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OHTA plant acquired
the accreditation
of ISO 9001
certification

INSTRUCTION MANUAL
FOR

NIIGATA DIESEL

MODEL
MG(L)28AHX

Niigata Power Systems Co., Ltd.

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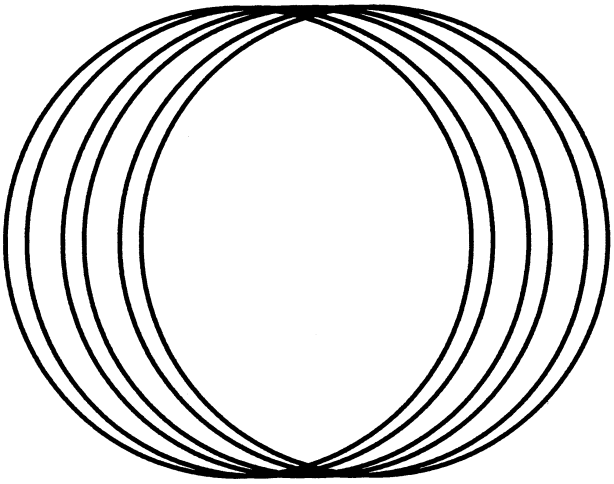

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1. FOREWORD & SAFETY PRECAUTIONS

1.1 FOREWORD

This manual describes the engine construction, and its operating and maintenance procedures for the engine operator.

The manual does not necessarily cover all the details of the problems which might occur during engine operation. It is suggested that, after carefully reading the manual, you pay attention to the condition of the engine at all times and study the engine yourself so that appropriate steps can be taken quickly against whatever trouble the engine has developed. It is important to perform routine inspection and maintenance to detect trouble symptoms and thus prevent trouble.

NOTES

(1) This manual gives general instruction for the engine, but no warranty provisions whatever.

(2) Any question about the contents of the manual should be addressed to the engine manufacturing plant via the Head Office, branch, or local office of Niigata Engineering.

(3) When exchanging a part, always use the part, which our company supplies.

(4) Include the following information in your order for parts.

(a) Customer's name（name of plant or ship)

(b) Engine model, Engine number

(c) Names of parts, parts catalog numbers

(Fig. No. , Item No. , Quantity)

(5) For details of accessories, refer to the individual Instruction Manuals.

(a) Turbocharger
(b) Governor
(c) Filters
(d) Pumps(if motor drive)
(e) Heaters
(f) Centrifuge
(g) Geislinger coupling (if provided)
(h) Remote control device (if provided)
(i) Marine gear（if provide)
(j) Propeller device (if provided)

1.2 Safety Precautions

Most of the accidents arising in handling the engine are caused by the operator's negligence of basic safety rules and precautions or maintenance inspection, etc. as specified by the manufacturer.

Prior to installation, assembly, running, maintenance service and inspection, persons engaged in these items of work should necessarily read through the instruction manual and all other exhibits carefully even for the prevention of danger and use the engine properly after familiarizing themselves with all of the knowledge of plant and equipment, safety information, and cautionary instructions. Besides the above, it is recommended to keep this manual near at hand so that the manual can be referred to at any time in carrying out the work.

“Basic Cautionary Instructions on Safety" in this manual gives a fundamental explanation necessary for securement safety. At the same time, labels gibing warnings to persons concerned are affixed for the prevention of physical accidents caused by mishandling during operation and those caused by inadvertence during maintenance service. It should be noted that the instruction manual and labels have to be followed up as necessary.

The rank of safety precautions is classified into “DANGER", ”WARNING" and “CAUTION" in this instruction manual as shown below.

! **DANGER**	Imminent danger of death or suffering from serious physical injuries.
! **WARNING**	Where possible danger of death or suffering from serious physical injuries, and occurrence of serious physical damage are presumable.
! **CAUTION**	Where possible danger of suffering from light or medium physical injuries, and occurrence of physical damage are presumable.

Even such matters which fall under ! **CAUTION** may possibly lead to serious results depending upon the circumstances. Be sure to observe the instructions given by ! **CAUTION** where every description covers important notes.

1.3 Basic Cautionary Instructions on Safety

1.3.1 General cautionary instructions

Cautions to be used inside engine room and enclosure

- Ventilate the interior of engine room of enclosure.
- Take care against fire, especially observe no-smoking when handling fuel oil and lubricating oil, and keep away from open fire and sparking objects.
- For the prevention of tumbling and upsetting, try to keep orderly arrangement at all times and leave out no articles on the passageway. Always try to keep clean such foothold places as floor surface, foot-plate, etc. that are made slippery and exposed to a danger of tumbling or falling if fouled with oil, water, or the like.
- Make sure of location of passageways and exits so as to take shelter in a safe area forthwith when put in dangerous state in the course of work.

Cautions for garments and protective outfits

- Put on helmet and safety shoes at all times inside the engine room and enclosure.
  When carrying out any work necessitating the Protective outfits (gloves, protective goggles, earplugs, etc.) as listed in “Practical cautionary instructions on safety", be sure to put on specified protective outfits.
- Do not put on any unmatched oversize garments and worn-out clothes. Take off jewels and accessories before starting on work.

Cautions in the course of running

- Where any unusual noise, malodor, or vibration is detected, stop the engine depending upon the circumstances. Clear up the cause and make repairs and restoration before restarting on running.

Cautions in handling outfits

- Use outfits under normal condition at all times and make sure of usage of them before starting on work.
- Make sure that lifting outfits such as chain, hook, rope, etc. are free from abnormalities at any time and observe service criteria and permissible load.
- Hang hooks on the proper positions and use stays necessary.
- Allow slinging and crane operations to be conducted by qualified persons.

Cautions during execution of works

- Prior to repair and inspection work, post a signboard, " NO RUNNING ", on the conspicuous place exposed to view to prevent the engine from being started by mistake during the work.
- When carrying the work by the use of foot plate, manifold, etc. as footholds, it may lead to a serious physical accident caused by falling. To prevent this, give careful attention to footings for the sake of safety.
- Since manual turning of the engine may lead to a danger of serious physical accidents, be sure to carry it out by selecting the proper method and place.
  Never carry out the following.
  - ※ Turning by the use of radiator fan.
  - ※ Turning by the use of starter motor and start air.
- When handling a weighty article exceeding 20kg in weight, use a crane or hoist, or allow two persons or more to engage in the handling work. (In the case of joint work also, the weight should be limited to less than 20kg per person.)
- When handling refrigerants such as liquid nitrogen, put on protective outfits for the prevention of difficulty in breathing and frostbite, and carry out the work in the well-ventilated area.
- When handling combustible substances such as solvent, degreaser, etc., carry out the work carefully in accordance with maker's instruction manual.
- When using compressed air for cleaning etc., put on protective mask and safety goggles.

Cautions in replacement of parts

- Unless our genuine parts are used for replacement of parts, it may result in serious failures and physical accidents. To prevent this, be sure to use our genuine parts.

Others

- Do not remodel the engine and plant equipment without our permission.
- Should there be any indistinct points on safety and handling, please contact us.

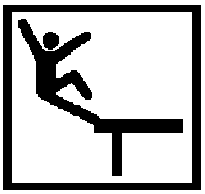
		Remarks
COMBUSTIBLE	1. Equipment and pipelines of fuel oil line, lubricating oil line, and gas fuel line for gas engine.	
	WARNING	
	(1) In cases of fuel leakage from equipment and pipelines of fuel oil line and gas fuel line for gas engine, there is a danger of fire hazard. Conduct inspection at all times to avoid causing bolt looseness, gasket deterioration, and equipment and pipeline cracking.	**6-1 ~ 6-16** **7-1 ~ 7-8**
	WARNING	
	(2) In cases of lubricating oil leakage from equipment and pipelines of lubricating oil line, there is a danger of fire hazard. Conduct inspection at all times to avoid causing bolt looseness, gasket deterioration, and equipment and pipeline cracking.	**6-1 ~ 6-16** **7-1 ~ 7-8**
	WARNING	
	(3) In case of a possibility of mist-kike leakage due to high pressures in fuel oil line and lubricating oil line, there is a danger of fire hazard. Stop the engine running forthwith and take preventive measures against leakage.	**6-1 ~ 6-16** **7-1 ~ 7-8**
	2. Equipment and pipelines of exhaust gas line	
	WARNING	
	(1) In cases of hot exhaust gas leakage from equipment and pipelines of exhaust gas line, there is a danger of fire hazard. Stop the engine running forthwith and take preventive measures against leakage.	**6-1 ~ 6-16** **7-1 ~ 7-8**

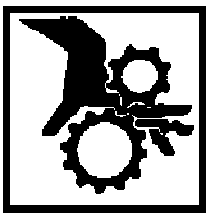
		Remarks
COMBUSTIBLE	3. Anti-freeze **WARNING** (1) Keep away form the fire since anti-freeze entails the danger of ignition to scald.	**3-23** **6-1 ~ 6-22**
EXPLOSION	1. Crankcase door **DANGER** (1) Where the engine is brought to a stop due to abnormal heat generation being detected inside the engine room, there is a danger of explosion if crankcase door is allowed to open forthwith. Open the door after the lapse of a cooling period of not less than 20 minutes. **WARNING** (2) There are cases where scald is caused by the actuation of crankcase safety valve due to abnormal pressure rise inside the crankcase. Do not gain access to the blow-off nozzle.	**6-1 ~ 6-32** **6-1 ~ 6-32**
	2. Cylinder safety valve **WARNING** (1) There are cases where scald is caused by the actuation of cylinder safety valve due to abnormal pressure rise inside the cylinder. Do not gain access to the blow-off nozzle.	**6-1 ~ 6-32**

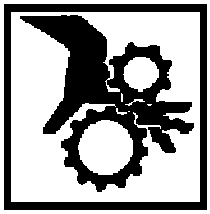
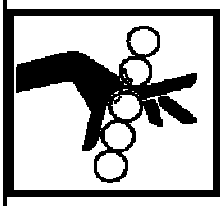
		Remarks
EXPLOSION	3. Exhaust flue safety valve of gas engine **WARNING** (1) There are cases where scald is caused by the actuation of the exhaust flue safety valve of gas engine due to flame failure, etc. Do not gain access to opening of safety valve.	-----
	4. Battery **WARNING** (1) There is a danger of fire hazard due to emission of flammable gas form battery. Keep the surroundings of battery away from the fire.	-----
	5. Engine room for gas engine **WARNING** (1) In cases of gas leakage from gas fuel pipeline, there is a danger of explosion inside the engine room and enclosure for gas engine. To prevent this, be sure to keep the ventilating fan running. **WARNING**	-----
	(2) In cases where the engine is brought to a stop by the actuation of gas detector, there is a danger of explosion caused by the actuation of gas detector. Close the gas partition valve and turn OFF AC power supply. Thereafter open the doors of engine room and enclosure to effect ventilation thoroughly. After making sure that the concentration of leak gas has come down to the alarm set point or below, carry out the repair work of gas leak location. **WARNING**	-----

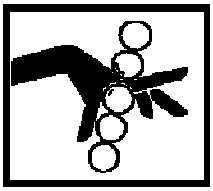
		Remarks
EXPLOSION	(3) In cases of where an alarm is given by the actuation of gas detector during the period of engine stop, there is a danger of explosion. Close the gas partition valve and turn OFF AC power supply. Thereafter open the doors of engine room and enclosure to effect ventilation thoroughly. After making sure that the concentration of leak gas has come down to the alarm set point or below, carry out the repair work of gas leak location. **WARNING**	-----
ELECTRIFICATION	1. Motor **WARNING** (1) Each kind of motor entails the danger of electrification. Before turning ON power supply, check if there are any abnormality in wire connections and peel-off of covering.	**6-1 ~ 6-16**
	2. Electrical devices **WARNING** (1) Electrical devices such as various switches, electrical governor, fuel scale level transmitter, etc. and wiring entail the danger of electrification. Before turning ON power supply, check if there are any abnormality in wire connections and peel-off of covering. **WARNING**	**6-1 ~ 6-16**
	(2) Electrical devices built into remote control stand, alarm panel, solenoid valve unit, etc. and separately-installed accessory devices entail the danger of electrification. Before turning ON power supply, check if there are any abnormality in wire connections and peel-off covering. **WARNING**	**6-1 ~ 6-16**

		Remarks
POISON	(3) Ignition line wiring, booster coil and high tension coil of gas engine entail the danger of electrification due to high voltage being applied to them while the engine is running. Never touch them until the engine has come to a stop. Before starting the engine, check if there are any abnormality in wire connections and peel-off of covering. **WARNING** 1. Mercury thermometer **CAUTION** (1) The mercury applied to mercury thermometers is poisonous. Wipe off the mercury spilt from broken thermometers. 2. Cooling water additives **CAUTION** (1) The rust-preventive agent, inhibitor and anti-freeze for use with cooling water line are poisonous to the human body. Handle them carefully so that they will not come into eyes or come in contact with the body. 3. Battery **WARNING** (1) Battery electrolyte is poisonous. Never allow it to come in contact with skins or come into eyes.	----- ----- **3-18 ~ 3-23** **7-1 ~ 7-8** ------

		Remarks
SLIPPING	1. Foot plate **⚠ CAUTION** (1) The top surface of foot plate, that is slippery if led with oil etc., entails the danger of tumbling and falling. Wipe off thoroughly the oily matter left on the foot plate and shoes.	**6-1 ~ 6-32** **7-1 ~ 7-87**
	2. Topside of engine **⚠ CAUTION** (1) The topside of engine intake manifold, air dust, etc., that is slippery in some cases, entails the danger of tumbling and falling. Do not step on their topside unless safety has been confirmed.	**6-1 ~ 6-32** **7-1 ~ 7-87**
FALLING 	1. Topside of foot plate **⚠ CAUTION** (1) The topside of foot plate entails the danger of falling. Watch your footing and hold the handrail to the extent possible when moving on the topside.	**6-1 ~ 6-32** **7-1 ~ 7-87**
	2. Topside of engine **⚠ CAUTION** (1) The topside of engine intake manifold, air dust, etc., entails the danger of tumbling and falling. Do not step on their topside unless safety has been confirmed.	**6-1 ~ 6-32** **7-1 ~ 7-87**

		Remarks
ENTANGLED 	1. Flywheel **WARNING** (1) There is a danger of parts of the body being entangled into the flywheel area in the course of engine running. Do not allow your hand, leg, etc. to gain access to the area.	**6-1 ~ 6-32**
	2. Rotating part **WARNING** (1) There is a danger of parts of the body being entangled into the rotating parts (coupling, output shaft, radiator fan, etc.) in the course of engine running. Do not allow your hand, leg, etc. to gain access to the parts.	**6-1 ~ 6-28**
	3. Turning device **WARNING** (1) There is a danger of parts of the body being entangled into the rotating parts or gears of turning device in the course of turning with the turning device. Do not allow your hand, leg, etc. to gain access to the parts.	**6-1 ~ 6-28** **7-1 ~7-87**
	DANGER (2) There is a danger of persons, working in the inside and in the vicinity of the engine, being entangled when turning the engine. Carry out the turning operation only after making sure of freedom from danger.	**6-1 ~ 6-28** **7-1 ~ 7-87**

		Remarks
ENTANGLED 	**⚠ WARNING**	
	(3) There is a danger of injuries being caused by contra rotation of crankshaft if turning is carried out without opening the indicator cock or explosion check plug. Be sure to open the indicator cock or explosion check plug when carrying out turning.	**6-1 ~ 6-28** **7-1 ~ 7-87**
	4. When machining	
	⚠ CAUTION	
	(1) There is a danger of hands or legs being entangled during the course of grinding, turning, and drilling work. Do not put on gloves.	**7-1 ~ 7-87**
	1. Moving parts of engine	
	⚠ CAUTION	
PINCHED 	(1) There is a danger of hands or legs being pinched by the moving parts (valve actuator, fuel injection pump roller guide, governor link, stopping piston, etc.)of the engine in the course of engine running. Never insert your hands and legs.	**6-1 ~ 6-28**
	2. Doors of enclosure and engine room	
	⚠ CAUTION	
	(1) There is a danger of your body being pitched by the doors of enclosure and engine room that are designed to be readily closed by the difference in atmosphere between the inside and outside. Take precautions so that your body will not be pinched.	**6-1 ~ 6-28** **7-1 ~ 7-87**

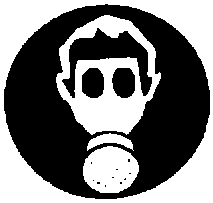
		Remarks
PINCHED 	3. When installing, disassembling and reassembling **WARNING** (1) There is a danger of your hands being pinched by the gear and cam roller of the engine. Never insert your hands in the course of turning.	**6-1 ~ 6-32** **7-1 ~ 7-87**
	CAUTION (2) There is a danger of your hands and legs being pinched by weighty parts or disassembling tools during overhaul inspection of the engine. Take precautions in handling such parts and tools.	**6-1 ~ 6-32** **7-1 ~ 7-87**
CUTTING/ CUT OFF	1. Fuel injection valve test pump **WARNING** (1) There is a danger of injuries caused if high-pressure oil droplets come in direct contact with your skins when conducting the injection test of fuel injection pump. Never allow your body to gain access to the range covered by oil droplets. In case where high-pressure oil droplets have come into your body through the skin, then it is necessary to undergo forthwith specialist's diagnosis and surgical treatment.	**7-19**

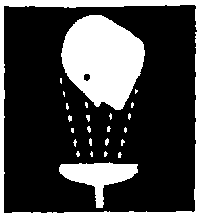
		Remarks
HOT/SCALD	1. Engine **⚠ CAUTION** (1) Since there are many hot parts in the engine during the course of running or right after stopping, there is a danger of scald caused by them. Do not allow your skins to come in direct contact with them. In particular, use extreme care for the following parts that are heated up to high temperatures. ・Exhaust line of the engine ・Indicator cock and cylinder safety valve ・Fuel oil line ・Steam line	**6-1 ~ 6-32**
	2. Inspection or measurement work **⚠ CAUTION** (1) In the case of carrying out the following work, there is a danger of scald caused by high-temperature parts or hot fluid. Put on protective gloves and use care in handling so that hot fluid will not splash over the skin. ・Sampling work of cylinder internal pressure. ・Cleaning of lubricating oil/fuel oil filters. ・When removing the caps of radiator and pressurized fresh water expansion tank.	**6-1 ~ 6-32** **7-1 ~ 7-87**
	3. When checking by finger touch **⚠ CAUTION** (1) In the case of checking by finger touch, there is a danger of scald. To prevent this, first allow your finger to approach to the work and make sure that it is not hot, followed by conducting the check by finger touch. If the work is hot, do not conduct the check by finger touch to avoid causing the scald.	**6-1 ~ 6-32** **7-1 ~ 7-87**

		Remarks
SAFETY/ WARNING	1. Control of cooling water, lubricating oil and fuel oil, and control of clamping work **⚠ WARNING** (1) Any negligence of controlling cooling water, lubricating oil, and fuel oil, and controlling the clamping in reassembly after overhaul inspection may lead to fault of the engine and result in physical accidents due to failure of parts. Unfailing control should be conducted on the basis of instruction manual or specifications. 2. Disassembly work of spring section **⚠ CAUTION** (1) When disassembling the spring section during the course of overhaul inspection, parts are caused to jump out due to disengagement of disassembly tools. Thus, there is a danger of injuries. Familiarize yourselves with the construction of component and use tools properly. Also give care full attention to the jumping direction of parts so that the body will be kept away from the jumping direction. 3. Hydraulic tool and fuel injection valve test pump **⚠ CAUTION** (1) When using hydraulic tools or when conducting the fuel injection valve injection test, high- pressure fluid will gush out , leading to the danger of injuries. Never allow your body to gain access to the range covered by oil droplets. In case where high-pressure oil droplets have come into your body through the skin, then it is necessary to undergo forthwith specialist's diagnosis and surgical treatment. Apply hydraulic pressure only after making sure that joints are securely connected.	**6-1 ~ 6-32** **8-1 ~ 8-12** **7-1 ~ 7-87** **7-1 ~ 7-87** **8-1 ~ 8-12**

		Remarks
SAFETY/ WARNING	4. Engine for auto start or remote start **⚠ WARNING** (1) The engine may start abruptly without notice through the auto start signal or by remote starting. As there is a danger of entanglement etc., do not gain access to rotating parts and moving parts. 5. Prevention of miss-starting during maintenance inspection **⚠ WARNING** (1) There is a possible danger of physical accidents that may be caused when the engine is started by mistake during the inspection and repair of the battery-started engine. Be sure to carry out the following items to prevent the erroneous start of the engine. ・Disconnection of battery power source. ・Capacitor discharge. **⚠ WARNING** (2) There is a possible danger of physical accidents that may be caused when the engine is started by mistake during the inspection and repair of the air-started engine. Be sure to carry out the following items to prevent the erroneous start of the engine. ・Close the main valve of starting air-tank outlet. ・Release the residual pressure remaining inside the starting air pipeline. (Between the starting air tank to the engine)	**5-1 ~ 5-17** **7-1 ~ 7-87** **8-1 ~ 8-12** ------ **5-1 ~ 5-17** **7-1 ~ 7-87** **8-1 ~ 8-12**

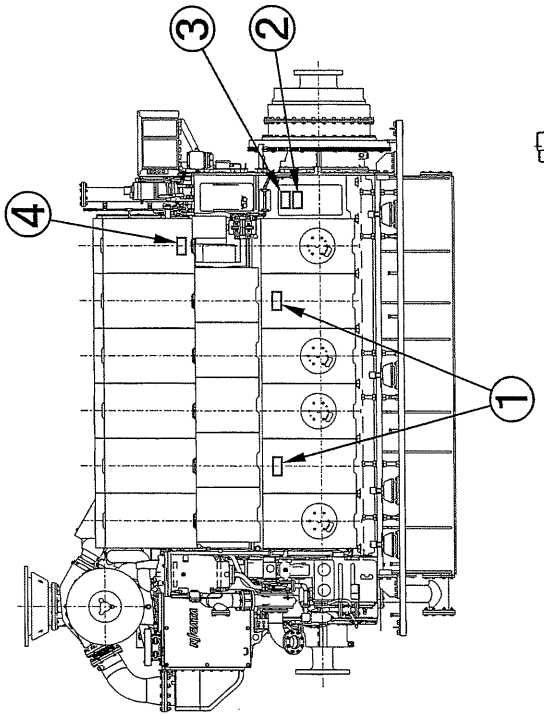
		Remarks
SAFETY/ WARNING	6. Fuel oil **⚠ CAUTION** (1) There is a danger of failure of the engine when gasoline or alcohol is used as a fuel or mixed into fuel oil. Be sure to use the specified fuel oil only.	**3-1 ~ 3-7**
ELECTRO-MAGNETIC WAVE	1. Electrical governor and remote controller **⚠ CAUTION** (1) There is a danger of critical accidents arising From such malfunction of electronic devices applied to electrical governor and remote controller as is caused by electromagnetic wave. Keep away from electromagnetic wave generating equipment.	**5-1 ~ 5-17** **7-1 ~ 7-87** **8-1 ~ 8-12**
PROTECTION OF EYES	1. Work necessitating protection of eyes **⚠ CAUTION** (1) Be sure to put on safety goggles in carrying out the following items of work being in danger of injury to eyes. ・When handling fuel oil, lubricating oil, cooling water and inhibitor, and anti-freeze solution ・In course of washing work ・In course of fuel injection valve injection test ・When handling battery electrolyte ・In course of grinding work ・In course of intake/exhaust valve grinding work	**5-1 ~ 5-17** **7-1 ~ 7-87** **8-1 ~ 8-12**

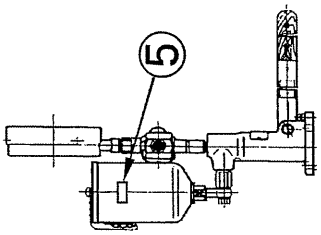
		Remarks
PROTECTION OF EARS	1. Inside the engine room and enclosure **⚠ CAUTION** (1) There is a danger of hard of hearing caused by noise when gaining access to the inside of engine room and enclosure in course of engine running. Be sure to put on ear plugs.	**5-1 ~ 5-17** **7-1 ~ 7-87** **8-1 ~ 8-12**
PROTECTION OF HEAD	1. Inside the engine room and enclosure **⚠ CAUTION** (1) There is a danger of injury to the head inside the engine room and enclosure. Be sure to put on a helmet for the protection of the head.	**5-1 ~ 5-17** **7-1 ~ 7-87** **8-1 ~ 8-12**
PROTECTIVE MASK 	1. Work necessitating protective mask **⚠ CAUTION** (1) Put on protective masks since the following items of work are in danger of adverse effect upon the health due to inhalation of deleterious mist or dust. ・In course of cleaning work with compressed air ・When handling heat insulation material (glass cloth etc.)	**5-1 ~ 5-17** **7-1 ~ 7-87** **8-1 ~ 8-12**

		Remarks
SAFETY SHOES	1. Inside the engine room and enclosure **⚠ CAUTION** (1) There is a danger of injury to your legs during the work inside the engine room and enclosure. Be sure to put on safety shoes for the protection of your legs.	**5-1 ~ 5-17** **7-1 ~ 7-87** **8-1 ~ 8-12**
PROTECTION OF HANDS	1. Inside the engine room and enclosure **⚠ CAUTION** (1) There is a danger of injury to your hands during the work inside the engine room and enclosure. Be sure to put on gloves for the protection of your hands except for the case of special work.	**5-1 ~ 5-17** **7-1 ~ 7-87** **8-1 ~ 8-12**
PROHIBITION OF GLOVES	2. During machining work **⚠ CAUTION** (1) There is a danger of entanglement in the course of grinding, turning and drilling work. Do not put on any gloves.	**7-1 ~ 7-87**
EYE-WASH 	1. Chemicals handling work **⚠ CAUTION** (1) When handling chemicals solution such as inhibitor, battery electrolyte, etc., there is a danger of injuries to your eyes or skins being contaminated with chemicals solution. In cases of contamination, wash your eyes or skins thoroughly with water or soapy water and consult a physician immediately.	**7-1 ~ 7-87**

		Remarks
FIRE EXTINGUISHER	1. Fire extinguisher **⚠ CAUTION** (1) In carrying out the work inside the engine room and enclosure, there is a danger of flammable liquid etc. being ignited by welding or electric sparks. Be sure to make a fire extinguisher ready for use during the course of work. When carrying out the work, be sure to install a shielding for the prevention of the danger of ignition.	. **7-1 ~ 7-87**

1.4 DANGER・WARNING・CAUTION PLATE POSITION





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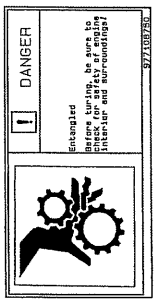
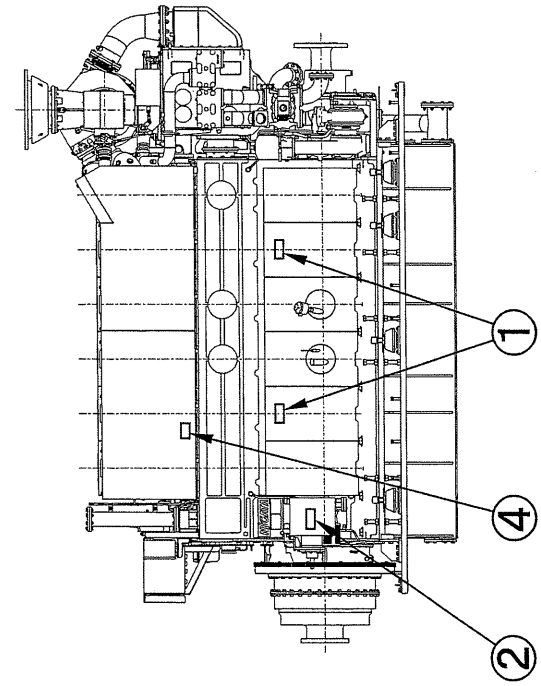


③Danger plate
for turning device



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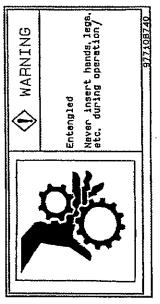

②Warning plate
for fly wheel

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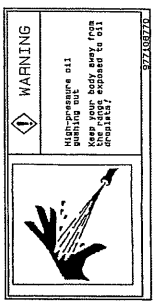

⑤Warning plate
for FV test pump

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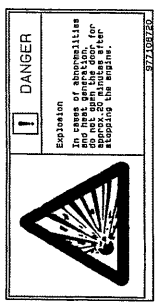
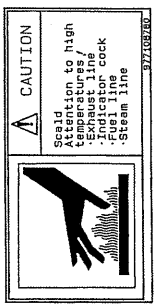


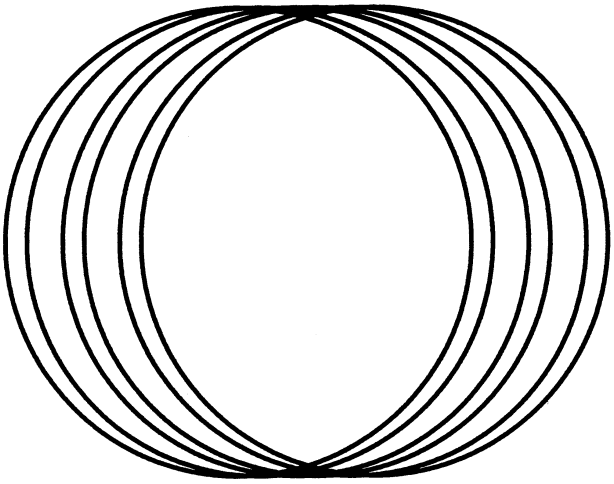
①Danger plate
for crank case door

97710878O



④Caution plate
for engine-heating

MEMO



NIIGATA DIESEL
INSTRUCTION MANUAL
MG(L)28AHX

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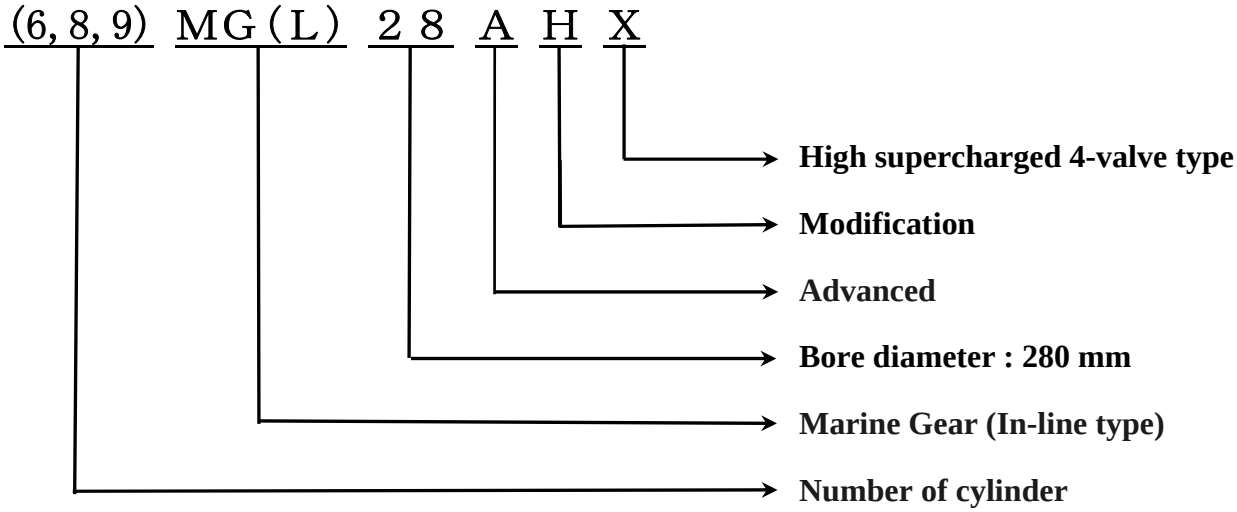
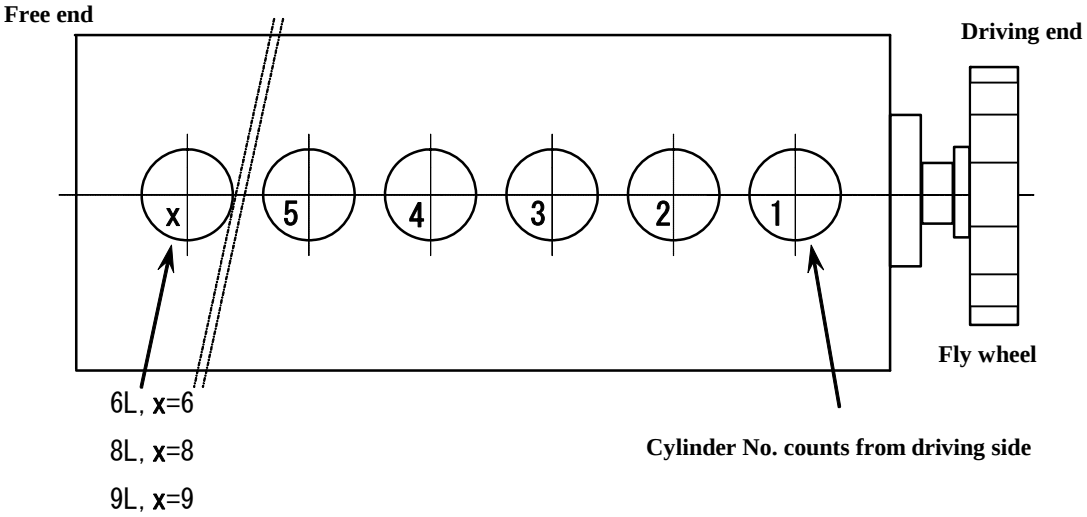
2.1 Engine Model ---------- 2-1
2.2 Cylinders arrangement ---------- 2-1
2.3 Manufacturer ---------- 2-1
2.4 Engine specification ---------- 2-2

2. GENERAL

2.1 Engine Model



2.2 Cylinders arrangement



2.3 Manufacturer

Niigata Power Systems CO., LTD.

MANUFACTURING PLANT :

OHTA PLANT

No.125-1, NISHISHINMACHI, OHTA-CITY, GUNMA-PREFECTURE, JAPAN

PHONE : +81-276-31-8113

FAX : +81-276-31-8119

NIIGATA ENGINE PLANT

No.1300, OKAYAMA, NIIGATA-CITY, NIIGATA-PREFECTURE, JAPAN

PHONE : +81-25-274-5115

FAX : +81-25-271-5825

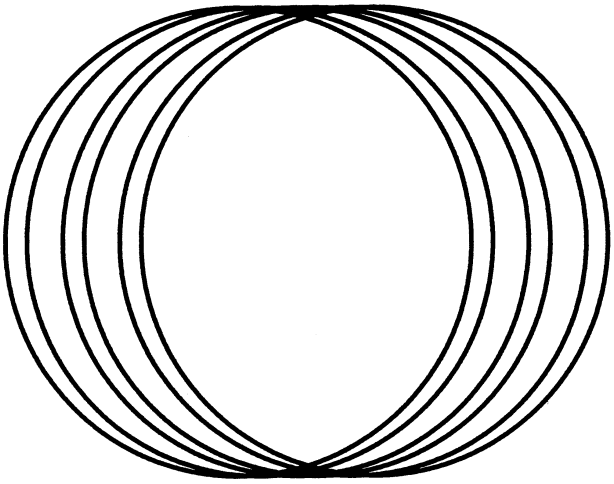
2.4 Engine specification

Model			6MG(L)28AHX	8MG(L)28AHX	9MG(L)28AHX
No. of cylinders			6	8	9
Cylinder bore		mm	280		
Piston stroke		mm	390		
Max. continuous Output		kW	As specified by the application		
Max. Cylinder pressure		MPa	18.0		
Rated speed		min^{-1}	As specified by the application		
Mean piston speed		m/s	As specified by the application		
Swept volume		L	144	192	216
Firing order	Clockwise		1-3-5-6-4-2	1-3-2-5-8-6-7-4	1-3-5-7-9-8-6-4-2
	Counter clockwise		1-2-4-6-5-3	1-4-7-6-8-5-2-3	1-2-4-6-8-9-7-5-3

Rotation direction		Clockwise or Counterclockwise (viewing from driving end side)
Starting system		By compressed air starter system
Lubrication System	System lubricating oil	By an engine driven gear pump＊
	Rocker gear lubricating oil	
	Turbocharger lubricating oil	
Cooling system	Cylinder jacket	By an engine driven water pump＊
	Cylinder head	
	Piston	By cocktail shaking method with system lubricating oil
	Air cooler	By an engine driven water pump.＊
	Lubricating oil cooler	
	Fresh water cooler	
Fuel oil supply system		By an engine driven trochoid pump＊
Turning device		By a motor driven reduction gear＊
Governor		Electro-hydraulic governor
Turbocharger		Exhaust gas turbocharger
Air cooler		2-stage fin-tube type
Fuel injection pump		Bosch type
Fuel injection valve		Multi-hole self injection type

＊It depends on a specifications.

MEMO



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3.Control of fuel oil, lubricating oil and cooling water

WARNING : Any negligence of controlling cooling water, lubricating oil, and fuel oil, and controlling the clamping in reassembly after overhaul inspection may lead to fault of the engine and result in physical accidents due to failure of parts. Unfailing control should be conducted on the basis of instruction manual or specifications.

3.1 Fuel oil

CAUTION : There is a danger of failure of the engine when gasoline or alcohol is used as a fuel or mixed into fuel oil. Be sure to use the specified fuel oil only.

3.1.1 Fuel oil properties

Specifications of Fuel Oils

Properties \ NES Class				AA	BA	C40A	C180A	C180B	C380B	C380C	C500C	C700C
Kinematic Viscosity	mm^2/s at50℃		max	5.5	20	40	180	180	380	380	500	700
	mm^2/s at100℃			— [*2]	5.4	10	25	25	35	35	45	55
Density	g/cm^3 at15℃		max	0.870	0.920	0.960	0.960	0.991	0.960	0.991	0.991	0.991
Flash Point	℃		min	60	60	60	60	60	60	60	60	60
Pour Point	℃	Winter [*1]	max	0	0	5	15	30	15	30	30	30
		Summer		5	5	5	15	30	15	30	30	30
Carbon Residue	%(m/m)		max	1.3 [*3]	4	10	10	10	15	15	15	15
Water	%(V/V)		max	0.1	0.3	0.3	0.5	1.0	0.5	1.0	1.0	1.0
Ash	%(m/m)		max	0.01	0.05	0.1	0.1	0.1	0.1	0.15	0.15	0.15
Sulfur	%(m/m)		max	1.0	2.0	2.0	2.0	3.5	3.5	3.5	3.5	3.5
Vanadium	mg/kg [*5]		max	0	100	100	100	100	100	300	300	300
Aluminum	mg/kg [*5]		max	0	0	0	0	(30) [*4]	(30) [*4	(30) [*4]	30	30
Silicon	mg/kg [*5]		max	0	0	0	0	(50) [*4]	(50) [*4]	(50) [*4]	50	50
Sodium	mg/kg [*5]		max	0	20	20	20	20	20	60	60	60
Asphaltene	%(m/m)		max	— [*2]	2.5	7	7	7	10	10	10	10
Cetane Index			min	45	— [*2]	— [*2]	— [*2]	— [*2]	— [*2]	— [*2]	— [*2]	— [*2]
CCAI			max	825	835	850	860	860	860	860	860	860
				The fuel shall be free of used lubricating oil.								

*1 Winter : When minimum temperature is equal to or less than +5℃
*2 Not specified
*3 On 10%(V/V) distillation bottom
*4 Not allowable in principle
*5 mg/kg=ppm(m/m)

NOTE : (1)When using high-viscosity oil with a kinematic viscosity of 30 cSt (at 50°C) or over, a specific pretreatment is necessary for heating and purifying the fuel oil.
(2) When using a special fuel oil, which does not satisfy these requirements , contact us to determine its usability.
(3) When using heavy oil, it is desirable for engine maintenance to use a purifier even if its viscosity is low.
(4) Content ratio of Sodium/Vanadium is less than 1/5.

Fuel oil for diesel engines must have good combustibility and produce as few combustion deposits as possible.

The required properties of fuel oil are as follows.

(a) Reaction

It must be chemically neutral, oils of acidity or of alkali may corrode metallic parts.

(b) Density

Generally speaking, fuel oil of higher density may be lower quality (excluding very waxy oil, F.C.C. products and thermal cracking products).

When density increases near to 1.0, water in the fuel is hardly separated in the settling tank and by the centrifugal purifier.

(c) Flash point

It does not directly influence combustion conditions of the engines, but should be taken into consideration at handling the fuels from the point of view of fire protection.

(d) Kinematic Viscosity

Viscosity varies with temperature. When temperature rises, viscosity drops. When burning heavy oil, good combustion is generally obtained if the particles of sprayed oil are uniform and small in size.

The atomization of oil depends largely on its viscosity so it is necessary to heat up the fuel oil to appropriate viscosity(55 - 65 s/RW No.1) suitable to atomization injection pressure. If fuel viscosity is very high, the flow efficiency of the fuel oil from the fuel tank to the fuel injection pumps is low, pump capacity efficiency drops, air bubbles get trapped in the fuel piping, and the fuel is not properly sprayed out of the fuel injector nozzles inhibiting combustion.

If fuel viscosity is too low, the fuel injection pumps and plungers become less lubricated, resulting in early plunger wear, fuel leakage, and nozzle sticking. In addition, poor penetration and dispersion through the fuel nozzles hinder fuel combustion.

(e) Pour point

This value concerns mobilization of the fuel oil, so that, if it is difficult to transfer the oil due to its high pour point the oil has to be heated up over the pour point.

(f) Residual carbon and ash content

Their presence does not directly affect combustion, but these substances hardly burn within the operating temperature range, and remain in the cylinders as deposits which cause faulty operation, piston ring sticking, and accelerate abrasive wear of various parts and the deposits fall into the lube oil, resulting contamination of the lube oil.

(g) Sulfur content

Sulfur is present as a compound of sulfur and high-molecular hydrocarbon.

During combustion, sulfur combines with oxygen at high temperatures to form sulfur dioxide(SO2) in gaseous form. SO2 does not burn, but when exposed to flame temperatures it can combine chemically with additional oxygen, to form sulfur trioxide(SO3). SO3 combines with the water in the oil and intake air and the water produced by combustion in the hydrogen in the fuel oil to form sulfuric acid (H2SO4). This substance causes corrosion and wear of the cylinder liners and piston rings.

Generally, a sulfur content of less than 1 (weight), won't to be a serious problem. If sulfur accounts for 2 or more, great care must be taken concerning the lubricating oil to be used.

(h) Water content

Much water causes lowering of calorific value, rusting, and valve sticking. It also combines with the sulfur dioxide and sulfur trioxide to produce various ill effects. Water can be removed to a certain degree by a centrifugal separator.

(i) Cetane Index

Cetane index represents the ignition property of diesel engine fuel oil. It is advisable to select fuel oils with a cetane index of 45 or over, because of difficult starting with lower cetane index fuels.

(j) CCAI（Calculated Carbon Aromaticity Index ）

CCAI represents the aromaticity of diesel fuel oil. This value is used to judge the ignition property of fuel oil. Upper limit of usable range is CCAI 860. If the value overcome 860, hard knocking occurs at low load. Cetane index of 45 corresponds to CCAI 825.

The density and the kinematic viscosity as the below equation determine CCAI value. If use the nomograph, you can determine about CCAI value easily.

— For the nomograph, refer to page 3-6

$CCAI = D - 141 \times \log \{\log (V+C)\} - 81$

D: Density〔kg/m^3,at 15 ℃〕　V: Kinematic viscosity〔mm^2/s,at 50 ℃〕

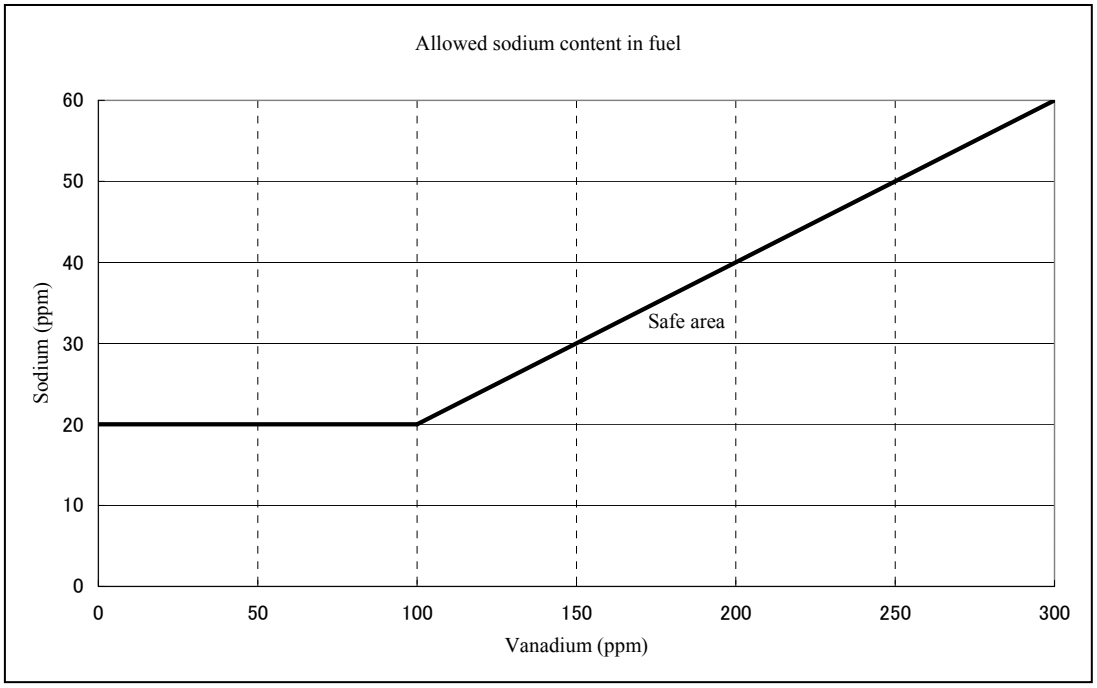
C: Constat 0.85

(k) Vanadium and sodium content

Vanadium content depends on crude oils, high content from VENEZUELA is known. Sodium contributes to hot corrosion on exhaust valves when combined with high vanadium contents. Also Sodium is one of a primary factor for strongly fouling turbine nozzles and blade at high load. If the vanadium content of the fuel is less than 300 ppm, the maximum sodium content is 60 ppm.

The relation between sodium and vanadium content of fuel according to fig. are allowed.

It is recommended to keep sodium content less than 1 / 5 the weight of vanadium.



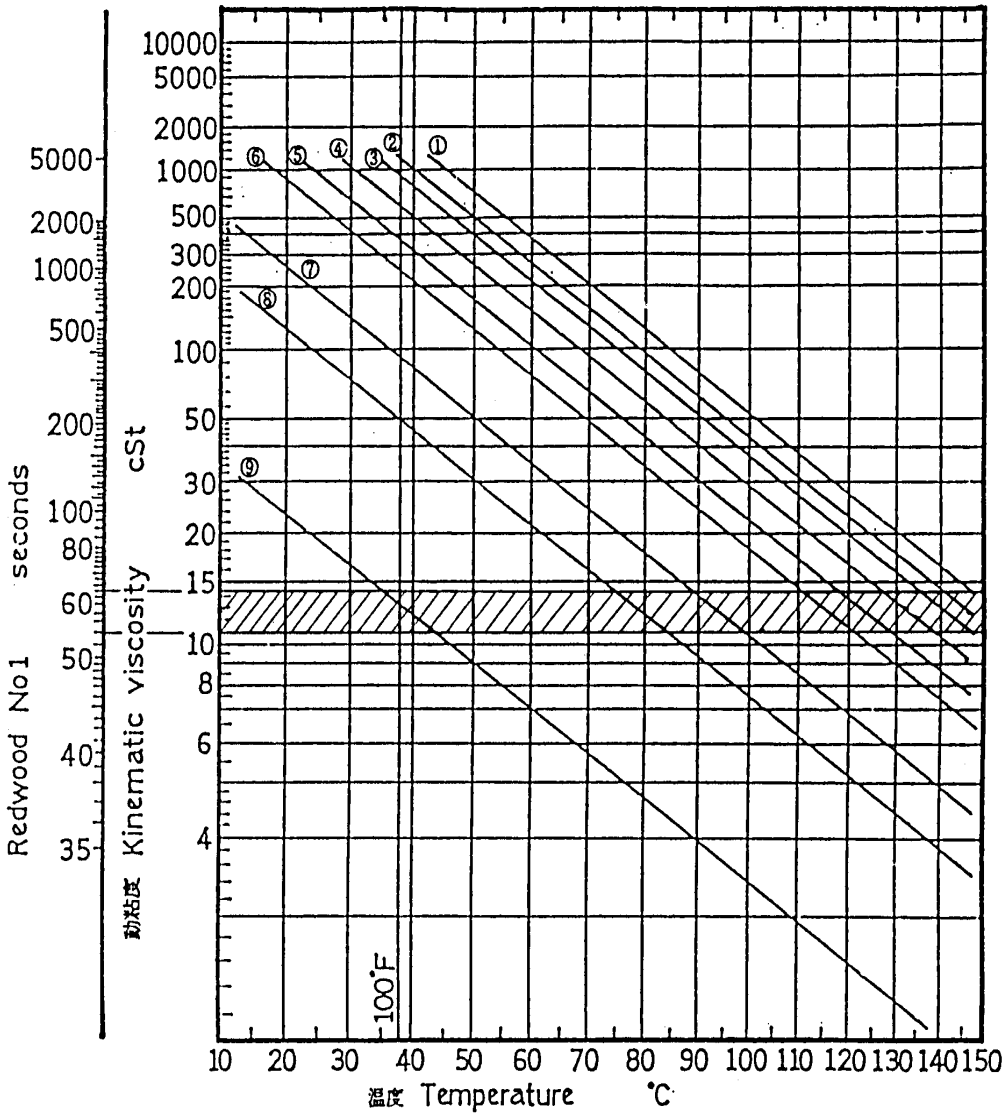
(l) Aluminum and silicon content

Heavy fuels blended by F.C.C. process products contain somewhat particles of aluminum-silica applied as a catalysis in the process.

These particles which are very small (to 100μm) and very hard cause wear of the fuel injection pump (plunger and liner), the fuel injection nozzle, the piston ring, the piston ring groove and the liner etc.

In principle, don't use F.C.C. oil, If cannot help using F.C.C. oil, must use a high performance fine filter due to removes alumina-silica.

Viscosity-Temperature diagram



NOTE : Viscosity-Temperature varies in accordance with chemical composition of fuels, therefore, exact values should be obtained by measuring the sample at two or three points.

The following is a conversion equation of °C and °F.

$$C = 5 / 9 \times (F - 32)$$

$$F = 9 / 5 \times C + 32$$

Nomograph for Determination of CCAI and CII

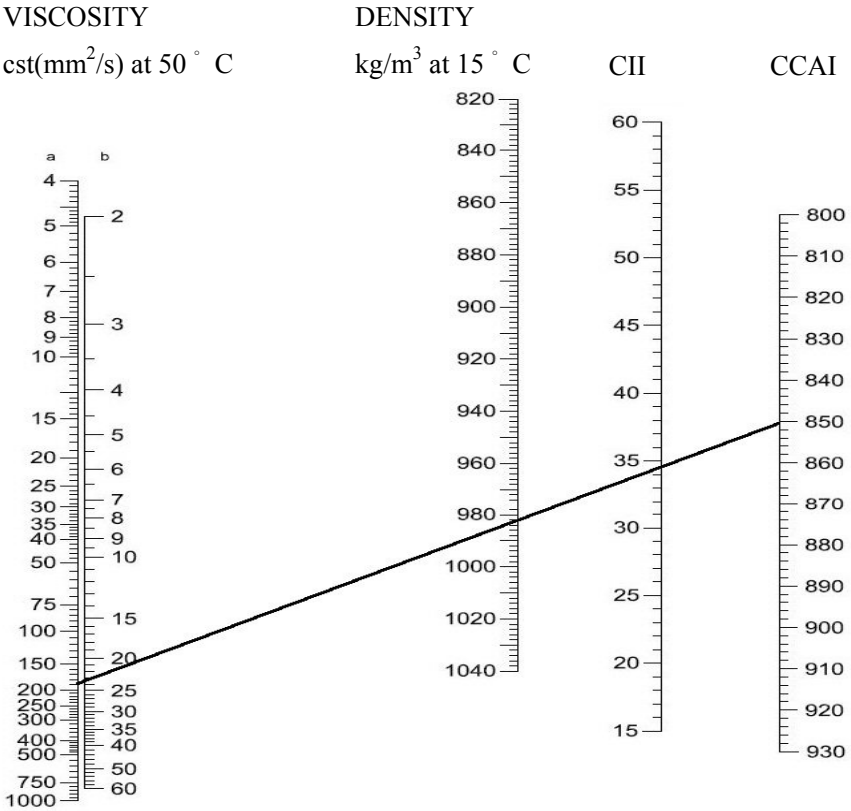
$$CCAI = D - 81 - 141 \times \log[\log(V + 0.85)] - 428 \times \log[(T+273)/323]$$

$$CII = (270.795 + 0.1038 \times T) - 0.25456 \times D + 23.708 \times \log[\log(V+0.7)]$$

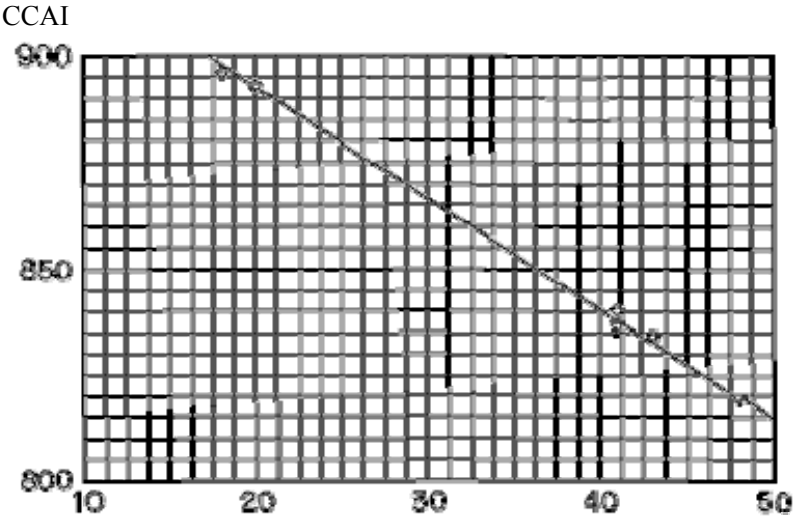
D:Density [kg/m^3,at 15 °C]

V:Kinematic viscosity [cSt (mm^2/s),at 50°C]

T: Temperature (°C)



CCAI-Cetane number diagram



3.1.2 Control of fuel oil

The following precautions must be observed concerning the control of fuel oil.

(a) Fuel oil purchase

Use recommended brand. It is most desirable that the same brand be use always. If the same brand is not available due to service overseas, for example, it is necessary to select a fuel oil having properties similar to those of the fuel oil, which has been used up to, that time.

(b) Precautions in filling the fuel tank

Before filling the fuel tank with a fresh supply of oil, empty the tank if possible. It is desirable that the bottom of the tank be cleaned of sludge, before refilling. When filling a fuel tank that is not empty with a fresh supply of fuel oil, the brand must be the same. Never mix uncertain brands of fuel oil or different brands of fuel oil in the fuel tank in an attempt to prepare a suitable viscosity.

(c) Precautions after filling the fuel tank

Prevent dust, seawater, and other foreign matter from getting into the fuel tank. If the fuel oil is stored for long time in tank, sludge settles in the bottom of the tank due to temperature variations and oil properties, causing problems. Therefore discharge the drains at the bottom of the fuel tank every day.

(d) Other precautions

(d1) Purifier

If the purifier is suspected to be faulty, read its Instruction Manual and check to see if it has been properly used. The purifier may not always operate properly depending on the kinds of fuel oil and the operating conditions of the engine. In that case, ask the purifier manufacturer for advice.

Some of the fuel oil contents can be easily removed, and some cannot. It is desirable for engine maintenance that a large enough purifier be installed if it is technically and possible.

(d2) Fuel oil additives

Fuel oil additives include combustion assistants and emulsion breakers. It is suggested, however, that a fuel oil with properties that require no such additives be selected.

3.2 Lubricating oil

Proper selection and monitoring of the lubricating oil is essential for satisfactory engine performance and life. The lubricating oil must be from a list approved by Niigata for the application and fuel-type being used. All instructions from Niigata and its dealers concerning lubricating oil must be followed to assure warranty coverage.

⚠ **CAUTION** : Be sure to put on safety goggles in carrying out the following items of work being in danger of injury to eyes.
・When handling lubricating oil

3.2.1 Lubricating oil properties

Lubricating oil for diesel engines must have the following properties.

(a) Appropriate viscosity and high viscosity index

(a1) If viscosity is too high, lubricating oil generates heat due to its own resistance, causing bearing temperature rise and power loss. If viscosity is too low, on the other hand, oil film becomes thin, causing metal-to-metal contact and possibly increased lubricating oil consumption.

(a2) Because the temperature inside the engine differs greatly at start up and during operation, a high viscosity index is required.

(b) Excellent detergent dispersion quality

(b1) The property of the lubricating oil which disperses unburnt carbon, the ash produced by combustion, and the sludge generated by heating and oxidation into the lubricating oil as fine particles instead of letting them aggregate in the oil is called dispersion quality. It is generally called detergent dispersion quality because it prevents such substances from sticking to piston heads, piston rings, and ring grooves, and settling inside the engine, and thereby keeps the inside of the engine clean.

(b2) Detergent dispersion quality can be improved by adding a detergent dispersion improver to lubricating oil. If the engine burns residual oil, or is high-powered with a turbocharger, or is operated under severe conditions, a lubricating oil with excellent detergent dispersion quality must be used.

(c) Excellent acid neutralizing quality

If the sulfuric acid generated by the sulfur content of fuel oil drops onto the oil pan, and is carried to various parts of the engine by the lubricating oil, it causes corrosion. Particularly if seawater gets in, the sulfuric acid reacts to the salt contained in the seawater to generate hydrochloric acid, which is still more corrosive. A powerful acid neutralizing quality is required to prevent corrosion by sulfuric acid and hydrochloric acid, which are extremely harmful to the engine.

(d) Excellent heat stability

When exposed to high temperatures, lubricating oil is decomposed by heat to produce carbon. Because the backs of the piston heads in a diesel engines will reach nearly 200°C, the lubricating oil used for lubrication and cooling must have high stability at high temperatures. Lubricating oil with poor heat stability produces carbon deposits with cause ring sticking, cooling inefficiency, and piston head cracking. Lubricating oil with poor heat stability produces carbon deposits with cause ring sticking, cooling inefficiency, and piston head cracking.

(e) Excellent oxidation stability

Lubricating oil changes its quality through oxidation reaction induced by the oxygen in the atmosphere. This oxidation quickens in reaction speed as the temperature rises. It is generally said that reaction speed increases two-fold as the temperature rises 10°C.

If water or metal dust gets into lubricating oil, it acts as a catalyst to quicken the reaction. When lubricating oil is oxidized, the viscosity increases and the color phase grows worse. In the meantime, black sediment(sludge) collects in the bottom of the oil pan, and part of the sludge may be carried away to stick to be bearings or settle around them, or clog the oil passages to cause bearing seizure.

If sludge is deposited around the cylinder liners or piston rings, it causes ring sticking, oil scraper ring groove blocking, increased wear, and piston or liner seizure (due to poor heat transmission). Add an anti-oxidant to prevent lubricating oil oxidation.

(f) Anti-rusting quality

The cooling water can accidentally get inside the diesel engine. If lubricating oil has no anti-rusting quality, the cooling water may be carried with the lubricating oil to various parts of the engine to generate rust.

(g) Excellent water separation quality

If water gets into the lubricating oil, it must separate quickly from the oil. Lubricating oil with poor water separating quality gets emulsified by water, which not only changes its quality soon but causes rusting, wear, and seizure.

(h) Excellent anti-foaming quality

An excellent anti-foaming quality is another important requirement for lubricating oil. Lubricating oil with foam can cause bearing trouble and serious pressure gauge misreading.

(i) High flash point

It is desirable that lubricating oil has high flash point because it is exposed to the hot parts of pistons, etc.

(j) Low pour point

A pour point is the standard of the right or wrong of the ability to transfer the pump of the lubricating oil to use in cold districts and the winter. When the minimum temperature become lower than a pour point, the piping, the tank and so on need heating equipment.

3.2.2 Lubricating oil selection

Because of the great effect of heat and combustion deposits, these must be carefully taken into account in selecting a lubricating oil for the diesel engines.

(1) Selection standard

(a) Trunk piston type(engine construction)

In the case of the trunk piston type, lubricating oil is directly affected by blow-by, and can be easily mixed with combustion deposits, carbide and sludge produced by exposure of the oil itself to high temperature gas, and metal dust from the rings and liners.

Therefore, it is necessary to select a lubricating oil having anti-oxidation properties to prevent oxidation of the lubricating oil itself and oxidation caused by foreign substances, and excellent detergent dispersion quality to remove combustion deposits, which are liable to settle on the liners and in the ring grooves, and to disperse them in the oil.

(b) Piston cooling type

In the case of piston cooling type, part of the cooling oil is thermally decomposed to produce carbides, which combine with sludge to form deposits on the piston cooling surfaces, thereby seriously affecting cooling and causing piston head cracking. It is necessary, therefore, to select a lubricating oil having excellent heat stability.

(c) Fuel oil

(c1) Use of low-cost, residual fuel oil for the engine may be desirable from the standpoint of economy. But fuel oil of lower quality causes greater wear to the cylinder liners and piston rings, more ring sticking, and more adhesion of carbon and other impurities to the sides of the pistons, ring grooves, and intake and exhaust valve ports. These are caused by foreign matter in the fuel oil; hard carbon and ash produced by burning fuel oil and lubricating oil; and sulfuric acid produced by burning the sulfur contained in the fuel oil. Apart from such countermeasures as purifying the fuel oil, and improving the material and shape of the cylinder liners and rings to cope with this problem, it is important to select a suitable lubricating oil.

(c2) Corrosion and wear by sulfuric acid can be effectively prevented by high-temperature cooling with fresh water and then raising the temperature of the cylinder liner walls. If seawater cooling must be used, some condensation of sulfuric acid cannot be avoided because the cooling water temperature cannot be raised so much to prevent scale formation in the water jackets. This is especially so in the case of the main engines for fishing boats that is kept in continuous operation at low load.

In that case, it is necessary to select a lubricating oil having an acid neutralizing quality to positively neutralize the condensed sulfuric acid.

Lubricating oil with a total base number can effectively prevent corrosion and wear because an acid neutralizing agent is added to it.

The standard total base number is mentioned in **3.2.2 (2)**.

(d) Operating conditions

Lubricating oil will seriously deteriorate due to imperfect combustion if the engine is operated at low load, or high load, or if engine load varies considerably. Thus a lubricating oil with excellent anti-oxidation and detergent dispersion qualities must be selected.

(e) Lubricating oil purifier

If a purifier is installed, its type and capacity are among the conditions that must be taken into account in lubricating oil selection.

(2) Kinematic viscosity and total base number

(a) Kinematic viscosity

Lubricating oil of SAE40 viscosity must be used for this engine.

⚠ **CAUTION**	**USE SAE40** But when use in the cold condition, admit to use SAE30. In that case, lower the lubricating oil temperature at the inlet of engine 5 - 10°C because oil film thickness keeping.

(b) Total base number(abbreviated to T.B.N) mgKOH/g

(b1) Select a total base number suitable to the properties of the fuel oil used.
A T.B.N holding standard is determined by the sulfur content of fuel oil and consumption (that is, the absolute quantity of sulfur generated).

(b2) A higher T.B.N is not necessarily better. If its main constituents of calcium and barium are combined with acid, no problem will arise; but if they are not (in case sulfur content is small relative to T.B.N), combustion deposits (residual carbon and ash) generated by combustion accelerate wear. If combustion is imperfect, the viscosity will increase so much that the exhaust manifold may be adversely affected. Actually, T.B.N should be considered on a case by case basic according to the rated output power, operating
conditions, and fuels consumption of the engine. Here is a standard for your reference.

Recommended brands based on the above selection standard shown next page.

NOTE : (1) When using other than the recommended brands, contact us to determine the usability of your selected oil.
(2) Avoid mixing different brands.

Table 1 Medium speed diesel engine (Marin use , Land Use) Recommend brands of SAE40 viscosity

If Pmax is more than approximate 13MPa, the marked "※" oil have to be used and have to be equipped the centrifugal oil.

The figure in ( ) means TBN of lubricating oil.

Fuel oil [NES class]	Bold box shows the recommended range of lubricating oil for each classified fuel. The figures in [ ] mean the lower limits of total base number(TBN) control condition in service.					
Kerosene ,Diesel fuel	〔50% min. of New Oil TBN and 8 min. of TBN〕			Permissible if necessary		
AA	(Conference)	〔50% min. of New Oil TBN and 10 min. of TBN〕			Permissible if necessary	
BA,C40A,C180A (S=2.0)			〔50% min. of New Oil TBN and 20 min. of TBN〕			Permissible if necessary
C180B,C380B,C380C,C500C,C700C (2.0＜S≦3.5)					〔50% min. of New Oil TBN and 20 min. of TBN〕	
C500H,C700H (3.5＜S≦5.0)						〔25 min. of TBN〕
Maker TBN	10	15	20	25	30	40
Idemitsu Kosam Co., Ltd.	Daphne Marine Oil SX-40(12)	————	Daphne Marine Oil SW-40(20)	Daphne Marine Oil MV-40(25)※	Daphne Marine Oil SA-40(30)※	————
Shell	GADINIA OIL 40(11)	————	————	————	ARGINAT OIL 40(30)※	ARGINA X OIL 40(40)※
EXXON MOBIL	EXXMAR 12TP40(12)	MOBILGARD 412(15)	————	————	MOBILGARD M430(30) EXXMAR 30TP40(30)	MOBILGARD M440(40) EXXMAR 40TP40(40)
Chevron (Chevron, Caltex and Texaco)	TARO 12XD40(12) DELO 1000 Marine40(12)	————	TARO 20DP40(20)	————	TARO 30DP40(30)	TARO 40XL40(40)
bp	————	Energol DS3-154(15) "#"	Energol IC-HFX204(20)	————	Energol IC-HFX304(30)	Energol IC-HFX404(40)
Castrol	————	MHP154(15) "#"	TLX Plus 204(20)	————	TLX Plus 304(30)	TLX Plus 404(40)
TOTAL	DISOLA M4010(10)	DISOLA M4015(15)	DISOLA M4020(20)	————	AURELIA XL 4030(30)	AURELIA XL 4040(40)
INDIAN OIL	SERVO MARINE C 104(10) SERVO ULTRA 40(10)	————	SERVO MARINE C 204(20)	————	SERVO MARINE C 304(30)	————
PETRON CORPORATION	————	PETROMAR 1540(15)	PETROMAR 2040(20)	————	PETROMAR 3040(30) PETROMAR TPO 40(30)	PETROMAR 4040(40)
PERTAMINA	————	————	SALYX 420(20)	————	SALYX 430(30)	SALYX 440(40)

(NOTE) If turbocharger is NHP or MAN diesel, lubricating oil use recommend brand.

"#" mark : When the marked "#" oil will be used contact with NIIGATA.

3.2.3 Lubricating oil for governor

Lubricating oil for governor is selected from the following.

Refer to the individual instruction manuals for lubricating oil recommendations for the individual accessories.

Lubricating oil viscosity	Remark
SAE10～SAE40	WOODWARD

3.2.4 Lubricating oil change

Lubricating oil should be laboratory analyzed at 500 hour intervals for viscosity, Total Base Number, detergent dispersibility, moisture, and impurities.

The results of the laboratory analysis should be recorded so that changes in the oil properties can be traced as function of engine operating hours. For those engines that accumulate hours rapidly, it is also recommended that on-site analysis of the oil condition be conducted every 100 hours.

(1) Lubricating oil change time judging method

(a) Ask the lubricating oil maker to analyze your oil and determine whether it can be used or not.

(a1) Normally, 1000cc(1 liter) of oil is enough for the purpose.

(a2) It is desirable that the following data be attached to the sample oil.

Customer	Customer's name	
	Use	
Engine	Engine model	
	Serial No.	
	Output	(kW)
	Operating speed	(min-1)
	Delivery	
	Cumulative operating	
Fuel oil	Diesel oil / heavy oil / residual oil	
	Fuel supplier	
	Use of purifier Cleaning interval / Overhaul interval	

Lubricating oil	Supplier / Brand	/
	lubricating oil consumption	L/day
	Use of purifier Cleaning interval / Overhaul interval	/ h
	Hour of use	h
	Oil change interval	h
	Lubricating system	Wet / Dry
	System oil quantity	L
	Operating temperature	°C
	Sampling point	
	Sampling date	
Remarks		

(b) Judge by the spot testing method (Spot testing kit is option part)

Although it is best to ask the oil maker to analyze your lubricating oil to determine its further usability, this cannot be down in urgent cases where time is limited. There is also a spot testing method for judging the residual T.B.N detergent dispersion quality, and contamination of the oil with relative ease. By this method, the oil properties can be determined approximately in 10 or 15 minutes without special equipment.

(b1) Testing method, reagent, and judging standard vary with oil makers. Ask your oil maker for detailed information.

(b2) If the spot testing method cannot determine the usability of your oil, it would be safer to change the oil.

NOTE : (1) When sampling lubricating oil, always sample it from the same place, but not the first portion that runs out. Don't take a sample from the oil sump. Otherwise, the wrong judgment might be made on the overall properties of the oil.

(2) Record the data at the time of sampling so they may be referred to later on for control purposes.

(2) Evaluation of properties at limits of use

(a) Flash point

The purpose of measuring the flash point is to prevent explosion accidents inside the crankcase due to fuel oil dilution.

(b) Viscosity

Viscosity generally increases with use. If it has decreased, it is perhaps due to the following:

- Dilution by fuel oil;
- Large quantity of fresh oil added;

Viscosity increase is generally due to the following:

- Contamination by oil drops from cylinders;
- Oxidation
- High-viscosity oil added
- Viscosity can increase even when water gets into the lubricating oil.

(c) Water

There may be various causes of water getting into the lubricating oil. Generally, faulty gaskets on the cylinder jackets and leakage from the oil cooler are probable sources. Care must be taken against seawater leaking into the lubricating oil because it poses a rust problem.

(d) Total acidity

Total acidity is important for straight oil and premium oil. An increased total acidity is caused by oil oxidation or contamination due to oil drops from the cylinders. Care must be taken to prevent it because it can seriously affect the bearings. Total acidity is expressed by potassium hydroxide(KOH) in milligrams for neutralizing all acid components contained 1(one) gram oil.

(e) Strong acidity

The strong acid in system oil is the sulfuric acid produced by combustion; hydrochloric acid will also be produced by seawater leaking into the oil. The strong acid causes engine troubles, such as corrosion to the crankshaft journals and pins, and produces milky spots on chromeplated liners or causes their surfaces to peel. Therefore, no strong acidity should be analyzed.

(f) T.B.N

When using HD type oil, its T.B.N must be measured. If HD type oil is used as system oil, a decreased T.B.N makes the oil useless. So pay attention particularly to its T.B.N, and if its T.B.N has decreased, either change the oil or add fresh oil as appropriate. A decreased T.B.N below the allowable limit virtually makes the acid neutralizing and detergent dispersion properties useless.

(g) Salt reaction

Salt reaction is a very important factor as mentioned in the paragraph on water content. If seawater gets into the lubricating oil, it must be changed.

(h) N-Pentane, toluene insoluble matter

Insoluble matter is an important element for judging system oil deterioration and contamination. Two different kinds of solvents, which differ in dissolving power, specifically N-Pentane and toluene are used. The effects of the insoluble matter of the solvents are as shown in the table below.

N-Pentane	Toluene	Observation
A little	A little	Contamination by insoluble matter is small
Much	A little	Oil is oxidized
Much	Much	Much contamination by carbon and inorganic substances.
Very Much	Much	Oil oxidized, and much contamination by carbon and inorganic substances.

N-Pentane insoluble matter can be reduced mainly by cleanliness control on carbon substances, soil, metal dust, etc.

(3) Precautions in changing lubricating oil

Careful observes the following precautions when changing lubricating oil.

(a) lean the oil sump and the inside of the engine as thoroughly as possible before filling with fresh oil. If the old oil remains or if the inside is dirty, the fresh oil will soon deteriorate in performance, and the detergent property of the new oil washes sludge out, possibly clogging the pipes and filters.

(b) When adding oil, be sure to add the same kind.
Because lubricating oil has various additives, mixing different kinds may emulsify the mixture or produce sediment, making the oil unusable.

(c) When changing or adding oil, be careful not to let in impurities and rags.

NOTE : (1) When lubricating oil consumption is less, the fresh oil added is less and then oil has more stress at early stage.
In this case it is recommended to shorten the oil change interval.
(2) The best way to determine them is to have the lubricating oil analyzed by the oil maker
or supplier in every month.

Lubricating oil changing standard

NES Class *		AA.AB		C40A,C180A,C180B, C380B,C380C,C500C, C700C,C500H,C700H		Remark
Kinematic Viscosity@40℃ [mm/s^{2}]		New Lubricating oil -20～+30%		New Lubricating oil -15～+30%		
Flash Point [℃]		Min.160℃				
Total Base Number(TBN) [mgKOH/g]		Refer to the Total base number changing standard				
		Not specified				
Total Acid Number [mgKOH/g]		Not specified				
Strong Acid Number [mgKOH/g]		Not specified				
Water [%]		Warning	Limit	Warning	Limit	
		0.1	0.3	0.1	0.3	
Insolubles [%]		Warning	Limit	Warning	Limit	
	(1) Pentane	1.0	1.5	1.0	1.5	
	(2) Toluene	0.8	1.0	0.8	1.0	
	(1)-(2)	Not specified				

Total Base Number changing standard

NES Class *	Sulfur (S)%	Total Base Number (TBN)	Remark
AA	S<=1.0	-50% New Oil and TBN 10 more	
BA,C40A,C180A	S<=2.0	-50% New Oil and TBN 15 more	
C180B,C380B, C500C,C700C	2.0<S<=3.5	-50% New Oil and TBN 25 more	
C500H,C700H	3.5<S<=5.0	TBN 25 more	

⚠ **CAUTION :** Be sure to put on safety goggles in carrying out the following items of work being in danger of injury to eyes.
- When handling cooling water

3.3 Cooling water

Seawater or fresh water may be used as cooling water. Whichever is used, the water must be kept free of mud and foreign matter.

When using seawater, it is necessary to periodically check the cooling water passages because scale adhering to them will adversely affect the cooling of the cylinder heads in particular, possibly causing cracks in them.

And when using fresh water, observe to the following selection standard.

3.3.1 Cooling water(primary water) selection standard for fresh water cooling

It is very important to be careful of the quality of the cooling water used for the engine. Even if fresh water is used for engine cooling, its dissolved substances can corrode the cooling water system, or cause scale or slime trouble. Corrosion of the engine cooling water system is generally caused by various kinds of chlorides, typical of which is chloric ion (Cl).

Other elements by which to judge the corrosiveness of cooling water are pH, electrical conductance, M-alkalinity, and ammonia. Scale trouble mostly occurs due to calcium(Ca) and magnesium(Mg) in the cooling water, which lower the cooling effect of each cooler and cause cracking in the high temperature parts of the cylinder head.

Attention must be paid to ammonia content because it corrodes the aluminum-copper alloy tubes of the coolers. In addition, silica(SiO_2), manganese(Mn), and iron(Fe) must also be borne in mind as substances causing formation of hard scale. It is necessary for satisfactory operation of the engine over a long period of time to analyze its cooling water and thus determine its suitability as such.

If it is found by analyzing the primary water that it is free of sand, mud, and floating particles, and is colorless and odorless, and if the water quality analyzed values are less than those shown in the table below, it can be used as cooling water.

Water quality standard

No.	Item	Unit	Recommended values
1	Turbidity		＜ 10
2	PH(25°C)		6 ～ 8.5
3	Conductivity (25°C)	$\mu\Omega^{-1}$／cm	＜ 400
4	＊Chemical oxygen demand(COD)	ppm	-
5	M-alkalinity ($CaCO_3$)	ppm	＜ 140
6	Total hardness ($CaCO_3$)	ppm	＜ 80
7	Chloric ion($C1^-$)	ppm	＜ 100
8	Sulfuric acid ion(SO_4^{2-})	ppm	＜ 150
9	Ammonia ion(NH^{4+})	ppm	＜ 10
10	＊Sulfuric ion(S^{2-})	ppm	-
11	Hydrogen sulfide(H_2S)	ppm	＜ 10
12	Total iron(Fe)	ppm	＜ 0.3
13	Silica(SiO_2)	ppm	＜ 50
14	Total residue on evaporation	ppm	＜ 400
15	＊Ignition residue	ppm	-
16	＊Dissolved oxygen	ppm	-
17	Manganese	ppm	＜0.2

The items with the mark ＊ are necessary when making a water quality analysis.

NOTE：

(1) Trouble due to cooling water occurs from the combined effects of dissolved substances, cooling water temperature and cooling water flow rate so that technical data below the values shown in the table above is no guarantee for absolute freedom from trouble. You are advised, therefore, to observe the following instructions, and inform us of the results of your analysis so that the suitability of cooling water may be determined by discussion between us.

(a) Be sure to add a corrosion inhibitor to the circulating cooling water system.

(b) Also use a scale inhibitor depending on the kind of corrosion inhibitor used.

(c) Circulation of the cooling water thickens the substances dissolved in it through evaporation and spraying so replace it with fresh water.

(d) After the first six to 12 months of engine operation, check the hot part of the engine (cylinder heads, cylinder liners) for scale adhesion, and the various parts of the cooling water system for corrosion, and select the optimum water quality control method.

(2) Distilled water or rainwater cannot be directly used as cooling water because of corrosion. In case one of them must be used, either adjust its hardness to more than 30 ppm, or add an inhibitor to it.

3.3.2 Cooling water(primary water) treating additives

Corrosion of the cylinders and the liners of diesel engines cooled by fresh water are generally said to be cavitation or galvanic corrosion. Such corrosion can be prevented by adding a cooling water inhibitor to the cooling water so that a powerful, steady protective film is formed over the metal surfaces to protect them.

Because of waste water control against water pollution and the possibility of increasing corrosion by wrong use, it is necessary in using an inhibitor that to talk with the inhibitor manufacture to decide upon correct use.

(a) Kinds

The following three kinds of inhibitors are generally used.

- Nitrite inhibitor ----- This inhibitor is used because it is not toxic, but is subject to COD control when water containing it is discharged.
- Phosphate inhibitor ----- Because this inhibitor has no toxicity at all, it can be discharged as it is. But it is necessary for the used water to be alkaline.
- Silicate inhibitor ----- Because this inhibitor has no toxicity at all, it can be discharged as it is.

COD : If waste water is added to fresh water (or seawater), the oxygen in the water is reduced so that the water will be depleted of oxygen. The required amount of oxygen is expressed in COD-( )ppm in order to prevent oxygen shortage. The COD requirement can be satisfied by dilution with water, or blowing air into the water, or adding a suitable oxidizer to the water.

(b) Precaution for use

⚠ **CAUTION**
- The rust-preventive agent, inhibitor and anti-freeze for use with cooling water line are poisonous to the human body. Handle them carefully so that they will not come into eyes or come in contact with the body.
- Be sure to put on safety goggles in carrying out the following items of work being in danger of injury to eyes.
- When handling cooling water

(b1) Inhibitor adding method, concentration control, and waste liquid treatment vary form one inhibitor manufacture to another so contact the inhibitor manufactures for advice before using inhibitor.
Generally, a solution of about 10 to 20% by volume is prepared, and is gradually added to the cooling water. If it is used together with an anti-freeze, make sure that the inhibitor and anti-freeze will not adversely affect each other.
If the concentration is incorrect, it may cause corrosion so it is necessary to control inhibitor concentration according to the inhibitor manufacturer standard. Concentration control instruments are available from inhibitor makers.

(b2) Observe the following precautions because intrusion of air into the cooling water will increase the amount of dissolved oxygen and accelerate corrosion.
- Be sure to install air vents at points where air is likely to collect.
- Let the fresh water expansion tank have a certain amount of head (more than 5 m above the axial center of the engine) to control evaporation by the rise of cooling water pressure.
- Use suitable partitions inside the fresh water expansion tank to prevent the cooling water from being unsteady.

(b3) When use zinc plated pipe with cooling water system, don't use nitrite inhibitor.

Brands of cooling water additives

CLASIFCATION	BRAND	MANUFACTURE	CONCENTRATION (ppm) (1)
Non-Nitrite type	DISTILLAN-RR	EXENO YAMAMIZU CORPORATION TEL 03-5201-4651	200～300
	SHADAN K	Otsuka Chemical Co.,Ltd TEL 03-5297-2727	20000
	BLUE COOL S	NIPPON OIL TRADING CORPORATION TEL 03-6803-8130	40000～70000
	EDLAS #25	RYOKO CHEMICAL CO.,LTD TEL 03-6861-0050	1000～2000
Nitrite type	AQUAS CHELATE D-801L	AQUAS CORPORATION TEL 03-3783-4857	6000～9000
	AQUAS DYNA CG-580		6000～9000
	ORGAFILM C-3 C-3S	ORGANO CORPORATION TEL 03-5635-5214	C-3:2000～3000 C-3S:4000～5000
	POLYCRIN I-175	KURITA WATER INDUSTRIES LTD. TEL 03-3347-3433	8000～12000
	KURILEX L-109		8500～12000
	KURILEX L-209		8500～12000
	HIMOL AM-5	Taiho Kozai Industries TEL 03-6414-5600	1000～3000
	HIMOL L-10		8000～12000
	NEOS PN-106 PN-106S	NEOS CORPORATION TEL 078-331-9381	106:2000～3000 106S:8000～12000
Long-life Coolants	APOLLO RADIATOR COOLANT	Apolloretailing Co.,Ltd TEL 03-5575-0302	300000～600000
	SHADAN A	Otsuka Chemical Co.,Ltd TEL 03-5297-2727	150000～300000
	KYGNUS LONG LIFE COOLANT	Kygnus Sekiyu K.K. TEL 03-3276-5255	300000～500000
	COSMO LONG LIFE COOLANT	COSMO TRADE & SERVICE CO.,LTD TEL 03-5462-2801	300000～600000
	LC SUPER SINKAITYOU	CCI CORPORATION TEL 0575-24-4844	300000～600000
	SUPER COOLANT X	NIPPON OIL TRADING CORPORATION TEL 03-6803-8130	300000～600000
For Cooling To wer Systems	TOWER CLEAN S-512	KURITA WATER INDUSTRIES LTD TEL 03-3347-3433	150～300

NOTE (1) ppm=mg/l

(2) Directions given by the manufacturer should be observed for methods of use and management.

(3) Brands without toxicity were selected out of those available on the market. It is permitted that other equivalent is used, but attention should be paid to toxicity.

3.3.3 Anti-freeze

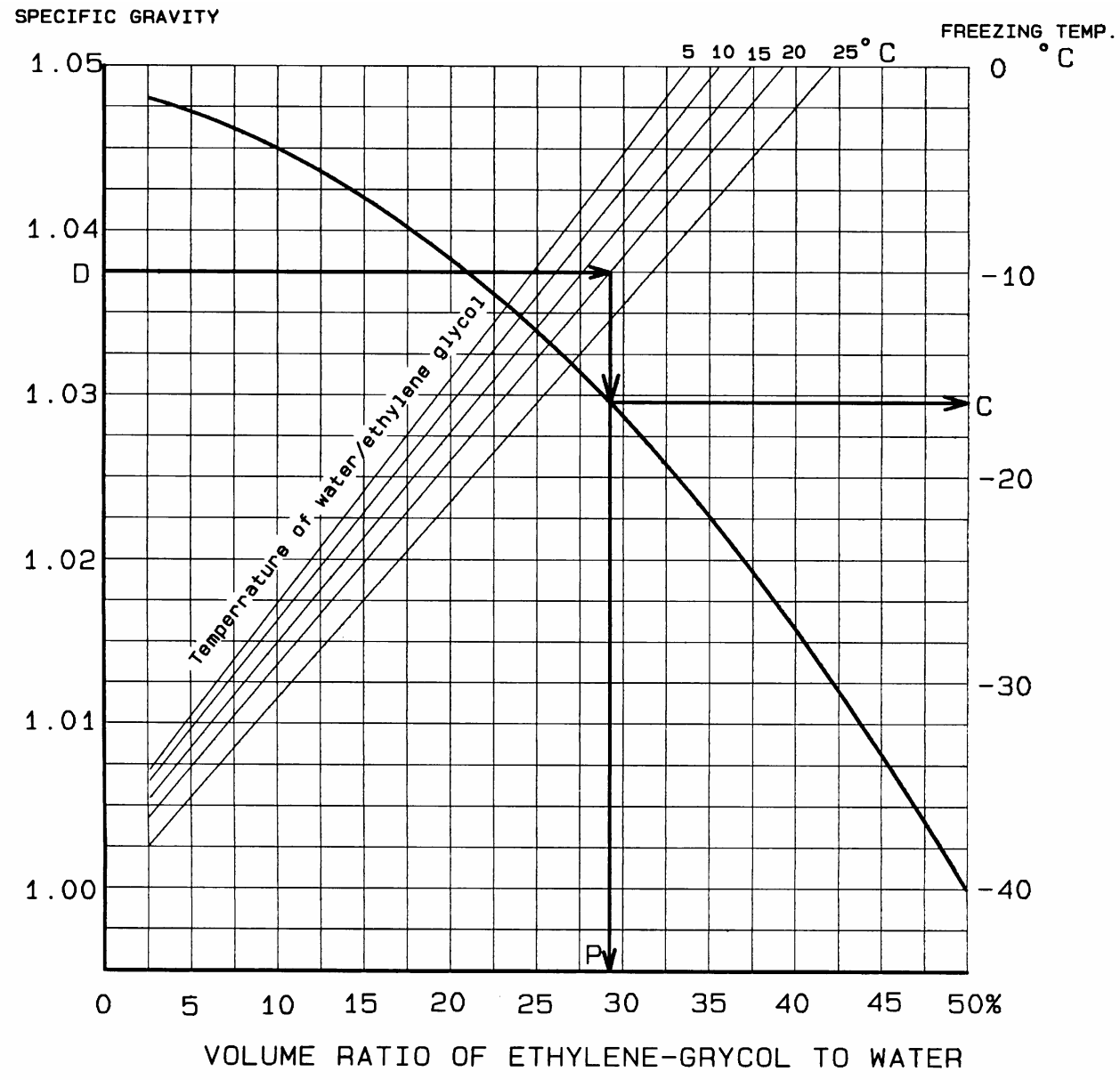
> ⚠ **WARNING :** Keep away form the fire since anti-freeze entails the danger of ignition to scald

Use anti-freeze using ethylene glycol as the base for the engine. Borate of nitrite type and benzoate of nitrite type may be used as the water treatment agent together with anti-freeze of this type, but water treatment agent of chromate type cannot be used together with anti-freeze of this type. The following figure indicates the following relations.

－Relation between ratio (P) and specific gravity (D) of anti-freeze.

It is for learning the concentration from the result of measurement using a hydrometer and the temperature at the time of measurement.

－Ratio (P) of anti-freeze and freezing temperature (C) of cooling water.



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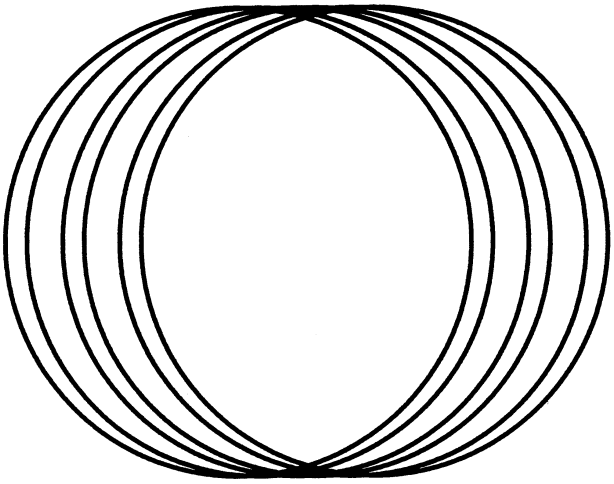

NIIGATA DIESEL
INSTRUCTION MANUAL
MG(L)28AHX

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4. CONSTRCTION

4.1 General construction

Model 28AHX comes in 6, 8, 9 inline-type, all of which have a cylinder bore of 280 mm and stroke of 390 mm. Most of the parts that are independent of the number of cylinders are common among them.

Normally, the gear train for camshaft drive and the governor drive gear are on the driving end, and the lubricating oil pump, cooling water pump, and its drive gear are on the free end.

The turbocharger and charge air cooler are located on the driving end.

(according to specification, these are located on the free end)

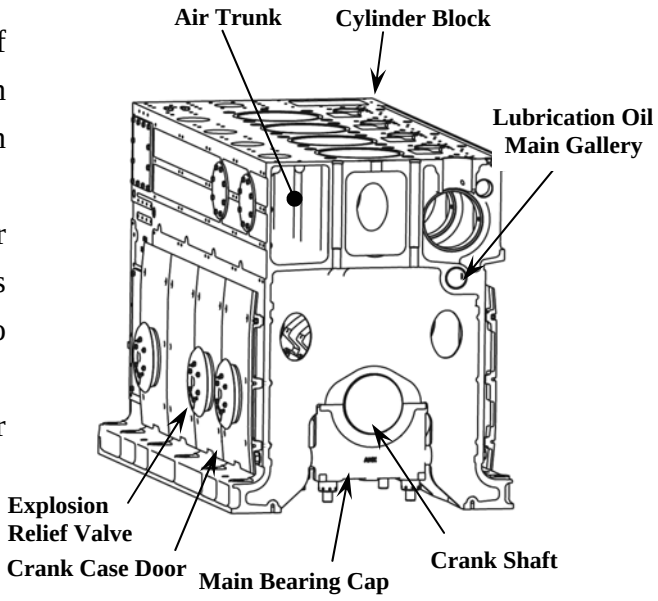
4.2 Cylinder block

The cylinder block has monoblock structure of nodular cast iron to acquire sufficient strength and rigidity to withstand the high-combustion pressure.

The crankshaft is installed using the hanger type, and the main bearing housing is tightened by stud bolts, nuts and side bolts to provide sufficient rigidity.

The cylinder block has big doors both sides for easy maintenance and inspection.

Also, one side crank case doors have explosion relief valves.



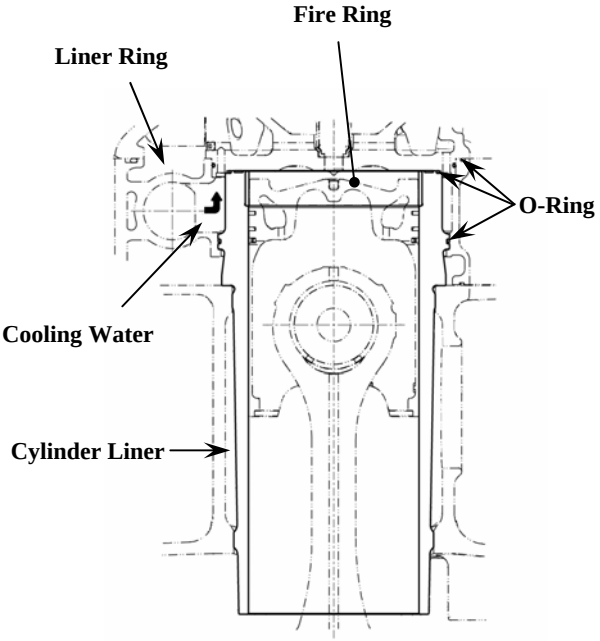
4.3 Cylinder liner

The cylinder liner is made of special wear resistant cast iron. The upper part of liner which is exposed to especially high temperature and pressure, has a rigid thick wall structure.

The jacket cooling system prevent thermal deformation. The liner ring has cooling water pipe that connected next cylinders.

The cooling water jacket is sealed with three O-rings at cylinder jacket.

A Fire ring inserted into the top of cylinder liner to prevent carbon polish and reduce lubricating oil consumption.

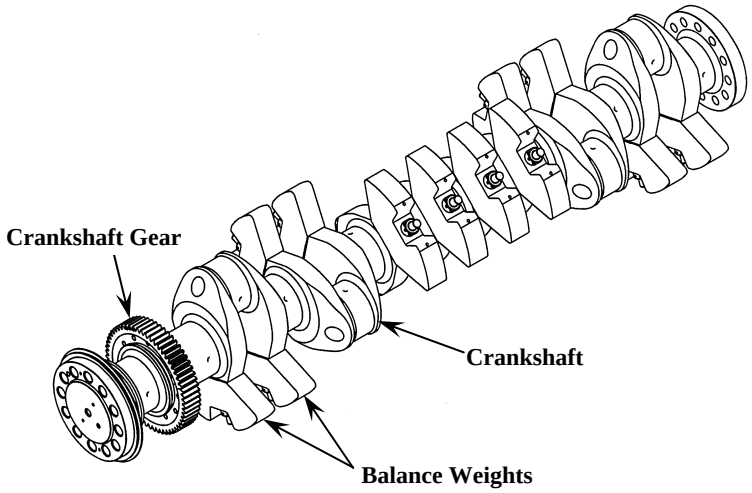


4.4 Crankshaft, Main Bearing and Location Bearing

(1) Crankshaft

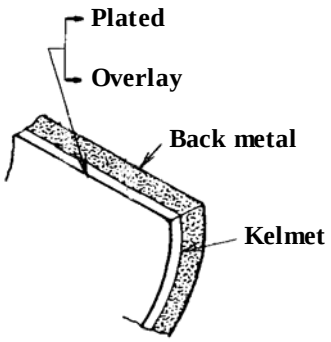
Crankshaft is made of high-strength special forged steel. Bearing can be used on the crank shaft. The crank shaft has two balance weights per throw to counteract the inertia of unbalanced weight generated by rotation, and to reduce the inertia force on the main bearings and reduce engine vibration.

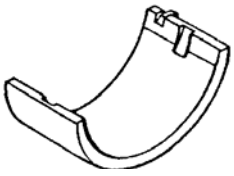
Crankshaft gear is installed to drive a camshaft by drive end side.



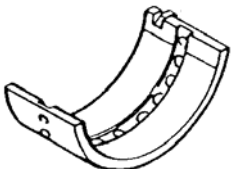
(2) Main Bearing

The main bearing is made of thin kelmet metal to provide resistance to pressure and strength. The kelmet metal is a multiple layer type composed of an iron back coated with kelmet (lead-bronze alloy), overlay with lead-tin alloy, and then plated flush with tin.





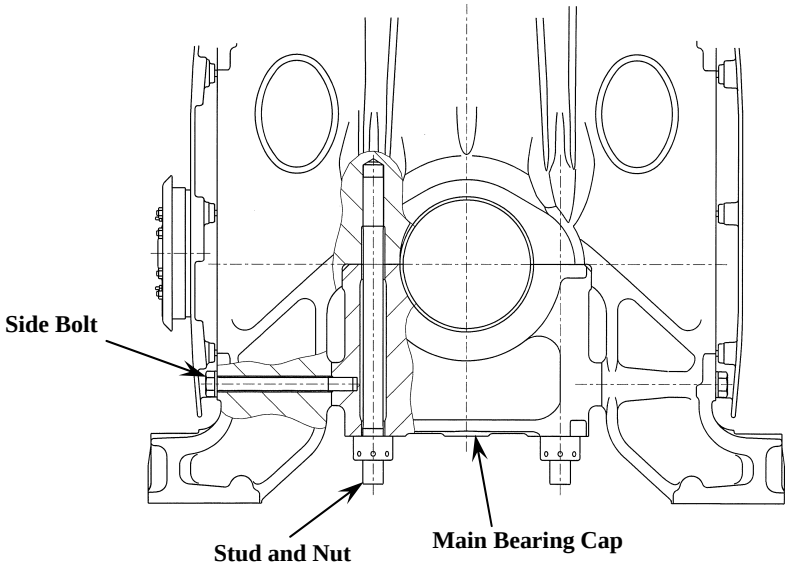
Lower bearing



Upper bearing

(3) Main Bearing Cap

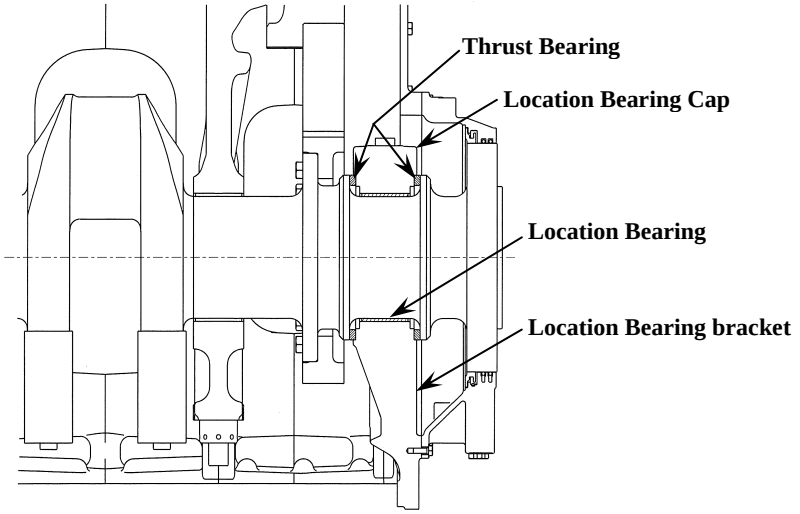
The main bearing caps are made of high-grade cast iron, and are designed large enough to increase the rigidity of the housing. The main bearing cap is fastened to the frame with two studs and two side bolts.



(4) Location Bearing

The outside bearing serves also as location bearing. The crankshaft is kept in position by the crankshaft thrust bearings on both sides of the location bearing cap. The thrust bearings consist of an iron back coated with metal, and are fixed to the upper half of the cap.

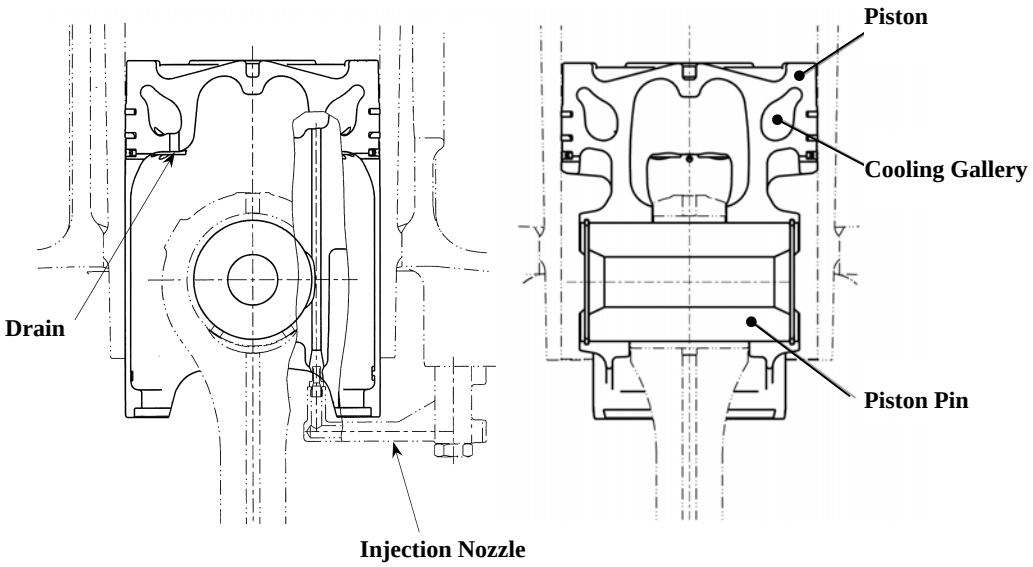
The outside bearing is the same as the main bearing.



4.5 Piston, Connecting Rod and Crank Pin Bearing

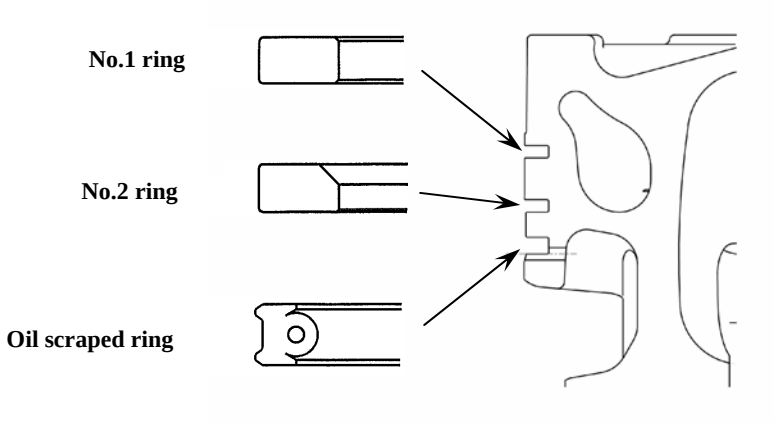
(1) Piston

The piston is monoblock type of nodular cast iron. The crown has a cooling gallery with sufficient volume and is cooled forcibly by a lubrication oil shaking system. Lubrication oil is injected by the injection nozzle located on the cylinder block. Lubrication oil through the cooling gallery in the piston, then discharge from drain hole. Piston cooling reduces the thermal deformation and stress of the piston head, and keeps the piston ring grooves at normal temperature, thereby preventing the rings from sticking



(2) Piston Ring

The piston rings are made of wear-resistant special cast iron. Those include two compression rings and one oil scrape ring. The No.1 ring(compression ring) is a specially coating ring. The one oil scraped ring is coil expander type.



(3) Piston Pin

Piston pin is made of hardened special steel. The piston pin is floating type. It bring good lubrication and excellent wear-resistant. The lubricating oil is flowing from the oil way in the crankshaft, crank pin bearing, connecting rod and piston pin bush.

(4) Connecting Rod

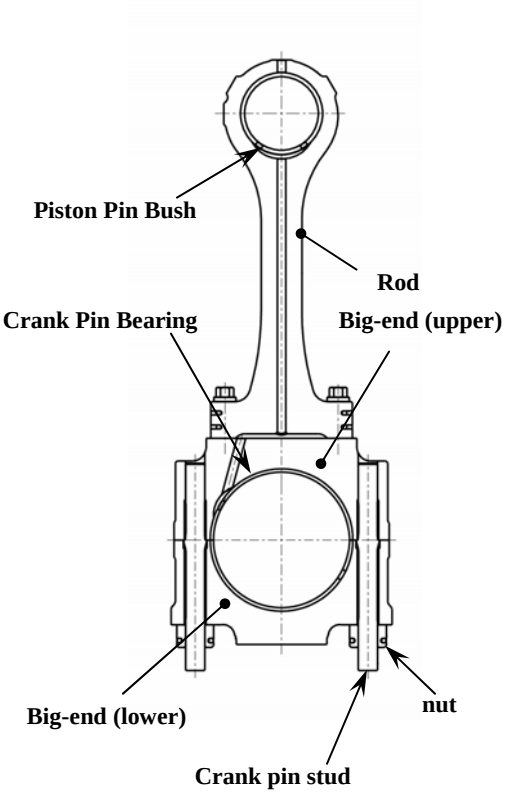
The connecting rod is made of special forged steel. The rod consists of three pieces, the rod(stem), the big-end cap(upper), and the big-end cap(lower).

Rod and big-end cap is tightened by 4 bolts, and cap is tightened by 2 stud bolts and nut.

When the piston is of pulled out in order to inspect the piston rings, the big-end does not need to be disassemble. Therefore height for disassemble of piston can be lowered.

As a result, allow for easy maintenance and inspection.

The small-end cap is equipped with a piston pin metal which back face is lined and overlaid the bearing alloy metal. The journal is connected to the piston via floating piston pin.



(5) Crank Pin Bearing

The crank pin bearing is made of thin kelmet metal of the same material and structure as the main bearing.

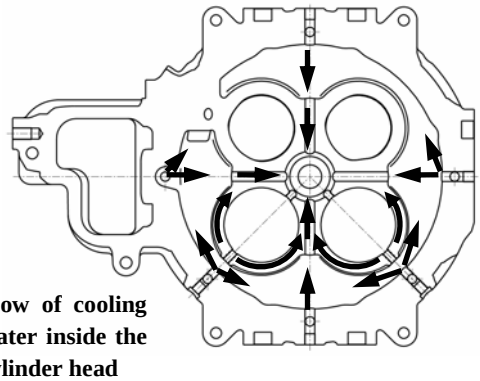
(6) Crank pin stud, nut

The crank pin stud is made of hardened special steel. The big-end cap and the crank pin bearing are tightened with two stud bolts by hydraulic jack.

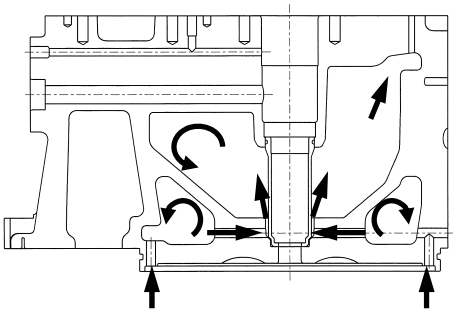
4.6 Cylinder Head

The cylinder head is made of CV(compacted vermicular) cast iron with high strength and thermal conductivity to withstand the thermal and mechanical stress caused by the increased combustion pressure.

Thermal stress is reduced through uniform cooling created by the optimized arrangement of the jacket cooling system. The highly rigid diagonal intermediate shelf structure and four bolts eliminate local stress concentration and gas leakage.



Flow of cooling water inside the cylinder head



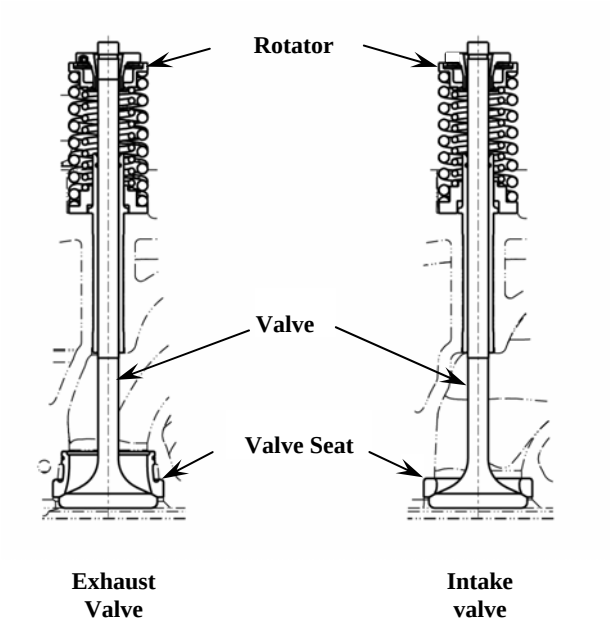
Cooling water from liner ring

4.7 Exhaust Valve, Intake valve

(1) Exhaust Valve

The exhaust valve is made of heat-resistant steel and a valve seat is installed into the cylinder head.

The exhaust valve seat receives cooling water from the cylinder head to cool itself enough, and then returns the water to the cylinder head. The exhaust valve has valve rotator, which extend maintenance intervals.

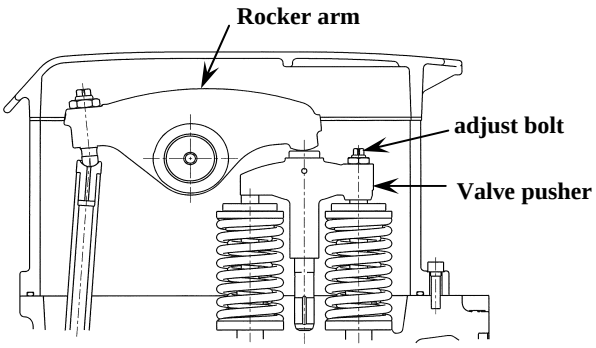


(2) Intake Valve

The intake valve consists of a valve spindle of heat-resistant steel and a valve seat of wear-resistant special steel. The intake valve seat is installed into the cylinder head. The intake valve has valve rotator, which extend maintenance intervals.

(3) Valve Rocker Gear

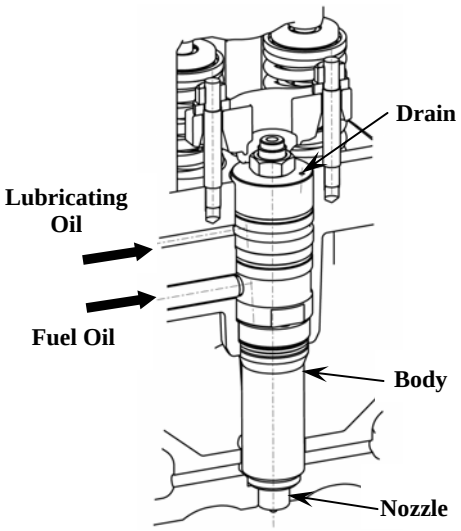
Each intake and exhaust valve is driven by one rocker arm via valve pusher. The valve pushers have an adjusting bolt. Adjusting bolt is installed due to match the valve timing during two intake valves or two exhaust valves.



4.8 Fuel Injector

The fuel injector consists of a forged steel body, a nozzle of heat-resistant, wear-resistant special steel, and an injection pressure regulating mechanism. The nozzle is a multiple-pore automatic valve. The diameter and number of pores and injection angle are so selected as to assure optimum combustion performance.

The injector nozzle is cooled by lubricating oil to prevent carbon flower formation on the tip of the nozzle.



4.9 Indicator Cock and Cylinder Safety Valve

(1) Indicator Cock

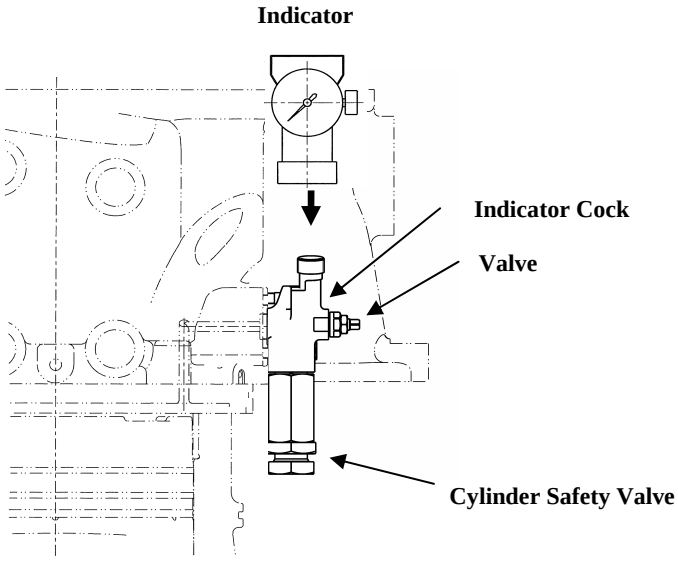
The indicator cock consists of a body of cast iron and a heat-resistant steel valve, and is opened and closed manually.

The indicator cock is used for decompression in turning or air running, and also for checking combustion in each cylinder with the cock opened during operation.

The indicator cock is also used for measuring maximum cylinder pressure with an indicator connected to the cock.

(2) Cylinder Safety Valve

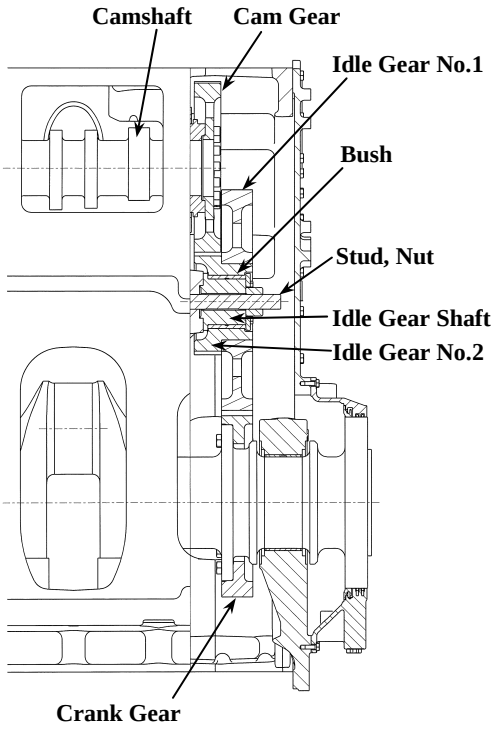
The cylinder safety valve is provided for protection from excessive cylinder pressure, and its opening pressure is selected to meet the applicable rules.



4.10 Gear Train for Camshaft

The camshaft gear drives the camshaft via idle gear from the crankshaft gear, which is fastened to the crankshaft. All gearwheels are made of special steel, and the tooth surfaces are hardened. The crankshaft gear is a half-split type, and is fastened to the crankshaft with reamer bolts.

The idle gear (double gear) is fitted over the hardened, forged steel shaft, which is fastened to the crankcase, and is turned via bronze bushings fixed into the gear.



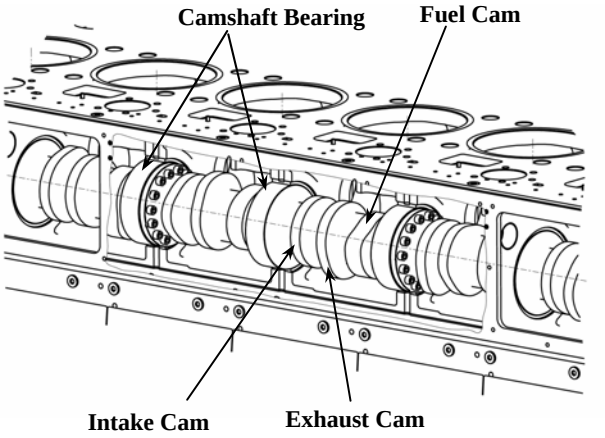
4.11 Camshaft and Camshaft Bearing

The camshaft is made of forged steel, and is driven by the camshaft gear fastened there.

A camshaft is divided two or three and is locked in position by some bolt.

The support of the camshaft is incorporated into the cylinder block. All cams actuate the fuel injection pumps and the intake and exhaust valves at the proper timing.

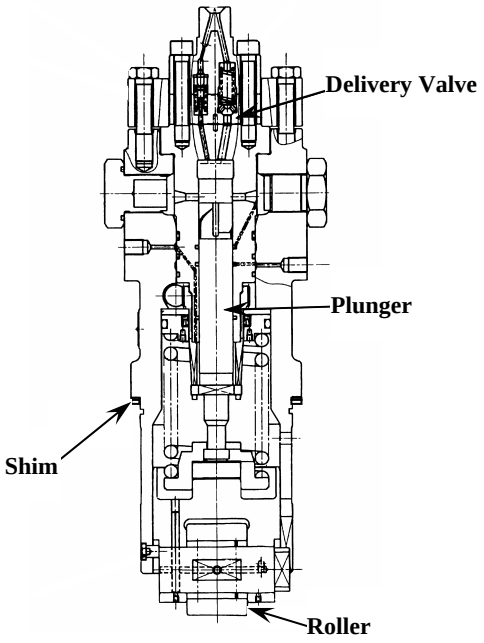
The camshaft bearing is made of steel-backed white-metal and is fitted in place by shrinkage.



4.12 Fuel Injection Pump

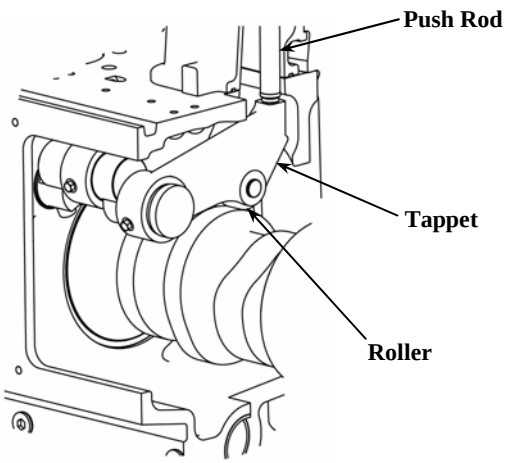
The fuel injection pump is a Bosch Type, the fuel injection pump and Roller guide became incorporate structure and their injection timing can be adjusted by shim thickness.

The delivery valve uses two-way delivery valve due to prevent cavitation erosion by change of pressure in injection pipe.



4.13 Cam Roller

The intake and exhaust push-rod are driven via roller and tappet by cam shaft.



4.14 VIVT(Variable Intake Valve Timing)Mechanism

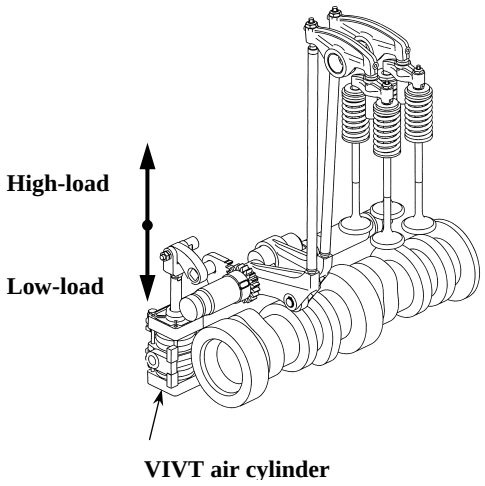
This engine has a VIVT(Variable Intake Valve Timing) system.

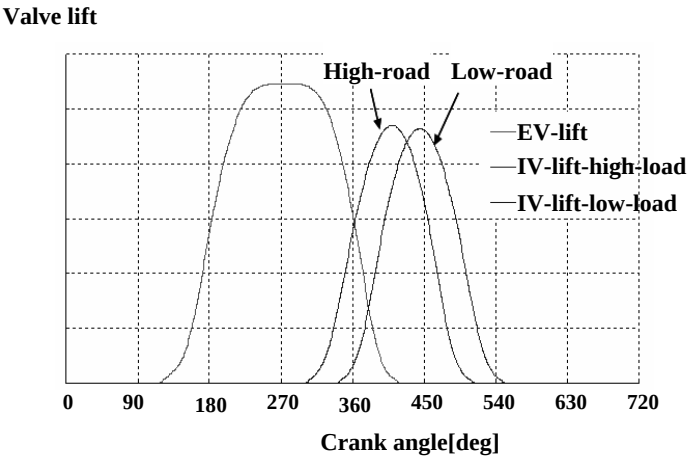
This mechanical VIVT system is used to achieve compatibility of high-load and low-load engine performance. The system shifts the intake valve timing, intake close timing and valve overlap are changed, simultaneously.

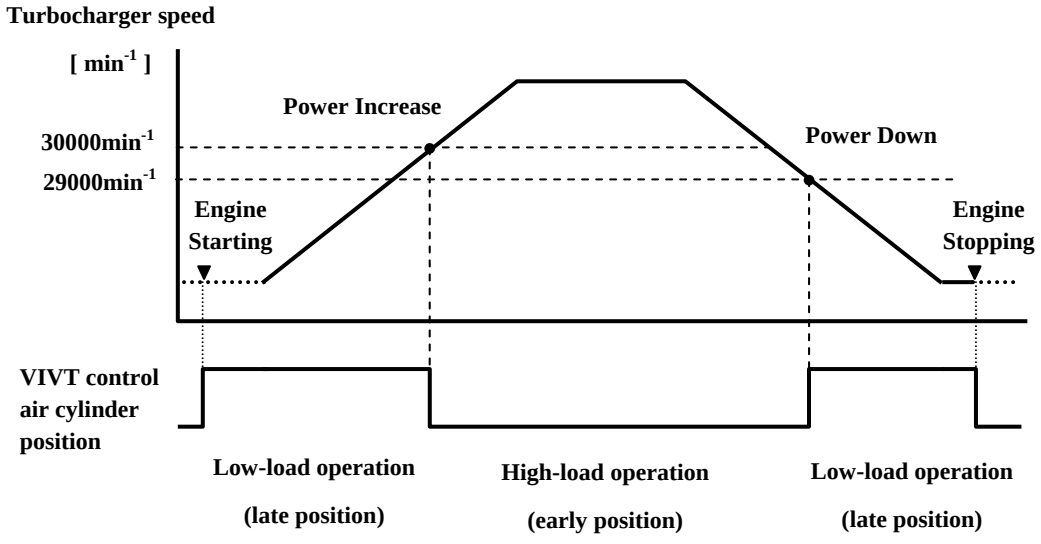
For low-load condition, this mechanism helps improvement of engine efficiency due to shortened valve overlap. On the other hand, the Miller cycle is achieved by advanced intake valve close timing and it leads lower NOx emission and good fuel consumption.

An air cylinder of VIVT is operated by control air. Operation of the VIVT system is controlled automatically the following base on the turbocharger speed.

- Low-load operation ：Intake valve timing is late position
- High-load operation ：Intake valve timing is early position







** These turbocharger speed are samples.

It depend on the engine output and specifications.

4.15 Air starter

The air starter is installed in driving end side, driven by compressed air.

Air run and engine starting can be controlled by remote control or switch of the Gauge board.

Operating theory of the air starter

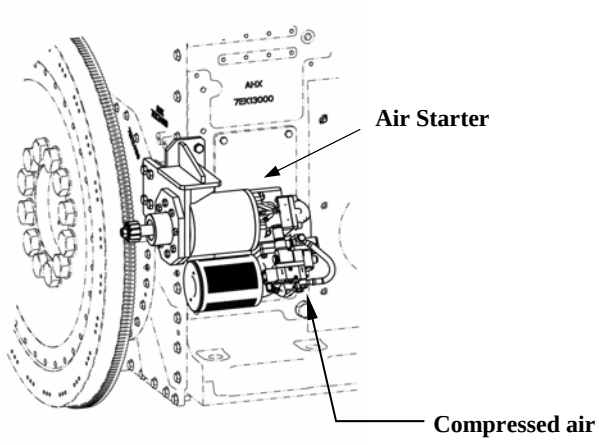
-First, the air starter drive pinion engages with the flywheel

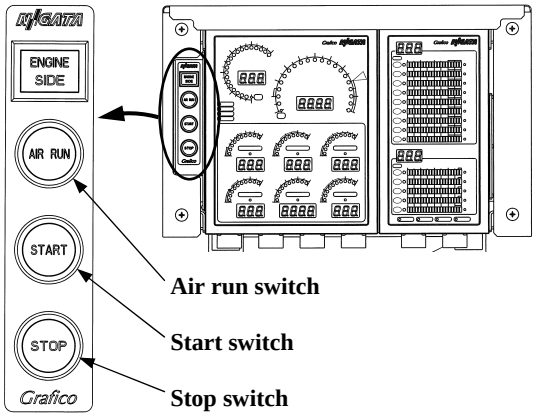
-Second, the main valve of the air starter opens

-Third, the engine is turned by the compressed air

If the drive pinion can not engage, or its working torque greater than starter one, drive pinion is automatically withdrawn to the idle position.

NOTE : For the construction and handling of the air starter , refer to the separate Instruction Manual for air starter.





4.16 Governor

The standard governor is a hydraulic type and controlled by microprocessor, which is accurate in operation and easy to maintain.

Speed command are given by the remote control or front control panel at the governor body.

NOTE : For the construction and handling of the hydraulic governor, refer to the separate Instruction Manual for Hydraulic Governor.

Maintain Governor every year. -Refer to paragraph **7.3**.

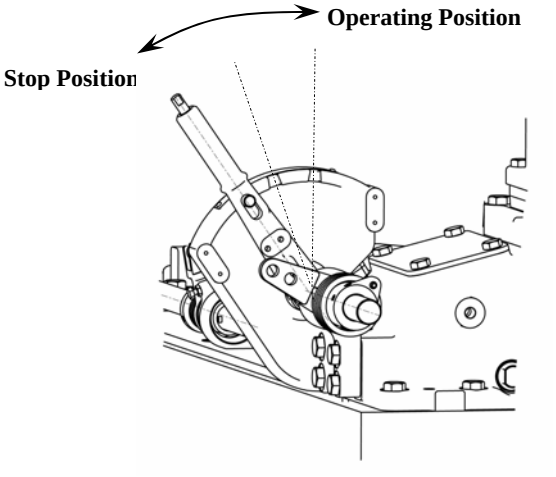
4.17 Maneuvering Device

The maneuvering device includes the fuel control lever, which is located on the driving end of the engine.

(1) Fuel Control Lever

The fuel control lever is connected to the fuel control lay shaft, and stops fuel injection at the “stop” position.

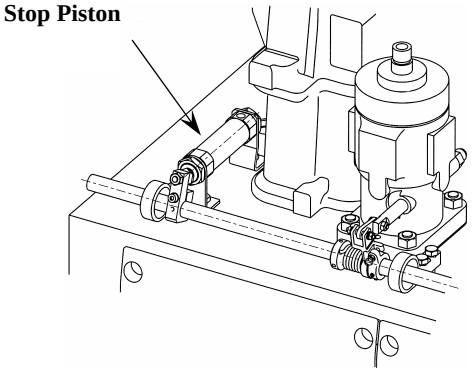
In “operating” position, the lever is disengaged from the fuel control lay shaft so that the fuel is controlled by the governor which interlocks with the fuel control lay shaft. Thus, operation by the governor takes place. The engine can be stopped and operated by means of the fuel control lever.



(2) Automatic stop valve

When automatically stopping the engine in the event of trouble, push the fuel control lay shaft toward STOP so that a fault signal will be emitted to the automatic stop device (air piston) via a solenoid valve.

The device is similarly used for remote control stop in general.



4.18 Front T/C Unit

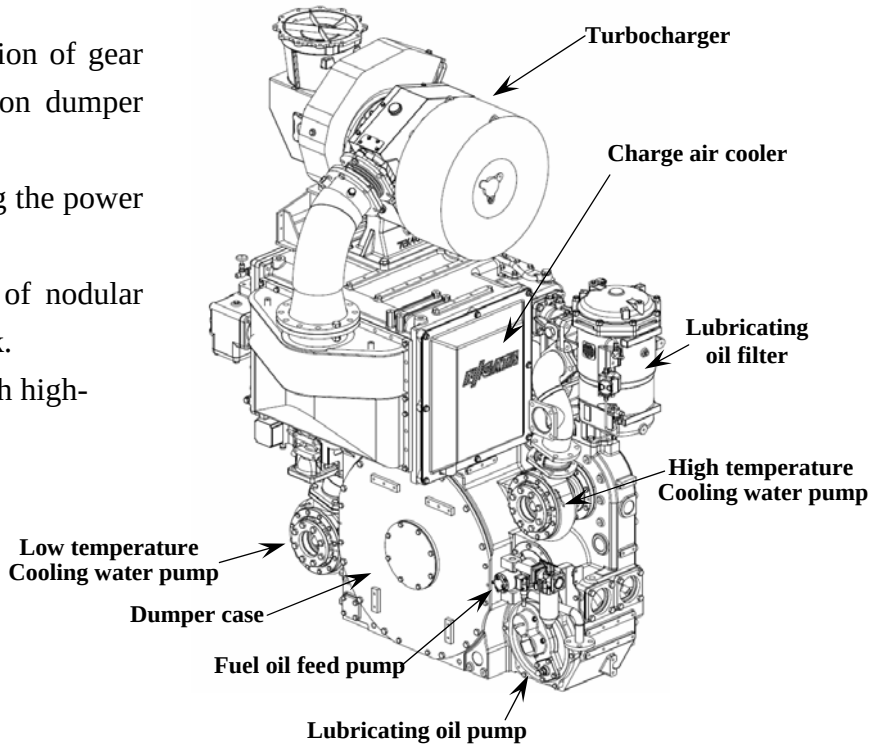
Auxiliary equipments are integrated into a unit (Front T/C Unit), it is located at free end of the engine.

(1) Front T/C block

＜Equipment＞

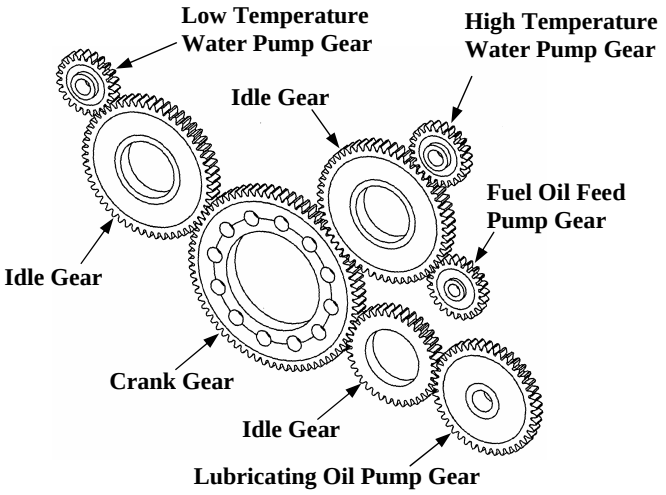
Lubricating oil systems ・・・・・ Lubricating oil pump, Filter
Cooling water systems ・・・・・ Cooling water pump
Fuel oil systems ・・・・・ Fuel oil feed pump, Filter
Turbocharger system ・・・・・ Turbocharger, Charge air cooler

The front T/C block has function of gear box case and torsional vibration dumper case.
Also, this case can be mounting the power take off shaft in free end side.
The front T/C block is made of nodular cast iron same as cylinder block.
It's fixed the cylinder block with high-tensile bolts and O-rings.



(2) Auxiliary pump driven gear train

Lubricating oil pump, cooling water pump, fuel oil feed pump are driven by the crank gear on the crankshaft through the idle gear in the dumper case.



4.19 Lubricating Oil system

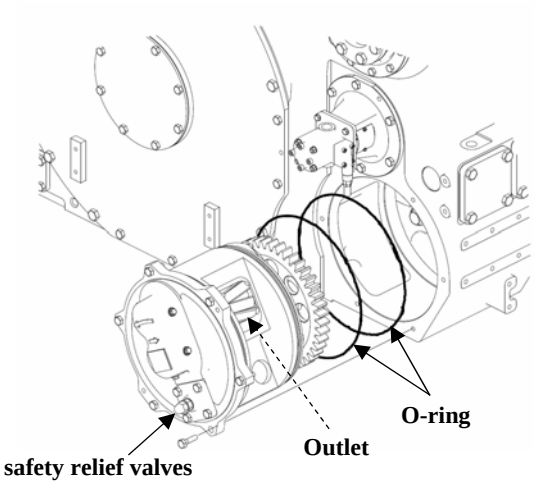
(1) Lubricating oil pump

The lubricating oil pump is a gear pump driven by the crankshaft gear via idle gear.

The lubricating oil pump is installed the front end unit with two O-rings.

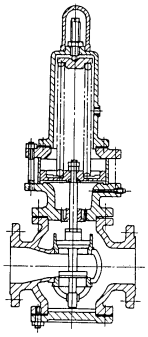
It is equipped with built-on safety relief valve.

Depending on the specification, an independent motor-driven pump may be used.



(2) Regulating valve

The lubricating oil regulating valve regulates lubricating oil pressure and also functions as a safety valve against excessive pressure rise.



Regulation valve

(3) Lubricating oil filter

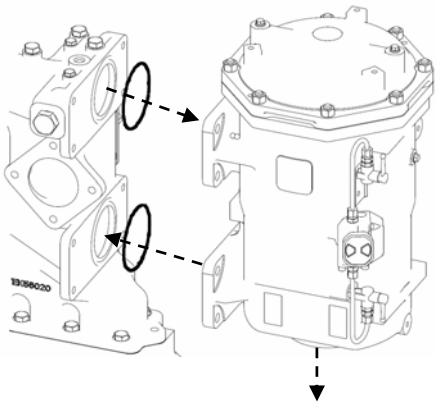
The lubricating oil filter is the candle element type filter of automatic backflushing type, and it locates on the engine.

The filter elements are cleaned automatically, so that engine dose not have to be switched off for cleaning.

The differential pressure monitoring system measures the differential pressure between the filter inlet and filter outlet.

As the contamination increases, the differential pressure in the filter also increases.

The differential pressure monitoring system indicates the differential pressure optically provides electrical signal.



Backflushing oil outlet

NOTE : For the construction and handling the filter, refer to the separated Instruction Manual for the filter.

4.20 Cooling water system

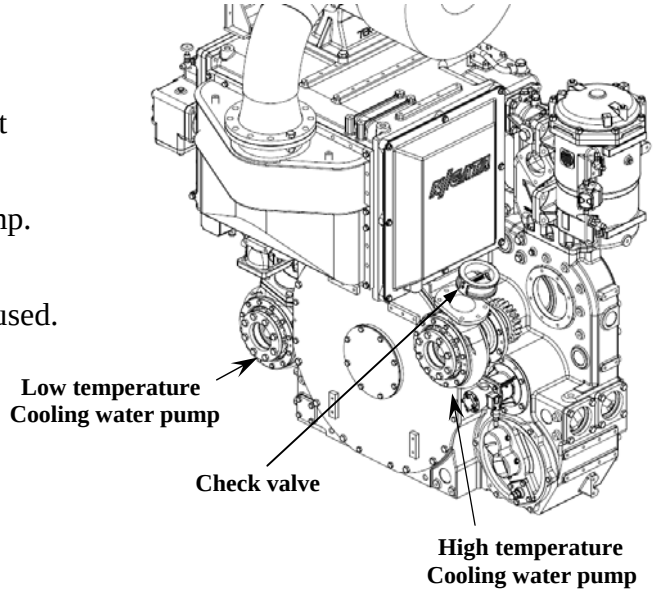
Cooling water system consist of two separate circuits or loops. High temperature fresh water feeds into the charge air cooler through the cylinder liner and cylinder head, the other low temperature fresh water (or sea water) feeds into the charge air cooler and lubricating oil cooler and fresh water cooler.

(1) Cooling Water Pump

It possible to equip two pumps for high temperature and low temperature (or sea water). These are driven by the crankshaft gear via idle gear.

There is the check valve for stand-by pump.

Depending on the specification, an independent motor-driven pump may be used.

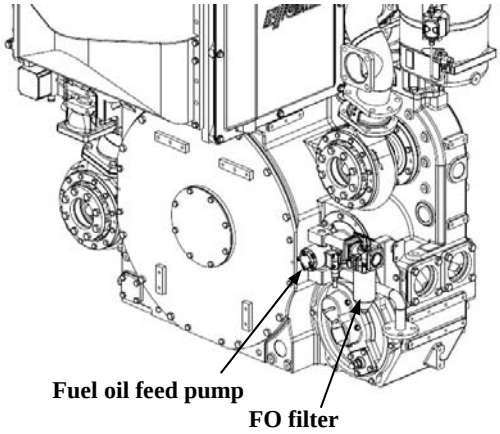


4.21 Fuel Oil Feed Pump

Fuel oil feed pump is a trochoid pump, which is driven by the crankshaft gear via idle gear.

Fuel oil discharged from the fuel feed pump passes the oil filter.

Depending on the specifications, an independent motor-driven pump may be used.

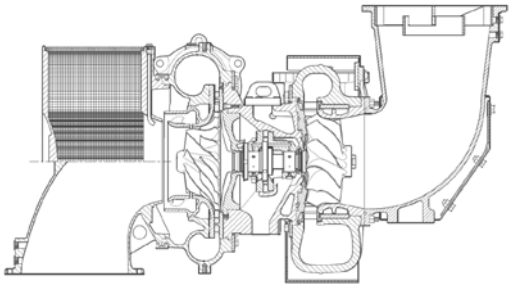


4.22 Turbocharger, Intake and Exhaust Manifolds

The turbocharger and charge air cooler are used for high engine performance and either of pulse charging system or constant pressure charging system is adopted depending on uses of the engine.

(1) Turbocharger

Type is ABB turbocharger and calculation and experiment select the best matching of turbine nozzle and diffuser to the engine.



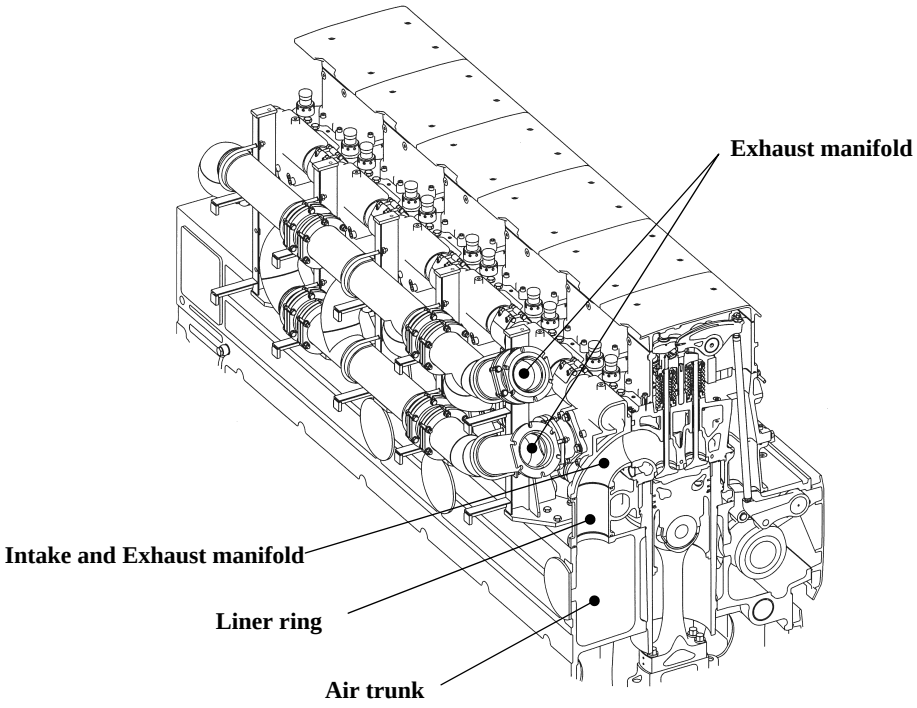
NOTE : For the construction and handling of the turbocharger, refer to the separated Instruction Manual for the turbocharger.

(2) Charge Air Cooler

The charge air cooler cools the air supplied from the turbocharger before it is fed into the cylinders. The air cooler is a 2-stage finned, multiple-tube type, whose capacity is selected as most suitable by calculation and experiment.

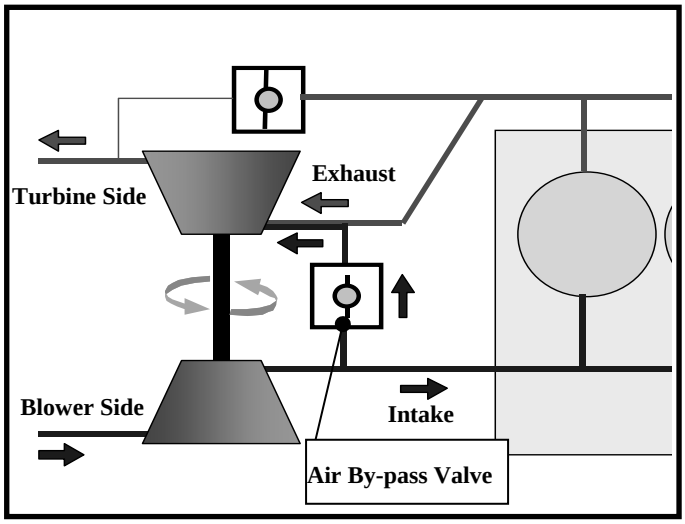
(3) Intake and Exhaust Manifolds

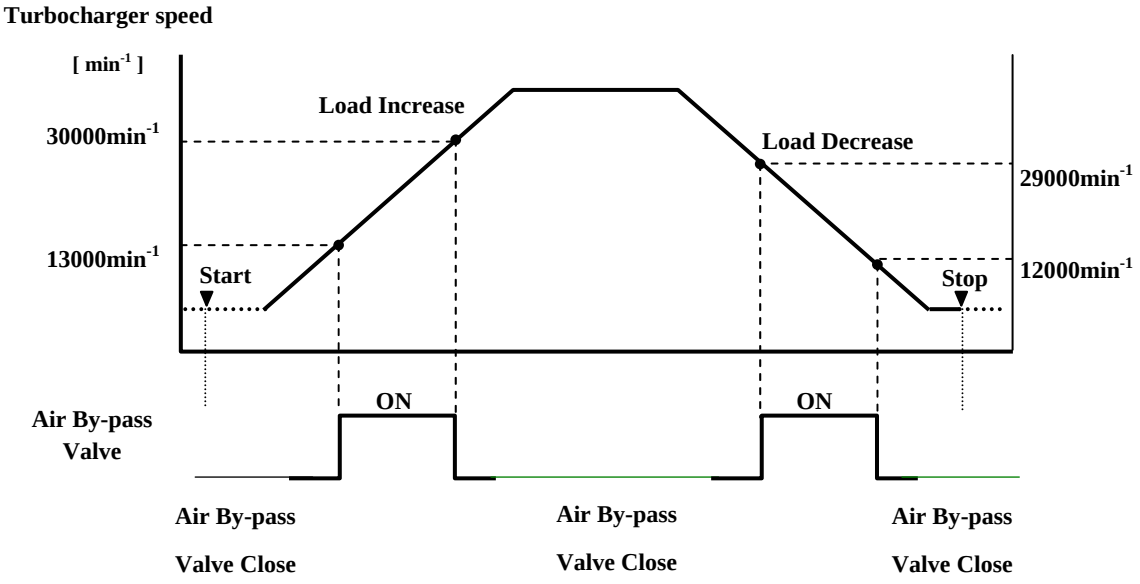
The air trunk is incorporated in the cylinder block and air inlet ducts integrated the liner ring and intake and exhaust manifolds connect the air trunk and the cylinder head.
It has flexible expansion joint to cope with thermal expansion.



(4) Air bypass system

The turbo charging system includes air bypass system. This system by-pass a part of compressed air to the blower of turbocharger at low and medium-load operation.
As a result, the turbocharger speed increase and charge air pressure and flow volumes increase.
Air bypass system improves combustion efficiency and reduce smoke emissions.
The air bypass system is operated by control air to the air bypass valve, and operation is controlled automatically base on the turbocharger speed as follow.



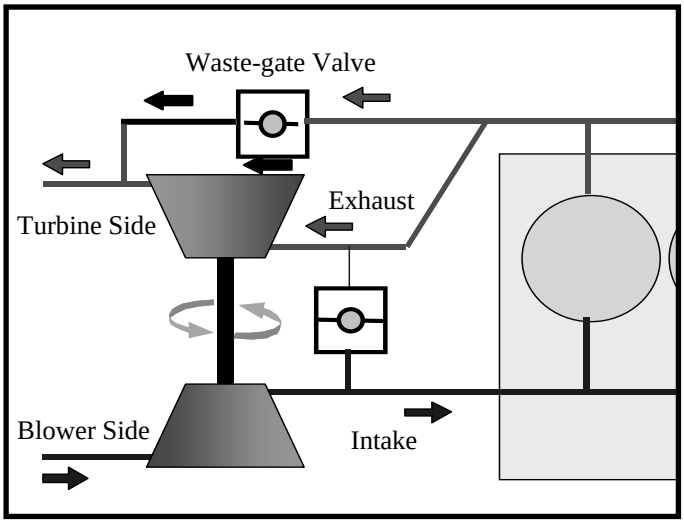


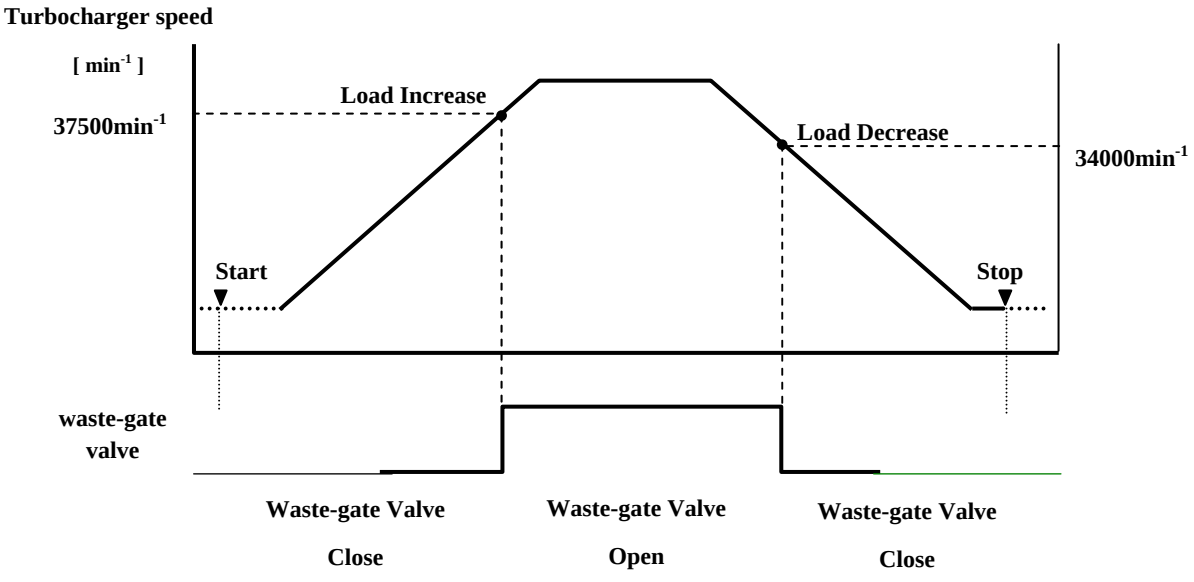
** These turbocharger speed are samples.
It depend on the engine output and specifications.

(5) Waste-gate system（Depend on specification）

The turbo charging system includes waste-gate system. This system controls the turbocharger speed and prevents the combustion pressure in the cylinder within the designed value at over-Load operation.

The waste-gate system is operated by control air to the waste-gate valve, and operation is controlled automatically base on the turbocharger speed as follow.

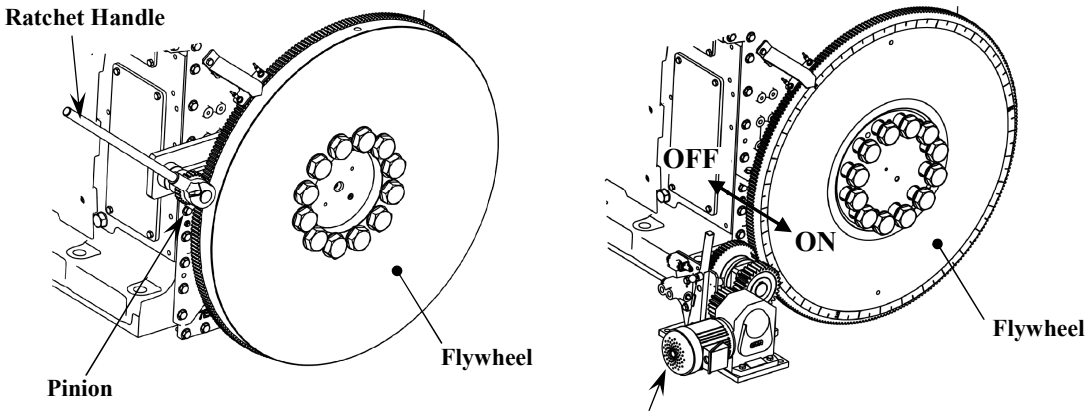




** These turbocharger speed are samples.
It depend on the engine output and specifications.

4.23 Turning Device

The normal turning device is a ratchet handle type. It turns the engine rotating the flywheel by ratchet handle and pinion. The optional turning device is a electrical motor type with a reduction gear. It can turn the engine to rotate the flywheel by electrical motor.



Ratchet handle type

(Normal)

Electrical motor type

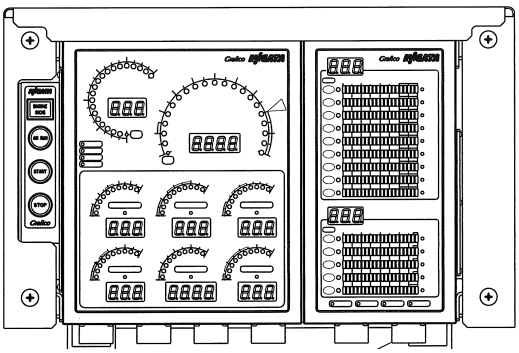
(Optional)

4.24 Gauge Board

This engine is use a electrical gauge board with digitally and bar graphs using LED for excellent visibility and rapid assessment of engine status, contributing to engine safety operations.

Display items

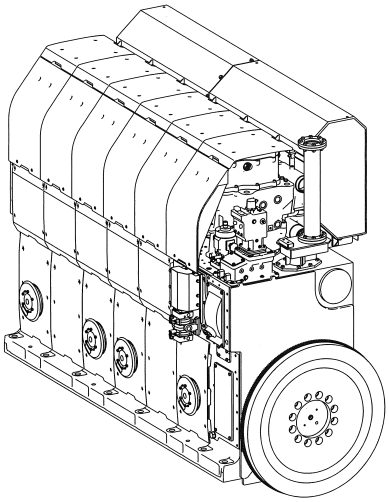
- Engine speed
- Turbocharger speed
- Lubricating oil pressure
- Cooling water pressure
- Fuel oil pressure
- Charge air pressure
- Exhaust temperature

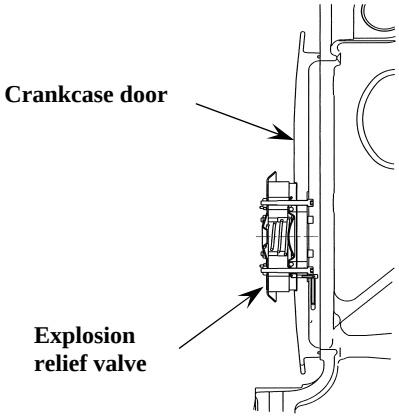


4.25 Crankcase Explosion relief Valve

Explosion relief valves are installed on the crankcase doors to prevent accidents due to abnormal pressure inside the cylinder block.

Explosion relief valve capacity and opening pressure are selected according to the applicable rules.

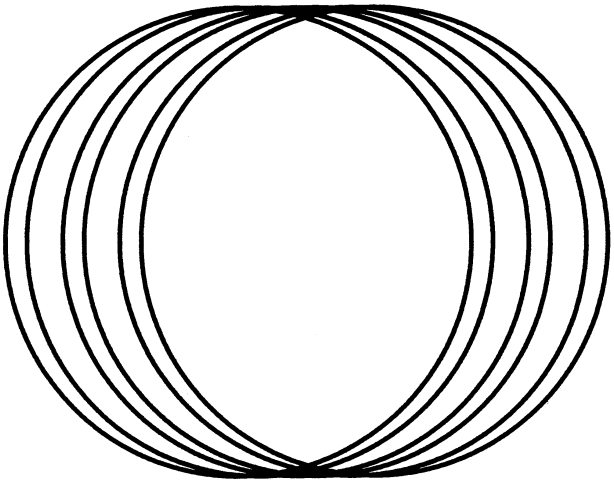




⚠ DANGER

Where the engine is brought to a stop due to abnormal heat generation being detected inside the engine room, there is a danger of explosion if crankcase door is allowed to open forthwith. Open the door after the lapse of a cooling period of not less than 20 minutes.

MEMO



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INDEX

5 ADJUSTMENT STANDARDS
FOR MAIN PARTS ---------- 5-1
5.1 Parts Adjustment Standards --------- 5-2
5.2 Tightening Specification
of Main Parts ---------- 5-13
5.3 Temperature settings ---------- 5-18
5.4 Pressure settings ---------- 5-18

5. ADJUSTMENT STANDARDS FOR MAIN PARTS

Adjust the main parts as indicated in the table after page 5-2. If the specified limits are exceeded, readjust, repair or replace the parts.

Standard ---------- Manufacturing standards for new engine.

Permissible limit ---- Parts exceeding the permissible limit must be repaired or replaced at periodic inspection and maintenance time.
(Maintenance control standard)

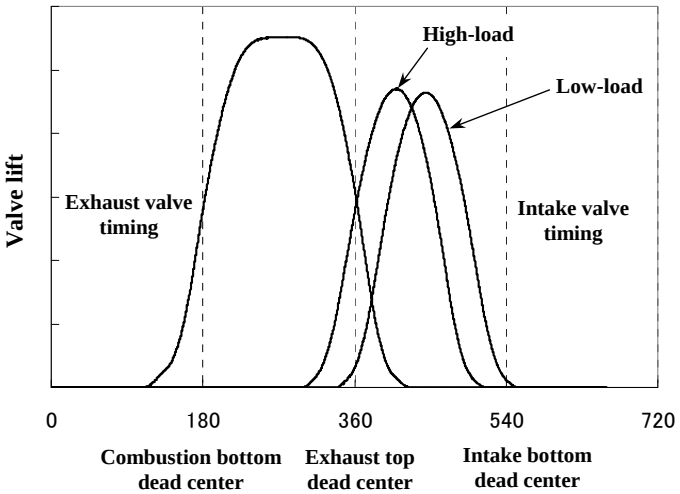
NOTES

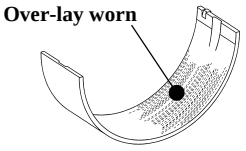
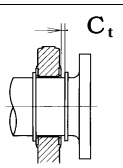
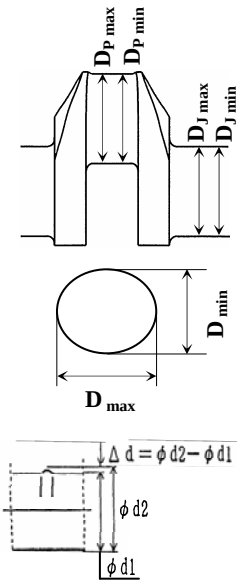
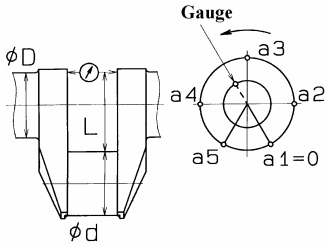
(1) Standard clearance shows dimensional difference of new engines.

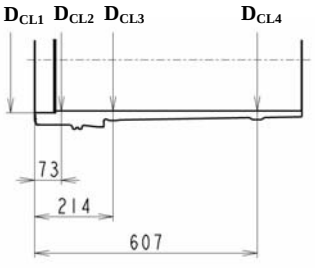
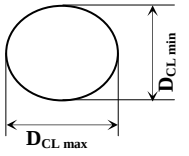
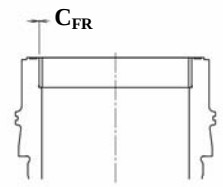
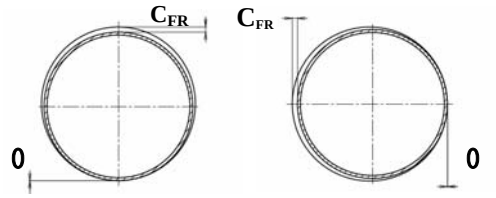
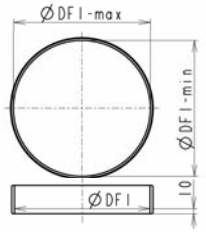
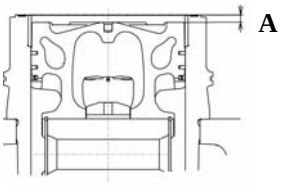
(2) When measuring clearance with feeler gauges, add 0.01 to 0.02 mm to the measured values for the correct clearance.

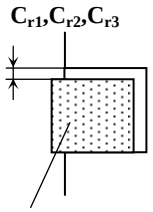
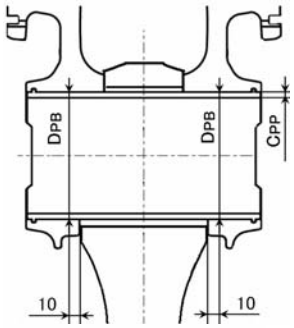
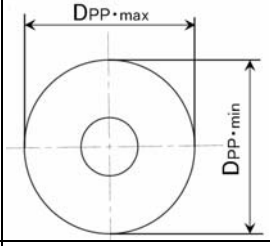
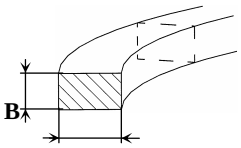
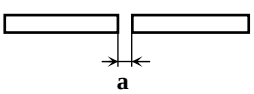
5.1 Parts Adjustment Standards

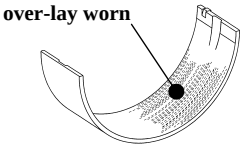
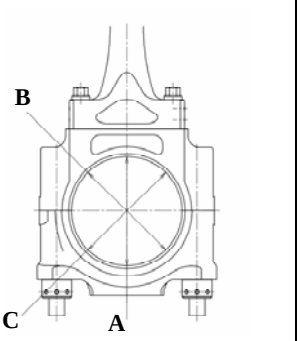
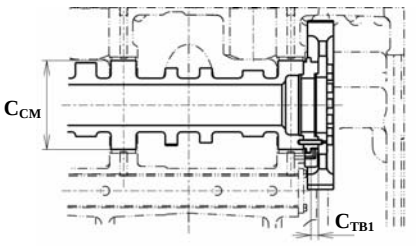
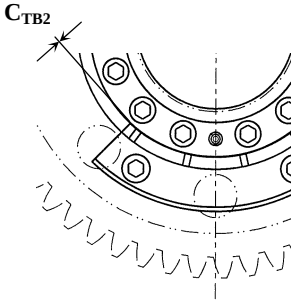
No.	Adjusting point			Nominal size (mm)	Clearance, Wear Limit		Description
					Standard (mm)	Permissible Limit (mm)	
1	Fuel Injection Nozzle Valve opening pressure				50MPa		Adjust with injection test pump
2	Fuel injection pump rack scale ・Rack scale at engine stop ・Scale difference during operation (at maximum continuous output)					0± 1 or less 3 or less	If serious difference is found, engine may not come to a stop even if fuel control lever is moved to STOP position.
3	Maximum cylinder pressure				18MPa below	Deviation less than 0.7MPa	Adjust at maximum continuous output (See test record)
4	Intake valve timing	Low-road	Opening start	—	13°	—	Before exhaust top dead center
			Closing end	—	6°	—	After intake bottom dead center
		High-road	Opening start	—	53°	—	Before exhaust top dead center
			Closing end	—	34°	—	Before intake bottom dead center
5	Exhaust valve timing		Opening start	—	59°	—	Before combustion top dead center
			Closing end	—	53°	—	After exhaust top dead center

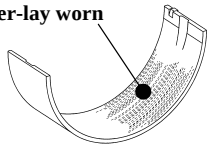
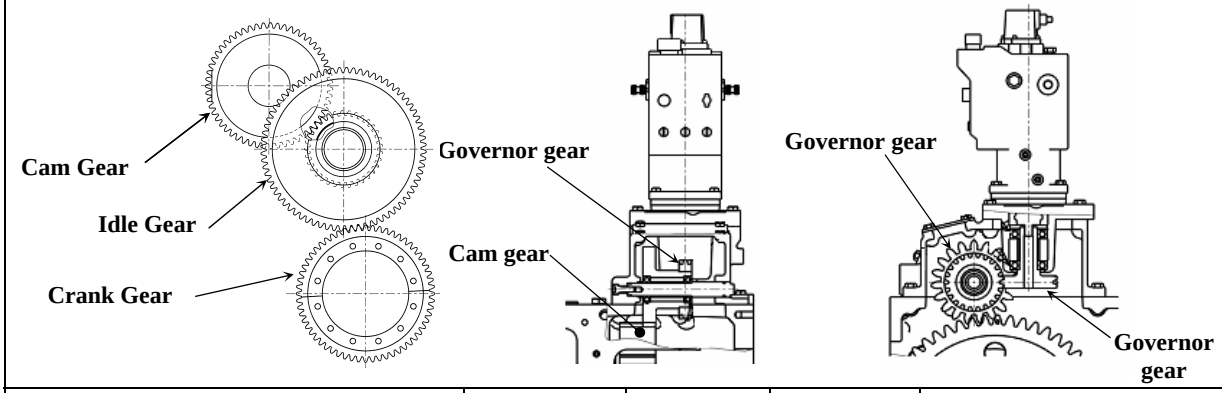
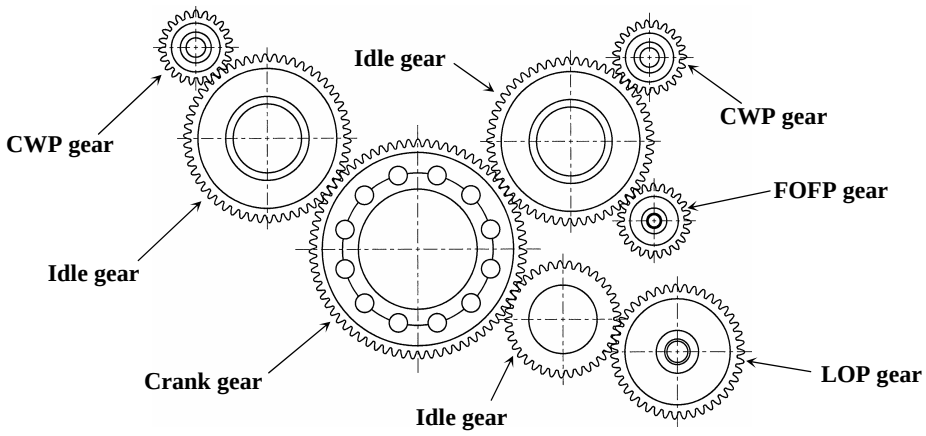


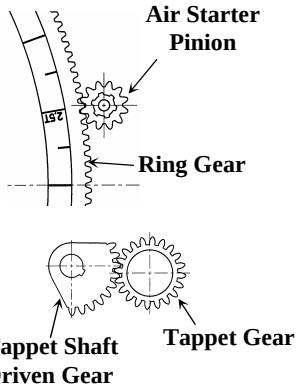
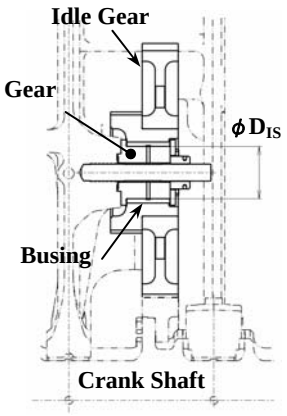
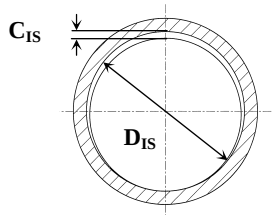
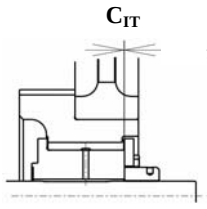
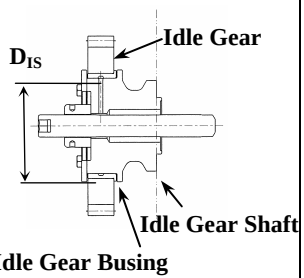
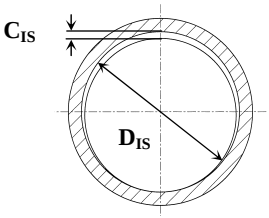
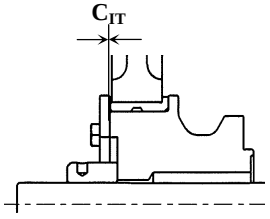
No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
6	Main Bearing • Clearance between main bearing and journal C_J	Journal dia. ϕ 240	0.24~0.331	Note,1	
	Note1 • Measure with feeler gauges when bearing is cold. • If overlay wear is more than 30%, replace bearing.				
7	Thrust bearing clearance C_t		0.50~0.602	0.75	
	Note • Adjust by oversize thrust metal or shim.				
8	Crankshaft •Crank pin diameter D_P	Crank pin dia. ϕ 240	0 240 -0.029	239.86	
	•Journal diameter D_J	Journal dia. ϕ 240	0 240 -0.029	239.86	
	• dimension				
	Crank pin $D_{P\,max} - D_{P\,min}$		—	0.04	
	Journal $D_{J\,max} - D_{J\,min}$		—	0.04	
	• Shaft uneven wear $D_{max} - D_{min}$		—	0.10	
	• Shaft cam wear $\phi d2 - \phi d1$		—	0.01	
	Note • If wear exceeds limit, grind crankshaft and use undersized bearing.				
9	Crankshaft deflection 		≤0.04 (1/10000×S)	≤0.08 (2/10000×S)	Value at left applies where L=195 when engine cold. If size L differs, repair as per formula at left.
			Deflection = $\frac{S/2+D/2}{d/2+L}$ × Actual measurement ・S : Stroke 390mm ・D : Journal diameter 240mm ・d : Crank pin diameter 240mm		
	Note • A1 should be 0 where gauge will Inter fare with connecting rod and piston close to bottom dead center. • Different between maximum and minimum value of a2, a3 ,a4 or a 5 represents crankshaft deflection.				

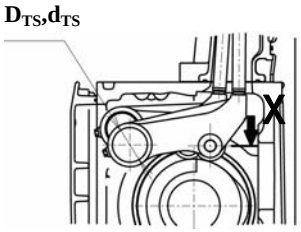
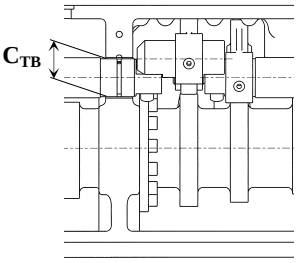
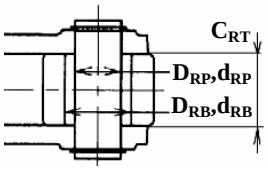
No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
10	Cylinder liner • Inner diameter				
	D_{CL1}	ϕ 290	$^{+0.052}_{0}$ 290		
	D_{CL2}	ϕ 280	$^{+0.052}_{0}$ 280	280.35	
	D_{CL3}	ϕ 280	$^{+0.052}_{0}$ 280	280.35	
	D_{CL4}	ϕ 280	$^{+0.052}_{0}$ 280	280.35	
	• Uneven wear $D_{CL\,max} - D_{CL\,min}$		0.02	0.4	
11	Fire ring • Clearance between liner and fire ring C_{FR}	ϕ 290	0.056 ～0.160	0.2	
	Note • Measures clearance between liner and fire ring , when fire ring get together other side.				
	• Fire ring uneven wear $D_{FR\,max} - D_{FR\,min}$	Inner dia. ϕ 278.5	—	0.2	
12	Piston • Top clearance **A**	14	—	—	**Top clearance** 
	Note • At the top dead center, measure the dimension A to remove the cylinder head, because measurement of the top clearance is impossible.				

No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
	Piston • Clearance between ring groove and piston ring				 Piston ring
	Top ring C_{r1}		0.21~0.25	0.35	
	2nd ring C_{r2}		0.11~0.15	0.25	
	Oil ring C_{r3}		0.043~0.078	0.25	
	Note • Measure with feeler gauge when engine cold.				
	• Piston pin boss diameter D_{PB}	ϕ 130	$130^{+0.06}_{+0.04}$	130.10	
	• Clearance between piston boss and piston pin C_{PP}		0.06～0.10	0.15	
	• Piston pin uneven wear $D_{PP\,max} - D_{PB\,min}$		≦0.01	≦0.03	
13	Piston ring				
	• Ring width B				
	Top ring	6	$6^{-0.01}_{-0.03}$	—	
	2nd ring	6	$6^{-0.01}_{-0.03}$	—	
	Oil ring	8	$8^{-0.013}_{-0.028}$	—	 T
	• Ring thickness T				
	Top ring	10.4	10.4±0.15	—	
	2nd ring	10.4	10.4±0.15	—	
	Oil ring	5.5	5.5±0.15	—	
	• Ring gap a				
	Top ring		1.1~1.4	—	
	2nd ring		1.1~1.4	—	
	Oil ring		0.90~1.30	—	

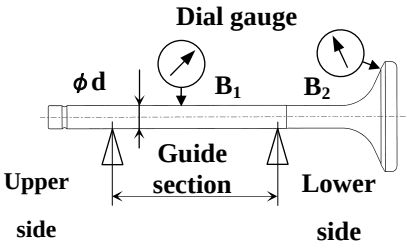
No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
14	Crank pin bearing • Clearance between crank pin bearing and crankshaft **C_p**	Pin dia. ϕ 260	0.18~0.271	Note,1	
	Note,1 • Measure with feeler gauges when bearing is cold. • If overlay wear is more than 30%, replace bearing.				
15	Connecting rod • Connecting rod uneven diameter **OV** **OV=A-(B+C)/2**		—	0.1	
	• Piston pin bush inner diameter **D_{PM}**	ϕ 130	$130^{+0.155}_{+0.10}$	130.21	
	• Clearance between piston pin bush and piston pin **C_{PM}**		0.12～0.195	0.30	
16	Cam shaft • Clearance between cam shaft and cam shaft bearing **C_{CM}**		0.15～0.288	0.4	
	• Clearance between cam shaft and thrust bearing **C_{TB1}**		0.2～0.4	0.7	
	• Clearance between cam shaft bearing and plate **C_{TB2}**		0.35～0.45	—	

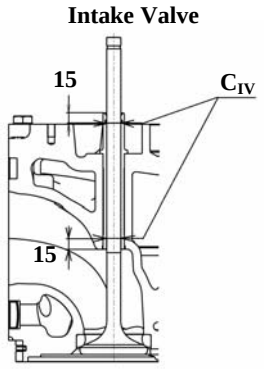
No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
17	Power take off shaft bearing • Clearance between bearing and power take off by free end side. C_{PT}	Journal dia. ϕ 185	0.14~0.238	Note,1	
	Note,1 • Measure with feeler gauges when bearing is cold. • If overlay wear is more than 30%, replace bearing.				
18	Gear train backlash				
	＜Driving end side＞	Module	Backlash		
	• Crank gear～Idle gear	m=8	0.24～0.40	0.6	
	• Idle gear～Cam gear	m=8	0.24～0.40	0.6	
	• Cam gear～Governor gear	m=8	0.24～0.40	0.6	
	• Governor gear～Governor gear	m=3.5	0.17～0.45	0.6	
					
	＜Free end side＞	Module	Backlash		
	• Crank gear～Idle gear	m=7	0.21~0.35	0.5	
	• Idle gear～LOP gear	m=7	0.21~0.35	0.5	
	• Idle gear～CWP gear	m=7	0.21~0.35	0.5	
	• Idle gear～FOFP gear	m=7	0.21~0.35	0.5	
					

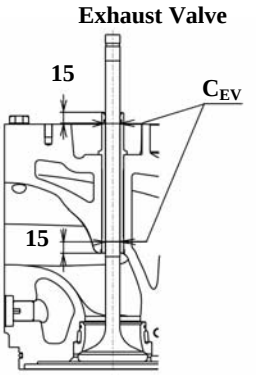
No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
	• Ring gear～Air starter pinion	Module m=5	Backlash 0.4~0.7		
	• Tappet Shaft driving gear		0.15~0.25		
19	Idle gear and gear shaft of transmission gear train ＜Driving end side＞ • Busing inside diameter D_{IS}	ϕ 120	+0.032 120 -0.078		
	• Clearance between busing and idle gear shaft C_{IS}		0.05～0.18	0.28	
					
	• Thrust clearance C_{IT}		0.20～0.60	0.70	
	＜Free end side＞ • Busing inside diameter D_{IS}	ϕ 145	+0.045 145 0	—	
	• Clearance between busing and idle gear shaft C_{IS}		0.10～0.18	0.28	
					
	• Thrust clearance C_{IT}		0.20～0.40	0.50	

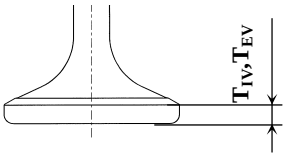
No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
20	Valve gear				
	• Tappet inner diameter **D_{TS}**	ϕ 70	$^{+0.025}_{70\ +0.011}$	—	
	• Shaft diameter **d_{TS}**	ϕ 70	$^{-0.010}_{70\ -0.029}$	—	
	• Clearance between tappet and shaft **C_{TS}**		0.02～0.05	0.10	
	• Clearance between tappet shaft and tappet bush **C_{TB}**		0.05～0.14	0.20	
	• Tappet bush inner diameter **D_{RP}**	ϕ 25	$^{+0.10}_{25\ +0.08}$	—	
	• Roller inner diameter **d_{RP}**	ϕ 25	$^{+0.026}_{25\ +0.018}$	—	
	• Clearance between bush and roller. **C_{RP}**		0.05～0.08	0.16	
	• Roller inner diameter **D_{RB}**	ϕ 36	$^{+0.07}_{36\ +0.05}$	—	
	• Bush diameter **d_{RB}**	ϕ 36	$^{-0.02}_{36\ -0.05}$	—	
	• Clearance between bush and roller **C_{RB}**		0.07～0.12	0.24	
	• Clearance between roller and tappet **C_{RT}**		0.5～0.7	—	

No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
21	Intake and Exhaust valve				
	• Intake valve stem diameter **d_{IV}**	ϕ 20	20 $^{-0.06}_{-0.08}$	19.80	
	• Intake valve guide inner diameter **D_{IV}**	ϕ 20	20 $^{+0.04}_{+0.02}$	20.25	
	• Clearance between intake valve stem and guide **C_{IV}**		0.08～0.12	0.45	
	• Exhaust valve stem diameter **d_{EV}**	ϕ 20	20 $^{-0.08}_{-0.10}$	19.80	
	• Exhaust valve guide inner diameter **D_{EV}**	ϕ 20	20 $^{+0.04}_{+0.02}$	20.25	
	• Clearance between exhaust valve stem and guide **C_{EV}**		0.10～0.14	0.45	
	• Intake valve com thickness **T_{IV}**		10.3	8.8	
	• Exhaust valve com thickness **T_{EV}**		10.3	8.8	
	• Bend of stem at center of stem				
	Center of guide section **B_1**		≤0.03	0.09	
	At center seating surface **B_2**		≤0.03	0.05	

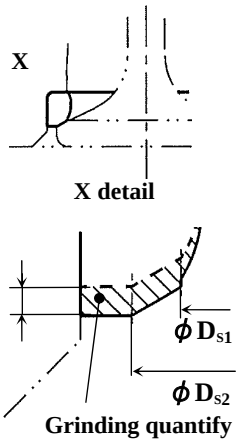


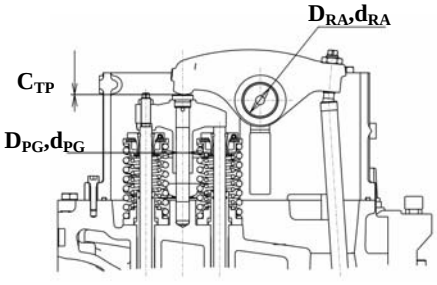




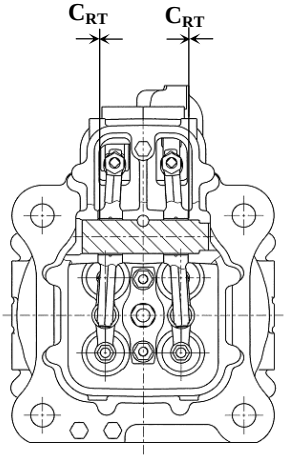


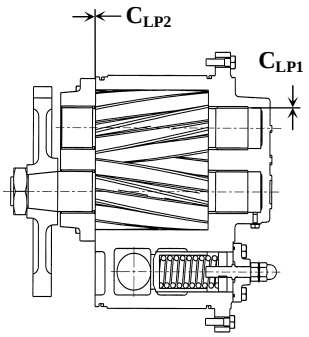
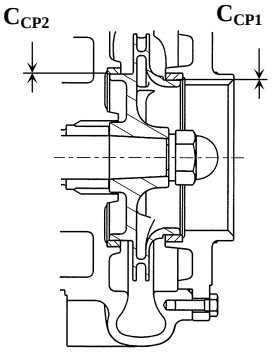
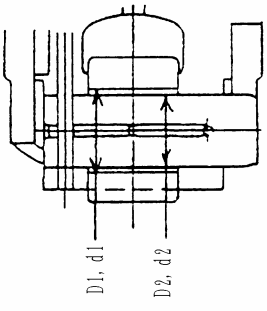
No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
22	Intake and Exhaust valve seat				
	• Grinding allowance : S				
	Intake valve seat			1.0	
	Exhaust valve seat			1.5	
	• Valve seat diameter				
	Inside : ϕ Ds1 (Intake valve)	ϕ 84	$84\ ^{+0.1}_{0}$		
	(Exhaust valve)	ϕ 84	$84\ ^{+0.1}_{0}$		
	Outside: ϕ Ds2 (Intake valve)	ϕ 94.3	94.3±0.1		
	(Exhaust valve)	ϕ 94.3	$94.3\ ^{+0.03}_{-0.02}$		
23	Rocker arm				
	• Intake and Exhaust valve tappet clearance C_{TP}		0.5	—	
	• Rocker arm bush inner diameter D_{RA}	ϕ 55	$55\ ^{+0.109}_{+0.04}$	—	
	• Rocker arm shaft diameter d_{RA}	ϕ 55	$55\ ^{-0.010}_{-0.029}$	—	
	• Clearance between rocker arm bush and shaft D_{RA}- d_{RA}		0.05~0.138	0.2	
	• Pusher inside shaft D_{PG}	ϕ 22	$22\ ^{+0.021}_{0}$	—	
	• Pusher guide diameter d_{PG}	ϕ 22	$22\ ^{-0.02}_{-0.033}$	—	
	• Clearance between pusher and pusher guide D_{PG}- d_{PG}		0.02~0.054	0.1	
	Rocker arm bush				
	• Thrust clearance C_{RT}		0.2~0.6	—	





Clearance



No.	Adjusting point	Nominal size (mm)	Clearance, Wear Limit		Description
			Standard (mm)	Permissible Limit (mm)	
24	Lubricating oil pump • Clearance between bush and shaft **C_{LP1}** • Clearance between case and gear **C_{LP2}**		0.03~0.17 0.10~0.18	0.25 0.25	
	Note ・Correct case depth and adjust				
25	Cooling water pump • Clearance between impeller and suction cover **C_{CP1}** **C_{CP2}**	 ϕ 135 ϕ 145	 0.15~0.21 0.15~0.21	 0.4 0.4	
26	Fuel injection pump • Roller inner diameter **D_1** • Bush diameter **d_1** • Clearance between roller and bush **D_1-d_1** • Bush inner diameter **D_2** • Roller pin diameter **d_2** • Clearance between bush and roller. **D_2-d_2**	 ϕ 48 ϕ 48 ϕ 38 ϕ 38			

5.2 Tightening Specification of Main Parts.

No.	Tightening Parts	Screw Size	Torque (Nm)	Tightening Angle (degree)	Jack oil Pressure (MPa)	Remarks
1	**Cylinder block**					
	Main bearing stud bolt and nut	M42×3.0	—	—	180	—
	Main bearing side bolt	M27×2.0	700 ※**1**	—	—	(M)
	Cylinder head stud bolt and nut	M36×2.0	—	—	130	—
	Location bearing stud bolt and nut	M42×3.0	—	—	180	—
2	**Crankshaft**					
	Balance weight stud bolt and nut	M36×2.0	—	—	130	—
	Crank gear bolt (Driving end side)	M22×1.5	480	—	—	(M)
	Crank gear stud bolt and nut (Free end side, without Damper)	M42×3.0	—	—	150	—
	Geislinger damper stud bolt and nut (Free end side, with dumper)	M42×3.0	—	—	150	—
	Free end side coupling shaft stud bolt and nut (With power take off shaft)	M42×3.0	—	—	150	—
3	**Flywheel**					
	Flywheel bolt	M48×3.0	Primary tightening 300	After primary tightening 25°	—	(M)
	Geislinger coupling-**BE63** type**< 6cyl >**					
	Flywheel／Geislinger coupling bolt (With flywheel and Geislinger coupling)	M48×3.0	Primary tightening 300	After primary tightening 40°	—	(M)
	Coupling bolt	M36×4.0	1470	—	—	(M)
	Geislinger coupling-**BC63** type**< 6cyl >**					
	Flywheel／Geislinger coupling bolt	M27×3.0	600	—	—	(M)
	Coupling bolt	M36×4.0	1600	—	—	(M)
	CENTA coupling - **CX-80** type**< 6cyl >**					
	CENTA coupling bolt	M18×2.5	240	—	—	(M)
	Coupling bolt	M30×3.5	1000	—	—	(M)
	Geislinger coupling-**BE72** type**< 8cyl >**					
	Flywheel／Geislinger coupling bolt	M48×3.0	Primary tightening 300	After primary tightening 15°	—	(M)
	Coupling bolt	—	—	—	—	(M)
	Geislinger coupling-**BC72** type**< 9cyl >**					
	Flywheel／Geislinger coupling bolt	M30×3.5	700	—	—	(M)
	Coupling bolt	—	—	—	—	(M)
	CENTA coupling-**CX-183** type**< 9cyl>**					
	CENTA coupling bolt	M20×2.5	240	—	—	(M)
	Coupling bolt	M30×3.5	1000	—	—	(M)

※1：Main bearing lateral bolt is Tightening Procedure, Refer to CHAPTER 7.5.11.

No.	Tightening Parts	Screw Size	Torque (Nm)	Tightening Angle (degree)	Jack oil Pressure (MPa)	Remarks
4	**Connecting rod**					
	Crank pin bolt	M25×2.0	Primary tightening 49	After primary tightening 85°	—	(M)
	Crank pin stud bolt and nut	M36×2.0	—	—	130	—
5	**Cam shaft**					
	Cam shaft bolt	M16×1.5	275	—	—	(L)
	Cam gear bolt	M16×1.5	275	—	—	(L)
	Thrust bearing bolt	M16×2.0	100	—	—	(L)
6	**Idle gear**					
	Idle gear stud bolt and nut (Driving end side)	M42×3.0	—	—	180	—
	Idle gear stud bolt and nut (Free end side)	M36×2.0	—	—	130	—
7	**Cylinder head**					
	FV sleeve nut	M70×2.0	588	—	—	(L)
	Rocker arm shaft support bolt	M16×2.0	150	—	—	(M)
8	**Fuel Injector**					
	Fuel injector nozzle nut	M39×1.5	300	—	—	(M)
	Fuel injector stud nut	M16×2.0	100 ※**2**	—	—	(O)
9	**Fuel injection pump**（**NICO** type）					
	Flange bolt	M14×2.0	90	—	—	(M)
	FIP delivery valve bolt	M12×1.75	75 ※**3**	—	—	(M)
	FO doorway hollow bolt	M32×1.5	130	—	—	(K)
	FIP stud bolt and nut	M18×2.5	235	—	—	(K)
10	**Fuel oil injection pipe**					
	Injection fitting bolt	M12×1.75	50 ※**2**	—	—	(M)
	Injection pipe nut (cylinder head side)	M45×1.5	95	—	—	(M)
	FO high pressure pipe nut (FIP side)	M30×1.5	75	—	—	(M)
11	**FOFP**					
	Drive gear nut	M24×3.0	440	—	—	(L)
12	**Cooling water pump**					
	Driving gear nut	M30×3.5	343	—	—	(L)
	Impeller nut	M24×2.0	216	—	—	(L)

※2：Fuel injector stud nut and Injection fitting Bolt is Tightening procedure, Refer to CHAPTER 7.5.6.
※3：FIP delivery valve bolt is Tightening procedure, Refer to CHAPTER 7.5.5.

No.	Tightening Parts	Screw Size	Torque (Nm)	Tightening Angle (degree)	Jack oil Pressure (MPa)	Remarks
13	**Lubricating oil pump**					
	Driving gear nut	M45×2.0	785	—	—	(L)
14	**Turbocharger system**					
	Turbocharger bolt (A140)	M24×3.0	960	—	—	(O)
15	**Tappet shaft**					
	Tappet shaft bolt	M16×2.0	235	—	—	(L)
16	**Cooling water pump driving gear**					
	Idle gear shaft bolt	M16×2.0	177	—	—	(L)
17	**Cooling water piping**					
	Flex coupling	—	15	—	—	—
18	**Bypass filter**					
	Hand clamp (FM200)	—	5~7	—	—	—
	Hand clamp (FM400)	—	7	—	—	—
	Hand clamp (FM600)	—	7	—	—	—
19	**Damper case cover**					
	Bearing case cover bolt For assembly	M20×1.5	280	—	—	(M)
	Bearing case cover bolt For mounting	M16×2.0	180	—	—	(L)
	Damper case cover bolt For mounting	M16×2.0	180	—	—	(L)
	(With power take off shaft)					

Tightening torque specification for general bolt. (Material : equivalent JIS SS400)

Screw size	Tightening torque (Nm)			Remarks
	Standard	Minimum	Maximum	
M8	9.8	8.8	14.7	(K)
M10	24.5	19.6	29.4	(K)
M12	44.1	34.3	49.0	(K)
M16	98.0	88.2	118	(K)
M20	216	186	245	(K)
M22	274	216	304	(K)
M24	363	284	392	(K)
M30	706	637	784	(K)
M36	1176	980	1372	(K)

Note

1.Clean bolts, nuts and screws, and to check that they are free of damage, them by hand until they come into with their seats.

2.Meanings of the symbols in the "Remarks column"

(M) : Apply MOLYBDENUM DISULFIED to the screw threads and seats surface.

(L) : Apply LOCKTITE 243 or equivalent to the screw threads.

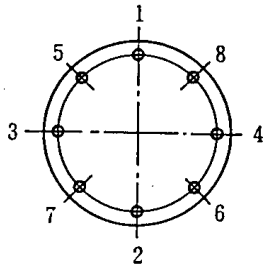
(O) : Apply lubricating oil to the screw threads.

(K) : Tighten after cleaning in light oil.

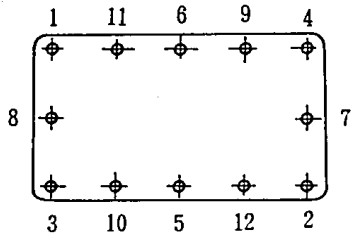
3. Tighten bolt and nut in the following three step to assure even tightening.

Primary tightening → **Intermediate tightening** → **Final tightening**

Tighten diametrically opposite bolts (or nuts) by turns as shown below.



Tightening order
1,2,3,4 …… 8

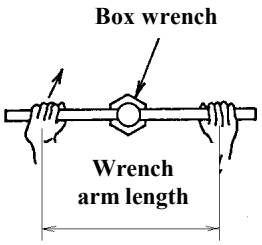


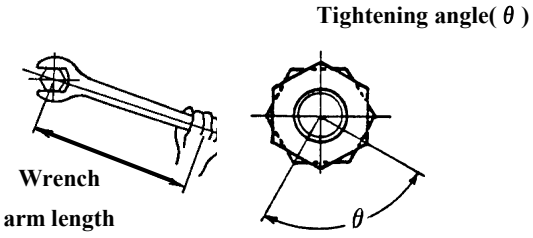
Tightening order
1,2,3,4 …… 12

4.Tightening force is specified as follows

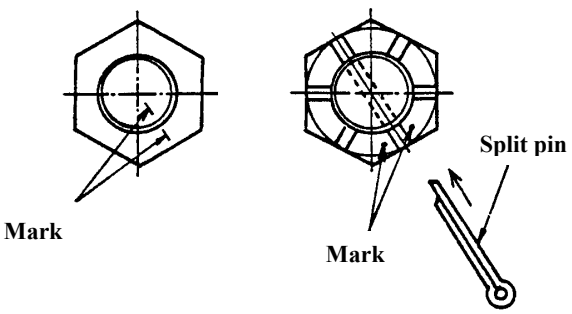
Primary tighten : To turn a bolt or nut to bring it into close contact with its seat

The force exerted by one person is assumed to be about 490N.(Single hand about 294N)
When using a box wrench, the standard tightening force is based on a position close to the center of the wrench held with both hands.





5.The counter-mark on bolts and nut were punched at the time of engine manufacture.
When reassembling the engine, use them only as rough yardsticks and be sure to correctly tighten them with the specified torque.



If a nut has split pin, change its position where necessary.

5.3 Temperature settings (STANDARD)

No.	Item		Temperature °C			
			Standard	Thermostat	Alarm	Trip
1	Lubricating oil	System lubricating oil (Engine inlet)	70~80	71~79.5	85≤	90≤
2	Cooling water (Jacket water)	Engine inlet	—	—	—	—
		Engine outlet	70~80	82-90	less than 50%load 88≤ over 50% load 85≤	90≤
3	Fuel oil	Diesel fuel oil	—	—	—	—
		Heavy fuel oil	Heat up to be 12±1.5cSt (mm^2/s) {60±5s/RWNo.1}			

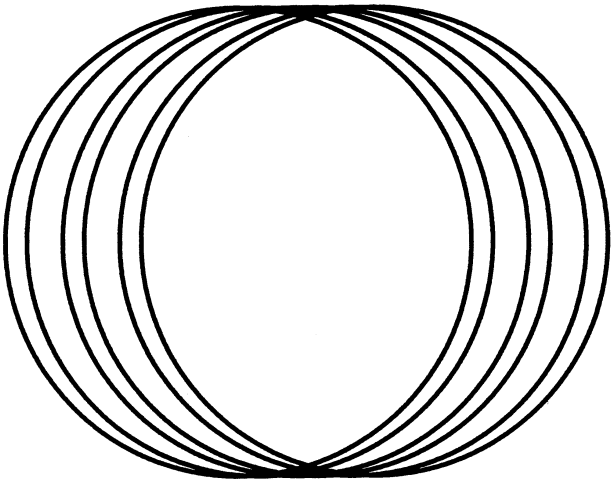
5.4 Pressure settings(STANDARD)

No.	Item			Pressure [MPa]					
				Variable Engine Speed			Constant Engine Speed		
				Standard	Alarm	Trip	Standard	Alarm	Trip
1	Lubricating oil	※ System lubricating oil (Engine inlet)		0.3~0.6	≤0.2	≤0.15	0.5~0.6	≤0.45	≤0.4
		Turbocharger lub oil (T/C inlet)		0.2~0.45	≤0.13	≤0.06	0.2~0.45	≤0.13	≤0.06
2	Cooling water	Jacket Water	Engine inlet	0.1~0.35	≤0.05	—	0.2~0.35	≤0.1	—
		Low temp Water	AC inlet	0.1~0.25	≤0.05	—	0.1~0.25	≤0.05	—
3	Fuel oil	Diesel fuel oil		0.05~0.15	≤0.03	—	0.05~0.15	≤0.03	—
		Heavy fuel oil (≤380cSt at 50℃)		0.3~0.6	≤0.25	—	0.3~0.6	≤0.25	—
4	Stating and control air	Starting air		2.2~3.0	≤1.8	—	2.2~3.0	≤1.8	—
		Control air		0.8~1.0	≤0.6	—	0.8~1.0	≤0.6	—

Note :(1) Aklarm and trip devices are equipped depend on the specification
(2) These standard values should be kept on normal operating conditions.
(3) These table show standard values.
The setting values are determined with specification

※ In case of idling speed, it is possible that lubricating oil pressure is lower than standard value by oil temperature.

※ When the variable engine speed spec engine operate at rated speed, lubricating oil pressure set the standard pressure as constant engine speed spec.



NIIGATA DIESEL INSTRUCTION MANUAL MG(L)28AHX

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6. ENGINE OPERATION PROCEDURE

6.1 Preparations for Starting

Preparations for starting the engine and the time required doing so vary with engine conditions.

(1) An engine out of operation without maintenance or inspection

(2) An engine out of operation for a long time for maintenance and inspection

(3) A newly mounted engine

In any of the above cases, do not start the engine without checking the engine parts, piping, and accessories as described below.

6.1.1 Preparations for starting an engine newly mounted or after a long period of non-operation or an overhaul

(1) Engine check

(a) Check the tightening torque of bolts

(a1) Check that the bolts and nuts inside the cylinder block are securely tightened.

- Main bearing stud nuts
- Crank pin stud nuts and crank pin bolts
- Piston cooling jet systems and jet nozzles

(a2) Check that the bolts and nuts inside the cylinder heads valves are securely tightened.

- Fuel injector stud and nuts
- Rock arm stud and nuts
- Cylinder head stud and nuts
- Tappet adjusting bolts and lock nuts

(a3) Check that the mounting bolts and anchor bolts are securely tightened.

(b) Checking the operation linkage

⚠ CAUTION
Make sure to close the main air stop valve, before moving the fuel control lever due to prevent unintentional engine start.

(b1) Move the fuel control lever, and check that the link pins for the fuel control layshaft and governor control link, and the knock pins and cotter pins for the levers are securely in place.

(b2) Check that, when the fuel control lever is moving, the linkage moves smoothly without lost motion.

(c)Checking the fuel injection pumps

(c1)Check the injection timing, and adjust it if necessary.

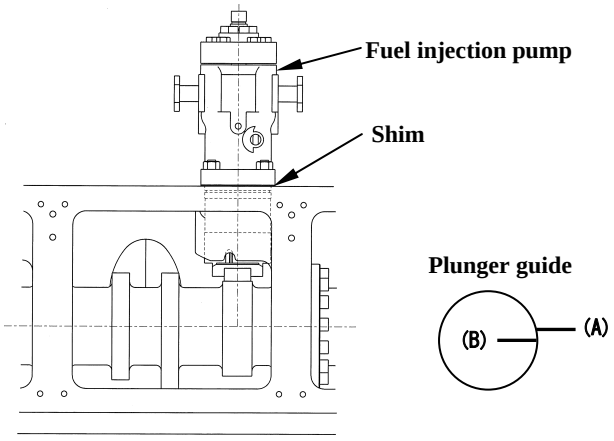
Injection timing adjustment range	
Injection beginning (before combustion top dead center)	
7.5～10.5	

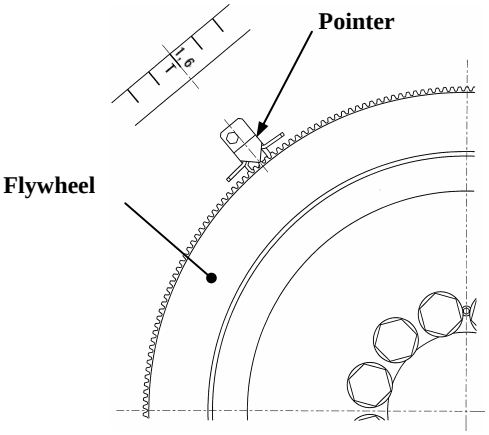
Fuel injection pump timing varies slightly from one engine to another. Refer to the shop trial performance data sheet for the fuel injection pump timing of your engine.

But the fuel injection timing can't advance beyond "NOx influencing parameter of engine" of IMO-NOx Technical File. It must be adjusted within this range.

Timing Adjustment Method

The fuel injection pumps are a Bosch type so when their injection beginning timing is adjusted their injection end is automatically settled at the same time. Injection beginning timing is expressed by the crankshaft angle (θ) where the plunger guide mark (B) visible through the plunger position check window in the injection pump body matches the mark (A) on the pump body. The timing can be adjusted by shim thickness.





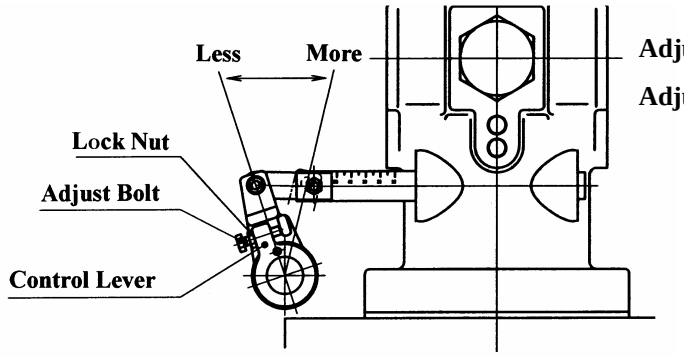
- Thin shim is advanced injection timing.
  (To increase maximum combustion pressure)
- Thick shim is delayed injection timing.
  (To decrease maximum combustion pressure)

(c2) Check that, when the fuel control lever is moved to the stop position, all of the fuel injection pumps are in the fuel cutoff state. In that case, rack scale indicate the range **between -1.0 and +1.0**. If not, adjust.

NOTE : Be sure to make this check because it is necessary to confirm that the engine will be stopped surely.

Fuel Injection Pump's Rack Scale Adjustment Method

Move the fuel control lever to the stop position, and loosen the lock nut to adjust the rack scale. After the adjustment, fasten the lock nut positively.



(d) Check the inside of the Cylinder block, in particular the cylinder liners, the connecting rods, and the crankshaft, to make sure that there is no rust.

(e) Check that the main bearings and crank pin bearings have clearances.

(f) Turn the engine, and make sure that no trouble symptoms can be observed.

(fl) After flushing the lubricating oil system, observe the following instructions prior to turning the engine. (See the attached flushing procedure)

- Fix the fuel control lever to the stop position.
- Open the crankcase doors, and check that there is no foreign matter left inside.
- Start the lubricating oil pump and prime well.
- Open the indicator cocks for all cylinders.

WARNING

Before starting the engine, check that there is nothing dangerous near it, and inform the people around the engine, that you are starting it.

CAUTION

1. When turning the engine, do not insert hand or foot at gear. There is a danger of injuring.
2. Before turning the engine, all indicator cocks open surely. If not,that is very dangerous, because crankshaft may be reverse turn.

(f2) Turn the engine, and check the following

- Check the inside of cylinders.

  Check to see if water or oil runs out of the indicator cocks.

  It indicates that water or oil remains in the cylinders. Check for the cause, and take an appropriate remedial step.

- Lubricating oil : −−−− Oil leakage due to some piston trouble.
- Cooling water : −−−− Water leakage due to some trouble with the cylinder heads, the exhaust valve seat rings or cylinder liners.
- Cooling water : −−−− Fuel oil leakage due to some fuel injector trouble.

CAUTION

If the engine is started without having made the above check and when there is water or oil in the cylinders, a serious accident can happen as, due to the non-compressibility of the liquid collecting in the cylinders, too great a compressive force acts on the pistons and cylinder heads. (this action is called "water hammering".) If fuel oil remains in the cylinders, even a small amount of it can cause an explosion in the engine, making it turn at too high a speed.

- Make sure that the engine is turned smoothly without abnormal resistance.

  If anything is found wrong, check for the cause, and take an appropriate remedial step.

(g) Checking the rocker gears and intake and exhaust valves.

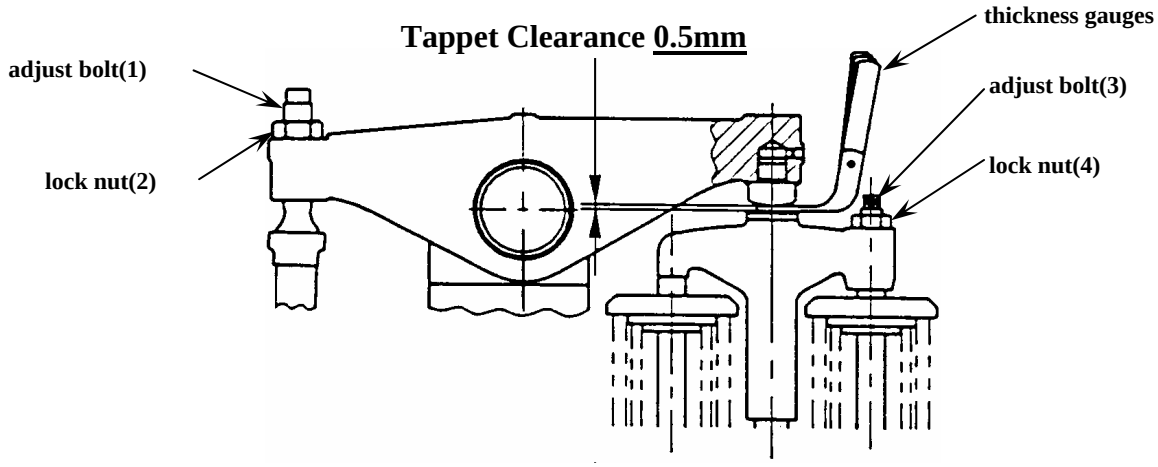
(g1) Check that the intake and exhaust valve rocker gears operate properly while the engine is turning.

- The rocker arms must be free of interference.
- The valves must properly follow the movement of the rocker arms.
- The valve guides must be free of sticking.

(g2) Adjust the intake and exhaust valve tappet clearances to **0.5 mm**.

Tappet Clearance Adjustment Method

When the engine is cold, bring the piston for the cylinder to be adjusted to the combustion top dead center, loosen the lock nut on the adjust bolt, turn the adjusting bolt(1) until the tappet clearance is **0.5 mm** as measured by thickness gauges, and then tighten the lock nut(2).



Adjustment Method of Valve Pusher Adjust Bolt(3)

Turn the adjusting bolt(3) gradually until contact the valve top face.

Check that the other side valve top has no clearance with thickness gauge.

Tighten the lock nut(4). If necessary, readjust.

(g3)Check the intake and exhaust valves timing.

-Refer to **5.1** parts adjustment standards.

(2) Checking the operation of protective devices

(Protective devices vary with specifications)

(a) Pressure switch

(a1) Checking method

- Close the cock on the pipe to the pressure switch, or loosen its joint, read the pressure at which the pressure switch operates, and check if the alarm sounds and the engine stops.

  -If the pressure gauge and pressure switches are distant, remember there is time lag.
- Check the pressure switch setting with a standard pressure tester.

(b) Temperature switch

(b1) Check the alarm by making contact.

(b2) Test the temperature switch alone, if necessary, by using boiling pot or the like.

(c) Water off relay

(c1) Slowly close the relay inlet valve, and check relay operation.

-Remember that a stop command is emitted after the timer is activated, which occurs when the water receiving plate has moved by the required angle.

(d) Check that the oil and water level alarms and control switches for the various tanks operate properly.

(e) Check that the lamps and buzzers operate properly.

-For the standard settings of the alarms and protective devices refer to Paragraph **5.3** Temperature Settings and **5.4** Pressure Settings. Check the individual devices by referring to their respective instruction manuals enclosed.

(3) Fuel oil system

(a) When diesel fuel oil is used.

(a1) If the fuel pipes have scale, rust or the like, clean them by pickling.

(a2) Discharge drains from the fuel service tank.

(a3) Check the oil level of the fuel service tank, and add fuel oil if necessary.

(a4) Open the fuel feed valve to the engine.

(a5) Start the fuel feed pump, and make sure that both the pump and motor operate properly.

-Check for abnormal noise, abnormal vibration, heat and oil leaks.

(a6) Clean the fuel oil filter (No.1, No.2), and vent air.

(a7) Check the oil leakage.

(a8) Vent air from the fuel injection pumps, fuel injection pipes, and fuel injectors.

(b) When heavy fuel oil is used.

(b1) If the fuel oil pipes have scale, rust or the like, clean them by pickling.

(b2) Discharge drains from the fuel service tanks (for heavy oil).

(b3) Operate the fuel oil heater and purifier, and circulate the heavy fuel oil through the heating circuit outside the engine. In this case, open the three-way changeover valve to the heavy oil position, and take Step(a3) through (a9) of before page.

(b4) When the fuel temperature has reached the required level, make sure it remains at that level. (Be careful not to overheat the fuel oil.)

(c) Check the fuel oil

-For details, refer to Paragraph **3.1** Fuel Oil.

(4) Lubricating oil systems

(a) System lubricating oil system

(a1) Check that the system is correctly piped, according to the specifications.

(a2) In the case of a newly installed engine or an overhauled engine, be sure to flush the lubricating oil system, and clean the piping by pickling.

(a3) Clean and check the lubricating oil cooler.

(a4) If the lubricating oil filter is a changeover open cleaning type, clean the filter, and set the changeover lever to the operating position.
-Refer to the Instruction Manual for the filters.

(a5) Check the lubricating oil properties.
-Refer to Paragraph **3.2** Lubricating Oil for details.

(a6) Discharge drains from the sump tank, and check to see if cooling water is mixed with it.
-If much water is present in the drains, make a careful check for water leakage from the lubricating oil cooler and the crankcase.

(a7) Check the sump tank oil level with the oil level gauge, and add oil if necessary.

(a8) If a lubricating oil heater is provided, operate it and heat the lubricating oil to 10°C to 20°C.(If a lubricating oil heater is used in a cold region, turn it on to heat the lubricating oil to 15°C or 30°C.)

(a9) Start the lubricating oil pump (or the standby pump if the lubricating oil pump is an engine driven type), and check the following while turning the engine.

- Check that the oil is fed.
  -If the oil is not fed, it may be due to faulty valve operation or air suction from the intake piping.
- Adjust the pressure regulating valve to the required lubricating oil pressure.
  -For the standard oil pressure, refer to Paragraph **5.3** Temperature Settings and **5.4** Pressure Settings.

・Check that enough lubricating oil is fed to various parts.

-Main Bearings	: Check that oil flows from the sides of the main bearings.
-Crank pin bearings	: Check that oil flows from the sides of the crank pin bearings.
-Piston pin bearings	: Check that oil flows along the connecting rods.
-Pistons	: Check that oil flows along the connecting rods.
	: Check that oil flows from the piston cooling nozzle.
	: Check that piston cooling oil flows straighter.
-Roller guides	: Remove the cam case covers, and check that oil flows over the cam surfaces
-Gear train	: Remove the cover of gear train inspection window, and check that oil flows.

・Check the pipe joints and plugs for oil leakage.
- If the joints and plugs are not sufficiently tightening, oil leaks on the delivery side, and air is inhaled into the piping on the suction side, and collects in the piping system, making the oil pressure unstable.

・If the filter is an automatic cleaning type, check its operation.
(Provided depending on specifications.)

・The cooler and filters tend to collect air. Open their cocks and plugs to discharge air.

・After priming for some time, check the oil level of the sump tank, and add as much oil as necessary.

・During operation, check that the motors and pumps are free of any trouble.
- Check for abnormal noise, vibration and heat.
- Carefully check that pipes disconnected or temporarily joined for flushing, or the orifices and blind plugs used for flushing are not left as they were during flushing.

・Continuously operate the lubricating oil purifier to remove foreign matter and water from the lubricating oil. (Provided depending on specifications)

(b) Checking the lubricating oil system of accessories

(b1) Hydraulic governor

Check the oil level gauge, and add the required amount of oil.

-Refer to the Instruction Manual for Hydraulic Governor.

(b2) Air cylinder

Clean the air cylinder and the linkages of VIVT drive unit, air by-pass system, and waste-gate system, and oil up them with an oilier.

(c) Other oiling points

(c1) Clean the moving parts (in particular, the fuel control lay shaft, and the governor control link) that are not oiled by forced lubrication, and oil up them with an oilier.

(c2) Grease the parts that require greasing, using a grease gun.

- turning handle etc.

(5) Cooling water system

(a) Fresh water cooling system

(al) Supply the cooling water to the engine and piping.

(a2) Turn the valves or cocks of the piping to the operation status.

(a3) Start the cooling water pump(or the standby pump if it is an engine driven type), and check the following

- Fill the piping with water, and make sure that no water leaks from the cylinder heads and cylinder block.
- Check the water leakage from pipe joint and plugs.

-If they are not completely sealing, water leaks on the pump delivery side, and air is inhaled into the piping on the suction side, and collects in the piping system, making the air pressure unsteady (as indicated by fluctuating pressure gauge readings). Eventually, this trouble will block the water passage.

- Open the air vent cocks or plugs on the piping, and discharge air.
- Check the pump seals for water leaks.

-A small amount of water leakage is normal. Check that the water leakage hole (or pipe) is not clogged.

-If much water leaks, the pump seal is defective.

-If the seal is gland packing, tighten the packing retainer.

-If it is a mechanical seal, replace it.

-If gland packing is damaged, replace it.

- During operation, check that the motors and pumps are free of any trouble.

-Check for abnormal noise, vibration, and heat.

- Check that the cooling water pressure meets the requirements.

-For the standard level, refer to Paragraph **5.4** Pressure Settings.

(a4) Check the water quantity in the fresh water (primary water) tank, and add water if necessary.

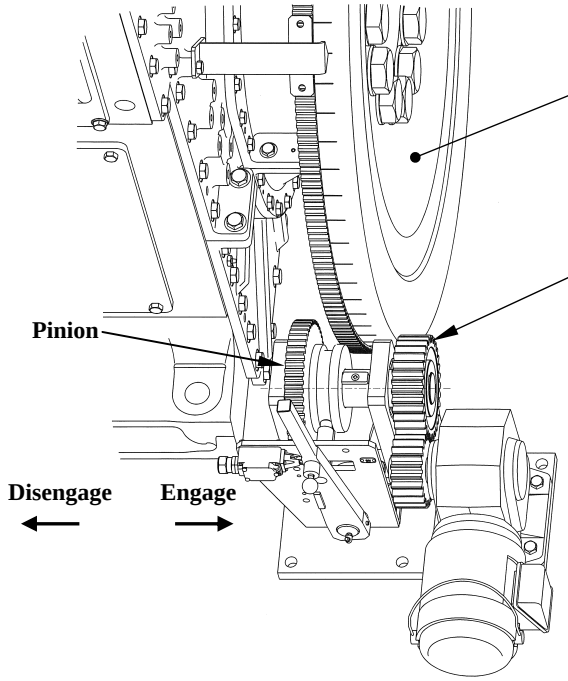
(a5) If a cooling water heater is used in a cold region, turn it on to heat the cooling water to 10°C or 20°C.

(b) Check the cooling water

-For details, refer to Paragraph **3.3** Cooling Water.

(6) Electrical motor type (Provided depending on specifications)

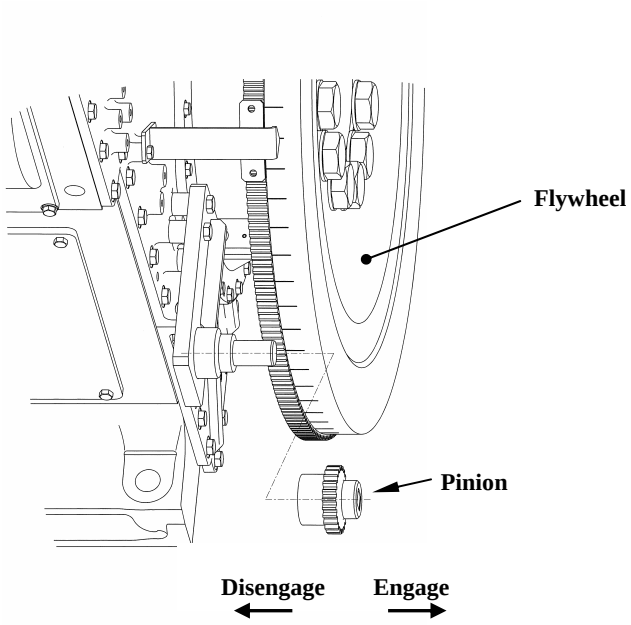
Check that, when the turning device is disengaged, the flywheel and pinion are well apart from each other.



Note: Always uses the fixation tool of the handle of the turning device in pinion connection and removal. Confirm that a handle is fixed on the fixation tool.

(7) Ratchet handle type

Check that, when the tuning device is disengaged, the pinion is removed from turning device.



(8) Stating air and mist piping system

NOTE : For the operating air system for the remote control device, refer to the Instruction Manual for Remote Control Device.

(a) Check the starting air receiver

(a1) Check the pinion of air starter and ring gear condition.

(a2) Check the pinion of air starter moves freely.

(a3) Fill the starting air receiver to the required pressure 2.5MPa ~ 3.0MPa.

(a4) After that, discharge drains by opening the drain valve for the starting air receiver.
-If drains cannot be discharge properly, check to make sure that the drain pipe is in an unclogged or place at the bottom of the receiver.

(a5) Open the valves of the starting air pipe.

⚠ CAUTION

Before turning the engine, check to no dangerous for the people near or inside the engine.

(b) Air running procedure

(b1) Start the lubricating oil pump (or the standby pump if it is an engine driven type) and check that lubricating oil is fed to various parts.

(b2) Fully open the indicator cocks for all cylinders.

(b3) Move the fuel control lever to the stop position.

(b4) Disengage the engine turning device .

(b5) If there is foreign matter in the exhaust manifold, it can damage the turbocharger nozzle, so disconnect the turbocharger short exhaust gas inlet duct, and cover the turbocharger inlet with a blind plate.

(b6) After that, push the switch "AIR RUN" at the gauge board , turn the air starter and turn the engine several times

(b7) Watch the indicator cocks during the air running for water or oil blowing out, refer to **6.1.1** (1)(f2)

(c) Check that the mist pipe is not clogged.
If the mist pipe outlet wire net is dirty and clogged, clean it.

(9) Load limiter(Governor)

Check that the load limiter is at the 100 to 110% position.(It determines with specifications)

NOTE : Never change the setting because the load limiter is set so that the fuel control lay shaft will not advance beyond the setting point.

6.1.2 Ordinary starting preparations

(a) Turn the valves and cocks of the piping to the operation status.

(b) Start each pump(or the standby pump if the pump is an engine driven type).

(b1) Check that the pressures of lubricating oil, cooling water and fuel oil meet the requirements.

-For the standard pressures, refer to paragraph **5.4** Pressure Settings.

(b2) Keep the indicator cocks opened for more than 30 minutes before starting, start the lubricating oil pump (or the standby pump if it is an engine driven type) while turning the engine, and prime it sufficiently.

Watch for water or oil blowing out of the indicator cocks.

(c) Check that the links operate smoothly when the fuel control lever is moved.

(d) Check operating about Air bypass and Waste gate Butterfly valve, using the manual device of solenoid valve panel.

(e) Perform air running

Watch for water or oil blowing out of the indicator cocks.

-Refer to **6.1.1**(1)(f2).

(f) After priming the engine, close the indicator cocks and disengage the turning device.

NOTE : Preheat cooling water and lubricating oil by operating their heaters, if provided.

Cooling water: 10°C to 20°C Lubricating oil: 10°C to 20°C

6.2 Starting the Engine

6.2.1 Before starting engine

(1) Reminders about engine stopping

(a) Before starting the engine, make sure that the engine can be stopped.

(a1) Check that, when the fuel control lever is moved to the stop position, the fuel injection pumps are in the fuel cut off position.

-Refer to **6.1.1**(1)(c2).

(b) For emergency stop, -Refer to **6.4.2.**

(c) For the method of stopping the engine, -Refer to **6.4.1** (2).

(2) Safety reminders

(a) Before starting the engine, check that there is nothing dangerous near it, and inform the people around the engine that you are starting it.

(b) Before starting a newly installed engine, or an engine out of use for a long time, or an overhauled engine, determine whether all the mechanical and electrical devices that are driven by or directly coupled to the engine are in position and in good condition, and take the steps necessary to ensure the cooperation of all persons involved.

(c) Make a safety check as necessary

NOTE : To be air running before starting engine.
Watch for water or oil blowing out of the indicator cocks.

6.2.2 Starting the engine

When all starting preparations have been made, start the engine by the following procedure.

(1) Starting conditions

(a) Check that all the pumps (or the standby pumps if they are an engine driven type) are running.

(b) Check that all pressure and temperature readings are correct.

(c) Disengage the turning device gear.

(d) Check that all indicator cocks are closed.

(e) Disengage engine load

(f) Set engines speed to about 1/2 the rated min^{-1} (idling) with the governor hand wheel or synchronizer.

(g) Close the protective device circuits.

(b) Starting procedure

(b1) Open the main valve for the starting air tank.

(b2) Move the fuel control lever to an operating position.

(b3) Push the switch "START" at the gauge board to start engine.

(b4) Close the main valve for the starting air tank.

NOTE: Make sure that the governor and fuel control system are in good condition (particularly after overhaul) because if the engine is started when something is wrong with them, the engine can suddenly operate at abnormally high speed.
If the engine appears to be running at abnormal speed, stop it immediately, check for the cause, and take a remedial measure.

6.2.3 Check immediately after starting engine.

(1) Set engines speed to about 1/2 the rated min^{-1} (idling), and check the following.
Avoid a speed within the range in which engine operation is prohibited due to shafting torsional vibration.

(a) Immediately after starting the engine, check that the pressure gauges and thermometers read normal.

-For standard pressures and temperatures, refer to **5.3** Temperature Settings and **5.4** Pressure Settings.

(a1) If engine driven pumps are installed, stop the standby pumps, and check that the pressures stabilize at normal level. If not, regulate the pressures with the pressure regulating valves. In this case, adjust the system lubricating oil pressure first.

(a2) If the oil pressure or cooling water pressure does not rise, stop the engine, check for the cause, and take a remedial measure. Do not restart the engine without remedying the problem.

NOTE : (1) If the lubricating oil is not preheated before starting the engine, the pressure rises higher than normal due to high viscosity; when the lubricating oil temperature rises with a resultant decrease of viscosity and the pressure.
After starting the engine, wait until the lubricating oil temperature and pressure become steady.

(2) When the oil and water pressure are not normal pressure, check the following

- Leaks from the piping
- Pressure gauge trouble
- Pressure gauge pipe blocking
- Lubricating oil pump trouble
- Cooling water pump trouble
- Faulty pressure regulation by lubricating oil pump pressure regulating valve
- Air inhalation in cooling water piping
- Wrong opening or closing of each valve
- Other

(b) Check the following during engine operation, and take appropriate steps.

(b1) Check that the engine is running at a steady speed. If engine speed is unsteady (if hunting is noted), governor control trouble may be suspected. Stop the engine, and check for the cause.

(b2) Check that all cylinders are working. Open the indicator cocks, and check the burnt gas.

⚠ CAUTION

Don't touch the blow off gas from the indicator cock, because it has high temperature.

(b3) Check each part around the cylinder heads.

- Check that the intake and exhaust valve rocker gears are properly lubricated.
- Check that the intake and exhaust valve rocker gears are operating properly without abnormal noise.
- No gas must be leaking from valves.

(b4) Touch the following parts on the outside to see whether they are overheated.

- Fuel injection pumps: ------- Check for plunger seizure.
- Governor driving gear case: --------- Check for gear bushings.
- Roller guide cases
- Crankcase door: ---------- Check the main bearings and crank pin bearings.
- Liner ring: ---------- Check the cylinder liners and pistons.
- Lubricating oil and cooling water pump (if provide): ------ Check for bearings.
- Cam case door: ---------- Check the cam bearings.
- Other

⚠ WARNING
When engine parts check, do not touch it by hand directly because it has high temperature.

(b5) Check various parts for abnormal vibration.

- Exhaust manifold
- Intake and exhaust manifold
- Intake and exhaust valve gears
- Turbocharger
- Air cooler
- Governor
- Pipes
- Other

⚠ WARNING
Don’t touch the bare hand during operation or after stop the engine because each parts have high temperature.

(b6) Check various parts for abnormal noise.

- Inside crankcase
- Inside gear case
- Exhaust manifold: ---------- Exhaust gas leaks
- Turbocharger: ---------- Exhaust gas leaks
- Other

(b7) Check various parts of the engine for oil, water and exhaust gas leaks.

(b8) Check the color and quantity of mist from the mist pipe of the crankcase.

-If mist quantity is excessive, or if mist color is too dark, something might be wrong with the pistons or cylinder liners.

(b9) Check exhaust gas color

-Immediately after starting the engine or during no load operation, some color is permissible if it disappears when the engine runs on load.

(b10) Check various bolts of the engine for tightness.

6.3 Engine Operation

6.3.1 Running in

A new engine, or an engine whose pistons, cylinder liners, piston rings, main bearings, crank pin bearings, or other major working parts have been disassembled or replaced during maintenance and inspection service, must be run in.

Running in is necessary to prevent scratching and scuffing of the liner, and keeps the oil thickness properly.

(1) Running in procedure

(a) Diesel fuel oils are recommended as fuel oil. (Never use heavy fuel oils)

(b) Run the engine as mentioned below.

(b1) No-load operation

Gradually increase engine speed with care as illustrated below.

When main parts replaced
(N: Rated speed)

Engine speed (rpm)	Operating time (min)
N× 0.3	10
Stop and internal check	
N× 0.3	5
N× 0.5	30
N× 0.75	30
N× 1.0	30
Stop and internal check	
Total time	105

When main parts disassembled
(N: Rated speed)

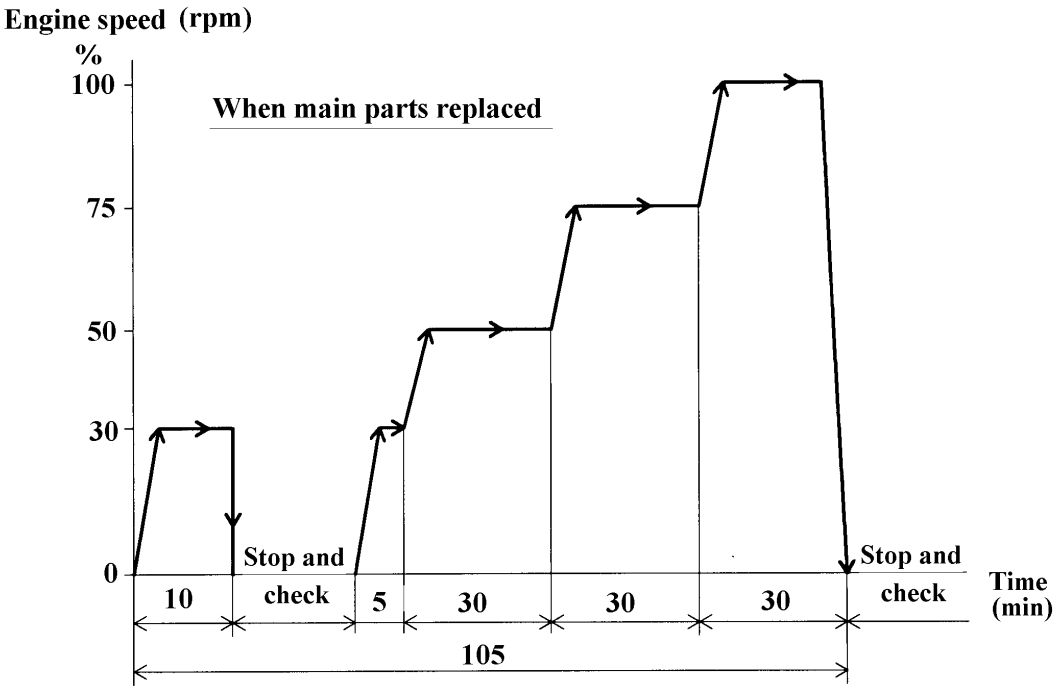
Engine speed (rpm)	Operating time (min)
N× 0.3	5
Stop and internal check	
N× 0.3	5
N× 0.5	15
N× 0.75	15
N× 1.0	15
Stop and internal check	
Total time	55

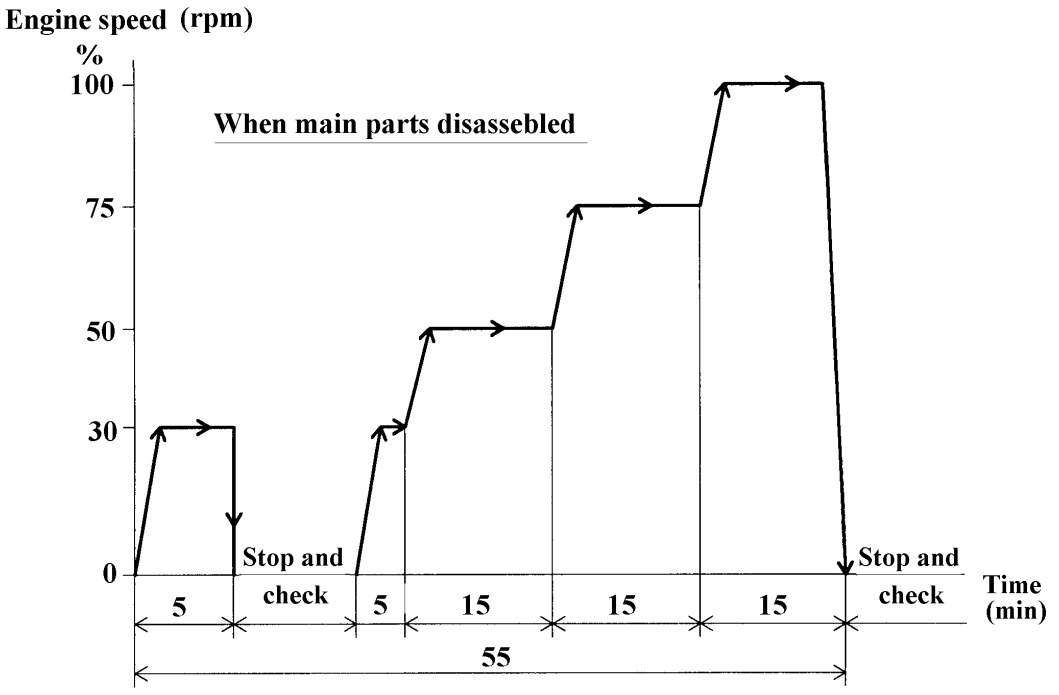
NOTE : (1) Avoid continuous operation in the speed range where engine operation is prohibited due to shafting torsional vibration. This range is indicated by the red zone on the tachometer dial. Check the tachometer for faulty indications from time to time, using a hand tachometer, or an integrating tachometer if one is installed.

(2) The internal checks do directly after engine stops, and check the each bearing temperature, cylinder liner internal surface condition, and each parts lubrication.

(3) When the minimum engine rated speed is prescribed by the setting rotation of the governor, implement running in from the setting rotation.

No-load operation





(b2) Load increase

Gradually increase engine load with care as illustrated below.

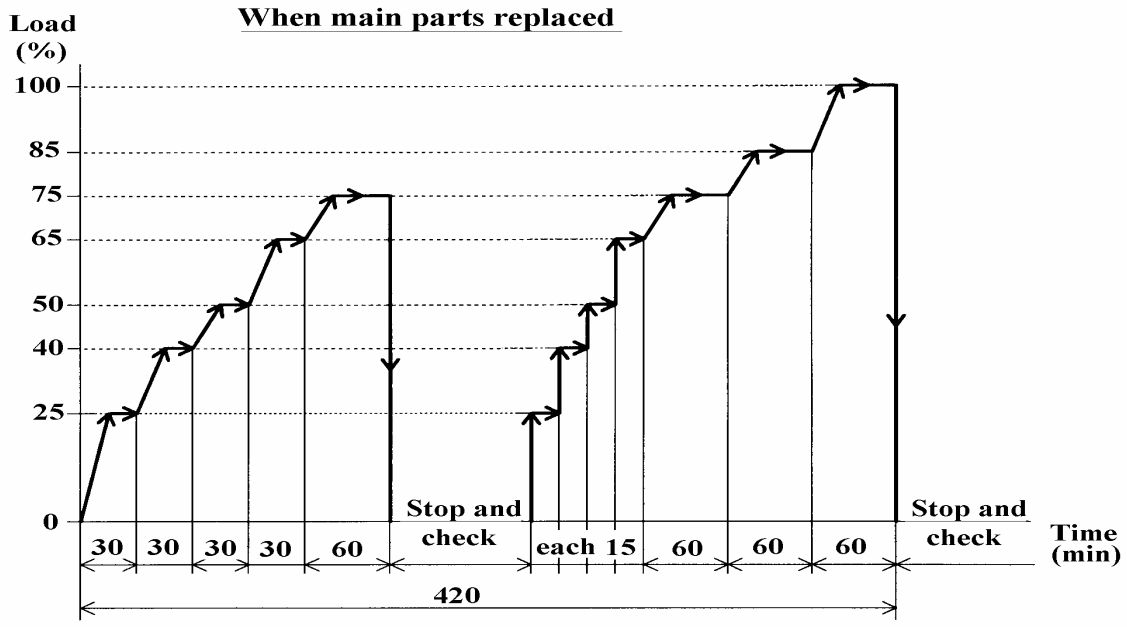
•When main parts replaced

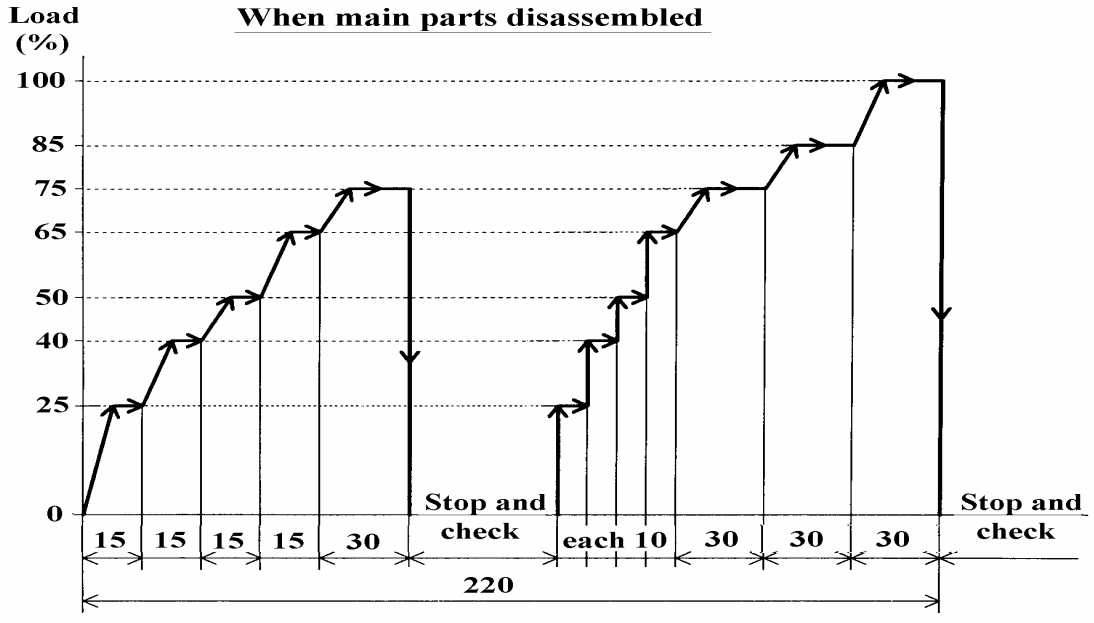
Engine load (%)	Operating time (min)
25	30
40	30
50	30
65	30
75	60
Stop and internal check	
25	15
40	15
50	15
65	15
75	60
85	60
100	60
Stop and internal check	
Total time	420

•When main parts disassembled

Engine load (%)	Operating time (min)
25	15
40	15
50	15
65	15
75	30
Stop and internal check	
25	10
40	10
50	10
65	10
75	30
85	30
100	30
Stop and internal check	
Total time	220

Load increase





(c) After starting the engine check the inside of it as described below.

No-load operation------After operation at 30% and 100% engine speeds

On-load operation------After operation at 75% and 100% loads

(c1) Remove the crankcase door, and check the main parts inside for trouble.

- Sliding surfaces of cams and rollers
- Temperatures of main bearings, crank pin bearings, and cylinder liners: Check by touching.
- Inner surface condition of cylinder liners

-If anything is found wrong, check for the cause, and disassemble if necessary.

(d) Pay special attention to the following during running in.

(d1) Abnormal noise or vibration

(d2) Overheat

(d3) Check that the bolts for various parts are tight enough and are locked.

(d4) Combustion: Check exhaust gas temperature and maximum cylinder pressure.

(d5) Colors of exhaust gas and mist

(d6) Turbocharger: Operating speed and charge air pressure.

(d7) Temperatures of fuel oil, lubricating oil, and cooling water.

(d8) Operation of accessories

(d9) Clean the lubricating oil filter at a suitable time and completely remove foreign matter.

6.3.2 Adjustment operation

Make an adjustment operation to check the performance of the engine.

(1) Adjustment operation check items

(a) Starting test

Fill the starting air tank with air, set it to the required pressure, and see how many times the engine can be started.

(a1) Perform this test when the engine is cold and without load.

(a2) Start the engine; when the sound of fuel burning is heard, stop it immediately. Repeat this start and stop.

(b) Adjust various parts of the engine as follows:

Adjust engine parts according to the shop trial performance sheet.

(b1) Adjust the lubricating oil pressure with the lubricating oil pressure regulating valve.

(b2) Adjust the maximum cylinder pressure:

-Refer to **6. 1.1** (1) (c)

(b3) Adjust exhaust gas temperature:

(c) Measure the engine performance at each load level.

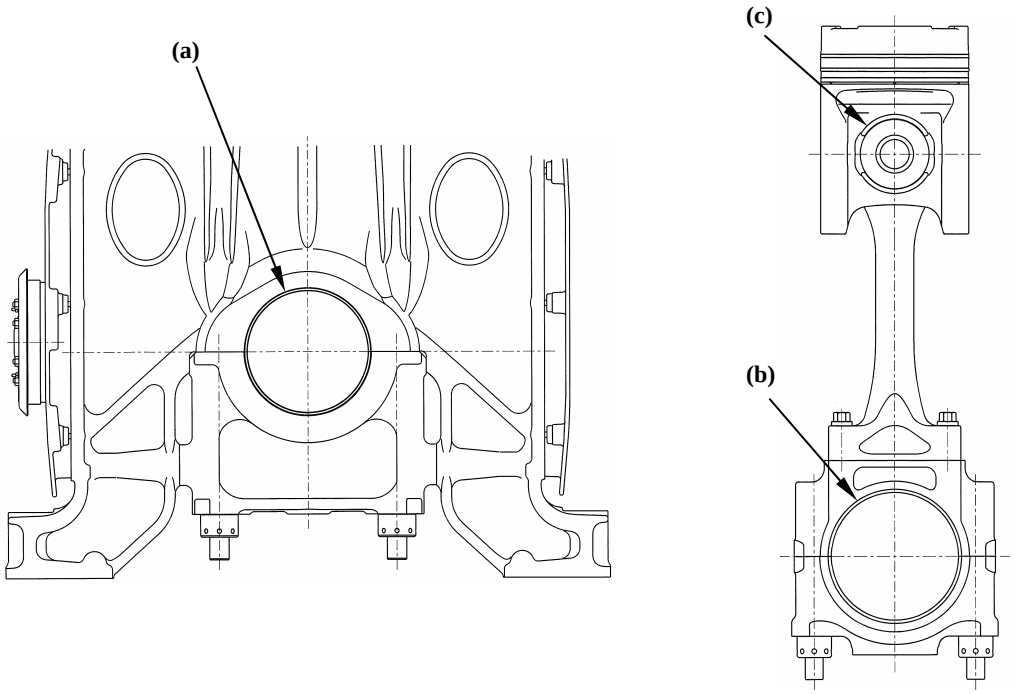
(d) Measure the temperature of each bearing.

(d1) After full-load operation, stop the engine immediately and measure each bearing temperature with a thermistor thermometer.

(d2) Reference bearing temperatures

Reference bearing temperatures are the standard engine inlet lubricating oil temperature plus the following values or less.

Measuring Point	Value to be added
Main bearing (a)	25 °C
Crank pin bearing (b)	30 °C
Piston pin bearing (c)	35 °C



(e) Governor test

Measure the momentary fluctuation rate and fluctuation rate at stabilized engine speed when the load is disengaged and engaged, and measure the time from a load change until the engine steadies (stabilizing time).

(The disengaged and engaged load determines with specifications.)

(f) Protective devices operation test

Check the pressure switches, thermal switches, and other protective devices for operation:

-Refer to **6.1.1** (2) (a), (b), (c) for the method of checking them.

6.3.3 Routine operation

(1) Load engaging procedure

As a rule, the engine should be loaded gradually. It is necessary to adjust as shown below at each stage of load increase according to the engine temperature at start. If the engine is warm when restarted after a stop, load increase intervals can be shortened accordingly.

(a) Load increasing procedure

Load increase intervals depend on mainly the following temperatures.

- Engine temperature
- Lubricating oil temperature
- Cooling water temperature
- Fuel oil temperature

(a1) Starting condition 1: Cooling water and lubricating oil temperatures between 20°C and 30°C.

Load	Normal	Sudden Load-On	Emergency Load-on
0~65%	8 min	4 min	2 min
65~90%	15 min	8 min	4 min
90~100%	7 min	4 min	2 min
Total	30 min	16 min	8 min

(a2) Starting condition 2: Cooling water 40°C or over, lubricating oil temperature30°C or over.

Load	Normal	Sudden Load-On	Emergency Load-On
0~65%	4 min	2 min	1 min
65~90%	8 min	4 min	0.5 min
90~100%	4 min	2 min	0.5 min
Total	16 min	8 min	2 min

(b) Precautions to follow while increasing load

If it is necessary to engage the load suddenly or urgently, make sure that the engine is free of any trouble, and be ready to deal with any emergency.

Be careful of the following:

- Variation in cooling water and lubricating oil pressures
- Variation in cylinder outlet exhaust gas temperature
- Variation in turbocharger speed
- Mist color and quantity

(2) Load decreasing procedure

The engine load must be decreased gradually except in emergencies.

-Refer to **6.4.1** (1).

6.3.4 Checks during operation

During engine operation, watch the pressures and temperatures of each fluid, detect anything abnormal in time by checking engine sound, vibration, temperature, and pressure, and take appropriate remedial steps. This is vital to maintaining normal engine operation.

Most daily check items are mentioned below.

(1) Fuel oil system

(a) Fuel oil service tank

(al) Check the fuel service tank oil level, and add oil if necessary.

(a2) Discharge drains from the fuel service tank.

(b) Fuel oil filter

Clean the filter if necessary.

(c) Fuel oil feed pump

Depending on specifications, an independent motor-driven fuel feed pump may be installed.

(c1) The pressure of fuel oil feed to the engine is controlled by the pressure regulating valve located between the fuel return main pipe and the service tank.

(c2) Check the feed pressure and temperature of the fuel oil to the engine.

-For standard pressure and temperature, refer to **5.3** Temperature Settings and **5.4** Pressure Settings.

(c3) Check the piping for oil leaks (on the delivery side) and air inhalation (on the suction side).If air inhalations in the piping are found, vent air by loosening the air vent plugs on the fuel injection pumps.

(c4) Check the piping clips for tightness.

(d) Shift from diesel fuel to heavy fuel (for engines burning heavy fuel)

This shift should be made after making sure that the engine satisfies the following conditions.

- Cylinder cooling water inlet temperature: Over 50°C
- Preheat the heavy fuel to raise the fuel oil temperature in the service tank.
- While the engine is operating, raise the diesel fuel temperature at the engine inlet to anywhere from 50°C to 60°C by the line heater at a heating rate of 3°C per minute.

- Keep the engine load at 40% to 50%, and change diesel fuel over to heavy fuel.
- Gradually increase the load

  Watch the variation of heavy fuel temperature at the engine inlet as the load is increased, and check that it stabilizes at the required temperature.

⚠ CAUTION

(1) It is desirable that the engine load is over 50% in continuous operation on heavy fuel. Continuous operation at less than 30% load should be avoided. Continuous operation on heavy fuel at a low load level for a long time can cause contamination of the combustion chamber and low-temperature corrosion.

(2) When heating diesel fuel to 50°C to 60°C, be very careful not to heat it too rapidly or overheat it. This is important to prevent vapor lock.

(e) Shift from heavy fuel to diesel fuel (for engines burning heavy fuel).

- Keep the engine load at 40% to 50%.
- Change heavy fuel over to diesel fuel.

(2)Lubricating oil system

(a) System lubricating oil

(a1) Check the lubricating oil sump tank oil level, record it, and check oil consumption. Add oil if necessary.

(a2) Discharge drains from the lubricating oil sump tank.

(a3) Check that the pump delivery pressure is correct.

(a4) Check that the engine inlet pressure and temperature are correct.

-For standard pressure and temperature, refer to **5.3** Temperature Settings and **5.4** Pressure Settings.

(a5) Check the piping for oil leakage and air inhalation.

(a6) Check the pipe clips for tightness.

(a7) Periodically analyze the properties of the lubricating oil.

-Refer to Paragraph **3.2** Lubricating Oil

- Take care to prevent the lubricating oil from mixing with the fuel oil

⚠ CAUTION

If the fuel oil gets into the lubricating oil, the viscosity and flash point of the lubricating oil drop, possibly causing an explosion. Check the following points for leakage.

- Oil seal of the fuel feed pump driving shaft (if attached to the engine)
- Fuel injection pump plunger, roller guide, oil pan

(b)Lubricating oil for auxiliaries

(b1)Hydraulic governor

- Check its oil level, record it, and check oil consumption. Add or change oil as necessary.

  -Refer to the Instruction Manual for Hydraulic Governor.

(3) Cooling water system

(a) Fresh water cooling system

Keep watching the pressure, temperature, and look for water leaks, and periodically check the quantity and quality of the cooling water in the water expansion tank.

(a1) Check that the engine inlet pressure and outlet temperatures are correct.

-For standard pressure and temperature, refer to Paragraph **5.3** Temperature Settings and **5.4** Pressure Settings.

(a2) Check the piping for water leaks (on the delivery side) and air inhalation (on the suction side).

(a3) Check the fresh water expansion tank for water quantity, and add water if necessary.

(a4) Periodically check the quality of the fresh water.

-Refer to Paragraph **3.3** Cooling Water.

(4) Turbocharger

A drop in turbocharger performance causes a drop in engine performance.

Thus it is important to keep the turbocharger in good operating condition.

Particularly where heavy fuel oil is used, turbocharger contamination and corrosion due to the harmful ingredients of the fuel pose problems.

(a) Check turbocharger performance.

To confirm turbocharger performance, take the following data periodically, and compare it with the shop trial data and local witness test data. Evaluate turbocharger performance, and take appropriate steps as necessary.

(a1) Periodically take operation data under the same conditions.

Compare the data (preferably prepared in graphs), and check variations in performance.

(a2) Watch for turbocharger speed variation, abnormal noise, and abnormal vibration.

If the turbocharger bearing or rotary parts have some trouble, the turbocharger generally produces an abnormal sound or abnormal vibration.

NOTE : As a simple method of checking trouble with rotary parts, stop an engine operating at dead slow speed, measure the time from fuel cut off till the stoppage of the turbocharger rotor shaft.

(1)The time is shortened if the rotary parts have trouble.

(2)If the rotor shaft runs backward after a stop, the rotary parts are out of balance.

-Turbine blades or impeller faulty.

(a3) Check for charge air pressure variation.

(5) Air cooler

(a) Check air cooler performance

A drop in air cooler performance cause a higher charge air temperature and a higher exhaust gas temperature.

(a1) Check for charge air temperature variation.

Calculate the cooling efficiency of the air cooler by the following equation.

$$\text{Cooling efficiency} = \frac{\text{Cooler inlet air temperature} - \text{Cooler outlet air temperature}}{\text{Cooler inlet air temperature} - \text{Cooler inlet cooling water temperature}}$$

- Allowable cooling efficiency: 0.60

-If cooling efficiency is less than 0.60, clean the cooling water side of the cooler.

-If cooling efficiency fails to return to more than 0.70, clean the air side of the cooler.

(6) Main parts of the engine

During engine operation, keep watching that the main parts of the engine, particularly its moving parts, are operating properly. Periodically take operation data, analyze the data, and take appropriate steps as necessary.

(a) The standard procedure is described below, though it may vary depending on the use of the engine and the extent to which the engine is equipped with automatic and safety devices.

(a1) Check around the cylinder heads

- Check the intake and exhaust valve rocker arm devices for operation.
- Check the each valve for gas leaks.
- Check for oil and water leaks.
- Check bolts and nuts for tightness.
- Check that the proper amount of oil is fed, that is, that the parts are not dry.

(a2) Check the pipe joints for water and oil leaks.
Be especially careful of fuel oil leakage because it can cause a fire.

(a3) Vent air from the piping and cooler.
Vent air from points where air collects easily (tops of piping, and cooler).
-Check the pressure gauges for abnormal readings.

(a4) Check various parts for overheat by touching or with a fixed thermometer.
-Refer to **6.2.3** (1) (b).

(a5) Check various parts for abnormal vibration.
(a6) Check various parts for abnormal noise.
(a7) Check bolts and nuts for tightness.
-Refer to **6.2.3** (1) (b).

(a8) Check exhaust gas color, mist quantity, and mist color.

(b) Engine performance journal
Periodically take engine operation data, compare the data continually, and use the results for grasping variation of the engine performance and out of order of engine condition in early stage, and preparing maintenance and inspection schedules.

(b1) Take operation data

- Cylinder outlet exhaust gas temperature
  Cylinder outlet exhaust gas temperature difference among the cylinders must be less than ± 30°C of average exhaust gas temperature.
- Maximum cylinder pressure
  Maximum cylinder pressure difference among the cylinders must be less than 0.7MPa of the rated maximum pressure.

6.4 Stopping the Engine

6.4.1 Ordinary engine stop

(1) Steps before stopping

(a) Decrease the load to cool the engine gradually except in emergencies.

(a1) Gradually decrease the load to 50% load (operating time : 15 min.).

(a2) After operating engine at 50% load during 30 minutes, gradually decrease the load again to zero.

(2) Stopping procedure

There are several ways to stop the engine, and it is necessary to be familiar with them so that, in the event that the ordinary stopping device should fail, quick action can be taken. The important point common to all methods is to cut off fuel oil supply.

(a) Move the fuel control lever to the stop position

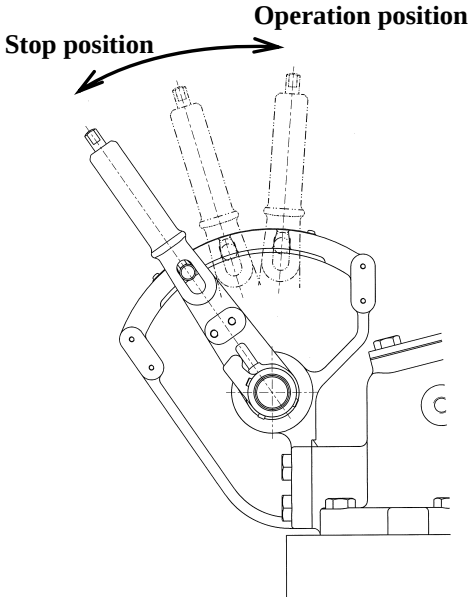
-Ordinary stopping method

(b) Close the main valve at the fuel main pipe inlet

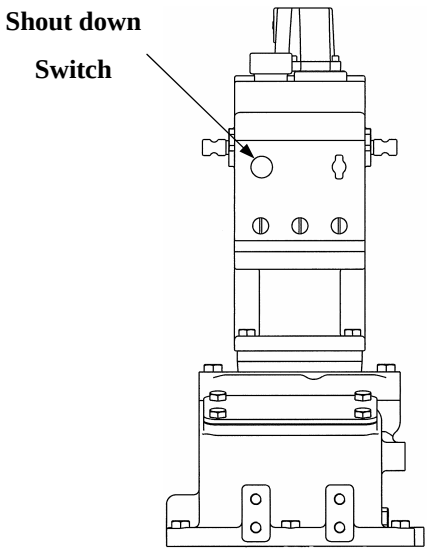
-Emergency stopping method

(c) Give a lowest-speed governor revolution command

-Emergency stopping method



Fuel control lever
(See from driving end)



Governor

(3) Steps taken after stopping the engine

(a) Keep the cooling water pump and lubricating oil pump operating (or immediately start the standby pump if those pumps are engine driven) for more than 30 minutes of after-cooling while turning the engine.

NOTE : 1. In the case of fresh water cooling system, stop the secondary pump and operate the fresh water pump only.
-To prevent rapid cooling of the engine.
2. After-cooling is absolutely necessary because it is of utmost importance to protect the engine and to prevent the lubricating oil from deteriorating.

(a1) Open the indicator cocks during after-cooling to discharge burnt gases out of the cylinders.

(b) Close those valves, which must be closed when the engine is still.

- Fuel oil main valve, etc.

(c) Take the following steps to ready the engine for the next start.

(c1) Fill the starting air receiver with air.

(c2) Add cooling water, lubricating oil, and fuel oil if necessary.

(c3) Clean all filters.

(c4) Service and repair as necessary.

(d) Cover the stack and mist exhaust port outside the engine if the engine is stopped for a long time, or if it is rainy even though engine stop period is short.

⚠ CAUTION

If the cooling water is likely to be frozen, open the drain valve on the cooling water inlet main pipe, and completely discharge the cooling water.
If the cooling water is frozen, its volume increases and will possibly crack the crank case , cylinder head and cooling water piping.

6.4.2 Emergency engine stop

(1) Where engine stop is urgent.

(a) Engine speed has increased on its own, or cannot be controlled.
(b) Fuel scale pointer has risen abnormally, and engine speed has dropped.
-This may be burnout of pistons, cylinder liners, or bearings.
(c) Bearings or other moving parts have been overheated.
(d) Engine vibrates abnormally.
(e) Engine makes abnormal noise.
(f) Crankcase mist quantity or color is abnormal.
-This may be burnout of pistons, cylinder liners, or bearings.
(g) Lubricating oil pressure has dropped suddenly.
(h) Cooling water temperature has risen suddenly.
(i) Turbocharger makes abnormal noise or vibration and is overheated.
(j) Exhaust gas temperature has changed suddenly.

(2) Steps taken after emergency stop.

If any of these symptoms is found, immediately stop the engine, check for the cause, and refrain from restarting the engine until the trouble is remedied.
-For trouble causes and remedies, refer to Chapter **8** Troubleshooting.

(a) After an emergency engine stop, keep the cooling water pump and lubricating oil pump operating (or immediately start the standby pumps if those pumps are engine driven) for after-cooling.

WARNING

Don't open the crankcase door during 20 minutes, when the engine stopped for emergency. If the crankcase door is opened immediately after a trouble, the mist in the crankcase may be fire and explode. Exercise care not to do so.
When removing the crankcase door, turn the bolts and nuts slightly to let fresh air into the crankcase so that the mist will not explode and then remove the crankcase door completely.

(b) If much mist is discharged from the mist pipe, it is because the mist pressure inside the crankcase is abnormally high. In this case, do not open the crankcase door until mist discharge rate decreases (about more than 20 minutes).
(c) In the case of engines burning heavy fuel oil, keep the line heater and fuel feed pump on to circulate the fuel oil as long as possible after stopping the engine.
If heavy fuel oil stops circulating, it may become too difficult to restart the engine.
If this occurs, the fuel oil piping must be cleaned.

6.4.3 Non-use of engine

When not using the engine for longer than a week, the following steps should be taken for engine protection.

(1) Steps taken immediately after engine stop.

Take the following steps as appropriate to the duration of non-use.

(a) Completely discharge the cooling water from the engine and coolers so no water remains in the piping.

- Otherwise, as it freezes, the water increases in volume, possibly causing cracks in the crank case, cylinder head and cooling water piping.
- To prevent various engine parts from corroding.

(a1) Open the drain valve on the cooling water inlet main pipe to discharge the cooling water from the engine.

(a2) Remove the drain plugs for the lubricating oil and fresh water coolers to discharge the cooling water from them.

(b) Spray or apply anti-corrosive oil to the shiny and sliding parts of the engine.

(b1) Starting air valve and starting air distributor

(b2) Fuel control lay shaft

(b3) Cylinder head top surface and fulcrum supporter

(b4) Other machined surface exposed parts

(c) Remove the exhaust valves or fuel injectors, spray anti-corrosive oil into the combustion chambers while turning the engine, and mount the removed valves.

(d) Check the bolts and pipes for the main parts of the engine. If anything wrong is found, immediately repair or replace the faulty parts.

(e) Put covers on the stack and mist outlet outside the engine.
Special caution must be exercised to protect the main parts of the engine (crankshaft, etc.) from rusting due to rainwater flowing backward.

(f) Ventilate the engine room.

(2) Steps taken during non-use of engine

(a) Turn the engine at least once a week to change the piston and bearing positions.

(a1) Prime the lubricating oil pump (or start the standby pump if it is engine driven), and oil the sliding parts with an oiler.

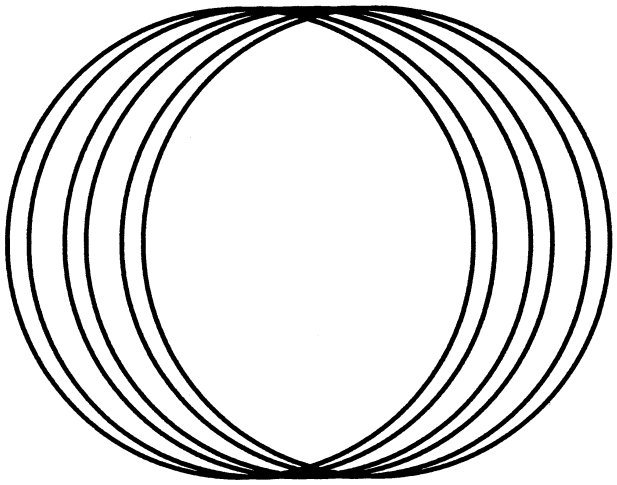
(a2) Lubricate the intake and exhaust valve rocker gears.

(b) Check the outside of the engine once a month for any signs of trouble.

(c) Spray or apply anti-corrosive oil to the shiny and sliding parts of the engine once a month.

(d) Remove the exhaust valves or fuel injection valves every three months, spray anti-corrosive oil into the combustion chambers while turning the engine, and remount valves.

(e) Analyze the lubricating oil properties every month.
-For details, refer to Paragraph **3.2** Lubricating Oil.



NIIGATA DIESEL INSTRUCTION MANUAL

MG(L)28AHX

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7. ENGINE MAINTENANCE PROCEDURE

(ASSEMBLY AND DISASSEMBLY PROCEDURES)

⚠ **WARNING**	1. Any negligence of controlling cooling water, lubricating oil and fuel oil, and controlling the clamping in reassembly after overhaul inspection may lead to fault of the engine and result in physical accidents due to failure of parts. 2. There is a possible danger of physical accidents that may be caused when the engine is started by mistake during the inspection and repair of the air-started engine. Be sure to carry out following items to prevent the erroneous start of the engine. ・Close the main valve of stating air tank. ・Release the residual pressure remaining inside the starting air pipeline. （between the starting air-tank to the engine） 3. The engine may start abruptly without notice through the auto start signal or by remote starting. As there is a danger of entanglement etc., do not be access to rotating parts and moving parts.
⚠ **CAUTION**	1. The top of surface of foot plate, that is slippery if led with oil etc., entails the danger of tumbling and falling. Wipe off thoroughly the oily matter left on the foot plate and shoes. 2. The topside of engine intake exhaust manifold, air dust, etc., that is slippery in some cases, entails the danger of tumbling and falling. Do not step on their topside unless has been confirmed. 3. There is a danger of hands or legs being entangled during the course of grinding, and drilling work. Do not put on gloves. 4. There is a danger of your hands and legs being pinched by weight part or disassembling tools during overhaul inspection of the engine. Take precautions in handling such part and tools. 5. Be sure to put on safety goggles in carrying out the following items of work being in danger of injury to eyes. ・When handling fuel oil, lubricating oil, cooling water and inhibitor, and anti-freeze solution ・In course of washing work ・When handling battery electrolyte ・In course of fuel injection valve injection test ・In course of grinding work ・In course of intake/exhaust valve grinding work 6. There is a danger of injury to the head inside the engine room and enclosure. Be sure to put on a helmet for the protection of the head. 7. Put on protective masks since the following items of work are in danger if adverse effect upon the health due to inhalation of deleterious mist or dust. ・In curse of cleaning work with compressed air ・When handling heat insulation material (glass cloth, etc) 8. There is a danger of injury to your hands during the work inside the engine room and enclosure. Be sure to put on safety shoes for the protection of your legs. 9. There is a danger of injury to your hands during the work inside the engine room and enclosure. Be sure to put on gloves for the protection of your hands except for the of case of special work

7.1 Foreword

To maintain the engine in the best operating condition, it is necessary not only to observe and check it daily but also to perform periodic maintenance and periodically change parts. Maintenance intervals and parts life are subject to change with engine running hours, maximum engine load, the environment in which the engine is located, the kind of fuel oil and lubricating oil used, the frequency of starts and stops, and the kind of loads (low load, or varying load), and can also differ greatly with the quality of maintenance. The following maintenance and inspection standards were prepared on the basis of our experience over many years; you are advised to prepare your own maintenance and inspection schedule suited to your particular conditions based on past data.

⚠ CAUTION

(1) The parts life that is described on the following list is not guaranty one.

(2) When you check the parts and confirm the abnormal condition of the parts, replace the parts immediately. (Replace the parts , if necessary.)

7.2 Maintenance and Inspection Planning

7.2.1 Maintenance and Inspection Planning

(1) Prepare your own maintenance and inspection plan by which to perform maintenance work.
-Refer to Paragraph **7.4** and Paragraph **7.5**

(2) When maintaining this engine, considerable attention must be paid to keeping safety.

(3) Keep an inventory of the parts in stock, and have the necessary parts ready in time.

(4) Keep the disassembly tools in order at all times so that they are ready for use when they are needed in emergencies.

(5) Be sure to replace the gaskets and O-ring.

(6) When exchanging parts, use Niigata original parts.

NOTE : When you need information of engine operation and maintenance, please inform us detail of it, beforehand.

7.2.2 Table of component mass

⚠ CAUTION

When lift the heavy part, use sufficiently powerful device. (Chain block hoist etc)
When handing weighty article exceeding 20kg in weight, use a crane or hoist or allow two persons or more to engage in the handing work.
(In case of joint work also, the weight should be limited to less than 20kg per per son.)

Main parts mass table

(unit:kg)

NO	Parts	Mass/unit			Remarks
		6cyl.	8cyl.	9cyl.	
1	Main bearing cap	63	←	←	
2	Locating bearing cap	50	←	←	
3	Locating bearing bracket	130	←	←	
4	Crank shaft ass'y	2650	3380	3750	With balance weights and crank gear
5	Torsional damper	320	680	←	
6	Flywheel	510	←	←	With ring gear
7	Cylinder liner	135	←	←	
8	Liner ring	55	←	←	
9	Piston ass'y	70	←	←	With piston pin and piston rings
10	Connecting rod ass'y	92	←	←	With bolts and bearings
11	Cam shaft ass'y	340	450	500	
12	Cam gear	40	←	←	
13	Idle gear (driving end side)	110	←	←	With gear shaft
14	Idle gear (free end side)	30	←	←	With gear shaft
15	Crank gear (free end side)	45	←	←	
16	Gear case cover	110	←	←	Turbocharger on free end side spec.
17	Gear case * CWP	65	←	←	Turbocharger on free end side spec.
18	Flyer cover ass'y	53	←	←	
19	Damper case cover	85	←	←	
20	Air starter	31	←	←	
21	Cylinder head ass'y	285	←	←	With I/E valves, safety valve, indicator cook and I/E manifold
22	Rocker arm ass'y	55	←	←	
23	Fuel injection pump	42	←	←	
24	Cooling water pump	75	←	←	With driving gear
25	Lubricating oil pump	120	←	←	With driving gear
26	Exhaust manifold ass'y	235	510	460	Pulse system
27	Turbocharger	450	720	←	
28	Turbocharger bracket	630	←	←	Turbocharger on driving end side
29	Charge air cooler	510	570	580	
30	Lubricating oil cooler	270	290	300	For engine mount
31	Lubricating oil filter	120	←	←	For engine mount
32	Power take off shaft	205	←	←	
33	Power take off shaft bearing cap	75	←	←	

7.3 Maintenance schedule

7.3.1 Outline of maintenance schedule

< Time schedule of maintenance & relevant spares >

" A " Daily check - - - Refer to **7.3.3**
" B " Maintenance - - - Every 1,500 hours operation (Every 3 month)
" C " Maintenance - - - Every 3,000 hours operation (Every 6 month)
" D " Maintenance - - - Every 6,000 hours operation (Every 1 year)
" E " Maintenance - - - Every 12,000 hours operation (Every 2 year)
" F " Maintenance - - - Every 24,000 hours operation (Every 4 year)

NOTE. ( ) shows operating interval

Maintenance Class	B	C	B	D	B	C	B	E	B	C	B	D	B	C	B	F
Operation hours	1,500	3,000	4,500	6,000	7,500	9,000	10,500	12,000	13,500	15,000	16,500	18,000	19,500	21,000	22,500	24,000
For "B" Maintenance	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
For "C" Maintenance		○		○		○		○		○		○		○		○
For "D" Maintenance				○				○				○				○
For "E" Maintenance								○								○
For "F" Maintenance																○

NOTE : Above figure shall be expected in case of the conventional operating conditions of fuel, load atmosphere, etc.

7.3.2 Contents of maintenance

○ : Check & Cleaning, △Partial Check & Cleaning

● : Replace

Inspection item	Contents of maintenance	B	C	D	E	F	Remarks
Cylinder head	• Check the cylinder head stud bolt tightening force check		○	○	○	○	
	• Combustion chamber, intake and exhaust passage clean and check			○	○	○	
	• Combustion surface dye check			○	○	○	
	• O-ring Pipe (FV body) check					●	
Intake and exhaust valve	• Valve check, measure, dye check			○	●	●	
	• Valve guide inner diameter measuring			○	○	●	
	• Valve seat lapping			○	●	●	
	• Spring check		○	○	○	●	
	• Valve rotator check			○	●	●	
	• Exhaust valve seat O-ring replace			●	●	●	
Fuel injection nozzle	• Fuel injection nozzle check	○	●	●	●	●	
	• Injection pressure test, spray check	○	○	○	○	○	
	• Fuel injector body dye check		○	○	○	○	
	• Spring check		○	○	●	●	
Indicator cock and Cylinder safety valve	• Indicator cock check			○	○	●	
	• Safety valve body and valve lapping			○	○	○	
	• Safety valve spring check			○	○	○	
Piston	• Piston cleaning and check			○	○	○	2 cylinder inspect at first year
	• Piston diameter measuring			○	○	○	
	• Piston pin boss inner diameter measuring			○	○	○	
	• Piston pin diameter measuring			○	○	○	
	• Ring groove clearance measuring			○	○	○	
	• Piston ring check			○	●	●	
	• Snap ring check			○	○	○	
Connecting rod	• Crank pin bearing check			○	●	●	**
	• Crank pin stud bolt check			○	○	●	
	• Oil holes check and cleaning			○	○	○	Air blow off after Washing
	• Big end and small end inner diameter measuring			○	○	○	Uneven wear Measuring
	• Rod and big-end (upper) contact surface check			○	○	○	
	• Piston pin bush check			△		●	
Cylinder liner	• Visual check through crankcase doors	○	○	○	○	○	
	• Combustion surface, and inner surface check			○	○	○	
	• Fire ring diameter measuring and dye check			○	●	●	
	• Deglazing				○	○	
	• Cylinder liner dismount				○	○	

** NOTE) After check the condition of bearing, if necessary replace crank pin bearing and main bearing.

○ : Check & Cleaning, △Partial Check & Cleaning
● : Replace

Inspection item	Contents of maintenance	B	C	D	E	F	Remarks
Crank shaft	• Deflection measuring	△	○	○	○	○	△: Check it at first 500 hours
	• Crank pin and journal measuring check			○	○	○	
	• Crank pin and journal dye check					○	
	• Balance weight stud bolts tightening force check	○	○	○	○	○	
Main bearing and location bearing	• Main bearing check and clearance measuring			△	○	●	** △:Check the bearing at middle throws only
	• Location bearing check and clearance measuring				○	●	
	• Thrust bearing check and clearance measuring				○	●	
Power take off shaft bearing (Depend on specification)	• Bearing check and clearance measuring				○	●	**
Torsional vibration damper (Depend on specification)	• Disassembly and check					○	Refer to the Instruction Manual for geislinger damper
Flexible coupling (Depend on specification)	• Disassembly and check					○	Refer to the Instruction Manual for flexible coupling
Rocker arm	• Tappet clearance adjustment	○	○	○	○	○	
	• Shaft check and oil hole cleaning			○	○	○	
	• Rocker arm bushing check			○	○	●	
	• Clearance between rocker arm shaft and rocker arm bushing measuring			○	○	○	
	• Adjust bolts check			○	○	●	
	• Rocker arm dye check			○	○	○	
Cam shaft, Cam roller, Cam bearing Thrust bearing	• Cam visually check	○	○	○	○	○	
	• Roller contact visually check	○	○	○	○	○	
	• Cam bearing clearance measuring				○	○	
	• Thrust bearing check					○	
	• Cam bearing check					○	
Valve gear	• Intake and exhaust push rod check		○	○	○	○	Top and bottom pieces check, and push rod bend check
	• Tappet disassembly and check, and oil holes cleaning				○	○	
	• Roller bush check				○	●	
	• Shaft, roller pin and tappet inner diameter measuring				○	○	
	• Roller pin, snap ring and tappet dye check				○	●	
	• Tappet bearing check and clearance measuring				○	●	
VIVT Tappet shaft drive unit	• Ball bearing check			○	●	●	
	• Reamer bolt, lever check			○	○	●	
	• Rubber hose of control air check				○	●	
	• Tappet driving gear check				○	○	

** NOTE) After check the condition of bearing, if necessary replace crank pin bearing and main bearing.

○ : Check & Cleaning, △Partial Check & Cleaning
● : Replace

Inspection item	Contents of maintenance	B	C	D	E	F	Remarks
Fuel injection pump	• Deflector(eye-bolt), delivery valve and plunger check			○	●	●	
	• Control rack scale position check			○	○	○	
	• Injection timing check			○	○	○	
	• Disassembly and cleaning			○	○	○	
	• Spring and plunger guide check			○	○	●	
Fuel injection pipe	• Injection pipe seat surface check			○	○	○	
	• Injection fitting seat surface check			○	○	○	
Air starter	• Visual check, grease condition check	○	○	○	○	○	Refer to the
	• Pinion gear, ring gear check	○	○	○	○	○	Instruction Manual
	• Air starter disassembly check			○	○	○	for air starter
Governor	• Governor oil change		○	○	○	○	
	• Governor overhaul at specialized shop			○	○	○	Send to supplier
Governor driving device	• Gear contact and pitting check				○	○	
	• Backlash check				○	○	
	• Ball bearing check				○	●	
	• Gear check				○	○	
Gear train	• Crank gear contact and pitting check			○	○	○	
	• Cam gear contact and pitting check			○	○	○	
	• Idle gear contact and pitting check			○	○	○	
	• Each pump driving gear contact and pitting check			○	○	○	
	• Each gear backlash check			○	○	○	
	• Idle gear bushing check					●	
Fuel control linkage	• Linkage looseness check	○	○	○	○	○	
	• Spring check			○	○	●	
	• Ball bearing and busing wear check			○	●	●	
	• Rack lever, reamer bolt, link wear check			○	○	●	
	• Link boll, rod end check			○	○	○	
	• Link pin check			○	○	●	
Turbocharger	• Disassembly, cleaning and check			○	○	○	Refer to the
	• Bearing check			○	○	●	Instruction Manual for turbocharger
Charge air cooler	• Cooling water passage cleaning			○	○	○	
	• Air passage cleaning			○	○	○	
	• Pressure test			○	○	○	
	• Anti-corrosion zinc replace		●	●	●	●	sea water cooling system specification

○ : Check & Cleaning, △Partial Check & Cleaning
● : Replace

Inspection item	Contents of maintenance	B	C	D	E	F	Remarks
Exhaust manifold	• Expansion joint check		○	○	○	●	
	• Lagging check, repair		○	○	○	○	
	• Manifold inner surface check and cleaning				○	○	
Intake and exhaust Manifold, Intake duct	• Intake and exhaust manifold inner surface check and cleaning			○	○	○	
	• Intake duct crack check			○	○	○	
Air bypass and Waste gate system	• Linkage looseness check	○	○	○	○	○	
	• Expansion joint check		○	○	○	●	
	• Lagging check, repair		○	○	○	○	
	• Ball bearing wear check			○	●	●	
	• Lever, reamer bolt wear check			○	○	●	
	• Link ball check			○	○	●	
	• Butterfly valve check		○	○	○	●	
Fuel oil feed pump	• Oil seal replace			●	●	●	In case of engine driven
	• Ball bearing check			○	●	●	
	• Coupling check			○	○	●	
Cooling water pump	• Oil seal replace			●	●	●	In case of engine driven
	• Mechanical seal replace			●	●	●	
	• Ball bearing check			○	●	●	
Cooling water pipe	• Flexible coupling replace				●	●	
Thermostat for cooling water	• Thermostat check, replace		○	○	●	●	
Cooling water cooler	• Cleaning and check			○	○	○	
Lubricating oil Ppump	• Gear contact and pitting check				○	○	In case of engine driven
	• Bushing check				○	●	
Lubricating oil regulating valve	• Valve check and lapping			○	○	○	
	• Valve spring check			○	○	●	
Thermostat for lubricating oil	• Thermostat check, replace		○	○	●	●	
Lubricating oil ckooler	• Cleaning and check			○	○	○	
Lubricating oil filter	• Automatic filter check			○	○	○	Refer to the Instruction Manual for lubricating oil filter
	• O-ring, seal replace				●	●	
	• Element check					●	

7.3.3 Contents of daily check

Inspection item	Contents of maintenance	Interval	Description
General item	・Each tank level check ・Each gauge indication check ・Each thermometer indication check ・Oil leak, water leak check ・Each part vibration check ・Each valve opening and closing check ・Each drain discharge ・Abnormal noise check	Every day Every day Every day Every day Every day Every day Every day Every day	Watch and record Record Record Watch Watch and touch
Fuel oil system	・Viscosity control ・Fuel oil drain quantity check ・Fuel oil temperature check	Every day Every day Every day	
Cooling water system	・Water quality analysis	500h	
Lubrication oil system	・Lubricating oil quality analysis ・Spot testing ・Sludge checker check	500h 500h Every day	
Turbocharger	・Sponge filter cleaning ・Blower washing ・Turbine washing	100h 500h 100h	Only case of filter silencer used
Engine mist	・Color and quantity check	Every day	
Exhaust gas	・Color and quantity check	Every day	Watch

7.4 Daily check

(1) Check and record the oil levels of the following oil tanks and oil sumps to confirm the oil consumption, and add oil if necessary.

(a) Tank and oil sump oil level check

(a1) Lubricating oil sump tank

(a2) Reversing-reduction gear or reduction gear

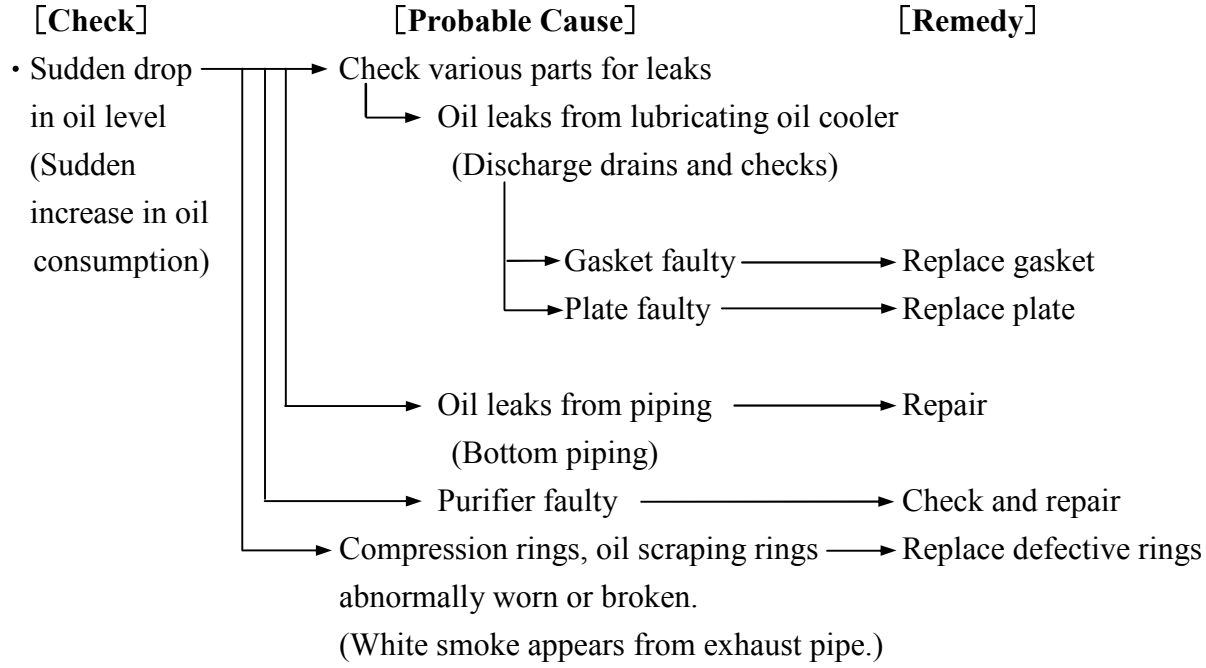
(a3) Stern bearings

(a4) Hydraulic governor

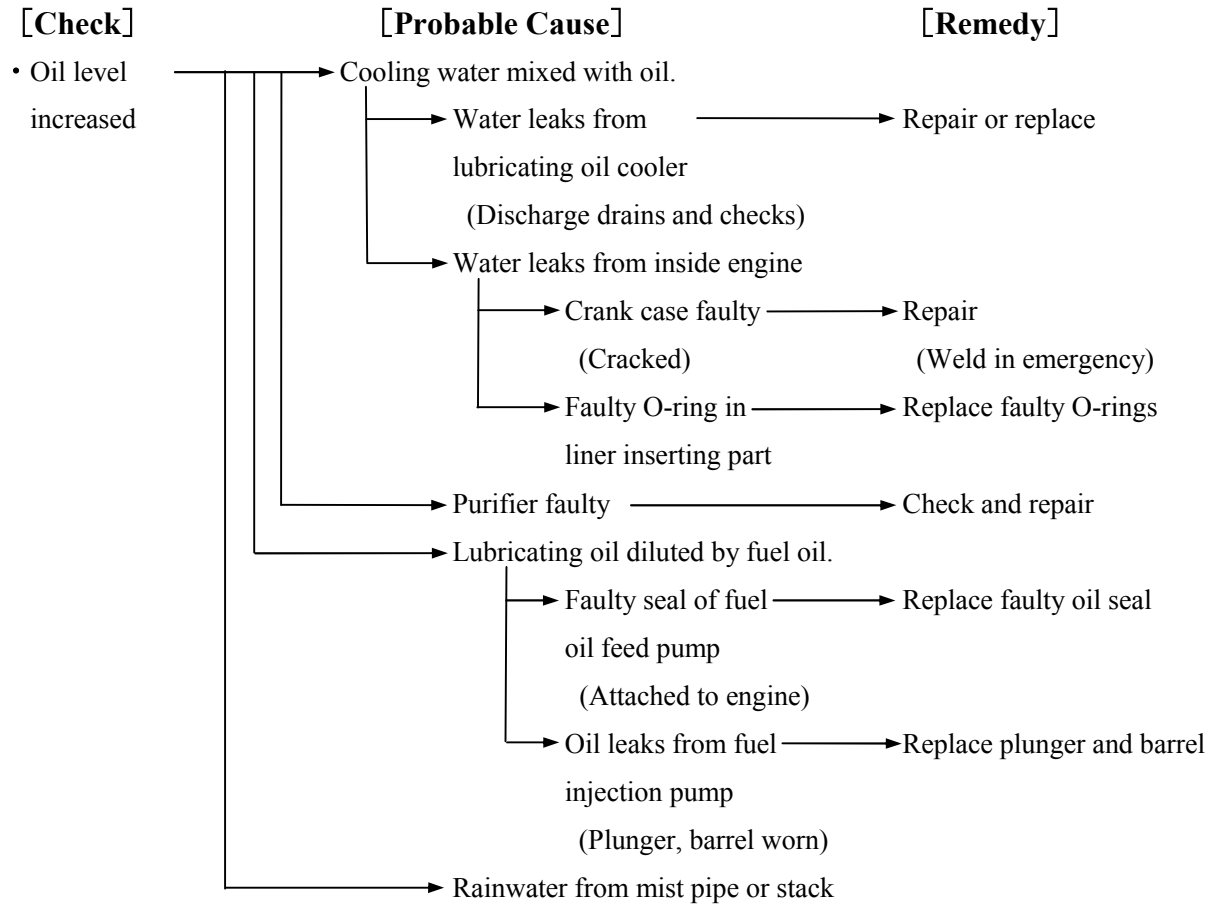
(a5) Oil cups and grease cups on engine

(b) Lubricating oil level check

(b1) System lubricating oil



NOTE : Lubricating oil Refer to **3.1.2**
When pouring lubricating oil in sump tank, don't pour huge lubricating oil at once. Sludge in the bottom of the tank soars and makes a filter be stopped up.



⚠CAUTION

Be especially careful to prevent water getting into the system lubricating oil because it can cause bearing seizure.

(2) Discharge drains from each tank and device

(a) Lubricating oil

・ Excessive water in drains → Water or rainwater leaks from Various parts → Refer to **7.4(1)**

(b) Fuel oil

・ Excessive water in drains
- → Fuel oil properties inappropriate → Analyze properties
- → Water entering from outside (From mist pipe, tank cover, etc) → Check and repair
- → Faulty purifier → Check and repair

・Excessive sludge in drains → Fuel oil properties inappropriate

・Foreign matter → Tank, pipes, devices not sufficiently cleaned

→ Analyze properties, operate Purifier continuously

(c) Starting air receiver

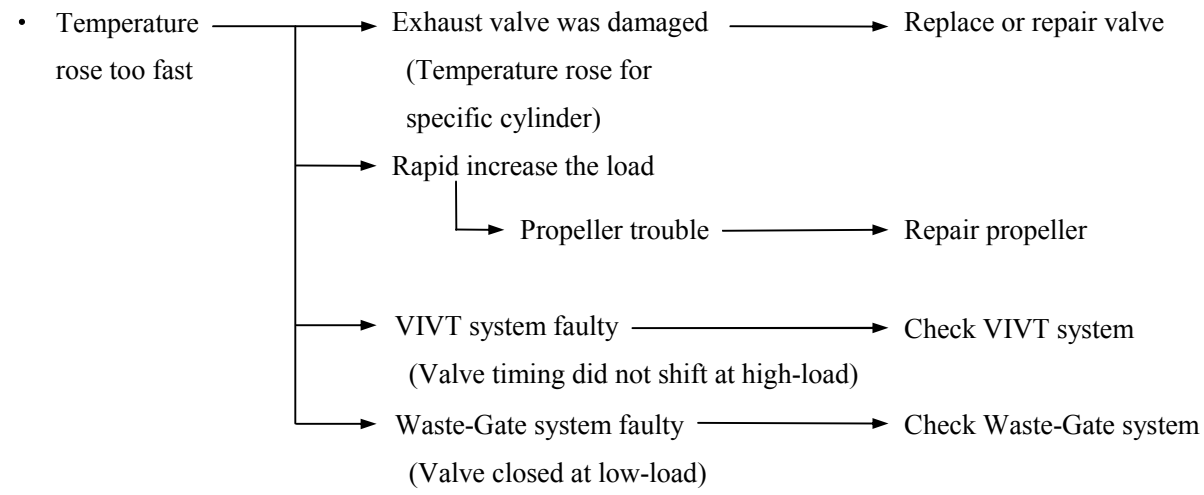
・Drains not discharged well → Inner drainpipe not properly positioned at tank bottom → Check inside from check door → repair

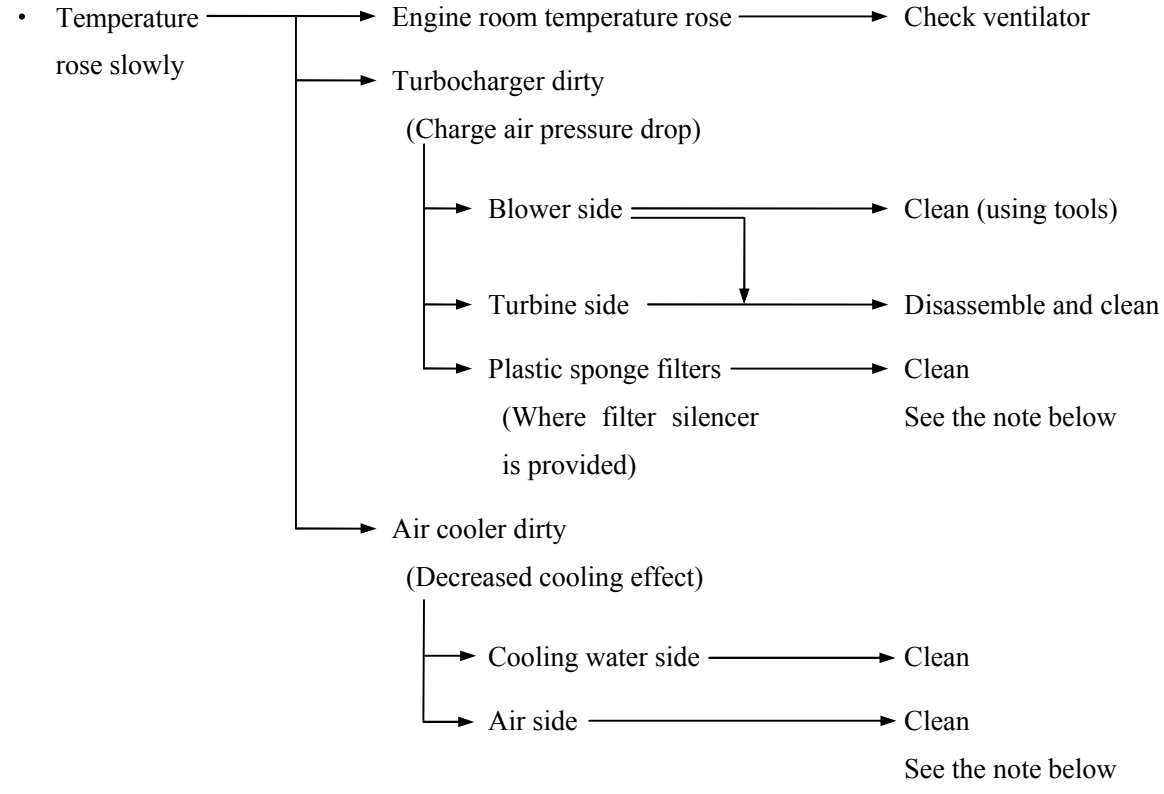
(3) Take engine performance data, and continually record data on shop trial, sea trial or local trial, and a maiden voyage. Items of data to be taken should be similar to those of the shop trial performance sheet. Pay particular attention to the following data.

(a) Performance analysis

［**Check**］ ［**Probable Cause**］ ［**Remedy**］

(a1) Exhaust gas temperature



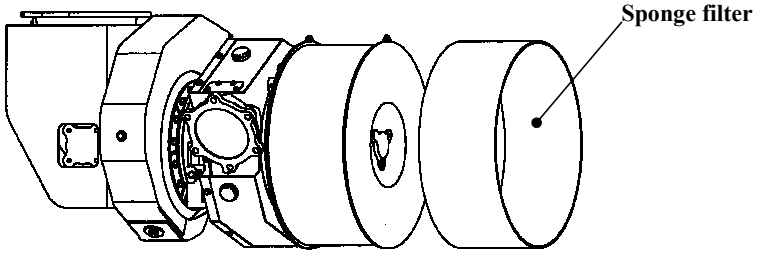


- Temperature dropped too low → Imperfect combustion (Temperature dropped for specific cylinder)
  - → Check nozzle performance
  - → Check fuel injection pump rack scale
  - → Check fuel injection pump (Plunger stick)
- → Intake and exhaust valve stick → Replace repair valves and valves guides
- → Air-Bypass system faulty (Valve did not closed at high-load) → Check Air-Bypass system

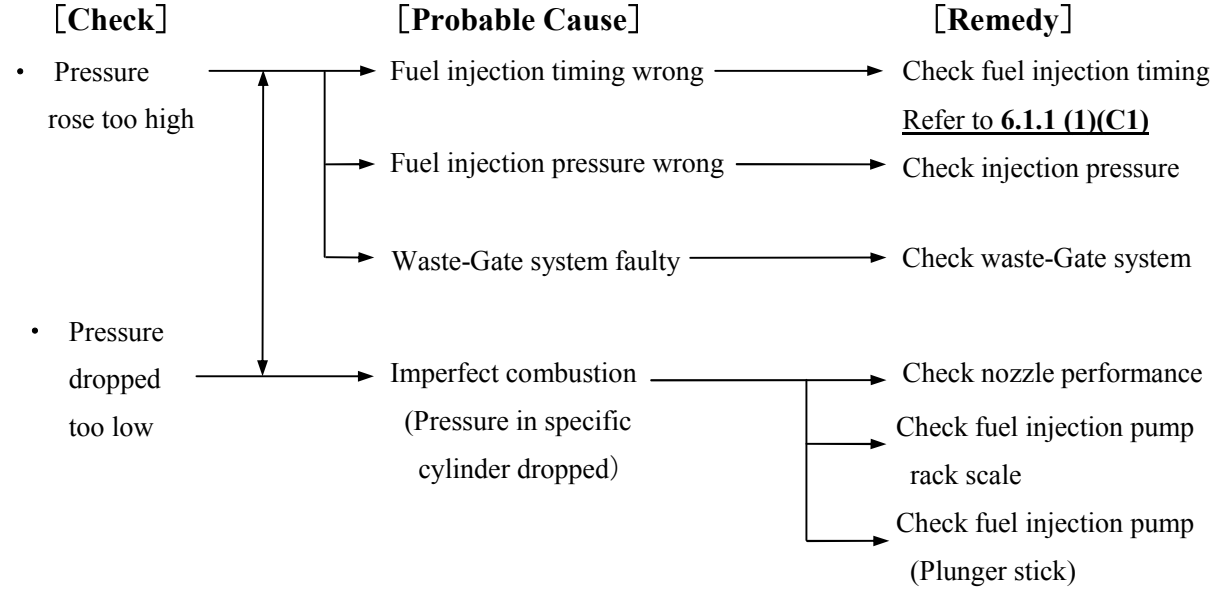
NOTE : (1) Clean the turbocharger's plastic sponge filter with neutral detergent, and dry it in the shade.
(2) The following detergent is recommended for cleaning the air cooler.
Supplier : Niigata Power Systems Co., Ltd.
TEL : 0276-31-8271 (Customer support center)
Trade name : NIIGATA SUPER-CLEAN
(3) Exhaust gas temperature difference of up to ± 30°C of average
Temperature among the cylinders is permissible at the rated output power in terms of engine performance.

WARNING

In case of rising cylinder pressure abnormally.
There is a danger of scald caused by the cylinder safety valve operation.
Never approach the spouting vent.



(a2) Maximum cylinder pressure



NOTE : (1) Maximum cylinder pressure difference of up to 0.7MPa among the cylinders is permissible at the rated output power in teams of engine performance.
(2) Adjustment of exhaust gas temperature and maximum cylinder pressure. Exhaust gas temperature and maximum cylinder pressure vary in a correlated manner, and an overall judgment is required in adjusting them.
Whichever must be adjusted, checks as mentioned above, and then proceeds to the following adjustment procedure.

(b) Adjusting exhaust gas temperature and maximum cylinder pressure

(b1) Exhaust gas temperature adjustment

Regulate fuel injection quantity for each cylinder.

→ Move the fuel control lever pointer to position 100% load
- → Cylinder with high exhaust gas temperature → Move back rack scale
- → Cylinder with low exhaust gas temperature → Advance rack scale

- Refer to **6.1.1**(1)(C) for the method of adjustment
- After this adjustment, the rack scale difference among the cylinders must meet the following requirements.

When fuel control lever is at the
stop position (fuel cut off) ---------- 0±1 or less
during operation ---------- 3 or less

NOTE : (1) If the rack scale difference is great, there is the danger of the engine not stopping when the fuel control lever is moved back to the stop position.
(2) Ideally, the exhaust gas temperatures and fuel injection pump rack scales for all the cylinders should be uniform, but this is unlikely due to manufacturing errors. So adjust the exhaust gas temperatures difference and rack scale difference to less than ± 30°C of the average temperature and less than 3, respectively, at normal engine output power. Avoid adjusting only one of them, and leaving the other with great difference.

(b2) Maximum cylinder pressure adjustment

Adjust the fuel injection beginning timing for each cylinder.

→ Cylinder with maximum pressure too high → Delay injection beginning → Thicken shim

→ Cylinder with maximum pressure too low → Advance injection beginning → Thin shim

- Refer to **6.1.1(1)(C1)** for the method of adjustment.
- Checks before adjustment.

  Before adjusting the maximum cylinder pressure, carefully check the cause of its variation. Do not carelessly attempt an adjustment.

  ① Conduct an injection tests on the fuel injection valves, and make sure that they operate properly. For the method of adjustment, refer to **7.5.1(1)(d).**

  ② Check that the engine is not over-loaded.

  ③ Read and record the fuel injection beginning crank angles, and checks that it agrees, with the shop test performance sheet.

(4) Check the lubricating oil automatic filter

(a) Daily check

This lubricating oil filter is automatic backflushing type. So the filter elements are cleaned automatically. However daily check is necessary as follow.

① Check for the differential pressure indicator

As the contamination increase, differential pressure in the filter also increase.

If differential pressure indicator became red color sign, check the filter elements.

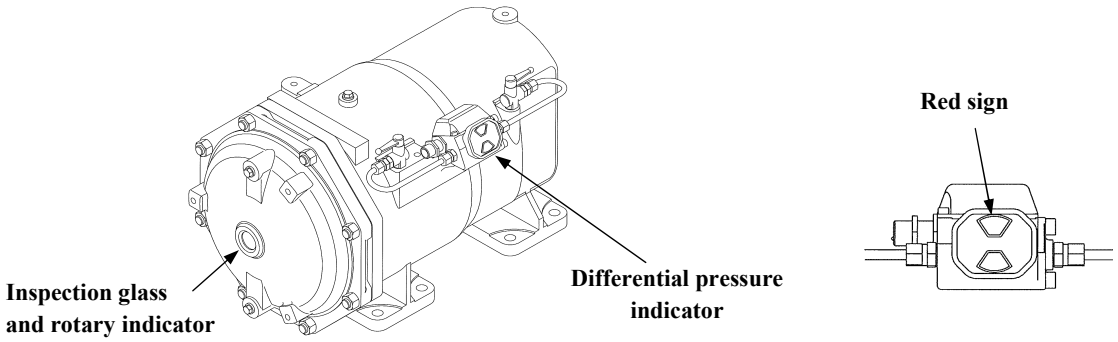
② Check for the rotating flushing arm

Check the rotating flushing arm (about 1 rotation/10sec) at the rotary indicator in the inspection glass.

③ Check for leakage

Check the leakage at connection of each filter.

NOTE : Refer to the Instruction Manual for the lubricating oil automatic filters.



(5) Check of Fuel oil filters

Clean the fuel oil filter

Determine the cleaning interval according to the condition.

If an automatic cleaning type is applied check its function being normal.

Refer to the Instruction manual for the filters.

(6) Check the combustion state

The fuel injectors must be checked whenever any of the following abnormalities is detected.

(a) Imperfect combustion → Dark smokes or sparks

→ Open the indicator cocks, and check which cylinder is faulty

(b) Maximum cylinder pressure drop

(c) Overheated fuel injection pump

(d) Cracked fuel injection pipe

(7) Check the lubricating oil

(a) Take sample (about 1 liter), have it analyzed by the oil supplier, and ask their advice on its usability.

(b) The spot testing method is a simple way of testing the lubricating oil.

NOTE : Lubricating oil changing intervals vary with the fuel oil used and the conditions of use. The best way to determine when to change the lubricating oil is to analyze it.

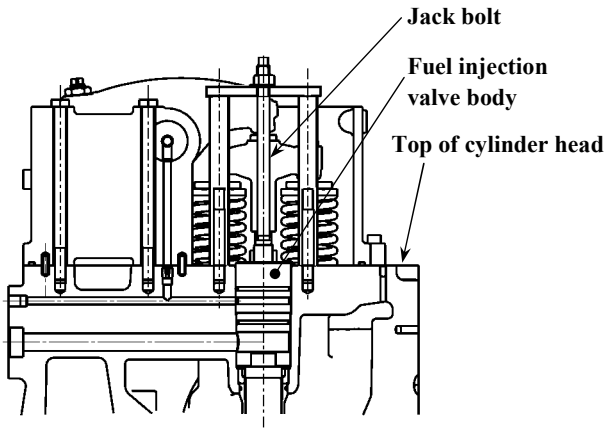
7.5 Check for each device

7.5.1 Cylinder head and around parts

(1) Check the fuel injectors

(a) Fuel injector removal procedure

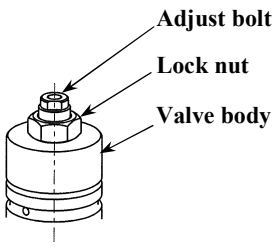
- Close the fuel oil main valve.
- Remove the cylinder head cover, fuel injection pipe.
- Remove the fuel injectors by using jack bolt.

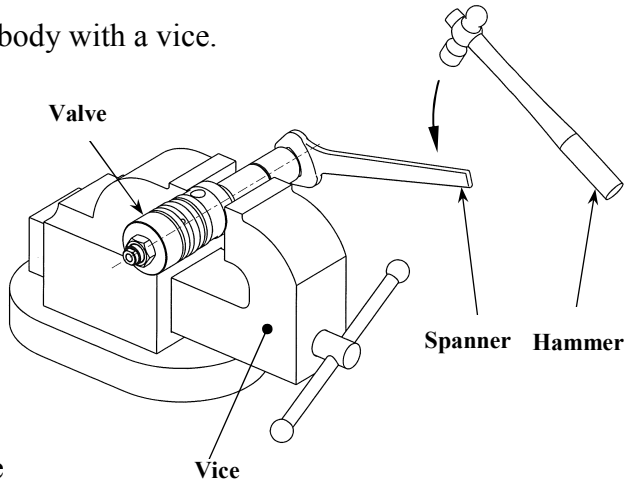


(b) Fuel injector disassembly and reassemble procedure

(b1) Disassembly

- Loosen the lock nut.
- Completely loosen the pressure adjust bolt.
- Lightly fasten the flanged part of the valve body with a vice.
- Loosen the nozzle nut.



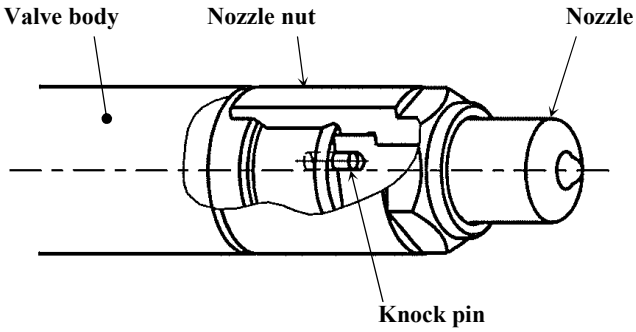


(b2) Fuel injection nozzle assembly procedure

Reassemble in the reverse procedure of disassembly.

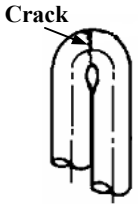
- Align the nozzle with the valve with the knock pin.
- Tighten the nozzle nut.

  -Refer to **5.2** Tightening Specification of Main Parts.
- After pressure adjustment, tighten the adjust bolt lock nut securely.



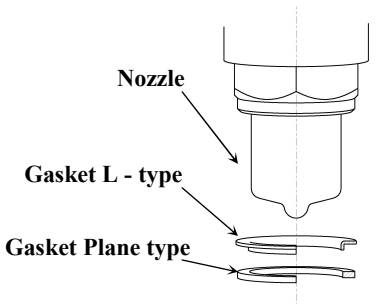
(b3) Fuel injector installation procedure

- Check the O-rings whenever the fuel injectors are disassembled.
  If that is damaged, deformed or hardened, change the O-ring.
  The O-ring hardened is cracked at bending 180°.
- If the fuel injector body appears rusty on the outside, remove the rust, and apply a suitable anti-corrosive.
  The following anti-corrosives are recommended.



Trade name: NIIGATA COAT 800
Agent: Niigata power systems Co., Ltd
Tel :+81-3-4366-1270 (Customer support center)

- Replace the gasket for seal.
- Clean the seat of the gasket of the cylinder head.
- Install the fuel injector into the cylinder heads.

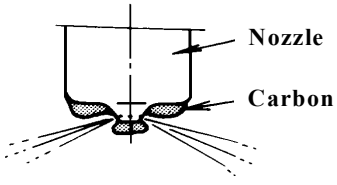


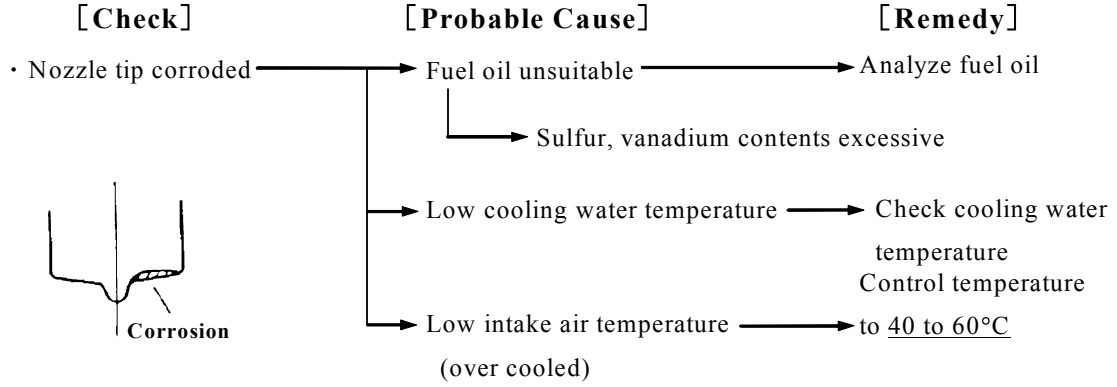
CAUTION : Be sure to replace the above-mentioned gasket whenever the fuel injectors are disassembled. The use of an imperfect gasket may cause carbon accumulation on the threaded parts of the nozzle nut, and make it too hard to turn.
And be sure to set gasket above-figure. Because this gasket has assembling order, assembling direction.

(c) Checks and remedies

(c1) External check

[Check]	[Probable Cause]	[Remedy]
• Excessive carbon deposits on nozzle tip. Some carbon deposits around injection hole (particularly around those of exhaust valves	Imperfect combustion	
	Fuel oil unsuitable	Analyze fuel oil
	Carbon residue excessive	
	Nozzle hole expanded	Change nozzle
	Low cooling water temperature	Check cooling water temperature
		Check fuel oil temperature
	Insufficient heating of fuel oil	

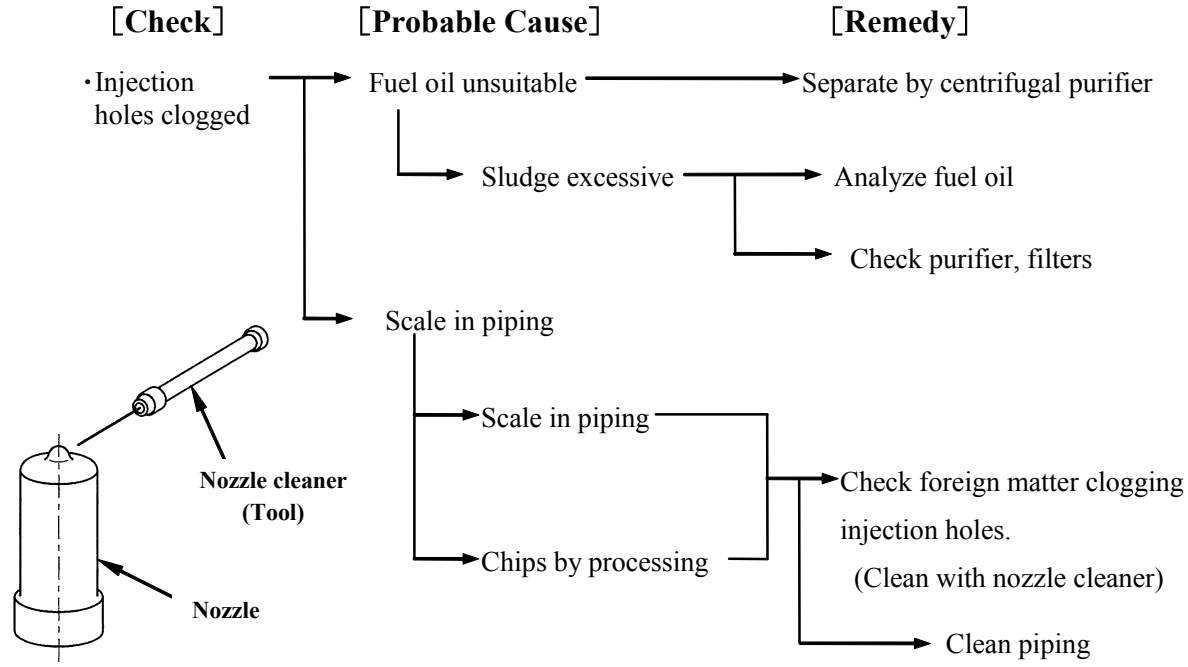




NOTE : (1) Exercise great care in handling the nozzle because they are precision-made parts.
- Be careful not to damage the seat and sliding parts.
- Keep parts immersed in fresh light oil to prevent rusting.
- Be careful of dust when reassembling.

(2) Be careful not to over-tightens the nozzle nuts. Otherwise, the nozzles will be deformed, causing the needles to stick.
(3) Nozzle performance and life depend largely on the properties of fuel oil. When using heavy fuel oil, exercise extra care in purity of the fuel oil and controlling the filters.

(c2) Injection hole check

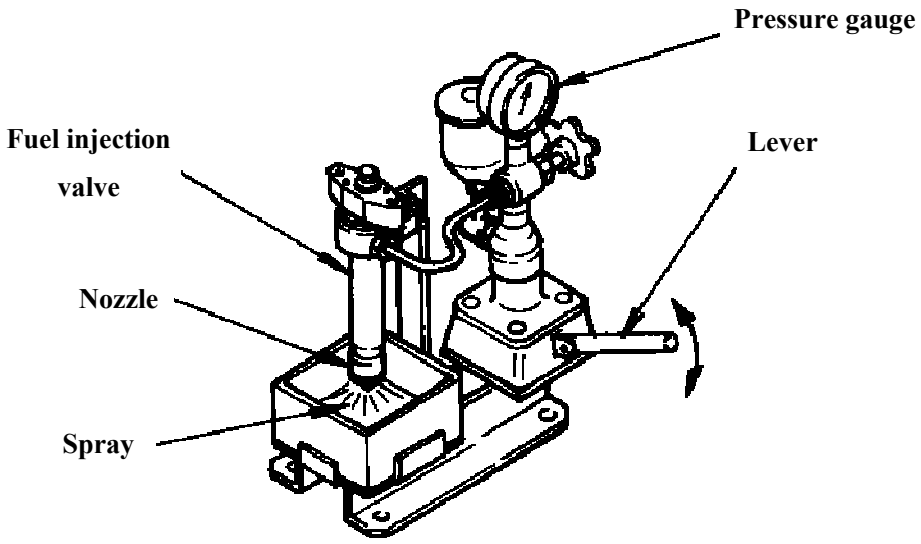


(c3) Fuel injection valve spring check ——→ If damaged, replace it

(d) Fuel injector test procedure

• Mount a fuel injection valve in the test pump.

Fuel Injector Tester



NOTE : First time injector testing must be performing within 500 hours because valve open pressure may be down for the first stage.

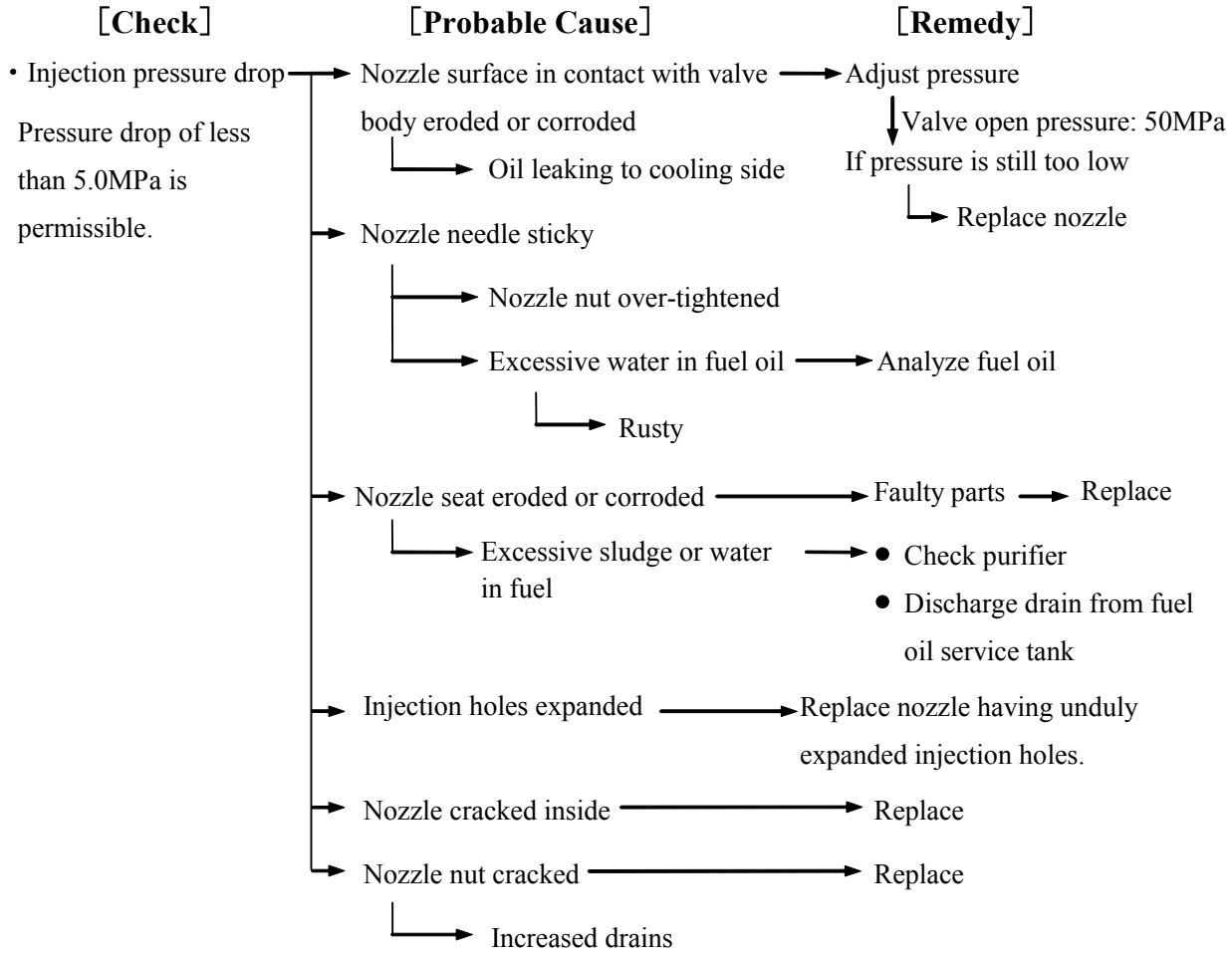
WARNIN

When perform injection test, if high-pressure oil spray touched the skin directly, should be damaged.
Do not bring hand or body near the oil spray area.
If oil spray enter into the body through the skin, consult a physician immediately.
Make sure carefully check the joint part of the fuel injector tester before rise up the hydraulic pressure.

CAUTION

Put on safety glasses when perform fuel injection testing.

(d1) Nozzle injection test by test pump



① Injection pressure check (Operate the pump lever slowly)

② Pressure holding check (Operate the pump lever slowly)
Good if pressure of anywhere 45～50MPa is kept after injection.

③ Spray check (Operate the pump lever as quickly as possible)
Good if fuel is completely sprayed uniformly from all injection holes.

④ Injection end check
Good if injection ends with a sharp injection sound without a fuel drip.
If all test results are good, the fuel injection valve can be used as it is.

If the test results are not good, take the following steps

- Disassemble and check nozzle → Refer to **7.5.1**(1)(C)
- Reassemble and test

<Nozzle assembly procedure>

- Locate the nozzle to the injector body by knock pin.
- Tighten the nozzle nut. → Refer to **5.2** Tightening Specification of Main Parts.
- Adjust the valve open pressure by test pump.
- Tighten the lock nut after adjusting.

→ Test at injection pressure 0MPa → Make sure that fuel is uniformly sprayed from all injection holes → Check that injection holes are normal

→ Gradually raise injection pressure.

Check minimum injection pressure at which the three factors in Item above, that is pressure holding, spray, and injection end, are satisfactory, and at which a Schnarr sound can be heard.

→ Good if minimum injection pressure is 18MPa or less.

If minimum injection pressure is more than 18MPa disassemble, repair, and test again.

→ If still not good, replace nozzle.

NOTE : The Schnarr sound is a soft of pulsating noise produced when the tester lever is pushed in slowly about 1 to 2 seconds after fuel has been fully injected by pushing the tester lever down quickly a few times. At this time, a pulsation can be felt through the lever.

(2) Cylinder head overhaul

(a) Prepare of cylinder head disassembly

Before cylinder head disassembly, it is necessary to discharge cooling water in cylinder head, liner ring, and intake and exhaust manifold.

(a1) Close the valves for the fresh water expansion tank connecting pipes.

(a2) Open the drain valves, and discharge the water.

(b) Cylinder head disassembly procedure

(b1) Remove following parts from them beforehand.

- Cylinder head cover
- Fuel oil pipe cover
- Exhaust manifold cover
- Rocker gears
- Fuel injector and injection pipe
- Fuel drain pipe
- Lubricating oil pipe
- Intake and exhaust push-rod

(b2) Loosen the cylinder head nuts with a hydraulic jack (tool).

Check for the following points before installing the hydraulic jack.

- Inspect the pressure gauge and hydraulic jack see if the hydraulic jack operates normally. Check the pressure gauge periodically to use the one that falls within the period of validity. (If pressure gauge is abnormal, clamping under the regular clamping force is impracticable.)
- Remove the rubber cap of cylinder head stud bolt and make sure that threads are kept clean.
- Clean up the topside of cylinder head and the underside of hydraulic jack so as to be free from foreign matter. (Use extreme care for the fact that inclusion of foreign matter may decrease the clamping force.)
- Apply the spray type MOLYKOTE to the threads of jack bolt**.**

Hydraulic jack using method

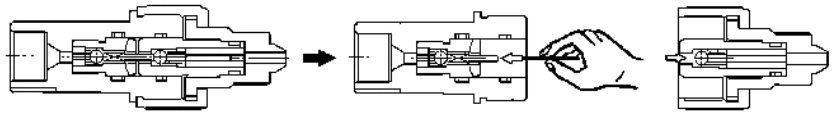
- Set the hydraulic jack to the four cylinder head studs.
  In case of tightening by 2 studs, set the hydraulic jack to diagonally opposite cylinder head studs.
- By hand until the bottom has come in contact lightly with the head of cylinder head stud.
  Make sure the top of jack and the top of cylinder head are parallel.
  (The clearance between the cylinder head stud nut and the underside of jack bolt becomes approx. 6.5mm.)
  Loosen nut by a half revolution. (When conducting disassembly by the hydraulic jack, nut maybe locked by the shrinkage of jack bolt)
- Connect the hydraulic jack with high-pressure hose.
- With the check valve of hydraulic pump being put in working condition, operate the hydraulic pump to increase hydraulic pressure gradually.
- After increasing the hydraulic pressure up to the minimum pressure of 130MPa at which the cylinder head stud nut becomes loose, loosen the nut by the use of Turning rod.
- If it is prevented from loosening, increase the hydraulic pressure up to 135MPa .
- In this case, make sure that all of the 4-nuts become loose.
  If even any one of them does not become loose, decrease the hydraulic pressure and check for possible abnormality in the hydraulic jack and pressure gauge. (if hydraulic pressure is increased excessively in the case where even any one of them dose not become loose, them the seat may sink and result in failure.)

NOTES : (a) It is necessary to discharge the remained oil in the hydraulic jack because it makes bad operation of the hydraulic piston. Discharge the remained oil as the following procedure.

(a1) Connect the high pressure hose to the hydraulic jack.
(a2) Open the oil pump valve.
(a3) Tighten the jack bolt.

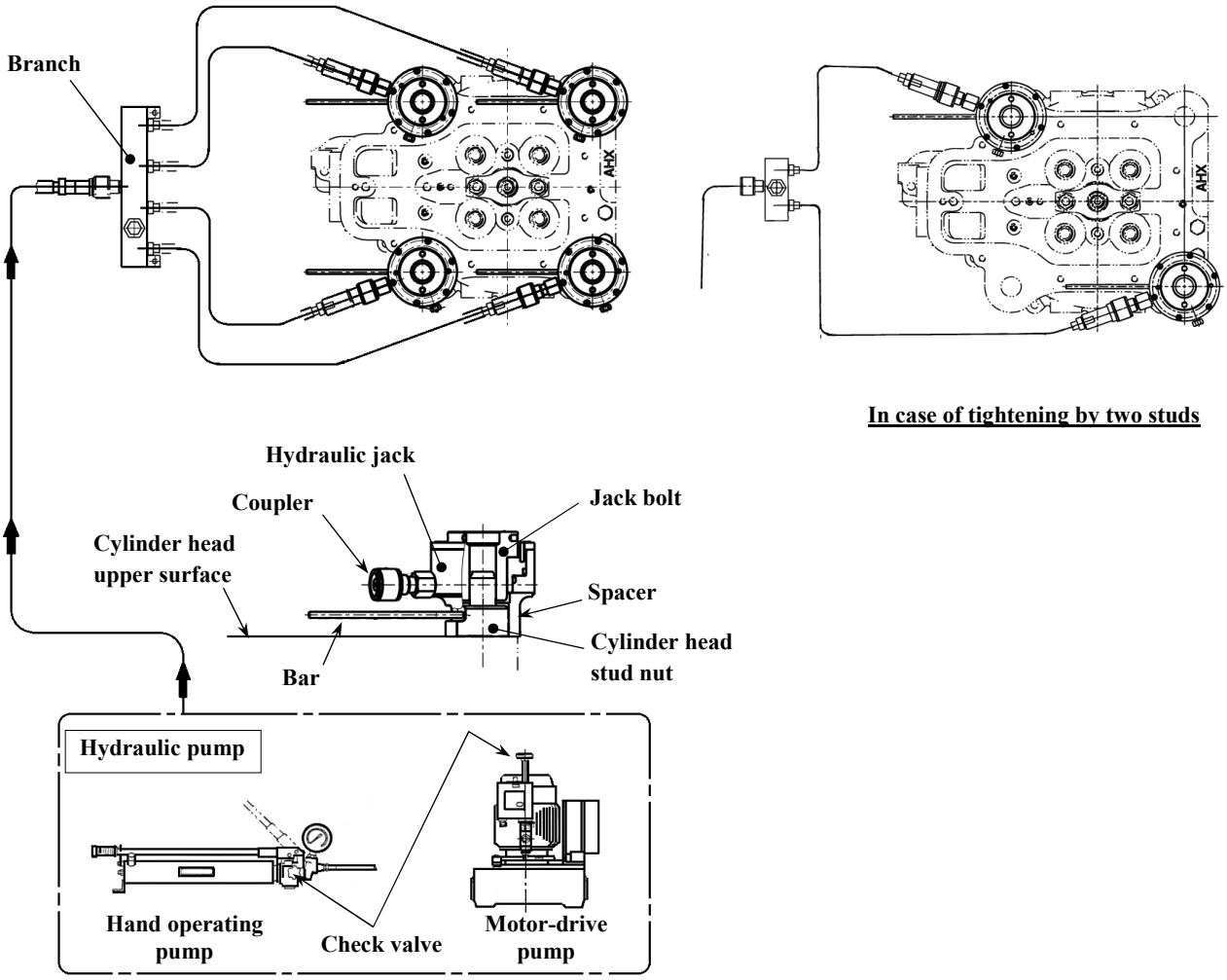
※ Even if jack bolt is tightened with the check valve of hydraulic pump being kept closed and the high-pressure hose being left unconnected, no oil returns, so that piston of hydraulic jack does not come down.
Operation of the hydraulic jack without lowering piston will oil-seal of inner cylinder to be disconnected when clamping, so that the resultant oil leakage will make regular clamping impracticable.

(b) Existence of air in the hydraulic pressure may encounter difficulty in pressure increase. In such cases, loosen Couplers of high-pressure hose joint and remove the air by thrusting the check ball valve with a nail or the like.



(c) If the cylinder head stud nut is excessively returned in contact with jack bolt there is a possibility of the nut being locked. To prevent this, do not return the nut excessively. For the amount of returning the nut, refer to the following as a standard.

Cylinder head hydraulic jack



In case of tightening by two studs

General Cautionary Instruction

(1) To prevent the stud and nut threads of cylinder head from being damaged by denting etc., protect them with rubber caps unless they are put to use.

(2) When using the hydraulic jack, make sure that each joint is from oil leaks.

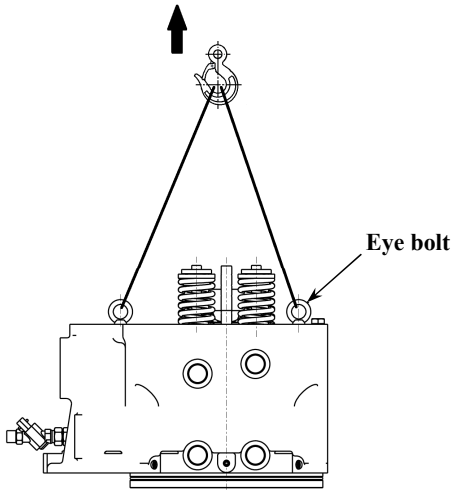
(3) During the hydraulic jack being in operation, do not gain access, closer them necessary to the high-pressure hose section for the sake of safety.

(4) periodically inspect each part of hydraulic pump.

Example)

High-pressure hose	-------	Occurrence of cracking, fissure, etc.
Hydraulic pump pressure gauge	---------	Periodically conduct inspection test or replacement. (At least once a year as a standard, and distinctly make the date of inspection and replacement on the pressure gauge.)
Various joints	---------	Occurrence of backlash and oil leaks.
Jack bolts	---------	Denting of threads.

•Lift up the cylinder head with eye-bolt.



(c) Combustion surface check

Remove the carbon perfectly before checking.

[Check]	[Probable Cause]	[Remedy]
(c1) Excessive carbon deposits	→ Fuel oil unsuitable	→ Analyze fuel oil

NOTE : Engines burning heavy fuel are liable to more carbon deposits, which are permissible, however, unless other parts are adversely affected.

(c2) White deposits excessive	→	Lubricating oil TBN unsuitable	→ Select lubricating oil with low TBN
(c3) Corroded	→	Cylinder overcooled	→ Enforce strict temperature control.

(c4) Make a dye check.

- •Cracked →
  - Cylinder overcooled (Temperature control faulty) → Enforce strict temperature control → Standard cylinder outlet temperature: 70°C to 80°C
    - Thermostat faulty → Replace element
  - Maximum cylinder pressure too high → Adjust maximum pressure
  - Cracked parts →
    - Slightly cracked → Repair by grinding
    - Seriously cracked → Replace

NOTE : Contact our service station if find corroded parts and cracked parts.

(d) Cylinder head reassembling

Reassembling is carried out in the reverse order to overhaul.

- Before mounting the cylinder head, carry out cleaning of the threads of cylinder head stud and also cleaning of the topside of cylinder head.

(Take remedies beforehand against the tear, impression etc, of the mating surface of cylinder stud nut.)

-Primary tightening

Tightening the nuts by hand after loosening the nuts.

-Intermediate tightening

Increase the hydraulic pressure up to 65MPa and turn the nut by Nut turning rod to tighten the nut so as to come in close contact securely with the bearing surface of cylinder head. Thereafter, open the check valve of hydraulic pump to return the hydraulic pressure to approx. 5MPa and make sure that the nut is in close contact with the bearing surface of cylinder head.

(There is a possibility that the jack may be caused to move when hydraulic pressure is returned to as low as 0MPa.)

-Final tightening

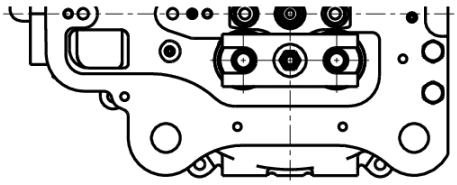
Close the check valve of hydraulic pump to increase the hydraulic pressure up to 130MPa and tighten the nut by Nut turning rod.

-In case of tightening by two studs

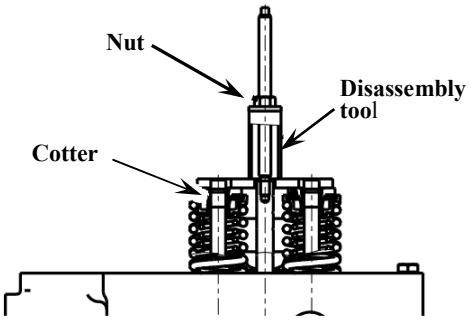
Tighten the diagonally opposite cylinder head stud nuts as intermediate tightening.
Then tighten the remaining two stud nuts equally.
After that tighten the two each stud nuts to final tightening.

(3) Exhaust valves and exhaust valve seats check

(a) Intake valve and exhaust valve disassembly procedur



- Remove the intake and exhaust valve rocker gears assembly.
- Attach the tool (spring remover).
- Tighten the nut, and remove cotter.



⚠ CAUTION
When disassemble the spring part, care must be taken not to damage with jumping part.

(a1)Checking exhaust valves and exhaust seats.

[Check]	[Probable Cause]	[Remedy]
•Carbon deposits excessive	Fuel oil unsuitable (Carbon residue or ash content excessive)	Analyze fuel oil
	Fuel injector not operating properly	Test fuel injector
•Valve seat damaged	Exhaust gas temperature too high	Grind or lap seat
	Valve rotator faulty	Replace
	Fuel oil unsuitable → Sulfur Vanadium Sodium Contents Excessive	Analyze fuel oil
•Valves and valve seats corroded		Replace if seriously corroded

(a2) Make a dye check exhaust valve stem → Replace if cracked

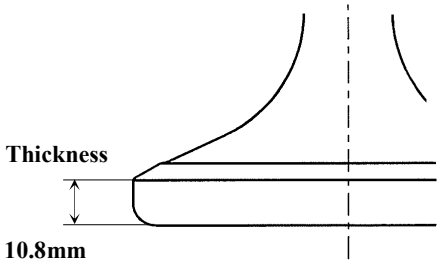
(a3) Measure the valve stem bend and diameter → Replace if over-limit

Refer to Paragraph **5.1** Parts Adjust Standers

(a4) Valve spring check → Replace if damaged

(b) Lathing or grinding exhaust valves and exhaust valve seat

(b1) Check the thickness of the bottom end of the valve, and see that the seat reinforcement has enough allowance for correction



(b2) Exhaust valve stem and seat correction

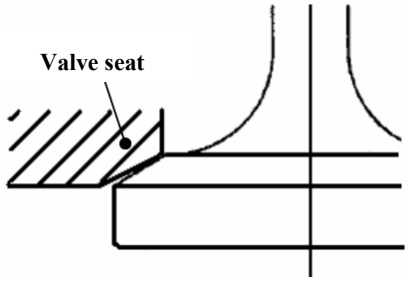
Correct the exhaust valve and valve seats only when correction is really necessary. Excessive correction thins the seat reinforcement, and thus shortens the lives of the valve and valve seat. After several hundred hours of operation, the valves and valve seats develop a pattern, which gives a misleading impression, as the valves and valve seats with such a pattern are still usable for quite a long time. The pattern on the seats is very fine, and hardly poses problems. Be careful not to unduly correct the seats having such a pattern because it can rather worsen them.

(b3) Hang a tool on the ditch in the upper part of the exhaust valve seat, and pull it out. Confirm whether to cause corrosion etc. in the exhaust valve seat and cylinder head. When the exhaust valve seat is assembled again, put dry ice into alcohol, place a new exhaust valve seat into it, to cooling in beginning.(Refer to**7.5.1(4)(C)**) In that case, do not put it in the O-ring part to prevent stiffening by cooling the O-ring. Next, the cooled exhaust valve seat is built into the cylinder head so as not to do damage O-ring. When it returned normal temperature, fit it securely into place by striking it with hummer. In that case, use a pad so as not to damage the exhaust valve seat by striking it.

Valve Seats Where Correction Is Required

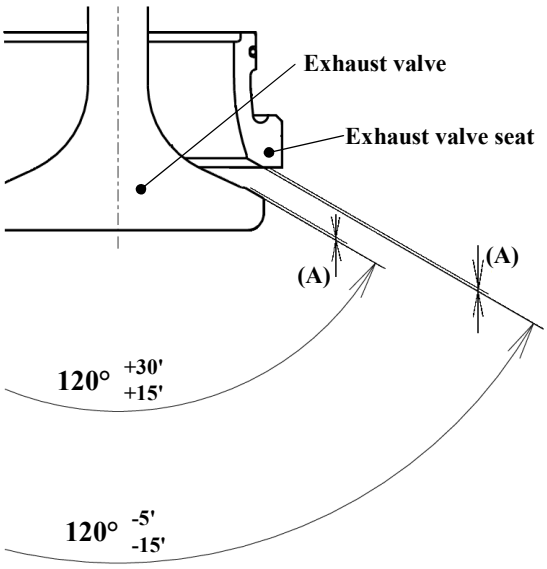
Correct the valve seats in any of the following cases.

- With the valve pushed to the valve seat by hand, a clearance gauge of 0.04 mm can be inserted between seat and valve.
- The valve and valve seat contact each other along the inner edge (As shown below).
- The seat is dented, burnt, or otherwise damaged.
  - If serious damage is found, or if the seat is cracked, the seat cannot be repaired for reuse.



(b4) Lathing seats

Lathe the exhaust valve to 120°(+15′~ +30′) and the exhaust valve seat to 120°(-5′~ -15′) as shown below. Use a lathe, avoid a grinding machine due to the cause of reinforcement cracking. Finish the surface like the mirror.



Correct limit (A)=1.5mm

NOTE : Observe the following conditions when lathing the exhaust valve seats.		
	Exhaust valve	Exhaust valve seat
Material in seat	NIMONIC	STELLITE No.6
Cutting speed min^{-1}	100 to 130	100 to 130
Feed mm/rev	0.1~0.12	
Cutting tool	JIS K10 or HTi 10 made by Mitsubishi Metal	

(b5) Seat contact check

Check seat contact after lathing or lapping the exhaust valves and exhaust valve seats. Make sure that the seats uniformly contact the peripheral edge or about 1/2 to 2/3 of the contact surface from the peripheral edge.

(b6) Exhaust valve lapping procedure

- Set the valve to lapping tool.
- Coarse lapping

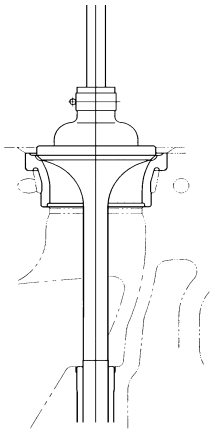
  Use carborundum No. 150. Hold the tool handle, and rotate it pressing below.
- Intermediate lapping

  Use chromium oxide powder
- Finish lapping

  Use seed oil for lapping

NOTES : (1) Be careful not to use mineral oil together with carborundum or chromium oxide because it tends to produce scratches.

(2) Continue each lapping until the seat face has a complete fit. Finish lapping, in particular, must make the seat face like a mirror.



Valve Seat Lapping Method

(c) Exhaust valve guide check

The exhaust valve guide is driven into the cylinder head. Measure its inside diameter as it is. If the inside diameter measurements taken at the top and bottom of the exhaust valve guide exceed the permissible limit, replace the valve guide.

-Refer to Paragraph **5.1** Parts Adjust Standards

NOTE : If the valve guide is very worn, gas leakage from the guide increases and simultaneously causes uneven wear to the valve seat and adversely affects valve durability.

(4) Intake valve and intake valve seat check

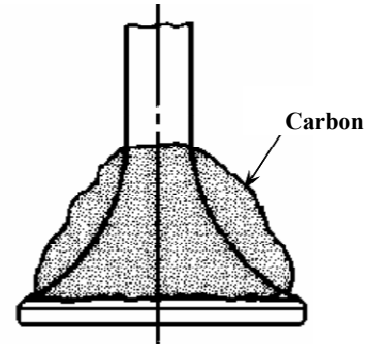
(a) Intake valve and intake valve seat check

[Check] **[Probable Cause]** **[Remedy]**

(a1) Carbon deposits on back of valve → Intake valve guide worn → Replace intake valve guide

→ Clearance excessive → Rocker gears lubricating oil drop

→ Low load operation long time → Prohibited



(a2) Seat face roughs → Lathe or lap seats.

Seat face irregularly → Intake air overcooled

→ Water condensation → Intake air temperature control: 40 to 60°C

NOTE : Intake valve sheet abrasion depends on the water condensation in the charge air. Check the air cooler outlet drain quantity. If the quantity is excessive , control water quantity , keep inlet air temperature 40~60°C.

(a3) Make a dye check intake valve stem → Replace if cracked

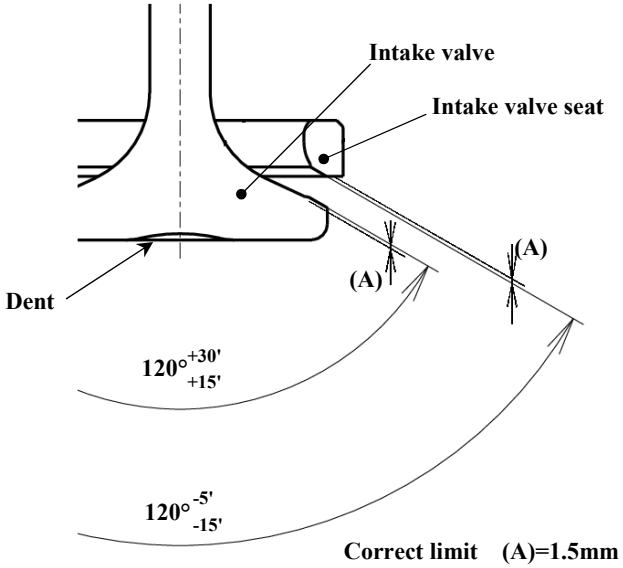
(a4) Measure the valve stem bend and diameter → Replace if over-limit Refer to Paragraph **5.1** Parts Adjust Standards

(a5) Measure the valve guide inner diameter → Replace if over-limit Refer to Paragraph **5.1** Parts Adjust Standards

(a6) Valve spring check → Replace if damaged

(b)Intake valve and intake valve seat lathing and lapping procedure

(b1)Intake valve and intake valve seat lathing ⟶ In case of damaged seat surface



NOTE : Be careful when valve assemble, the seat angle same as exhaust valve.
It possible to distinguish intake and exhaust valve, check the distinct dent at the center of valve .

NOTE : Observe the following conditions when lathing the intake valve seats.		
	Intake valve	Intake valve seat
Material in seat	heat-resistant cast iron	STELLITE No.6
Cutting speed min^{-1}	xxx ~ xxx	100 ~ 130
Feed mm/rev	0.1 ~ 0.12	0.1 ~ 0.12
Cutting tool	JIS K10 or HTi20 ,made by Mitsubishi Metal	Igetalloy H2 made by Sumitomo Metal or H10 made by Mitsubishi Metal

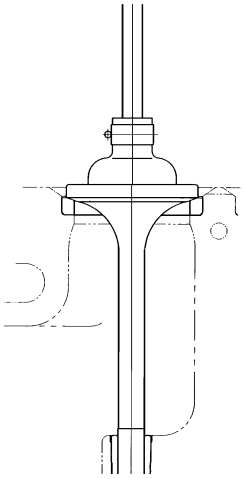
(b2) Seat contact check

Check seat contact after lathing or lapping the exhaust valves and exhaust valve seats. Make sure that the seats uniformly contact the peripheral edge or about 1/2 to 2/3 of the contact surface from the peripheral edge.

(b3) Exhaust valve lapping procedure

- Set the valve to lapping tool.
- Coarse lapping
  Use carborundum No. 150. Hold the tool handle, and rotate it pressing below.
- Intermediate lapping
  Use chromium oxide powder
- Finish lapping
  Use seed oil for lapping

NOTES : (1) Be careful not to use mineral oil together with carborundum or chromium oxide because it tends to produce scratches.
(2) Continue each lapping until the seat face has a complete fit. Finish lapping, in particular, must make the seat face like a mirror.



Valve Seat Lapping Method

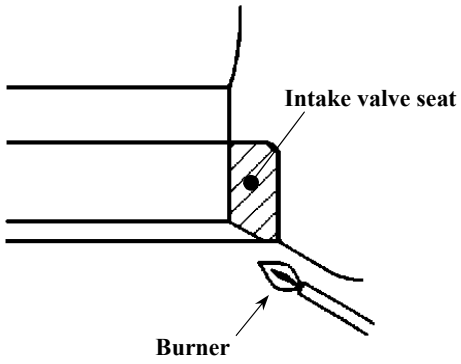
(c) Intake valve seats exchanging procedure

If an intake valve seat is seriously worn, replace it as mentioned below.

Intake valve seat removing method

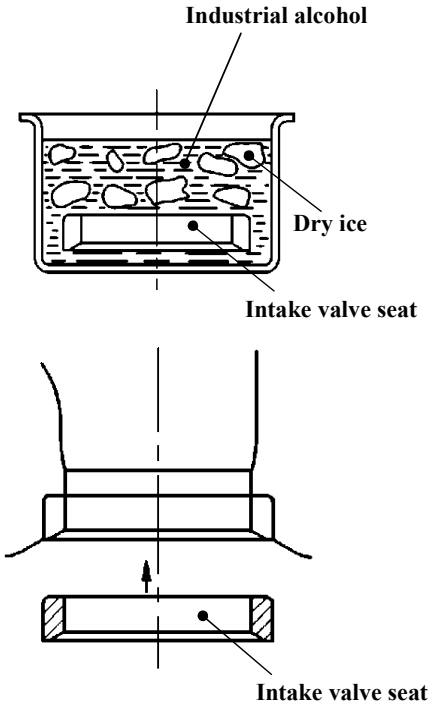
Heat and blow off the intake valve seat at 2 or 3 points with a burner, and then cool it rapidly.

The intake valve seat shrinks so it can be taken out.



Intake valve seat assembling method

- Put dry ice into alcohol. Place a new intake valve seat into it, and let it cool for about 20 minutes.
- Fit the cooled intake valve seat into the cylinder head.
- When the intake seat has returned to normal temperature, fit it securely into place by striking it with a hammer. Use a pad so the striking will not damaged the intake valve seat.



CAUTION
Wear thick groves or similar protection and excise much care in doing the above work because the cooling liquid is very cold.

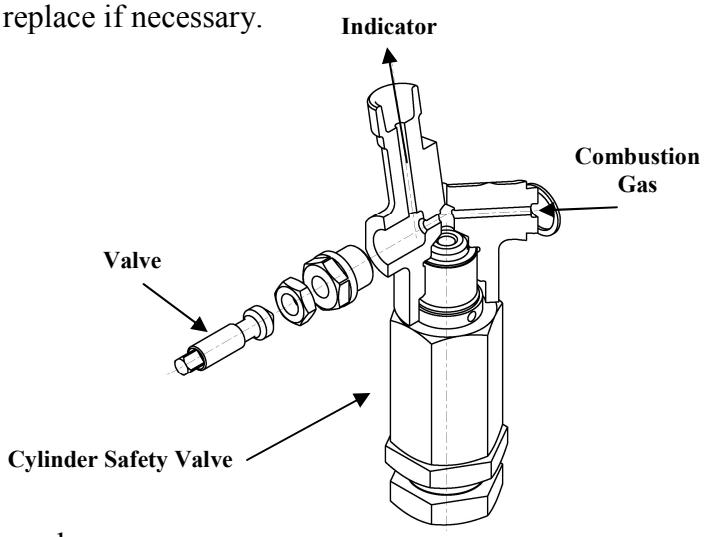
(d) Intake valve assembling procedure

Use the same tools as used for disassembly, and reverse the disassembly procedure.

(5) Intake and exhaust valve rotator check

Check the valve rotators for rotation, and replace if necessary.

(6) Indicator cock check



(a) Mounting and reassemble of the indicator cock

Must stop the engine when Mounting or reassemble of the indicator cock.

(b) Indicator cock check

・Indicator cock seat check.

・Indicator cock seat lapping. ⟶ Replace if damaged.

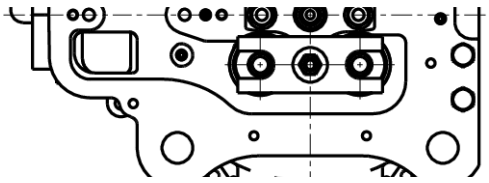
⚠ CAUTION
(1) Installation and disassembly may only be done on switched-off engine.
(2) Even on a switched-off engine the parts can be very hot for reasonable period of time. Wear protective gloves.

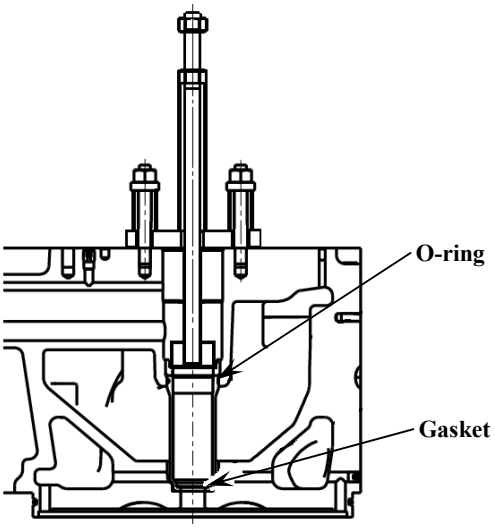
(7) Fuel valve body pipe check

(a) Fuel valve body pipe removal

・Remove the fuel vale body pipe

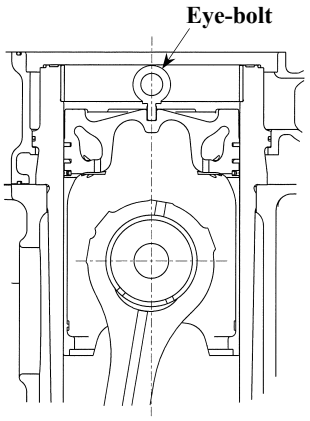
・Replace the O-ring and gasket.





7.5.2 Piston, connecting rod check

(a) Piston and connecting rod removal

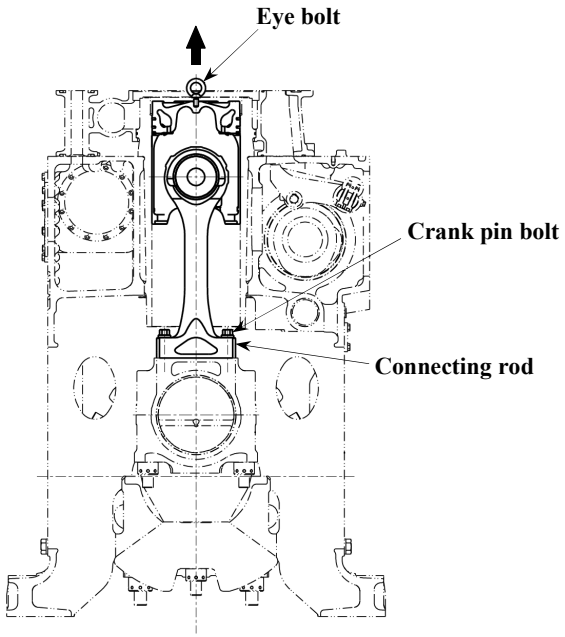


(a1) Preparations for removing piston and connecting rod

- Remove the cylinder heads --- Refer to **7.5.1 (2)**
- Remove the fire ring. --- Refer to **7.5.3 (1)**
- Turn the crankshaft until a piston comes to 40° before top dead center, and stuff grease between the piston and liner.
- Thoroughly remove carbon from the tops of the liners in which the pistons do not slide. Exercise care not to damage the liners or touch the sliding face.
- The above steps are preparations for smooth removal of the pistons from the cylinder liners.
- Clean the tapped hole for lifting tool in the top of the piston heads, using a tap.
  - Screw size : M16×2.0 (pitch)
- Set a eye-bolt to the cleaned screw holes.

(a2) Piston and Connecting rod cap removal procedure

- Set the socket and the ratchet handle from the crankcase door
- Loosen the crank pin bolts.
  At this time, the bolts are temporarily tightened in the extent that can be turned by the hand.
- Turn and adjust the piston to the top dead center**.**
- Remove the crank pin bolts.
- Pull out the piston and the connecting rod gradually.



It is dangerous to rotate the big end cap when crank pin bolts are removed.
Be careful to pull out connecting rod.

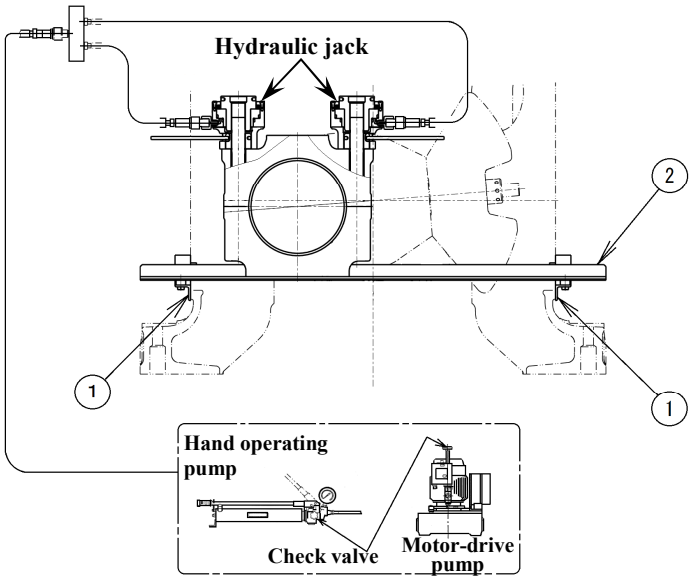
(b) Connecting rod big end cap removal procedure

- **T**urn the crankshaft, the crank pin set to the 90° before top dead center position.
- Install the guide rail bracket ① in the crankcase door on both side.
- Install the guide rail ② in the crankcase, and fix to the guide rail bracket ①.
- Loosen the crank pin stud nuts by hydraulic jack.

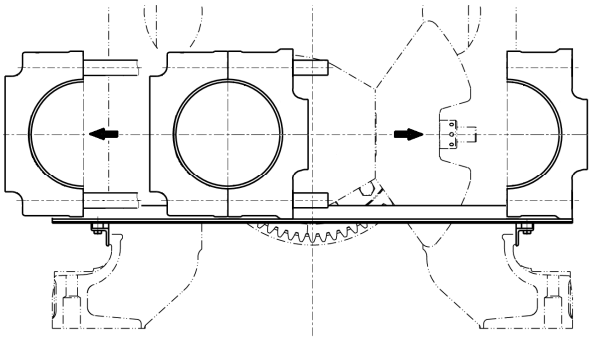
(b1) Big end cap put on the guide rail. At this point, set the crank pin stud nut to upper.

(b2) Set the two hydraulic jacks to crank pin stud nut.

(b3) Loosen the crank pin nut. At this time, the nut is temporarily tightened in the extent that can be turned by the hand.



- Make the connecting rod big end horizontal. The big end cap put on the guide rail and remove the nuts.
- Separate the end cap and pull out from the cylinder block.



＊ Reassembly procedure

Assembly procedure is carry out in the reverse order to disassembly procedure.

The mark of crank pin and stud nut fit securely.

(c) Piston check

(c1) Pistons

[Check] **[Probable Cause]** **[Remedy]**

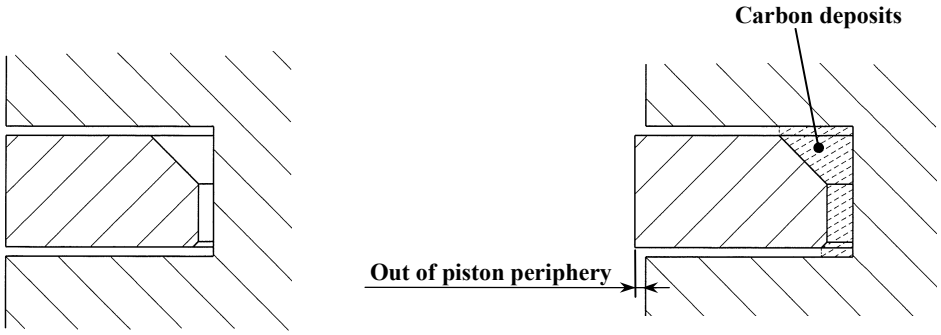
- Excessive carbon deposits on surface
  - → Fuel oil unsuitable
    - → Carbon residue excessive → Analyze fuel oil
  - → Imperfect combustion
    - → Fuel injection valve faulty → Test fuel injectors
- Excessive white deposits
  - → Lubricating oil T.B.N. unsuitable → Use lubricating oil with low T. B. N
  - → Lubricating oil consumption too much → Consumption measures

(c2) Piston ring check

- Check the piston rings for stains and stickiness.

  Piston rings that have an appropriate amount of lubricating oil and that move freely are normal.

  If carbon deposits in the gaps between the piston rings and ring grooves make the rings stick or hard to move, it is abnormal. If this is the case, the rings might be out of the piston periphery.



Carbon Deposits in Ring Groove Clearances

[Check] **[Probable Cause]** **[Remedy]**

- Ring groove dirty or worn → Oil rings faulty → Measure rings and ring grooves or worn → Refer to **5.1** Adjustment Standards for main parts. Replace if necessary
- Lubricating oil deteriorated → Analyze lubricating oil → Change lubricating oil if analysis results require it

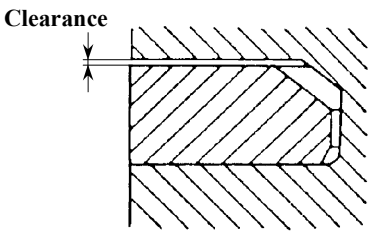
- Measuring ring dimensions

  It is necessary to measure all the rings.

  (No.1 and No.2 compression rings and the oil ring.)

Measuring Ring Groove Clearance

With clearance gauges, measure the clearances between the piston rings (No. 1 and No. 2 compression rings, and the oil ring) and the piston ring grooves at several points of the circumference and records the measurements.



[Check] **[Probable Cause]** **[Remedy]**

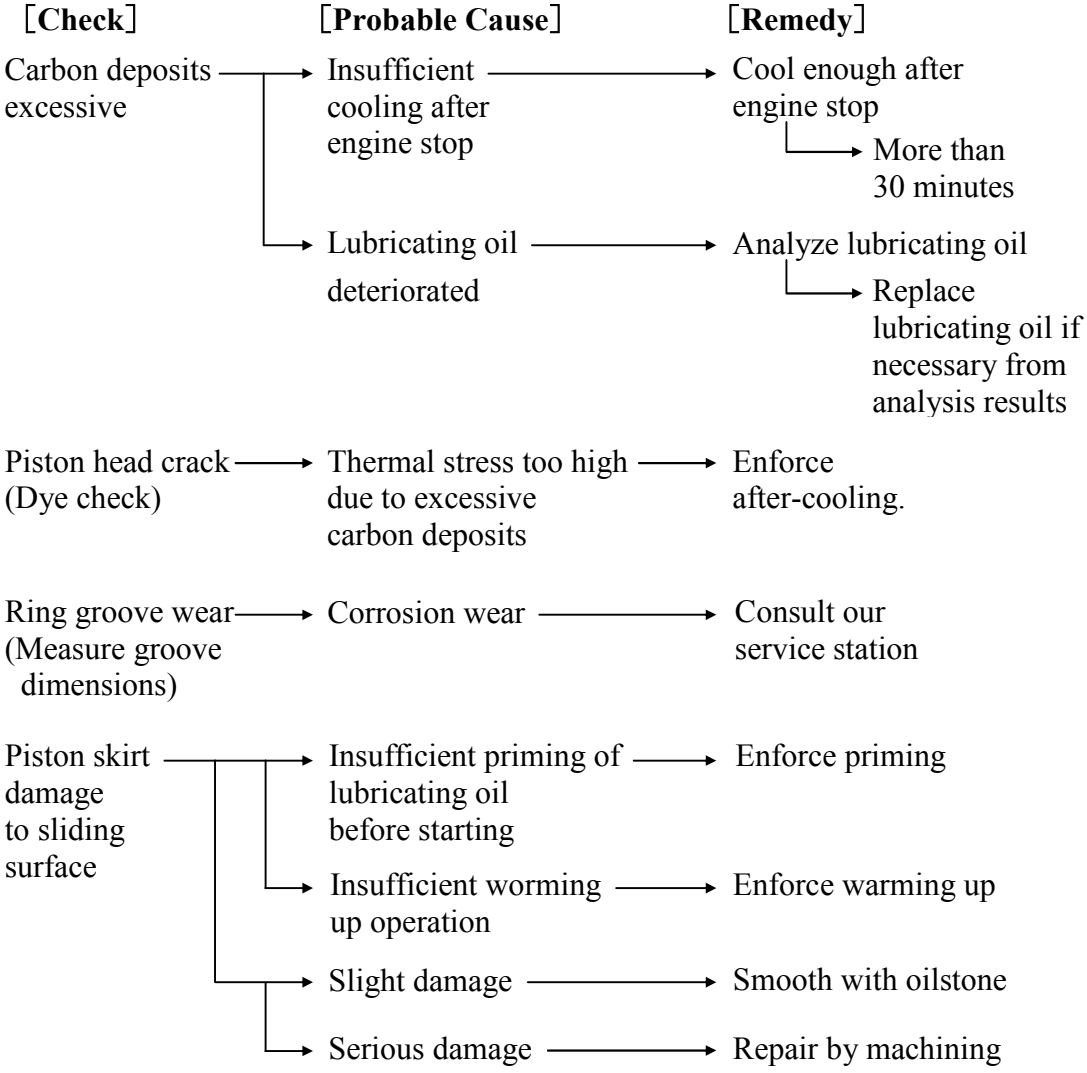
Excessive clearance

- Ring worn → Replace
- Ring groove worn
  - Work groove over size
  - Use over sized rings

NOTE : When you need over-sized rings, please inform us detail of it, beforehand.

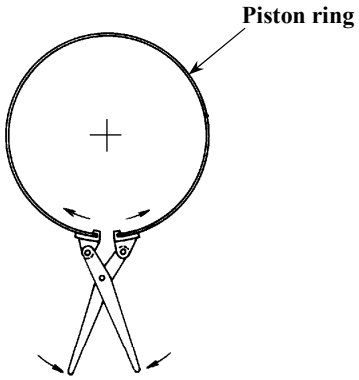
- Check that the compression rings (No.1 ring is made of special coating) have normal chrome plating on their outer surfaces, and no traces of blowby.
- Check that the oil rings are free of abnormal (uneven) wear, and have no damage to the lip at all.

(c3)Piston check

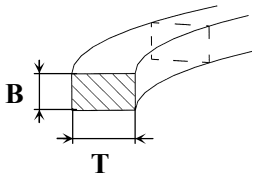


(d) Piston ring removal

Use the piston ring removing/fitting tool when removing piston rings.



Piston ring removing/fitting tool



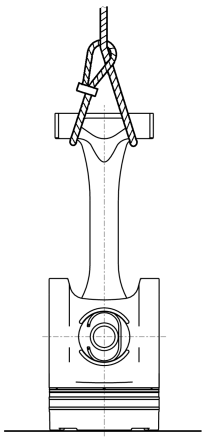
Ring	Original size	
	B [mm]	C [mm]
Top ring	6 -0.01 -0.03	10.4 ±0.15
Second ring	6 -0.01 -0.03	10.4 ±0.15
Oil ring	6 -0.013 -0.028	5.5 ±0.15

(d1) Measure piston rings and oil rings for wear

→ Replace rings seriously or unevenly worn

(e) Piston and connecting rod disassembly procedure

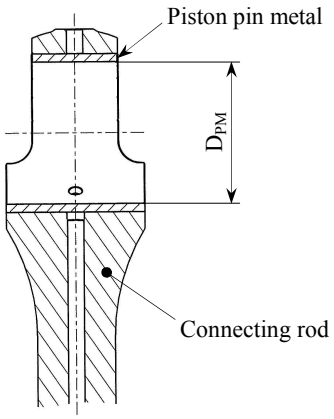
- Lift the piston and connecting rod assembly upside down, place it on a wooden board, and keep the connecting rod lifted so it will not fall.
- Remove the piston pin snap ring of one side with snap ring pliers.
- Pull up the connecting rod slightly and extract the piston pin



Piston and Connecting Rod Assembly Lifting and Placement

(f) Piston pin bearing check

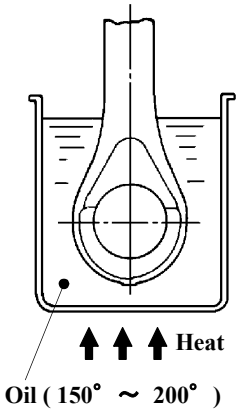
- Visually check the inner surfaces of the piston pin bearings.
  -Replace piston pin bearings that have serious scratches on their inner surfaces.
- Make a dye check on the inner surface.
  -Replace piston pin bearings that have cracked surfaces.
- Measure the inside diameter.



Measuring points		Measured valves	Permissible value
D_{PM1}	X direct.		Φ130.21 mm or less
	Y direct		
D_{PM2}	X direct		
	Y direct		

Piston Pin Bearing Inside Diameter Measuring Piston Pin Bearing Replacement Procedure

- In the shop, use a hydraulic jack to push out piston pin bearings.
- Measure the inside diameter of the connecting rod small end and the outside diameter of the bearing, and verify that shrink fit allowance is within the standard range of 0. 075 to 0. 12 mm.
  Heat the small end of the connecting rod in heated oil of 150°C to 200°C for 20 to 30 minutes.
  Don't use the fuel oil for heating.



- Completely wipe the oil off the contact surfaces of the connecting rod and bearing, and fit the bearing into the connecting rod. Heat the connecting rod until the bearing can be easily fitted into place.

NOTES : (1) The piston pin bearings have an overlay of lead and tin, but whether they should be replaced is not determined by the extent of wear to the overlay.
(2) Never use a file or sandpaper for smoothing roughened bearing surfaces. Simply use a scraper to remove projections.
(3) Determine whether piston pin bearings require replacement by measuring bearing wear. Clearances between piston pins and bearings may be used as reference data for repairs.
(4) Don't use the fuel oil for heating connecting rod.

(g) Connecting rod check

- Visually check the trunks of the connecting rods, or make a dye check on them, to verify that they are free of cracks and scratches.
- Check for condition of the mating surface of the connecting rod big-end and ,if occurrence of fretting etc. is observed ,make repairs with oil-stone.

⚠ CAUTION

If damage are found as below, consult our service station for repair methods because it may cause serious accident.

(1) Crack or scratches on the trunks of the connecting rods.
(2) Crack or fretting at serration parts.
(3) Crank pin stud screw hole is damaged.

(h) Crank pin stud check

- Check the threaded parts and seats of the crank pin studs for scratches. Replace if damaged.
- Check the shanks of the crank pin studs for rust and corrosion, and replace rusty studs.

NOTES : (1) The crank pin studs are the most important parts, which are exposed to the severest conditions. Thus, it is necessary to replace them periodically even if they appear normal.

Standard replace period 24,000 hours.

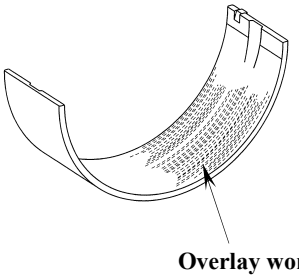
(2) If an abnormal force is suspected to have been applied to the crank pin studs during engine operation (due to overspeed, for example), replace them regardless of their appearance.
(3) If crank pin stud seats are corrected, or if crank pin studs are replaced, tighten the bolts in according to Paragraph **5.2** Tightening Specification of Main Parts and punch countermarks.

(i) Crank pin bearing check

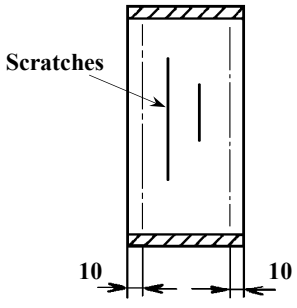
[check] **[Probable Cause]** **[Remedy]**

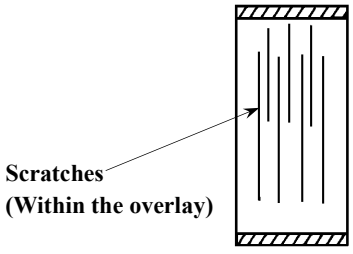
- Surface peeled or cracked → Lubrication faulty → Replace bearings
  - → Check lubricating oil system
- → Lubricating oil deteriorated → Analyze lubricating oil

- Overlay worn → Worn more than 30% → Replace
  - → If overlay wear is less than 30%, bearing is still usable
    (If overlay wear is expected more than 30% by next maintenance. Replace)



- Check inner surfaces for scratches due to foreign matter.
  Used bearings have some scratches due to foreign matter, but serious scratches may cause problems. Observe the following criteria.
  - Scratches made by foreign matter within 10 mm from the bearing edges are permissible.
  - Bearings with scratches made by foreign matter more than 10 mm inward from the bearing edges may be used again in the following cases.
  - Scratches reaching the kelmet layer and shiny, but not continuous all around, and more than 2 mm apart from each other are permissible.
  - Scratches within the overlay (not reaching the kelmet layer) are permissible even if they are continuous all around and are close to one another.

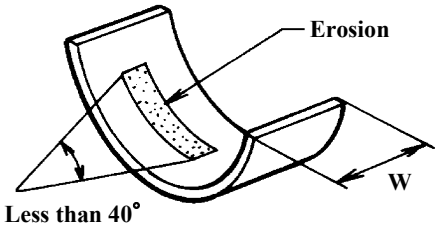




⚠ CAUTION

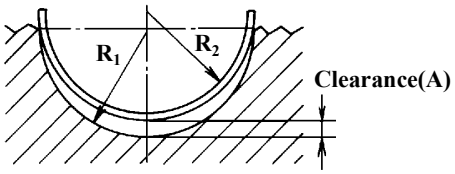
Do not repair bearing surface because will cause bearing seizure.

- Check for foreign matter which stuck into the bearing surface.
  If foreign matter is striking into the bearing surface and makes a bulge around it and has gloss, remove the foreign matter, and carefully finish the part around it with a scraper.
  If the sticking of foreign matter occupies as much as 2/3 of the bearing surface, replace the bearing
- Check for erosion.
  The bearings are subject to erosion due to lubricating oil pressure distribution, but these hardly cause problems. Whether eroded bearings are usable can be determined by the following standard.
  - Bearings eroded less than 1/5 of their width at the center and less than 40° of their inner circumference can still be used.



[Check]	[Remedy]
• Lack of tension	Replace.

Place a bearing in the bearing housing in a natural state, and if the clearance (A) between its outer surface and the bearing housing is less than 0.5 mm, replace the bearing.

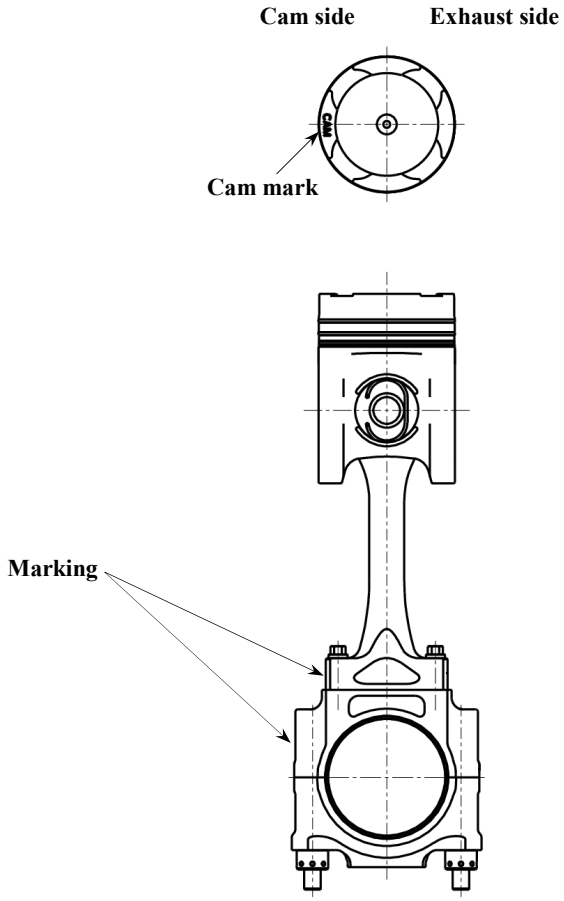


(j) Lubricating oil hole check
Clean the oil hole with light oil, and air blow.

(k) Measuring big end and small end inner diameter

(l) Piston and connecting rod assembly procedure

- Place a piston upside down.
- Make sure air to flow through the oil way to clean up the inside and, at the same time, make sure that the oil way is free from abnormality.
- Fit a piston pin snap ring into place on one side only.
- Apply lubricating oil to the piston pin and piston pin bearing , insert piston pin into piston.
- Place the together snap ring into place.

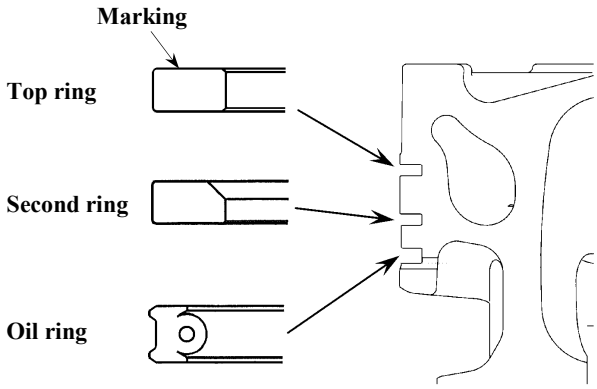


Assembly marks on piston and connecting rod

NOTES : (1) Check that piston and connecting rod are same cylinder number and it marking (cam side) before assembling them. And check that assembling directions are correct and agreement.
(2) Check that snap ring has properly tension. Replace, if not.

(m)Piston ring installation procedure

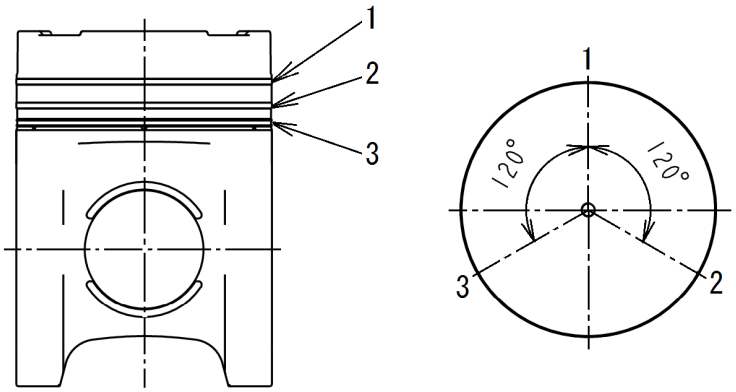
- Fit new piston rings into the ring grooves with the piston ring removing/ fitting tool.
  -Refer to **7.5.2(d)**
- At first, insert the oil ring with the piston groove.
- Be careful of the ring directions, and make sure that the various rings are installed in the correct position in the correct way.（Piston ring and oil ring's marking is combustion side）



Kinds of piston ring and their installation positions

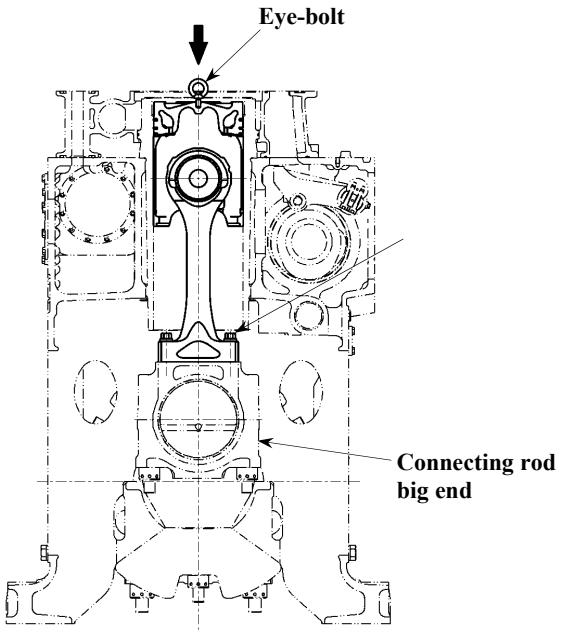
(n) Piston and connecting rod installation procedure

- Thoroughly clean the crank pin bearings with light oil.
  As in cleaning the crank pin bearings, do not use coarse rags, but wipe them carefully with a soft, clean cloth.
- After wiping the backs of the bearings and the inner surfaces of the connecting rods and caps dry with a clean cloth to remove oil, fit the bearings into the connecting rods and caps.
- Apply fresh lubricating oil to the inner surfaces of the bearings, using the palm of your hand.
- Make sure that the ring end gaps of adjacent rings are diametrically opposite each other.

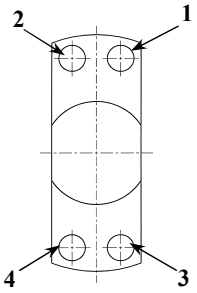


Piston Ring End Gap Positions

- Set a eye-bolt.
- For the subsequent steps, assembly procedure is carry out in the reverse to disassembly procedure.



- Tighten the crank pin bolts as described below until the counter-marks are aligned. Tighten the four bolts uniformly in diagonal order in three steps - primary tightening, intermediate tightening, and final tightening.



Tightening order: 1→2→3→4

- When replacing crank pin bolts, tighten them in the above manner in three steps - primary tightening, intermediate tightening, and final tightening - by referring to the bolt elongation standard described in Paragraph **5.2** Tightening Specification of Main Parts.

⚠ CAUTION

(1) The crank pin bolts are particularly important parts which must handled with great care, and tightened with the correct tightning force.

Faulty, tightning, and, in particular, insufficient tightning is very dangerous as it can lead to a serious accident.

(2) Whenever engine overspeed trouble or a serious piston scuffing has occurred, be sure to replace the crank pin bolts even if they appear normal. This is essential for safety.

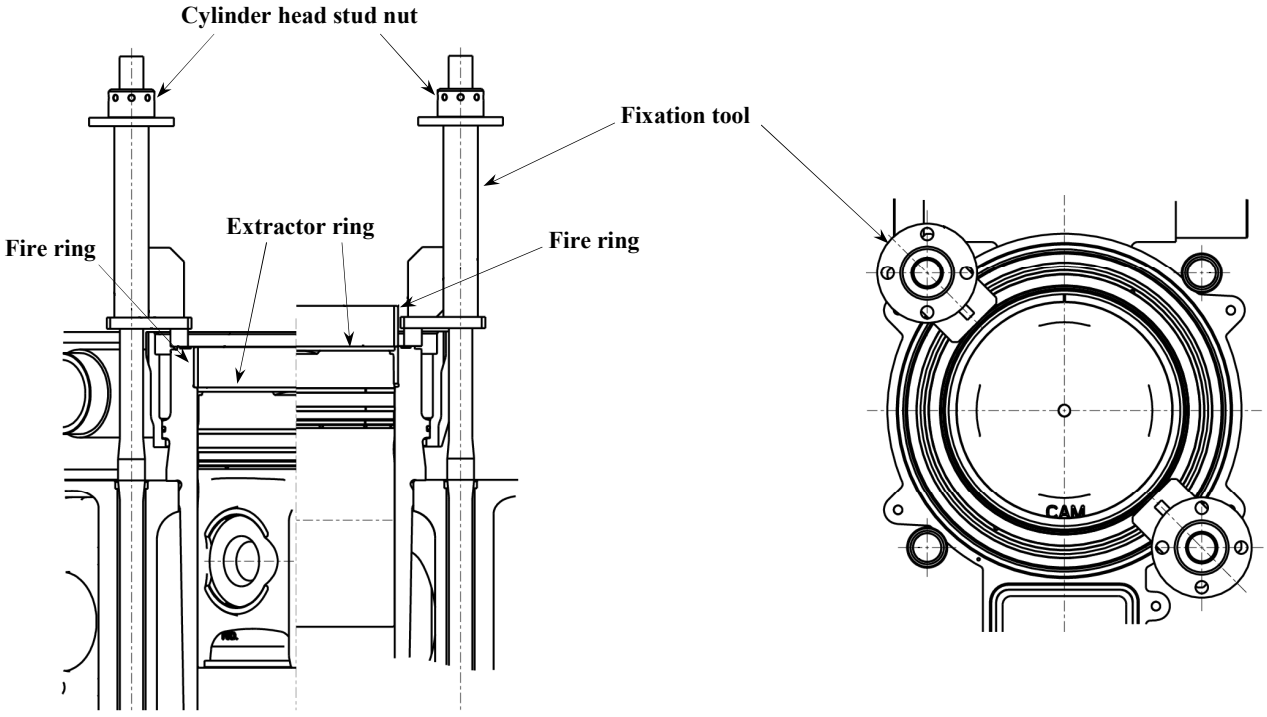
(3) When renewing the crank pin stud & nut. Clamp them temporarily under the regular hydraulic presser outside the engine. After stamping match, assemble them into the engine and be sure to check that match marks will match with each other.

7.5.3 Cylinder liner check

(1) Fire ring check

(a) Fire ring removal procedure.

- Set the fixation tool using the cylinder head stud nuts.
- Turn crank shaft and go down piston.
- Set the extractor ring between piston and fire-ring.
- Remove the pin and the fire ring after raise the piston position by turning.



Before turning **After turning**

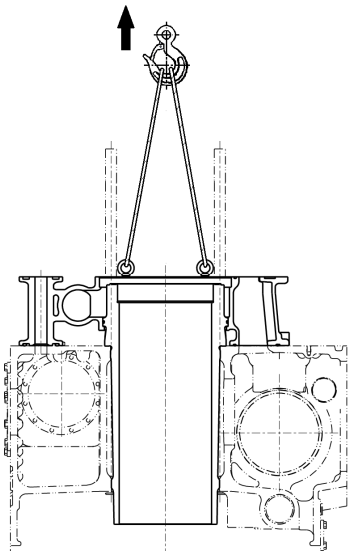
(b) Fire ring check

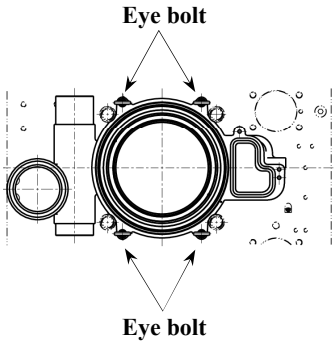
[Check]		[Remedy]
(b1) Damage to sliding	Slight	Smooth with oilstone
	Serious	Replace gears
(b2) Make a dye check		Replace if cracked
(b3) Measure the fire ring diameter		Replace if over-limit
(b4) Measure clearance between liner and fire ring		Replace if over-limit

(2) Cylinder liner check

(a) Cylinder liner removal procedure

- Remove piston and connecting rod.
- Fix the eye bolt at the top of liner ri (M12 4 place)
- Pull out the liner ring with cylinder liner.





(b) Liner check (without removing the cylinder liner from the engine)

(b1) Inner surface condition

[Check]	[Probable Cause]	[Remedy]
• Scuffing • Scratching	Cylinders overcooled	Carefully regulate cooling water temperature - Refer to Paragraph **5.3** Temperature Settings
	Sudden increase load	Gradually increase in load
	Piston cooling is not enough	Check cooling water jacket of piston head for carbon deposits, and cooling oil hole for blockage.
	Compression	Check compression rings for stickiness and breakage ring faulty
	Oil ring faulty	Check oil rings for breakage
	If scuffs are slight	Smooth with oilstone
	If scuffs are serious	Replace
• Combustion parts cracked	Over load	Replace

NOTE : Liners tend to be scuffed or scratched in a relatively early period (when the liners and pistons have not yet been enough run in.)
Old scratches may be permissible if the scratches are smoothed already.

(b2) Bore measuring

- Measure the bore, and compare the values with shop inspection records to confirm the amount of liner wear.
- Measure the amounts of liner wear in crankshaft directions and at right angles thereto to confirm whether or not the cylinder liners are evenly worn.

(b3) Make a dye check

- Cylinder liner upper part (inner and outer) check

[Check]	[Remedy]
Cracked	Replace

(c) Liner check (with removing the cylinder liner from the engine)

(c1) Outer surface corrosion

[Check]	[Probable Cause]	[Remedy]
• Outer surface corrosion	Primary cooling water pressure dropped	Adjust water pressure Refer to Paragraph **5.4** Pressure Settings
	Cylinder vibration excessive	Measure vibration
	Air mix into cooling water (Air venting incomplete)	Completely remove air from cooling water
	Primary cooling water quality unsuitable	Use inhibitor
		Spread plastic metal into corroded part
		If corroded more than 8mm deep, replace

NOTE : Corrosion of the outer surface of the liner is described as cavitation corrosion, it is caused by the explosive power generated by burning fuel, liner vibration by piston slapping, and cooling water pressure, and generally occurs in thrust directions. Thus, it is necessary to regulate the primary cooling water pressure carefully. The following steps are recommended if cavitation corrosion is found.

(1) Repair method

- Smooth the corroded part with a sander or grinder.
  Necessary to completely flatten the recess made by corrosion
- Remove rust from the corroded part with a wire brush.
- Remove oil from the corroded part with paint thinner or gasoline.
- Fill the corroded recess with a well-prepared repair material such as plastic metal

using a spatula in a rubbing manner.

(2) Repair material

Repair material recommended

BELZONA MOLECULAR

Ceramic S-metal

Supplier;

BELZONA MOLECULAR INCOP.,

222 Seven Street Garden City New York 11530

Tel: (516) 746-7030

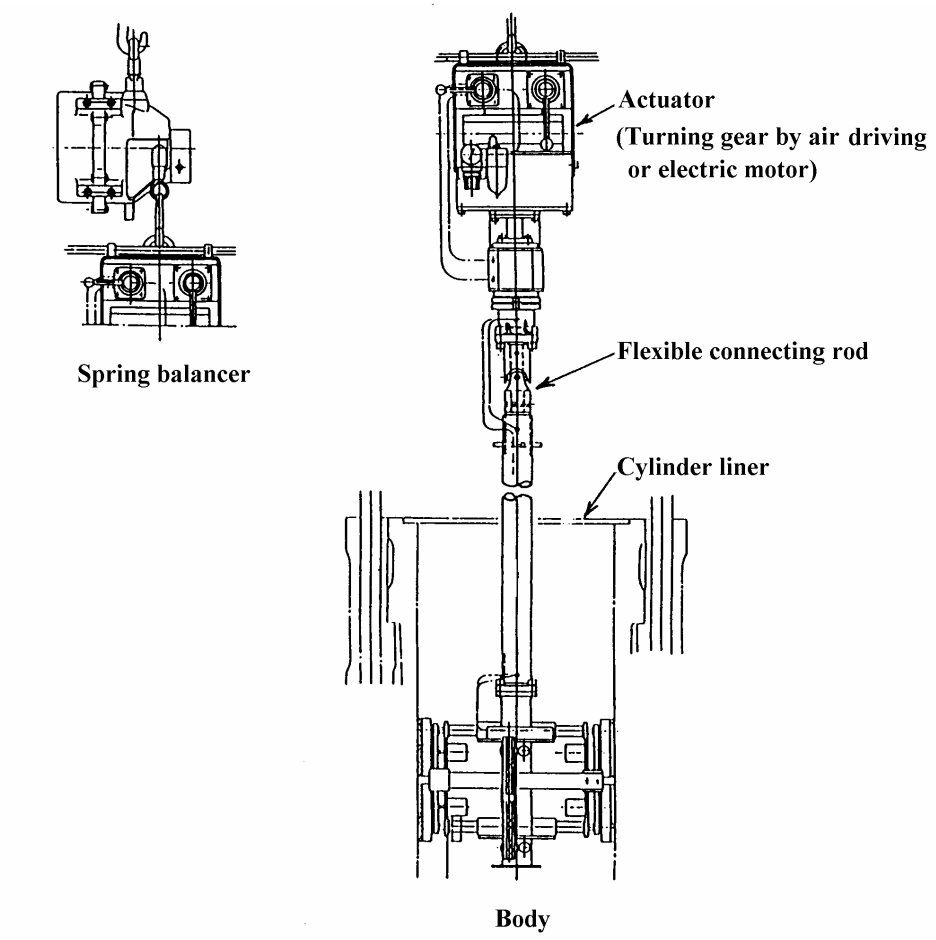
(d) Cylinder liner deglazing

If the inner surfaces of the cylinder liner are like a mirror, deglazing them to make fine oil recesses on the liner surfaces, which will ensure satisfactory lubrication and reduce liner wear.

(d1) By honing (Ra 1.6 μm): Cylinder liners must be sent to a service shop.

(d2) By grazing machine : Cylinder liner can be repaired on site.

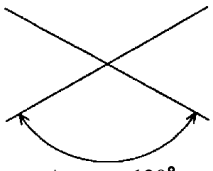
Grazing is without removing the cylinder liners from the engine. And cover the liner bottoms with a vinyl bag or the like so that grazing dust will not fall into the crankcase.

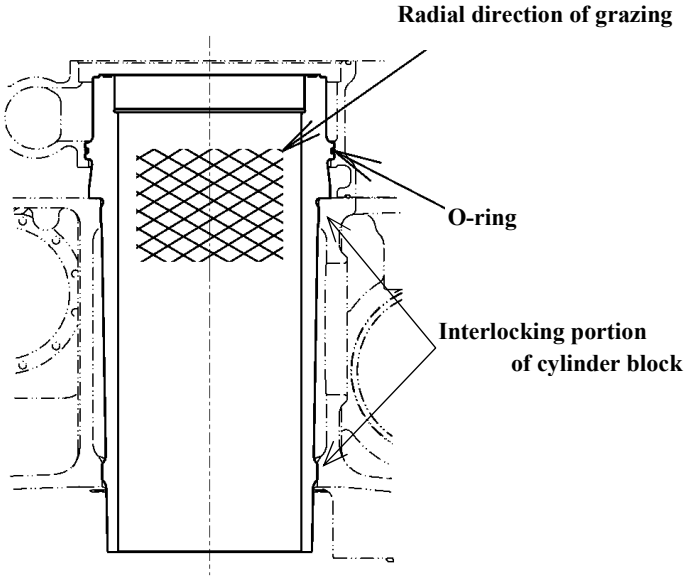


(d3) With sandpaper (No.40): Cylinder liners can be repaired on site.

Polish the cylinder liners with sandpaper (No.40) in a circumferential 120° direction, but never vertically, until traces of sandpaper are visible.

When doing this without removing the cylinder liners from the engine, cover the liner bottoms with a vinyl bag or the like so that sandpaper dust will not fall into the crankcase.





(e) Liner ring check

[Check]	[Remedy]
• Liner ring faulty	→ Repair or replace
• Check and clean rust in the water jacket.	
• Check and clean intake manifold	

(f) Cylinder liner assembly procedure

- Thoroughly clean the outer surface, and apply anti-corrosive paint to them.
- Set the cylinder liner to liner ring.
- Use the eye-bolt for lifting the liner ring with cylinder liner.

NOTE : The cylinder liners fall into place under their own weight or are pushed into place by lightly tightening the cylinder heads. If insertion is difficult, do not force them because it indicates that something must be wrong. Check for the cause of the trouble.

- O-rings not fitted properly
- Check the clearances between the cylinder liners and crank case.

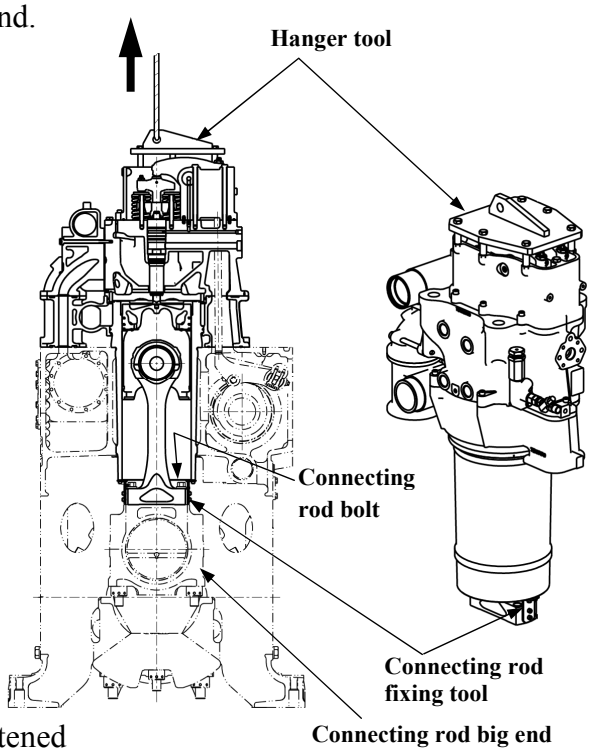
7.5.4 Cylinder unit removal, assembly procedure

(Component part: Cylinder head assembly, Rocker arm assembly, Piston assembly, Cylinder liner assembly, Connecting rod assembly, Intake and Exhaust valve assembly.)

(a) Cylinder unit disassembly procedure

(a1) Remove following parts from them beforehand.

- Cylinder head cover
- Fuel oil pipe cover
- Fuel injection pipe
- Fuel drain pipe
- Lubricating oil pipe
- Cooling water pipe
  (connection pipe, coupling)



(a2) Disassemble and fix the connecting rod

- Set the socket and a ratchet handle from the crankcase door.
- Loosen the connecting rod bolts.
  At this time, the bolts are temporarily tightened in the extent that can be turned by the hand.
- Turn and adjust the piston to the top dead center**.**
- Remove the crankpin bolts.
- Fix the cylinder liner on the connecting rod by the bolts with the connecting rod fixing tool.

(a3) Loosen the cylinder head stud nuts by hydraulic jack (tool).

- Refer to **7.5.1**(2) Cylinder head overhaul.

(a4) Lift the cylinder head unit

- Set the bracket into rocker arm support, and then pull the cylinder unit guradually.

It is dangerous to rotate the big end cap when crank pin bolts are removed.
Be careful to pull out connecting rod.

(b) Cylinder head unit reassembly procedure

Assembly procedure is carried out in the reverse order to disassembly procedure.

- Refer to **7.5.1**(2)(d) Cylinder head assembly procedure.

7.5.5 Fuel injection pump check

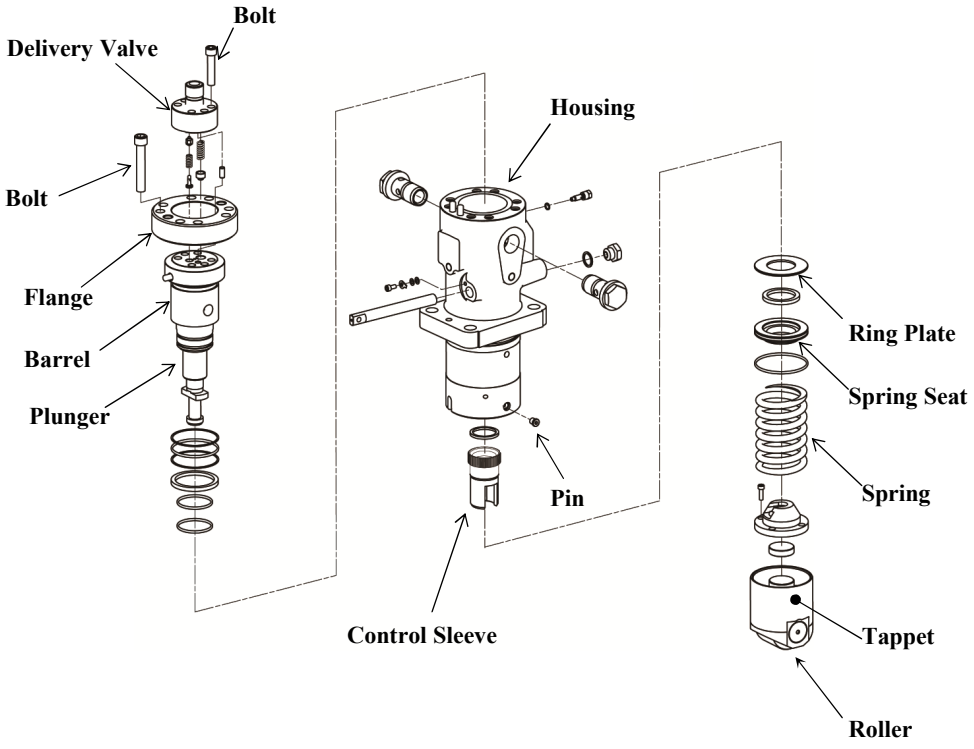
(a) Assume pump performance drop from engine performance.

[Check]	[Probable Cause]
• Maximum cylinder pressure dropped	Plunger wear increased
Rack scale advanced	
Pump oil leakage increased	

NOTE : The lives of the fuel injection pump plungers and barrels depend largely on the properties of the fuel oil. It is advised to send the pumps to a qualified shop for judging whether the plungers and barrels are good or not.

(b) Pump disassembly procedure

- Remove the delivery valve holder at the top, and take out the delivery valve.
- Remove the flange and the barrel.
- Remove the dowel pin first and then the tappet with the plunger.
- Remove the spring and the control sleeve.
- Push out the ring plate and spring seat from the housing.



NOTE : The fuel injection pump parts are precision-finished. Immerse disassembled parts in fresh light oil to keep them free of rust and dust.

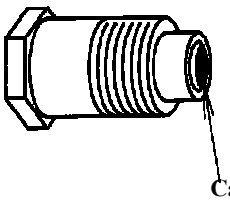
(c) Disassembly check

(c1) Plungers and barrels

[Check]	[Probable Cause]	[Remedy]
• Sliding part worn	Fuel oil unsuitable (FCC oil)	Analyze fuel oil
	Not cleaned properly	Cleaning of fuel oil tank and discharge drains
	Clean filter carefully	
		Replace filter element if necessary
• Plunger top edge broken		Replace
• Cavitation		Replace

NOTE : (1) Be sure to replace plunger and barrel as a pair.
(2) If performance has dropped without any specific trouble, replace the plungers and barrels for all the cylinders at the same time. This is necessary to prevent uneven performance (uneven rack scale positions).
(3) When changing the plunger and barrel for a specific cylinder only, adjust the rack scale by refer to **6.1.1(1)(c)** to prevent uneven loading.

(c2) Deflector inner surface cavitation eroded ⟶ Replace

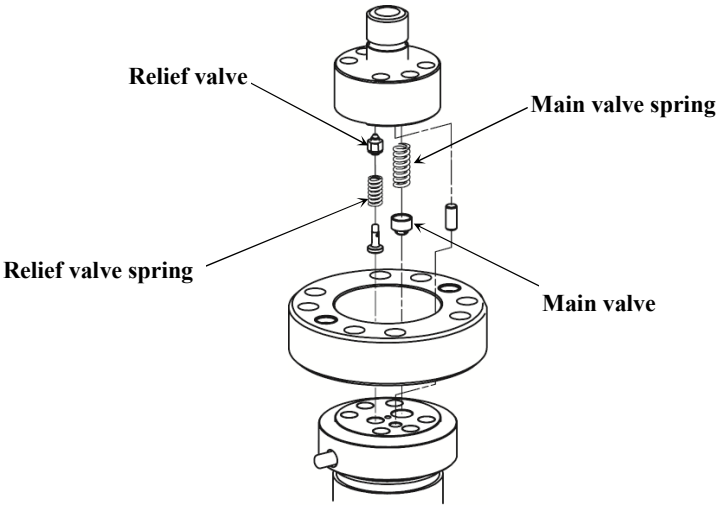


NOTE : The deflector is provided for protecting the pump body from erosion due to the return oil (high-pressure rushing oil) at the end of fuel injection. Replace it periodically because its tip becomes eroded with use.

(c3) Delivery valve check

- Disassemble the main valve and relief valve.
- Check the above valve seats and springs.

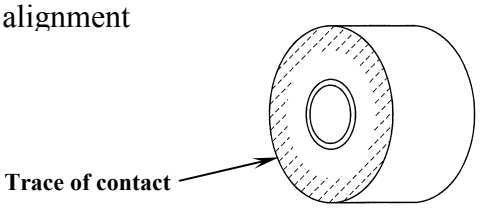
[Check]	[Remedy]
Spring and valve seat faulty	→ Replace
Irreparable body	→ Replace as assembly



Delivery valve (Constant pressure type)

(c4) Tappet roller Check

[Check]	[Probable Cause]	[Remedy]
• Damage to surface and corners		
→ Cracked or peeled	→ Slight	→ Smooth with oilstone
→ Wear	→ Serious	→ Replace
• Side contact	→ Tappet roller and camshaft out of alignment	→ Check roller and cam contact, and align them



(c5) Roller bushing

• Damage to sliding surface	→ Slight	→ Smooth with sandpaper
	→ Serious	→ Replace

(c6) Lubricating oil hole cleaning

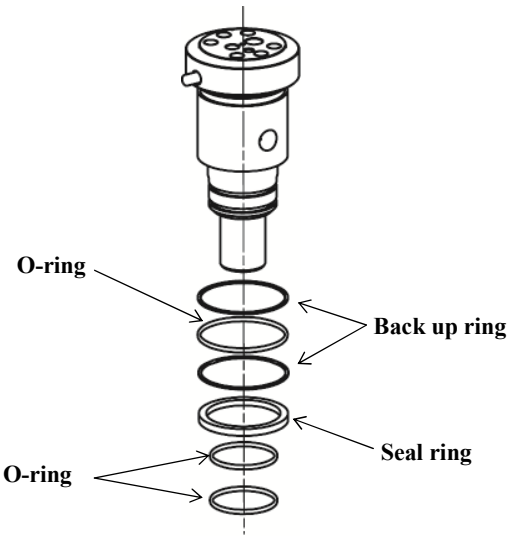
- Clean that the tappet oil hole with light oil.

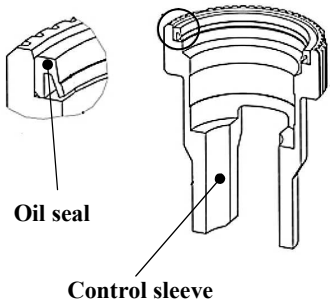
(d) Fuel injection pump assembly procedure

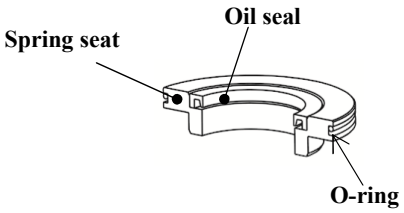
(d1) Clean the parts with fresh light oil. It is afraid to rust if assemble to leave the parts cleaning with light oil.

(d2) Apply grease to the parts, and carefully assemble them same as the figure to keep them face of foreign matter.

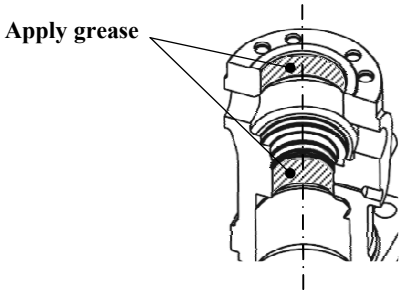
(d3) Replace the O-rings, back up rings, and oil seal.
Apply grease to the O-ring, seal ring and set them on the barrel.

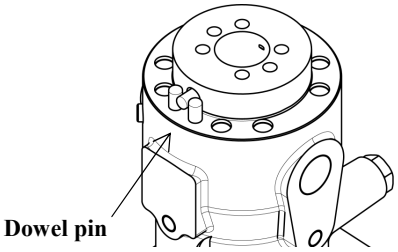




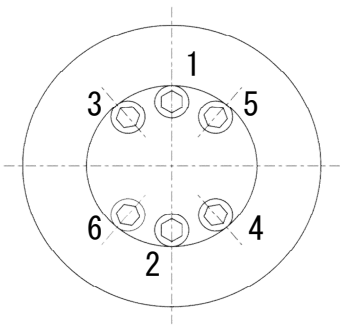


(d4) Apply grease to inside of the housing, install the barrel and set the dowel pin.





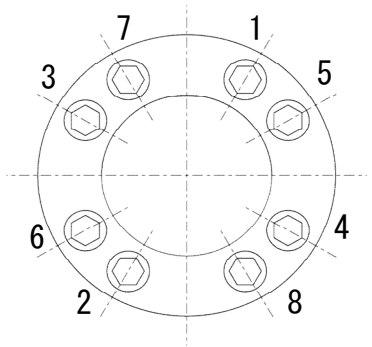
(d5) Tighten the bolts of delivery valve and flange.



a. Delivery valve

Tightening torque of three step.

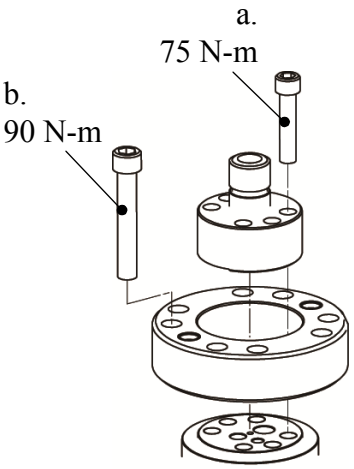
1) 25 N-m
2) 50 N-m
3) 75 N-m



b. Flange

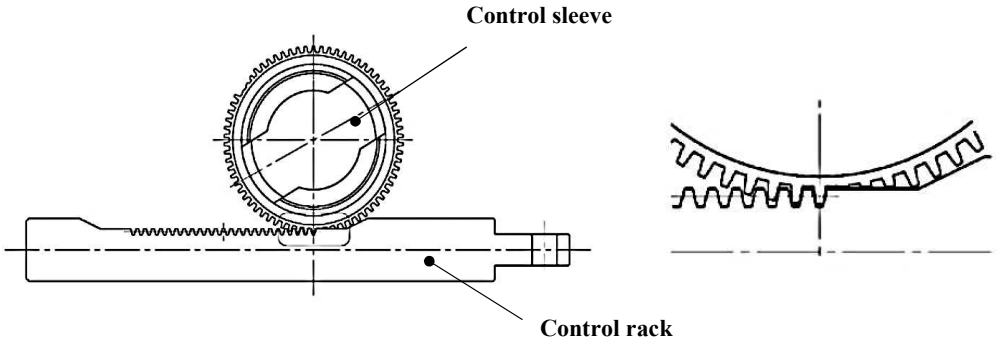
Tightening torque.

1) 90 N-m



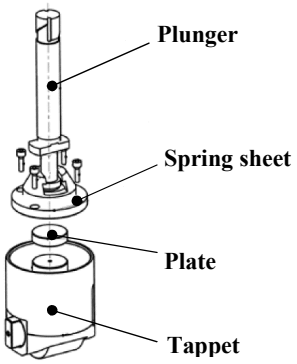
(d6) Reassemble rack and control sleeve by following method.

-Engage first tooth of rack and control sleeve.



(d7) Set the plate on the tappet and hang the spring seat on the plunger, install the plunger with spring seat into the tappet barrel so that the vane of the plunger engages the slots in the control sleeve.

(d8) Install the plunger into the barrel.



NOTE : (1) Be careful to avoid slantingly install.
(2) Be sure not to damage plunger.

7.5.6 Fuel injection union and joint check

(a) Fuel injection unions check

Visually check

[Check]			[Remedy]
• Seat surface contact incomplete	→	Slightly	→ Lapping
		Serious	→ Replace

(b) Bolt check

- Thread scratch cracked → Replace

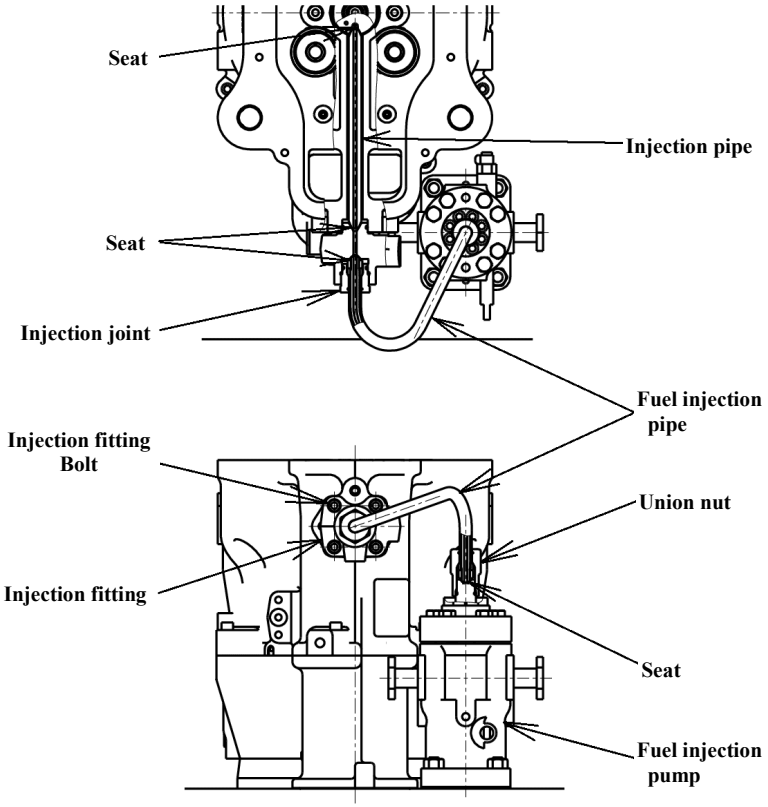
(c) Fuel injection union and joint assembly procedure

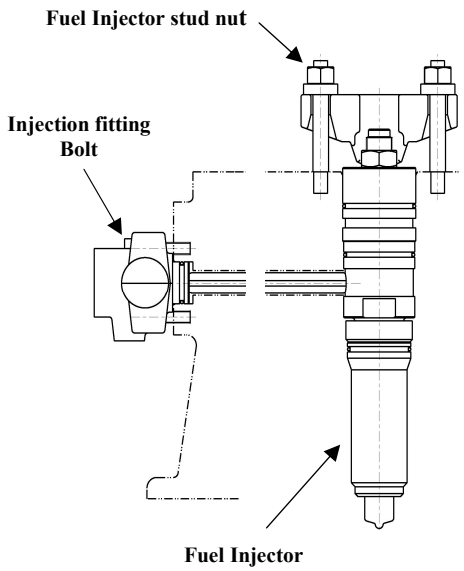
- Tightening procedure , as follows :
  - (1) Injection fitting Bolt preliminary tighten.
  - (2) Fuel Injector stud nut tightening torque : 100 N-m. Apply lubricating oil
  - (3) Injection fitting Bolt tightening torque : 50 N-m.
  - (4) Injection Joint and Union nuts tightening.

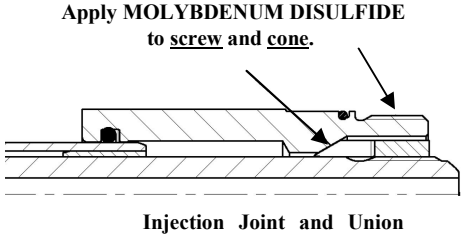
    Apply MOLYBDENUM DISULFIDE to screw and cone.

    Joint Tightening torque : 95 N-m

    Union nuts Tightening torque : 75 N-m





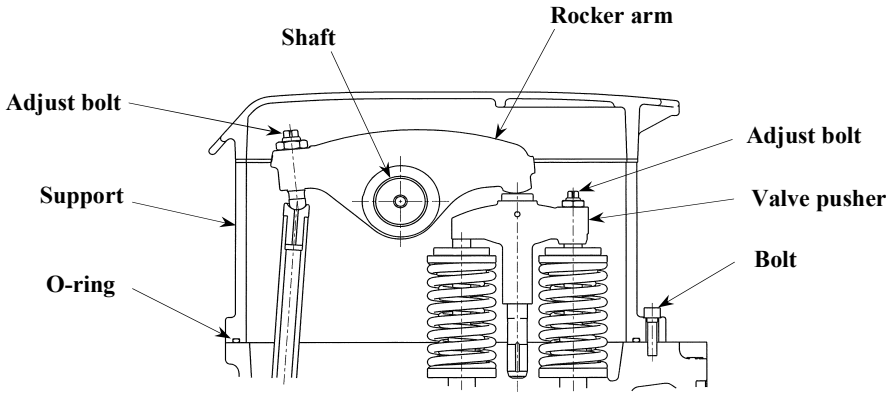


Injection Joint and Union

7.5.7 Intake and exhaust valve rocker gear check

(a) Intake and exhaust valve tappet clearance check

[Check]	[Probable Cause]	[Remedy]
• Excessively large tappet clearance	Push rod top and bottom pieces worn	Refer to each maintenance procedure
	Roller guide push rod pieces worn	
	Adjust bolt tip and each pieces worn	
	Cam and cam roller worn	
• Excessively small tappet clearance	Valve and valve seat worn	Refer to intake and exhaust valve maintenance



(b) Rocker arm disassembly procedure

- Loosen the support upper bolt, and remove the rocker arm, then pull out valve pushers.
- Remove the snap ring and collar, and pull out the rocker arm.

(c) Rocker arm gears check

[Check]	[Probable Cause]	[Remedy]
(c1) Rocker arm shaft worn	Lubricating faulty	Repair by grinding
		Replace rocker arm bushing (with an underside bushing)
	Lubricating oil pump faulty	Check pump

(c2) Rocker arm bushing

- Worn → Replace
- Inner surface roughened → Smooth with sandpaper or replace

(c3) Adjust bolt tip and each piece worn → Replace

(c4) Rocker arm dye check

- Cracked → Slight → Repair by grinder
- Cracked → Serious → Replace

(c5) Lubricating oil hole cleaning

Clean that the support, rocker arm, and shaft lubricating oil hole with light oil.

(c6) Measure the clearance between shaft and bushing

— Refer to Paragraph **5.1** Parts adjustment standard.

(d) Rocker arm gears reassembling

Reassembling is carried out in the reverse order to disassembly procedure.

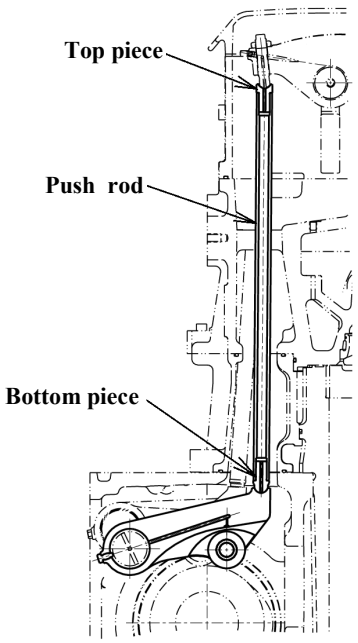
- When set rocker arm gears into cylinder head, bring the piston for the cylinder to be adjusted to the combustion top dead center, tighten the bolt of support.

  — Refer to Paragraph **5.2** Tightening Specification of Main Parts
- Adjust the tappet clearance to 0.5mm

  — Refer to Paragraph **6.1.1(1)(g2)**

7.5.8 Intake and exhaust push rod check

[Check]	[Remedy]
• Push rod top and bottom pieces worn	→ Replace
• Push rod bend	→ Repair or replace



7.5.9 Cams and valve gear check

(a) Disassembly

(a1) Remove the valve gear from the cylinder block.

(a2) Remove the snap ring from roller pin.

(a3) Remove the roller.

(b) Check

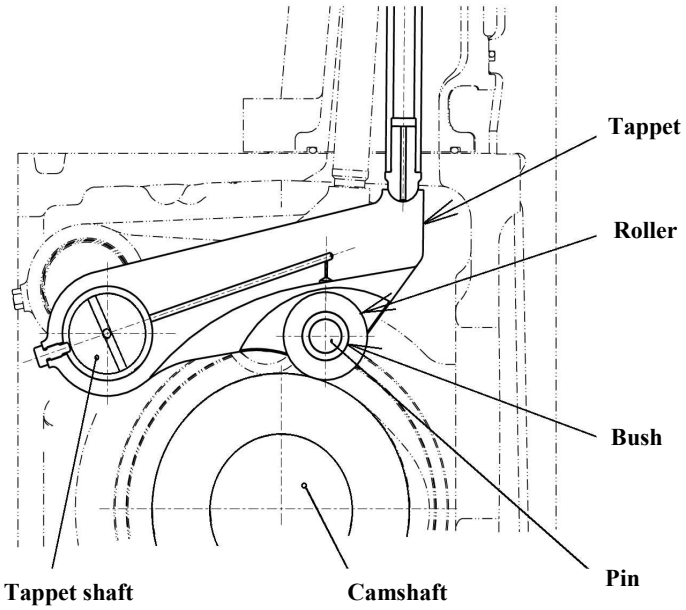
[Check]		[Remedy]
• Damage to cam surface and cam rollers		
→ Cracked or peeled	→ Slight	→ Smooth with oilstone
→ Worn	→ Serious	→ Replace
• Cam deviation	→ Serious	→ Replace
• Roller bush		
• Damage to sliding surface	→ Slight	→ Smooth with sandpaper
	→ Serious	→ Replace

(c) Make a Dye check

Intake and exhaust roller check same procedure of fuel injection pump.

(d) Reassembly procedure

Assembly procedure is carried out in the reverse order to disassembly procedure.

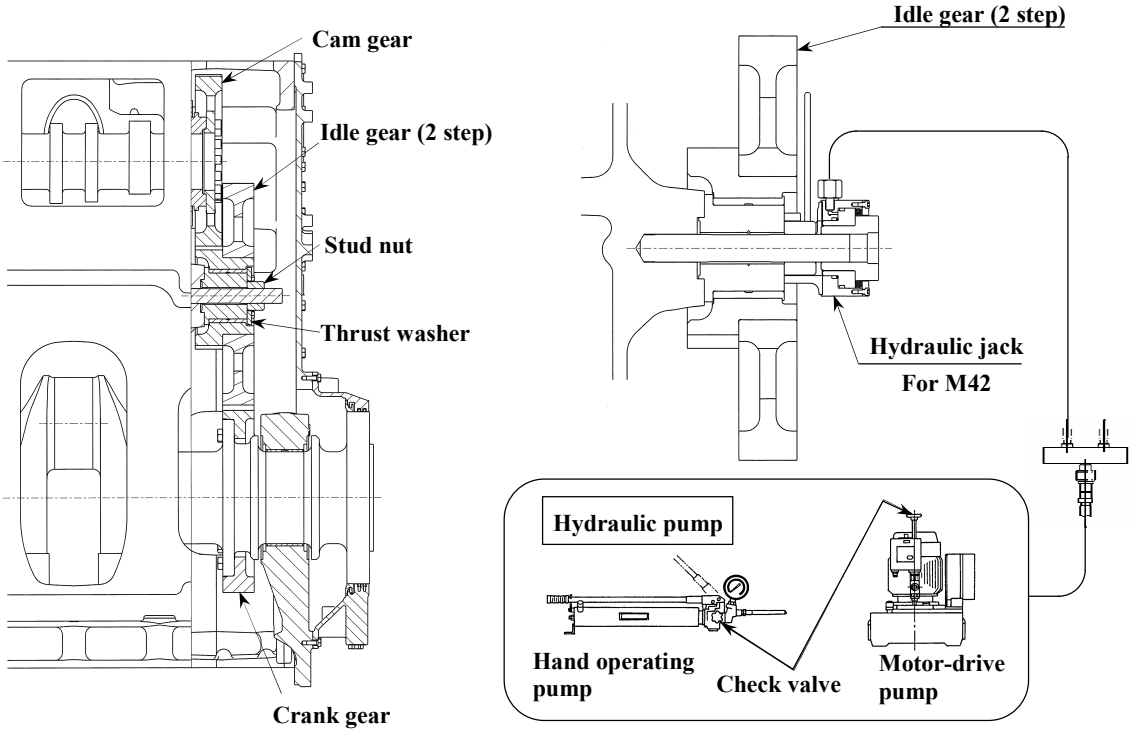


7.5.10 Gear wheel check

(1) Driving end side gear train

(a) Disassembly procedure

- Remove the turbo charger bracket (T/C driving end side spec) or gear case cover (T/C free end side spec.)
- Remove the thrust washer , and then loosen the stud nuts by hydraulic jack.



(b) Check

(b1) Visually check each gear from the check window or disassembled.

［Check］		［Remedy］
• Gear surface pitted	Slight	Smooth with oilstone
	Serious	Replace gear
• Check gear backlash		Repair if necessary Refer to Paragraph **5.1** Clearance and Wear Limit

(b2) Bushing check

• Measuring inner diameter	Replace if excessive worn
• Measuring clearance	Replace if excessive clearance Refer to Paragraph **5.1** Clearance and Wear Limit

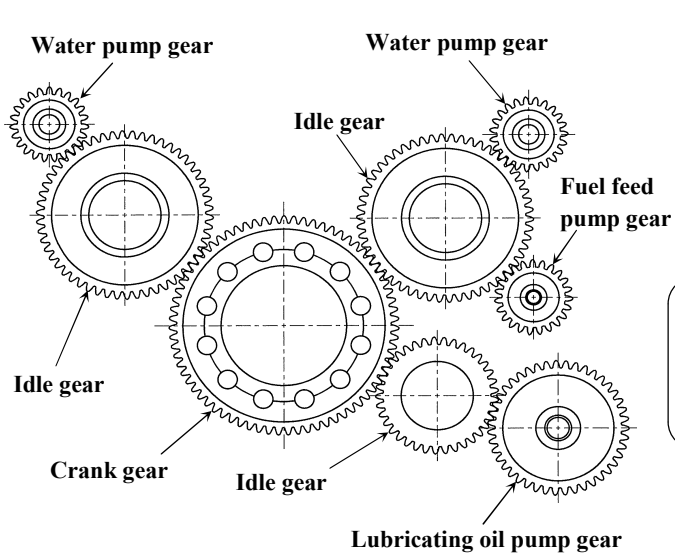
(c) Reassembly procedure

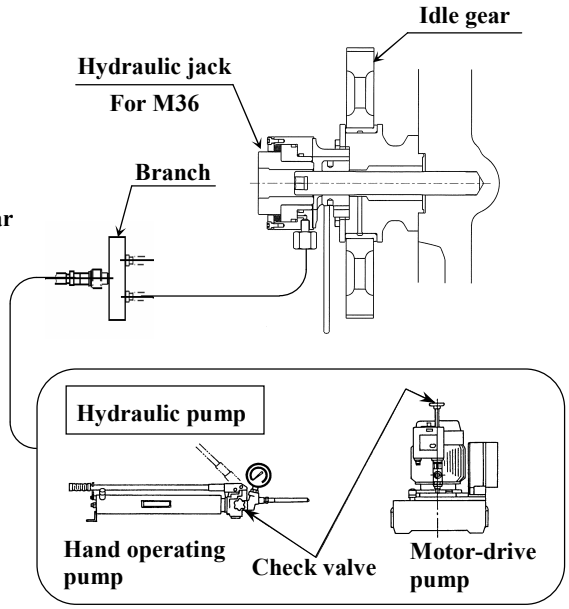
- Assembly procedure is carried out in the reverse order to disassembly procedure.

(2) Free end side gear train

(a) Disassembly procedure

- Remove torsional damper
- Remove crank gear
- Loosen the stud nuts by hydraulic jack





(b) Check

(b1) Visually check each gear from the check window or disassembled.

［**Check**］ ［**Remedy**］

- Gear surface pitted → Slight → Smooth with oilstone
  → Serious → Replace gear
- Check gear backlash → Repair if necessary
  Refer to Paragraph **5.1** Clearance and Wear Limit

(b2) Bushing check

- Excessive clearance → Replace bearing
- Inside surface peeled → Lubrication faulty → Replace bearing
  → Check lubricating oil system
  → Lubricating oil deteriorated → Analyze lubricating oil

(c) Reassembly procedure

- Assembly procedure is carried out in the reverse order to disassembly procedure.

7.5.11 Main bearing check

(a) Main bearing disassembly procedure

(a1) Loosening bearing stud nuts (Refer to **7.5.11** Fig.1)

⚠ WARNING
When using the hydraulic tools, if high pressure oil ejected, there is a danger of injuring. If high pressure oil spray enter into the body through the skin, consult a physician immediately. Make sure carefully check the joint part of the hydraulic tools before increasing the hydraulic pressure.

- Screw ① clamp and ② nut onto the main bearing cap bottom surface.
- Set the ③ telescopic jack, and lift up until upper limit.
- Adjust the ② nuts, and set it into the tip of telescopic jack.
- Set the ④⑤⑥ hydraulic jack to the two main bearing studs.
- Screw the ⑥ jack bolt by hand, and then screw it until the ④ spacer touches the main bearing cap. At this time, check parallel between the under surface of the ⑤ jack body and the seat of the main bearing cap.
  (The clearance between the main bearing stud nut and jack bolt becomes approx. 7mm.)
  After that, half turn of the jack bolt. (Because of s case of shrinking and locking the jack bolt when it is disassembled with the hydraulic jack)
- Connect the hydraulic jack and ⑧ distributor with the ⑨ high pressure hose.
- Connect the ⑧ distributor and the ⑩ hydraulic pump with the ⑨ high pressure hose.
- Increasing the hydraulic pressure slightly with the ⑩ hydraulic pump.
- Operate ⑩ hydraulic pump to rise hydraulic pressure to 180MPa, and then turn back the main bearing stud nut with ⑦ bar.
- If it is hard to turn, increase the hydraulic pressure up to 190MPa.

NOTE : (1) If the hydraulic pressure is hard to rise it may be due to remaining air in the pump and hoses, then, disconnect the hoses at jack connection(couplers) to discharge the air.
(2) If it is hard to turn back the main bearing stud nut with the jack at the pressure 190MPa, something may be matter with the tools or fitting work.

(a2) Main bearing disassembly (Refer to **7.5.11** Fig.1 and Fig.2)

- Loosen and remove the side bolts.
- Remove the ⑨ high pressure hose from the hydraulic jack.
- Remove the ④⑤⑥ hydraulic jack from the main bearing stud nuts.
- Loosen and remove the main bearing stud nuts by hands.
- Screw the ② nut until touching the ① clamp. (Main bearing cap took down)
- Reduce hydraulic pressure of the ③ telescopic jack gradually until lower limit of the main bearing cap position.
- Remove the lower bearing shell.

(a3) The upper bearing shell disassembly procedure.

- Insert the ⑪ bearing pusher(with O-ring) into the crankshaft oil hole. (Refer to **7.5.11** Fig.3)
- Turn the crankshaft in the arrow direction, and remove the upper shell.

WARNING

Before turning the engine, check that there is nothing dangerous near it, and inform the people around the engine, that you are turning it.

CAUTION

(1) When turning the engine, open the all indicator cocks surely. There is a danger of injuring.
(2) Before turning the engine, open the all indicator cocks surely. If not, there is very dangerous because the crankshaft may be reverse.

NOTE : (1) When the main bearing cap does not go down by the gravity, you have to loosen the fixation bolts around bearing.
(2) When the upper shell is extracted by ⑪bearing pusher, special care should be taken for operation of the turning motor. And be careful turning direction, because the bearing has a location notches.

(b) Main bearing check

Check the middle bearing only, and judge from it whether the other main bearings need to be checked.

Check the main bearing in the same way as the crack pin bearing by referring to **7.5.2**(i).

(c) Main bearing assembly procedure (Refer to **7.5.11** Fig.4)

- Wash and clean the upper bearing shells and wipe them with dry waste cloth.
- Apply new lubricating oil on the bearing inner surface only.
- Place the upper bearing shell on the crankshaft journal so their location notches agree, and then, insert the shell into the housing as deep as possible by hand.

If the upper bearing shell cannot be inserted to the right position, follow to the next.

- Place ⑫ shell guide on the main bearing cap.
- Set ⑪ bearing pusher(with O-ring).
- Operate ③ telescopic jack until ⑫ guide touches the housing.
- Turn the crankshaft to the arrow direction to insert the upper bearing shell.

NOTE : When the upper bearing shell is extracted by ⑪ bearing pusher, special care should be taken for operation of the turning motor. And be careful turning direction, because the bearing has a location notches.

- Lower the ③ telescopic jack until the bottom, and set the lower bearing shell.
- Jack up ③ telescopic jack again until an upper limit.
- Adjust the ② nut until the main bearing cap touches the housing.
- Screw the nuts by hand.
- Tighten the Exhaust manifold side bolt with a half of normal torque.
  (Apply MOLYBDENUM DISULFIED)
- Tighten the main bearing stud nuts in the reverse procedure of disassembly.
- Tighten the Exhaust manifold side bolt.
- Tighten the Camshaft side bolt.

— Refer to Paragraph **5.2** Tightening Specification of Main Parts

Fig.1 Main bearing cap lowering procedure

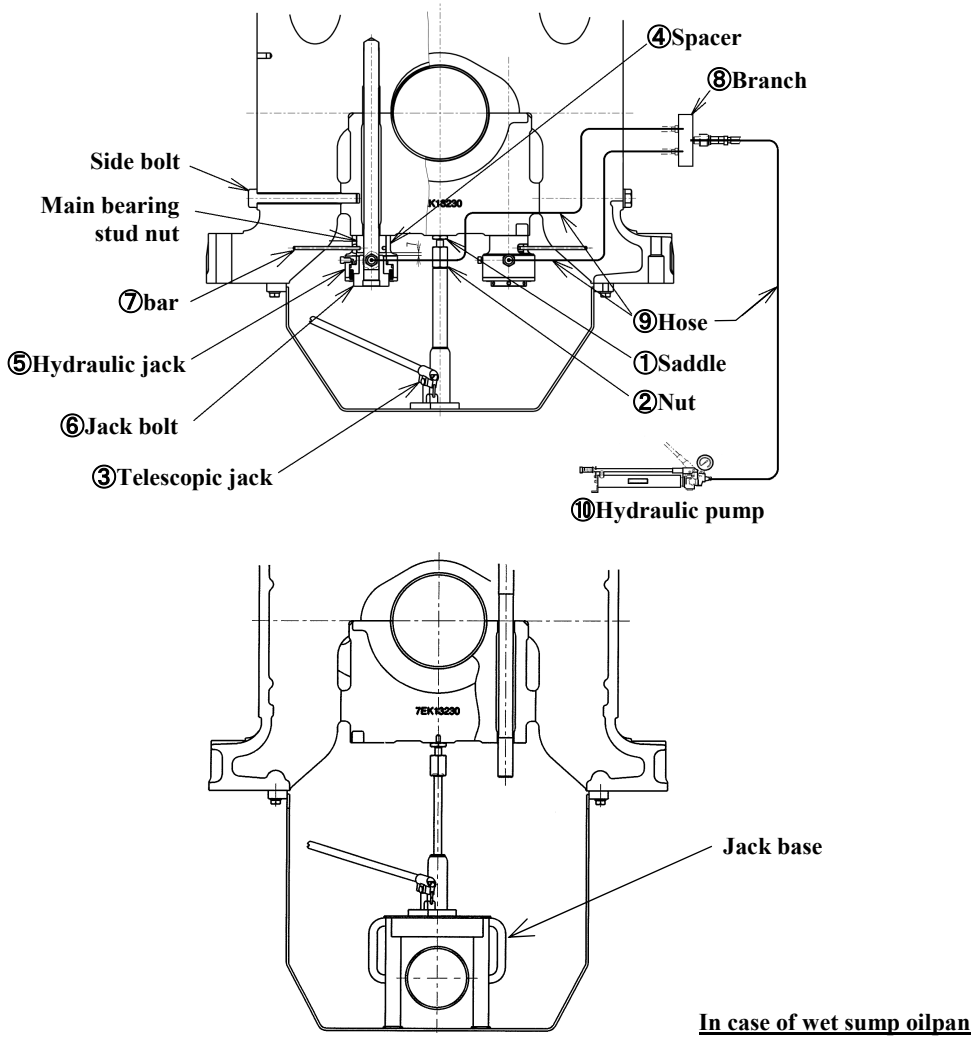


Fig.2 Main bearing cap lowering procedure

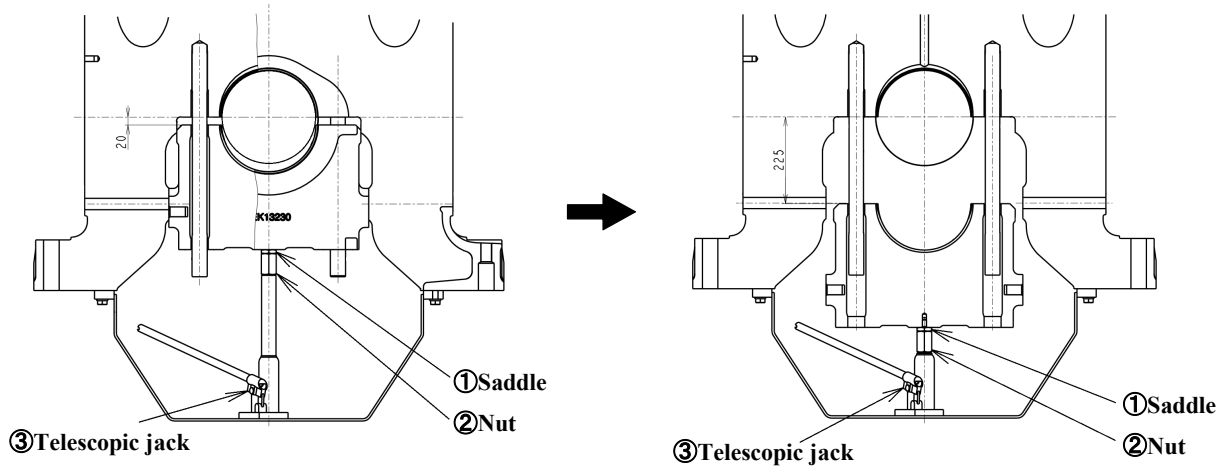


Fig.3 Upper bearing shell removing procedure

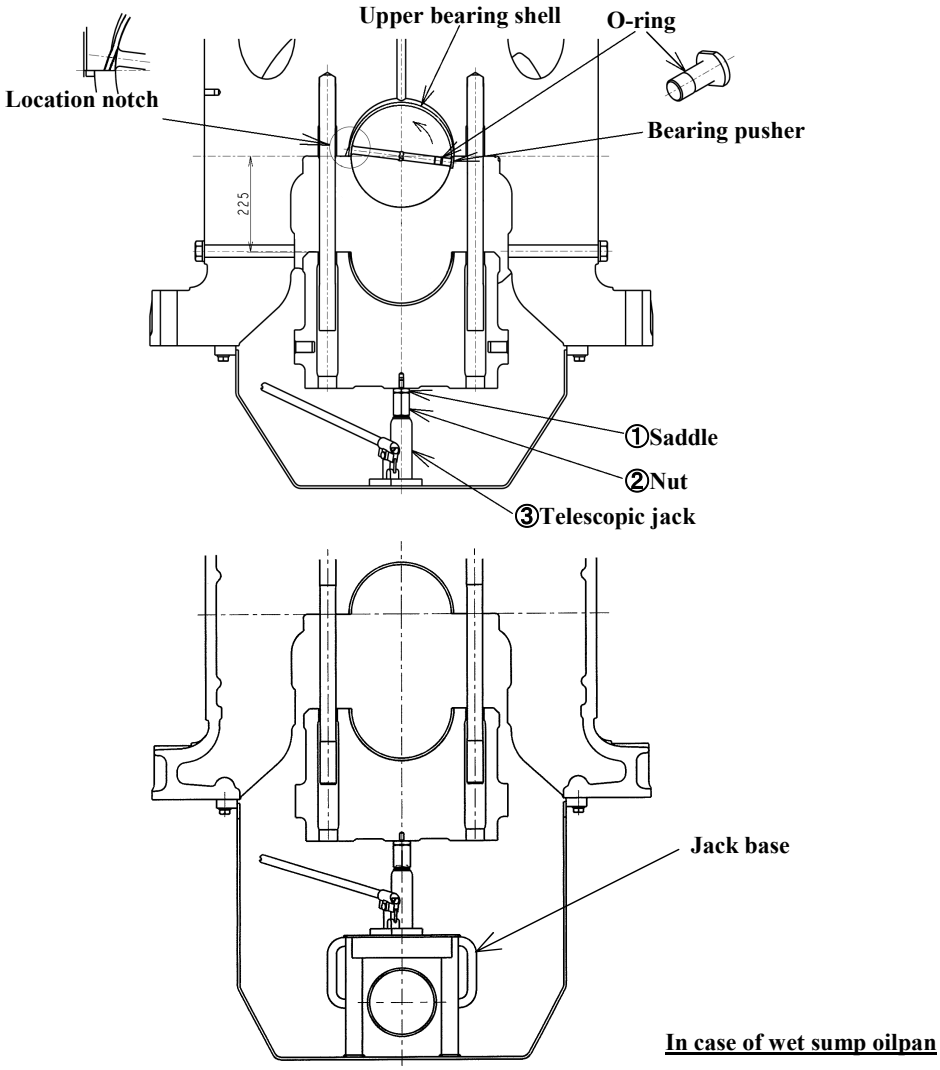
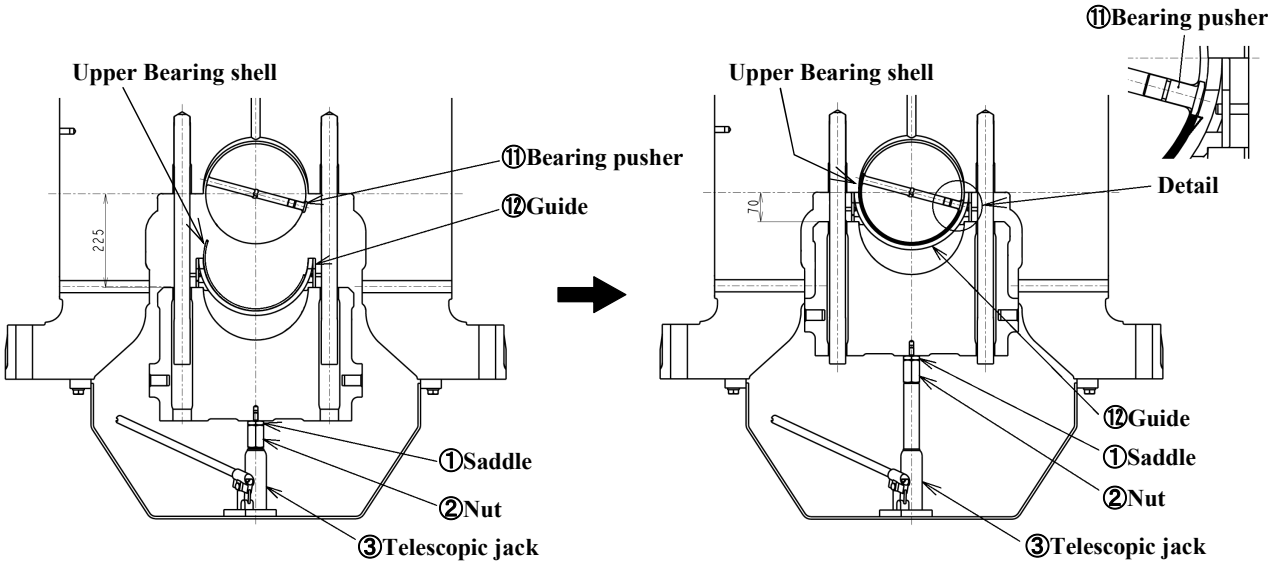


Fig.4 Upper bearing shell inserting procedure



7.5.12 Location bearing, thrust bearing check

(1) Location bearing check

(a) Disassembly

- Remove the oil flyer cover and gear case cover.

(a1) Loosen the stud nuts of location bearing. (Refer to **7.5.13** Fig.1)

(Use by hydraulic jack same as main bearing disassembly)

- Set the ④⑤⑥ hydraulic jack to two location bearing stud nuts.
- Screw the ⑥ jack bolt by hand, and then screw it until the ⑤ jack body touches lightly. At this time, make sure the top of ⑤ jack and top of location bearing cap.
- The following is same as main bearing disassembly procedure. Refer to main bearing disassembly procedure. (Refer to WARNING and NOTE)

(a2) Disassembly location bearing (Refer to **7.5.13** Fig.2)

- Remove the location bearing cap, and then remove upper bearing shell, thrust bearing (upper).
- Insert the ⑪ bearing pusher (with O-ring) into the crankshaft oil hole.
- Turn the crankshaft in the arrow direction, and remove the lower bearing shell.

⚠ CAUTION

(1) When turning the engine, do not insert hand and foot to gear parts. There is a danger of injuring.

(2) Before turning the engine, open the all indicator cocks surely. If not , there is very dangerous because the crankshaft may be reverse.

NOTE : When the lower bearing shell is extracted by bearing pusher, special care should be taken for operation of the turning motor. And be careful turning direction, because the bearing has a location notches.

Fig.1 Location bearing cap removing procedure

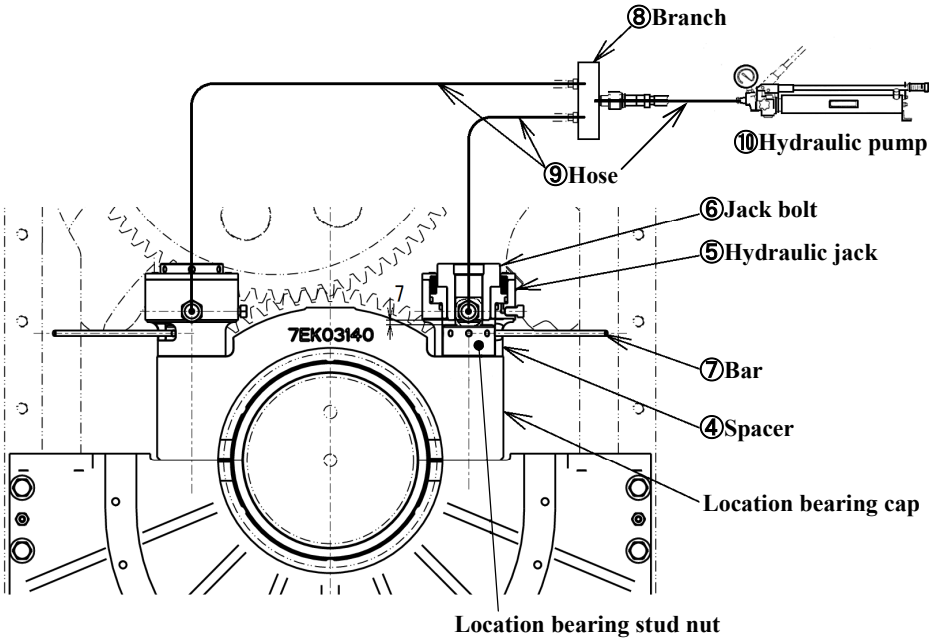
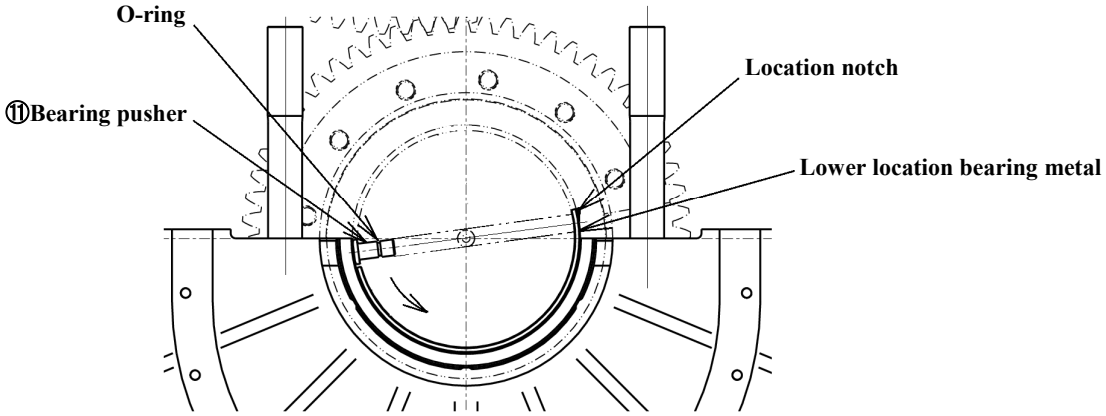


Fig.2 Lower location bearing removing procedure



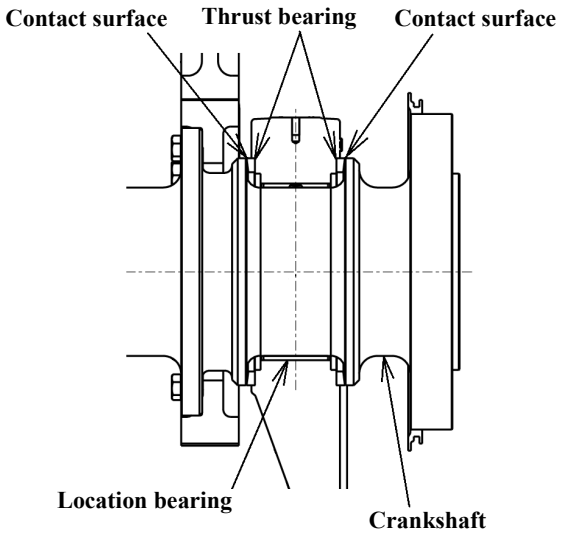
(b) Check

(b1) Check the surface condition of the location bearing (upper and lower) and thrust bearing.
Check the bearings in the same way as the crank pin bearings by referring to **7.5.2**(i).

(b2) Measure the clearance between thrust bearing and crankshaft flange.

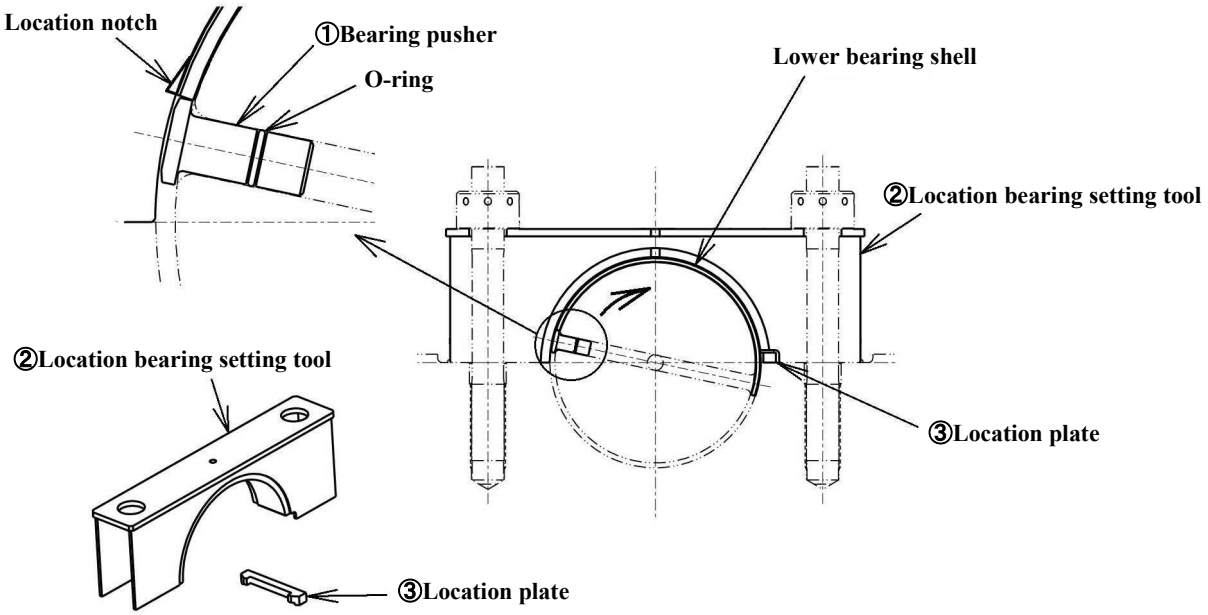
- If permissible limit over, replace the thrust bearing.

— Refer to Paragraph **5.1** Parts adjustment standards



(c) Assembly procedure

- Wash and clean the bearing shells and wipe them with dry waste cloth.
- Apply new lubricating oil on the bearing inner surface only.
- Set the ③ location plate right side as under figure.



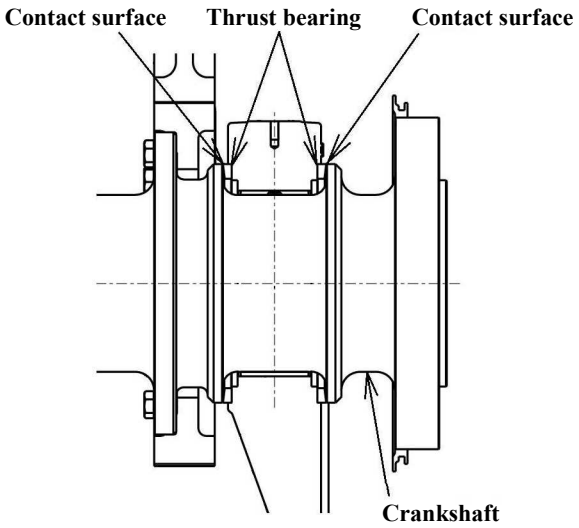
- Place the lower bearing shell on the crankshaft journal so their location notches agree, and then, insert the shell into the housing as deep as possible by hand.
- Insert the ① bearing pusher (with O-ring) into the crankshaft oil hole.
- Set the ② location bearing setting tool by location bearing stud nuts.
- Turn the crankshaft in the arrow direction to insert the lower bearing shell.
- Fit the upper bearing shell to the location bearing cap.
- Assembly procedure is carried out in the reverse order to disassembly procedure.

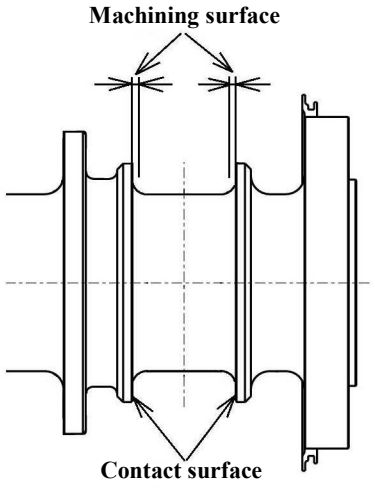
(2) Thrust bearing check

［**Check**］ ［**Remedy**］

•Worn, damage → Slight → Smooth with oilstone

→ Seriously worn or damaged → Repair by machining → Replace thrust bearing (Oversize)





7.5.13 Crankshaft check

(a) Remove the main bearing cap, and check the crankshaft.

［**Check**］ ［**Remedy**］

・Pin and journal check

- Measure wear of crank pin → Worn (unevenly worn) → Slight → Smooth with sandpaper and oilstone. Refer to Paragraph **5.1** Clearances and Wear Limit
- Surface damage → Worn (unevenly worn) → Slight → Smooth with sandpaper and oilstone. Refer to Paragraph **5.1** Clearances and Wear Limit
- Worn (unevenly worn) → Seriously worn or damaged → Machine to undersize

NOTE : When machining the crankshaft to undersize, special undersize bearings must be used. Be sure to consult us beforehand.

(b) Make a dye check

［**Check**］ ［**Remedy**］

・ Crank pin outer part ⟶ Cracked ⟶ Contact our service station

(c) Crankshaft deflection measuring

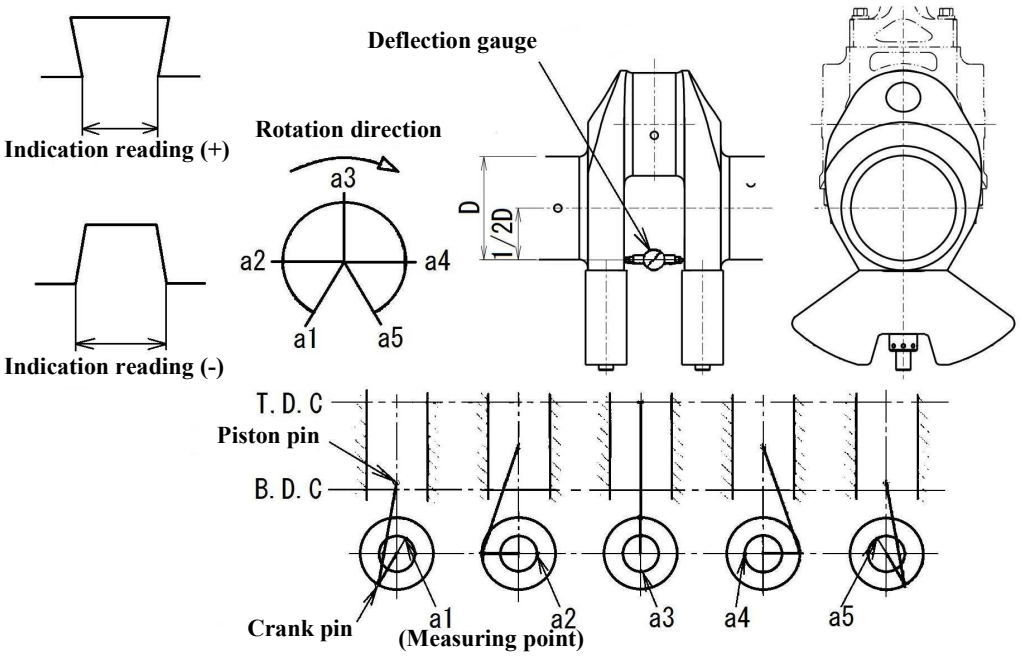
—Refer to Paragraph **5.1** Parts Adjustment Standards

Depending on the measuring results, re-centering of the crankshaft.

NOTE : (1) Measure crankshaft deflection 500 hours after a new engine is put into use, or after crankshaft centering, involving bearing replace, and verify that the crankshaft is free of deflection.

(2) Measure the deflection when engine is cold.

(3) When crank arm is closed, the gauge will show positive value, and when crank arm is opened, the gauge will show negative value. (Refer to under figure)

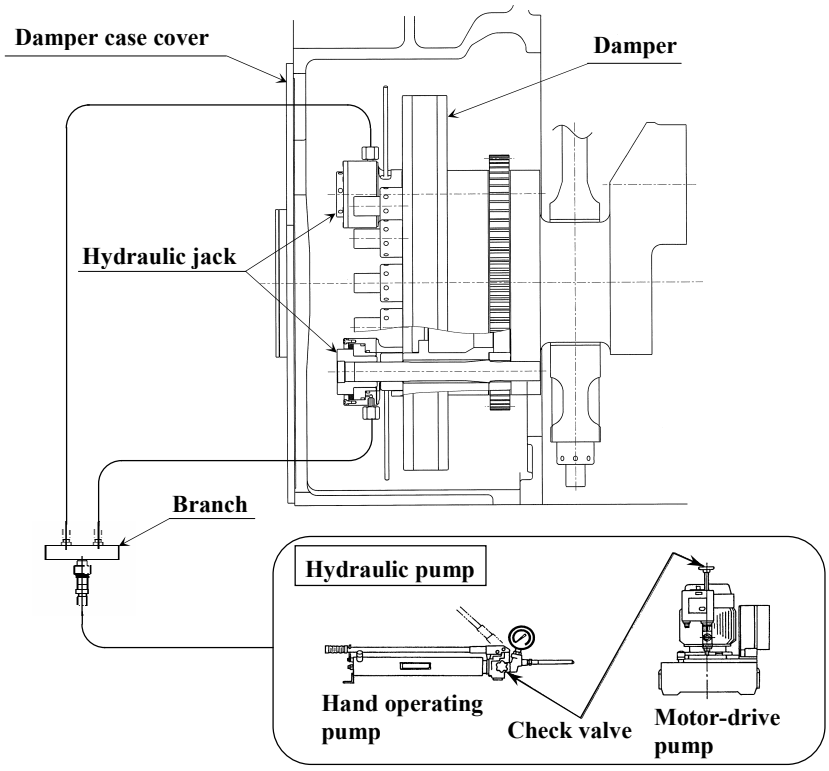


7.5.14 Crankshaft torsional damper check

(a) Disassembly procedure

- Remove the damper case cover.
- Loosen the stud nuts by hydraulic jack.
- After hanging by lifting wire, remove the temporary bolts, and pull out the damper from the damper case.

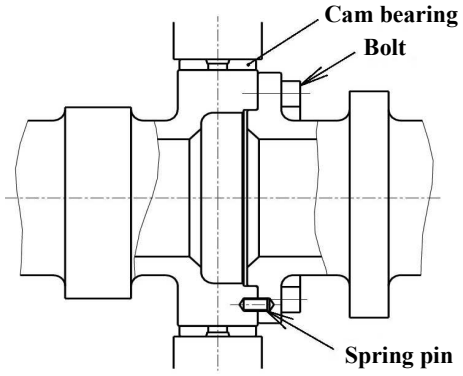
NOTE : Refer to the manufacturer's instruction manual as to check the geislinger damper.



7.5.15 Cam bearing, thrust bearing check

(a) Disassembly procedure

- Remove cam case cover.
- Remove cam gear cover, fuel injection pumps, intake and exhaust valve gear
- Loosen the fitting bolts of the thrust washer on idle gear, and then remove the idle gear.
- Loosen the cam gear bolts, and remove the cam gear.
- Apply new lubricating oil on all of bearings inner surface.
- Loosen the fitting bolts of the cam shaft, and then remove the cam shaft from driving end.



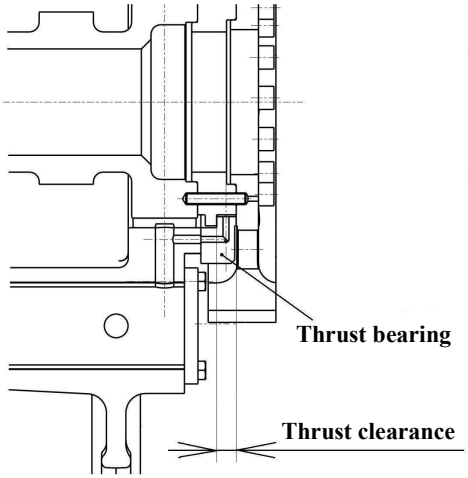
(b) Check

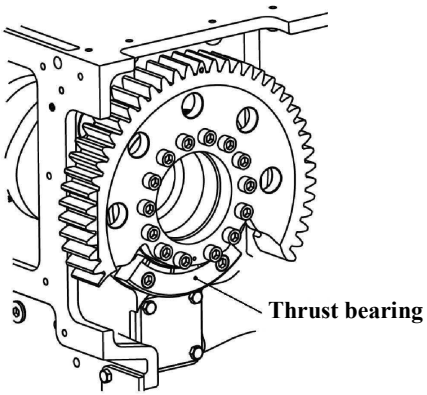
(b1) Clearance check

[Check]	[Probable Cause]	[Remedy]
• Excessive clearance		→ Replace bearing
• Inside surface peeled	→ Lubrication faulty	→ Replace bearing
		→ Check lubricating oil system
	→ Lubricating oil deteriorated	→ Analyze lubricating oil

(b2) Thrust bearing check

- Thrust clearance excessive large → Replace if necessary
  Refer to Paragraph **5.1** Clearance and Wear Limit

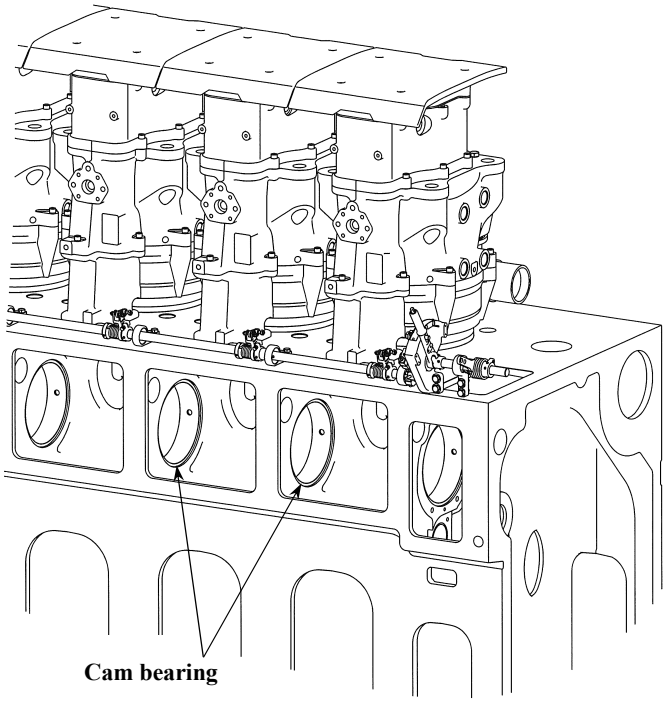




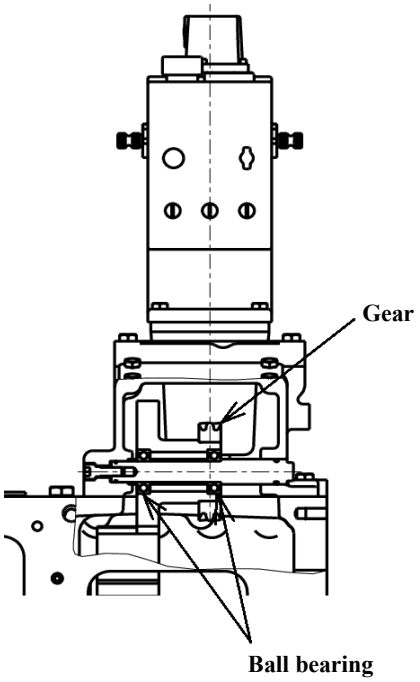
(c) Reassemble procedure

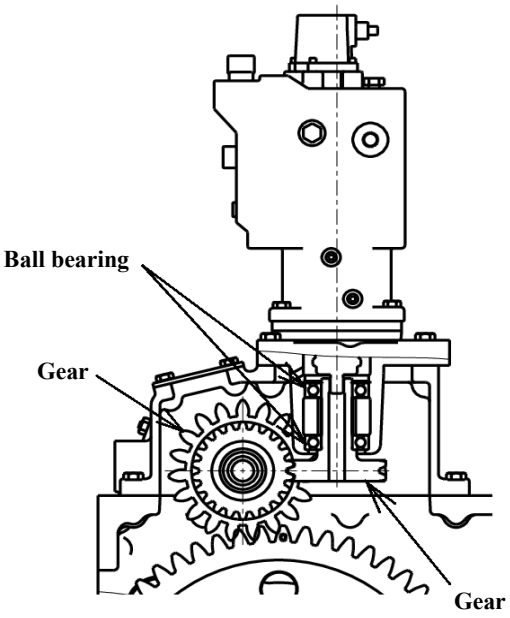
Assembly procedure is carried out in the reverse order to disassembly procedure.

- Wash and clean the bearings, and wipe them with dry waste cloth.
- Apply new lubricating oil on the bearing inner surface only.
- Insert the cam shaft.
- Keep cam shaft flange out of the cylinder block.
- Adjusts the phase of flange with the position nock pin, tighten up bolts.
- Assemble the cam gear after camshaft finished assembly.
- Assemble the driving end idle gear.
- Tighten up bolts a diagonal line.
- Refer to paragraph **5.2** Tightening Specification of Main Parts.



7.5.16 Governor driving device check





[Check]		[Remedy]
•Gear surface pitted	Slight	Smooth with oilstone
	Serious	Replace gear

NOTE : When changing the bevel gear, be sure replace a pair (driving and driven gear).

[Check]	[Probable Cause]		[Remedy]
•Gear backlash incorrect Refer to Paragraph **5.1** Clearance and Wear Limit	Gear worn	Slight	Repair
		Serious	Replace
	Ball bearing worn	Slight	Repair
		Serious	Replace

7.5.17 Governor, governor linkage, Fuel linkage check

(1) Governor check

(a) Remove the governor from governor linkage, and send to Governor Maker for check.

NOTE : When removing serration part, pull out perpendicularly to shaft.
Be careful, don't damage serration part.

(b) Changing of governor oil

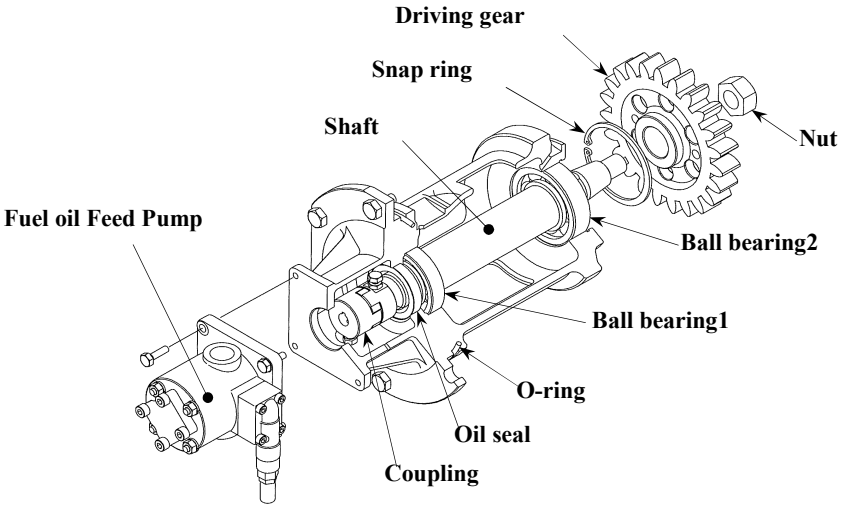
— Refer to the Instruction Manual for Hydraulic Governor.

(2) Governor linkage, Fuel linkage check

[Check]	[Probable cause]	[Remedy]
•Linkage action not smooth	Link pin worn	Replace
	Link pin stick	Replace
	Bearing or ball bearing stick	Replace
	Bearing or ball bearing eccentricity	Repair
	Deformed, damaged	Replace
	Bearing or ball bearing worn	Replace
• Linkage excessive loose	Link pin worn	Replace
	Bearing worn	Replace
• Spring action not smooth	Bearing worn	Replace
	Bearing stick	Replace
	Spring stick	Replace
• Rack lever excessive loosened (forked part)	Forked part worn	Replace

NOTE : If linkage has excessive looseness, shall be occur hunting. Make sure replace necessary parts.

7.5.18 Fuel oil feed pump check



(a) Disassembly procedure

- Remove the driving device of the fuel oil feed pump from the gear case.
- Remove the fuel oil feed pump from driving device.
- Loosen the nut and remove the driving gear from shaft.
- Remove the coupling and snap ring, pull out the shaft.

(b) Check

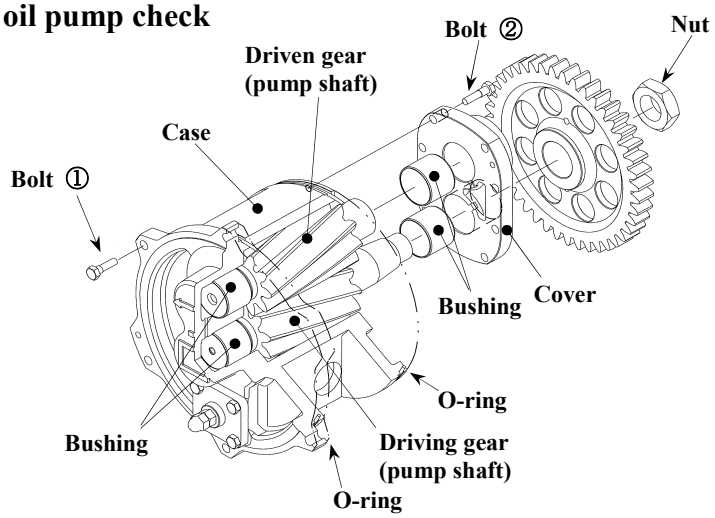
[Check]	[Probable Cause]		[Remedy]
(b1) Gear surface pitted		Slight	Smooth with oilstone
		Serious	Replace gear
(b2) Gear backlash incorrect Refer to **5.1** Adjustment Standards for Main Parts	Gear worn	Slight	Repair
		Serious	Replace
	Ball bearing worn	Slight	Repair
		Serious	Replace

(c) Reassemble procedure

Reassembling is carried out in the reverse order to overhaul

- Replace the o-ring and oil seal.
- Replace the coupling if necessary.

7.5.19 Lubricating oil pump check



(a) Disassembly

- Loosen the ① bolt and remove the lubricating oil pump from gear case.
- Loosen the nut and remove the driving gear from shaft.
- Loosen the bolt ② and remove the cover.
- Remove the pump gear. (driving and driven gear)

(b) Check

(b1) Pump gear

[Check]	[Probable Cause]	[Remedy]
• Gear surface pitted	Slight	Smooth with oilstone
	Serious	Replace gears
	Pump shaft worn bushing	Replace bushing

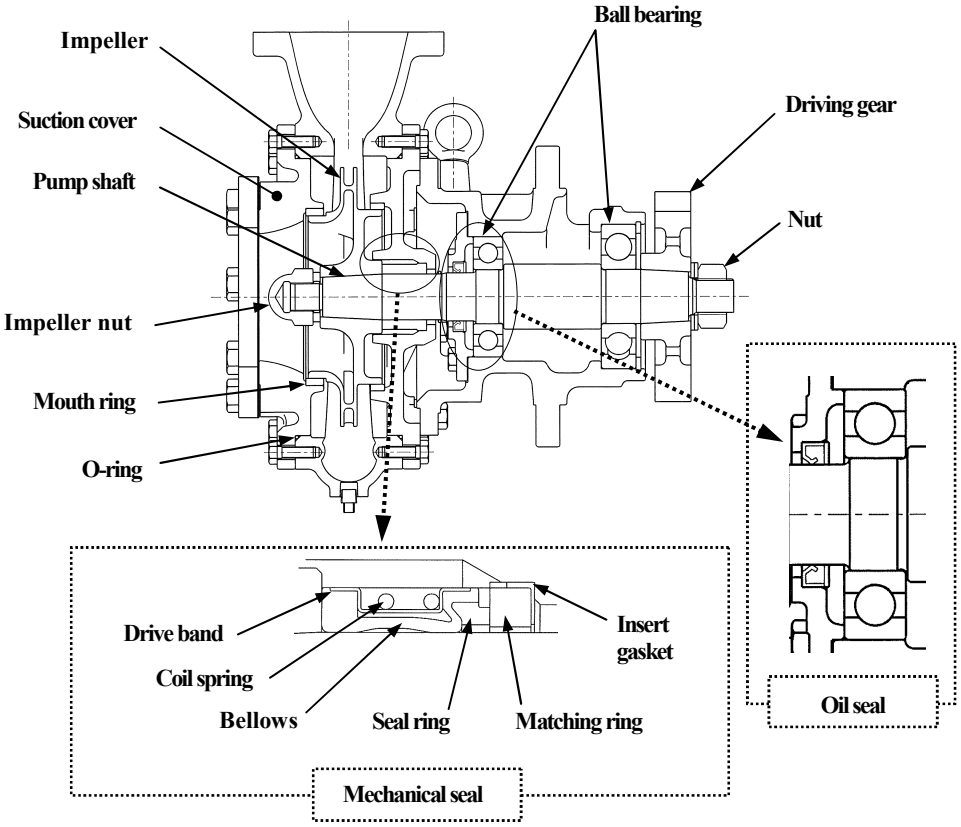
NOTE : When changing the gear, be sure replace a pair (driving and driven gear).

• Gear circumference in contact with case		Repair Refer to Paragraph **5.1** Clearance and Wear Limit
	Pump shaft worn bushing	Replace bushing
•Foreign matter	Suction filter faulty	Check suction filter Check gear surface
•Check gear backlash		Repair if necessary

(b2) Measure shaft bushing wear

•Faulty contact or rough surface	Smooth with sandpaper, or replace Refer to Paragraph **5.1** Clearance and Wear Limit

7.5.20 Cooling water pump check



(a) Disassembly procedure

- Remove the cooling water piping and take out the cooling water pump.
- Remove the suction cover, impeller nut and take out the impeller.
- Take out the mechanical seal. Be careful, don't damage shaft part.
- Loosen the nut and remove the driving gear.
- Pull out the shaft from the pump case and remove the ball bearing and oil seal.

(b) Check

- Impeller and mouse ring.

[Check]	[Probable Cause]	[Remedy]
Sliding part worn	⟶	If permissible limit over, replace the impeller and mouse ring. Refer to **5.1** Adjustment Standards for Main Parts

- Impeller, Pump case, Suction cover

Cavitation, erosion	Slight ⟶	Repair with sand paper
	Serious ⟶	Replace

(c) Reassemble

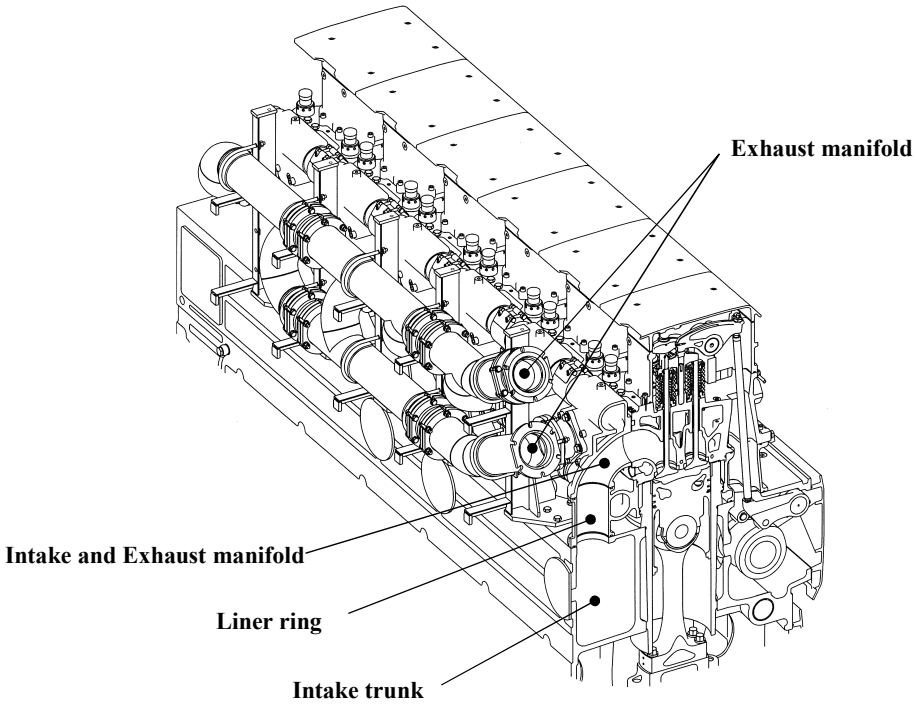
- Remove the dirt and rust by washing.
- Assemble the exhaust valve in the sequence opposite to that disassembly. Replace the following part whenever the cooling water pump are disassembled.
  - Mechanical seal
  - Oil seal
  - Ball bearing
- Mechanical seal setting procedure
  ① After insert the pump shaft, unitize the insert gasket and matching ring.
  ② Apply the fresh water on the circumference surface. Set in the pump case.
  ③ Apply the liquid detergent to the bellows interior surface and pump shaft. Push the pump shaft into the bellows carefully.
- Apply LOCTITE 242 to the impeller nut and driving gear nut. Tighten with regulation torque.
  Refer to **5.2** Tightening Specification of Main Parts.

7.5.21 Exhaust manifold check

[Check]	[Remedy]
•Lagging damaged	→ Repair
•Piping deformed	→ Repair
•Piping cracked or corroded	→ Repair or replace
•Bracket loosened	→ Replace
•Expansion joint damaged	→ Replace

7.5.22 Intake manifold and intake trunk check

[Check]	[Remedy]
•Intake duct broken	→ Repair or replace
•Intake manifold inside check and cleaning	

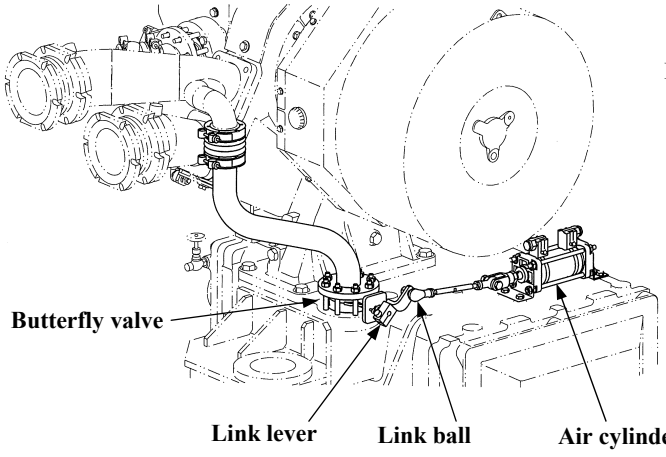


7.5.23 Air bypass and Waste gate check.

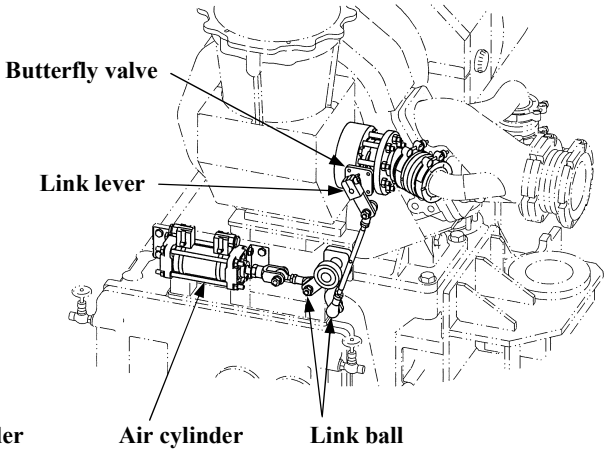
[Check]	[Probable Cause]	[Remedy]
• Check valve marking position		Repair or replace
• Check valve working smooth		Repair or replace
• Linkage action not smooth	Reamer Bolt worn	Replace
	Reamer Bolt stuck	Replace
	Ball bearing stuck	Replace
	Ball bearing eccentricity	Repair
	Deformed, damaged	Replace
	Ball bearing worn	Replace
• Linkage excessive loose	Reamer Bolt worn	Replace
	Ball bearing worn	Replace
• Lagging damaged		Repair
• Piping deformed		Repair
• Piping, expansion joint damaged		Repair or replace
• Check air cylinder operation		Repair or replace
• Check control air piping		Repair or replace

NOTE : When disassemble the valve and lever, don't damage serration of valve.

Air bypass



Waste gate
(Depend on specification)



7.5.24 Cooler check

(a) Lubricating oil cooler, jacket water cooler

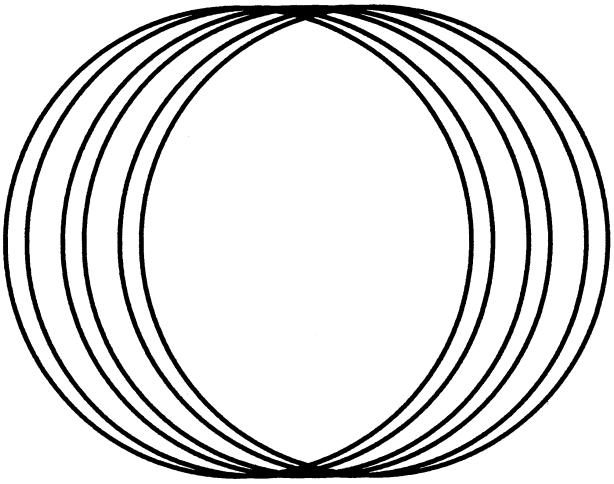
(b) Check

[Check]		[Remedy]
• Inside Cleaning	⟶	Disassemble and clean
• O ring check	⟶	Replace
• Pressure test after assembly		
↳ Jacket water cooler	⟶	Test pressure : 0.45 MPa
↳ Lubricating oil cooler	⟶	Test pressure : 1.00 MPa

7.5.25 Remote control device check

Refer to the Instruction Manual for Remote Control Device.

MEMO



NIIGATA DIESEL INSTRUCTION MANUAL

MG(L)28AHX

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z8. TROUBLESHOOTING

The purpose of troubleshooting is investigating the fundamental causes of troubles and preventing the reoccurrence of the same trouble after repairs are made.

In troubleshooting, an intimate knowledge of the mechanism of the device and its operating principle is of essential importance. With this knowledge, you can check the various functions in the proper sequence and locate the cause.

8.1 Procedures Before Investigating the Cause of Trouble

8.1.1 Early detection of troubles

Engine failure is usually preceded by certain signs. Therefore, whenever even a minor or negligible abnormality is observed, the suspected parts must be immediately checked for early detection of the trouble area and for minimizing accidents.

8.1.2 Preliminary work

Before attempting troubleshooting, keep watch for the following and make a complete study of the parts involved.

- Was there an alarm before the trouble occurred?
- Had there been a similar trouble in the past?
- What repairs and maintenance work done before?
- Is it safe to continue operation while troubleshooting?

8.1.3 Investigating the cause

Begin investigation of the cause with simple items: First check those easy and obvious, then proceed to those complicated gradually to save time.

8.1.4 Re-inspection before overhaul

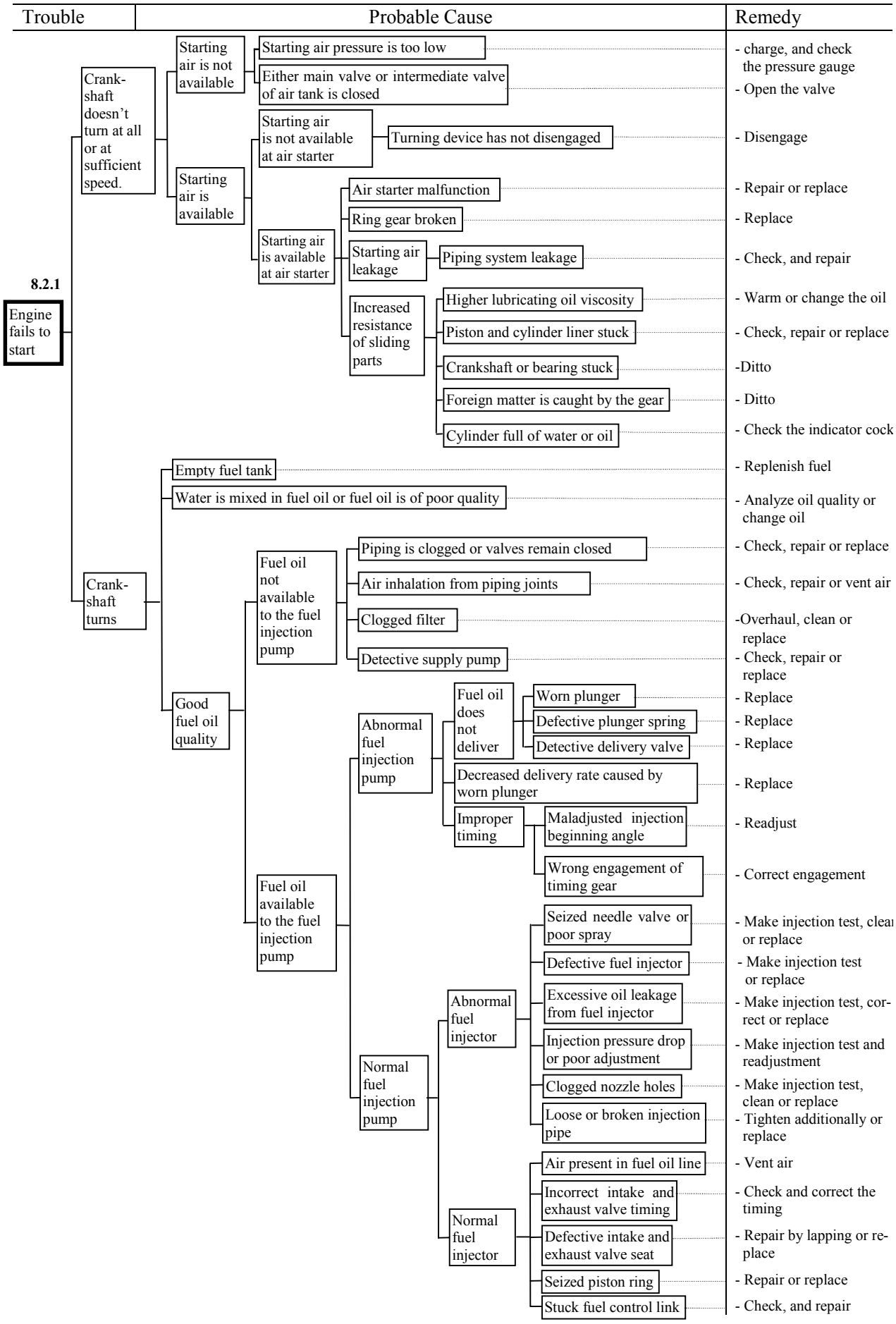
In many cases, a trouble may be related to not only one part but to other parts as well. Carry out an additional inspection before disassembling the device to confirm that the approach is correct and to prevent missing of evidence in related parts.

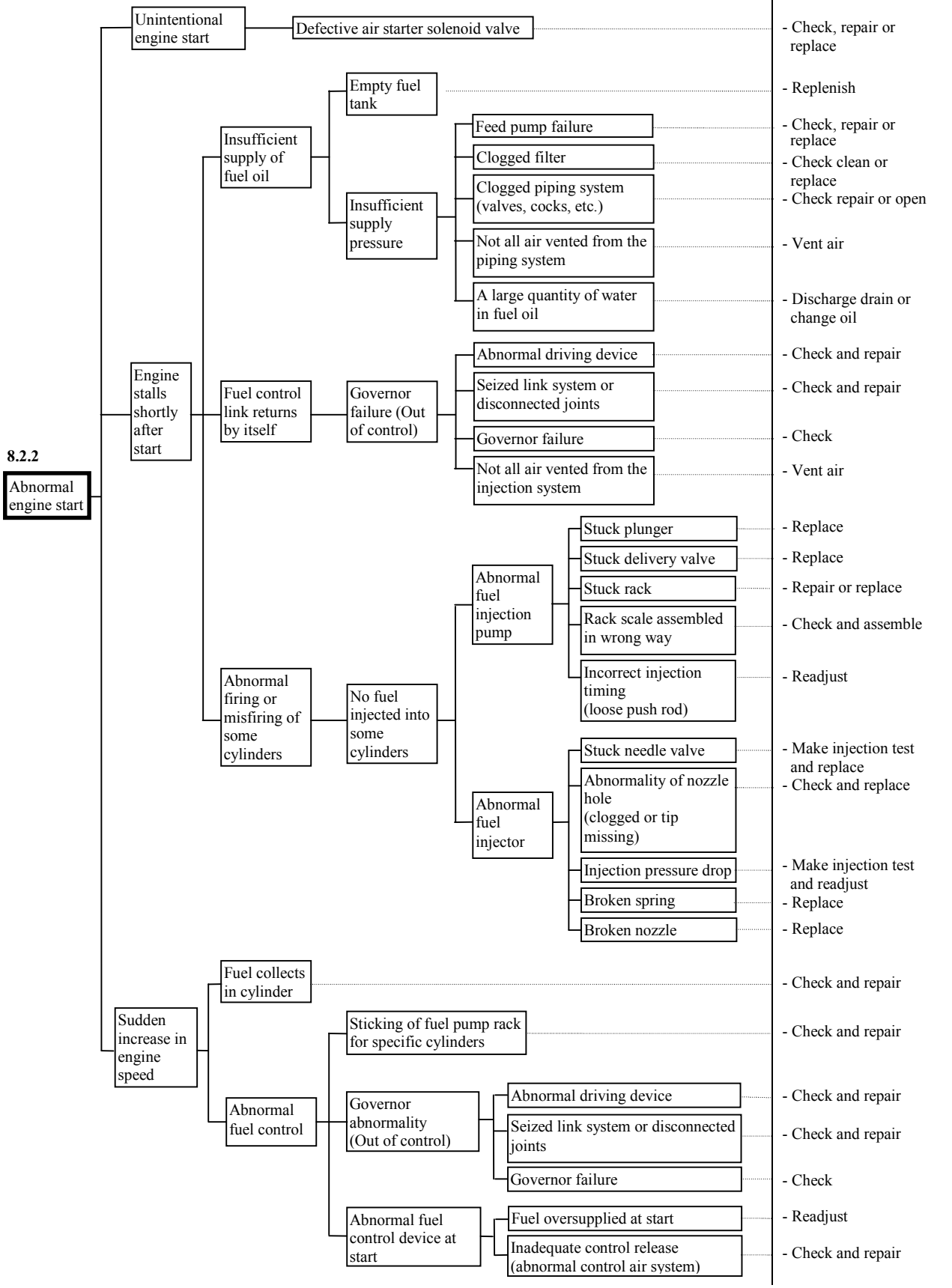
8.1.5 Correcting the sources of problems

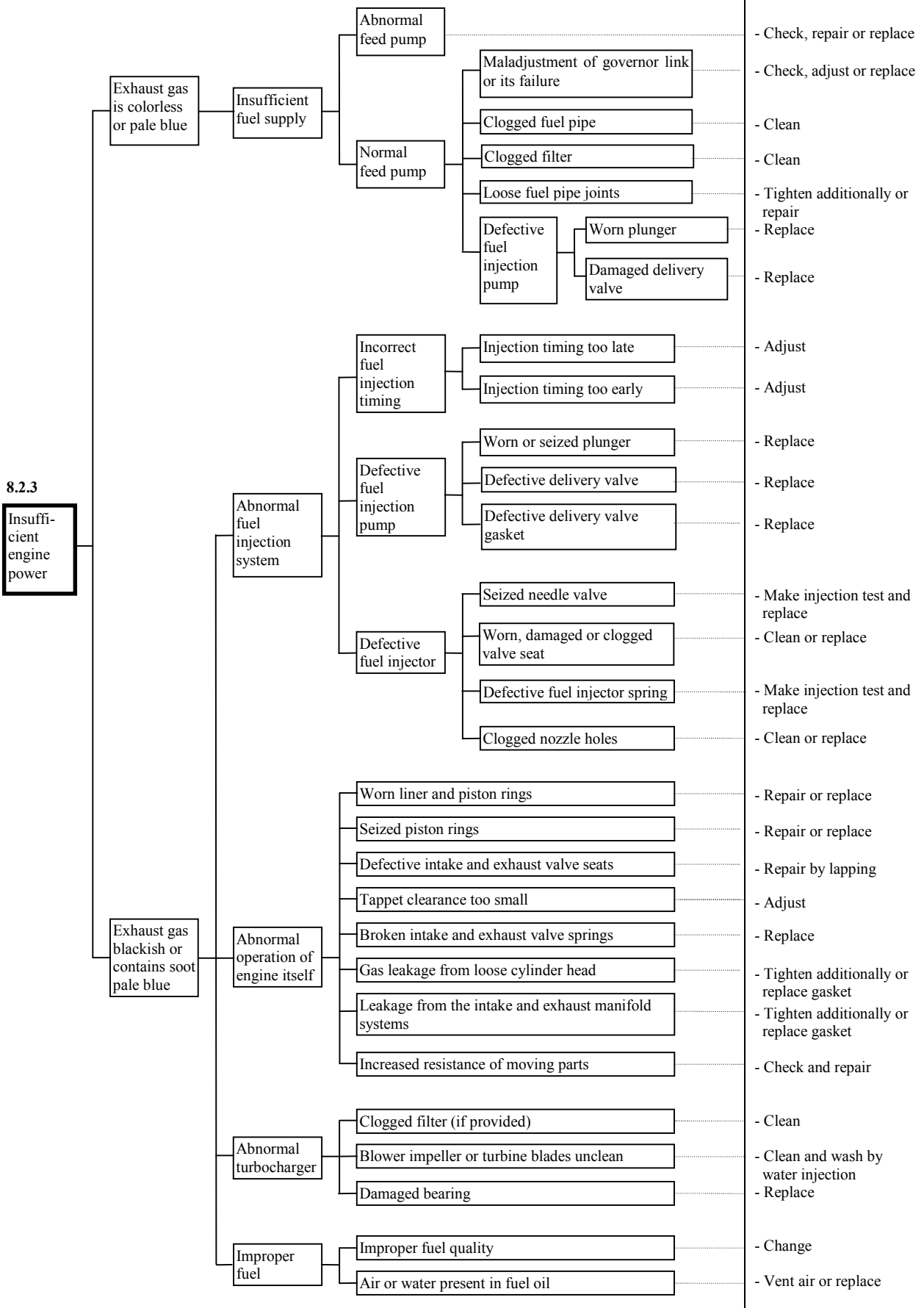
Make it a rule to not only remedy the trouble but to identify the cause of the trouble. For example, a stuck fuel injection pump plunger can be remedied by repairing the plunger or replacing it with a new one. However, the cause of the trouble remains yet to be eliminated.

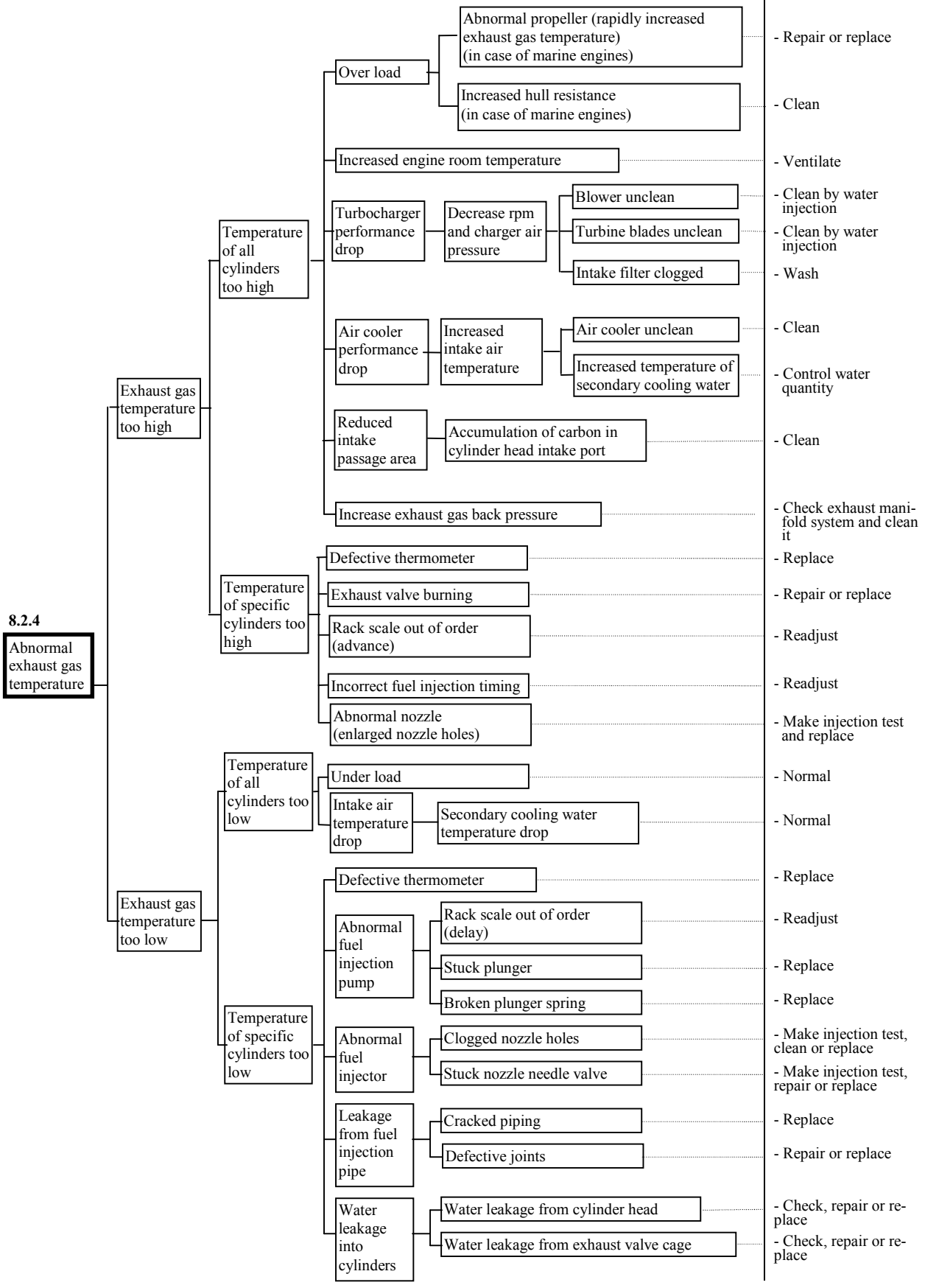
8.2 Causes of Troubles and Countermeasures

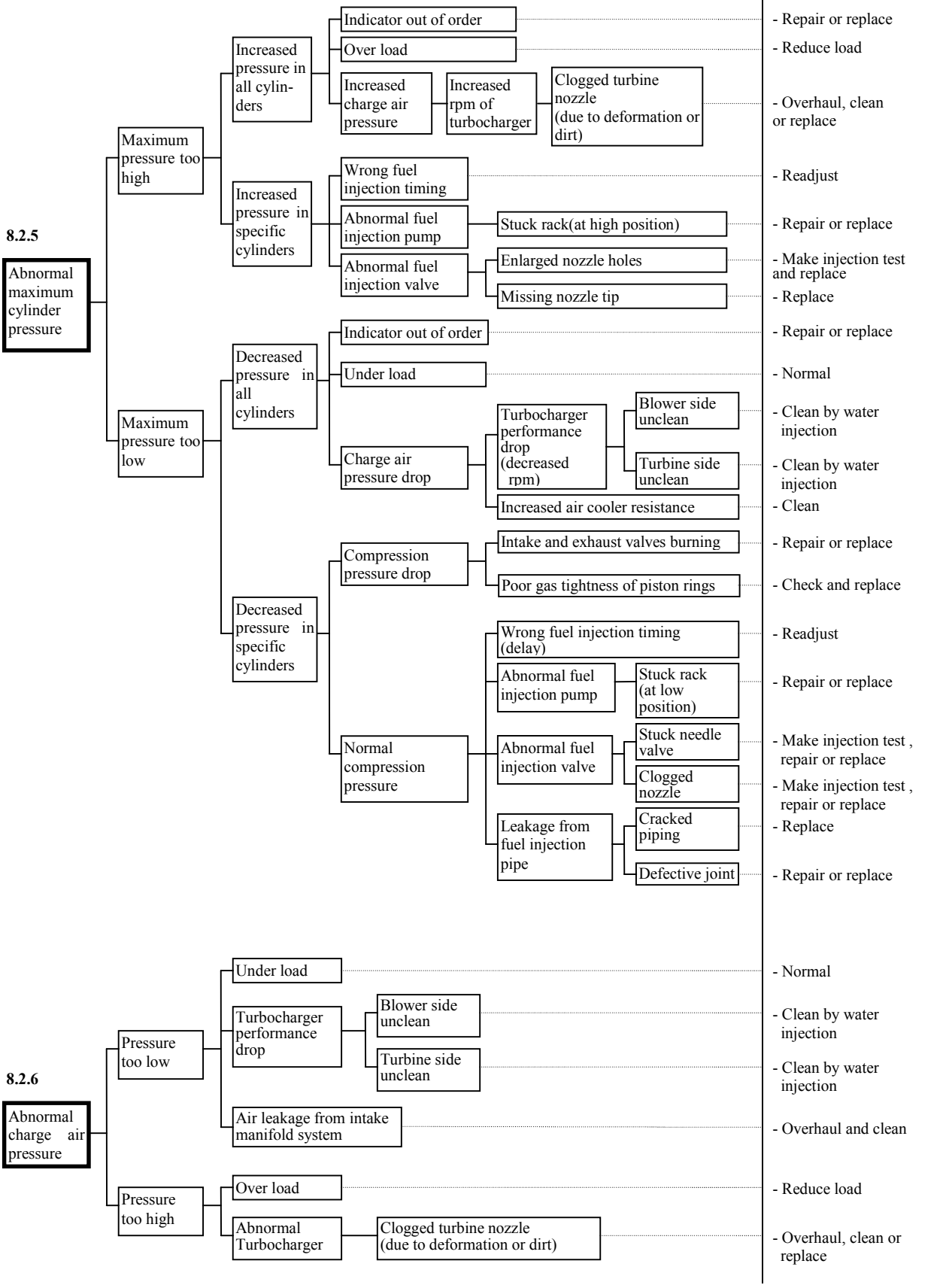
The following chart gives a listing of probable troubles during diesel engine operation and their causes as well as remedies against them. It should be borne in mind that the chart does not provide answers to all possible cases.

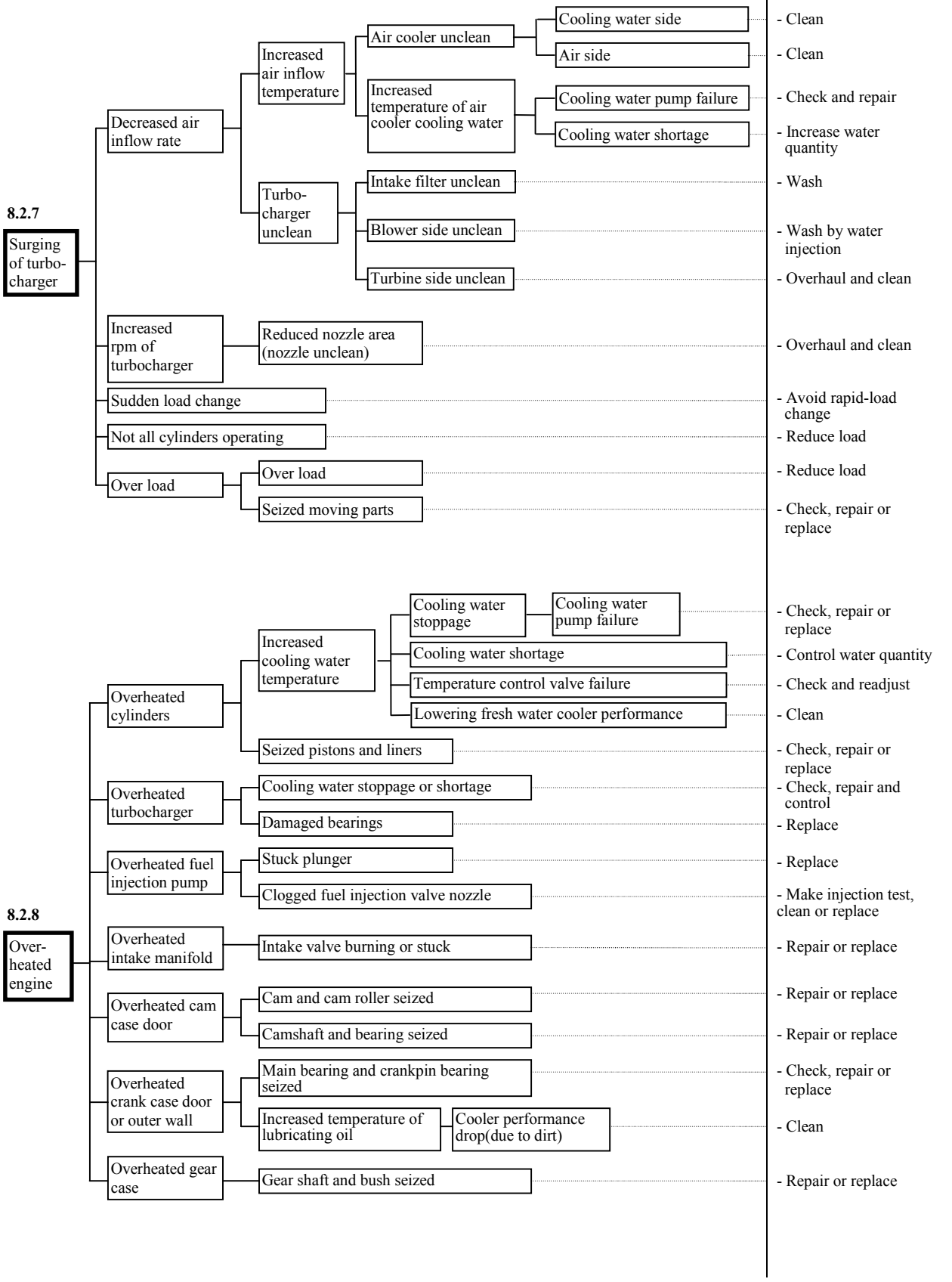

Trouble
Probable Cause
Remedy
8.2.1
Engine fails to start
Crank-shaft doesn't turn at all or at sufficient speed.
Starting air is not available
Starting air pressure is too low
- charge, and check the pressure gauge
Either main valve or intermediate valve of air tank is closed
- Open the valve
Starting air is available
Starting air is not available at air starter
Turning device has not disengaged
- Disengage
Starting air is available at air starter
Air starter malfunction
- Repair or replace
Ring gear broken
- Replace
Starting air leakage
Piping system leakage
- Check, and repair
Increased resistance of sliding parts
Higher lubricating oil viscosity
- Warm or change the oil
Piston and cylinder liner stuck
- Check, repair or replace
Crankshaft or bearing stuck
-Ditto
Foreign matter is caught by the gear
- Ditto
Cylinder full of water or oil
- Check the indicator cock
Crank-shaft turns
Empty fuel tank
- Replenish fuel
Water is mixed in fuel oil or fuel oil is of poor quality
- Analyze oil quality or change oil
Good fuel oil quality
Fuel oil not available to the fuel injection pump
Piping is clogged or valves remain closed
- Check, repair or replace
Air inhalation from piping joints
- Check, repair or vent air
Clogged filter
-Overhaul, clean or replace
Detective supply pump
- Check, repair or replace
Fuel oil available to the fuel injection pump
Abnormal fuel injection pump
Fuel oil does not deliver
Worn plunger
- Replace
Defective plunger spring
- Replace
Detective delivery valve
- Replace
Decreased delivery rate caused by worn plunger
- Replace
Improper timing
Maladjusted injection beginning angle
- Readjust
Wrong engagement of timing gear
- Correct engagement
Normal fuel injection pump
Abnormal fuel injector
Seized needle valve or poor spray
- Make injection test, clean or replace
Defective fuel injector
- Make injection test or replace
Excessive oil leakage from fuel injector
- Make injection test, correct or replace
Injection pressure drop or poor adjustment
- Make injection test and readjustment
Clogged nozzle holes
- Make injection test, clean or replace
Loose or broken injection pipe
- Tighten additionally or replace
Normal fuel injector
Air present in fuel oil line
- Vent air
Incorrect intake and exhaust valve timing
- Check and correct the timing
Defective intake and exhaust valve seat
- Repair by lapping or replace
Seized piston ring
- Repair or replace
Stuck fuel control link
- Check, and repair

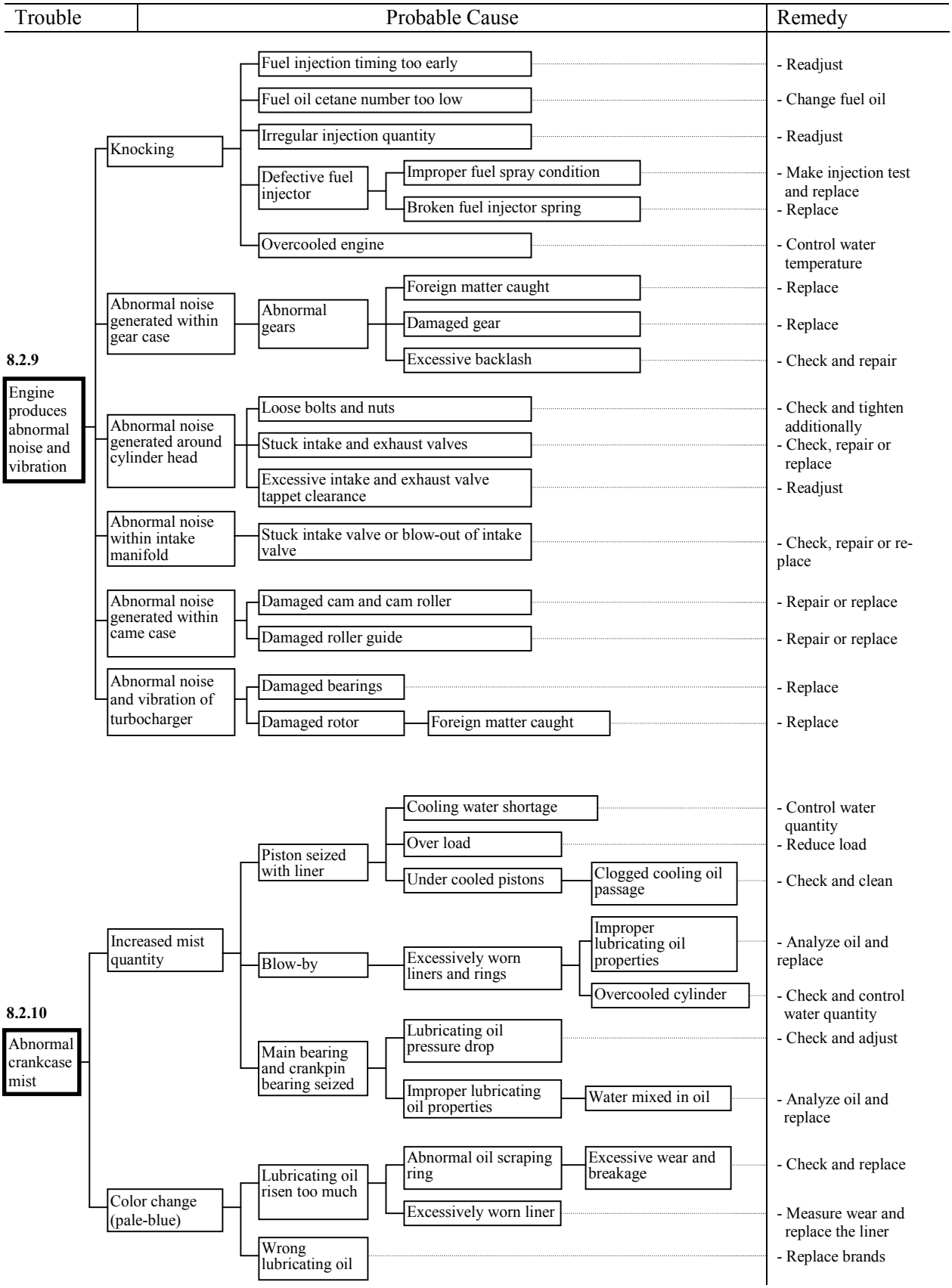

Trouble
Probable Cause
Remedy
8.2.2
Abnormal engine start
Unintentional engine start
Defective air starter solenoid valve
- Check, repair or replace
Engine stalls shortly after start
Insufficient supply of fuel oil
Empty fuel tank
- Replenish
Insufficient supply pressure
Feed pump failure
- Check, repair or replace
Clogged filter
- Check clean or replace
Clogged piping system (valves, cocks, etc.)
- Check repair or open
Not all air vented from the piping system
- Vent air
A large quantity of water in fuel oil
- Discharge drain or change oil
Fuel control link returns by itself
Governor failure (Out of control)
Abnormal driving device
- Check and repair
Seized link system or disconnected joints
- Check and repair
Governor failure
- Check
Not all air vented from the injection system
- Vent air
Abnormal firing or misfiring of some cylinders
No fuel injected into some cylinders
Abnormal fuel injection pump
Stuck plunger
- Replace
Stuck delivery valve
- Replace
Stuck rack
- Repair or replace
Rack scale assembled in wrong way
- Check and assemble
Incorrect injection timing (loose push rod)
- Readjust
Abnormal fuel injector
Stuck needle valve
- Make injection test and replace
Abnormality of nozzle hole (clogged or tip missing)
- Check and replace
Injection pressure drop
- Make injection test and readjust
Broken spring
- Replace
Broken nozzle
- Replace
Sudden increase in engine speed
Fuel collects in cylinder
- Check and repair
Abnormal fuel control
Sticking of fuel pump rack for specific cylinders
- Check and repair
Governor abnormality (Out of control)
Abnormal driving device
- Check and repair
Seized link system or disconnected joints
- Check and repair
Governor failure
- Check
Abnormal fuel control device at start
Fuel oversupplied at start
- Readjust
Inadequate control release (abnormal control air system)
- Check and repair

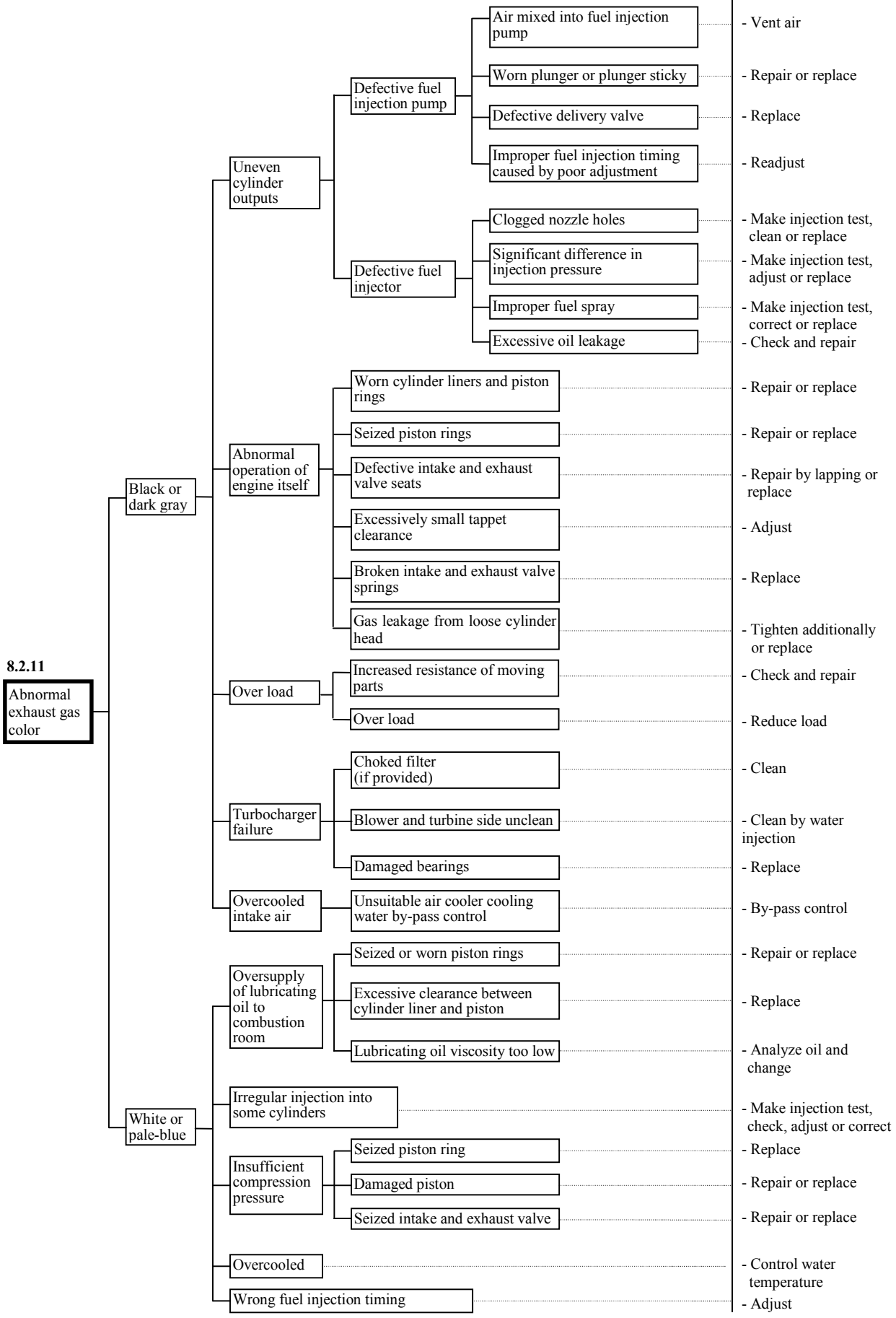

Trouble
Probable Cause
Remedy
8.2.3
Insuffi-cient engine power
Exhaust gas is colorless or pale blue
Insufficient fuel supply
Abnormal feed pump
- Check, repair or replace
Normal feed pump
Maladjustment of governor link or its failure
- Check, adjust or replace
Clogged fuel pipe
- Clean
Clogged filter
- Clean
Loose fuel pipe joints
- Tighten additionally or repair
Defective fuel injection pump
Worn plunger
- Replace
Damaged delivery valve
- Replace
Abnormal fuel injection system
Incorrect fuel injection timing
Injection timing too late
- Adjust
Injection timing too early
- Adjust
Defective fuel injection pump
Worn or seized plunger
- Replace
Defective delivery valve
- Replace
Defective delivery valve gasket
- Replace
Defective fuel injector
Seized needle valve
- Make injection test and replace
Worn, damaged or clogged valve seat
- Clean or replace
Defective fuel injector spring
- Make injection test and replace
Clogged nozzle holes
- Clean or replace
Exhaust gas blackish or contains soot pale blue
Abnormal operation of engine itself
Worn liner and piston rings
- Repair or replace
Seized piston rings
- Repair or replace
Defective intake and exhaust valve seats
- Repair by lapping
Tappet clearance too small
- Adjust
Broken intake and exhaust valve springs
- Replace
Gas leakage from loose cylinder head
- Tighten additionally or replace gasket
Leakage from the intake and exhaust manifold systems
- Tighten additionally or replace gasket
Increased resistance of moving parts
- Check and repair
Abnormal turbocharger
Clogged filter (if provided)
- Clean
Blower impeller or turbine blades unclean
- Clean and wash by water injection
Damaged bearing
- Replace
Improper fuel
Improper fuel quality
- Change
Air or water present in fuel oil
- Vent air or replace

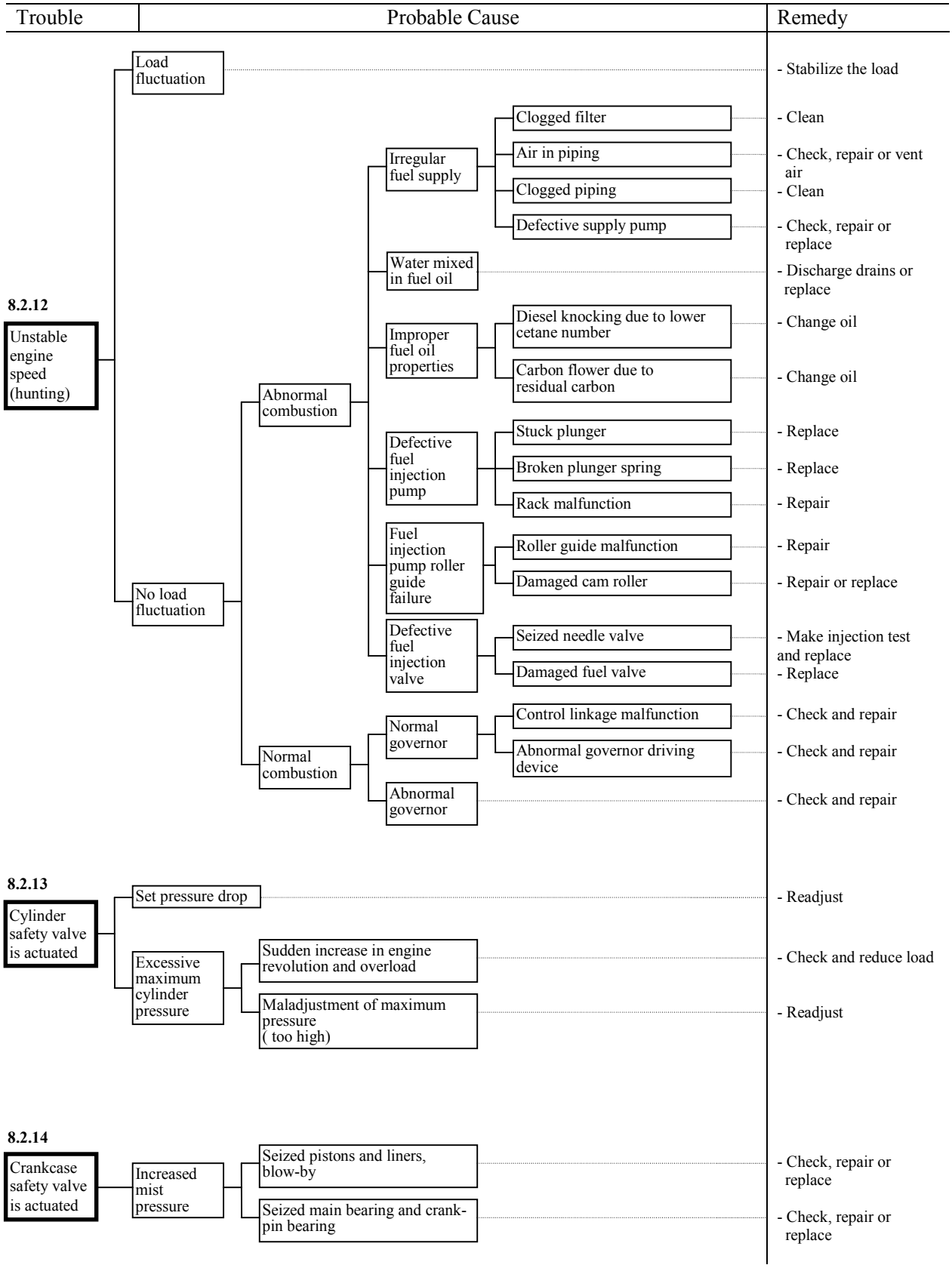

Trouble
Probable Cause
Remedy
8.2.4
Abnormal exhaust gas temperature
Exhaust gas temperature too high
Temperature of all cylinders too high
Over load
Abnormal propeller (rapidly increased exhaust gas temperature) (in case of marine engines)
- Repair or replace
Increased hull resistance (in case of marine engines)
- Clean
Increased engine room temperature
- Ventilate
Turbocharger performance drop
Decrease rpm and charger air pressure
Blower unclean
- Clean by water injection
Turbine blades unclean
- Clean by water injection
Intake filter clogged
- Wash
Air cooler performance drop
Increased intake air temperature
Air cooler unclean
- Clean
Increased temperature of secondary cooling water
- Control water quantity
Reduced intake passage area
Accumulation of carbon in cylinder head intake port
- Clean
Increase exhaust gas back pressure
- Check exhaust manifold system and clean it
Temperature of specific cylinders too high
Defective thermometer
- Replace
Exhaust valve burning
- Repair or replace
Rack scale out of order (advance)
- Readjust
Incorrect fuel injection timing
- Readjust
Abnormal nozzle (enlarged nozzle holes)
- Make injection test and replace
Exhaust gas temperature too low
Temperature of all cylinders too low
Under load
- Normal
Intake air temperature drop
Secondary cooling water temperature drop
- Normal
Temperature of specific cylinders too low
Defective thermometer
- Replace
Abnormal fuel injection pump
Rack scale out of order (delay)
- Readjust
Stuck plunger
- Replace
Broken plunger spring
- Replace
Abnormal fuel injector
Clogged nozzle holes
- Make injection test, clean or replace
Stuck nozzle needle valve
- Make injection test, repair or replace
Leakage from fuel injection pipe
Cracked piping
- Replace
Defective joints
- Repair or replace
Water leakage into cylinders
Water leakage from cylinder head
- Check, repair or replace
Water leakage from exhaust valve cage
- Check, repair or replace

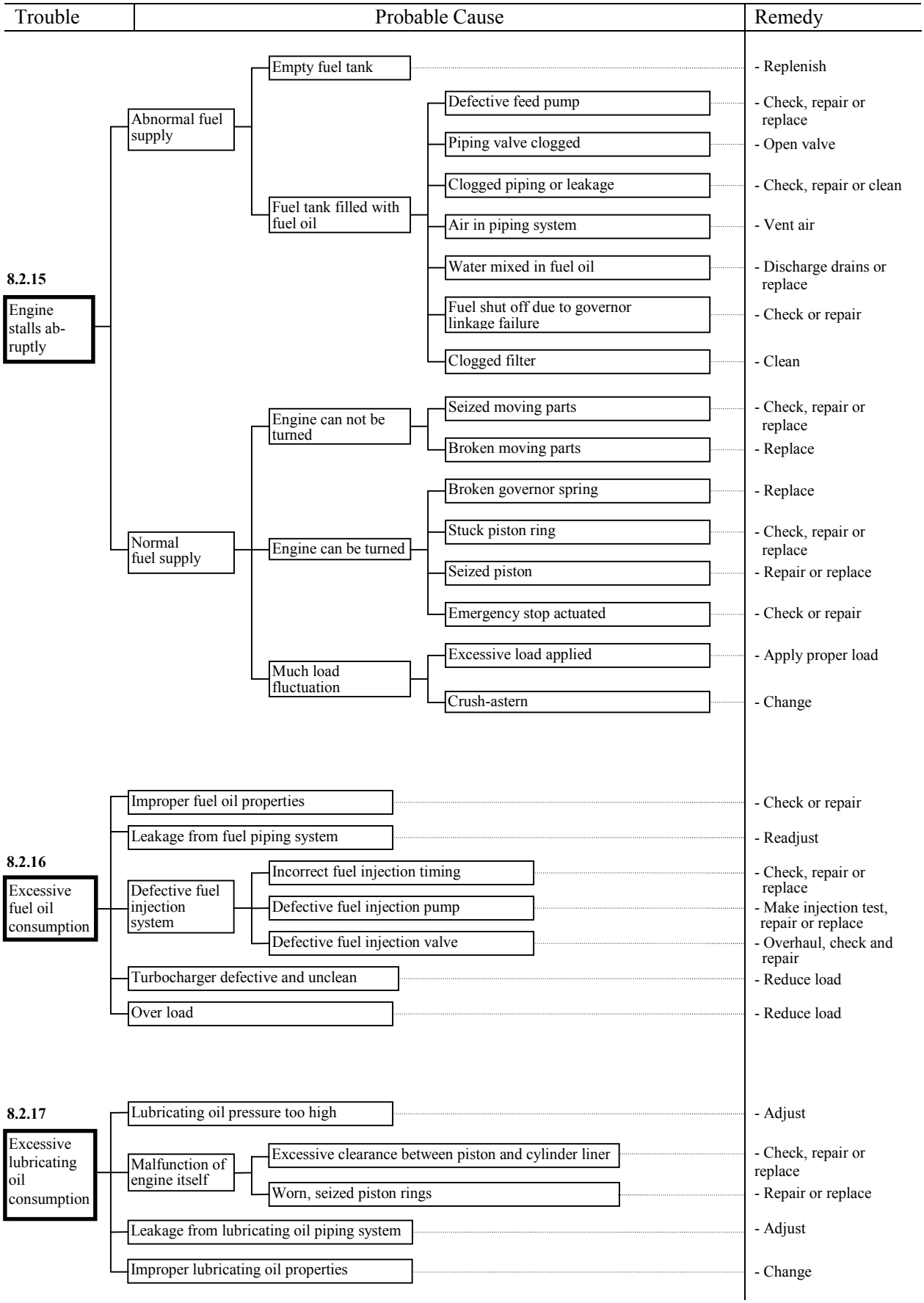

Trouble
Probable Cause
Remedy
8.2.5
Abnormal maximum cylinder pressure
Maximum pressure too high
Increased pressure in all cylinders
Indicator out of order
- Repair or replace
Over load
- Reduce load
Increased charge air pressure
Increased rpm of turbocharger
Clogged turbine nozzle (due to deformation or dirt)
- Overhaul, clean or replace
Increased pressure in specific cylinders
Wrong fuel injection timing
- Readjust
Abnormal fuel injection pump
Stuck rack(at high position)
- Repair or replace
Abnormal fuel injection valve
Enlarged nozzle holes
- Make injection test and replace
Missing nozzle tip
- Replace
Maximum pressure too low
Decreased pressure in all cylinders
Indicator out of order
- Repair or replace
Under load
- Normal
Charge air pressure drop
Turbocharger performance drop (decreased rpm)
Blower side unclean
- Clean by water injection
Turbine side unclean
- Clean by water injection
Increased air cooler resistance
- Clean
Decreased pressure in specific cylinders
Compression pressure drop
Intake and exhaust valves burning
- Repair or replace
Poor gas tightness of piston rings
- Check and replace
Normal compression pressure
Wrong fuel injection timing (delay)
- Readjust
Abnormal fuel injection pump
Stuck rack (at low position)
- Repair or replace
Abnormal fuel injection valve
Stuck needle valve
- Make injection test , repair or replace
Clogged nozzle
- Make injection test , repair or replace
Leakage from fuel injection pipe
Cracked piping
- Replace
Defective joint
- Repair or replace
8.2.6
Abnormal charge air pressure
Pressure too low
Under load
- Normal
Turbocharger performance drop
Blower side unclean
- Clean by water injection
Turbine side unclean
- Clean by water injection
Air leakage from intake manifold system
- Overhaul and clean
Pressure too high
Over load
- Reduce load
Abnormal Turbocharger
Clogged turbine nozzle (due to deformation or dirt)
- Overhaul, clean or replace


Trouble
Probable Cause
Remedy
8.2.7
Surging of turbo-charger
Decreased air inflow rate
Increased air inflow temperature
Air cooler unclean
Cooling water side
- Clean
Air side
- Clean
Increased temperature of air cooler cooling water
Cooling water pump failure
- Check and repair
Cooling water shortage
- Increase water quantity
Turbo-charger unclean
Intake filter unclean
- Wash
Blower side unclean
- Wash by water injection
Turbine side unclean
- Overhaul and clean
Increased rpm of turbocharger
Reduced nozzle area (nozzle unclean)
- Overhaul and clean
Sudden load change
- Avoid rapid-load change
Not all cylinders operating
- Reduce load
Over load
Over load
- Reduce load
Seized moving parts
- Check, repair or replace
8.2.8
Over-heated engine
Overheated cylinders
Increased cooling water temperature
Cooling water stoppage
Cooling water pump failure
- Check, repair or replace
Cooling water shortage
- Control water quantity
Temperature control valve failure
- Check and readjust
Lowering fresh water cooler performance
- Clean
Seized pistons and liners
- Check, repair or replace
Overheated turbocharger
Cooling water stoppage or shortage
- Check, repair and control
Damaged bearings
- Replace
Overheated fuel injection pump
Stuck plunger
- Replace
Clogged fuel injection valve nozzle
- Make injection test, clean or replace
Overheated intake manifold
Intake valve burning or stuck
- Repair or replace
Overheated cam case door
Cam and cam roller seized
- Repair or replace
Camshaft and bearing seized
- Repair or replace
Overheated crank case door or outer wall
Main bearing and crankpin bearing seized
- Check, repair or replace
Increased temperature of lubricating oil
Cooler performance drop(due to dirt)
- Clean
Overheated gear case
Gear shaft and bush seized
- Repair or replace

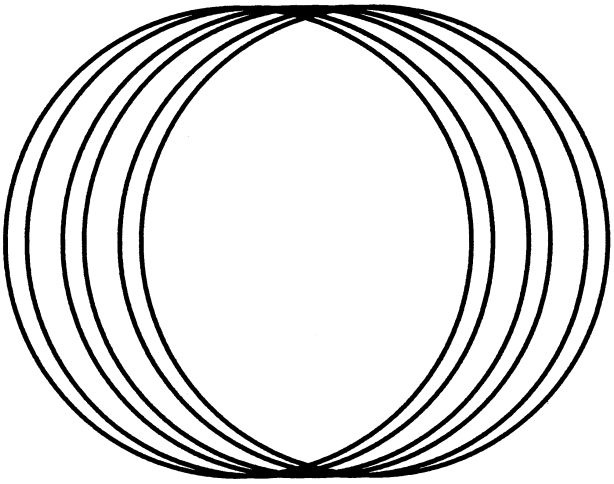

Trouble
Probable Cause
Remedy
8.2.9
Engine produces abnormal noise and vibration
Knocking
Fuel injection timing too early
- Readjust
Fuel oil cetane number too low
- Change fuel oil
Irregular injection quantity
- Readjust
Defective fuel injector
Improper fuel spray condition
- Make injection test and replace
Broken fuel injector spring
- Replace
Overcooled engine
- Control water temperature
Abnormal noise generated within gear case
Abnormal gears
Foreign matter caught
- Replace
Damaged gear
- Replace
Excessive backlash
- Check and repair
Abnormal noise generated around cylinder head
Loose bolts and nuts
- Check and tighten additionally
Stuck intake and exhaust valves
- Check, repair or replace
Excessive intake and exhaust valve tappet clearance
- Readjust
Abnormal noise within intake manifold
Stuck intake valve or blow-out of intake valve
- Check, repair or replace
Abnormal noise generated within came case
Damaged cam and cam roller
- Repair or replace
Damaged roller guide
- Repair or replace
Abnormal noise and vibration of turbocharger
Damaged bearings
- Replace
Damaged rotor
Foreign matter caught
- Replace
8.2.10
Abnormal crankcase mist
Increased mist quantity
Piston seized with liner
Cooling water shortage
- Control water quantity
Over load
- Reduce load
Under cooled pistons
Clogged cooling oil passage
- Check and clean
Blow-by
Excessively worn liners and rings
Improper lubricating oil properties
- Analyze oil and replace
Overcooled cylinder
- Check and control water quantity
Main bearing and crankpin bearing seized
Lubricating oil pressure drop
- Check and adjust
Improper lubricating oil properties
Water mixed in oil
- Analyze oil and replace
Color change (pale-blue)
Lubricating oil risen too much
Abnormal oil scraping ring
Excessive wear and breakage
- Check and replace
Excessively worn liner
- Measure wear and replace the liner
Wrong lubricating oil
- Replace brands


Trouble
Probable Cause
Remedy
8.2.11
Abnormal exhaust gas color
Black or dark gray
White or pale-blue
Uneven cylinder outputs
Defective fuel injection pump
Air mixed into fuel injection pump
- Vent air
Worn plunger or plunger sticky
- Repair or replace
Defective delivery valve
- Replace
Improper fuel injection timing caused by poor adjustment
- Readjust
Defective fuel injector
Clogged nozzle holes
- Make injection test, clean or replace
Significant difference in injection pressure
- Make injection test, adjust or replace
Improper fuel spray
- Make injection test, correct or replace
Excessive oil leakage
- Check and repair
Abnormal operation of engine itself
Worn cylinder liners and piston rings
- Repair or replace
Seized piston rings
- Repair or replace
Defective intake and exhaust valve seats
- Repair by lapping or replace
Excessively small tappet clearance
- Adjust
Broken intake and exhaust valve springs
- Replace
Gas leakage from loose cylinder head
- Tighten additionally or replace
Over load
Increased resistance of moving parts
- Check and repair
Over load
- Reduce load
Turbocharger failure
Choked filter (if provided)
- Clean
Blower and turbine side unclean
- Clean by water injection
Damaged bearings
- Replace
Overcooled intake air
Unsuitable air cooler cooling water by-pass control
- By-pass control
Oversupply of lubricating oil to combustion room
Seized or worn piston rings
- Repair or replace
Excessive clearance between cylinder liner and piston
- Replace
Lubricating oil viscosity too low
- Analyze oil and change
Irregular injection into some cylinders
- Make injection test, check, adjust or correct
Insufficient compression pressure
Seized piston ring
- Replace
Damaged piston
- Repair or replace
Seized intake and exhaust valve
- Repair or replace
Overcooled
- Control water temperature
Wrong fuel injection timing
- Adjust


Trouble
Probable Cause
Remedy
8.2.12
Unstable engine speed (hunting)
Load fluctuation
- Stabilize the load
No load fluctuation
Abnormal combustion
Irregular fuel supply
Clogged filter
- Clean
Air in piping
- Check, repair or vent air
Clogged piping
- Clean
Defective supply pump
- Check, repair or replace
Water mixed in fuel oil
- Discharge drains or replace
Improper fuel oil properties
Diesel knocking due to lower cetane number
- Change oil
Carbon flower due to residual carbon
- Change oil
Defective fuel injection pump
Stuck plunger
- Replace
Broken plunger spring
- Replace
Rack malfunction
- Repair
Fuel injection pump roller guide failure
Roller guide malfunction
- Repair
Damaged cam roller
- Repair or replace
Defective fuel injection valve
Seized needle valve
- Make injection test and replace
Damaged fuel valve
- Replace
Normal combustion
Normal governor
Control linkage malfunction
- Check and repair
Abnormal governor driving device
- Check and repair
Abnormal governor
- Check and repair
8.2.13
Cylinder safety valve is actuated
Set pressure drop
- Readjust
Excessive maximum cylinder pressure
Sudden increase in engine revolution and overload
- Check and reduce load
Maladjustment of maximum pressure (too high)
- Readjust
8.2.14
Crankcase safety valve is actuated
Increased mist pressure
Seized pistons and liners, blow-by
- Check, repair or replace
Seized main bearing and crank-pin bearing
- Check, repair or replace


Trouble
Probable Cause
Remedy
8.2.15
Engine stalls abruptly
Abnormal fuel supply
Empty fuel tank
- Replenish
Fuel tank filled with fuel oil
Defective feed pump
- Check, repair or replace
Piping valve clogged
- Open valve
Clogged piping or leakage
- Check, repair or clean
Air in piping system
- Vent air
Water mixed in fuel oil
- Discharge drains or replace
Fuel shut off due to governor linkage failure
- Check or repair
Clogged filter
- Clean
Normal fuel supply
Engine can not be turned
Seized moving parts
- Check, repair or replace
Broken moving parts
- Replace
Engine can be turned
Broken governor spring
- Replace
Stuck piston ring
- Check, repair or replace
Seized piston
- Repair or replace
Emergency stop actuated
- Check or repair
Much load fluctuation
Excessive load applied
- Apply proper load
Crush-astern
- Change
8.2.16
Excessive fuel oil consumption
Improper fuel oil properties
- Check or repair
Leakage from fuel piping system
- Readjust
Defective fuel injection system
Incorrect fuel injection timing
- Check, repair or replace
Defective fuel injection pump
- Make injection test, repair or replace
Defective fuel injection valve
- Overhaul, check and repair
Turbocharger defective and unclean
- Reduce load
Over load
- Reduce load
8.2.17
Excessive lubricating oil consumption
Lubricating oil pressure too high
- Adjust
Malfunction of engine itself
Excessive clearance between piston and cylinder liner
- Check, repair or replace
Worn, seized piston rings
- Repair or replace
Leakage from lubricating oil piping system
- Adjust
Improper lubricating oil properties
- Change

Trouble	Probable Cause	Remedy
8.2.18 Lubricating oil pressure gauge malfunction	Pressure gauge pointer does not rise after engine start: Lubricating oil shortage	- Replenish
	Lubricating oil viscosity too low	- Analyze oil and change
	Defective lubricating oil pressure sensor	- Replace
	Clogged pressure gauge sensor piping	- Clean
	Excessive bearing clearance	- Check, repair or replace
	Lubricating oil pump malfunction: Air inhalation into suction piping	- Check, repair or vent air
	Clogged suction piping or filter	- Clean
	Worn gear case	- Check and replace
	Pressure regulating valve failure	- Check, repair or replace
	Clogged filter	- Clean
	Pressure gauge pointer drops suddenly during operation: Excessive oil leakage caused by damaged piping or cooler	- Check, repair or replace
	Blind plug for oil hole fallen off	- Check and attach plug
	Cracked lubricating oil piping or leakage from joints	- Repair
	Pressure gauge pointer oscillates during operation: Air inhalation through inlet due to lubricating oil shortage	- Replenish
	Clogged lubricating oil piping	- Check and clean
	Poorly adjusted pressure regulating valve	- Adjust
8.2.19 Cases where engine requires emergency stop	Engine revolution has risen spontaneously or cannot be controlled	
	Fuel scale pointer abnormally advanced and engine revolution dropped	
	Bearings or other moving parts overheated	
	Engine produces abnormal vibration	
	Engine produces abnormal noise	
	Mist in crankcase abnormal in quantity or color	
	Lubricating oil pressure sudden drop	
	Cooling water temperature sudden rise	
	Turbo-blower produces abnormal noise, vibration or heat	



NIIGATA DIESEL
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9. APPENDIX

9.1 Lubricating oil system flushing procedure

When an engine is newly installed, or when the engine is overhauled, the lubricating oil system must be flushed to remove sludge and other foreign matter. This Manual describes a standard flushing procedure, and it must be understood that, particularly when an engine is newly installed, a special method may have to be used because the amount and kind of foreign matter in the piping may vary. Choose an appropriate method as instructed by your installation advisor.

9.1.1 Cases requiring flushing

(a) Newly installed engine

The first stage to the third flushing mentioned later is necessary for removing scale, dust, etc. Generated by piping and welding.

(b) Overhauled engine

A flushing similar to that applied to a newly installed engine is necessary to remove substances resulting from lubricating oil deterioration and combustion.

(c) Change of lubricating oil

The first to the third flushing are necessary for removing substances resulting from lubricating oil deterioration and preventing fresh oil contamination. Particularly when using heavy fuel oil, flushing is important for washing away the burnt residues that have been deposited on various parts.

(d) Other

If foreign matter is suspected to have entered the lubricating oil system accidentally, flush the system in a similar way.

9.1.2 Parts requiring flushing

(1) Lubricating oil circulation system

- Sump tank, lubricating oil pump, cooler, filters, temperature control valve, bypass valves, and pipes connecting them
- Crankcase and Oil pan
- Lubricating oil return pipe (Engine $\rightarrow$ Sump tank)
- Engine inside oil paths - The third flushing only.

9.1.3 Preparations for Flushing

(1) Parts not flushed

In the case of the first stage and the second stage flushing, engine inside oil paths are not flushed, therefore the oil engine inlet pipe have to be disconnected and to be led into the crankcase by connecting a temporary pipe or a hose.

(2) Have a temporary pump and filter (First stage ; 150-mesh. Second stage ; 250-mesh.), if equipped pumps and filters are not available.

(3) Temporary filter mounting

At the outlet of the temporary pipe in the crankcase, put a basket type filter of 250-mesh gauze wire to collect and remove foreign matter.

9.1.4 Flushing Oil

(1) Flushing oil selection

Various brands of flushing oil are available from oil makers. Ask them for advice. Flushing conditions.

(2) Flushing oil amount

Fill the sump tank to more than 60% of its capacity with flushing oil. Record the amount of flushing oil put into the sump tank to check against the amount of oil withdrawn later.

(3) Oil circulating temperature

Standard oil circulating temperature at the engine inlet is 60 to 80°C (First stage) and 50 to 70°C (Second stage). If the oil temperature is lower than that, use a heater to heat the oil.

(4) Oil pressure

Fit pipe outlet in the crankcase with a suitable throttle so that the flushing oil will circulate full in the piping. This is necessary because the oil is not supplied to the inside of the engine. Be careful of differential filter pressure because large amounts of foreign matter may flow into the filter when oil circulation through the filter is started.

9.1.5 Flushing

(1) A flushing schedule is shown below.

Flushing	Oil	Oil temperature (°C)	Oil pressure (MPa)	Hours	Piping
First stage flushing	Flushing oil	60 ~ 80	0.1 ~ 0.2	72	Engine inlet pipe is Disconnected and oil Returns directly to the crankcase. -Temporary piping
Second stage flushing	Normal Lubricating oil	50 ~ 70	0.1 ~ 0.2	2	Same as above
Third stage flushing	Normal Lubricating oil	50 ~ 70	0.4 ~ 0.6	3	Normal piping

※The first stage and the second stage flushing, engine inside oil paths are not flushed.

(2) Record the following information to use as data for judging flushing condition and in order to thoroughly control the flushing process as a whole.

Data	Time	Cumulative oil circulation time	Lubricating Oil pump Pressure (MPa)	Lubricating oil filter pressure		Oil temperature (°C)	Foreign matter						Remarks
				Outlet	Inlet		Sand	Fiber	Iron rust	Spatter	Paint	Sludge	

(3) The filters tend to be clogged with foreign matter immediately after flushing begins.
(4) Hammering is necessary to completely remove scale after welding.
(5) Collect foreign matter with the temporary filter and the equipped filters.
(6) As a rule, foreign matter should be collected and various parts checked every 4 hours.
(7) Ideally, flushing should be continued until foreign matter has been completely removed. If no foreign matter is seen caught by the filters, however, the flushing may be regarded as nearly finished. End the first stage flushing when the amount of foreign matter caught by the temporary filter on the main bearing branch pipe is less than 0.05g/24 hours.
(8) After finishing the first flushing, discharge all the flushing oil from the system. Because a considerable amount of flushing oil may remain in the cooler, filters and the bottom parts of the piping, discharge all the oil and measure the quantity of oil withdrawn. If a very large amount of flushing oil remains, it will dilute the system oil and consequently deteriorate it. The allowable amount of remaining flushing oil is less than 5% of the amount of system oil used.
(9) Clean the inside of the sump tank and the bottom of the oil pan (before filling the system with flushing oil, and after the flushing oil is discharged following the completion of the first flushing). Use oil-resistant sponge, not waste cloth, for cleaning.
(10) After finishing the above, fill the system with recommended lubricating oil, and circulate it under the required conditions for the second flushing.
(11) Be careful of differential filter pressure during the second flushing. Discharge drains, and make sure that no foreign matter has collected in the blow filter.
(12) After finishing the second flushing, remove the temporary filter, and reconnect the engine inlet pipe normally, observing the checking instructions above to prevent any difficulties.
(13) During the third flushing, check the filter differential pressure and discharge drains to see that the oil is free of foreign matter. Also, thoroughly vent air from the cooler and filters. Turn the engine (making use of the turning device) for about 30 minutes at the same time. This third flushing has the dual purpose of internal flushing and priming.