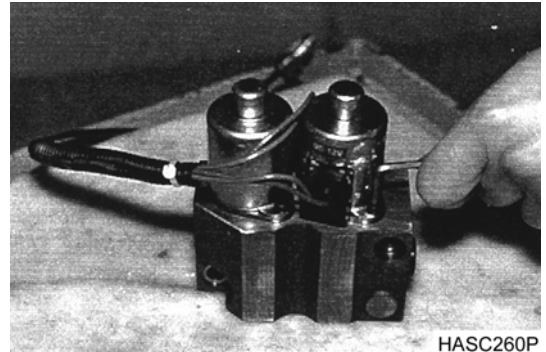


Figure 125

6. Install O-ring.

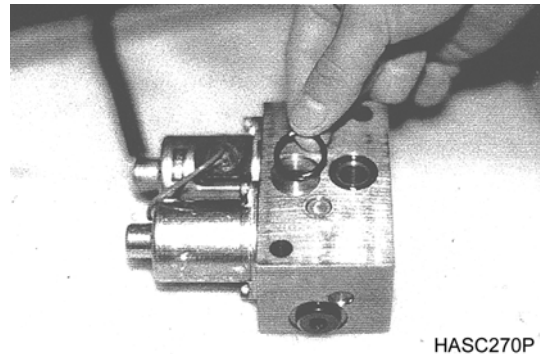


Figure 126

7. Mount solenoid assembly onto main pump using socket head bolts. (M4 x 10, 4 each)

NOTE: *Tightening Torque 28 - 35 Nm (2.9 - 3.6 kg•m)
(21 - 26 ft lb)*

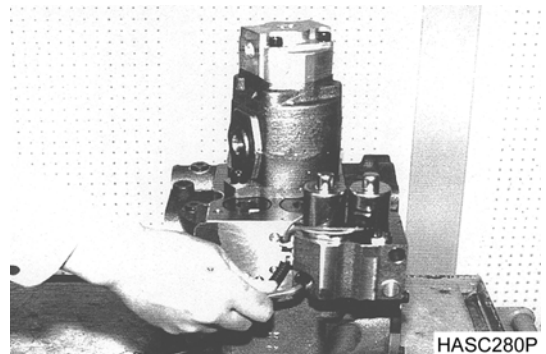


Figure 127

Remote Control Valve (Work Lever / Joystick)

Edition 1

MEMO

Table of Contents

Remote Control Valve (Work Lever / Joystick)

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

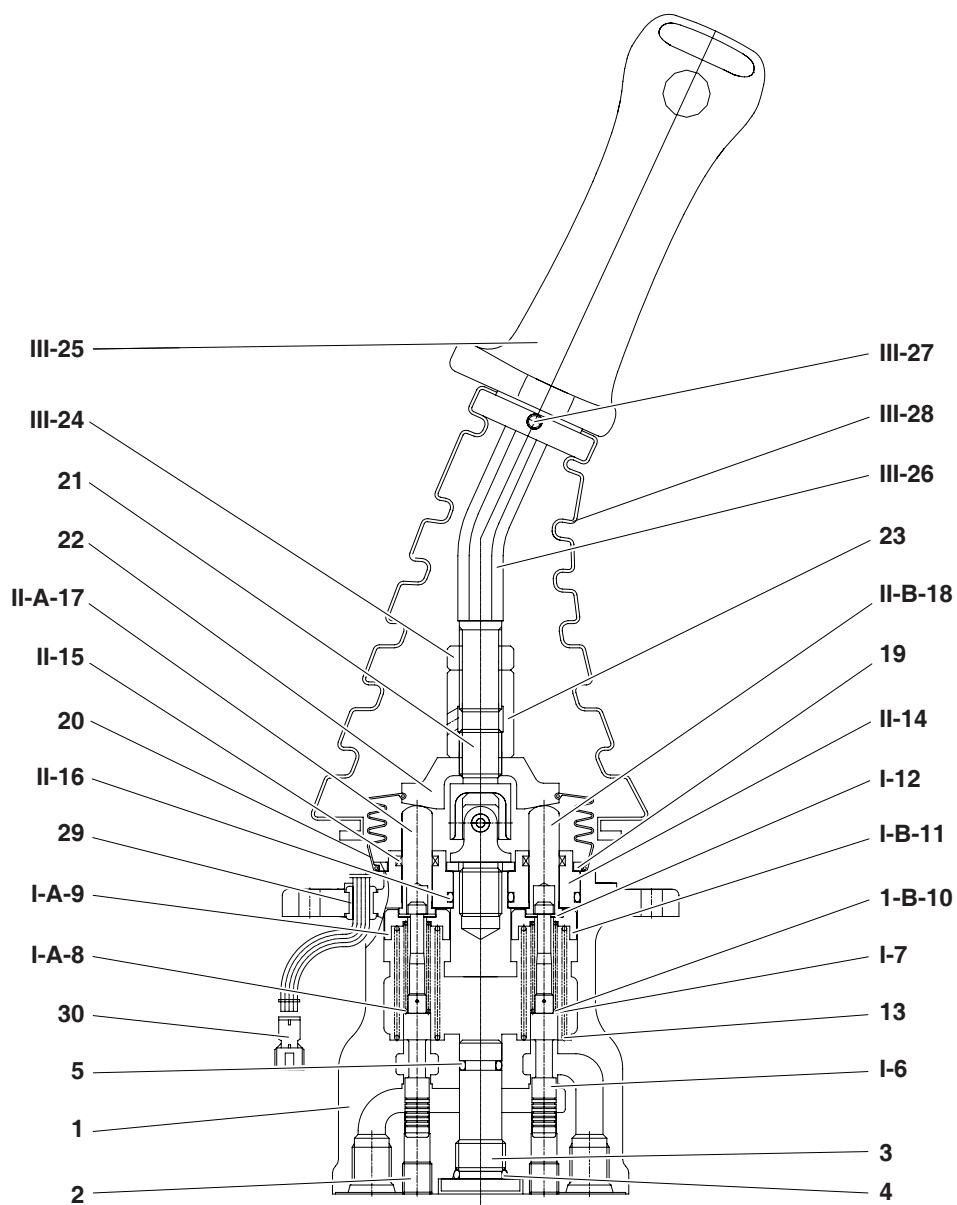
Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

STRUCTURE DIAGRAM



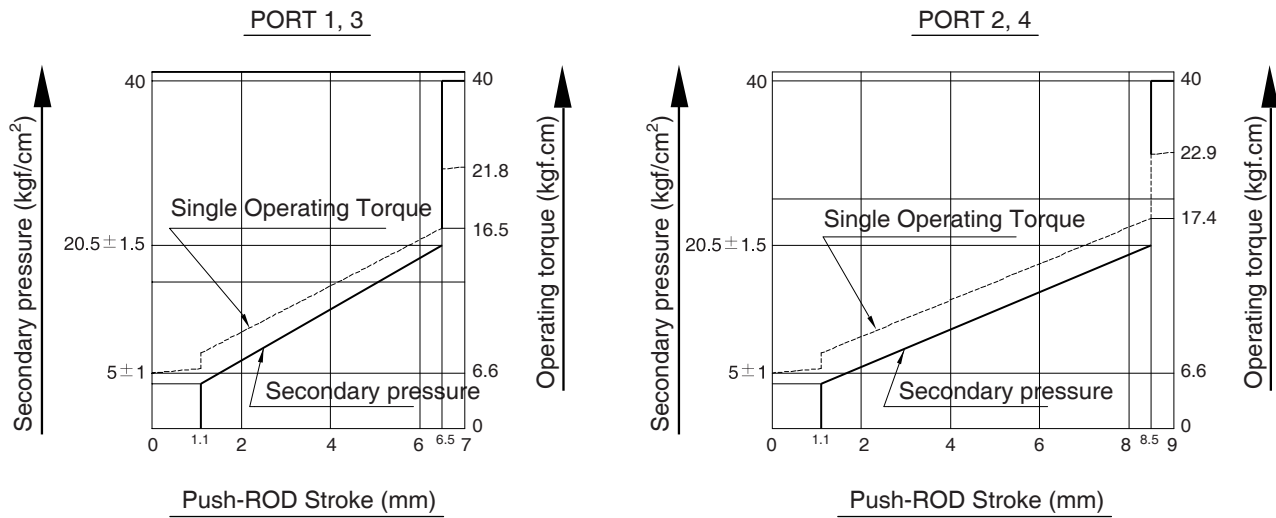
FG010350

Figure 1

PARTS LIST

No.	Part Name	Standard	Material	Q'TY	Remark	RSP
1	Case			1	J95C1001	O
2	Plug	PT 1/8	SCM440	4	WPT18	O
3	Plug	PF 3/8		1	J95C1002	O
4	O-Ring	P14	N,B,R	1	PO 014	X
5	O-Ring	P10A	N,B,R	1	PO 010A	X
I-A	Spool Kit	Port 1, 3			JA6H6011	O
I-B	Spool Kit	Port 2, 4			JA6H6012	O
I-6	Spool			4	J95C1003	X
I-7	Shim			AR	J95C1004	X
I-A-8	Spring	Port 1, 3		2	J95C1005	X
I-A-9	Spring Seat	Port 1, 3		2	J95C1006	X
I-A-10	Spring	Port 2, 4		2	J96C1008	X
I-A-11	Spring Seat	Port 2, 4		2	J96C1009	X
I-12	Stopper			4 set	J24D2011	X
13	Spring			4	J96C2001	O
II-A	Plug Kit	Port 1, 3			JA7L4013	O
II-B	Plug Kit	Port 2, 4			JA7L4014	O
II-14	Plug			4	JA2M5017A	X
II-15	Rod Seal	10×16×4.5	N.B.R	4	C1-1008	X
II-16	O-Ring	4D-P20	FKM	4	PO 020(F)	X
II-A-17	Push Rod	Port 1, 3			J95C1009	X
II-B-18	Push Rod	Port 2, 4			J96C1001	X
19	Plate			1	JA1G1002	O
20	Boot			1	J97A5018	O
21	Joint Ass'y			1	J95C1012	O
22	Swash Plate			1	J97A5016	O
23	Hex Nut			1	J95C1014	O
III	Handle Kit	LH			JA7L4015	O
III	Handle Kit	RH			JA7L4016	O
III-24	Nut			1	HNM14	X
III-25	Handle Ass'y	LH		1 set	JA2M5010	X
III-25	Handle Ass'y	RH		1 set	JA2M5011	X
III-26	Handle Bar			1	JA7L4001	X
III-27	Spring Pin			1	SP0528	X
III-28	Bellows			1	JA2M5012	X
29	Bushing			1	JA1G1003	O
30	Connector Ass'y			1 set	JA2M5013	O
IV	Seal Kit	4,5, II-15, II-16			JA7L4017	O

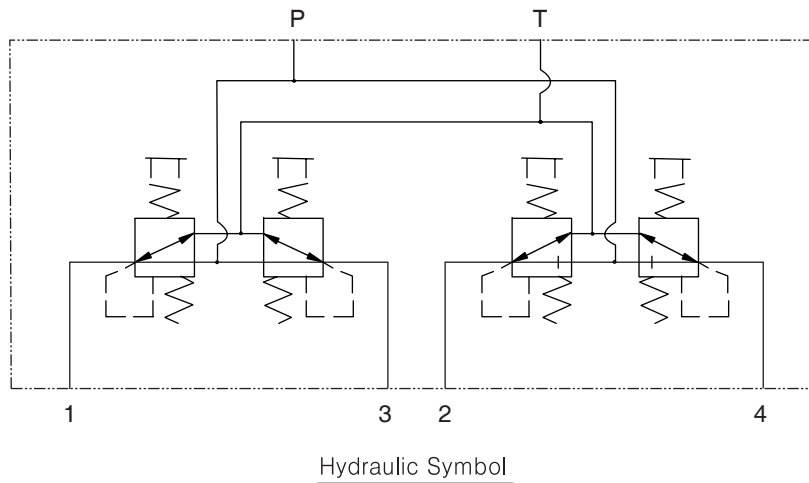
PERFORMANCE SPECIFICATION



FG013465

Figure 2

HYDRAULIC PRESSURE CIRCUIT DIAGRAM



FG011413

Figure 3

DISASSEMBLY AND ASSEMBLY TOOL

Part no.	Tool	Specification	Remarks
21	Driver	- type	
29	Driver	- type	Small size
22	Spanner	27 mm	
22	Spanner	22 mm	
III-26	Spanner	13 mm	

DISASSEMBLY METHOD

1. Separate the HANDLE KIT (III) from the HEX NUT (23).

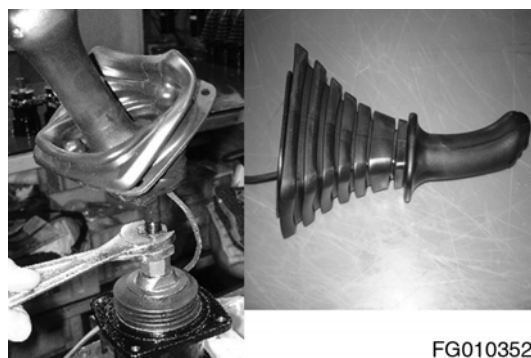


Figure 4

FG010352

2. Separate the BOOT (20) from the SWASH PLATE (22).



Figure 5

FG010353

3. Separate the HEX NUT (23) from the SWASH PLATE (22), and remove the SHAWH PLATE (22).



Figure 6

4. Separate the JOINT ASS^ØY (11) from the BODY (1).

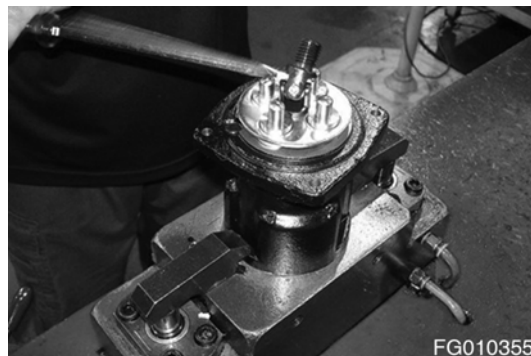


Figure 7

5. Remove the PLATE (19) and separate the PLUG KIT ((II-A, II-B) from the BODY (1).

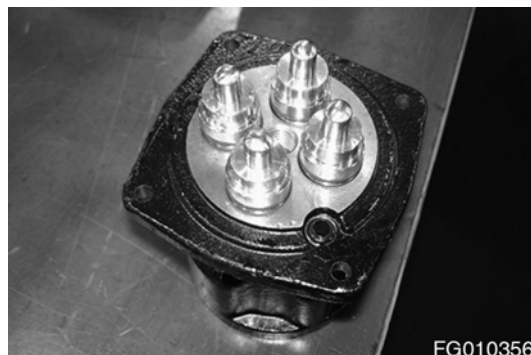


Figure 8

6. Separate the BUSHING (29) from the BODY (1).

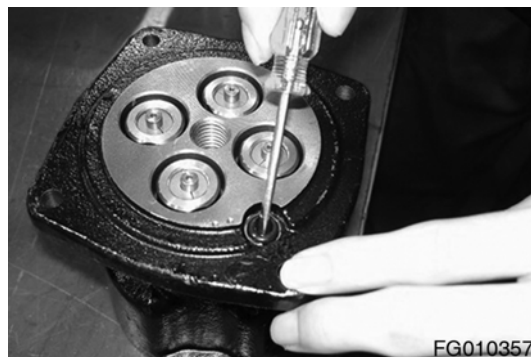


Figure 9

7. Separate the SPOOL KIT (I-A, I-B) from the BODY (1).

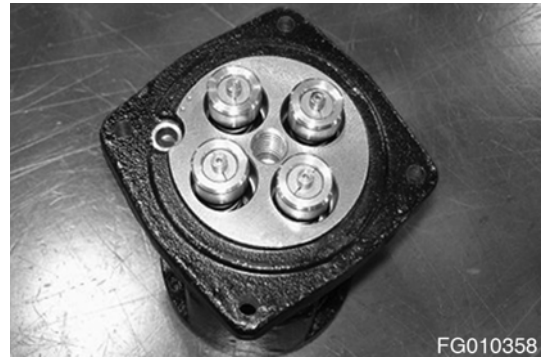


Figure 10



Figure 11

8. Separate SPRING (13) from the BODY (1).

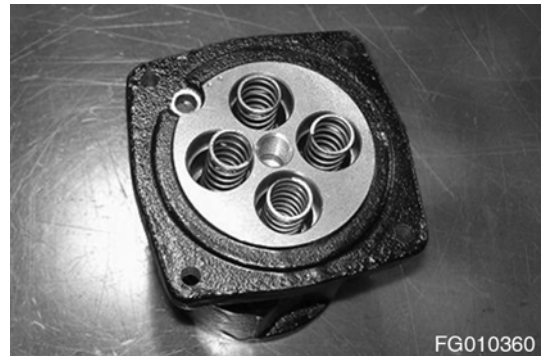


Figure 12

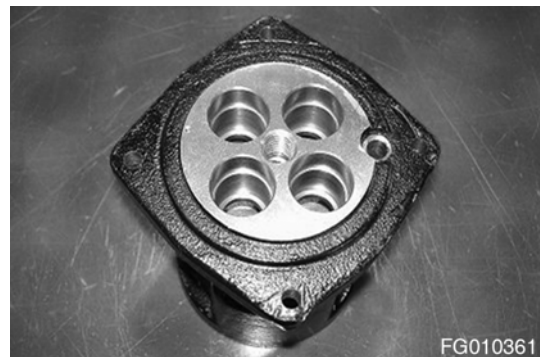


Figure 13

ASSEMBLY METHOD

1. Assemble the SPRING (13) to the BODY (1).

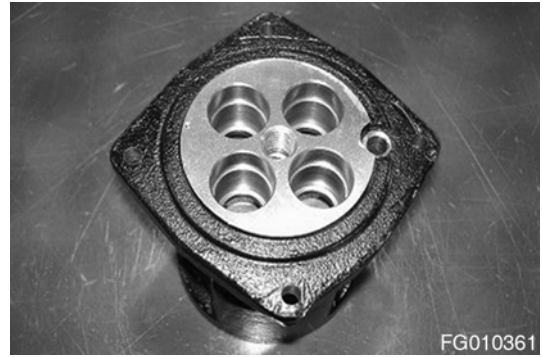


Figure 14

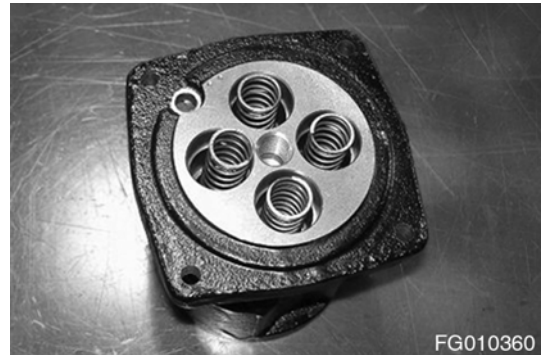


Figure 15

2. Assemble the SPOOL KIT (I-A, I-B).

Assembly order

SPOOL KIT(I-A) : SPOOL(I-6) SHIM(I-7) → SPRING(I-A-8) → SPRING SEAT(I-A-9) → STOPPER(I-12)

SPOOL KIT(I-B) : SPOOL(I-6) SHIM(I-7) → SPRING(I-B-10) → SPRING SEAT(I-B-11) → STOPPER(I-12)

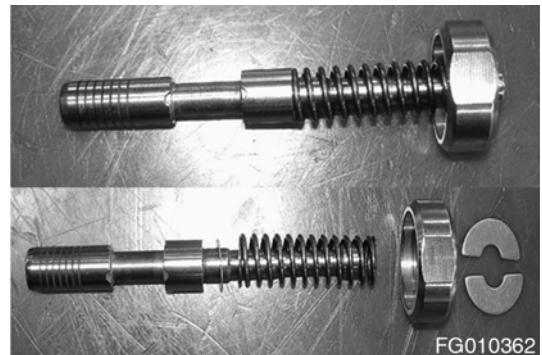


Figure 16

3. Assemble the SPOOL KIT (I-A, I-B) BODY (1).

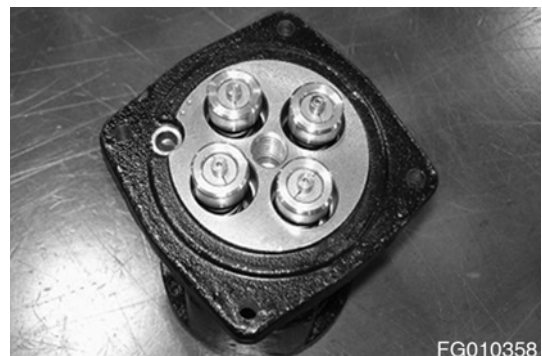


Figure 17

4. Install the BUSHING (29) on the BODY (1).

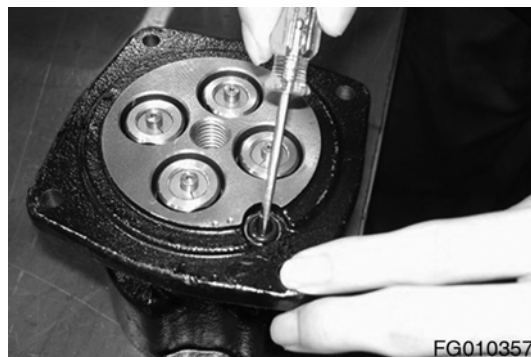


Figure 18

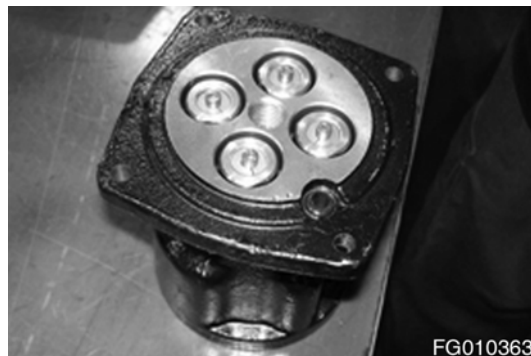


Figure 19

5. Assemble the PLUG KIT (II-A, II-B).

Assembly order

PLUG KIT(II-A) : PLUG(II-14) → PUSH ROD(II-A-17)

PLUG KIT(II-B) : PLUG(II-14) → PUSH ROD(II-B-18)



Figure 20



Figure 21

6. Install the PLUG KIT (II-A, II-B) on the BODY (1).

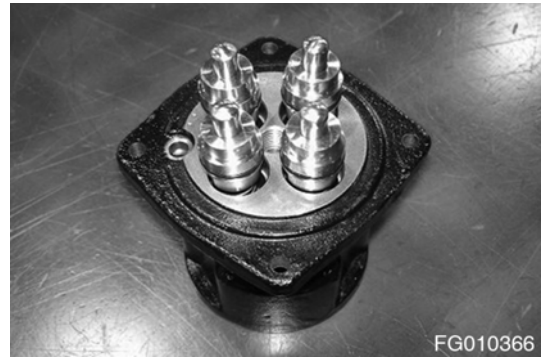


Figure 22

7. Install the PLATE (19).



Figure 23

8. Assemble the BODY (1) to the JOINT Ass'y (21).



Figure 24

9. Apply enough grease on the PUSH ROD and JOINT Ass'y part.



Figure 25

10. Insert the SWASH PLATE (22) and assemble the HEX NUT (23).



Figure 26

11. Use the spanner to fixate the HEX NUT (23) firmly to the BODY (1).



Figure 27

12. Install the BOOT (20) on the SWASH PLATE (22).



Figure 28

13. Assemble the HANDLE KIT (III) to the HEX NUT (23).
Insert the wire in the BUSHING (29).



Figure 29



Figure 30

Dozer Valve

Edition 1

MEMO

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Dozer Valve

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Disassembly	9
Assembly Method.....	11

MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX55	50001 and Up
DX60R	50001 and Up

STRUCTURE DIAGRAM

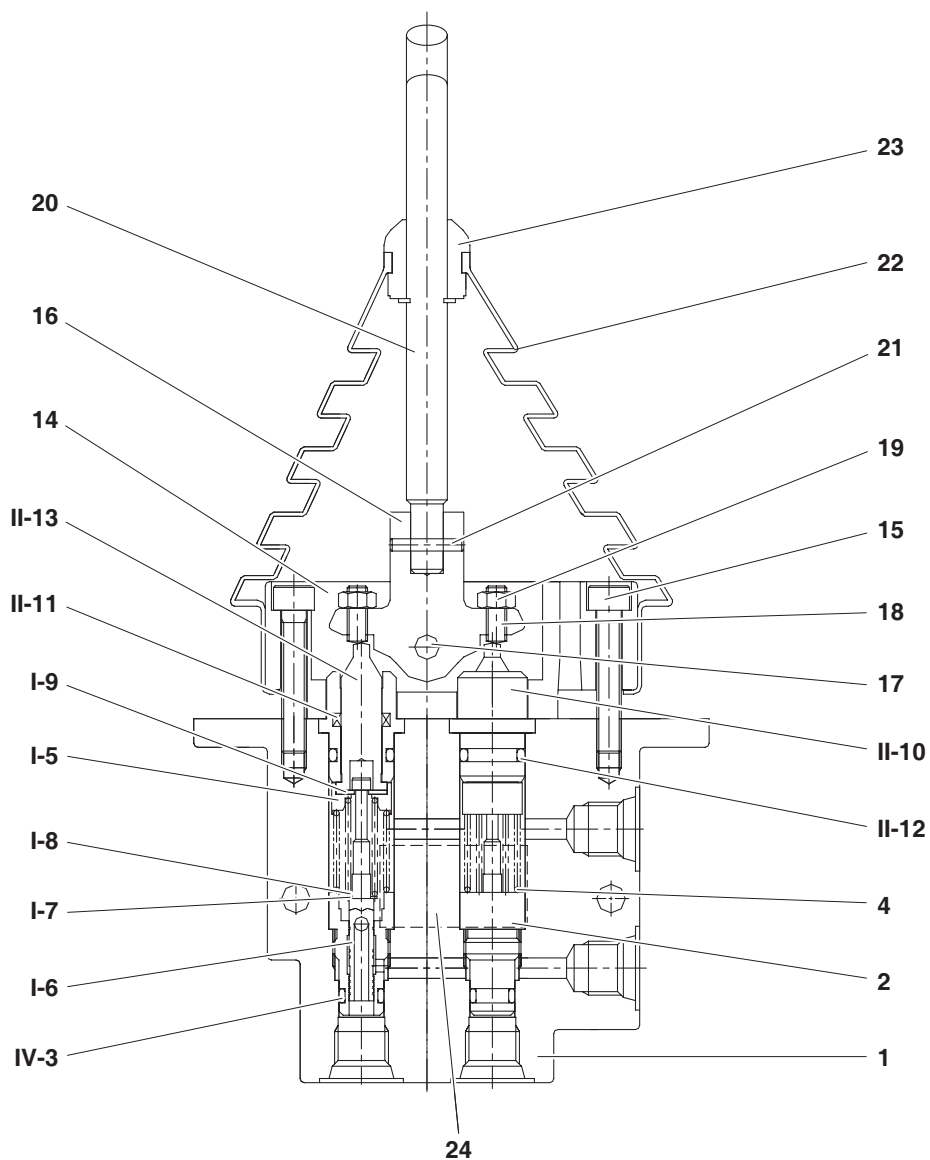


Figure 1

FG010372

PERFORMANCE SPECIFICATION

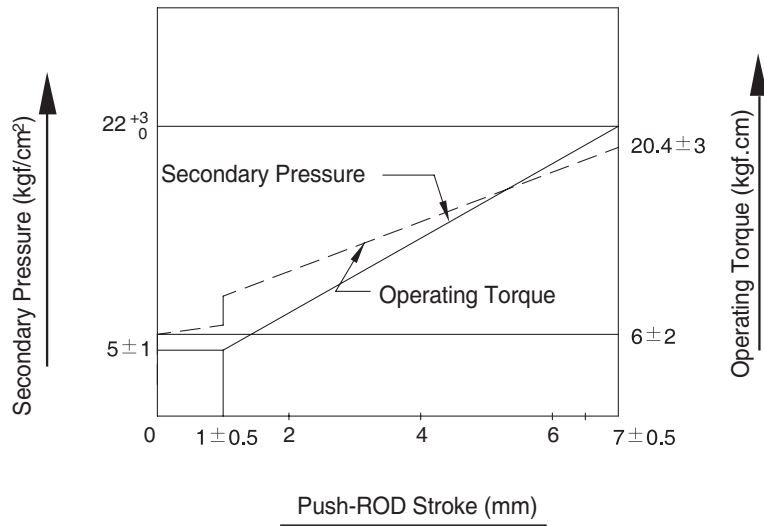


Figure 2

FG011414

HYDRAULIC PRESSURE CIRCUIT DIAGRAM

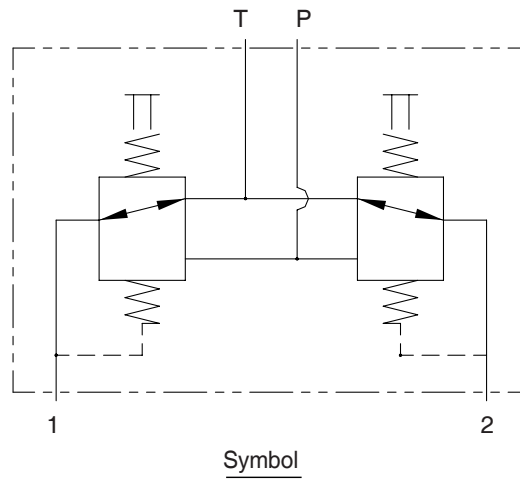


Figure 3

FG011415

PARTS LIST

No.	Part Name	Standard	Material	Q'TY	Remark	RSP
1	Body			1	JA3H1001	O
2	Plug			2	J96H2002	O
IV-3	O-ring	P8	N.B.R	2	PO 08	X
4	Spring			2	JAOL6001	O
I	Spool Kit				JA6J8010	O
I-5	Spring Sea			2	J96H2004	X
I-6	Spool			2	J96H2005	X
I-7	Spring Sea			2	AJV12D103	X
I-8	Spring			2	JAOL6002	X
I-9	Stopper			2set	AJV12D106	X
II	Plug Kit				JA6J8011	O
II-10	Plug			2	J96H2007	X
II-11	Rod Seal	DYR 10	N.B.R	2	RSY 10	X
II-12	O-ring	P14	N.B.R	2	po 014	X
II-13	Push Rod			2	J96H2008	X
14	Cover			1	J96H2009	O
15	Wrench Bolt	M6×35L	SCM440	2	WBM0635	O
16	Guide			1	J96H2010	O
17	Pin			1	J96H2011	O
18	Socket Bolt	M5×15L		2	J96H2012	O
19	Nut	M5	SCM440	2	HNMO5	O
20	Lever			1	JA2C1001	O
21	Spring Pin	ø3×18L		1	SP0318	O
22	Boot			1	JA2C1003	O
23	Bushing			1	JA2C1002	O
24	Name Plate			1	JA6J8001	O
III	Seal Kit	III-3 II-11, 12			JA6J8012	O

DISASSEMBLY AND ASSEMBLY TOOL

Part no.	Tool	Specification	Remarks
15	Torque wrench	L35 mm	150 Kgf/cm ²
17	L wrench	10 mm	
18	L wrench	15 mm	
19	Spanner	8 mm	

DISASSEMBLY

1. Separate the BOOT (22).

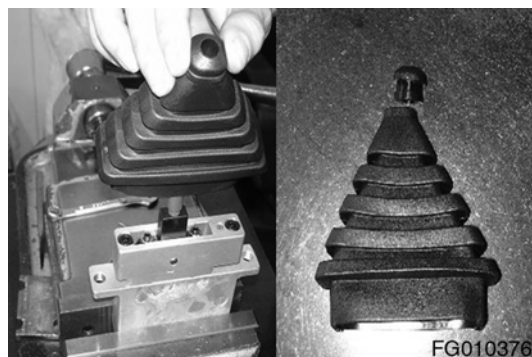


Figure 4

2. Remove the PIN (17) and separate the LEVER (20).



Figure 5

3. Loosen the fixated WRENCH BOLT (15) and separate the COVER (14).

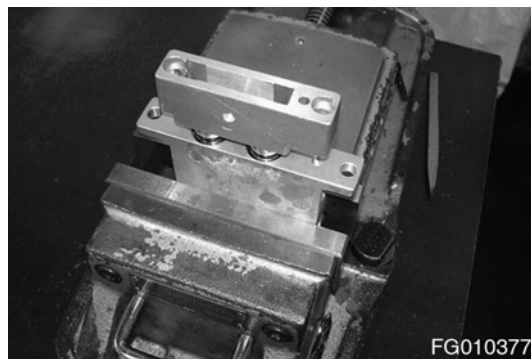


Figure 6

4. Separate the PLUG KIT (II) from the BODY (1).

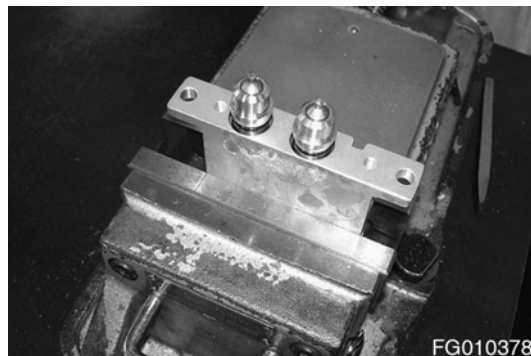


Figure 7

5. Separate the SPOOL KIT (I) from the BODY (1).

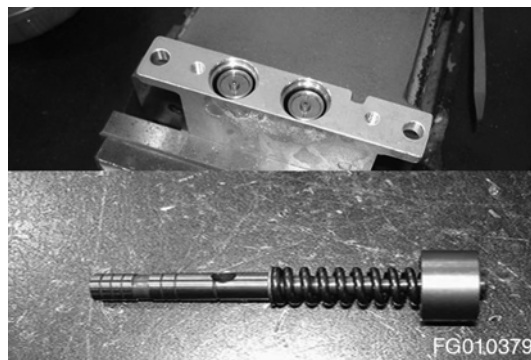


Figure 8

6. Separate the SPRING (4) from the BODY (1).

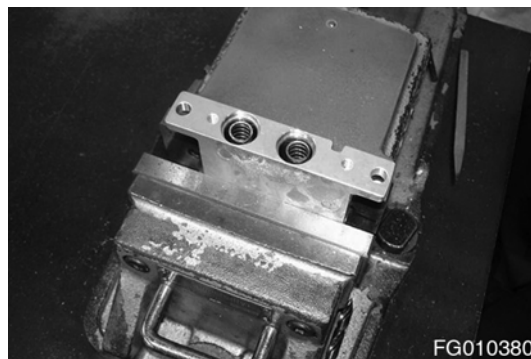


Figure 9

7. Separate the PLUG (2) from the BODY (1).

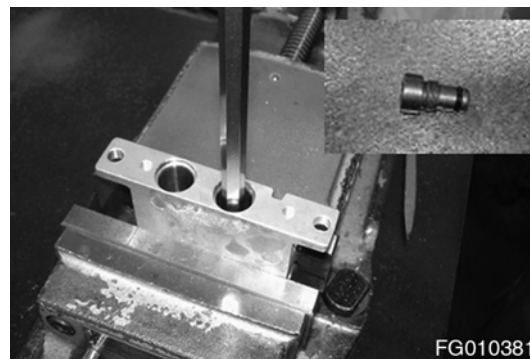


Figure 10

ASSEMBLY METHOD

1. Assemble the PLUG (2) to the BODY (1).

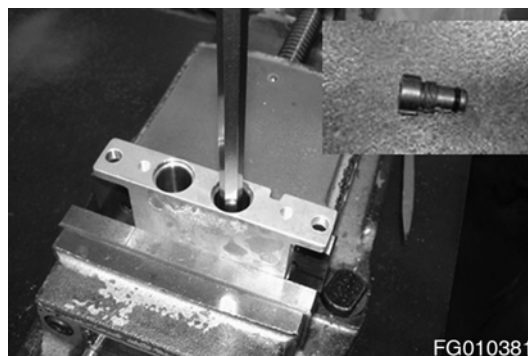


Figure 11

2. Assemble the SPRING (4) to the BODY (1).



Figure 12

3. Assemble the SPOOL KIT (I).
Assemble SPRING SEAT (I-5), SPRING (I-8), SPRING SEAT (I-5) STOPPER (I-9) to SPOOL (I-6) in this order.



Figure 13

4. Assemble the SPOOL KIT (I) to the BODY (1).

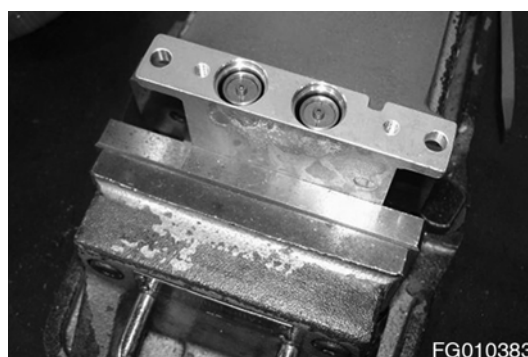


Figure 14

5. Assemble the PLUG KIT (II).
Assemble the ROD SEAL(II-11), O-RING(II-12) and PUSH ROD(II-13) to the PLUG (II-10) in this order.



Figure 15



Figure 16

6. Assemble the PLUG KIT (II) to the BODY (1).

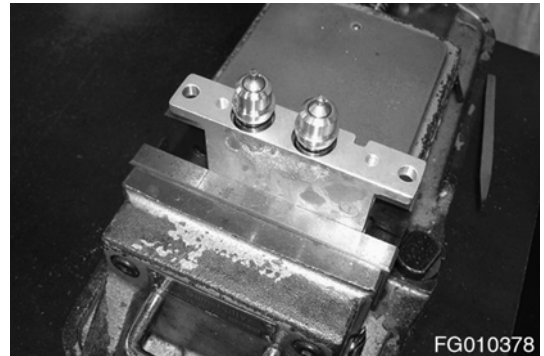


Figure 17

7. Assemble the COVER (14) to the BODY (1).

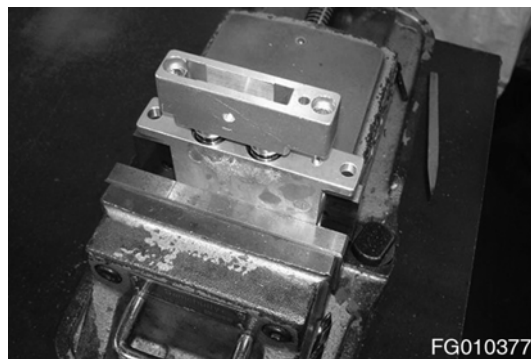


Figure 18

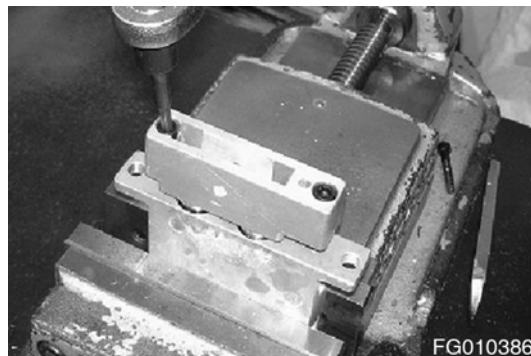


Figure 19

8. After assembling the LEVER20 (20) and GUIDE (16), then install it on the BODY (1) and fixate the assemble with the PIN (17).

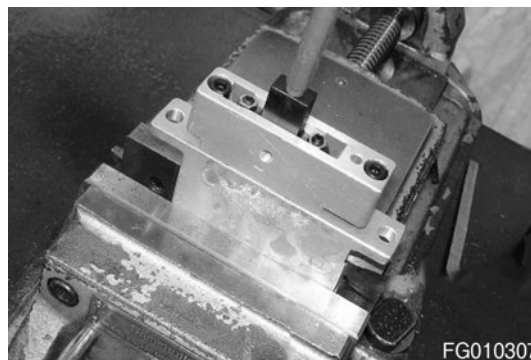


Figure 20



Figure 21

9. Adjust the gap between the GUIDE (16) and PUSH ROD (11-13).

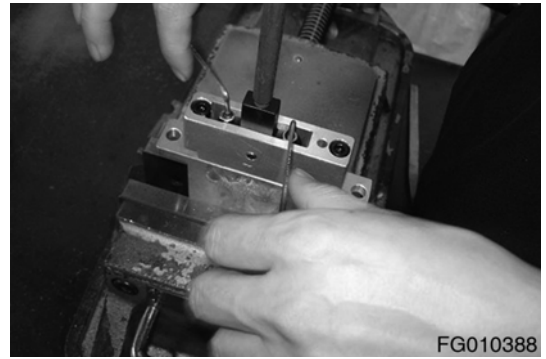


Figure 22

10. Assemble the BOOT (22).

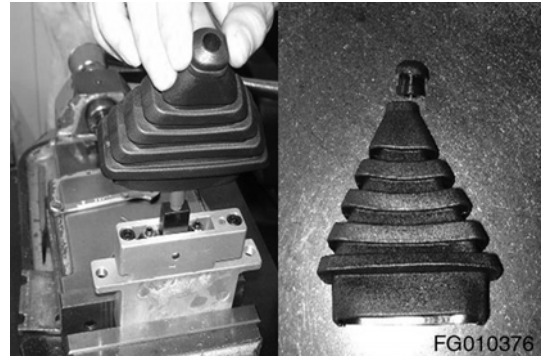


Figure 23

Travel Contorl Valve

Edition 1

MEMO

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Travel Control Valve

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Maintenance Standard	9
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General Caution	21
Troubleshooting and Resolution	21

MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

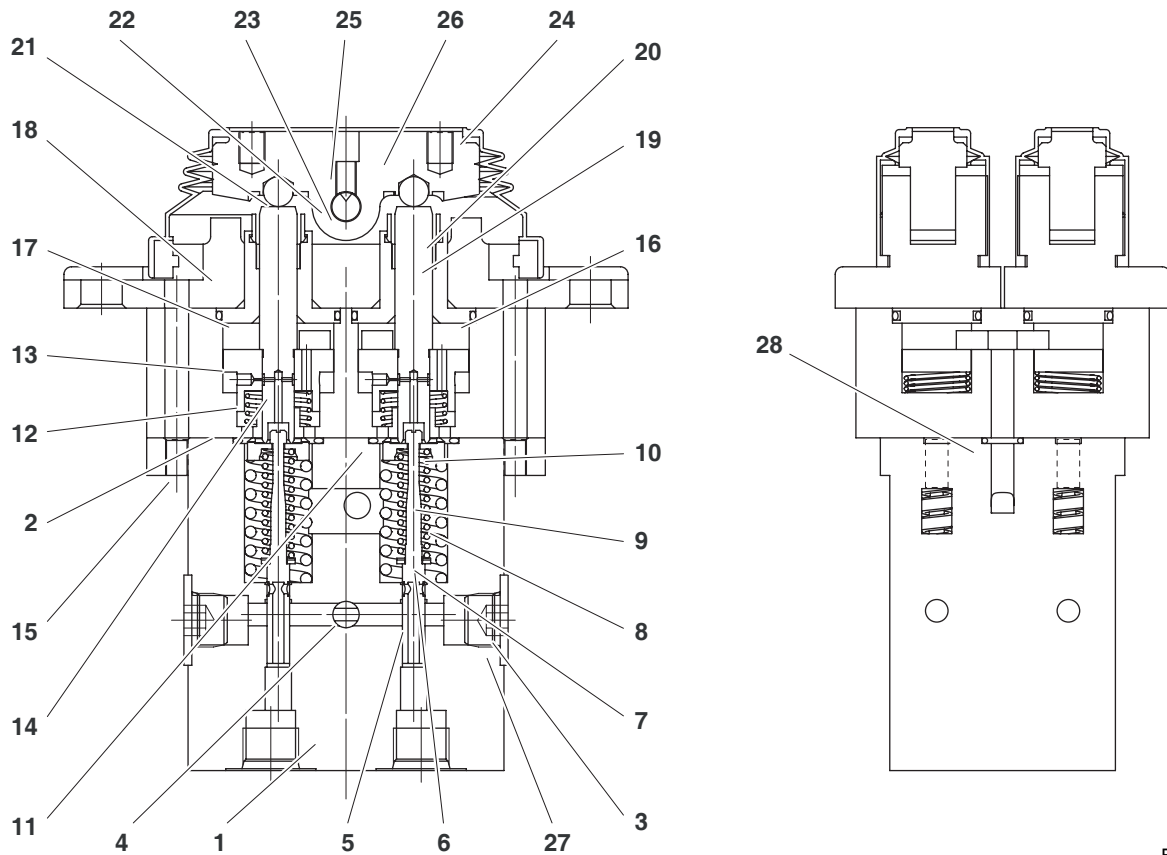
APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

GENERAL DESCRIPTION

Parts List



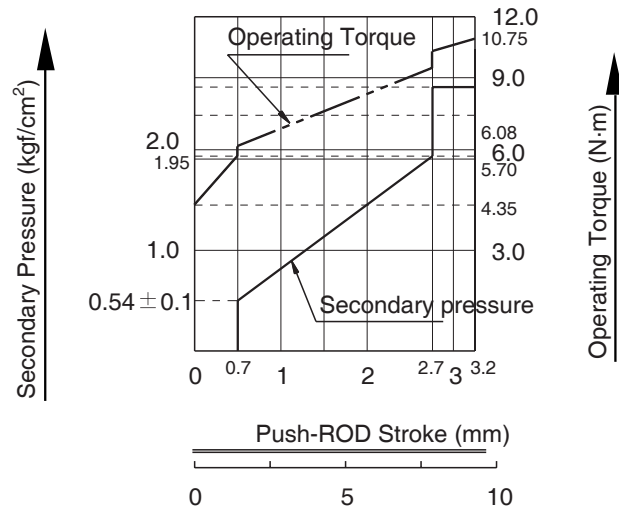
FG013466

Figure 1

Reference Number	Description
1	Casing (1)
2	Casing (2)
3	RO Plug
4	PT Plug
5	Spool
6	Washer
7	Washer
8	Spring
9	Spring
10	Spring Seat
11	O-ring
12	Spring
13	Piston
14	Push Rod

Reference Number	Description
15	Socket Bolt
16	O-ring
17	Plug
18	Cover
19	Packing
20	Grease Cap
21	Steel Ball
22	Bush
23	Cam Shaft
24	Bellows
25	Screw
26	Cam
27	O-ring
28	O-ring

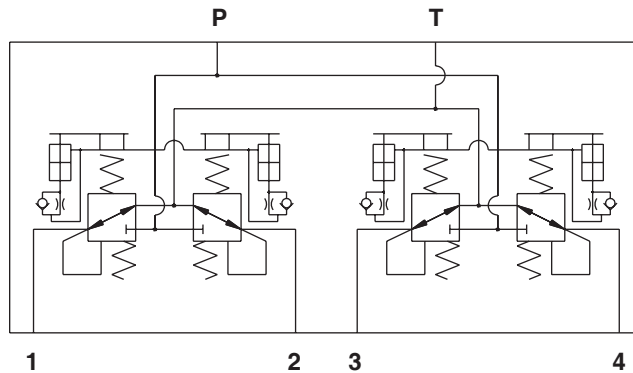
PERFORMANCE SPECIFICATION



FG013468

Figure 2

HYDRAULIC PRESSURE CIRCUIT DIAGRAM



FG013469

Figure 3

MAINTENANCE

Required Tool and Tightening Torque

Tool	Product number	Product name	Size	Tightening Torque	Remarks
Torque-Wrench	15	Socket Bolt	M6	170±15	-
	25	Screw	M6	83±10	-
	3	Po Plug	PF1/4	300±20	-
	4	Pt Plug	NPTF1/16	70±10	-
Driver	19	Nhu Packing	-	-	-
Hammer	22	Bush	-	-	-
	23	Cam Shaft	-	-	-
Special tool	22	Bush	-	-	-

Others:

- Vibration damper
- Cleaning solvent
- Heat resistance grease (Spray type is recommended)
- Loctite #241
- Sand paper
- Oil stone #1000, #2000
- Vice
- Grease spoon

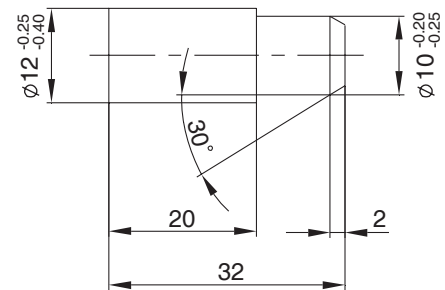
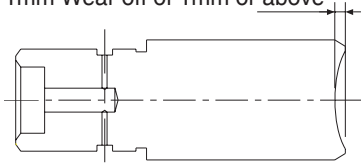


Figure 4

FG010491

Maintenance Standard

Check item	Standard	Remarks
Leakage	Neutral: 500 cc/min or above During operation: 1,000 cc/min or above Exchange according to above condition	Test condition: * 1st pressure: 35 kg/cm * Oil level: 23 cst * When there are 4 pressure drop valves
Spool	Exchange when the sliding part is worn off 10um or above compared to non-sliding part	Leakage level is expected to be same
Push rod	1mm Wear off of 1mm or above  FG011406 Exchange when the top part is worn off 1mm or above	-
Controller clearance	Exchange when the clearance of cam, cam shaft and controller bush is 2mm or above from wear off	When the part or bolt is loose or when there is a gap, tighten according to regulated torque
Operation safety	Exchange when you hear abnormal noise and sound or when there is 1st pressure drop during operation, and when the problem cannot be corrected based on 'Troubleshooting'.	

NOTE: *In principle, you must exchange the O ring and seal during reassembly,*

But when it is confirmed to not have any damage, it can be reused.

Disassembly

Preparation

1. First, clean the exterior of the valve cleanly before the disassembly. Execute the disassembly process in a clean environment.
2. Prepare the tool and material.

General precaution during disassembly

1. Because all parts are assembled with precision with permitted tolerance, special care is required not to damage these parts.
2. Do not apply excessive force or impact on the part.
3. Protect the parts from dust before the assembly. Also check all surface of the valve before the assembly to check for scratch, dent and wear off. Exchange any suspicious parts.

Disassembly procedure

1. Clean the pedal valve with the cleaning solvent.

Block each port with the blind plug.

2. After separating the bottom of the bellows (24) from the cover (18), pull it up to take it off.



Figure 5

3. Use the torque wrench to loosen the socket bolt (15).

NOTE: *Because the return spring (8) is compressed, the cover (18) and casing [2] (2) can pop out as soon as the bolt is disassembled. Level the cover while disassembling the cover.*



Figure 6

4. Disassemble the cover (18) and cam (26) assemble from the casing [2] (2).



Figure 7

5. Use the torque-wrench to unscrew the screws (25).

NOTE: *Be careful because the loosening torque can be high from the applied Loctite #242.*



Figure 8

6. Align the rot to one end of the cam shaft (23) and lightly use the hammer to disassemble it.



Figure 9

7. Disassemble the cam (26) from the cover (18) as the assembly with the steel ball (21) and bush (22) attached.

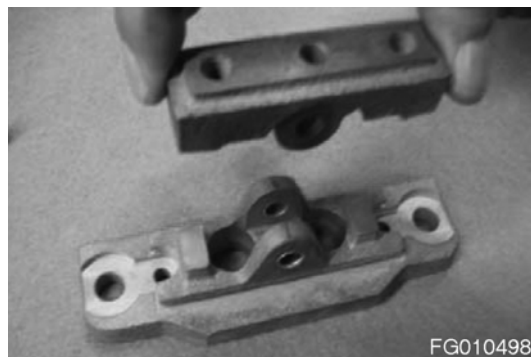


Figure 10

8. Disassemble the casing [2] (2) from the casing [1] (1).

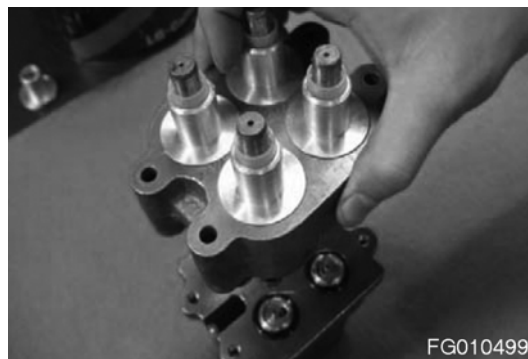


Figure 11

9. Disassemble the push rod (14) from the plug (17).



Figure 12

10. Disassemble the plug (17) from the casing [2] (2).

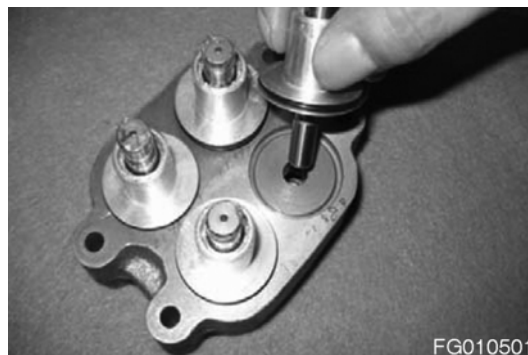


Figure 13

11. Disassemble the grease cap (20) from the plug (17).



Figure 14

12. Disassemble the O ring (16) and dust seal (19) from the plug (17). Disassemble the dust seal with a small screw driver.



Figure 15

13. Disassemble the piston (13) from the casing [2] (2).



Figure 16

14. Disassemble the spring (12) from the casing [2] (2).



Figure 17

15. Disassemble the pressure drop valve sub-assembly from the casing [1] (1).



Figure 18

16. Disassemble the spring (8) from the casing [1] (1).



Figure 19

17. Disassemble the O-ring (11), (28) from the casing [1] (1).



Figure 20

18. Press the spring sheet (10) down and disassemble it from the spool (5).



Figure 21

19. Disassemble the spring (9), washer (7) and washer (6) from the spool in this order.



Figure 22

Assembly

Preparation

1. Prepare the tool and parts, and assemble the valve at a location where it is clean and dust free.

General precaution during reassembly

1. It is the same as disassembly.
2. Clean each part and remove any alien particles. Then check whether there are any rough marks and damages. If there are rough marks and damages, remove them with oil stone or exchange the part.
3. In principle, O-ring and dust seal (NHU PACKING) must be exchanged with a new product.
4. When exchanging the O-ring or dust seal (NHU PACKING), be careful not to damage the part. (When assembling the part, apply a small amount of grease on the O-ring so that the part does not come off.)
5. Apply the grease even when assembling a small part so that the part does not come off.
6. Tighten the bolt according to the 'Tightening torque table'. Measure the tightening torque with the torque wrench.
7. Block the port with the plug after the assembly so that alien particles do not get inside.

Assembly

1. Assemble the washer (6), washer (7) and spring (9) to the spool in this order.



Figure 23

2. Put the spring seat (10) on the spool and press down to assemble it.



Figure 24

3. Assemble the O-ring (11), (28) on the casing [1] (1).

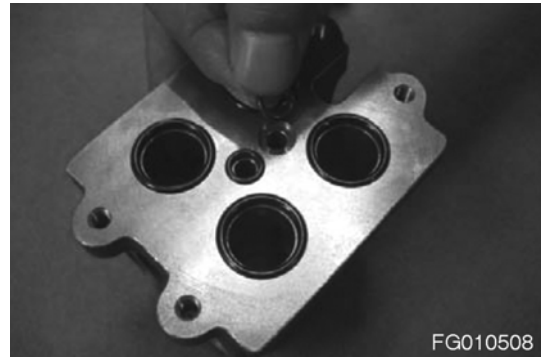


Figure 25

4. Assemble the return spring (8) on the casing [1] (1).
Assemble the sub-assembled pressure drop valve assembly as shown above.

NOTE: Assemble to its original location.

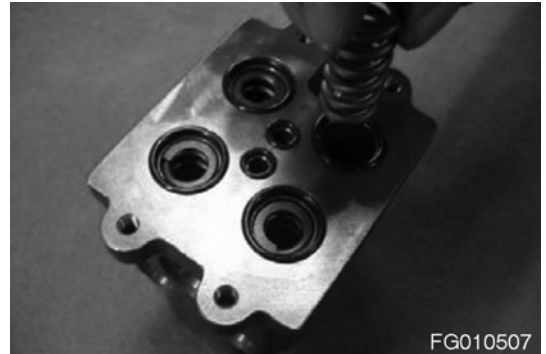


Figure 26

NOTE: When installing the pressure drop valve sub-assembly, be careful not to hit the bottom part of the spool to the corner part of the casing.



Figure 27

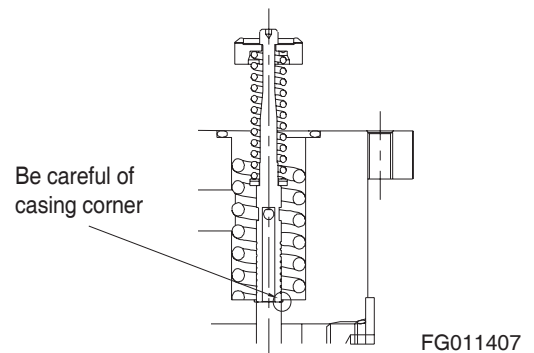


Figure 28

5. Assemble the spring (12) and piston (13) to the casing [2] (2).



Figure 29

6. Assemble the O-ring (16) on the plug (17).



Figure 30

7. Assemble the dust seal (19) on the plug (17).

NOTE: *Be careful of the direction of the dust seal during the assembly.*

NOTE: *Apply a thin layer of grease on the dust seal before the assembly.*



Figure 31

8. Insert the push rod (14) to the plug (17).



Figure 32

9. Assemble the push rod (14) and plug (17) assembly to the casing [2] (2).

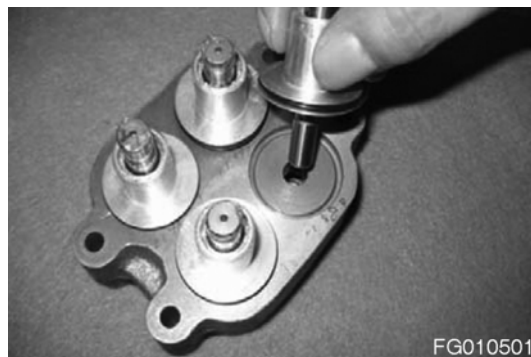


Figure 34

10. Assemble the grease cap (20) on the plug (17).



Figure 35

11. Press the bushing into the cover (18) using the special tool.

NOTE: *Be careful not to project the bush corner to the inner side.*



Figure 36

12. Put the steel ball (21) on the cam (26) and use the hammer to press it in.

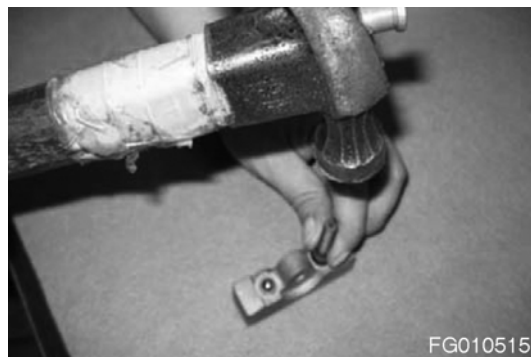


Figure 37

13. Assemble the cam (26) on the cover (18) and insert it on one end of the cam shaft (23).

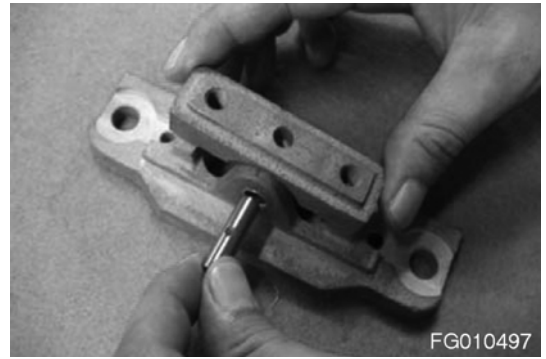


Figure 38

14. Apply Loctite #241 or equivalent material on the surface of the hexagonal hole set, and tighten it according to the regulated torque.



Figure 39

15. Assemble the casing [2] (2) on the casing [1] (1).

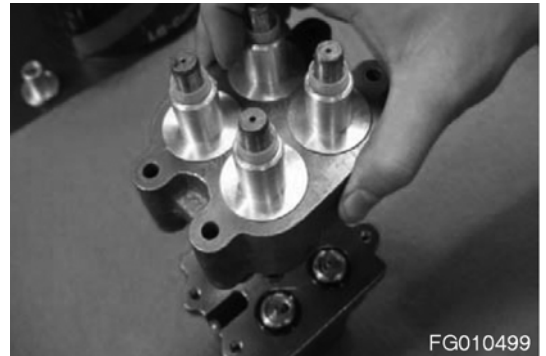


Figure 40

16. Apply the grease on the top of the push rod (14) and top of the plug (17).

NOTE: *When applying the grease, use the spoon made of soft material so that it does not damage the surface of the push rod and plug.*



Figure 41

17. Assemble the cover (18) on the casing [2] (2), and tighten the hexagonal socket bolt (15) according to the regulated torque.



Figure 42

18. Insert the top of the bellows (24) to the groove of the cam, and insert the bottom of the screw into the groove of the cover.

NOTE: *When inserting the bottom of the bellows to the groove of the cover, apply the rust oil on the internal part.*

NOTE: *When the bellows is not inserted properly or straight, the vibration damper and rust prevention function will significantly deteriorate.*



Figure 43

TROUBLESHOOTING

General Caution

This describes the general caution that can be applied in case of a problem during the operation.

1. When there is a problem, first check at which condition the problem occurred.
2. Alien particles are very harmful to the hydraulic pressure device and adequate care must be put.
3. Take special care when handling variable parts. If there is a small damage, remove the damage or exchange with a new part.
4. Be careful not to cause any damage on the operating surface of the seal material including O-ring etc.
This damage can always cause leakage.

Troubleshooting and Resolution

Symptom	Cause	Resolution
When 2nd pressure does not increase	1. 1st pressure is low 2. Damage in 2nd pressure setting spring 3. Excessive gap between spool and casing 4. Clearance in controller	1. Adjust 1st pressure 2. Exchange with new part 3. Exchange the spool casing assembly 4. Disassemble and repair, or exchange the controller part
When 2nd pressure is unstable	1. Sliding part issue 2. Tank line pressure change 3. Air intake within hydraulic pressure circuit	1. Repair/Exchange related part 2. Directly recover oil to tank 3. Repeat the pedal operation multiple times to exhaust the air
When 2nd pressure is high	1. Pressure of tank line is high 2. Sliding part issue	1. Directly recover oil to tank 2. Repair/Exchange defective part

Pedal Valve

Edition 1

MEMO

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Pedal Valve

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling load.

Remember, that ultimately safety is your own personal responsibility.

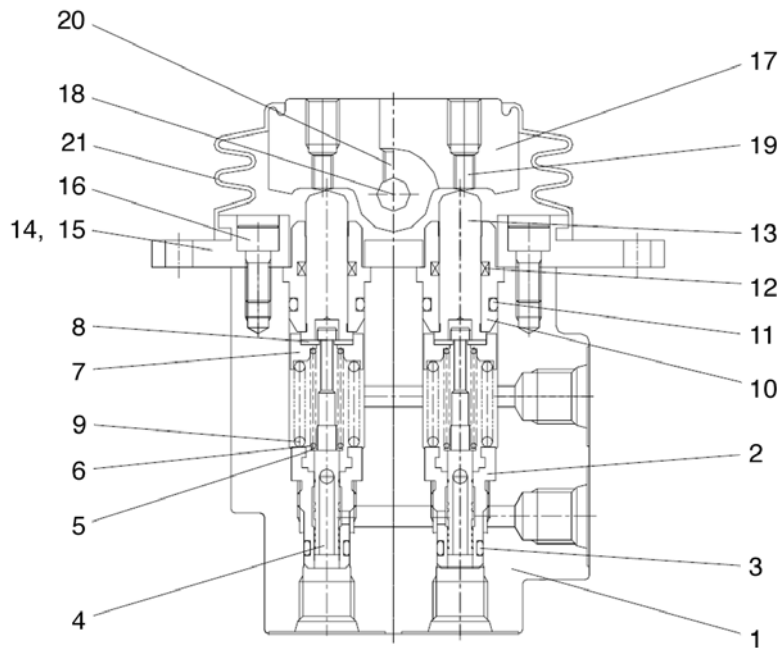
APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX27Z	5001 and Up
DX35Z	5001 and Up
DX60R	50001 and Up

GENERAL DESCRIPTION

Parts List



FG008546

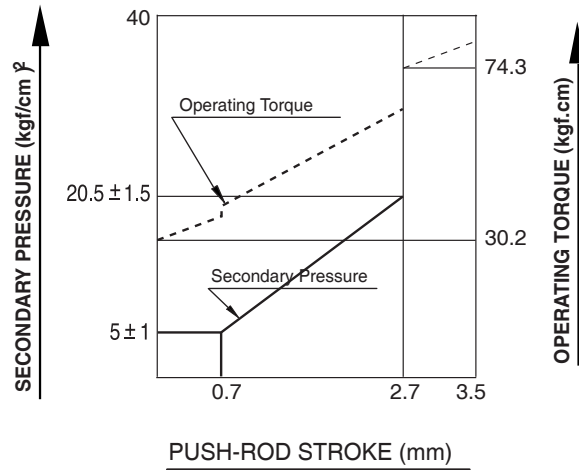
Figure 1

Reference Number	Description
1	Body
2	Plug
3	O-ring
4	Spool
5	Spring Seat
6	Spring
7	Spring Seat
8	Stopper
9	Spring
10	Plug
11	O-ring

Reference Number	Description
12	Rod Seal
13	Push Rod
14	Cover
15	DU Bush
16	Wrench Bolt
17	Cam
18	Pin
19	Adjust Screw
20	Socket Bolt
21	Bellows

Specifications

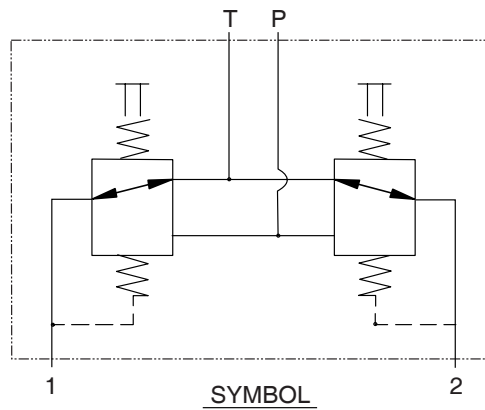
Performance



FG008547

Figure 2

Hydraulic Circuit Diagram



FG008548

Figure 3

TOOLS AND MATERIALS

No.	Tool	Standard	Remark
2	L Wrench	10 mm	
16	L Wrench	5 mm	
19	L Wrench	3 mm	
20	L Wrench	2.5 mm	

DISASSEMBLY

1. Remove Bellows (21) from cover (14) and cam (17).



Figure 4

2. Remove cam (17) from cover (14).



Figure 5

3. Loosen wrench bolt (16) to remove cover (14) from body (1).



Figure 6

4. Remove flug kit from body (1).



Figure 7

5. Remove spool kit from body (1).

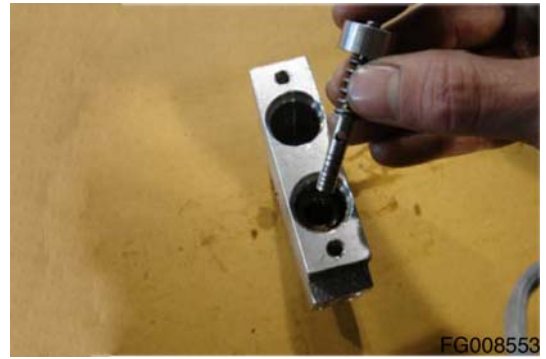


Figure 8

6. Remove spring (9) from body (1).

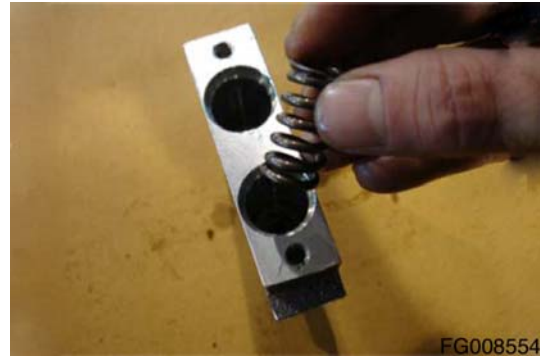


Figure 9

7. Remove plug (2) from body (1).

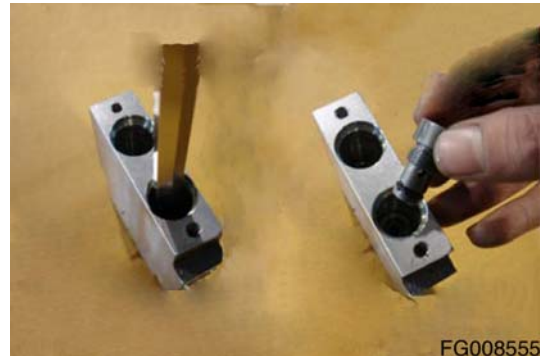


Figure 10

ASSEMBLY

1. Install plug (2) to be assembled o-ring (3) into body (1).

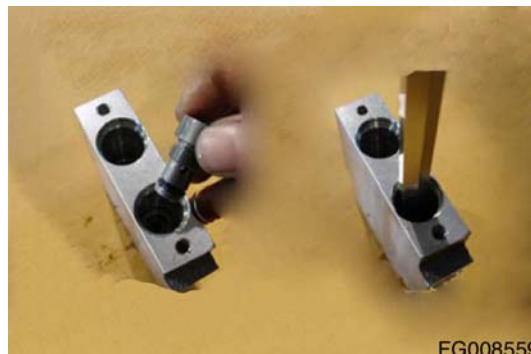


Figure 11

2. Install spring (9) into body (1).



Figure 12

3. Take care when assembling spool kits assemblies. They should be assembled in same way.

The assembly order is spool (4), spring seat (5), spring (6), spring seat (7) and stopper (8).



Figure 13

4. Install four spool kit assemblies into body (1).



Figure 14

5. Take care when assembling plug kit assemblies. They should be assembled in same way.

The assemble order is : plug (10), rod seal (12), o-ring (11) and push rod (12)

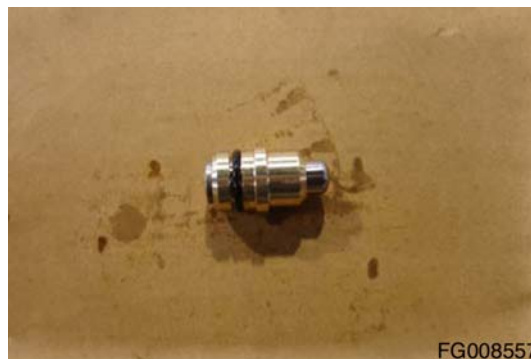


Figure 15

6. Install plug kit into body (1).



Figure 16

7. Install DU bush into cover (14).



Figure 17

8. Tighten wrench bolt (16) to install cover (14) into body (1).



Figure 18

9. Install adjust screw (19) socket bolt (20) into cam (17).

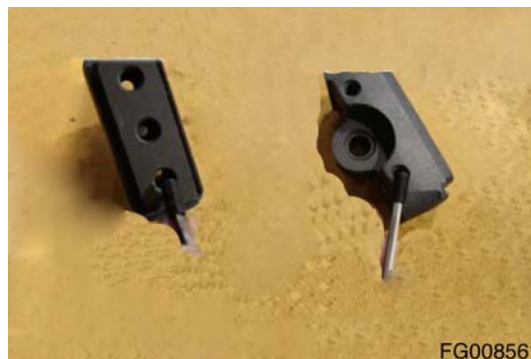


Figure 19

10. Install cam (17) into the cover (14) .
Holding down the cam (17), insert the pin (18) from outside.

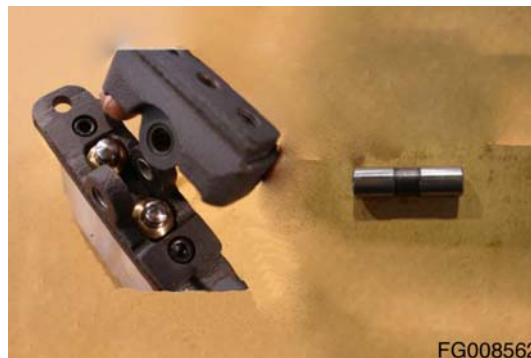


Figure 20

11. Set the cap (17) balance by the L wrench.



Figure 21

12. Install bellow (21) from cover (14) and cam(17).



Figure 22

13. Complet Assembly.



Figure 23

Hydraulic Schematic

Edition 1

MEMO

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Hydraulic Schematic

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MEMO

SAFETY PRECAUTIONS



CAUTION

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Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

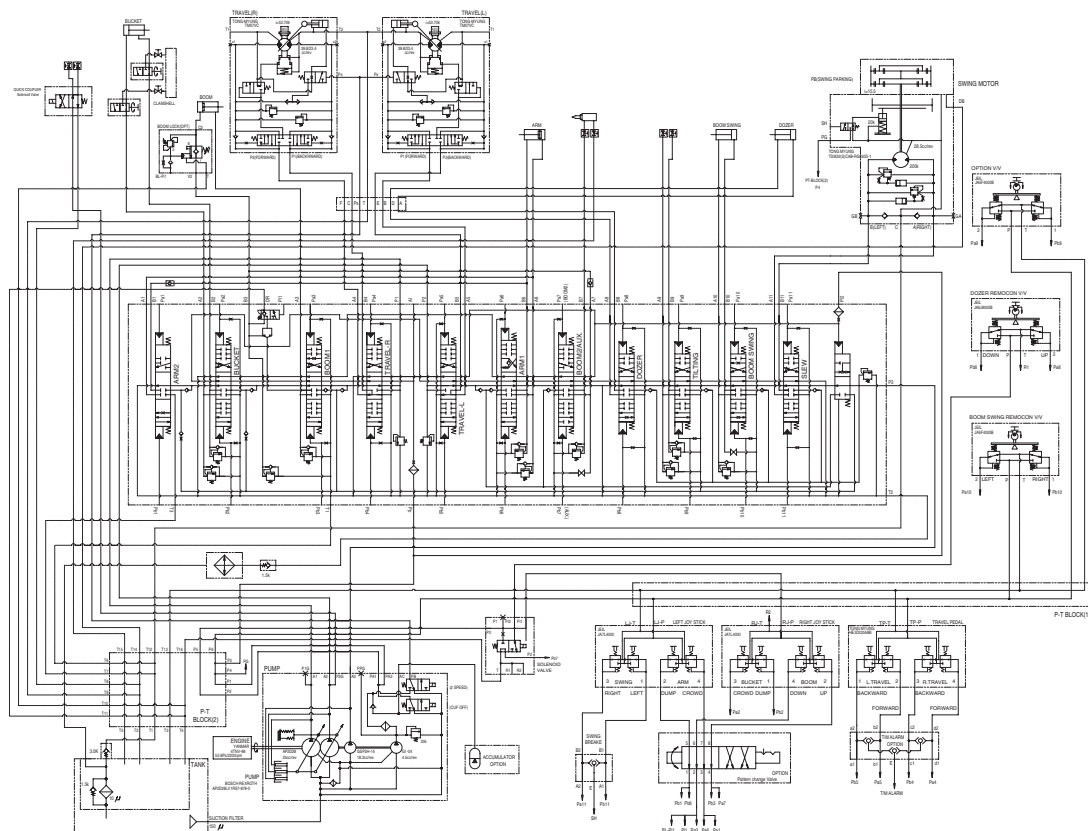


Figure 1

FG014076

<https://truckmanualshub.com/>

Electrical System

Electrical System

Edition 1

MEMO

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SAFETY PRECAUTIONS



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APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up
DX80R	50001 and Up

OVERVIEW

The electrical system for this equipment is DC 12 volts. The rated voltage for all electric components is 12 volts. The system contains one 12 volts battery and a three phase AC generator with a rectifier. The electric wiring used in the system is easily identifiable by the insulator color. The color symbols used in the electric system are listed in the following chart.

Electrical Wire Color

Symbol	Color
W	White
G	Green
Or	Orange
B	Black
L	Blue
Lg	Light Green
R	Red
Gr	Gray
P	Pink
Y	Yellow
Br	Brown
V	Violet

NOTE: *RW: Red wire with White stripe*
R - Base Color, W - Stripe Color

NOTE: *0.85G: Nominal sectional area of wire core less insulator = 0.85 mm²*

ELECTRICAL SUPPLY SYSTEM

The electric power circuit supplies electric current to each electric component. It consists of battery, starter switch fusible link and fuse box.

The negative terminal of battery is grounded to negative body.

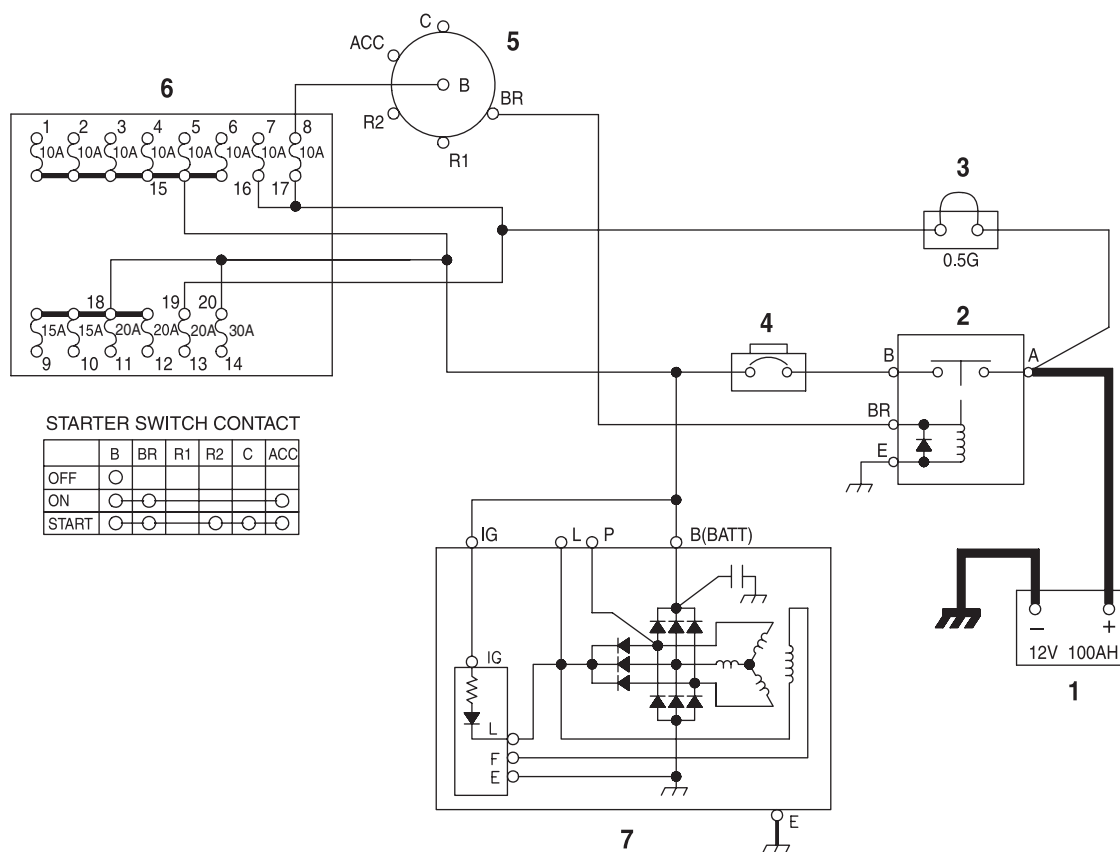
Even when starter switch (5) is in "OFF" position, electric current is supplied to following components through battery (1) → fusible link (3) → fuse (6).

1. Cabin light, fuel pump switch No.5 terminal of car stereo for backup and No.22 terminal of AC panel for backup.
2. "B" terminal of starter switch, No.1 terminal of hour meter.
3. No.34 terminal of ECU (Engine control unit)

When the starter switch is in the ON and START positions, the current flows from the battery (1) → fusible link (3) → fuse box (6) → starter switch (5) "B" terminal / "BR" terminal → battery relay (2) → 'B' terminal which activates the coil of the battery relay and the electric supply system is energized.

When the battery relay's contacts are connected, the current flows from the circuit breaker (4) → fuse box (6) and all electric devices can be operated.

While the engine is not running, the battery supplies the electric power for all electric components. Once the engine is started, the power is supplied from the alternator (7).



FG012303

Figure 1 ELECTRIC POWER CIRCUIT DIAGRAM

Reference Number	Description
1	Battery
2	Battery Relay
3	Fusible Link
4	Circuit Breaker

Reference Number	Description
5	Starter Switch
6	Fuse Box
7	Alternator

ENGINE STARTING

Start Operation

When the starter switch (6) is turned to the ON position, the ECU (9) performs rack self diagnostics directly.

At this time, the starter relay prevents the starter motor from starting until the diagnostics is completed.

When the starter switch (6) is turned to the START position, the contacts in the starter relay (11) are closed by the current flow from battery (1) → fusible link (3) → "B" terminal of starter switch (6) → "C" terminal → "86" terminal of the starter relay (11) → "85" terminal → "20" terminal of ECU (5) → ground.

When the contact point of "30" and "87" of starter relay (11) are connected, the pinion gear of the starter (12) is pushed forward and makes contact with the ring gear of the flywheel and the internal contacts of the starter are connected.

The current flows from the battery (1) → "A" terminal of battery relay (2) – "B" terminal → "B" terminal of starter (12). The starter motor is rotated and the engine is started.

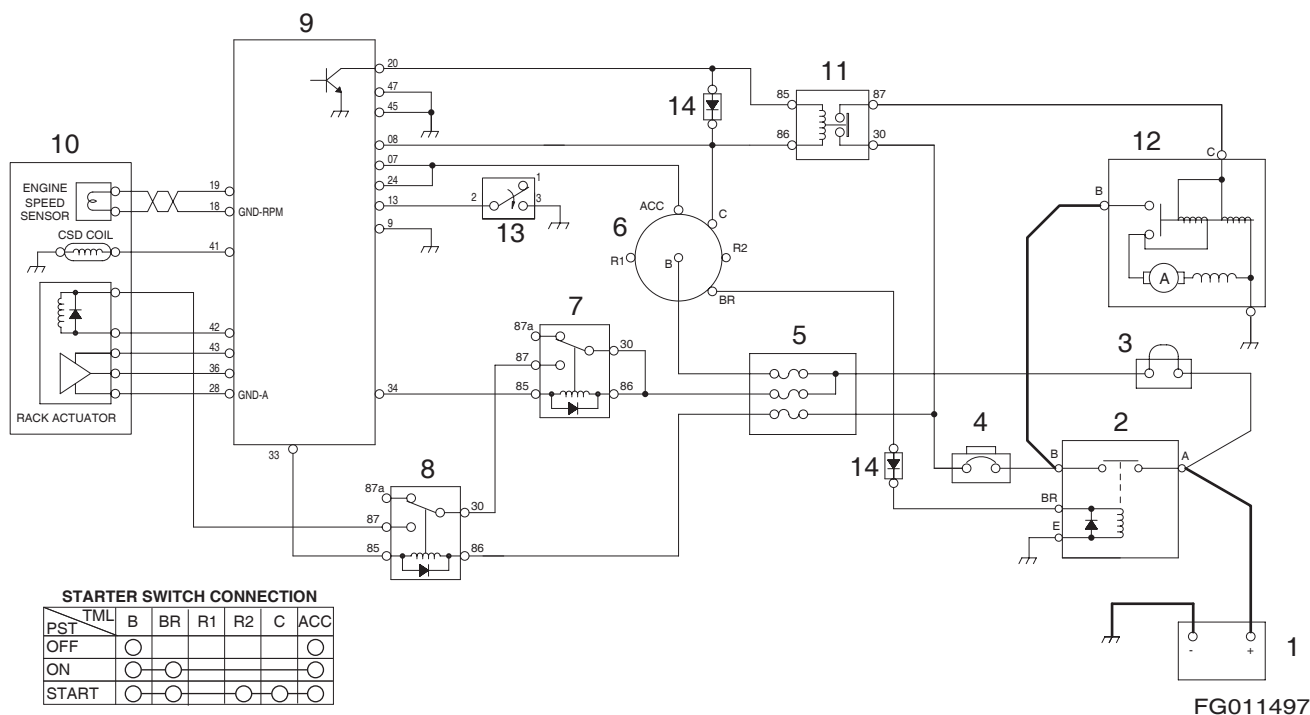


Figure 2 STARTER CIRCUIT

Reference Number	Description
1	Battery
2	Battery Relay
3	Fusible Link
4	Circuit Breaker
5	Fuse Box
6	Starter Switch
7	Main Relay

Reference Number	Description
8	Rack Actuator Relay
9	Engine Control Unit
10	Fuel Injection Pump
11	Starter Relay
12	Starter
13	Engine Emergency Stop Switch
14	Diode

After Start

when the engine speed goes over 675 rpm, the connection between "20" and "ground" terminals of ECU (9) and the connection between "30" and "87" terminals of starter relay (11) are opened.

As a result the rotation of the starter (12) is stopped.

Once the engine is running, the starter (12) will not operate even if the starter switch (6) is moved to the start position, preventing possible damage to the starter.

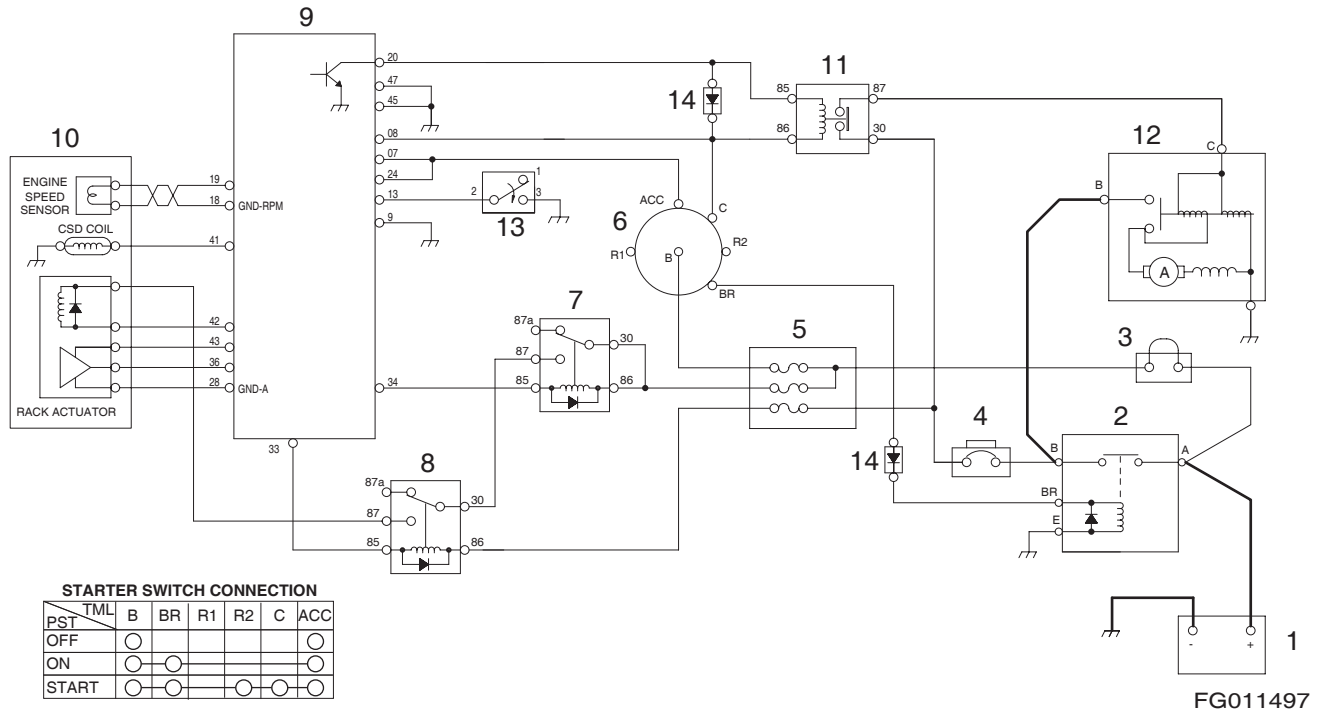


Figure 3 START CIRCUIT

Reference Number	Description
1	Battery
2	Battery Relay
3	Fusible Link
4	Circuit Breaker
5	Fuse Box
6	Starter Switch
7	Main Relay

Reference Number	Description
8	Rack Actuator Relay
9	Engine Control Unit
10	Fuel Injection Pump
11	Starter Relay
12	Starter
13	Engine Emergency Stop Switch
14	Diode

ENGINE PREHEATING SYSTEM

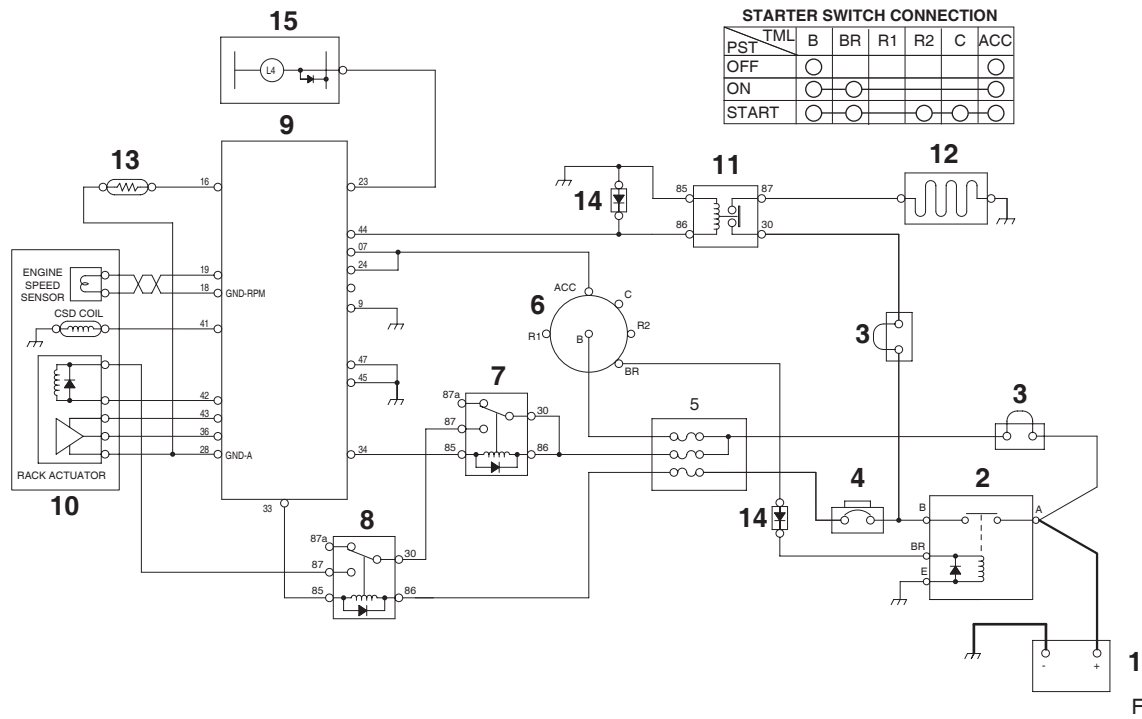
An air heater (12) is installed in the intake manifold of the engine.

When the starter switch(6) is turned "ON" position, the current flows from the battery (1) → fusible link (3) → fuse box (5) → "B" terminal of starter switch (6) → "ACC" terminal of stater switch → "7" terminal of ECU (9) → "24" terminal of ECU (9). At this time, the ECU (9) senses the temperature of engine coolant by coolant temperature sensor (13).

After sensing the temperature of engine coolant, ECU controls the preheat relay (11) and current flows from the "44" terminal of engine control unit (9) → "86" terminal of preheat relay (11) → "85" terminal of preheat relay (11) → ground. This current flow causes the coil in preheat relay (11) to be activated, closing contacts.

When the contacts of the preheat relay (11) are closed, the heating coils of the air heater (12) is heated by current flowing from battery (1) → battery relay(2) → fusible link (3) → preheat relay(11) → air heater(12) → ground.

The duration of heating cycle depends on the temperature of engine coolant. The preheat indicator light in the instrument panel(15) will turn "ON" during preheating cycle. The longer the preheating period, the lower the temperature of coolant is.



FG011498

Figure 4 ENGINE PREHEAT CIRCUIT

Reference Number	Description
1	Battery
2	Battery Relay
3	Fusible Link
4	Circuit Breaker
5	Fuse Box
6	Starter Switch
7	Main Relay
8	Rack Actuator Relay

Reference Number	Description
9	Engine Control Unit
10	Fuel Injection Pump
11	Preheat Relay
12	Air Heater
13	Engine Coolant Temperature Sensor
14	Diode
15	Instrument Panel

ENGINE STOP

When the starter switch (6) is turned "ON" position, the ECU (9) is activated.

The ECU(9) controls the rack actuator in the fuel injection pump(10) to control the fuel deliver rate.

When the start switch (6) is turned "OFF" position, the ECU(9) stops supplying power to the rack actuator relay (8). As a result, the power supplying from rack actuator relay (8) to fuel injection pump (10) stops. This stops fuel from being injected into the engine, thus stopping the engine.

In the event that the engine can not be shut down using the starter switch (6), an emergency stop switch (13) is provided to shut down engine.

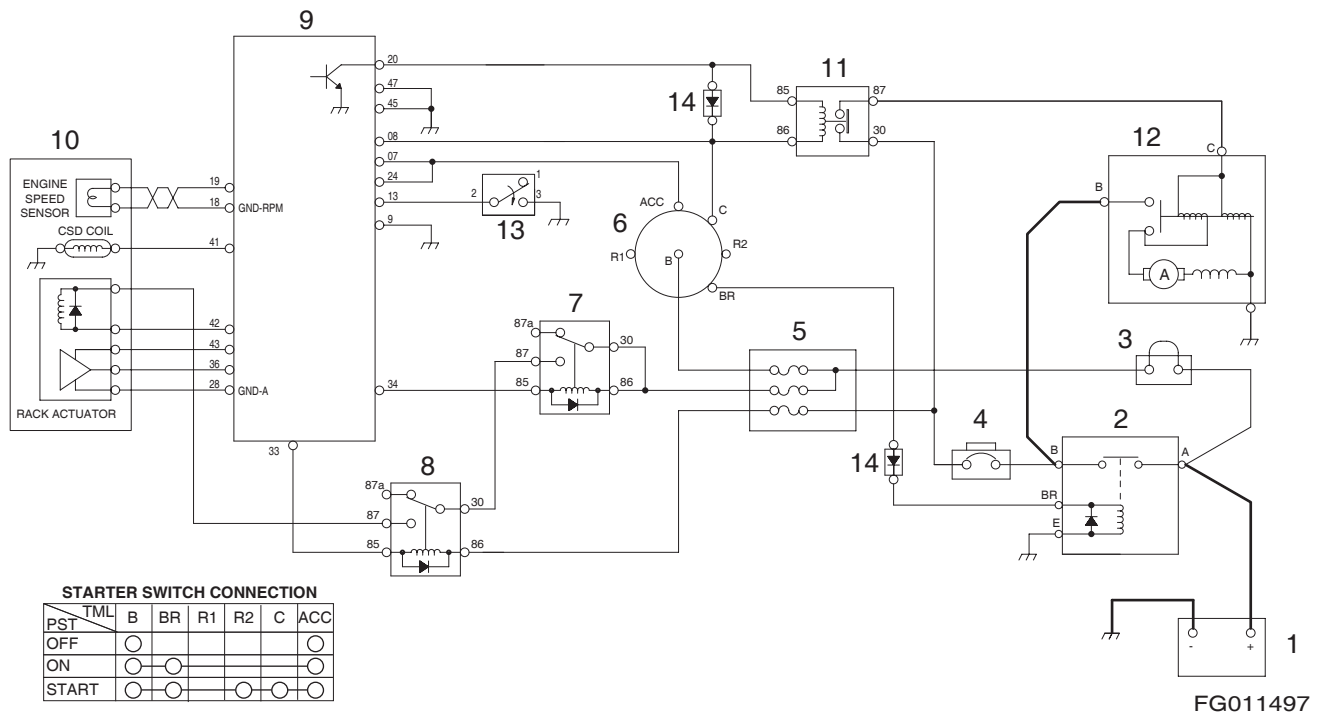


Figure 5 ENGINE STOP CIRCUIT

Reference Number	Description
1	Battery
2	Battery Relay
3	Fusible Link
4	Circuit Breaker
5	Fuse Box
6	Starter Switch
7	Main Relay

Reference Number	Description
8	Rack Actuator Relay
9	Engine Control Unit
10	Fuel Injection Pump
11	Starter Relay
12	Starter
13	Engine Emergency Stop Switch
14	Diode

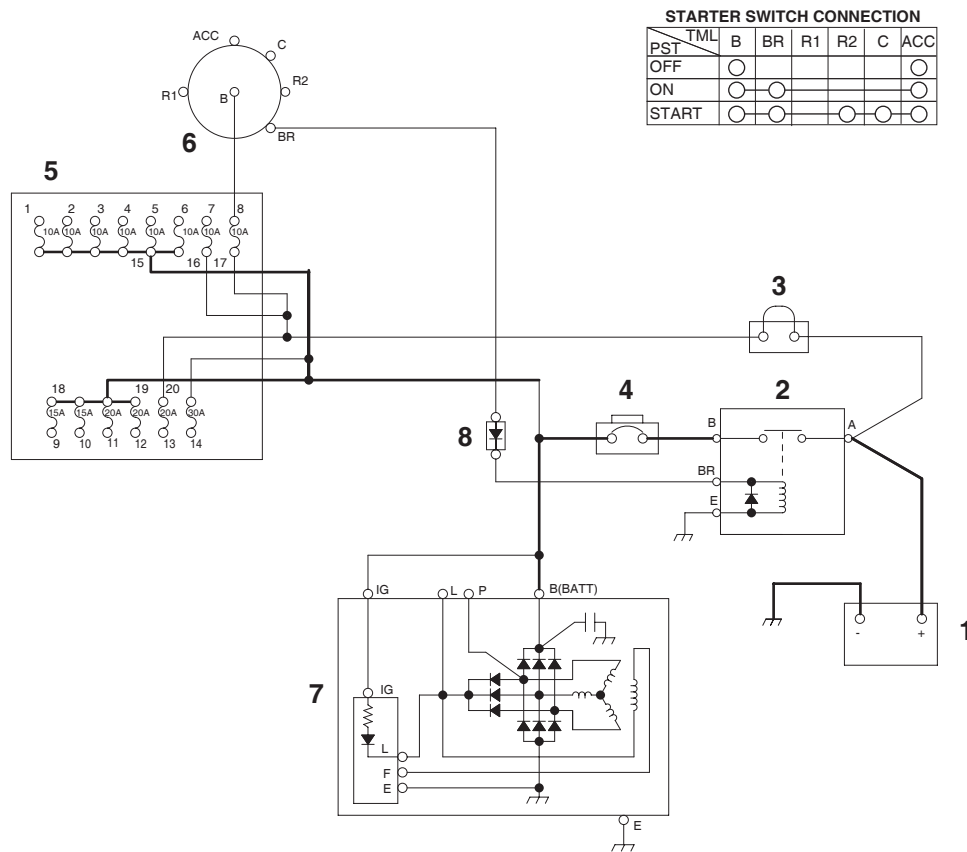
CHARGING SYSTEM

When the starter switch (6) is turned "ON" position, an initial excited current flows to the field coil of alternator (7) through the battery (1), battery relay (2) and circuit breaker (4).

When the engine is started from this condition the alternator (7) starts charging.

The current flows from the "B" terminal of alternator (7) → circuit breaker (4) → battery relay (2) → battery(1).

The alternator also supplies electric current to other electric components.



FG011499

Figure 6 CHARGING CIRCUIT

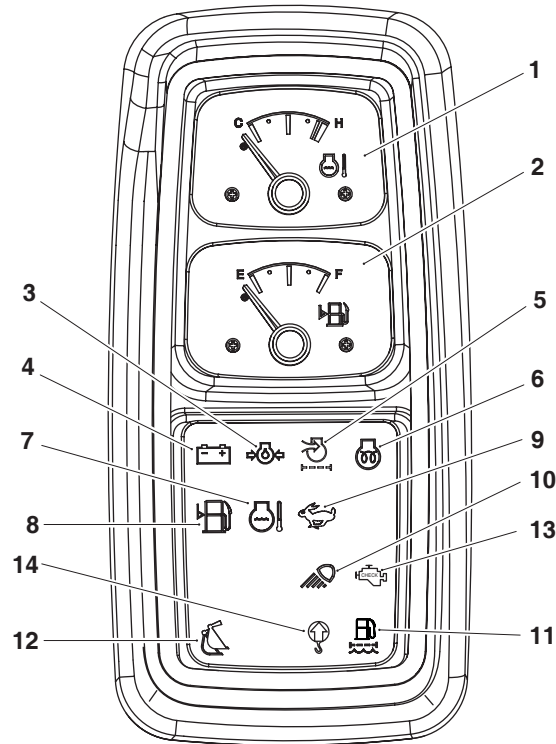
Reference Number	Description
1	Battery
2	Battery Relay
3	Fusible Link
4	Circuit Breaker

Reference Number	Description
5	Fuse Box
6	Starter Switch
7	Alternator
8	Diode

INSTRUMENT SYSTEM

Instrument Panel

The instrument system displays the equipment conditions and warning signals onto the instrument panel by processing the information gathered from the various sensors throughout the equipment.

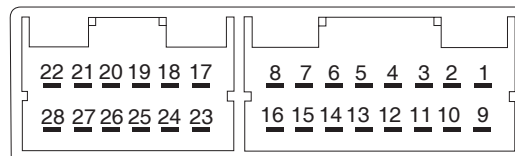


FG010730

Figure 7

Reference Number	Description
1	Engine Coolant Temperature Gauge
2	Fuel Gauge
3	Engine Oil Pressure Warning Light
4	Charge Warning Light
5	Air Cleaner Clogging Warning Light
6	Preheat Indicator Light
7	Engine Coolant Temperature Warning Light

Reference Number	Description
8	Fuel Level Warning Light
9	High Travel Speed Indicator Light
10	Working Light Indicator Light
11	Water in Fuel Warning Light
12	Quick Clamp Indicator Light (Optional)
13	Engine Check Warning Light
14	Overload Warning Light (Optional)



FG011463

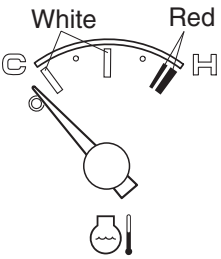
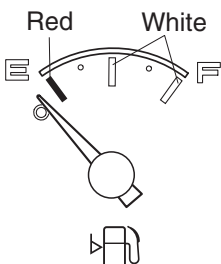
Figure 8

Function Check

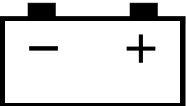
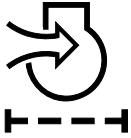
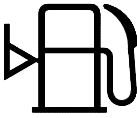
When the starter switch is turned to the "ON" position, all indicator lights and warning lights will be lit for 2 seconds and the warning buzzer will sound. If there is any light that does not go on during the function check, replace or repair.

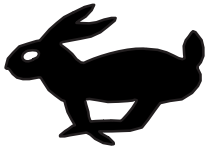
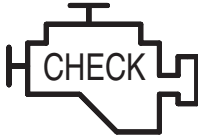
OPERATION

Gauge

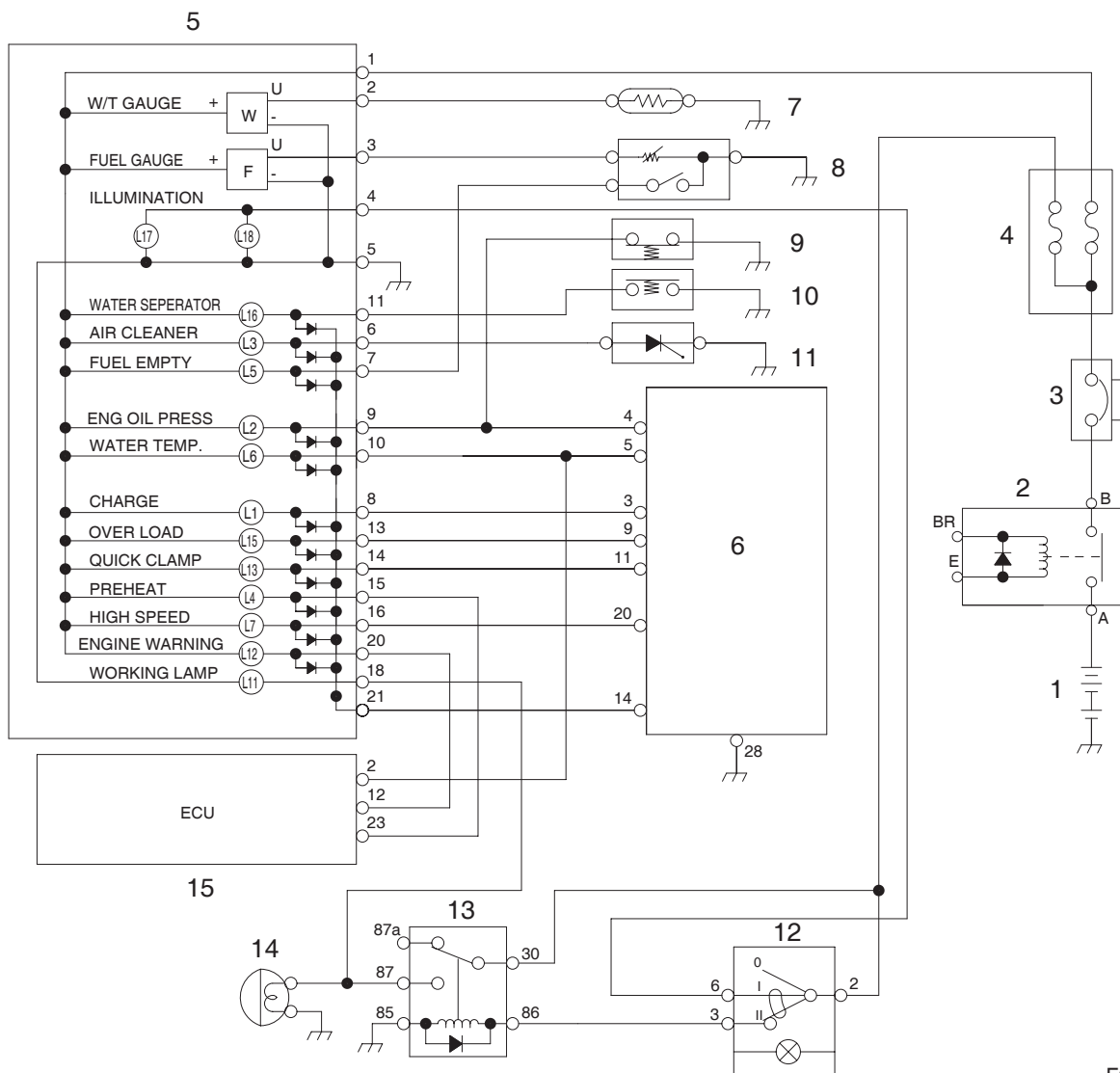
Function	Display	Sensor Specification	
		Input Terminal	Input Specification
Engine Coolant Temperature	 AXO0280L	2	50°C - Over 188.2Ω 67°C - 102Ω 105°C - 32Ω 125°C - below 19.8Ω
Fuel Quantity	 AXO0290L	3	Empty - Over 90Ω 1/2 - 38Ω Full - below 10Ω

Warning Lights

Description	Symbol	Input Terminal	Operation	Remarks
Engine Oil Pressure	 HAOA620L	9	Lights up when oil pressure drops below 0.5 kg/cm ² .	After starting engine, if engine oil pressure is insufficient after 8 seconds, a warning buzzer will sound.
Charging	 HAOA610L	8	Lights up when not charging. ("L" terminal output of alternator drops below 5V)	Under normal condition, it will light up before engine start up and shut off once engine is running.
Air Cleaner	 FG000053	6	Lights up when air cleaner is clogged.	
Preheating		15	It lights during preheating and turns "OFF" after completion of preheating.	
Engine Coolant Temperature	 HAOD350L	10	Lights up when coolant temperature increase over 110°C.	The warning buzzer sounds simultaneously.
Fuel Exhausted	 FG000057	7	When fuel is almost exhausted.	

Description	Symbol	Input Terminal	Operation	Remarks
High Speed	 FG010190	16	Lights up when the high speed switch turns "ON".	
Work Light	 HB402003	18	It lights when work light turns "ON".	
Water in Fuel	 FG010520	11	Lights up when water quantity is increased in the water separator.	
Quick Clamp	 FG010192	14	Lights up when the quick clamp switch turns "ON".	
Engine Check	 FG000045	20	It lights in case of failure in engine system.	
Overload warning	 FG000253	13	Warning buzzer also starts when boom pressure voltage is about 1.9 while overload warning switch is "ON".	

Circuit Diagram of Instrument Panel



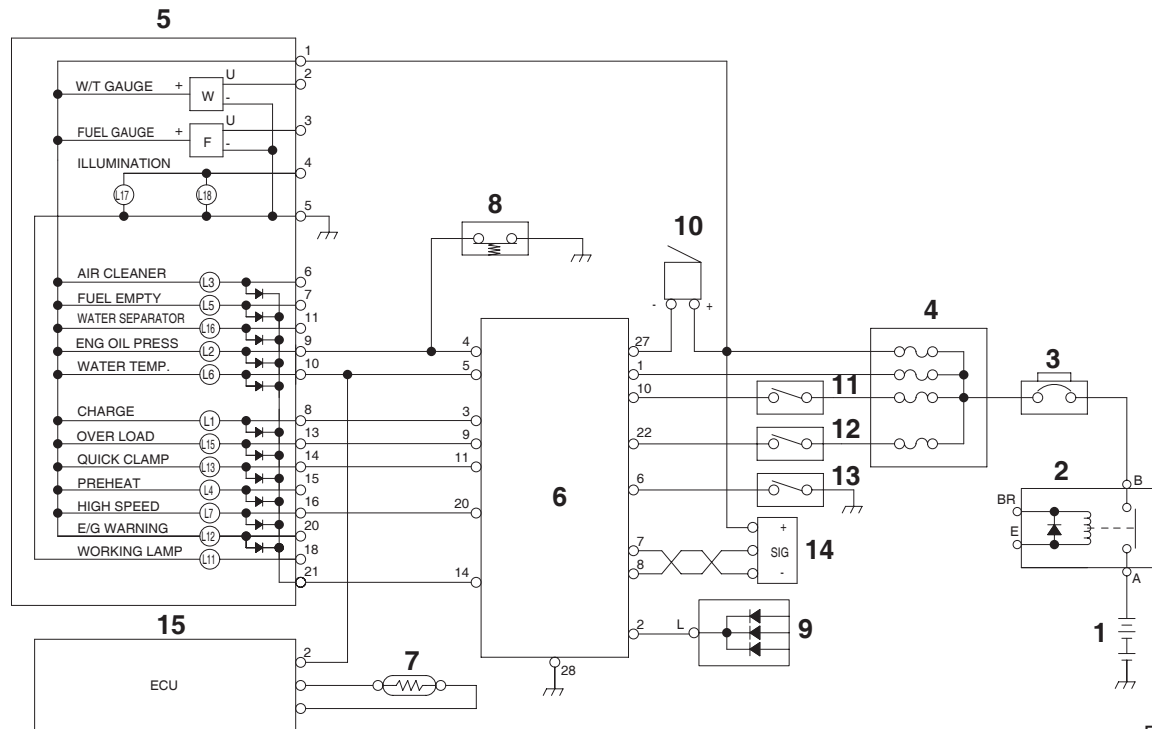
FG011500

Figure 9

Reference Number	Description
1	Battery
2	Battery Relay
3	Circuit Breaker
4	Fuse Box
5	Instrument Panel
6	Control Unit
7	Engine Coolant Temperature Sensor

Reference Number	Description
8	Fuel Sensor
9	Engine Oil Pressure Switch
10	Water In Fuel Warning Switch
11	Air Cleaner Indicator
12	Light Switch
13	Light Relay
14	Working Light
15	ECU (Enging Control Unit)

Control unit circuit



FG011501

Figure 10

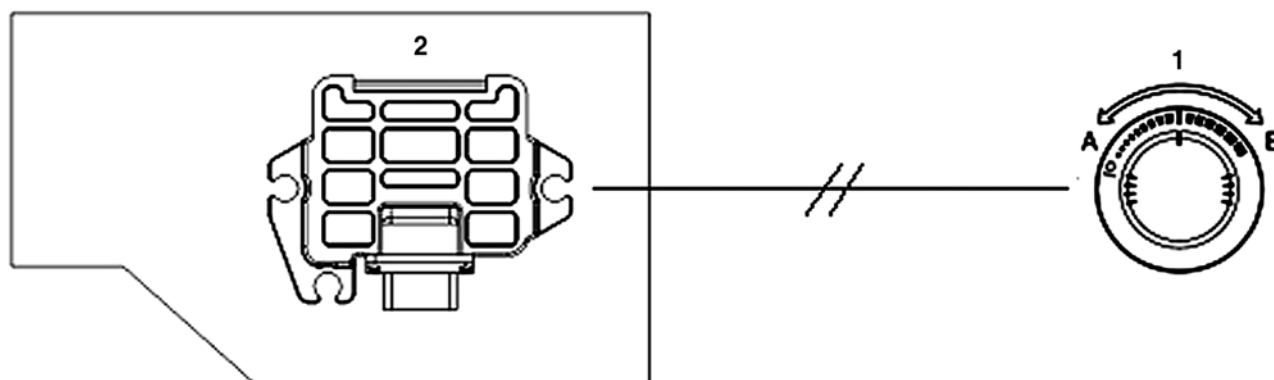
Reference Number	Description
1	Battery
2	Battery Relay
3	Circuit Breaker
4	Fuse Box
5	Instrument Panel
6	Control Unit
7	Engine Coolant Temperature Sensor
8	Engine Oil Pressure Switch

Reference Number	Description
9	Alternator
10	Pilot Buzzer
11	Quick Clamp Select Switch
12	High Speed Select Switch
13	Overload Warning Switch
14	Pressure Sensor
15	ECU (Enging Control Unit)

Performance Specification

No	Input		Output
1	Starter switch "ON"		All warning lights and warning buzzer are turned on and turned off after approximately 2 seconds.
2	Starter switch "ON"	High speed switch "ON"	"L7" turned on
3		Quick clamp switch "ON"	"L13" and pilot buzzer turned on
4	Starter switch "ON" and Alternator "L" terminal	6.5 ± 1V Below	"L1" turned on
5		6.5 ± 1V Over	"L1" turned off
6	Alternator terminal 6.5 ± 1V "L" over state	Engine oil pressure switch "ON"	"L2" turned on and pilot buzzer will be turned on after approximately 8 seconds.
7		Engine coolant temperature : 110°C over	Pilot buzzer will be turned on immediately
8		Overload warning switch "ON" and Pressuresensor voltage : 1.9 ± 0.1V over	"L15" and pilot buzzer turned on
9		Overload warning switch "ON" and Pressuresensor voltage : 1.9 ^{+0.1V} _{-0.2V} below	"L15" and pilot buzzer turned off

Engine Control System



FG011493

Figure 11

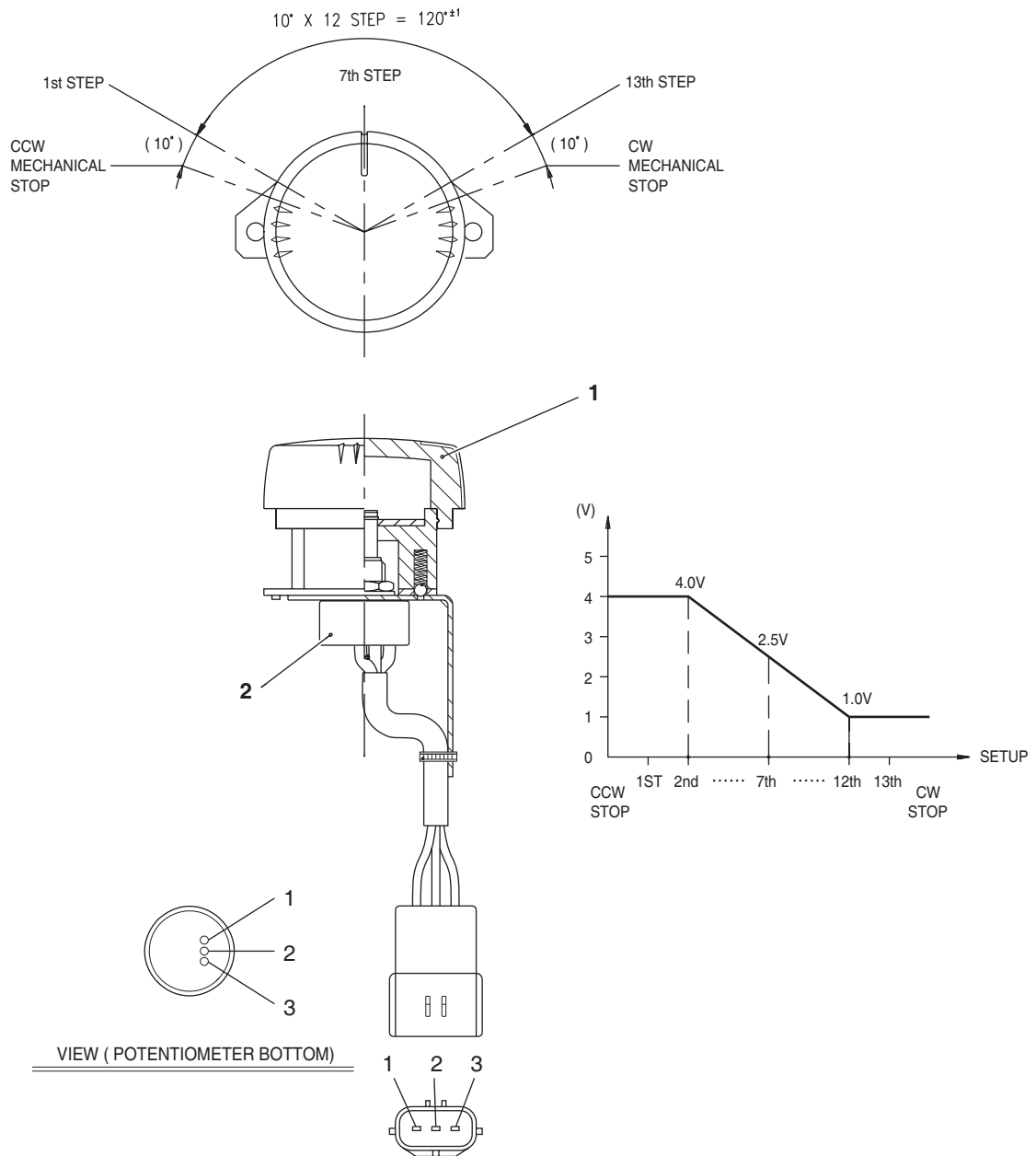
Reference Number	Description
1	Engine Control Dial

Reference Number	Description
2	ECU (Engine Control Unit)

When the engine control dial is moved the output voltage changes according to the dial position

According to the dial command, the quantity of fuel injection is adjusted.

ENGINE CONTROL DIAL



HDA6033L

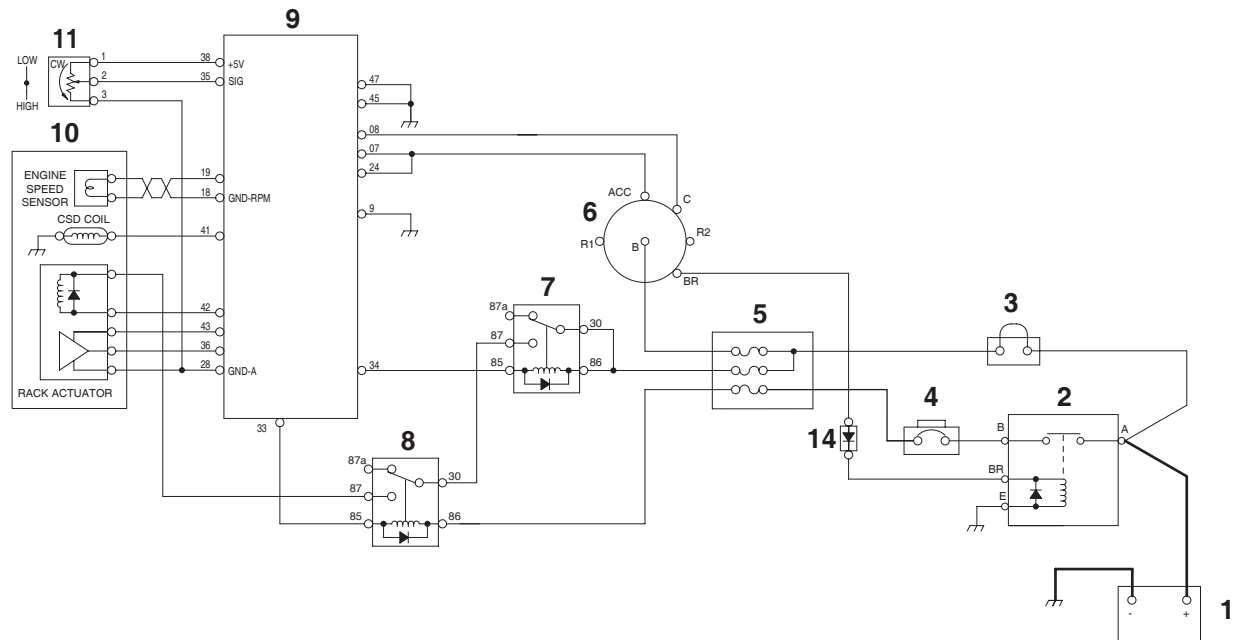
Figure 12

Reference Number	Description
1	Knob

Reference Number	Description
2	Potentiometer (Variable Resistor)

The engine control dial has a built in potentiometer. When the control knob is moved the output voltage (through 2 and 3 terminals) will vary from 5V supplied from the engine throttle controller as shown in the graph.

Engine Control Circuit Diagram



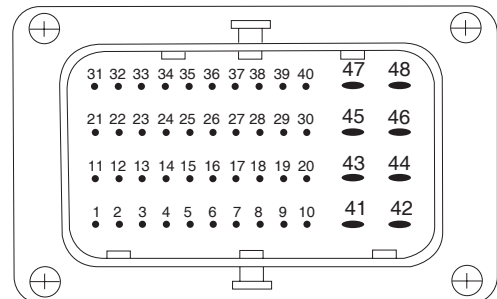
FG011494

Figure 13

Reference Number	Description
1	Battery
2	Battery Relay
3	Fusible Link
4	Circuit Breaker
5	Fuse Box
6	Starter Switch

Reference Number	Description
7	Main Relay
8	Rack Actuator Relay
9	ECU (Engine Control Unit)
10	Fuel Injection Pump
11	Engine Control Dial

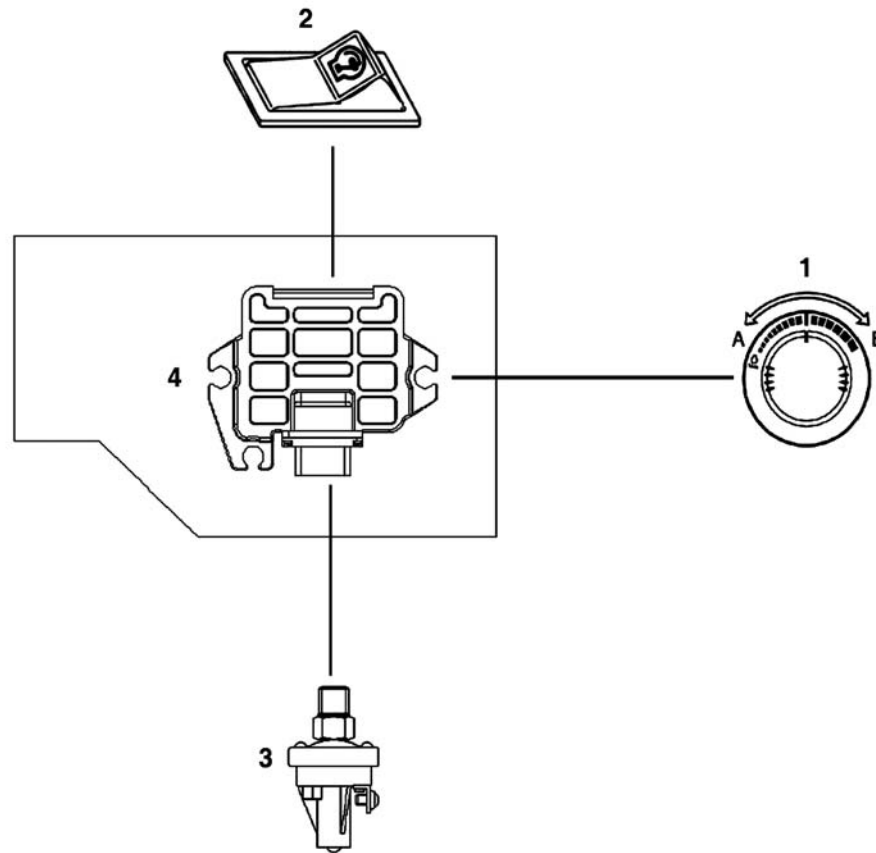
Connector and Terminal Number



FG011571

Figure 14

Automatic Deceleration Control (Auto Idle Control)



FG011495

Figure 15

Reference Number	Description
1	Engine Control Dial
2	Auto Idle Select Switch

Reference Number	Description
3	Auto Idle Pressure Switch
4	ECU (Engine Control Unit)

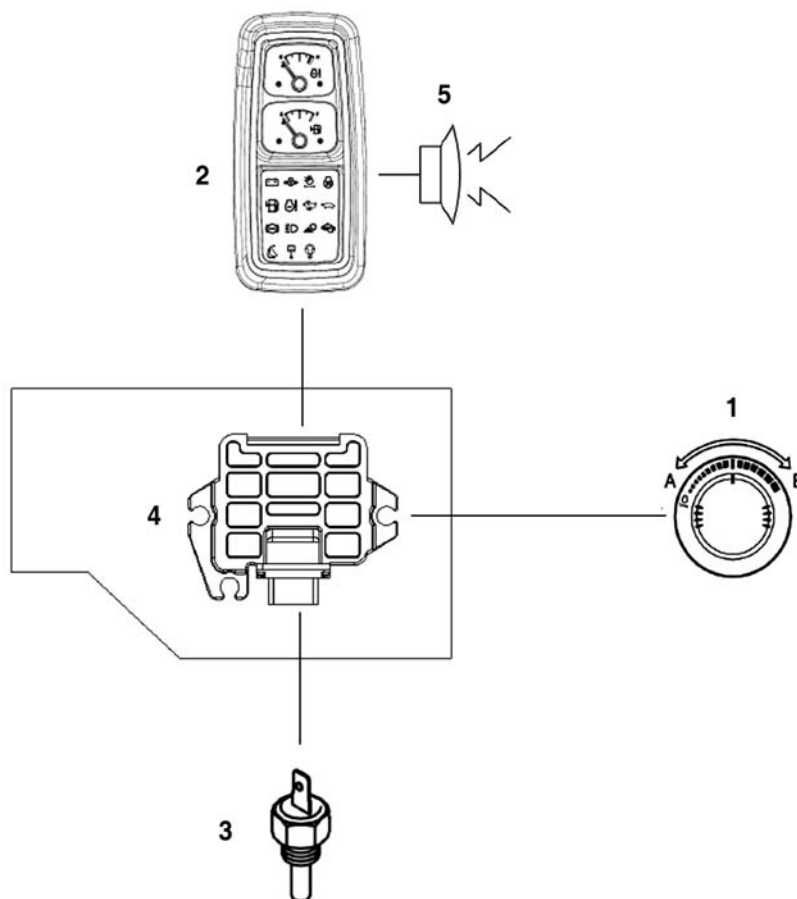
If the machine is idling without the controls being operated or is waiting for a dump truck the engine speed is automatically lowered. Once the controls are operated and work is being started the machine will be restored to the previous settings. As a result, noise and fuel consumption will be reduced. This function can be selected or cancelled through the Auto idle selector switch on the instrument panel.

The initial setting at start-up is with switch in the select position. Approximately 4 seconds after this function is selected, if all work levers are in the neutral position, the ECU compares the automatic reduction signal with the signal set by engine control dial. The lower of the two signal is selected, the ECU sends a signal to the ECU to control the engine speed.

The neutral status of the machine is detected by the pressure switch in the control valve.

When the work levers are in the neutral position, the switch is in the "ON" position.

Engine Overheat Protection System



FG011502

Figure 16

Reference Number	Description
1	Engine Control Dial
2	Instrument Panel
3	Engine Coolant Temperature Sensor

Reference Number	Description
4	ECU (Engine Control Unit)
5	Pilot Buzzer

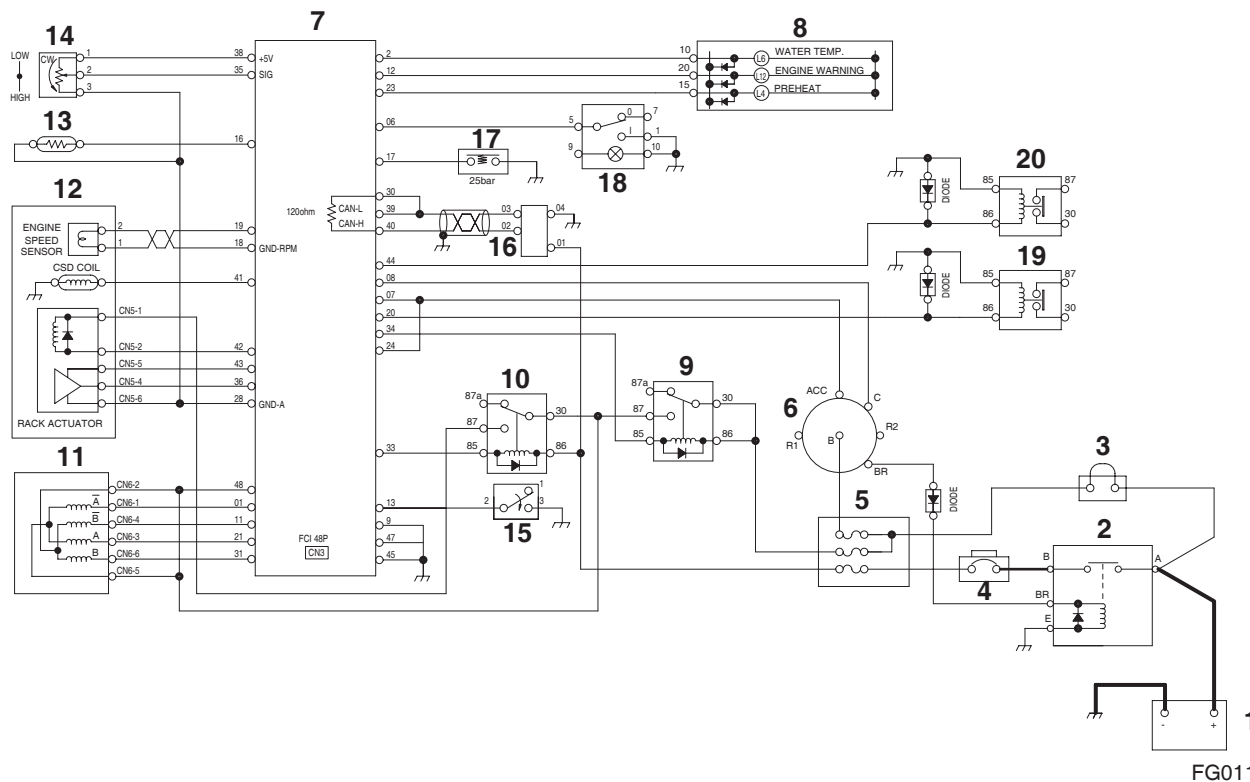
The ECU detects engine coolant temperature from the sensor mounted in the coolant line.

When the engine coolant temperature increases to over 110°C, the overheat warning light in the instrument panel will be turned on and the pilot buzzer sounds simultaneously.

At this time the engine speed is set a low speed by the ECU.

When coolant temperature falls below 105°C, normal operation will resume.

Engine Control Unit



FG011503

Figure 17

Reference Number	Description
1	Battery
2	Battery Relay
3	Fusible Link
4	Circuit Breaker
5	Fuse Box
6	Starter Switch
7	ECU (Engine Control Unit)
8	Instrument Panel
9	Main Relay
10	Rack Actuator Relay

Reference Number	Description
11	EGR Valve
12	Fuel Injection Pump
13	Engine Coolant Temperature Sensor
14	Engine Control Dial
15	Engine Emergency Stop Switch
16	CAN check connector
17	Auto Idle Pressure Switch
18	Auto Idle Select Switch
19	Starter Relay
20	Preheat Relay

Control Failure Detection

The E-ECU performs various self-diagnostics.

Diagnostic items are divided into "Always enable", "Default to enable" and "Default to disable" in the table.

Diagnostic list

No	Item	Failure detection conditions	Operation when failure occurs	Action/condition for recovery	Category	Number of flashes
1	Coolant temperature sensor failure	Sensor voltage is 4.8V or more, or 0.2V or less.	Engine runs with a coolant temperature of 30°C	Correct failure.	Always enable	4
2	Accelerator sensor failure	Sensor voltage is 4.6V or more, or 0.2V or less.	[Without optional backup accelerator sensor] Engine runs at 1500min ⁻¹ . (Option can change) [With optional backup accelerator sensor] Select backup accelerator sensor : No limitation Backup accelerator sensor failure : Engine runs at 1500min ⁻¹ . (Option can change)	Correct failure.	Default to disable	5
3	Speed sensor failure	Engine start signal (E8) is on, but the engine speed is zero. Engine speed decreases by 480 min ⁻¹ or more in 40 ms	[With optional backup speed sensor] Backup speed sensor becomes active ; speed is limited to 1800 min ⁻¹ . (Option can change) Backup speed sensor failed : Engine stops. [Without optional backup speed sensor] Engine stops.	Turn key off.	Always enable	6
4	Rack position sensor failure	Correlation between rack actuator output and rack position exceeds threshold upper limit by 0.32 sec. or more. Correlation between rack actuator output and rack position exceeds threshold upper limit by 0.16 sec. or more.	Engine runs with limited output and speed. (Rack position control is inactive and speed control is active).	Turn key off.	Always enable	7
5	Rack actuator failure	Rack actuator current is too high. Rack actuator current is too low. Engine accelerates with minimum rack actuator output Engine stalls while rack position sensor is failed.	Engine stops.	Turn key off.	Always enable	8
6	Over speed	Idling engine speed exceeds high idling speed plus 600 min ⁻¹ .	Engine stops.	Turn key off.	Always enable	9

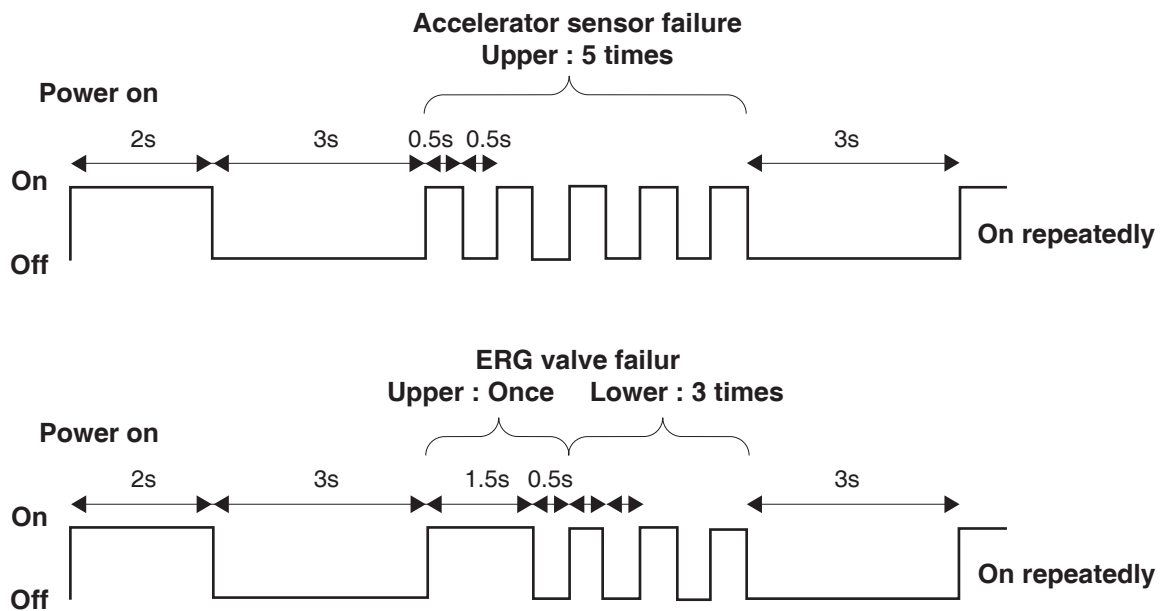
No	Item	Failure detection conditions	Operation when failure occurs	Action/condition for recovery	Category	Number of flashes
7	Backup speed sensor failure	Engine start signal (E8) is on, but the engine speed is zero.	Engine continues to run while main speed sensor is used. Backup speed sensor failed : Engine stops.	Turn key off.	Default to disable	1-1
		Engine speed decreases by 480 min ⁻¹ or more in 40ms.				
8	CAN communication failure	CAN communication packets cannot be received.	Last value is retained. Backup sensor becomes active.	Correct failure.	Default to disable	1-2
9	EGR valve failure	Low status is detected even through port is off.	Engine runs with limited output (92%) and speed (1800min ⁻¹)	Turn key off.	Default to disable	1-3
		High status is detected even through port is on.				
10	CSD solenoid valve failure	High status is detected even through port is off.	Engine continues to run with port being off.	Turn key off.	Always enable	1-4
		Low status is detected even through port is on.				
11	Air heater relay failure	High status is detected even through port is off.	Engine runs with air heater relay being off.	Turn key off.	Default to disable	1-5
		Low status is detected even through port is on.				
12	Main relay failure	Power is not shut off even though main relay is off.	Engine runs normally.	Correct failure. Or turn key off.	Default to disable	1-6
13	Rack actuator relay failure	Low status is detected even through port is off.	Engine stops.	Turn key off.	Always enable	1-7
		High status is detected even through port is on.				
14	Backup accelerator sensor failure	Sensor voltage is 4.6V or more, or 0.2V or less.	Engine continues to run while main accelerator sensor is used. Main accelerator sensor failure : Engine runs at 1500min ⁻¹ . (Option can change)	Correct failure.	Default to disable	1-8
15	Atmospheric pressure sensor failure		Atmospheric pressure compensation is canceled.	Turn key off.	Default to disable	1-9
16	Oil pressure switch failure	Oil pressure switch fails to turn on when engine is off.	Engine runs normally. (Option can change)	Turn key off.	Default to disable	2-1
17	Charge switch failure	Charge switch fails to turn on when engine is off.	Engine runs normally.	Turn key off.	Default to disable	2-2
18	Power supply voltage abnormal	E-ECU supply voltage exceeds 10.0V.	Engine runs normally.	Correct failure.	Always enable	2-3
		E-ECU supply voltage exceeds 16.0V.				

No	Item	Failure detection conditions	Operation when failure occurs	Action/condition for recovery	Category	Number of flashes
19	Sensor failure 5V	Monitoring voltage is approx. 0 V.	Engine runs normally.	Turn key off.	Always enable	2-4
		Monitoring voltage is 4.5 V or less.				
		Monitoring voltage is 5.5 V or more.				
20	E-ECU overheat alarm	E-ECU temperature exceeds 105°C. Alarm is canceled when E-ECU temperature decreases to 100°C. (option can change)	Engine runs normally. (Option can change)	Correct failure.	Default to disable	2-5
21	Oil pressure low	Oil pressure switch fails to turn off when engine is running.	Engine runs normally. (Option can change)	Correct failure.	Default to disable	3-1
22	Charge failure	Charge switch fails to turn off when engine is running.	Engine runs normally.	Turn key off.	Default to disable	3-2
23	Coolant temperature abnormal	Coolant temperature switch turns on.	Engine runs normally. (Option can change)	Turn key off.	Default to disable	3-3
24	Air cleaner blockage alarm	Air cleaner switch turns on.	Engine runs normally. (Option can change)	Turn key off.	Default to disable	3-4
25	Oily water separator alarm	Oily water separator switch turns on.	Engine runs normally. (Option can change)	Turn key off.	Default to disable	3-5
26	Coolant temperature high alarm	Coolant temperature is 115°C or higher. alarm is canceled when Coolant temperature decreases to 110°C. (Option can change)	Engine runs normally.	Correct failure.	Default to disable	3-6
27	E-ECU failure [ROM error]	Flash ROM suffers checksum error.	Engine stops.	Turn key off.	Always enable	4-1
28	E-ECU failure [EEPROM error]	Reading /Writing fails.	Engine runs normally.	Turn key off.	Always enable	4-1
		EEPROM suffers checksum error.				
29	E-ECU failure [EEPROM failure]	E-ECU fails to communicate with sub CPU.	Engine runs normally.	Turn key off.	Always enable	4-1
30	E-ECU failure [Mapping error]	Map format is invalid.	Engine stops.	Turn key off.	Always enable	4-1
31	E-ECU failure [E-ECU temperature sensor failure]	Sensor voltage is 4.6V or more, or 1.0V or less.	Engine runs normally.	Correct failure.	Always enable	4-1

Flashing patterns of engine check lamp

When detecting these failures, the E-ECU (Engine control unit) flashes the engine check lamp to alert the operator to the occurrence of failure conditions. The engine check lamp will illuminate for 2 sec. when the E-ECU is power on. This allows checking if the E-ECU is supplied with power normally.

Flashing patterns of the engine check lamp are shown in Figure 18. When accelerator sensor failure (flashing 5 time) and EGR valve failure (flashing 1-3 times) occur, the engine check lamp flashes as shown in Figure 18. When two or more failures have occurred simultaneously, the engine check lamp indicates all the failures in order of increasing number of flashes cyclically.



FG011504

Figure 18 Flashing patterns of the engine check

FUEL INJECTION PUMP

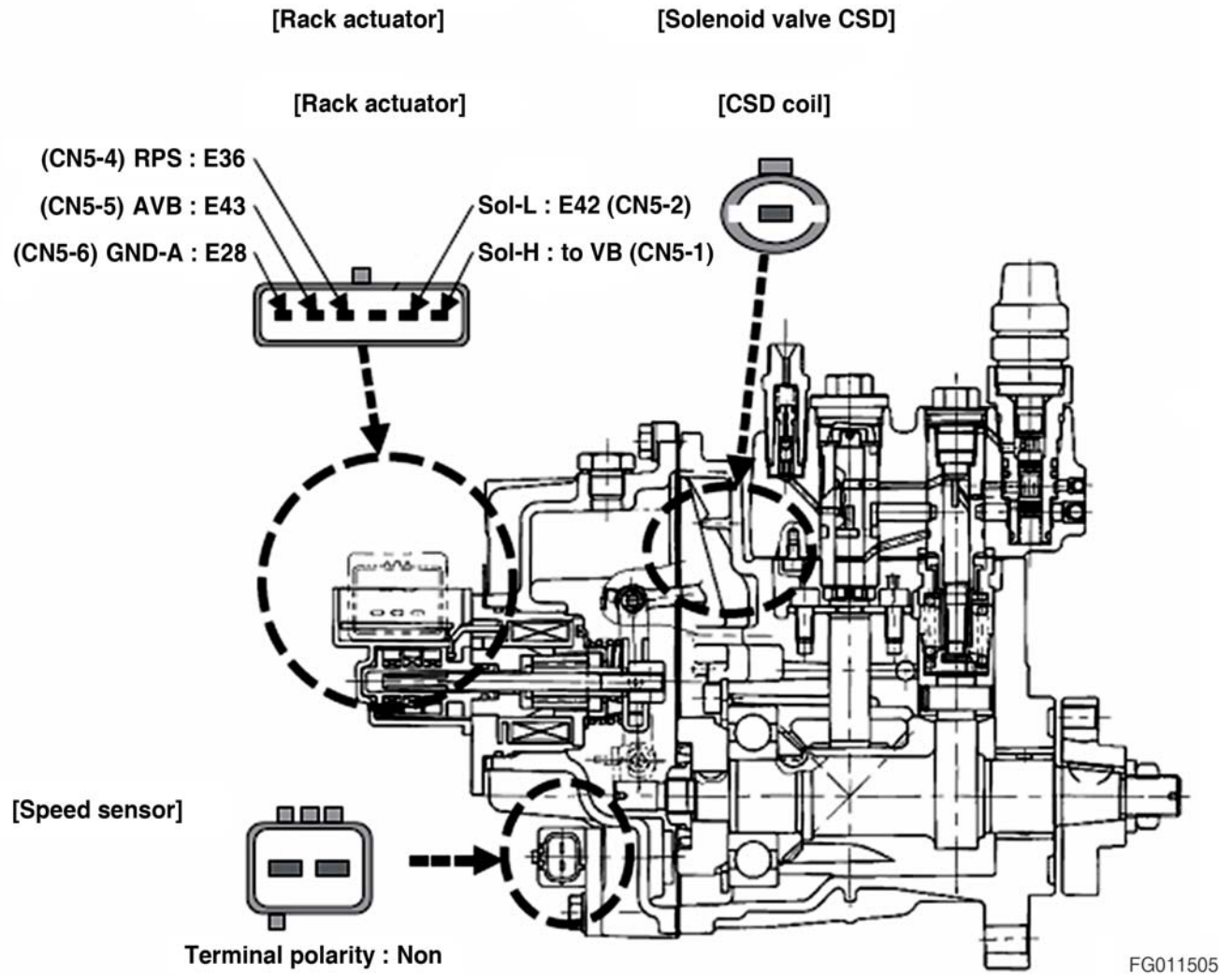


Figure 19

EGR VALVE

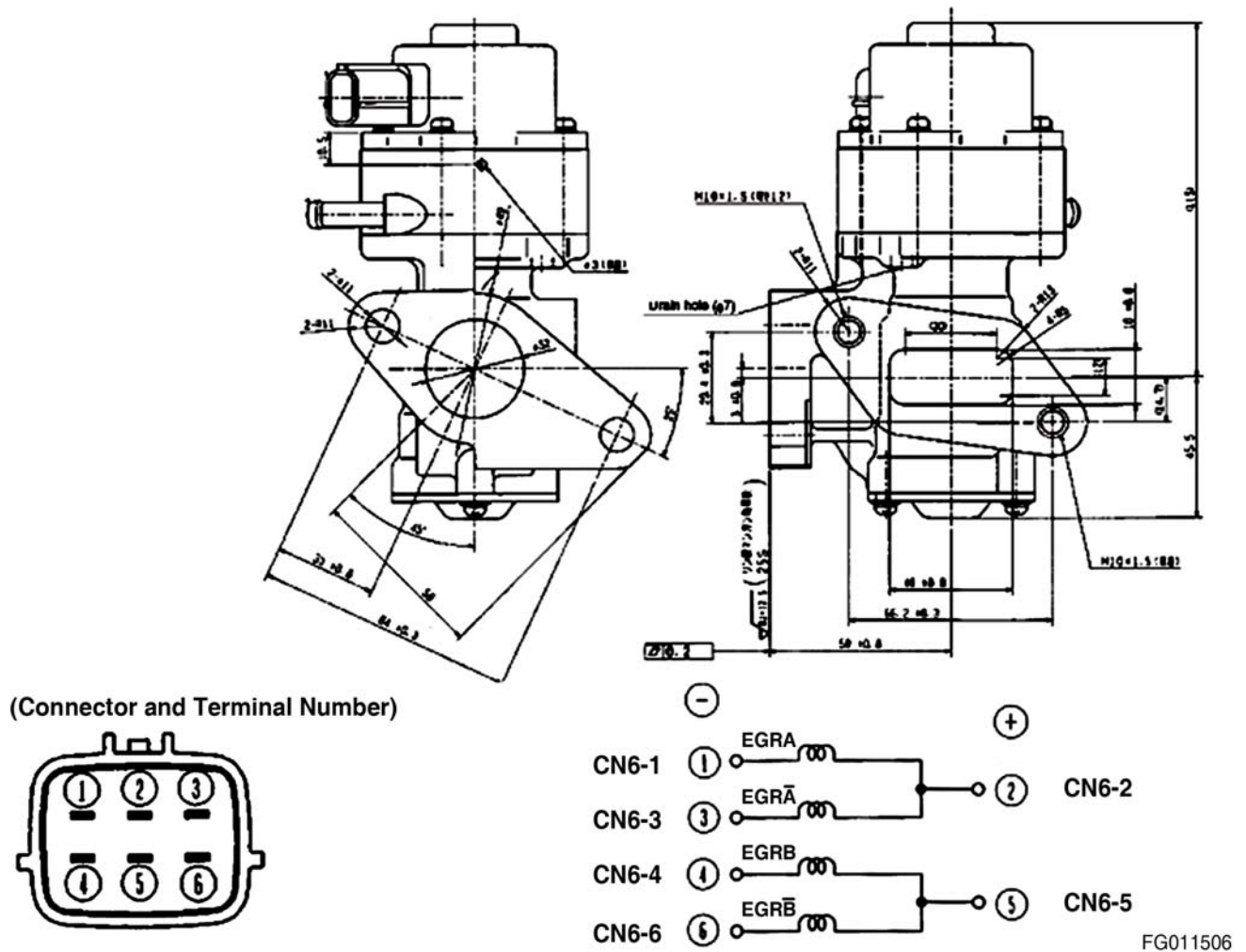
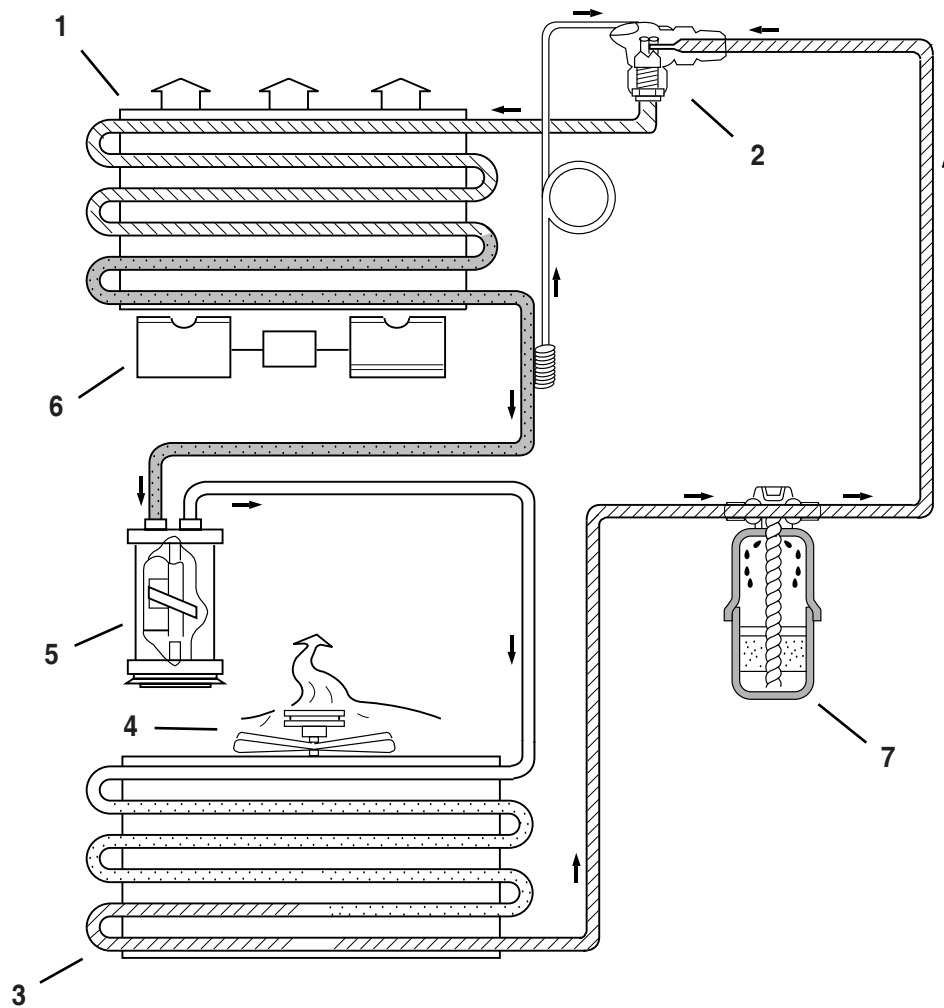


Figure 20

REFRIGERANT CIRCULATION

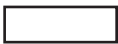


HBOI020L

Figure 21

Reference Number	Description
1	Evaporator
2	Expansion Valve
3	Condenser
4	Condenser Fan

Reference Number	Description
5	Compressor
6	Blower Fan
7	Receiver Dryer

Shading	Temperature	Refrigerant State
	High	High-pressure Gas
	High	High-pressure Liquid
	Low	Low-pressure Liquid
	High	High-pressure Gas/Liquid
	Low	Low-pressure Gas

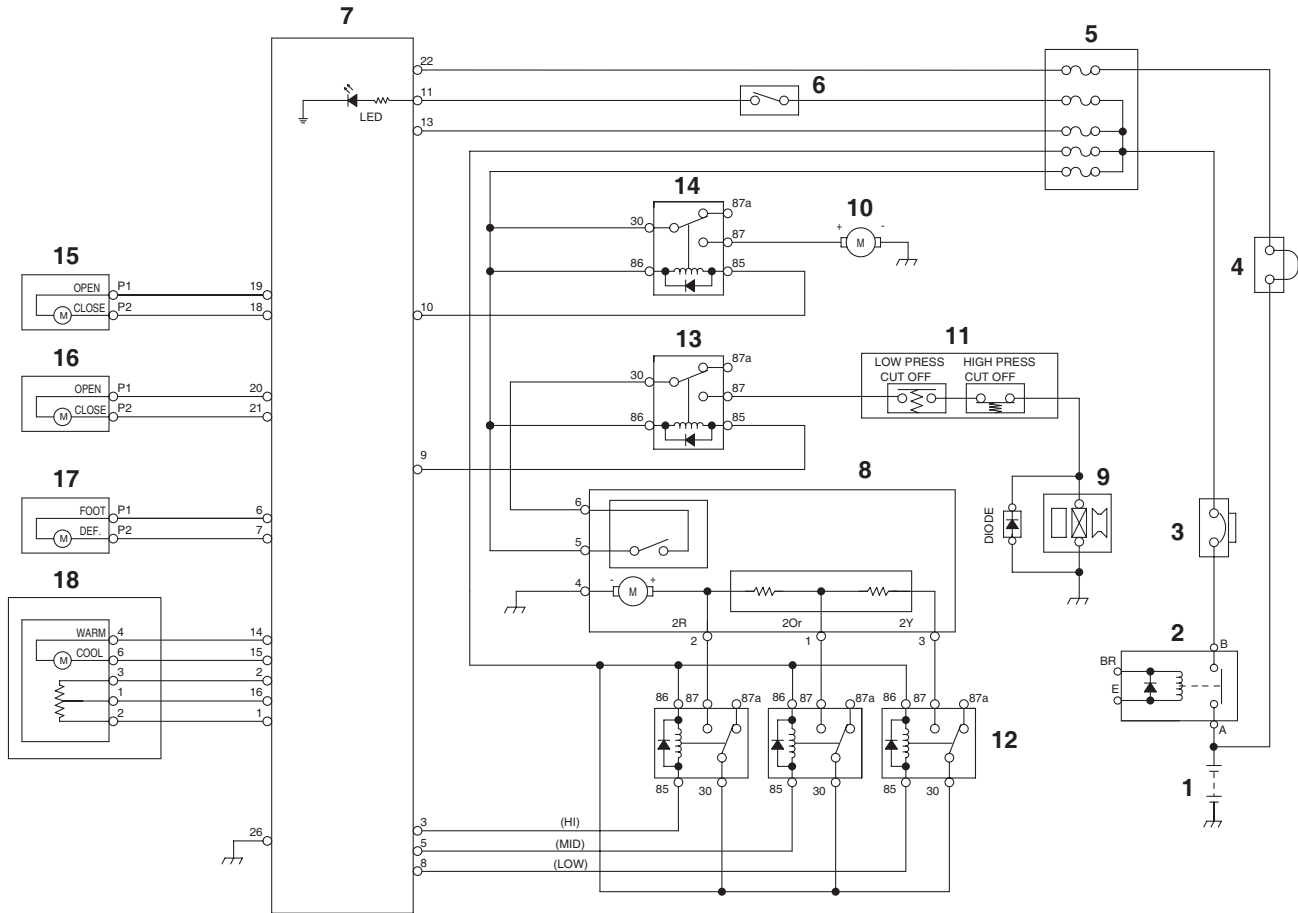
- Refrigerant (R134a) is compressed to approximately 15 kg/cm² (210 psi) within the compressor.
- The compressed refrigerant flows into the condenser at high temperature (approximately 80°C (176°F)).
- The refrigerant in the condenser is cooled to approximately 60° by the condenser fan. At this time the refrigerant changes from the gas to the liquid state, even though the temperature has only been reduced 20°C (68°F). (From 80° - 60°C (176° - 140°F)).
- The refrigerant in its liquid form is injected into the evaporator through the expansion valve. At this time the pressure is reduced by approximately 2 kg/cm² (28 psi) and the temperature is also reduced. As a result, the refrigerant absorbs the heat from the air surrounding the evaporator creating a cooling effect and changes from the gas to the liquid state.
- The refrigerant once again flows into the compressor in the gaseous state and the process is repeated.



CAUTION

Refrigerant gas is pressurized and sealed in the air-conditioning system. Special precautions are required for the proper recharging or release of refrigerant. Release of refrigerant into the atmosphere is strictly regulated by law. Make sure that you are in compliance with all mandated federal, state and municipality requirements, before starting any service or repair of the air conditioner. Refrigerant gas used in the system must meet or exceed specifications for R134a refrigerant, or any subsequently issued environmentally mandated standard.

Air-conditioning System Circuit Diagram



FG010308

Figure 22

Reference Number	Description
1	Battery
2	Battery relay
3	Circuit breaker
4	Fusible link
5	Fuse box
6	Light switch
7	AC panel
8	AC unit
9	Compressor

Reference Number	Description
10	Condenser fan
11	Receiver dryer
12	Blower relay
13	Compressor relay
14	Condenser fan relay
15	Air flow control motor (A)
16	Air flow control motor (B)
17	Air flow control motor (C)
18	Coolant flow control valve

Air Flow Control

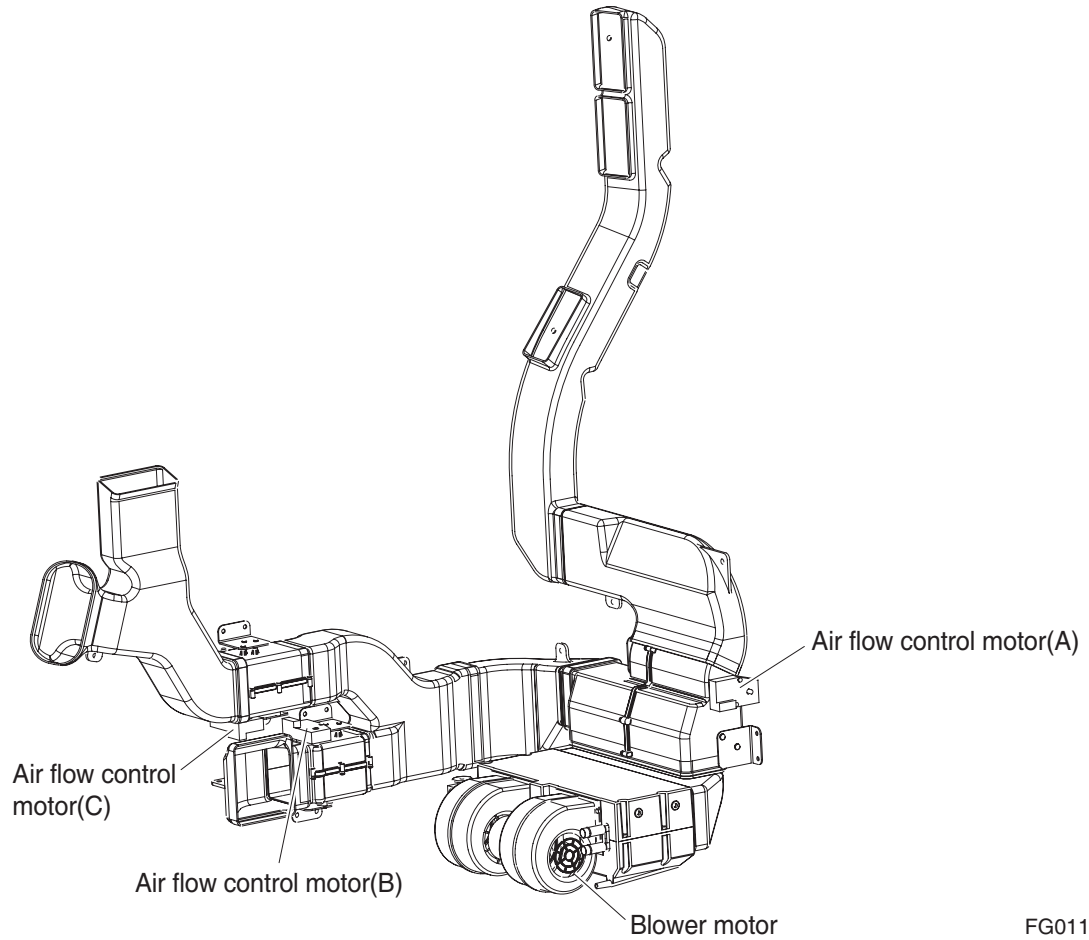


Figure 23

FG011507

	Air flow control motor (A)	Air flow control motor (B)	Air flow control motor (C)
	Open	Open	Close
	Close	Open	Close
	Close	Open	Open
	Close	Close	Open
	Open	Open	Open

Air Flow Control Motor

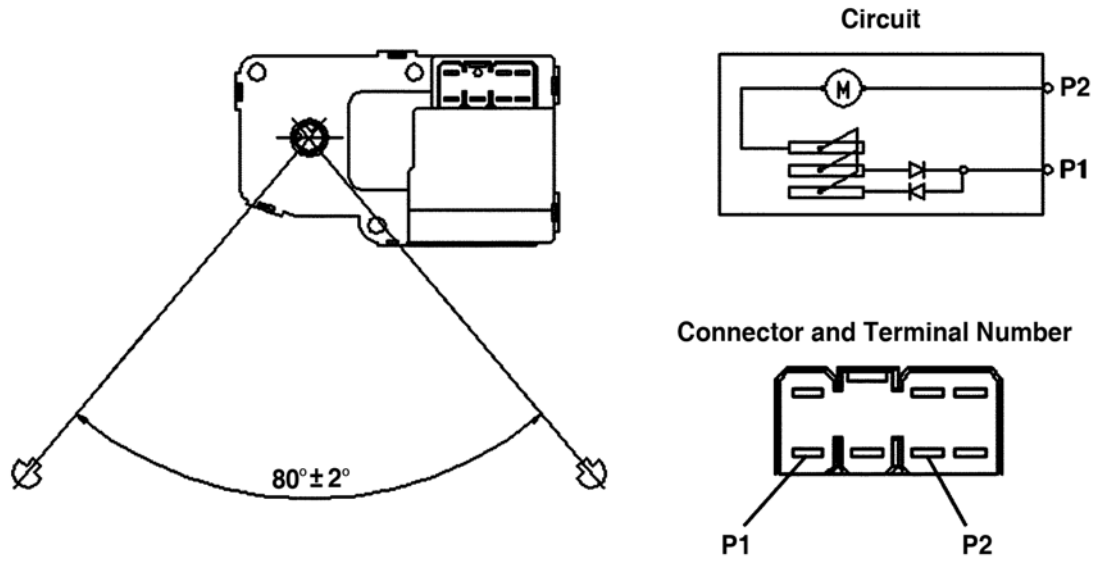


Figure 24

FG011509

Blower Motor

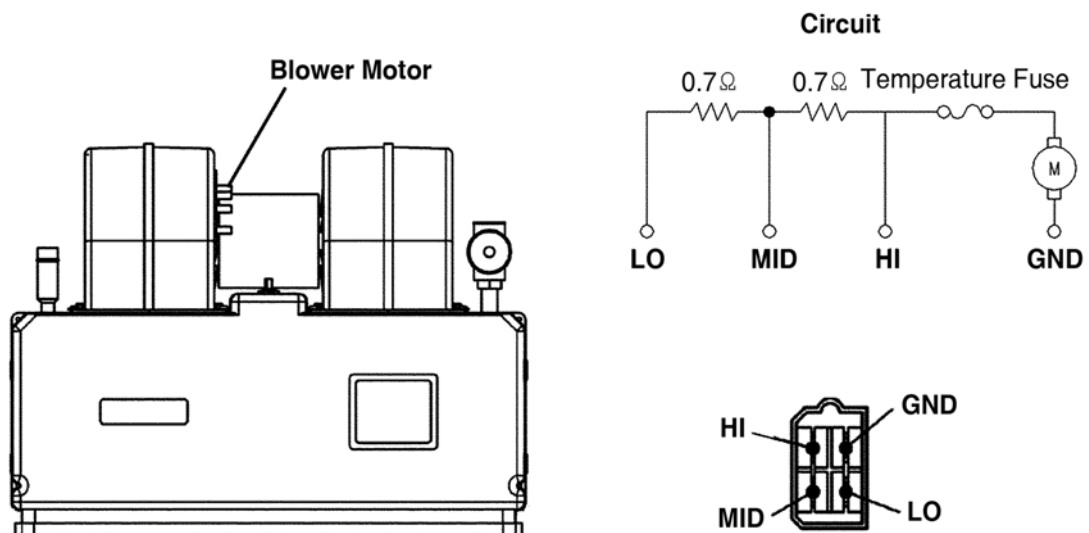


Figure 25

FG010673

Coolant Flow Control Valve

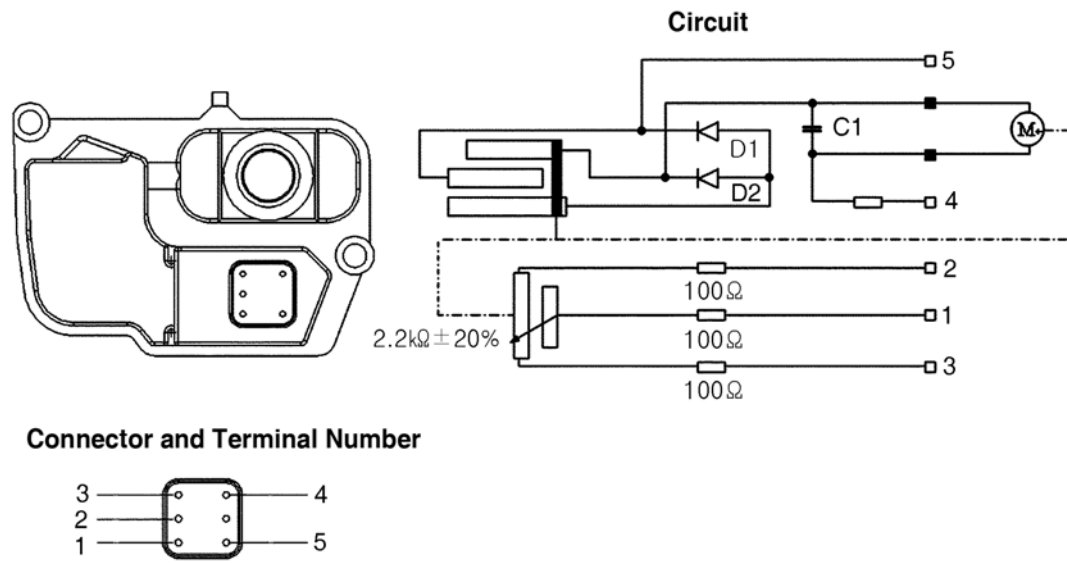


Figure 26

FG011511

Temperature Level Control And Display

Step	LED 1	LED 2	LED 3	LED 4	LED 5	LED 6	LED 7	Position Sensor Voltage	Remark
0	Green	Green	Green	Green	Green	Green	Green	4.50V $\pm$ 0.2	MAX. COOL
1	Green	Green	Green	Green	Green	Green	Green	4.33V $\pm$ 0.2	
2	Green	Green	Green	Green	Green	Green	Green	4.15V $\pm$ 0.2	
3	Red	Green	Green	Green	Green	Green	Green	3.98V $\pm$ 0.2	
4	Red	Green	Green	Green	Green	Green	Green	3.80V $\pm$ 0.2	
5	Red	Green	Green	Green	Green	Green	Green	3.63V $\pm$ 0.2	
6	Red	Red	Green	Green	Green	Green	Green	3.46V $\pm$ 0.2	
7	Red	Red	Green	Green	Green	Green	Green	3.28V $\pm$ 0.2	
8	Red	Red	Green	Green	Green	Green	Green	3.11V $\pm$ 0.2	
9	Red	Red	Red	Green	Green	Green	Green	2.93V $\pm$ 0.2	
10	Red	Red	Red	Green	Green	Green	Green	2.76V $\pm$ 0.2	
11	Red	Red	Red	Green	Green	Green	Green	2.59V $\pm$ 0.2	
12	Red	Red	Red	Red	Green	Green	Green	2.41V $\pm$ 0.2	
13	Red	Red	Red	Red	Green	Green	Green	2.24V $\pm$ 0.2	
14	Red	Red	Red	Red	Green	Green	Green	2.07V $\pm$ 0.2	
15	Red	Red	Red	Red	Red	Green	Green	1.89V $\pm$ 0.2	
16	Red	Red	Red	Red	Red	Green	Green	1.72V $\pm$ 0.2	
17	Red	Red	Red	Red	Red	Green	Green	1.54V $\pm$ 0.2	
18	Red	Red	Red	Red	Red	Red	Green	1.37V $\pm$ 0.2	
19	Red	Red	Red	Red	Red	Red	Green	1.20V $\pm$ 0.2	
20	Red	Red	Red	Red	Red	Red	Green	1.02V $\pm$ 0.2	
21	Red	Red	Red	Red	Red	Red	Red	0.85V $\pm$ 0.2	
22	Red	Red	Red	Red	Red	Red	Red	0.67V $\pm$ 0.2	
23	Red	Red	Red	Red	Red	Red	Red	0.50V $\pm$ 0.2	MAX. HOT

WEIGHT OF R134A GAS USED IN MACHINES

Model	Weight of Gas
DX35Z	450 ± 20 gram (15.9 ± 0.7 oz)
DX55	500 ± 20 gram (17.6 ± 0.7 oz)
DX60R	550 ± 20 gram (19.4 ± 0.7 oz)
DX80R	650 ± 20 gram (22.9 ± 0.7 oz)

REFRIGERANT SYSTEM REPAIRS



WARNING

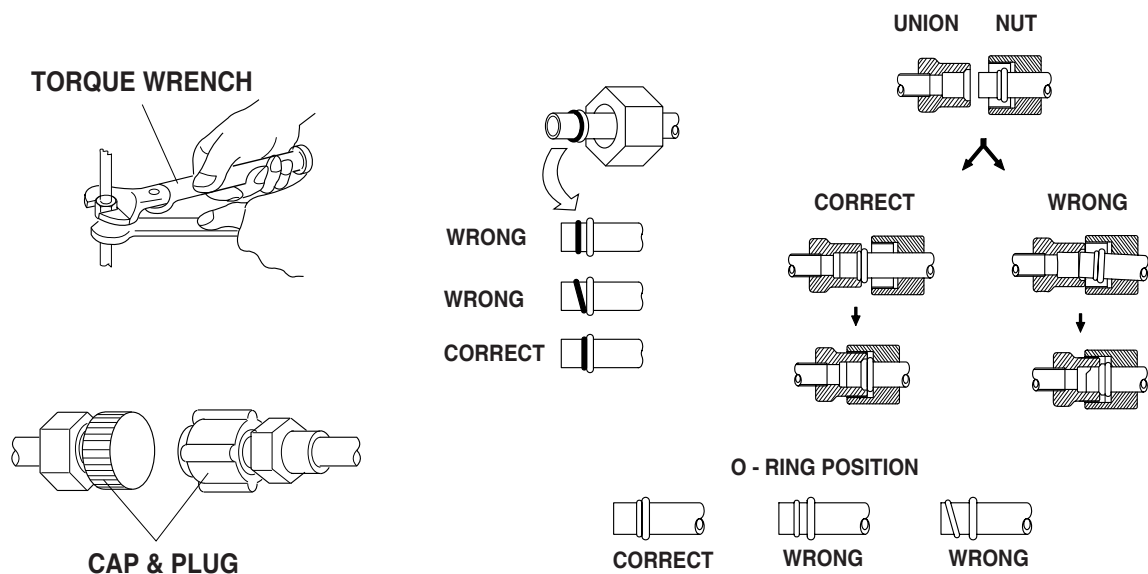
Always wear protective glasses and gloves when handling refrigerant. If refrigerant comes in contact with the skin or eyes, immediately flush with clean, running water and consult a physician.

Select a clean and well-ventilated area to work.

The refrigerant container is under high-pressure and should be stored below 40°C (104°F). Be careful not to drop the container from a high location

The contents are under high-pressure and should not be used with compressed air or near an open flame.

Refrigerant Safe Handling Procedures



HDA6066L

Figure 27

The following procedures should be observed for safe handling of refrigerant during vacuum and charging process.

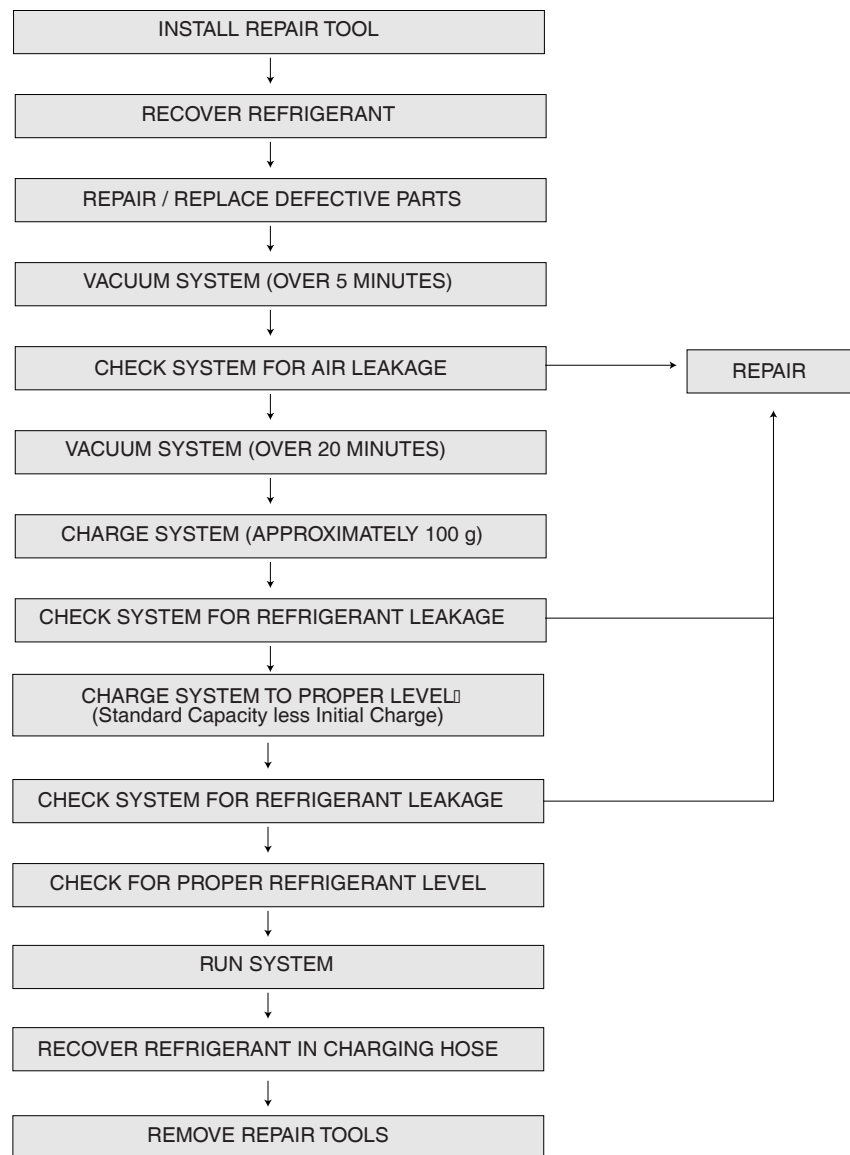
1. Use an approved recovery / charging device which can safely perform vacuum and charge work simultaneously.
2. The new refrigerant has improved cooling characteristics than the old type and care should be used not to overcharge the system.

3. Do not over tighten connections when working on refrigerant system.
4. The new refrigerant system standards require new tools, equipment and parts. Do not attempt to use equipment use in servicing the old refrigerant system.
5. The new refrigerant oil (PAG type) has a high moisture absorption characteristic. When the refrigerant system vacuum seal has been broken, immediately plug up all openings to prevent moisture from entering into the system.
6. When joining unions which use O-ring seals, lightly coat O-rings with refrigerant oil. Be careful not to drip oil on the threads of the nut.
7. Be certain the O-rings are seated properly on the refrigerant line lip. Always use new O-rings when reassembling parts. Do not reuse old O-rings.
8. Use a vacuum pump to evacuate refrigerant system of air.
9. When charging the refrigerant system with the engine running, do not open the high-pressure valve on the manifold gauge as the reverse flow of high-pressure refrigerant will rupture the hose.
10. When releasing the high-pressure hose after completing the charging process, quickly disconnect the hose to minimize refrigerant released to the air.

Repair and Replacement Procedure

1. Work Procedure;
 - A. Before repairing or replacing any refrigerant components first, return all refrigerant oil to the compressor and perform recovery procedures.
2. Operating Condition;
 - A. Run engine at maximum engine speed.
 - B. Select "HI" blower fan speed and select A/C switch to "ON".
 - C. Set the temperature control switch for maximum cooling and leave running for approximately 20 minutes.

NOTE: *The manifold gauge dial pointer can vary depending on the outdoor temperatures.*



HDA6067L

Figure 28

Refrigerant Recovery

Reference Number	Description
1	To Compressor
2	Low-pressure Side
3	High-pressure Side
4	From Receiver
5	Refrigerant Recovery Tank

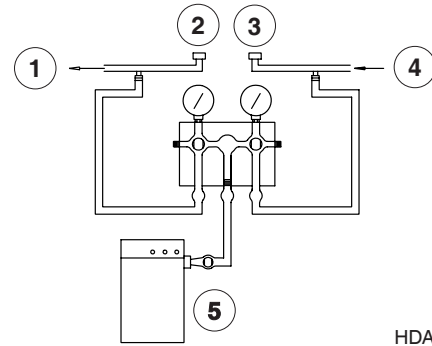
1. Attach the manifold gauges and the refrigerant recovery unit to the refrigerant lines as shown.

NOTE: *Be careful not to switch the connections for the low and high-pressure valves.*

2. Open the high-pressure valve slowly to release the refrigerant to the recovery unit.

NOTE: *Open the valve slowly, while checking to see that refrigerant is not leaking out.*

3. When the manifold gauge dial falls below 3.5 kg/cm² (50 psi), slowly open the low-pressure valve.
4. Open both the high and low-pressure valves slowly until the manifold gauge dials indicates 0 kg/cm² (0 psi).



HDA6067L

Figure 29

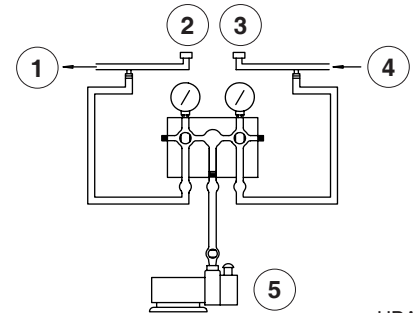
Vacuuming Refrigerant System

Reference Number	Description
1	To Compressor
2	Low-pressure Side
3	High-pressure Side
4	From Receiver
5	Vacuum Pump

1. Vacuuming Procedure;

NOTE: *When the A/C system has been exposed to the air, it must be vacuumed out. Perform vacuum process for 30 minutes for complete moisture and air evacuation.*

- A. Attach the manifold gauges and vacuum pump to the refrigerant system as shown.
- B. Turn on the vacuum pump and open both valves.
- C. When the low-pressure gauge shows approximately 710 mmHg, close both valves and turn off vacuum pump.



HDA6068L

Figure 30

2. Check system for vacuum leak;
 - A. Allow system to sit for 10 minutes and check whether the system is holding the pressure. If the pressure has dropped, it must be repaired before proceeding to the next step.

3. Vacuuming Procedure;

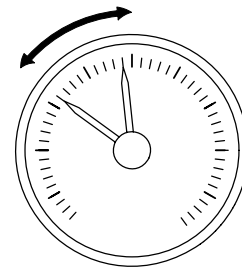
NOTE: *If the system is holding the pressure and it has not changed for 10 minutes, vacuum out the system for an additional 20 minutes.*

- A. Turn on the vacuum pump and slowly open both valves.
- B. Allow vacuum pump to run for additional 20 minutes until the low-pressure gauge dial reads approximately 750 mmHg.
- C. Close both valves and stop the vacuum pump.

4. Installation of Refrigerant Container

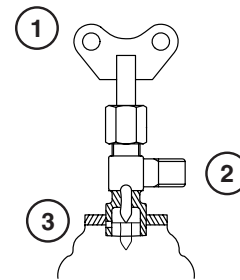
Reference Number	Description
1	Handle
2	Hose Connection
3	Mounting Disk

- A. Before mounting valve on the container, make sure the handle is in the counter clockwise most position, with the puncture pin retracted and the mounting disk is in the raised position.
- B. Attach the manifold gauge center hose to the valve assembly.
- C. Turn the disc in the clockwise direction and securely mount valve onto refrigerant container.
- D. Turn the valve handle in the clockwise direction and puncture the container seal with the pin.
- E. Once the can has been punctured, turn the handle in the counter clockwise direction so the refrigerant can flow into the manifold gauge center hose. At this time, do not open the low and high-pressure valves of the manifold gauge.
- F. Press the manifold gauge low side valve to eliminate the trapped air in the hose.



HDA6069L

Figure 31



HDA6070L

Figure 32

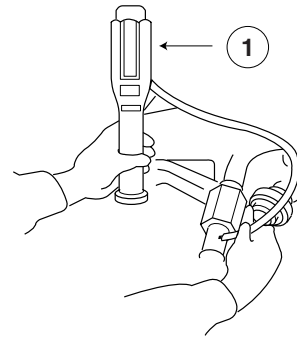
Leakage Check

NOTE: Perform the leakage check after completing vacuuming process.

1. After attaching the manifold gauge, open the high side valve.
2. Charge system until the low side gauge dial indicates a pressure of 1 kg/cm² (14 psi) and close the high side valve.
3. Using a refrigerant leak detector or soapy water check each joint for leakage.

Reference Number	Description
1	Refrigerant Leak Detection Device

4. If a leak is detected, check for O-ring damage or correct tightening torque and replace or repair as necessary.
5. If no leaks are detected, proceed with the charging process.



HDA6071L

Figure 33



CAUTION

For accurate refrigerant leak detection, perform leak detection procedure in a well-ventilated area.

Refrigerant Charging

1. Perform the vacuuming procedure, vacuum holding and leaking tests as described in the proceeding headings.

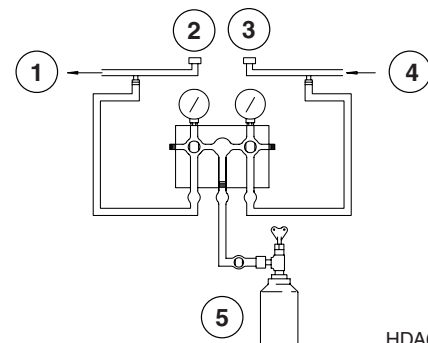
NOTE: First charge the refrigerant system with 100 g (3.5 ounces) of refrigerant with the engine off. Then using the manifold gauges as a guide fully charge the system with the engine running.

When exchanging refrigerant containers, press the manifold gauge low side valve to eliminate air from the charging hose.

Reference Number	Description
1	To Compressor
2	Low-pressure Side
3	High-pressure Side
4	From Receiver
5	Refrigerant Supply Container

2. Charge the system by opening the manifold gauge low side valve.

Initial charge amount: 100 g (3.5 ounces).



HDA6072L

Figure 34

3. If refrigerant does not flow freely into system, try starting engine first before operating air conditioner.
 - Temperature control switch setting: Maximum Cooling.
Blower Speed Setting: Hi (3 step).
Engine Speed: 1,300 - 1,500 rpm.



CAUTION

When charging refrigerant system with the engine running;

- **Always keep refrigerant supply container in the upright position.**
- **Never open the high side pressure valve.**

-
4. Open the manifold gauge low side valve and charge system to standard capacity.

Gauge Dial	Standard Reading
High Side Gauge	13 - 20 kg/cm ² (185 - 285 psi)
Low Side Gauge	1.5 - 3.5 kg/cm ² (21 - 49 psi)

NOTE: *These standards are for outside temperatures between 30° - 35°C (86° - 95°F). The gauge readings may vary for extreme temperature conditions.*



CAUTION

-
- **When outside temperature is low, warm the refrigerant supply container with warm water not exceeding 40°C (104°F). Do not allow water to come in contact with the charging adapter valve handle.**
 - **When outside temperature is high, cool off refrigerant supply container and condenser to aid the refrigerant charging process.**

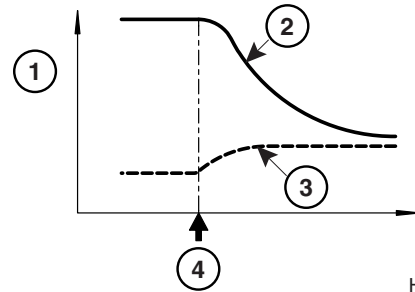
-
5. Close low-pressure side valve.
 6. Shut off engine and close refrigerant supply container adapter valve. Disconnect manifold gauge hoses from vehicle.

Inspecting System for Leakage

After completing charging procedures, clean all joints and connections with a clean dry cloth. Using a refrigerant leak detecting device or soapy water, inspect system for leaks starting from the high-pressure side.

NOTE: *When the refrigerant circulation has been stopped the high-pressure will start to decrease and the low-pressure will start to increase until they are equalized. Starting the inspection from the high side will result in a accurate test.*

Reference Number	Description
1	Pressure
2	High-pressure
3	Low-pressure
4	Compressor Stop



HDA6073L

Figure 35

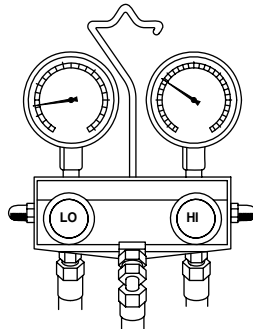
Inspection Procedure

- High-pressure Side.
Compressor outlet → condenser inlet → receiver dryer inlet → air conditioner unit inlet
- Low pressure side.
Compressor inlet → air conditioner unit outlet
- Compressor.
Compressor shaft area, bolt hole area and magnetic clutch area.
- Receiver dryer.
Pressure switch and plug area.
- Connection valve area.
Inspect all valve areas.
Verify all valves are capped to prevent leaking.
Check for foreign material inside of valve cap.
- Interior of air conditioner unit.
After stopping engine, insert detector probe into drain hose. (Leave inserted for 10 seconds minimum.)

NOTE: *When inspecting leakage from the air conditioner unit, perform the inspection in a well ventilated area.*

TROUBLESHOOTING

Refrigerant Pressure Check



HDA6074L

Figure 36

1. Open all doors and windows.
2. Install manifold gauge set.
3. Start engine and maintain engine speed at 1,800 - 2,000 rpm.
4. Check high / low-pressure of refrigerant.

1	High-pressure: 8 - 10 kg/cm² (114 - 142 psi) Low-pressure: Approximately 1 kg/cm² (14 psi)		
Possible Cause: Low Refrigerant Level			
Step	Inspection Item		Remedy
1	Check for traces of refrigerant oil.	Yes	Reassemble using correct tightening torque.
		No	Go to next step.
2	Using a leak detection device or soapy water check for refrigerant leakage at all major components and joints.	Yes	Repair leaking component.
		No	Recharge system to correct pressure.

2	High-pressure: Over 23 kg/cm² (327 psi) Low-pressure: Approximately 2.5 - 3 kg/cm² (35 - 42 psi)		
Possible Cause: Overcharge, Frost on condenser			
Step	Inspection Item		Remedy
1	Check for condenser pin damage or contamination.	Yes	Clean, repair or replace condenser.
		No	Refrigerant overcharge.

3	High-pressure: Approximately 20 - 25 kg/cm² (285 - 355 psi) Low-pressure: Approximately 2.5 - 3.5 kg/cm² (35 - 50 psi)
Possible Cause: Air in system.	
1. Recover any remaining refrigerant. 2. Vacuum out system. 3. Recharge system. NOTE: <i>If the system has been exposed to the air for a long period of time, replace the receiver dryer.</i>	

4	High-pressure: Over 6 kg/cm ² (85 psi) Low-pressure: Approximately 760 mmHg (Negative Pressure)		
Possible Cause: Refrigerant does not circulate			
Step	Inspection Item		Remedy
1	1. Connect manifold gauge and start engine. 2. Turn on air conditioner. 3. Set blower switch to "HIGH" position.	Yes	Moisture in system, replace receiver dryer.
	4. Turn air conditioner "OFF" and wait 10 minutes. 5. Recheck high / low-pressure readings. High-pressure: 13 - 19 kg/cm ² (185 - 270 psi) Low-pressure: 1.5 - 3.3 kg/cm ² (21.3 - 46.9 psi)	No	Contaminated system, replace expansion valve. (Replace evaporator core assembly.)

5	High-pressure: Over 6 - 18 kg/cm² (85 - 256 psi) Low-pressure: 500 mmHg (Negative Pressure) - Dial indicator needle unstable.
Possible Cause: Moisture in system has iced up the expansion valve.	
NOTE: <i>When the absorbed moisture freezes the pressure readings may look normal. Careful readings should be made to determine whether pressure is in normal range.</i>	
1. Recover any remaining refrigerant. 2. Vacuum out system. 3. Recharge system. NOTE: <i>If the system has been exposed to the air for a long period of time, replace the receiver dryer.</i>	

6	High-pressure: Over 22 - 23 kg/cm² (313 - 327 psi) Low-pressure: 2.5 kg/cm² (36 psi)		
Possible Cause: Refrigerant pressure problem due to defective expansion valve or temperature sensor.			
Step	Inspection Item		Remedy
1	Inspect whether the temperature sensor is installed properly.	Yes	Replace expansion valve.
		No	Exchange duct sensor.

7	High-pressure: Over 7 - 11 kg/cm² (100 - 156 psi) Low-pressure: 4 - 6 kg/cm² (57 - 85 psi)
Possible Cause: Low refrigerant pressure due to poor compressor compression	
Inspect and replace compressor if necessary.	

Electrical Schematic (DX60R/DX80R)

Edition 1

MEMO

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up
DX80R	50001 and Up

DX60R/DX80R

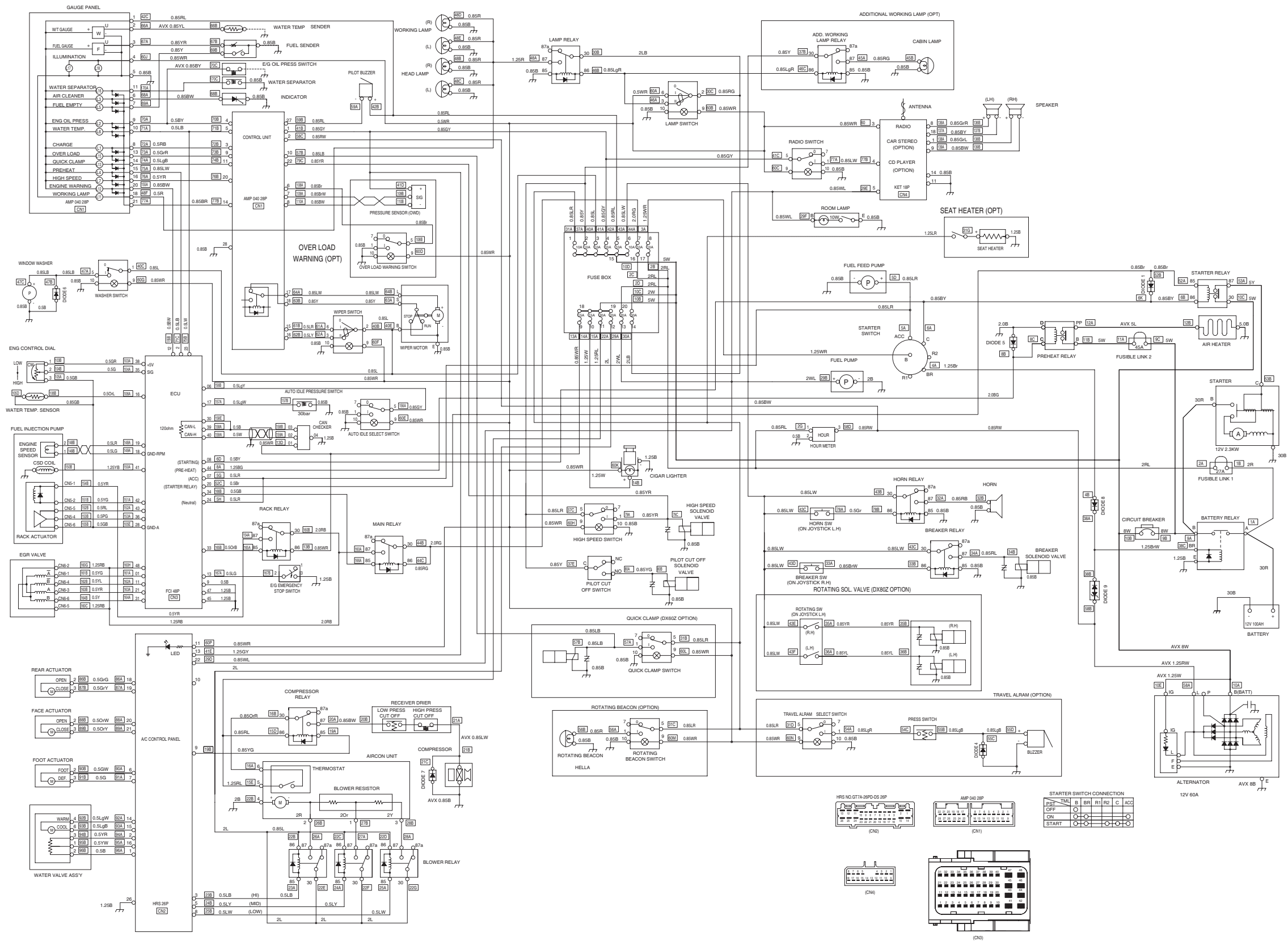


Figure 1

Attachments

Boom and Arm

Edition 1

MEMO

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Boom and Arm

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling load.

Remember that ultimate safety is your own personal responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up

NOTE: *Some mounting pins must be drilled and tapped for lubrication fittings and piping, or may have other required specifications. Consult DOOSAN After Sales Service for information on wear tolerances and replacement limits for mounting pins.*



Figure 1

Mark	Measuring Pin	Criteria						Remedy
		Size		Tolerance		Standard Clearance	Clearance Limit	
		Diameter	Length	Pin	Hole			
A	Boom Foot Pin	55 mm (2.17 in)	357 mm (14.06 in)	-0.05	+0.29 4	0.294 ~ 0.364	1.5	Replace
				-0.07	+0.24 4			
B	Boom Cylinder Head Pin	50 mm (1.97 in)	224 mm (8.82 in)	-0.05	+0.20	0.05 ~ 0.27	1.5	
				-0.07	0			
C	Boom Cylinder Rod Pin	50 mm (1.97 in)	206 mm (8.11 in)	-0.04	+0.20	0.04 ~ 0.29	1.5	
				-0.09	0			
D	Boom to Arm Pin	50 mm (1.97 in)	287 mm (11.30 in)	-0.04	+0.29 4	0.284 ~ 0.384	1.5	
				-0.09	+0.24 4			
E	Arm Cylinder Head Pin	50 mm (1.97 in)	189 mm (7.44 in)	-0.04	+0.20	0.04 ~ 0.29	1.5	
				-0.09	0			
F	Arm Cylinder Rod Pin	50 mm (1.97 in)	174 mm (6.85 in)	-0.04	+0.20	0.04 ~ 0.29	1.5	
				-0.09	0			
G	Arm Link Pin	45 mm (1.77 in)	286 mm (11.26 in)	-0.05	+0.27 8	0.278 ~ 0.348	1.5	
				-0.07	+0.22 8			
H	Arm End Pin	45 mm (1.77 in)	285 mm (11.22 in)	-0.04	+0.27 8	0.268 ~ 0.368	1.5	
				-0.09	+0.22 8			
I	Bucket Cylinder Head Pin	50 mm (1.97 in)	174 mm (6.85 in)	-0.04	+0.20	0.04 ~ 0.29	1.5	
				-0.09	0			
J	Bucket Cylinder Rod Pin	50 mm (1.97 in)	286 mm (11.26 in)	-0.05	+0.29 4	0.294 ~ 0.364	1.5	
				-0.07	+0.24 4			
K	Push Link to Bucket Pin	45 mm (1.77 in)	285 mm (11.22 in)	-0.04	+0.27 8	0.268 ~ 0.368	1.5	
				-0.09	+0.22 8			

FRONT ATTACHMENT - REMOVAL AND INSTALLATION



DANGER

DOOSAN warns any user, that the removal of the counterweight from the machine, front attachment or any other part, may affect the stability of the machine. This could cause unexpected movement, resulting in death or serious injuries. DOOSAN is not liable for any misuse.

Never remove the counterweight or front attachment unless the upper structure is in-line with the lower structure.

Never rotate the upper structure once the counterweight or front attachment has been removed.

IMPORTANT

Always break down the front attachment by removing outermost sections first - the bucket before the arm, the arm before the boom. Reinstallation of the attachment should begin with the boom and end with the bucket.

Refer to the appropriate Bucket section for its removal and installation procedure before going onto the initial step of the front attachment removal or installation procedure.

Arm Removal Procedure

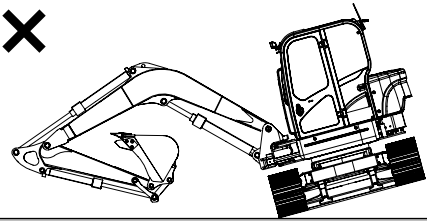


WARNING

This procedure is only intended for routine removal or replacement of the attachment, while working under normal, safe operating conditions. In the event of a major structural collapse of some part of the attachment, an accident or complete loss of attachment hydraulic function, DO NOT proceed with attachment disassembly unless you are completely sure of what you are doing. Please call your local DOOSAN distributor or DOOSAN After Sales Service for assistance. DO NOT allow personnel to stand underneath a weakened or only partially supported attachment section. Keep clear of hydraulic lines that may have fluid escaping at high-pressure - it can cause severe or even fatal injuries.

Complete the bucket end removal procedure by pulling out the two bucket linkage pins and the bucket cylinder mounting pin, on the arm. Use an assist crane or hoist to lift the cylinder and relieve weight on mounting pins.

×



×

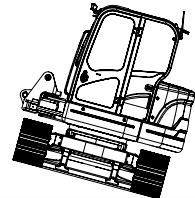


Figure 2

FG012419

Park the excavator away from obstructions and all traffic on clear, flat, level ground. Extend the arm cylinder and crowd the arm into the boom. Partially retract the boom cylinder so that the boom is stretched out in front of the excavator, as low to the ground as possible, with the arm crowded under the boom.

The tip of the arm point should be lowered to secure blocking that will safely support the weight of the arm. Place the blocking directly in front of the excavator and make sure that it will not be unbalanced with an initial weight load that is all to one end, under the arm point.

Shut off the engine and release hydraulic system pressure - move any of the control levers with the engine off to release pressure built up in the accumulator. Manually vent residual hydraulic pressure in the tank by moving the lever near the cap, on top of the reservoir.

 WARNING

Secure the swing lock and tag and lock out controls in the operator's cabin to keep anyone from moving or inadvertently starting the engine. Restrict access to the work site while sections of the attachment are in the air, or while they are being supported by the assist crane. The safe lifting capacity of the assist crane or hoist that is used must exceed the weight of the heaviest section of the attachment, the boom (approximately 756 kg [1,667 lb], not including the weight of accessories or fixtures).

Before beginning the disassembly of attachment mounting pins, disconnect the arm cylinder hydraulic hose couplings and put a clean plug in the end of each one. Use any and all reasonable precautions necessary to avoid introducing dirt or other contaminants into the hydraulic system. Wipe down coupling points before disconnecting hydraulic lines and use evaporative type solvent spray cleaner. Tag and mark hoses for reassembly, if necessary.

Place a sling under the arm cylinder (the cylinder used to extend and retract the attachment arm, pinned to the top of the boom). Lift the sling so that the weight load on the rod end of the arm cylinder (pinned to the ears on the inner end of the arm) is released. Prepare blocking under the arm that will securely support the weight of the arm and arm cylinder.



CAUTION

To make sure that the polished surfaces of cylinder rod ends will not suffer accidental damage during disassembly or removal procedures, wrap exposed rod surfaces (especially those of boom cylinders) with a protective covering material. Immediately following disassembly and removal, cylinder rods should always be fully retracted. This eases handling problems and also avoids possible damage.

Remove retainers on the end of the mounting pin for the arm cylinder rod end. Use the assist crane to relieve the weight load and withdraw the pin. Lower the arm down to the blocking support for any continued disassembly procedures.

Boom Removal Procedure

NOTE: *Boom removal may be simplified if the shell of the operator's cabin is taken off the turntable deck first. Refer to the Operator's Cabin Removal procedure before continuing, if both components are to be removed from the excavator.*

After the bucket, arm and arm cylinder have been removed, lower the end of the boom to a stable, secure blocking support.

Attach the assist crane sling to the body of either boom cylinder, break the mounting pin connection to the boom by tapping through the pin from the same side of the boom and repeat for the opposite cylinder.

Release hydraulic pressure and disconnect line couplings as previously outlined in the Arm Removal Procedure, observing the same precautions.

Disconnect wiring for work light assemblies and any other accessory lines or connections. Locate the sling of the assist crane near the center of gravity, optimum lift point for the boom, and use the crane to take pressure off the boom foot pin. Drive out the pin after disassembling retainers and carefully lift away the boom.



WARNING

Traveling the excavator, swinging the turntable or movement over bumps or sloping, uneven surfaces could all produce loss of control and possible accidents or injuries, if the turntable deck has been unbalanced by removal of weight from one end only.

To maintain stability, the counterweight should be removed whenever the front attachment is taken off the machine.

INSTALLATION

Arm Installation Procedure

Reattach the base of the arm cylinder to the mounting point on top of the boom.



Before assembling the front attachment, make sure that the individual boom, arm and bucket sections are all compatible and can be used safely for work intended. Refer to the General Safety Pages, Lift Ratings, Working Range Diagrams and Weights of Materials sections in the Operation and Maintenance Manual. Consult your dealer or DOOSAN After Sales Service for more information if you have any questions or require more information.

Begin with the arm securely supported on blocking in front of the excavator. Pregrease the mounting pin for the rod end of the arm cylinder and push it through the ears on the end of the arm. Attach a sling around that mounting pin and lift the arm with an assist crane until it is in position for the boom-arm pin connection to be made.

Relieve hydraulic pressure from all points of the system before any hydraulic lines are opened, then carefully assemble hydraulic connections to the arm cylinder.

Remove the sling from around the rod end arm cylinder pin, withdraw the pin and lift the body of the arm cylinder to re-pin the mounting connection.

Boom Installation Procedure

Before reassembling the attachment, make sure to inspect all bushings and pivot points of each section. To avoid damaging the seats, bushings should never be hammered or chiseled out of their seats.

Installation is otherwise a reversal of the removal procedures.

START-UP PROCEDURES

Once the boom has been serviced, it should be lubricated as outlined in the initial start-up procedures of the operation manual. Refer to the appropriate operation and maintenance manual for unit.

Bucket

Edition 1

MEMO

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MEMO

SAFETY PRECAUTIONS



CAUTION

Follow all safety recommendations and safe shop practices outlined in the front of this manual or those contained within this section.

Always use tools and equipment that are in good working order.

Use lifting and hoisting equipment capable of safely handling the load.

Remember that ultimate safety is your own responsibility.

APPLICABLE MODELS

The contents of this section apply to the following models and serial number ranges.

MODEL	SERIAL NUMBER RANGE
DX60R	50001 and Up
DX80R	50001 and Up

BUCKET TOOTH REPLACEMENT



WARNING

Due to the possibility of flying metal objects, always wear safety helmet, protective gloves and eye protection when changing bucket teeth.

Curl the bucket upwards and place the round rear surface of the bucket firmly on the ground. Shut the engine off and lock out the hydraulic controls before working on the bucket.

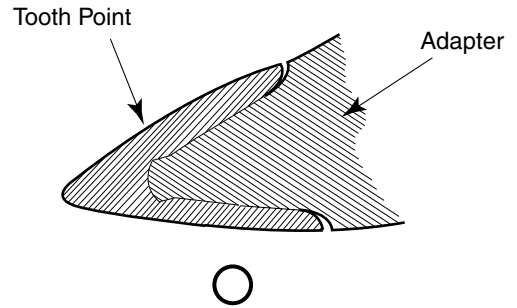
NOTE: *These instructions are only for DOOSAN OEM buckets. If you are using other manufacturers buckets, refer to their specific instructions.*

Inspect locking pin assembly and replace it if the following conditions exist:

1. The locking pin is too short when both surfaces are aligned.
2. The rubber has been torn and bosses of the steel balls are liable to slip off.
3. Pressing steel ball causes the boss to go inside.

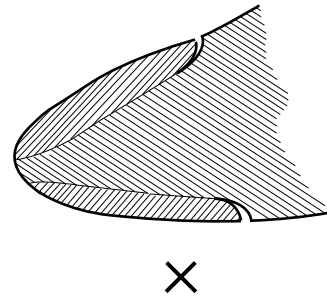
Procedures of Bucket Tooth Replacement

1. On a routine basis, inspect bucket teeth to make sure that tooth wear or breakage has not developed. Do not allow replaceable bucket teeth to wear down to a point that bucket adapter is exposed. See Figure 1, Figure 2.
2. To replace a tooth, use a hammer (1, Figure 3) and punch (2, Figure 3) to drive locking pin (4, Figure 4) and locking rubber (3, Figure 4) out of tooth adapter.
3. Once worn tooth has been removed, use a putty knife to scrape adapter as clean as possible.
4. Slide new tooth into position and insert lock washer.
5. Insert locking pin into tooth and with a hammer, drive pin in until lock washer seats in locking groove.



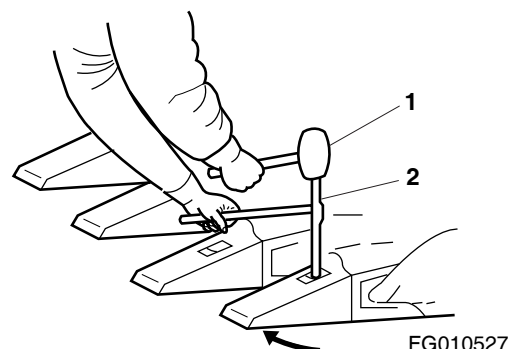
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Figure 1



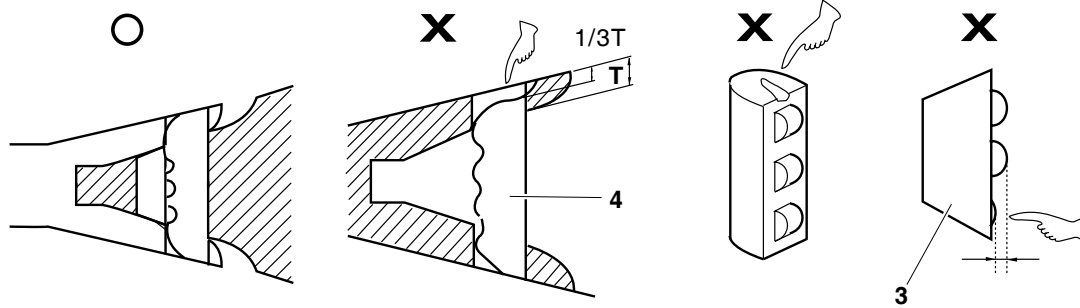
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Figure 2



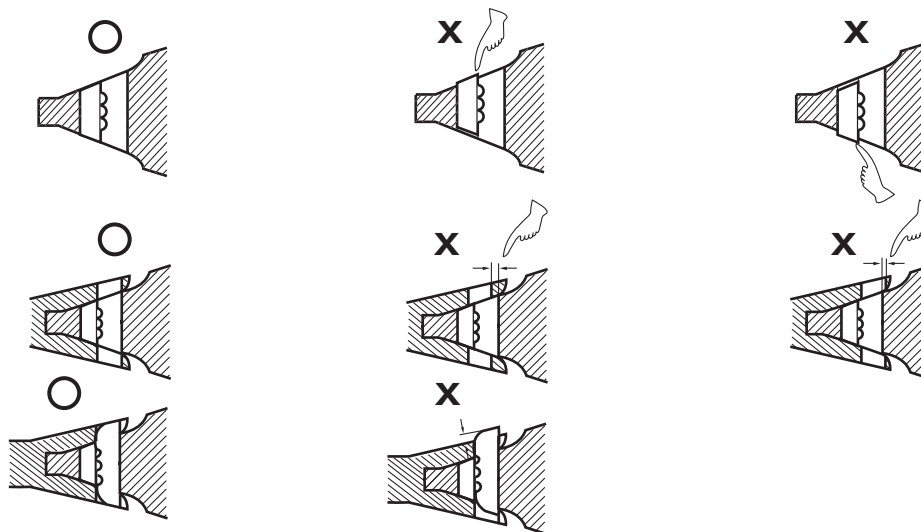
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Figure 3



FG012221

Figure 4



HFO3043I

Figure 5

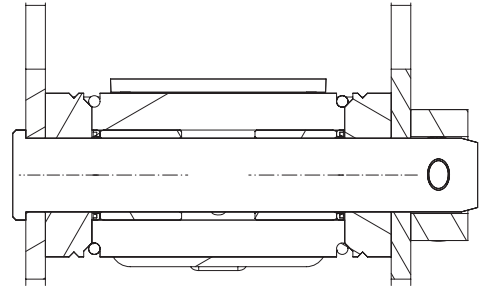
BUCKET O-RING REPLACEMENT



WARNING

Due to possibility of flying metal objects, always wear safety helmet, protective gloves and eye protection when changing pins.

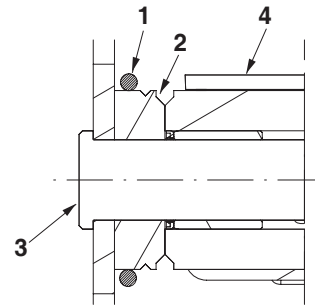
1. Inspect the bucket O-rings on a routine basis. If worn or damaged, replacement is necessary.



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Figure 6

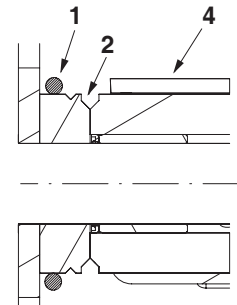
2. Roll the old O-ring (1, Figure 7) onto the boss (2) around the bucket pin (3). Remove the bucket pin and move the arm or bucket link (4) out of the way.



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Figure 7

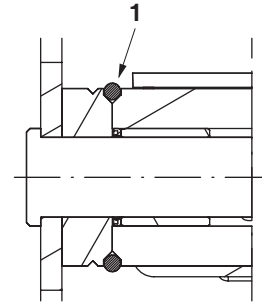
3. Remove the old O-ring and temporarily install the new O-ring (1, Figure 8) onto the bucket boss (2). Make sure that the O-ring groove on both the bucket link (4) and boss (2) have been cleaned.
4. Realign the arm or link with the bucket pin hole and insert the bucket pin (3, Figure 7).



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Figure 8

5. Roll the new O-ring (1, Figure 9) into the O-ring groove.



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Figure 9

BUCKET ATTACHMENT, REMOVAL AND REVERSAL

Detaching the Bucket

Park the excavator away from obstructions on clear, flat, level ground. Lower the bucket carefully to preassembled blocking on the ground. Brace the bucket so that there is no load weight on the pin connecting the bucket and arm. Disassemble the fasteners on the end of the bucket pin and pull out the pin.

If the pin sticks and resists normal withdrawal, there may be a load on it. Raise and lower the arm slightly until the unstressed pin position is located.



WARNING

Use care pulling out the pin to avoid damaging the dust seals on either end of the arm.

When the pin has been withdrawn, move the operating joystick slightly to take weight off the remaining link pin. Disassemble the link pin end retainers and pull out the pin.

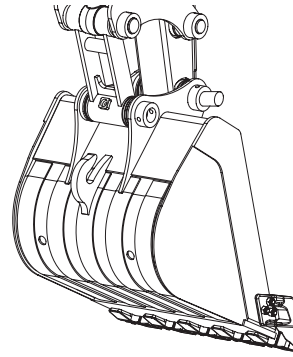
Lift the arm away from the bucket so that the bucket can be carried away or another end attachment can be put on the excavator.

Attaching the Bucket

Carefully inspect all parts before reassembling the bucket linkage. Look for cracks or any other evidence of physical damage and replace any seal or O-ring that is not in like-new condition. Prelube linkage pins before assembly.

Use an old cylinder rod, a long breaker bar or a similar, relatively thin diameter support bar for making the first (temporary) pin connection, between the bucket and arm. If the support bar is straight, the arm can be raised and the bucket will hang level, allowing direct insertion of the bucket ear-attachment linkage pin.

When the link pin has been installed, withdraw the temporary support rod from the bucket pin holes, lower and raise the arm and boom and install the bucket pin.



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Figure 10

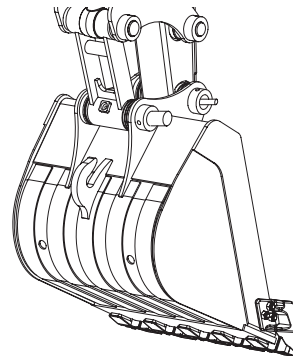


WARNING

When making linkage alignments, never insert fingers into pin holes. The attachment or bucket could shift position and cause a severe injury. Match holes by visually lining them up. Use the sharp tipped, soft point of a pencil or a similar tool to check for high spots or irregularities.

Reversing the Bucket

Follow instructions for "Detaching the Bucket" and remove both the bucket and link pins. Rotate the bucket 180° to change bucket configuration. This procedure is greatly simplified if some type of rotating or swiveling support can be used, on the ground underneath the bucket. Follow instructions for "Bucket Attachment" to replace pins.



FG010395

Figure 11



WARNING

Bucket curl and dump levers must be used in opposite directions, after the bucket has been reversed.