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United Kingdom

Ref: FOI2018/09032

E-mail: ISS-SecretariatGpMbx@mod.gov.uk

[redacted]

16 July 2018

Dear [redacted],

Thank you for your email of 1 July 2018 requesting the following information:

"*I have recently purchased a used harrington generator (HGI) and was looking for a wiring drawing, manual and maintenance information.*

Its serial number is 19768/2
Manufacured 09/02.
Its a 20 kva single phase unit.

I have requested this information from hgi but the have been unable to help because of it being an ex mod unit."

I am treating your correspondence as a request for information under the Freedom of Information Act 2000 (FOIA).

Thank you for providing additional photographs that have allowed us to idenfify your generator. A search for the information has now been completed within the Ministry of Defence, and I can confirm that all the information in scope of your request is held. The information you have requested can be found attached with this response.

If you have any queries regarding the content of this letter, please contact this office in the first instance.

If you wish to complain about the handling of your request, or the content of this response, you can request an independent internal review by contacting the Information Rights Compliance team, Ground Floor, MOD Main Building, Whitehall, SW1A 2HB (e-mail CIO-FOI-IR@mod.gov.uk). Please note that any request for an internal review should be made within 40 working days of the date of this response.

If you remain dissatisfied following an internal review, you may raise your complaint directly to the Information Commissioner under the provisions of Section 50 of the Freedom of Information Act. Please note that the Information Commissioner will not normally investigate your case until the MOD internal review process has been completed. The Information Commissioner can be contacted at: Information Commissioner's Office, Wycliffe House, Water Lane, Wilmslow, Cheshire, SK9 5AF. Further details of the role and powers of the Information Commissioner can be found on the Commissioner's website at https://ico.org.uk/.

Yours sincerely,

ISS Secretariat

[redacted]

6115-L-400-201
Edition 1 December 2006

CORMORANT

20kVA DIESEL GENERATOR

OPERATION AND MAINTENANCE MANUAL

By Command of the Defence Council

Ministry of Defence

Prepared by: EADS, Newport, South Wales
Publications Authority: TFCS IPT

Army Equipment Support Publication

[redacted]

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PRELIMINARY MATERIAL Page

PREFACE

1 Each initial issue leaf bears the date of issue. Each leaf of a subsequent amendment bears the date of issue and the number of the amendment with which the subsequent leaf was issued.

2 New or amended technical matter will be indicated by triangles positioned outside the type area thus: > < to show the extent of amended text. When a Part, Section or Chapter is issued in a completely revised form, the triangles will not appear and the material will carry the note '(Completely revised)'.

3 The content of the COTS manuals supplied for the Cormorant generator equipment is reproduced 'as given'. Only the presentation, to comply with MoD specifications, has been changed. Harrington Generators International Ltd cannot accept responsibility for the technical accuracy of the information supplied in the COTS manuals.

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LIST OF RELATED PUBLICATIONS

012-01K	Isuzu Diesel Engine Instruction Manual (Industrial) - 4LB1, 4LC1, 4LE1
107-04K	Isuzu Diesel Engine Workshop Manual (Industrial) - 4LB1, 4LC1, 4LE1
	Isuzu L-Series Diesel Engine Technician Guide
BCH-018 Ed 12	Newage Alternator - Installation, Service and Maintenance Manual
DSE 520 Issue 4	Deep Sea Electronics Engine Management System – Model 520

The commercial publications associated with the Harrington 20 kVA Diesel Generator system are located in Annexes A, B, C, D and E of this Operation and Maintenance Manual.

WARNINGS

PERSONAL INJURY. ALWAYS READ THE HAZARD NOTICES ASSOCIATED WITH OPERATING AND MAINTAINING THIS MACHINE. IF IN DOUBT ABOUT THE SAFE OPERATION OF THE EQUIPMENT, CONSULT THE MANUFACTURER OR A QUALIFIED OPERATOR.

PERSONAL INJURY. DO NOT REMOVE THE RADIATOR CAP WHILST THE ENGINE IS RUNNING OR HOT.

LETHAL VOLTAGE. DO NOT CARRY OUT HIGH VOLTAGE INSULATION TESTS ON THE GENERATOR OR ON THE DISTRIBUTION SYSTEM WHILST THE GENERATOR IS CONNECTED.

PERSONAL INJURY. BEFORE COMMENCING ANY SERVICE OR REPAIR WORK, ENSURE THAT THE CONTROL MODULE IS IN THE 'OFF/RESET' POSITION. OPERATE THE EMERGENCY STOP PUSHBUTTON. DISCONNECT THE NEGATIVE TERMINAL ON THE BATTERY. ENSURE THAT THERE IS NO CONNECTION TO THE 24V INTER-VEHICLE SOCKET.

PERSONAL INJURY. EACH BATTERY WEIGHS 40Kg AND THE BATTERIES SHOULD BE LIFTED BY TWO PEOPLE.

DAMAGE TO HEARING. OPERATORS SHOULD WEAR EAR DEFENDERS WHILST THE 20KVA GENERATOR IS IN OPERATIONWITH DOORS/PANELS OPEN.

PERSONAL INJURY. 20KVA GENERATOR COOLANT – ETHYLINE GLYCOL IS HARMFUL IF SWALLOWED. IN CASE OF CONTACT WITH EYES, RINSE IMMEDIATELY WITH PLENTY OF WATERAND SEEK MEDICAL ADVICE. ALWAYS WEAR PROTECTIVE CLOTHING, GLOVES AND EY/FACE PROTECTION. IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE IMMEDIATELY.

PERSONAL INJURY. EXHAUST EXTENSIONS MUST BE DEPLOYED OUTSIDE CAMOUFLAGE NETTING WHILST THE GENERATOR IS RUNNING. WHEN DEPLOYING GENERATORS ENSURE EXHAUSTS AND EXHAUST EXTENSIONS ARE POINTED AWAY FROM THE VEHICLE.

CAUTIONS

EQUIPMENT DAMAGE. Caution should be exercised when using the 'Emergency Start' feature as damage may be caused whilst it is in use and the generator is allowed to exceed its normal operational parameters.

EQUIPMENT DAMAGE. All PERSONNEL in the vicinity should be made aware that the emergency stop is inoperable whilst using the 'Emergency Start' feature.

EQUIPMENT DAMAGE. Caution should be exercised when refueling and using the fuel gauge to monitor the contents of the fuel tank. The fuel gauge is damped so it does not register changes in fuel level instantaneously.

LIST OF ABBREVIATIONS

COTS	Commercial Off The Shelf
EC	Emission Control
IRR	Infra-Red Reflective
Kg	Kilogramme
Mcb	Miniature circuit breaker
PCLM	Pilot Circuit Line Monitor
RCD	Residual Current Device

CATEGORY 1 **PLANNING AND SUPPORT INFORMATION**

SUB-CATEGORY 1.0 PURPOSE AND PLANNING INFORMATION

SUB-CATEGORY 1.0

PURPOSE AND PLANNING INFORMATION

CONTENTS

INTRODUCTION

1 The Cormorant 20kVA Generator consists of a four-cylinder diesel engine close-coupled to a 1-phase brushless alternator, housed within an acoustic/weatherproof canopy.

2 The self-contained unit has the capability to operate autonomously for 12 hours, utilising the on-board fuel, batteries and a control and monitoring system.

3 The canopy (Fig 1) houses the exhaust silencer and provides shielding.

4 The compact, integral control system monitors critical performance parameters of the engine, alternator and electrical output, reporting indications, warnings and shutdowns.

5 The electrical power output interface is via two connectors. The 230V, 1-phase, 50Hz output is protected against overload, short-circuit and earth leakage.

Canopy

6 The canopy is fabricated from steel and aluminium alloy and is finished with an Infra-Red Reflective (IRR) powder coating. The function of the canopy is to provide mechanical and weather protection and to restrict noise and heat emissions.

Generator

7 The engine is an Isuzu 4LE1, 4-cylinder water-cooled diesel engine, naturally aspirated. The engine has mechanical speed governing with 5% regulation. The electrical system is 24 volt and includes a belt-driven battery charge alternator. The alternator is a Newage BCI182J 2-pole machine of rotating field, brushless construction.

Generator control module

8 The generator control module monitors the operational status of the generator and checks engine, alternator and control system parameters against pre-programmed levels. The LED display indicates operational sequences, warning and fault conditions.

SAFETY

WARNING

PERSONAL INJURY. ALWAYS READ THE HAZARD NOTICES ASSOCIATED WITH OPERATING AND MAINTAINING THIS MACHINE. IF IN DOUBT ABOUT THE SAFE OPERATION OF THE EQUIPMENT, CONSULT THE MANUFACTURER OR A QUALIFIED OPERATOR.

9 Observe the following instructions and precautions before attempting to operate or maintain the 20kVA diesel generator.

(1) READ the associated engine and alternator operation manuals.

(2) ENSURE that you know how to stop the engine in an emergency.

(3) BE AWARE that the generator has the facility to be started remotely.

(4) BEFORE commencing any service, maintenance or repair work, ensure that the control module is in the OFF/RESET position. Operate the emergency stop pushbutton.

(5) DO NOT operate the generator in confined areas. Exhaust fumes are poisonous and can KILL.

(6) ENSURE that the surrounding area of the machine has no restrictions that would prevent an adequate flow of clean, ambient air.

(7) DO NOT operate the generator with the canopy doors open.

(8) DO NOT smoke when refuelling.

(9) AVOID overfilling when refuelling.

(10) WIPE up any fuel spilt on the machine and move the equipment away from the area where fuel has been spilt.

(11) OPERATE the equipment at least 1 metre from other equipment and buildings. The area should be clear of any combustible materials, ie cardboard, dried grass, timber etc.

(12) DO NOT use the equipment with loose or missing components or guards.

(13) REMEMBER that parts of the engine and particularly the exhaust system remain hot for some time after the generator has stopped.

(14) EARTHING is the responsibility of the persons installing the generator and its distribution system.

SPECIFICATIONS

10 Table 1 details the specifications of the Cormorant 20kVA generator.

TABLE 1 CORMORANT 20kVA GENERATOR SPECIFICATIONS

Generator Component	Specification
Output (Main)	20kVA 230V 50 Hz 1-phase. 10% overload capacity 1 hour in 10.
Power Factor	0.8 lag.
Output Power	16.0 kW
Rated Current	87.0 Amps (0.8pf). 69.6 Amps (1.0pf).
Voltage Regulation	+/- 2.5%
Engine	Isuzu 4LE1 4 cylinder, water-cooled. 3000 rev/min nominal. 24 volt electric start.
Alternator	Newage BCI182J 2-pole, rotating field. Brushless, Class H insulation.
Fuels	Dieso (Ambient temperatures -5°C to +44°C). AVTUR (Ambient temp below -5°C). 100 litre tank. 12 hours operation at full load.
Lubricating Oil	Multi-viscosity diesel engine oil. SAE 15W-40 (Ambient temp -15°C to +49°C). SAE 5W-30 (Ambient temp below -15°C).
Coolant	Ethylene glycol (50%) and water mixture (50%) with inhibiting coolant additives.
Battery	UK 6TN FV546133. 12 volt lead acid 100 Ah rating. Two in series.
Output Connectors	2 x 50A max rating 4 pin. Mcb protection 45A per connector.
Inter-vehicle Connector	24 Volt FV634300. NATO No. 4910997234625. (ABPC20352806SFOO).
Operating Conditions	Ambient temperatures -31°C to +44°C. Altitude up to 3000 masl.
Dimensions	1990L x 870W x 1325H (millimetres).
Weight	890kg maximum (fully loaded).

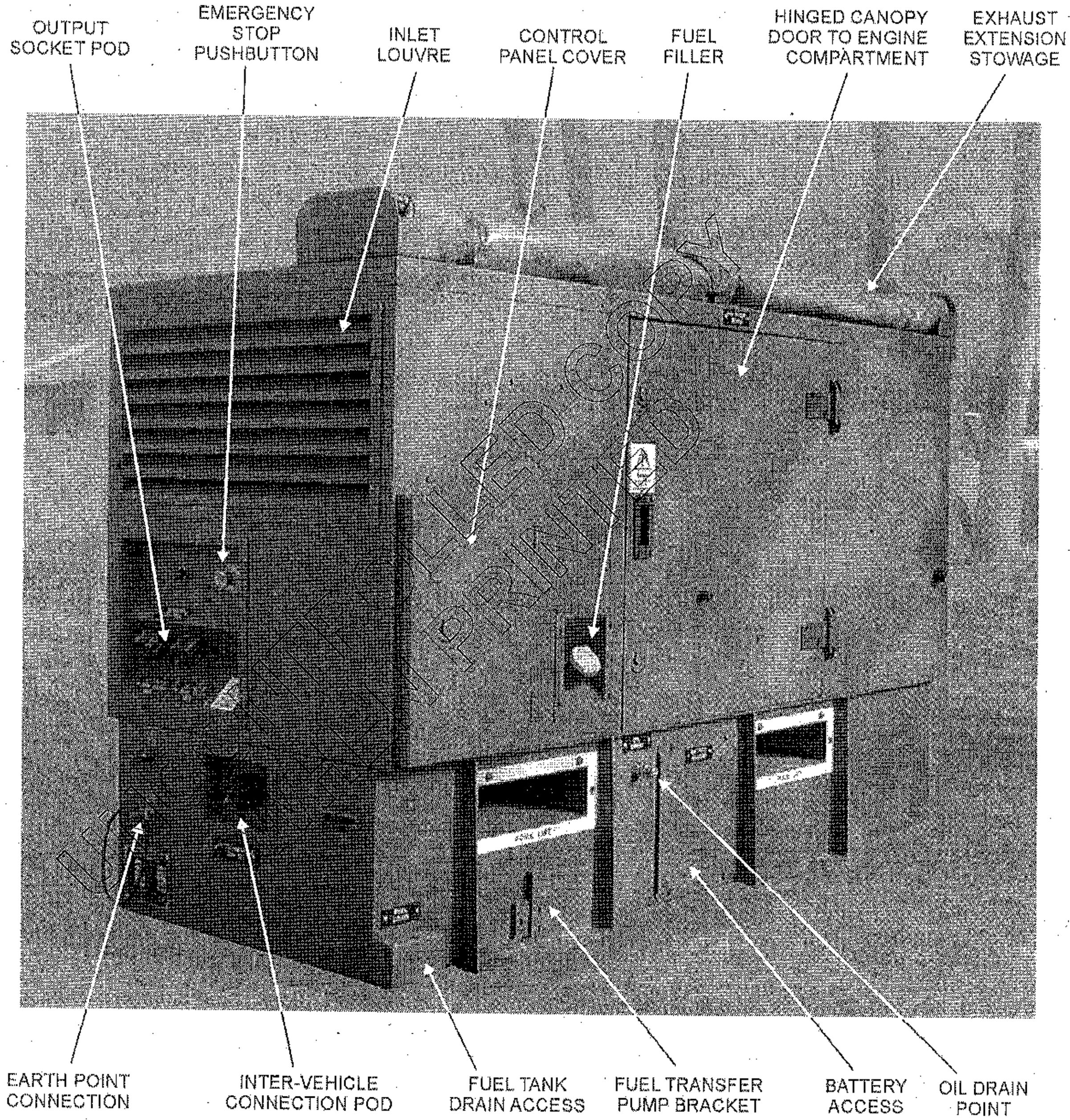


Fig 1 Cormorant 20kVA generator canopy front view

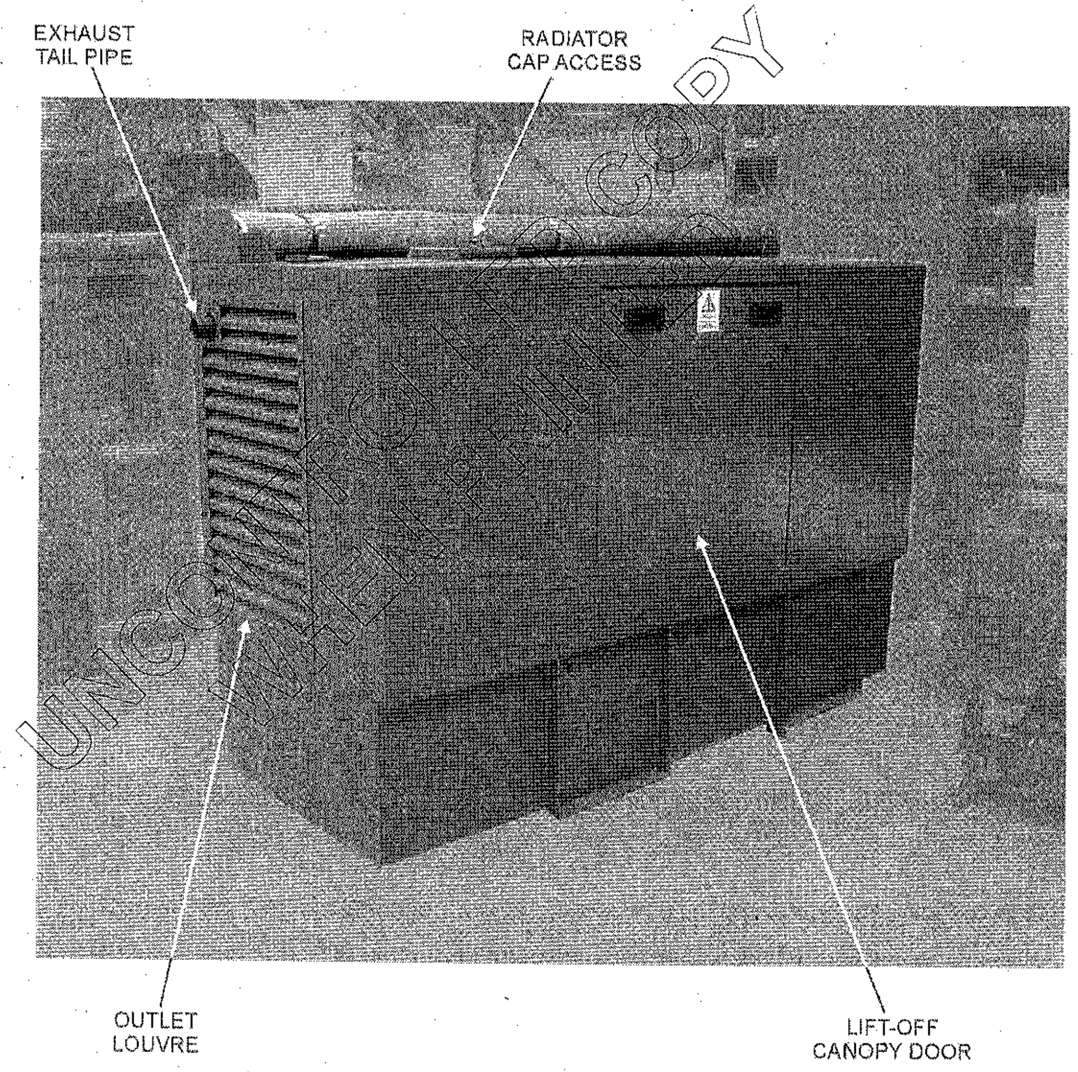


Fig 2 Cormorant 20kVA generator canopy rear view

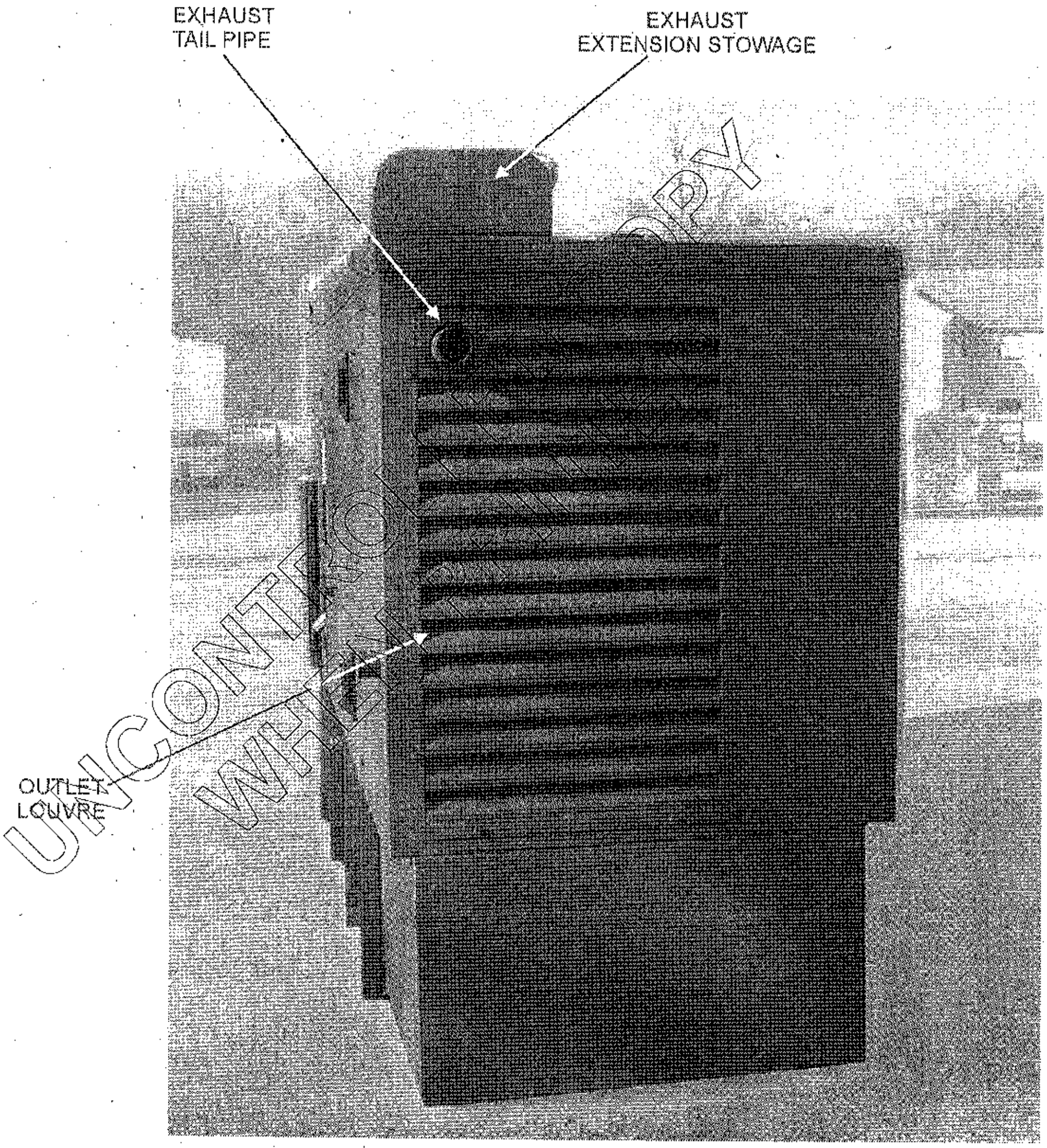


Fig 3 View on hot air louvre end

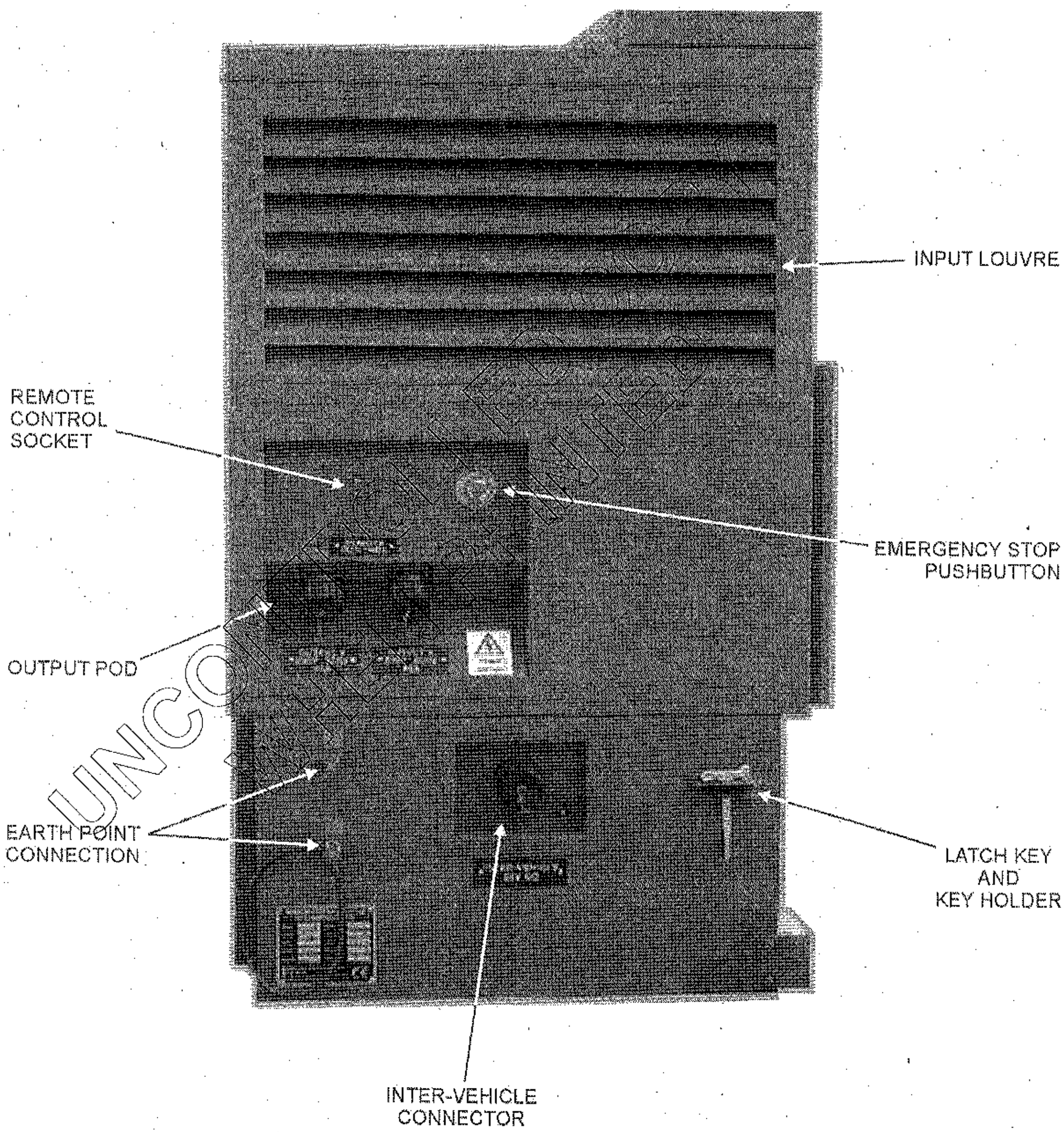


Fig 4 View on output panel end

CATEGORY 2 **OPERATING AND TRAINING INFORMATION**

SUB-CATEGORY 2.0 OPERATING INFORMATION

SUB-CATEGORY 2.0

OPERATING INFORMATION

CONTENTS

PRE-START CHECKS

1 Reference should be made to Fig 1 Control Module and Fig 2 Control Panel throughout the operating instructions. Pre-start checks are as follows:

(1) Check that the generator is stood on reasonably level ground.

(2) Check the generator earthing arrangements. Earthing is the responsibility of the persons installing the generator and its distribution system.

(3) Open the hinged access door to the engine compartment. Check the lubricating oil level in the engine. (Refer also to the Engine Instruction Manual at Annex A, Para 29.) Add oil as necessary using the grade according to the site conditions (refer to Sub-cat 1.0).

(4) Check there is sufficient fuel in the tank using the Fuel/Hours status switch. Add fuel as necessary using the fuel type according to the site conditions (refer to Sub-cat 1.0).

WARNING

PERSONAL INJURY. DO NOT REMOVE THE RADIATOR CAP WHILST THE ENGINE IS RUNNING OR HOT.

(5) Check the coolant level in the expansion bottle (Fig 3). Coolant may be added to the expansion bottle (<u>only if there is already water in the bottle</u>) or via the radiator filler cap (Sub-cat 5.3, Fig 4). Add coolant as necessary so that the level touches the bottom of the radiator filler neck. Use 50% ethylene glycol and water mixture with supplemental coolant additives. (Refer also to Annex A, Para 37.)

(6) Check that the canopy inlet and outlet louvres are not blocked. Brush away any heavy sand or dust deposits that have collected at the bottom of the louvres.

(7) Squeeze the dust unloader valve on the engine air cleaner to remove dust deposits. If clogged, remove and clean the dust unloader valve. Replace if damaged.

(8) When operating in extremely dusty/sandy conditions, check the air restriction indicator. If this shows restriction in the air intake system, remove and inspect the primary air cleaner element. Service as necessary. (Refer also to the Engine Instruction Manual at Annex A, Para 108.)

CHECKING THE SERVICE STATUS

2 Operate the Fuel/Hours Status switch and check the recorded 'hours run'. Check this against the service/maintenance program for the generator and take the appropriate measures if attention is due. (See the Maintenance Schedule summary in Sub-cat 5.3.)

STARTING

3 To start the 20kVA generator:

(1) Ensure that the DC selector is ON.

(2) Turn the generator mode selector switch to the 'RUN' position.

(3) Check that there are no warning lamps illuminated. If warning lamps are lit, refer to Sub-cat 5.1, Fault Diagnosis.

(4) Press the engine 'Start' button and release.

(5) If the ambient temperature is below -12°C, the cold start system will be activated. The 'Cold Start' LED will illuminate for 20 seconds whilst the induction air heater operates.

(6) Following the 20 second cold start period, or immediately if the temperature is above -12°C, the 'Pre-heat' (Glow) LED will illuminate. The engine cylinder head glow plugs will heat for 10 seconds before cranking begins.

NOTE

When the starting sequence has begun, the 'Stop' button will not halt the procedure until the generator has run up to speed.

(7) To abort the start sequence, turn the mode selector switch to 'STOP/RESET'.

(8) The control system will automatically start the generator and disconnect the starter. The system will make up to three attempts to start with a short rest between each crank period to allow the batteries to recover and prevent starter burn-out.

(9) If the generator fails to start after three attempts, the 'Fail to Start' warning lamp will illuminate and the 'Common alarm' lamp will flash. Refer to Sub-cat 5.1, Fault Diagnosis.

NOTE

In an **EMERGENCY**, press the Emergency Stop pushbutton.

CHECKING THE OUTPUT

4 Before connecting equipment to the generator, it is advisable to check that the off-load voltage is stable and within limits.

5 The voltage can be checked using the voltmeter. The voltage should be 230 Volts +/- 6V. If the voltage is not within this range, DO NOT PROCEED with connection of the load.

CONNECTING LOAD

6 To connect the load:

(1) Remove the cap(s) on the output socket(s) marked '230V 50Hz'. (Refer to Fig 4).

(2) Push the power lead connector firmly into the socket and tighten the locking ring.

(3) Operate the relevant Mcb, ie Mcb Output 1 or Mcb Output 2, to connect the generator to the load.

(4) If the Mcb will not set, it may be due to a pilot wire incontinuity or an earth leakage in the distribution system. (See Sub-cat 5.1, Fault Diagnosis.)

CHECKING THE GENERATOR LOADING

7 The amount of load supplied by the generator can be monitored using the ammeter.

8 The load current should not exceed 87 amperes as a continuous load. A 10% overload, ie 96 amperes, is allowable for 1 hour in every 10 hours.

SHUTDOWN

9 To shutdown the generator:

(1) Switch off the power at the Mcb(s).

(2) Press the engine 'Stop' button.

(3) When the generator has come to a halt, turn the control module mode selector switch to 'STOP/RESET'.

(4) There is no requirement to disconnect cabling.

EARTHING

WARNING

LETHAL VOLTAGE. DO NOT CARRY OUT HIGH VOLTAGE INSULATION TESTS ON THE GENERATOR OR ON THE DISTRIBUTION SYSTEM WHILST THE GENERATOR IS CONNECTED.

10 The neutral of the generator winding is electrically bonded to the metalwork of the generator and to the Earth Point connection on the generator canopy (see Fig 4 in Sub-cat 1.0).

11 The generator is fitted with over-current protection, residual current protection and pilot wire monitor devices. The operation of these devices is described in Sub-cat 3.0 of this manual.

12 Tests should be carried out on new installations and at appropriate intervals thereafter to ascertain that earth fault (loop) impedances are low enough to ensure that electrical protection devices operate in the event of a breakdown of insulation leading to an 'earth fault'

13 Further advice on earthing can be found in the following Health & Safety Executive publications (available from HMSO):

Guidance note	GS27	Protection Against Electric Shock
	GS24	Electricity on Construction Sites

CONTROL MODULE

14 The control module (Fig 2) is a microprocessor-based unit and is the hub of the dc and ac control system. The module is programmed during manufacture. To assist in understanding the operation of the control system, refer to the DSE 520 Engine Management System manual at Annex E, the programme configuration in Para 16, and to the wiring diagrams in Sub-cat 3.0.

15 Operation is as follows:

(1) The module uses a 24V dc supply at Terminals 1 and 2. The supply positive is protected by a single-pole miniature circuit breaker, 35A.

(2) The engine fuel control solenoid and starter motor solenoid are supplied via Terminal 3 and the emergency stop pushbutton.

NOTE

This complies with CE Safety Machinery legislation that dictates that emergency shutdown systems are not associated with microprocessor circuits.

(3) The generator start sequence commences when a supply negative is connected to Terminal 13 and the module is in 'RUN' mode. This is initiated when the 'Start' button is pressed momentarily. An auxiliary output signal at Terminal 17 latches the start interlock relay.

(4) If the ambient temperature is below -12°C, the cold start timer is energised. This holds off the signal to Terminal 13 for 20 seconds whilst the induction air heater operates.

(5) As soon as the signal is received at Terminal 13, the pre-heat timer commences. Auxiliary output at Terminal 6 energises the pre-heat slave relay. This energises the cylinder head glow plugs. Following the pre-heat time (10 seconds), the fuel relay is energised via Terminal 4 and the engine fuel solenoid operates.

(6) The start relay is energised via Terminal 5 for the duration of the first crank period (10 seconds).

NOTE

All LEDs are extinguished during cranking.

(7) If the engine does not start during this time, there follows a crank rest period (1 second). Three crank attempts are made with a rest period between each. If the engine has still not started after three attempts, the fail to start alarm is latched and the 'Fail to start' LED is lit. The 'Common alarm' LED flashes.

(8) When the engine starts, the main alternator voltage is monitored at Terminals 14 and 15 via circuit breaker Mcb2. When the frequency reaches 21.0Hz, cranking is stopped.

(9) Monitoring of the oil pressure, engine temperature and charge alternator are held off for the safety on delay time (10 seconds).

(10) The generator is running and available to supply the load. While the fuel solenoid is energised, an auxiliary output at Terminal 17 energises the fuel gauge.

(11) During operation, the following parameters are monitored:

Low oil pressure	(N/O switch).
High engine temperature	(N/O switch).
Underspeed/Frequency	(Limit 42Hz).
Overspeed/Frequency	(Limit 55Hz).
Battery charge alternator	(Limit 8.0V).
Low fuel alarm 1.5 hrs	(20 litres remaining).
Low fuel alarm 0.5 hrs	(6 litres remaining).
Pre-heaters energised.	
Cold start circuit operational.	

CONTROL MODULE

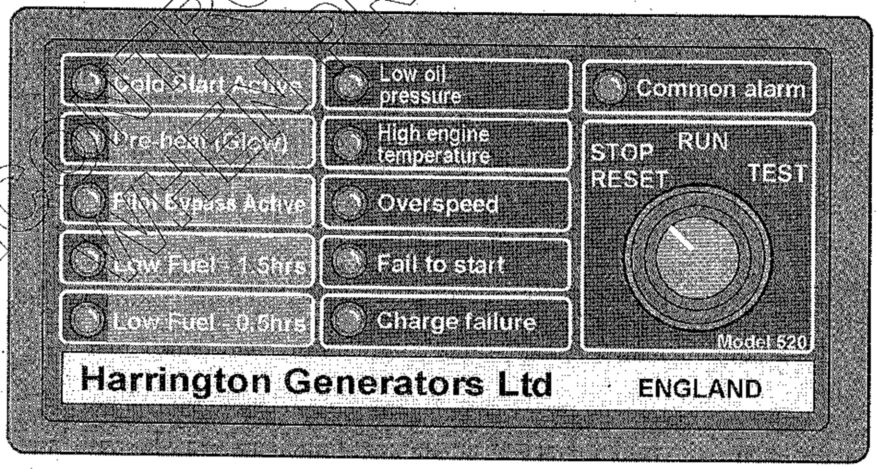


Fig 1 Control module

(12) In normal operation, generator shutdown is initiated by pressing the 'Stop' button momentarily. This removes the supply negative at Terminal 13. The remote start signal is removed and the auxiliary output at Terminal 17 is de-energised along with the start interlock relay.

(13) The fuel relay is de-energised from Terminal 4 and the engine stops.

(14) At this point, the fail to stop timer is initiated for 30 seconds.

(15) If oil pressure or alternator frequency are detected after this time, a fail to stop alarm is generated. The 'Common alarm' LED flashes.

CORMORANT 20kVA MANAGEMENT MODULE PROGRAM

16 Pre-programmed parameter levels as shown at Para 15(11) are entered during commissioning of the Control Module.

17 Refer to the Model 520 Engine Management System manual at Annex E for control module factory default configuration details. The configuration for a standard module, if no configuration interface is available, gives values and details of the following:

(1) Miscellaneous items.

(2) Configurable inputs.

(3) Relay outputs.

(4) Front panel LEDs.

(5) System timers.

(6) Analogue levels.

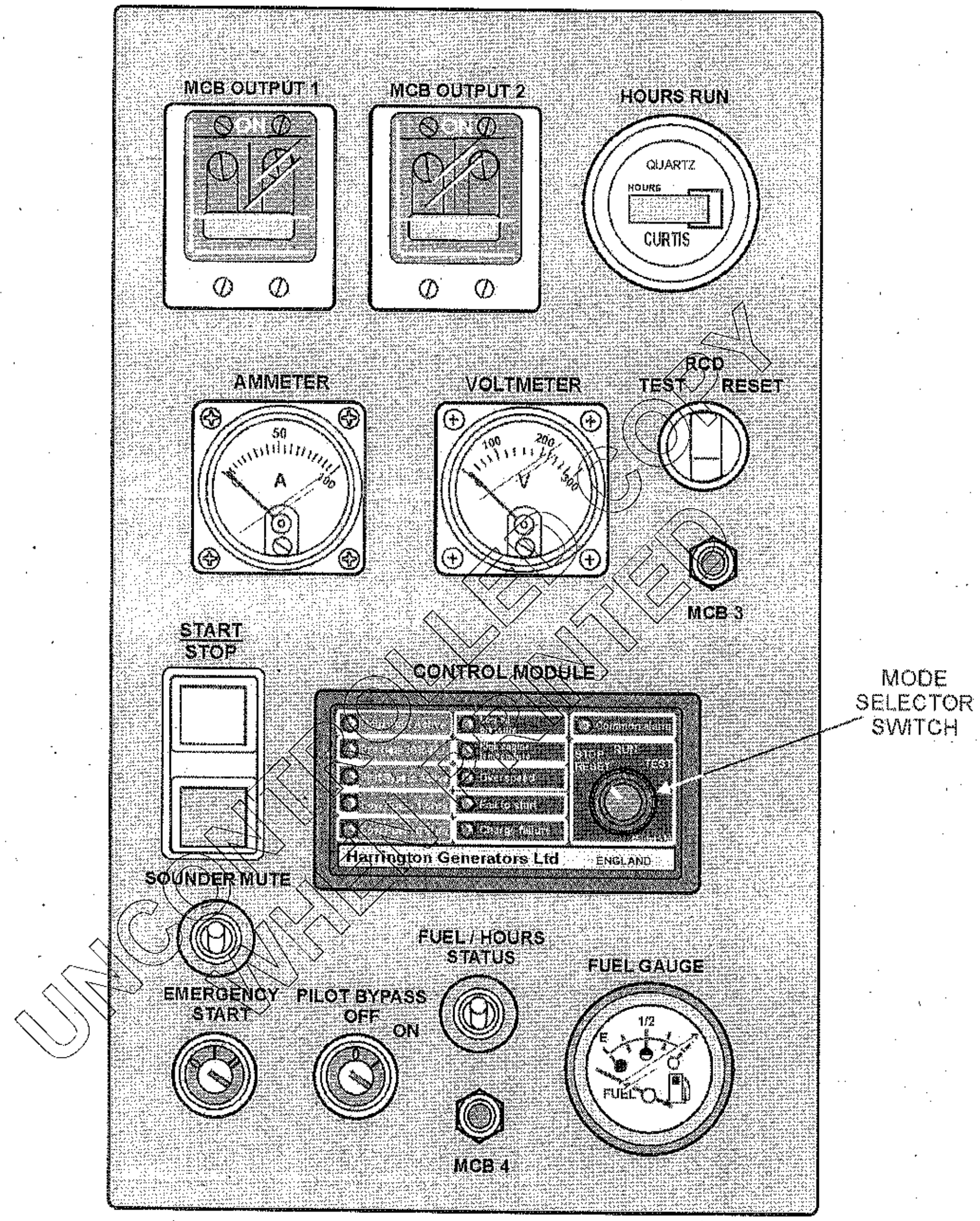


Fig 2 Control panel

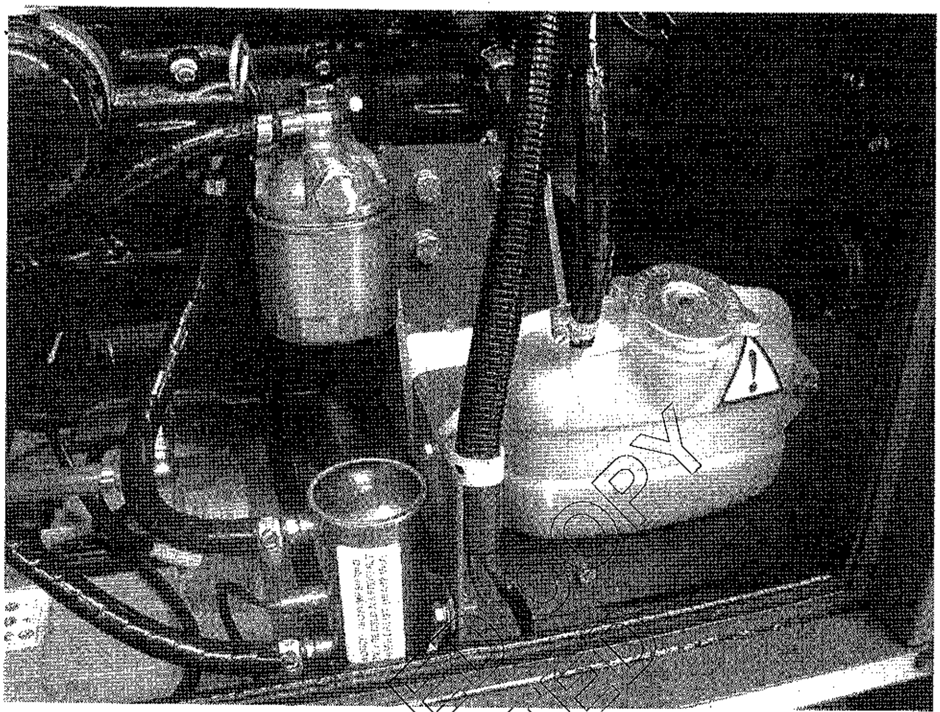


Fig 3 Expansion bottle

Fig 4 Output pod

CATEGORY 3 **TECHNICAL DESCRIPTION**

SUB-CATEGORY 3.0 20 KVA GENERATOR EQUIPMENT DESCRIPTION

SUB-CATEGORY 3.0

TECHNICAL DESCRIPTION

CONTENTS

SUB-CATEGORY 3.0

TECHNICAL DESCRIPTION

GENERAL

1 The Cormorant 20kVA generator set consists of a four-cylinder diesel engine, close-coupled to a 1-phase brushless alternator, housed with the ancillary systems within an acoustic/weatherproof canopy.

2 The self-contained unit has the capability to operate autonomously for 12 hours, utilising the on-board fuel, batteries and control and monitoring system.

3 The generator has a high power-to-weight ratio, achieved by using a high speed engine/alternator combination and alloy canopy components where possible.

4 The canopy houses the exhaust silencer and provides shielding, thus reducing the infra-red, acoustic and electro-magnetic signature from the machine. Exhaust extension pipework and insulation is provided and stowed on-board for use when camouflage nets are deployed.

5 The compact, integral control system monitors critical performance parameters of engine, alternator and electrical output, reporting indications, warnings and shutdowns as appropriate.

6 The electrical power output interface is via two connectors. The 230V, 1-phase, 50Hz output is protected against overload, short-circuit and earth leakage.

7 The pilot wire (Pilot Circuit Line Monitor (PCLM)) protection system is also fitted (Fig 3), although this can be disabled when the generator is required to operate with incompatible equipment.

8 A remote control interface socket is fitted, which facilitates monitoring and limited control of the generator at a suitably equipped remote station.

9 An inter-vehicle connector is provided to allow remote 24V batteries to be utilised to supplement deficient generator batteries. Alternatively, the connector allows the generator batteries to be used as a slave power source.

ENGINE

10 The engine is an Isuzu 4LE1, 4-cylinder water-cooled diesel engine, naturally aspirated.

11 Engine displacement is 2.9 litres and the combustion system is direct injection for improved cold starting performance.

12 Nominal operating speed is 3000 rev/min for 50Hz electrical output.

13 The engine has mechanical speed governing with 5% regulation. The electrical system is 24 volt and includes a belt-driven battery charge alternator.

ALTERNATOR

14 The alternator is a Newage BCI182J 2-pole machine.

15 The unit is of rotating field, brushless construction and therefore has no slip rings or brushes to maintain.

16 The engine and alternator are directly coupled via a flexible disc system, the alternator having a single bearing at the non-drive end. The alternator is fitted with an electronic voltage regulator that monitors the terminal voltage and adjusts the exciter field current to maintain a constant voltage independent of load.

CONTROL AND ELECTRICAL SYSTEMS

17 Reference should be made to the four wiring diagrams (Figs 6, 7, 8 and 9) whilst reading the Control and Electrical Systems section of Sub-cat 3.0.

Generator control module

18 The generator Control Module (Fig 1), which is located in the centre of the Control Panel (Fig 2), monitors the operational status of the generator and checks engine, alternator and control system parameters against pre-programmed levels. The LED display indicates the following operational sequences, warnings and fault conditions:

Cold start active	Operational indicator
Pre-heat (Glow)	Operational indicator
Pilot Bypass Active	Operational indicator
Low oil fuel 1.5 hours	Warning indicator
Low oil fuel 0.5 hours	Warning indicator
Low oil pressure	Shutdown alarm
High engine temperature	Shutdown alarm
Overspeed	Shutdown alarm
Fail to start	Shutdown alarm
Charge failure	Warning indicator

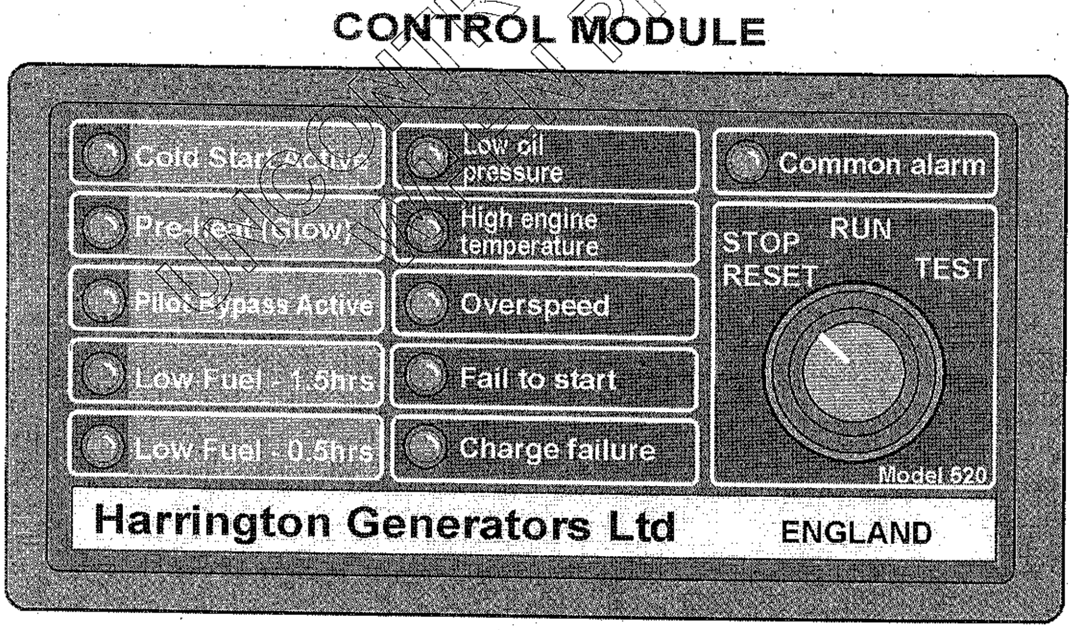


Fig 1 Generator control module

19 Warnings are self-resetting once the fault has been removed. Shutdowns are latching and stop the generator. The mode selector switch must be turned to 'STOP/RESET' and the fault removed to reset the module after a shutdown alarm.

Engine Start/Stop pushbuttons

20 The momentary pushbutton switches (Fig 2) start and stop the generator under normal conditions. The switches are only operational when the control module mode selector is in the 'RUN' position.

Fuel gauge

21 The fuel gauge gives a continuous reading of the fuel level whilst the engine is running. The Fuel/Hours Status switch enables a fuel level reading to be obtained when the unit is not running. Operation of the switch (Fig 2) whilst the engine is running is not detrimental.

DC control system circuit breaker (Mcb 4)

22 The circuit breaker protects the 24V control system circuits against overload and short-circuit. The button protrudes when the breaker has tripped. Press in to latch and reset.

AC metering circuit breaker (Mcb 3)

23 The circuit breaker protects the voltmeter, engine management module and the shunt trip circuits on Mcb 1 and Mcb 2 from overload and short-circuit (refer to Paras 27 to 30). The button protrudes when the breaker has tripped. Press in to latch and reset.

Hours-run counter

24 Records the cumulative total of operational hours of the generator set. The display is activated whilst the engine is running. To check the hours run with the engine stationary, operate the Fuel/Hours Status switch (Fig 2).

Voltmeter

25 Indicates the voltage of the single-phase AC output.

Ammeter

26 Indicates the total load current being supplied by the generator via the two output sockets.

Output circuit breakers - Output 1(Mcb 1) and Output 2 (Mcb 2)

27 Each output socket (Fig 2) is protected by a Miniature circuit breaker (Mcb) that is multi-functional. Primarily, the Mcb(s) protect the generator from overloads and short-circuits. Each Mcb is rated to allow approximately 50% of the generator's full output via each socket.

28 The Mcb(s) can be used as isolator switches for each output socket.

29 Each Mcb is fitted with a shunt trip, which, when energised, will trip the breaker to the 'Off' position.

30 The shunt trip is used in two control circuits as follows:

(1) An earth leakage, detected by a RCD (Residual Current Device) sensing imbalance on the live and neutral of each output, will cause both circuit breakers to trip.

(2) A pilot wire incontinuity on either output circuit will cause that particular circuit breaker to trip. The other output circuit will continue to operate normally.

Pilot wire monitor

31 The Pilot Wire Monitor (Fig 3) is a safety feature, which checks the continuity of a pilot circuit from the generator through to a terminator at the load.

32 The Pilot Wire Monitor prevents the output of the generator being energised, ie the circuit breakers cannot be switched on unless all connectors in the circuit are in place and the pilot wire is intact. The pilot wire monitor also relies on a 'good' earth return (less than 5Ω) to the generator. This may be via the earth conductor in the power cable or via an earth spike system.

33 There are independent monitors on each of the outputs allowing the two output sockets to be utilised individually if required.

Pilot bypass keyswitch

34 The Pilot Bypass switch (Fig 2) disables the pilot wire monitor system on both output circuits. This feature is provided to allow connection of loads that do not have pilot wire terminators fitted.

Emergency start keyswitch

CAUTIONS

(1) EQUIPMENT DAMAGE. Caution should be exercised when using this feature as damage may be caused whilst it is in use should the generator be allowed to exceed its normal operational parameters.

(2) EQUIPMENT DAMAGE. All personnel in the vicinity should be made aware that the emergency stop is inoperable whilst using this feature.

35 The emergency start keyswitch overrides the DSE520 engine management module and all engine safety features to enable the user to start the generator. This switch disables the emergency stop, the low oil pressure and the high engine temperature safety features on the generator. Using this keyswitch does not affect the operation of the pilot wire monitor or the RCD trip.

RCD test/reset switch

36 In the event of earth fault current detection and the RCD module (Fig 3) causing both output Mcb(s) to trip, the RCD Test/Reset switch will illuminate (Fig 2). The switch is used to reset the RCD circuit, extinguish the warning lamp and allow the output Mcb(s) to be reset to 'ON'. The switch is also used to test the RCD circuit. With both output Mcb(s) in the 'ON' position, switching to 'Test' will cause both Mcb(s) to trip. Reset as above.

Fuel/hours status switch

37 The switch energises the Fuel Gauge and Hours Run counter when engine is not running.

CANOPY

38 The canopy is fabricated from Zintec steel and aluminium alloy and is finished with an Infra-Red Reflective (IRR) powder coating. The function of the canopy is to provide mechanical and weather protection and restrict noise and heat emissions.

39 An acoustic lining of Class O 'fireproof' foam assists with noise attenuation, breakout and vibration reduction.

FUEL TANK

40 The generator is fitted with a base fuel tank of 100 litres capacity. Filling is via an external hand pump.

41 The tank has a fuel gauge sender and low-level warning switch (Fig 4). The first low-level warning is annunciated on the control module when the fuel level falls to approximately 20 litres although this will be affected if the generator is located on uneven ground. This is sufficient fuel for the generator to operate at full load for at least 1.5 hours. One hour later, a second warning is given and the fuel should be replenished within 30 minutes to avoid 'running out of fuel'.

42 The fuel gauge is located on the control panel and gives a constant indication while the generator is running. To check the fuel level when not running, the Fuel/Hours Status switch is provided. Press and hold to read the gauge.

43 A tank drain point is provided behind a small cover plate on the side of the base (refer to Fig 1 in Sub-cat 1.0).

BATTERIES

44 The engine starting and generator control systems are powered by two AUK6TNMF batteries (Fig 5) in series to provide a 24 Volt system. The batteries are the sealed, valve-regulated type and are maintenance free. Charging is by a belt-driven alternator and regulator mounted on the engine.

EXHAUST SILENCER SYSTEM

WARNING

PERSONAL INJURY. EXHAUST EXTENSIONS MUST BE DEPLOYED OUTSIDE CAMOUFLAGE NETTING WHILST THE GENERATOR IS RUNNING. WHEN DEPLOYING GENERATORS ENSURE EXHAUSTS AND EXHAUST EXTENSIONS ARE POINTED AWAY FROM THE VEHICLE.

45 The exhaust silencer is a reactive/absorptive type. Exhaust gases from the engine are fed into the silencer via a stainless steel flexible bellows manifold pipe. This flexible section limits the amount of engine vibration transmitted to the silencer and canopy. The silencer itself is mounted in the hot air duct, so that the relatively cooler air extracted from the canopy is used to cool the body of the silencer. Two exhaust extension sections, each two metres in length, are stowed on top of the canopy. These can be coupled to the generator tail-pipe and up to four sections in series can be used. The primary use of these is to ensure that exhaust gases are directed clear of the generator when camouflage nets are being used. This reduces the risk of hot gases setting fire to the nets.

FUEL TRANSFER PUMP

CAUTION

EQUIPMENT DAMAGE. Caution should be exercised when refueling and using the fuel gauge to monitor the contents of the fuel tank. The fuel gauge is damped so it does not register changes in fuel level instantaneously.

46 The fuel transfer pump is stowed on the generator trailer and is used to transfer fuel from jerry cans or other containers into the generator tank. A bracket is provided on the generator base to hold the pump whilst in use (refer to Fig 1 in Sub-cat 1.0). The maximum transfer rate is 45 litres per minute.

WIRING DIAGRAMS

47 The wiring diagrams for the 20kVA Cormorant diesel generator are shown in the following Harrington drawings:

PD 951-049	Cormorant 20kVA Generator AC control and metering (see Figure 6)
PD 951-050	Cormorant 20kVA Generator output socket wiring (Figure 7)
PD 961-069	Cormorant 20kVA Generator DC control wiring (Figure 8)
PD 951-070	Cormorant 20kVA Generator DC engine wiring (Figure 9)

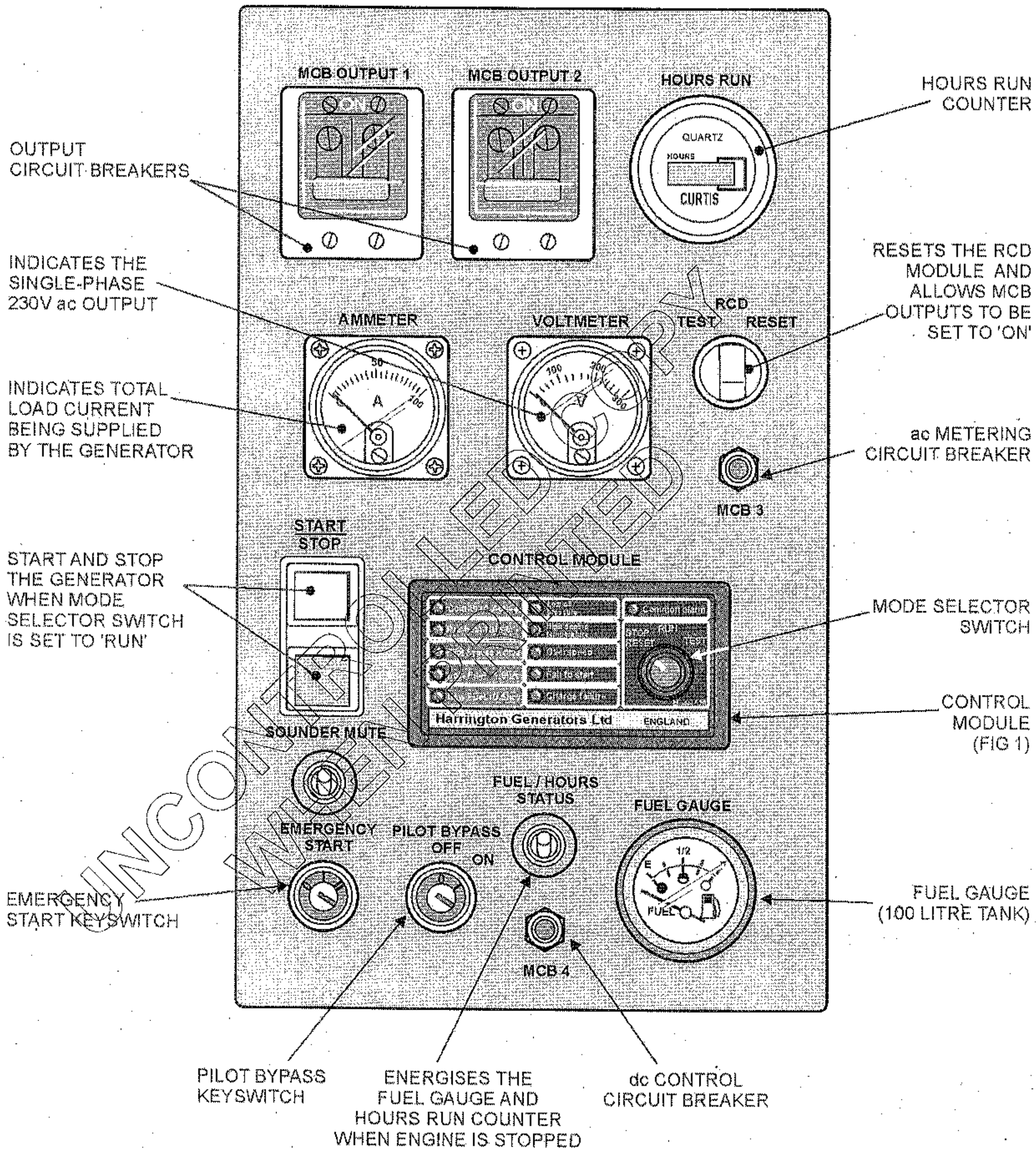


Fig 2 Control panel

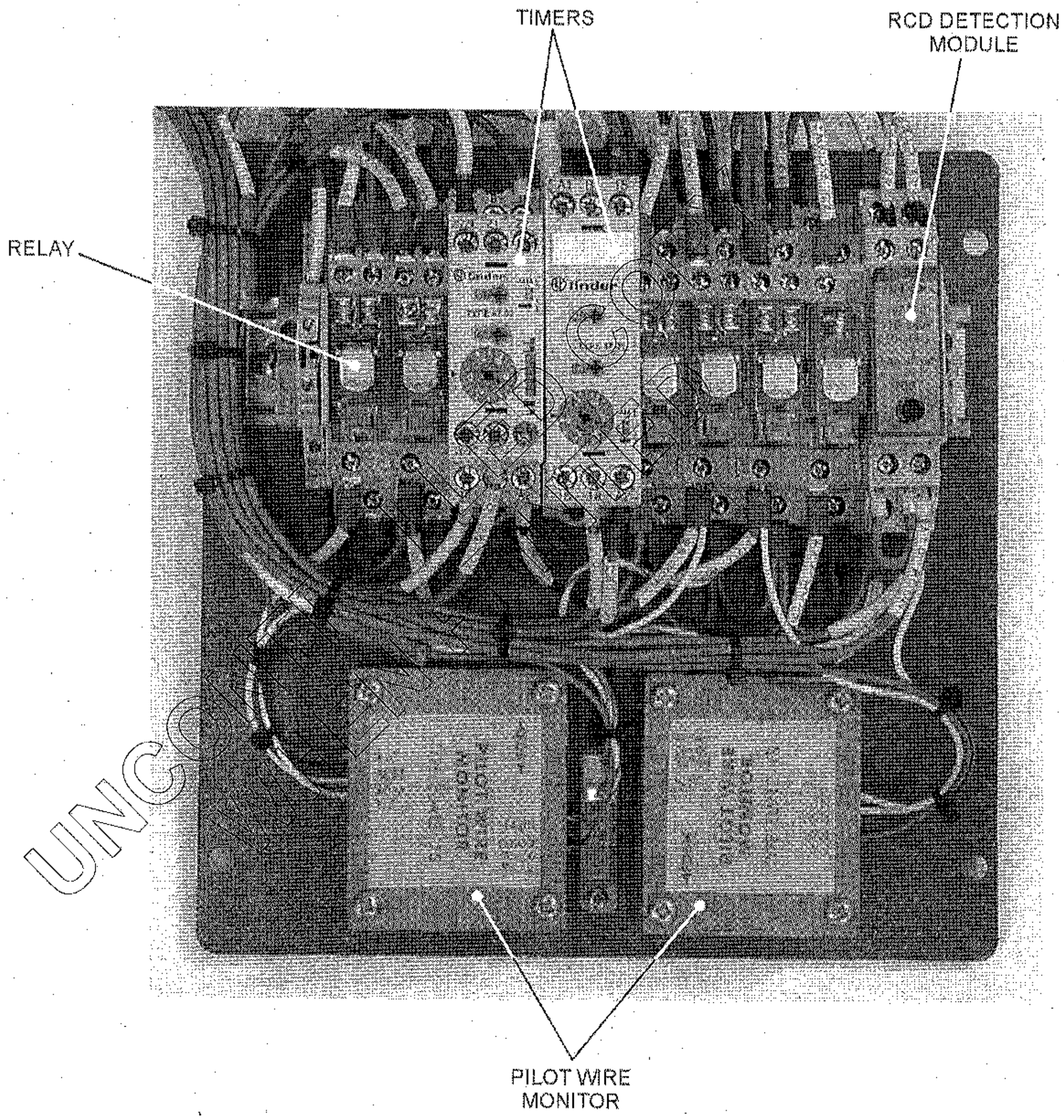


Fig 3 Pilot wire monitor devices and RCD detection module

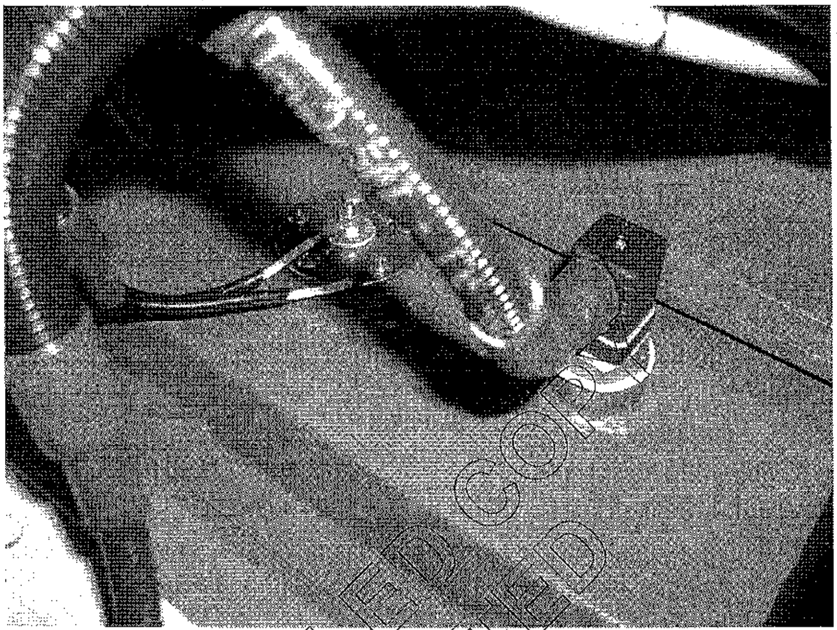


Fig 4 Fuel sender and level switch

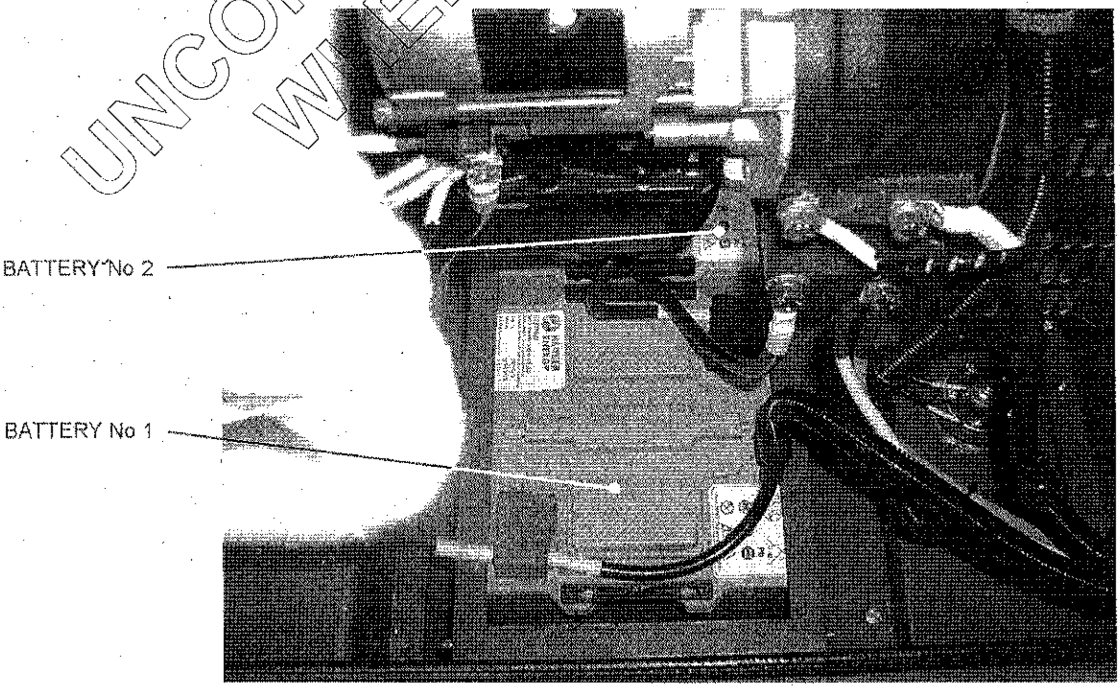
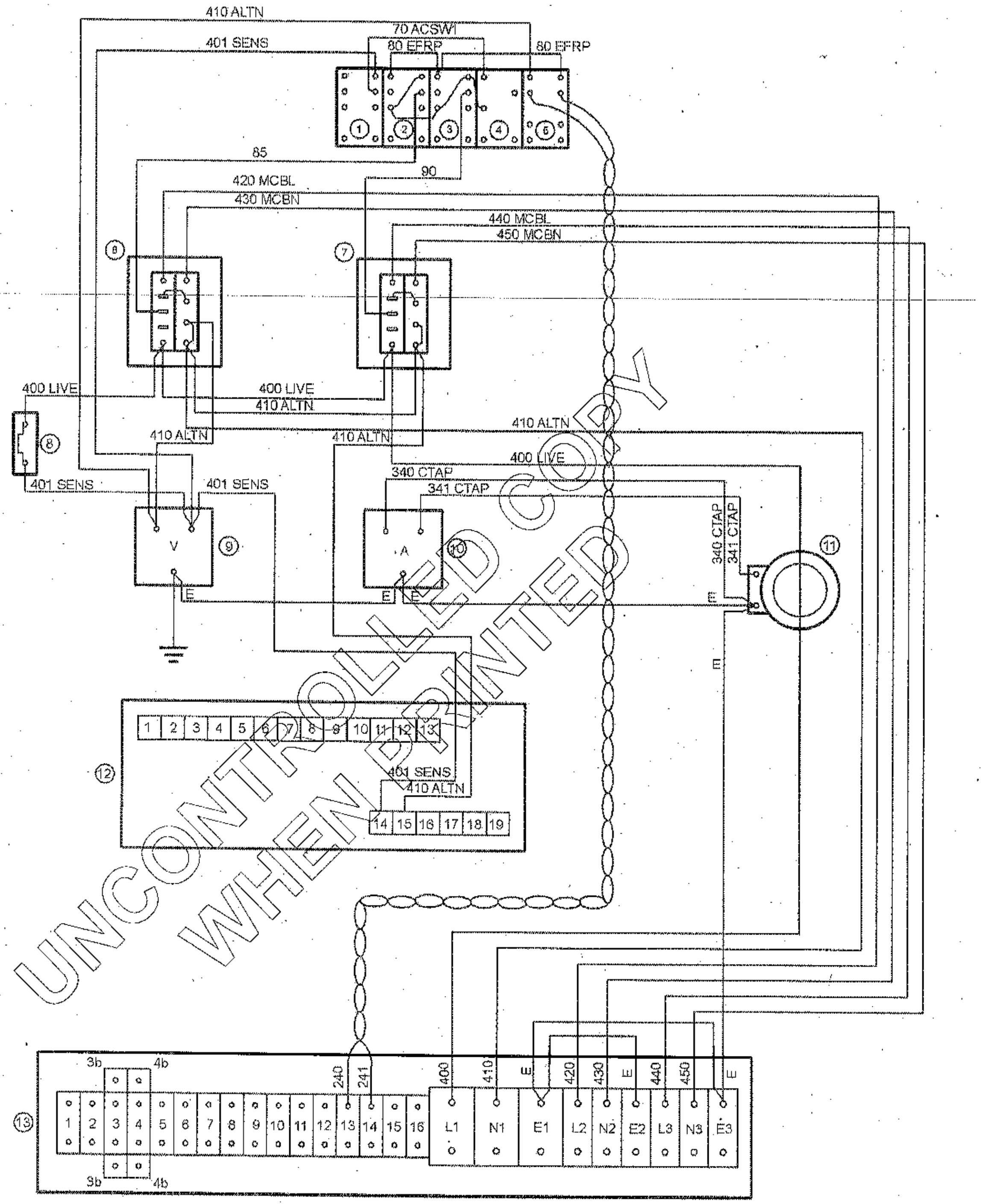
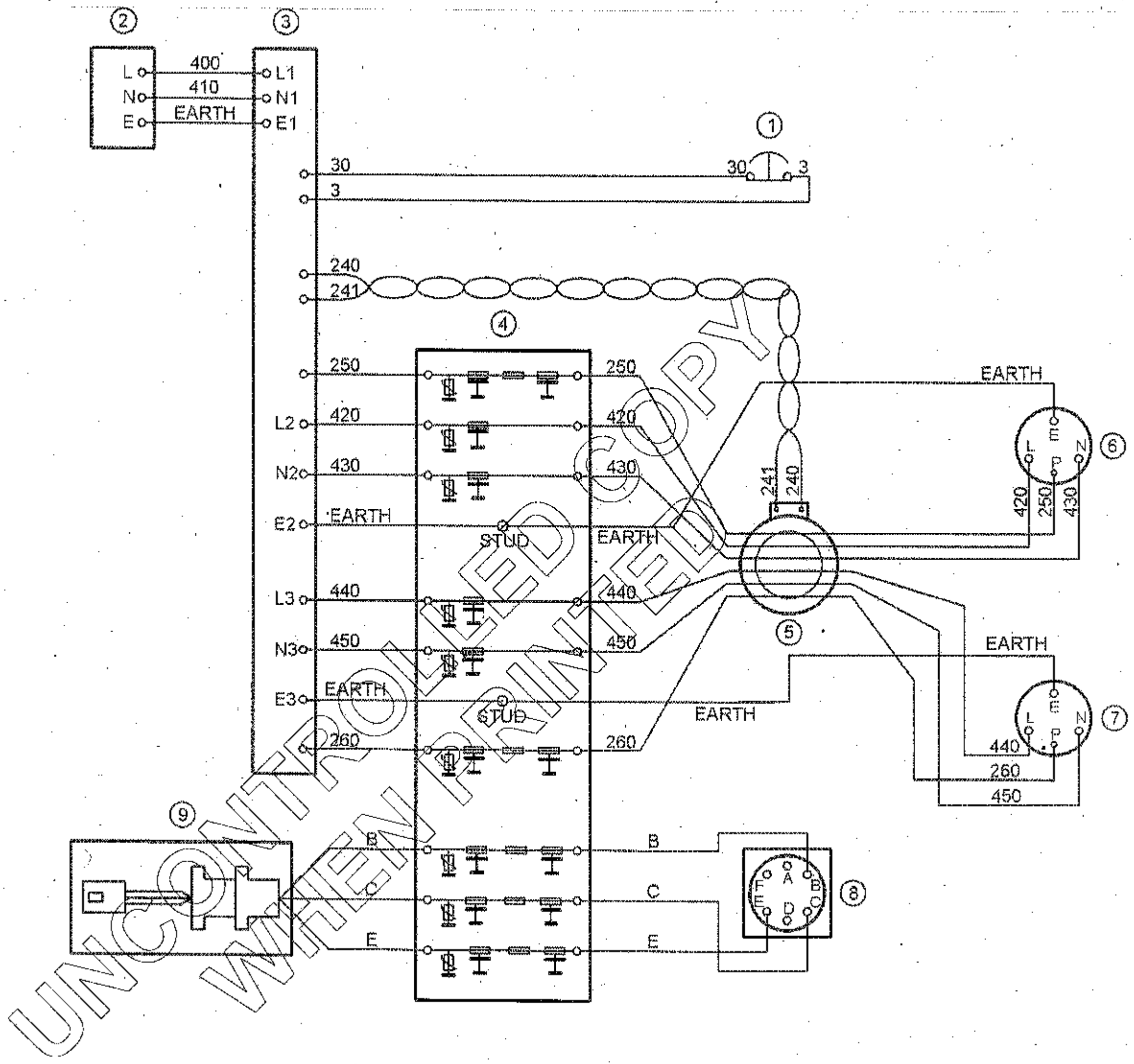


Fig 5 Batteries



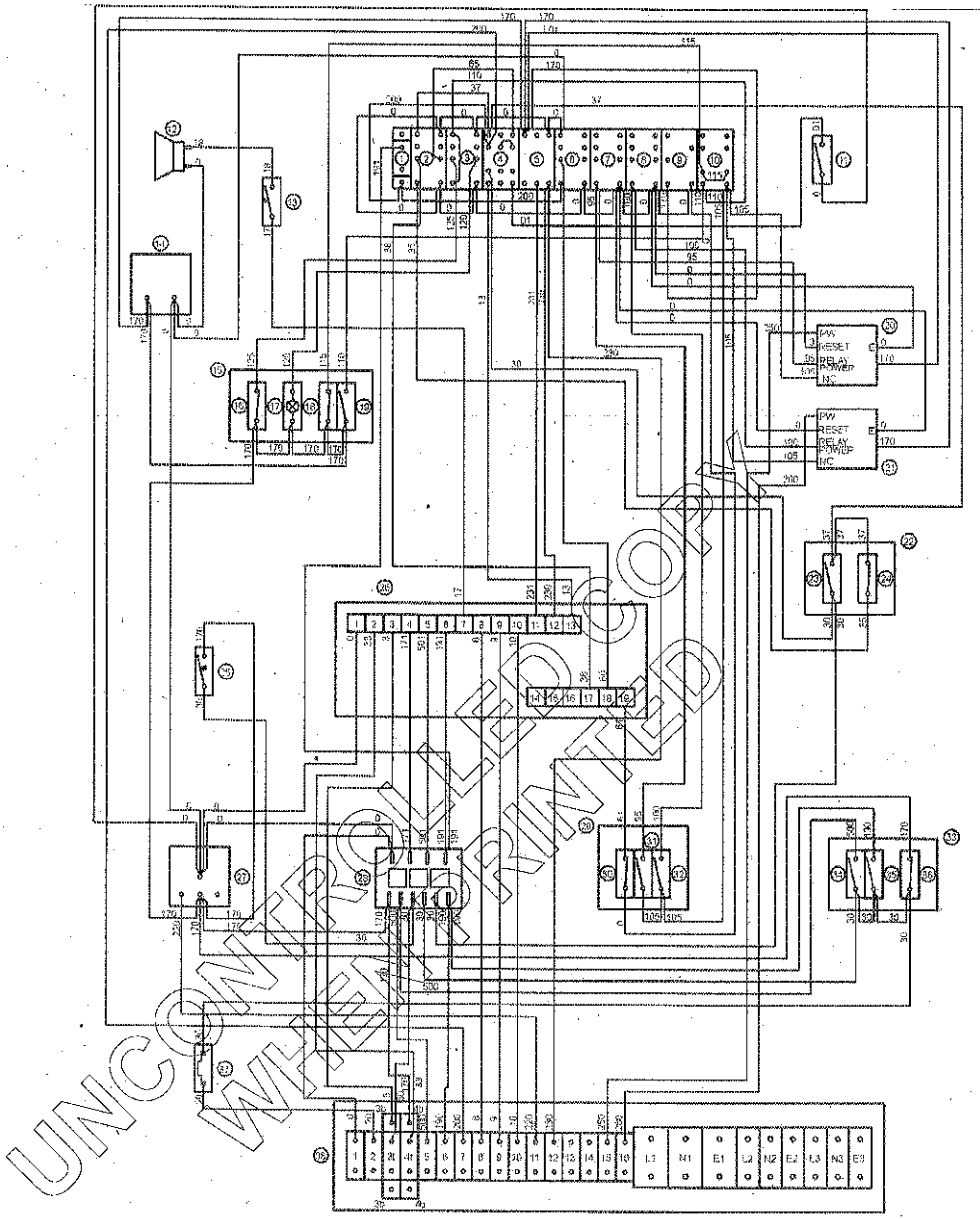
ID	DESCRIPTION	PART No.	ID	DESCRIPTION	PART No.
1	RELAY, RUN-UP RCD INHIBIT	140-031	8	MCB 3, AC METERING	110-067
2	RELAY, OUTPUT 1 RCD LATCH	140-031	9	VOLTMETER, 0-300V	085-057
3	RELAY, OUTPUT 2 RCD LATCH	140-031	10	AMMETER, 0-100A	085-255
4	RELAY, RUN-DOWN RCD INHIBIT	3RS353-837	11	CURRENT TRANSFORMER, AMMETER 100:5	085-257
5	RCD DETECTION MODULE	110-869	12	ENGINE MANAGEMENT MODULE	125-043
6	MCB 1, OUTPUT 1, OVERLOAD/SHUNT TRIP	110-843	13	TERMINAL BLOCK, CONTROL PANEL	N/A
7	MCB 2, OUTPUT 2, OVERLOAD/SHUNT TRIP	110-843			

Fig 6 Cormorant 20kVA generator AC control and metering



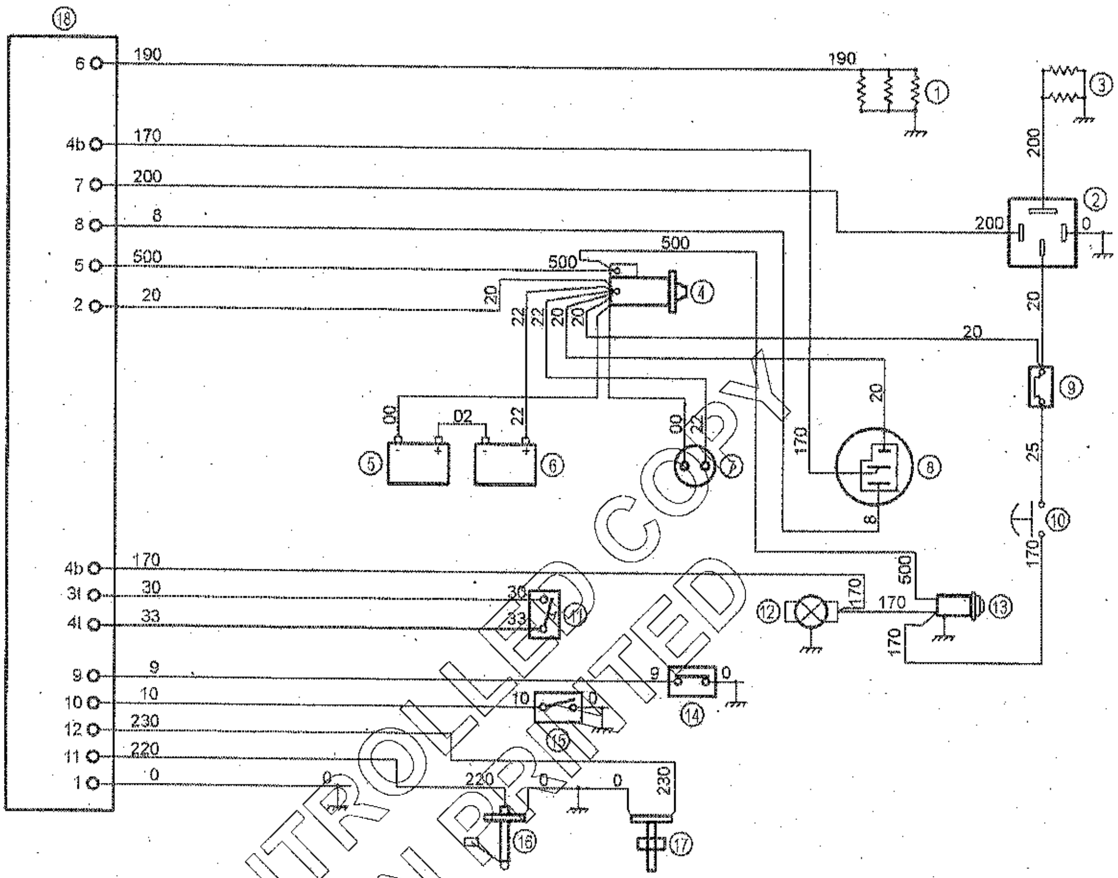
ID	DESCRIPTION	PART No.
1	SWITCH, EMERGENCY STOP	3RS318-979
2	TERMINAL BLOCK, ALTERNATOR	N/A
3	TERMINAL BLOCK, CONTROL PANEL	N/A
4	FILTER, LEMP/NEMP	136-501
5	CURRENT TRANSFORMER, RCD DETECTION	110-864
6	SOCKET, OUTPUT 1, 45A	090-611
7	SOCKET, OUTPUT 2, 45A	090-611
8	SOCKET, REMOTE CONTROL	090-612
9	INTERFACE CONVERTER	501-808

Fig 7 Cormorant 20kVA generator output socket wiring



ID	DESCRIPTION	PART No.	ID	DESCRIPTION	PART No.
1	COLD START BLOCKING DIODE	116-781	21	PILOT WIRE MONITOR, OUTPUT 2	110-601
2	RELAY, START/STOP LATCH	140-031	22	SWITCH, START/STOP PUSH BUTTON	080-801
3	RELAY, RCD LAMP RESET	140-031	23	CONTACT BLOCK, START/STOP N/O	080-802
4	TIMER, COLD START HEATER	140-437	24	CONTACT BLOCK, START/STOP N/C	080-802
5	TIMER, LOW FUEL WARNING	140-430	25	SWITCH, HOURS/FUEL STATUS	080-031
6	RELAY, RUN-UP RCD INHIBIT	140-031	26	ENGINE MANAGEMENT MODULE	125-043
7	RELAY, OUTPUT 1 RCD LATCH	140-031	27	FUEL GAUGE, ANOLOGUE	170-620
8	RELAY, OUTPUT 2 RCD LATCH	140-031	28	SLAVE RELAY MODULE, 24V	140-048
9	RELAY, RUN-DOWN RCD INHIBIT	3RS353-837	29	KEYSWITCH, PILOT BYPASS	080-479
10	RCD DETECTION MODULE	110-869	30	CONTACT BLOCK, N/C, MODULE INPUT	080-475
11	THERMOSWITCH, COLD START	110-865	31	CONTACT BLOCK, N/O, LATCH OUTPUT 1	080-474
12	SOUNDER, WARNING ALARMS	RS178-4197	32	CONTACT BLOCK, N/O, LATCH OUTPUT 2	080-474
13	SWITCH, SOUNDER MUTE	080-004	33	KEYSWITCH, EMERGENCY START	080-476
14	HOURS RUN COUNTER	085-307	34	CONTACT BLOCK, N/O, CRANK	080-474
15	SWITCH, RCD TEST/RESET	080-472	35	CONTACT BLOCK, N/O, PRE-HEAT	080-474
16	CONTACT BLOCK, RCD LAMP LATCH N/C	080-475	36	CONTACT BLOCK, N/C, FUEL	080-475
17	LAMP, RCD TRIP/TEST	080-473	37	MCB 4, DC CONTROL CIRCUITS	110-066
18	CONTACT BLOCK, RCD RESET N/C	080-475	38	TERMINAL BLOCK, CONTROL PANEL	N/A
19	CONTACT BLOCK, RCD RESET N/O	080-474			
20	PILOT WIRE MONITOR, OUTPUT 1	110-601			

Fig 8 Cormorant 20kVA generator DC control wiring



ID	DESCRIPTION	PART No.
1	PRE-HEAT RAIL, GLOW PLUGS	ENGINE
2	RELAY, COLD START SLAVE	140-035
3	HEATER, COLD START	ENGINE
4	STARTER MOTOR	ENGINE
5	BATTERY NO.1	120-034
6	BATTERY NO.2	120-034
7	SOCKET, 24V INTER-VEHICLE	090-601
8	CHARGE ALTERNATOR	ENGINE
9	MCB 5, FUEL PUMP PRIMING	110-083
10	SWITCH, FUEL PRIME PUSHBUTTON	080-051
11	SWITCH, DC POWER ISOLATOR	080-004
12	FUEL PUMP, 24V	ENGINE
13	FUEL SOLENOID, 24V	ENGINE
14	SWITCH, OIL PRESSURE, N/C	ENGINE
15	SWITCH, ENGINE TEMPERATURE, N/O	ENGINE
16	FUEL GAUGE SENDER	170-620
17	SWITCH, LOW FUEL LEVEL	080-021
18	TERMINAL BLOCK, CONTROL PANEL	N/A

Fig 9 Cormorant 20kVA generator DC engine wiring

CATEGORY 5	**MAINTENANCE INFORMATION AND INSTRUCTIONS**
SUB-CATEGORY 5.1	FAULT DIAGNOSIS
SUB-CATEGORY 5.2	REPAIR INSTRUCTIONS
SUB-CATEGORY 5.3	ROUTINE MAINTENANCE

SUB-CATEGORY 5.1

FAULT DIAGNOSIS

CONTENTS

DIAGNOSTICS

1 In addition to traditional fault finding and diagnostics techniques using diagrams and meters etc, the generator has the benefit of diagnostics available via the control module and a PC.

2 The appropriate software, interface link and, CMIS workstation or LMT are required.

3 Access to the control module (Fig 2) for the interface link is via the 'Remote Control' connector adjacent to the output sockets (Fig 1). The interface link connects into the serial port of the computer.

4 Two versions of the diagnostic facility are available, a Mimic display and a Status display.

Mimic display

5 The first diagnostic is the Mimic Display, which is provided to allow at-a-glance monitoring of the system. All non-essential information is hidden. Clear graphical displays of the measured values allow easy performance monitoring. Should an alarm occur this is clearly displayed by a flashing red 'Alarm' legend. Details on the system operation are provided to give more information if required.

Status display

6 The second diagnostic is the Status Display, which allows the user to see the value of all measured inputs and the status of any of the digital inputs. Output state of the relays and LED operation are also displayed. A text display indicates the present state of operation of modules, shows the time remaining on any system timer that is in operation, and will give details on any shutdown alarm that has occurred.

7 As the diagnostics are real-time the opening and closing of the inputs can be viewed allowing simple checks to be made on panel wiring if this is thought to be at fault. It is therefore possible to simulate a switching signal by earthing the appropriate input connection in the panel. If the input state displayed on the diagnostic page changes this indicates that the wiring is correct. It is possible that the module configuration is incorrect and further investigation is required using the configuration program.

8 Refer also to the DSE P808 for Windows Software Manual, pages 47 to 49.

FAULT FINDING

9 Fault finding information is detailed in Table 1 below:

TABLE 1 FAULT FINDING

Symptom	Possible Cause	Solution
Generator will not crank.	Controller mode switch in 'OFF/RESET' position. Discharged batteries. Poor battery/starter connections. dc protection Mcb tripped.	Switch to 'RUN'. Charge batteries or use inter-vehicle connector to 'jump-start'. Check connections. Tighten and clean as necessary. Push to reset Mcb. If Mcb trips again, investigate wiring on engine systems.
Engine cranks but will not start. ('Fail to Start' alarm.) No white smoke from exhaust whilst cranking.	Insufficient fuel in tank. Fuel filter blocked. Fuel solenoid faulty.	Re-fill with fuel. Replace fuel level and bleed system. Check for 24 Volts at fuel solenoid (fuel pump) during cranking. Repair/replace as necessary.
Engine cranks, but will not start (Fail to start alarm.) White smoke from exhaust whilst cranking.	Cold ambient conditions. Batteries in poor condition - Insufficient crank speed	Reset fail to start alarm at controller. Re-try cranking. Charge batteries or use inter-vehicle connector to jump-start.
Low oil pressure at shutdown.	Low oil level in engine sump.	Top up sump oil to maximum level. Reset alarm at controller. Re-start generator.
High temperature shutdown.	Low coolant in radiator. Engine fan belt broken. ('Charge Fail' LED also lit) Cooling air circuit blocked or re-circulating. Generator overload.	Allow engine to cool before removing radiator cap. Fill radiator with water/additive mixture. Reset alarm at controller. Replace fan belt. Check generator canopy inlets and outlets for obstructions. Clear airways. Reset alarm at controller. Check value of connected load. Reduce to within rated value of generator. (See Sub-cat 1.0.)

(continued)

TABLE 1 FAULT FINDING (continued)

Symptom	Possible Cause	Solution
Overspeed shutdown.	Engine overfilled with oil.	Check oil level on dipstick. Drain excess oil until level is at 'maximum'. Reset alarm at controller.
	Engine governor fault.	Refer to engine handbook or Service Agent.
Underspeed shutdown.	Generator overload.	Check value or connected load. Reduce to within rated value of generator. (See Sub-cat 1.0.)
	Air cleaner blocked.	Clean/replace air cleaner element.
	Fuel filter blocked.	Replace fuel filter element and bleed system.
Charge Fail warning.	Engine fan belt broken.	Replace fan belt.
Generator runs but main output circuit breaker (Mcb) will not latch.	Pilot wire incontinuity.	Check all connectors in supply line from generator to load are in place and secure.
	Poor earth return.	Check earth bonding and earth continuity between generator and load.
	Earth fault on distribution system or load.	Check system and appliances for earth fault. Optionally systematically disconnect appliances to identify faulty item.

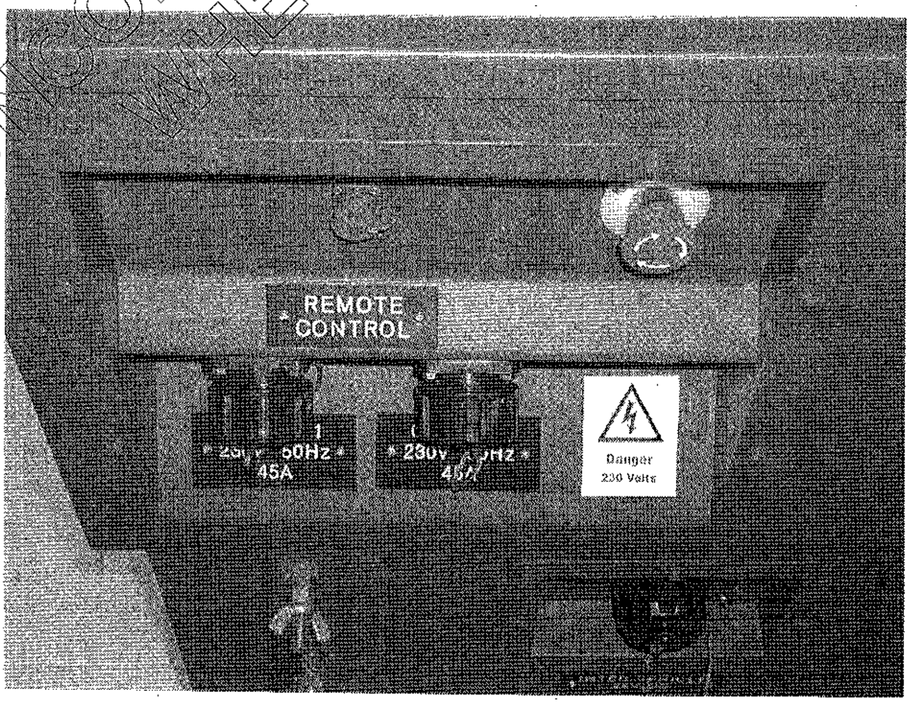


Fig 1 Remote control socket

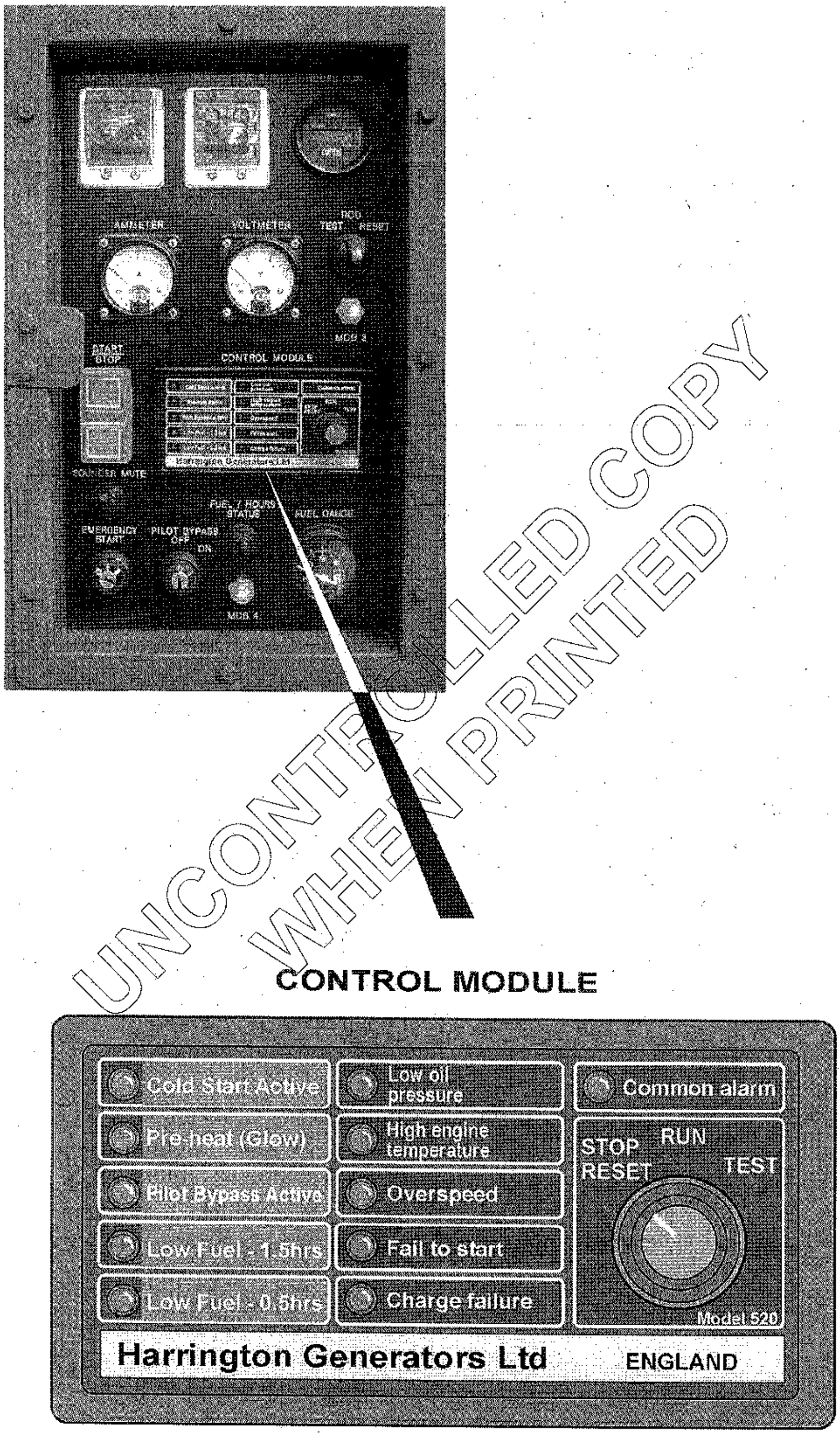


Fig 2 Control panel and control module

SUB-CATEGORY 5.2

REPAIR INSTRUCTIONS

CONTENTS

DISCONNECTING THE BATTERY NEGATIVE TERMINAL

WARNING

> **PERSONAL INJURY. BEFORE COMMENCING ANY SERVICE OR REPAIR WORK, ENSURE THAT THE CONTROL MODULE IS IN THE 'OFF/RESET' POSITION. OPERATE THE EMERGENCY STOP PUSHBUTTON. DISCONNECT THE NEGATIVE TERMINAL ON THE BATTERY. ENSURE THAT THERE IS NO CONNECTION TO THE 24V INTER-VEHICLE SOCKET.**

1 Open the hinged canopy access door and fasten back. Working through the door opening, lift the black terminal boot off the negative terminal on the nearest battery. Loosen and remove the negative terminal and bend or tie back the battery lead to prevent it inadvertently re-connecting with the battery.

REMOVING/REPLACING THE BATTERIES

WARNING

> **PERSONAL INJURY. EACH BATTERY WEIGHS 40kg AND THE BATTERIES SHOULD BE LIFTED BY TWO PEOPLE.**

2 The generator is fitted with two batteries connected in series. Before removing either or both batteries, disconnect the negative terminal as described in Para 1.

(1) Unlatch and remove the lift-off canopy door. Working through the door opening (Fig 1 and Fig 2), lift the red terminal boot off the positive terminal on the nearest battery.

(2) Loosen and remove the positive terminal and bend or tie back the battery lead to prevent it inadvertently re-connecting with the battery.

(3) Remove the four M8 setscrews and remove the battery access cover plate. Remove the two M8 setscrews that hold the battery clamp bracket.

(4) Lift the hinged battery clamp top frame and tie up.

(5) Pull/slide the first battery, until it is flush with the canopy battery access opening.

(6) Lift the red terminal boot off the positive terminal.

(7) Loosen and disconnect the link cable from the positive terminal.

(8) The first battery can now be withdrawn and lifted clear of the generator.

(9) Pull/slide the second battery until it is flush with the canopy battery access opening.

(10) The second battery, with the link cable attached, can now be withdrawn and lifted clear of the generator.

REMOVING/REPLACING THE CONTROL PANEL

3 Before commencing work, disconnect the battery negative terminal as described in Para 1.

(1) Unlatch and open the control panel weather cover (Fig 3).

(2) Remove the nine M6 setscrews that secure the control panel frame to the canopy.

(3) Ease the control pod out through the aperture and support it, face down, just forward and below the aperture.

(4) Remove the four M5 pozi screws that secure the control panel near cover and remove the cover.

(5) Remove the four M5 pozi screws that secure the Current Transformer Plate to the control pod.

(6) Ease the Current Transformer Plate forward to gain access to the back.

(7) Unscrew and disconnect the 25-way D connector leaving the mating half clamped to the tie.

(8) Remove the four M5 setscrews that secure the gland plate to the bottom of the control panel at the rear.

(9) Systematically loosen and remove the cables from the terminals until the gland plate with its conduits and cable-ends is separated from the control pod. The control pod can now be lifted clear of the generator.

NOTE

The terminals used are the spring-loaded type and the cables are terminated with hook crimps.

(10) To remove each cable, loosen the screws and with the screwdriver still in the slot, press the screw against the spring and pull the cable and hook crimp.

4 Replacement of the control pod is a reversal of the removal procedure.

REMOVING/REPLACING THE OUTPUT POD

5 Before commencing work, disconnect the battery negative terminal as described in Para 1.

(1) Remove the control pod as described in Para 3.

(2) When the gland plate has been separated from the control panel, remove the conduit gland nut from conduit number 3 and conduit number 5 and withdraw the cables through the gland plate. These are the conduits to the main alternator and the engine respectively.

(3) Remove the eight M6 setscrews (Fig 4) that secure the Output Pod to the canopy end panel.

(4) Ease the Output Pod forward and lift it clear of the generator, complete with the NEMP/LEMP filter and conduits attached.

(5) The Output Pod can be replaced complete with conduits. Alternatively, systematically remove the cover plates and swap the conduit and NEMP/LEMP filter from the outgoing pod to the incoming pod.

6 Replacement of the Output Pod is a reversal of the removal procedure.

REMOVING/REPLACING THE 24V INTER-VEHICLE CONNECTION POD

7 Before commencing work, disconnect the battery negative terminal as described in Para 1.

(1) Unlatch and remove the lift-off canopy door.

(2) Working through the door opening, lift the red terminal boot cover off the positive terminal on the nearest battery (see Fig 2).

(3) Leave the positive battery terminal clamp in place and remove the lead marked *22BAT+* from the clamp.

(4) Remove the lead marked *00BAT-* that is bolted onto the side of the engine flywheel housing.

(5) Remove the four M6 setscrews (Fig 4) that secure the Inter-vehicle Socket Pod to the canopy end panel.

(6) Ease the pod out through the aperture and withdraw with the conduit attached.

(7) The Inter-vehicle Socket Pod can be replaced complete with conduit.

(8) Alternatively remove the cover plate and swap the conduit assembly from the outgoing pod to the incoming one.

8 Replacement of the Inter-vehicle Socket Pod is a reversal of the removal procedure.

REMOVING/REPLACING THE CANOPY ROOF

9 For better access during service and repair work, it may be beneficial to remove the canopy roof. Refer to Fig 5.

(1) Unlatch and remove the lift-off door.

(2) Unlatch and open the hinged canopy door.

(3) Remove the fourteen M6 setscrews that secure the roof to the canopy end panels.

(4) With assistance and using the handles on the roof, lift the roof off and clear of the generator.

10 Replacement of the canopy roof is a reversal of the removal procedure.

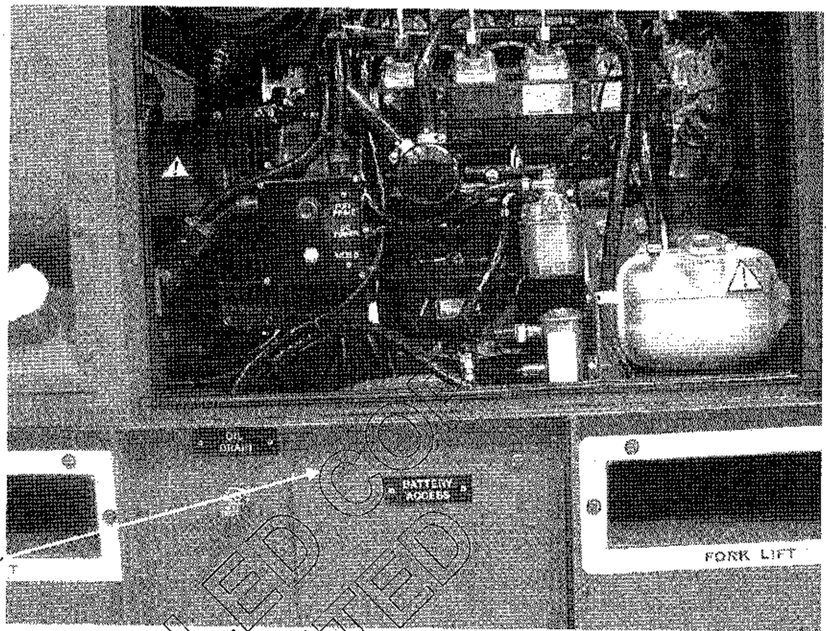


Fig 1 Battery access cover

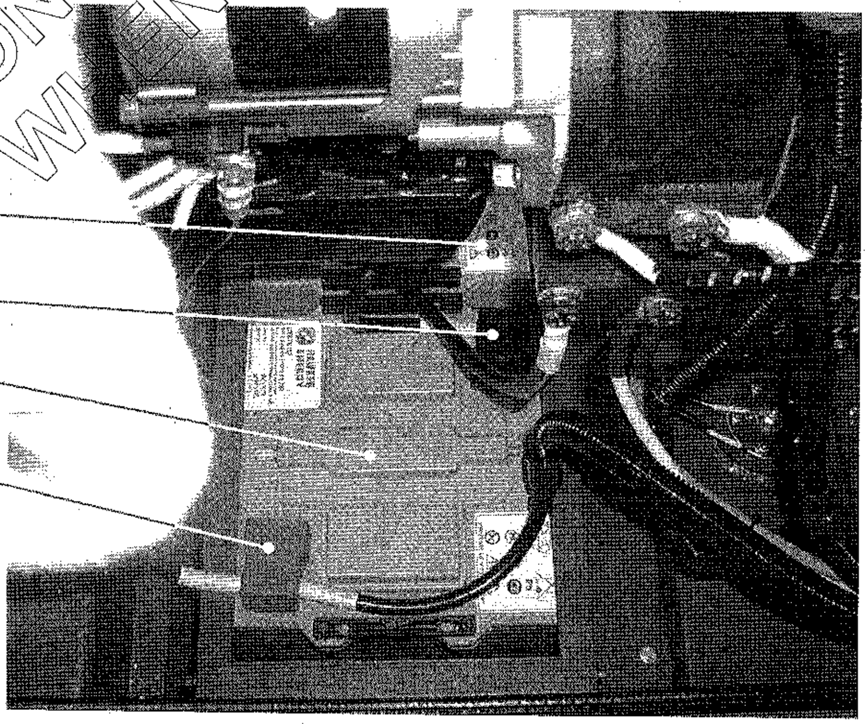


Fig 2 Battery terminals

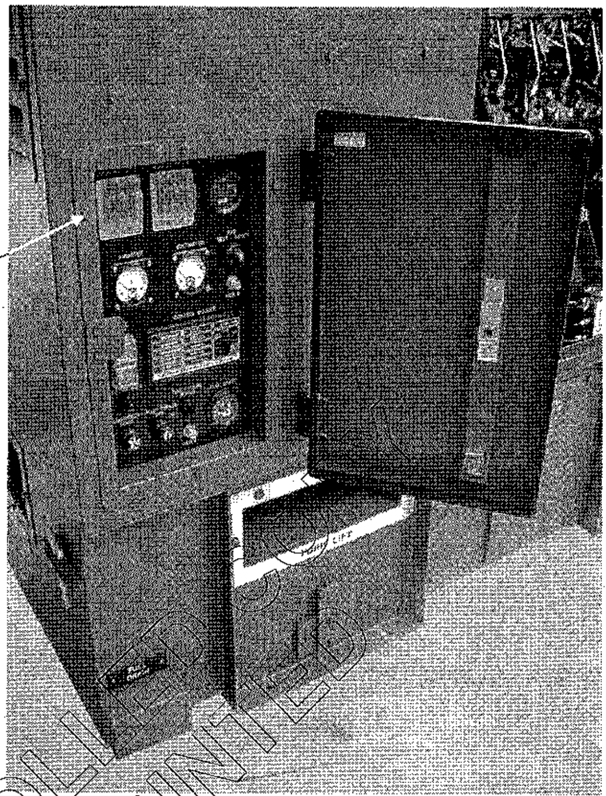


Fig 3 Control panel and door

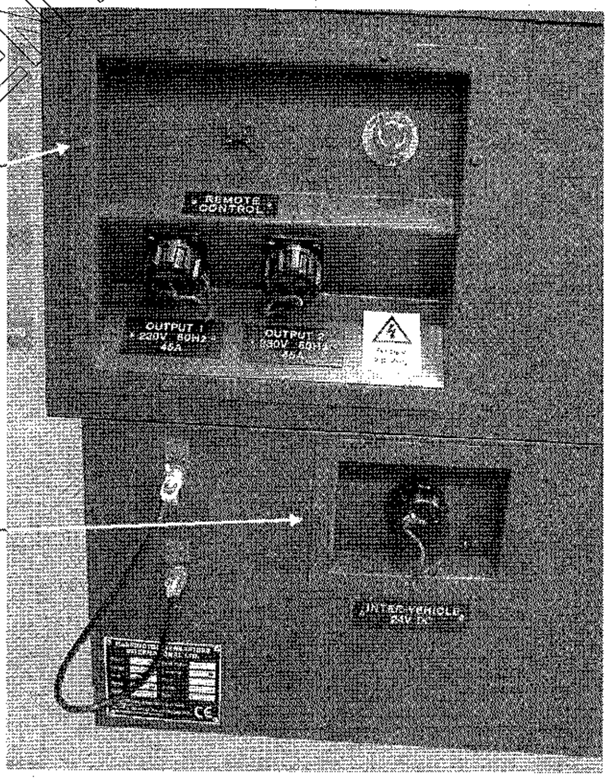


Fig 4 Output pod and inter-vehicle connection pod

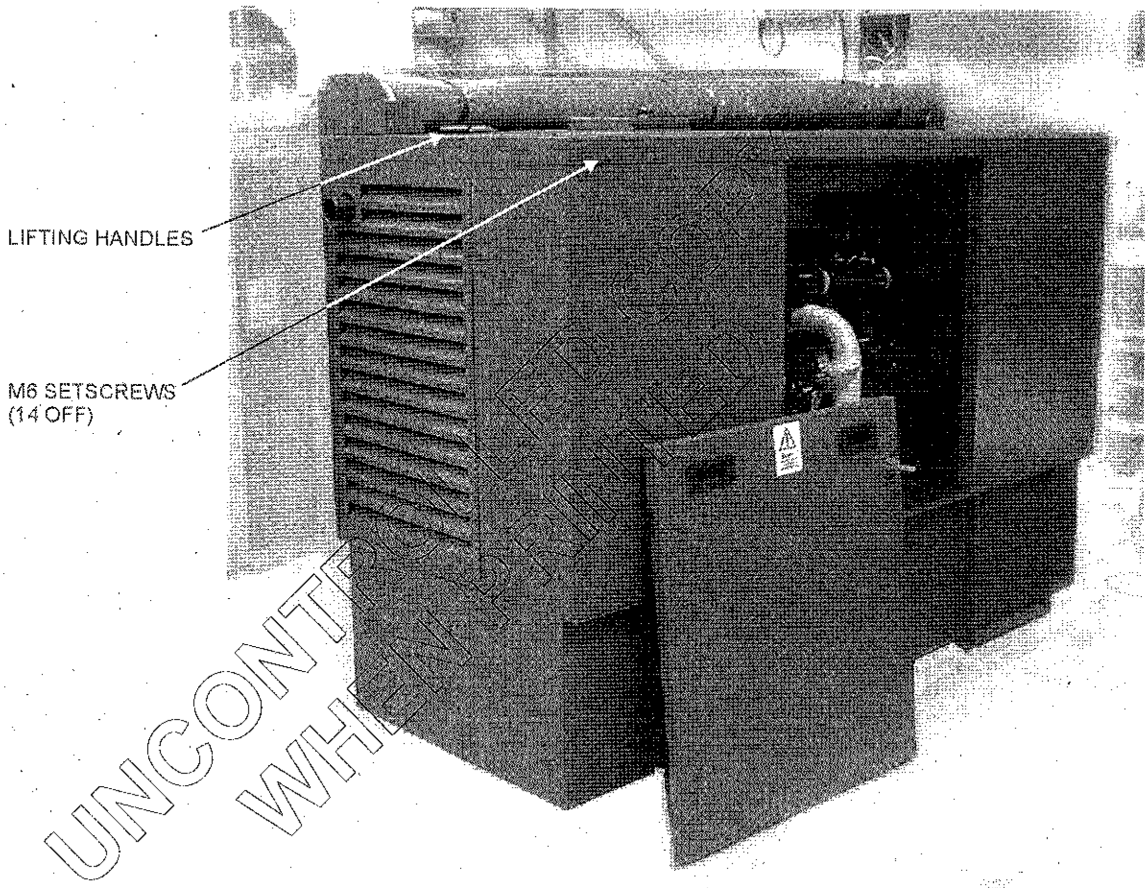


Fig 5 Canopy roof removal

SUB-CATEGORY 5.3

ROUTINE MAINTENANCE

CONTENTS

ENGINE

1 The Lubrication and Maintenance schedule for the engine is detailed in Para 145 of the 4LE1 Engine Instruction Manual (Annex A). A summary of the schedule is also shown in Paras 10 to 16. In addition, the following information details the engine maintenance in relation to the canopy. Daily engine maintenance is via the hinged door on the canopy (Fig 1).

Coolant level

2 The coolant level should be checked when the engine is cold (Annex A, Para 94 of the 4LE1 Engine Instruction Manual). To completely refill the radiator and engine with coolant, use the radiator access flap in the canopy roof (Fig 3 and Fig 4).

Oil level fill and drain

NOTE

Run the engine, on load if possible, for approximately 15 minutes to warm up the oil before draining. This will significantly reduce the drainage time.

3 Draining of the lubricating oil is achieved using the hose drain point on the side of the canopy base. Remove the cap/end stop and position a suitable receptacle for the collection of the waste oil, or connect a hose leading to a receptacle (thread type ½ inch BSP). Oil draining will begin when the sump tap, positioned just inside the canopy, is turned ON. Refer to the 4LE1 Engine Instruction Manual (Annex A, Para 84) for further information.

ALTERNATOR

4 The alternator requires no maintenance other than to ensure that the cooling air vents do not become blocked by dirt, debris, etc. Every 50 operating hours is recommended.

Automatic voltage regulator

5 Restricted access to the voltage regulator is via the lift-off canopy door (Fig 2). The voltage regulator is located behind the side plate of the alternator terminal box. No routine maintenance is required.

CANOPY

6 Every 250 operating hours check the security of fixings and fasteners on the machine.

7 Lubricate hinges and latches with light machine oil.

8 Ensure that the inlet and outlet louvres are kept clean and unimpeded at all times.

FUEL TANK

9 It may be prudent to drain and flush the fuel tank every 500 operating hours, particularly when the generator has operated in high humidity and dusty environments.

MAINTENANCE SCHEDULE SUMMARY

10 The following schedule summary details the MINIMUM recommended routine maintenance required for the upkeep of the 20kVA generator set. Refer also to the Maintenance Schedule in the 4LE1 Engine Instruction Manual (Annex A, Para 145) and to the schedule in the Technician Guide (Annex C, Table 1).

11 Operating conditions and experience may lead to the reducing of some of the intervals.

Initial 50 hour service

12 Replace the engine oil filter and change the engine oil after the initial 50 hours of engine operation. Thereafter follow the regular maintenance schedule.

Daily

13 The following routine maintenance checks should be carried out on a daily basis:

(1) Check engine oil level.

(2) Check engine coolant level.

(3) Check air cleaner dust valve.

(4) Check air cleaner restriction indicator.

(5) Check canopy air inlets and outlets.

(6) General visual inspection.

Every 50 hours

14 The following routine maintenance procedures should be carried out after every 50 hours of operation:

(1) Check fan belt tension.

(2) Drain water from fuel filter.

(3) Clean alternator air vents.

Every 250 hours

15 The following routine maintenance procedures should be carried out after every 250 hours of operation:

(1) Change lubricating oil.

(2) Check fan belt tension.

(3) Check exhaust flanges and joints for tightness and leaks.

(4) Check machine fixings and fastenings.

Every 500 hours

16 The following routine maintenance procedures should be carried out after every 500 hours of operation:

(1) Change lubricating oil filter. Change fuel filter element.

(2) Check air intake hoses, connection and system.

(3) Clean crankcase vent tube.

(4) Check cooling system.

(5) Check coolant concentration.

(6) Flush and drain the fuel tank.

Every 1000 hours

17 The following maintenance procedures should be carried out after every 1000 hours:

(1) Check and adjust engine valve clearances.

(2) Flush cooling system and re-fill.

(3) Pressure test cooling system.

(4) Clean the starter motor commutator.

(5) Clean the generator slip ring.

(6) Check brush length and contact pressure.

CONDITIONING

Winter operation

18 Operation and storage/transit of the generators at temperatures below -5°C requires special preparation to ensure reliability.

WARNING

PERSONAL INJURY. DO NOT REMOVE THE RADIATOR CAP WHILST THE ENGINE IS RUNNING OR HOT.

PERSONAL INJURY. 20KVA GENERATOR COOLANT – ETHYLINE GLYCOL IS HARMFUL IF SWALLOWED. IN CASE OF CONTACT WITH EYES, RINSE IMMEDIATELY WITH PLENTY OF WATER AND SEEK MEDICAL ADVICE. ALWAYS WEAR PROTECTIVE CLOTHING, GLOVES AND EY/FACE PROTECTION. IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE IMMEDIATELY

Coolant

19 The coolant must be a 50/50 mixture of water and ethylene glycol antifreeze. Check the concentration using a hydrometer. If no method of checking is available, it is advisable to completely drain the coolant and refill with a new mixture of known concentration. Refer to the 4LE1 Engine Instruction Manual when required (Annex A, Paras 90 to 98).

Oil change - winter grade

20 Run the engine, on load if possible, for 15 minutes to warm up the oil before draining. This will significantly reduce the drainage time. Refer to the 4LE1 Engine Instruction Manual when required (Annex A, Paras 81 to 89).

21 Stop the engine and drain the oil as described in Para 3.

22 Re-fill the engine with Multi-viscosity diesel oil - grade SAE 5W-30. The Military equivalent is OMD-55 (25 litre, NSN 9150-99-477-3153).

23 Changing the oil filter element is not essential unless the generator is due for service.

Fuel system

24 Refer to the 4LE1 Instruction Manual when required (Annex A, Paras 99 to 105). It is recommended that Dieso (even with winter additives) be not used at temperatures below -5°C.

25 Any Dieso in the fuel tank should be completely drained using the drain plug on the side of the canopy base (Fig 5).

26 Change the fuel filter element (Fig 6). Refer to Annex A, Para 104.

27 Re-fill the fuel tank with AVTUR and bleed the engine fuel system as described in the 4LE1 Engine Instruction Manual (Annex A, Para 102).

28 Run the engine for 30 minutes, on load if possible, to ensure that all Dieso within the fuel system has been replaced by AVTUR.

Summer operation

29 For operation at high ambient temperatures, Harrington recommends the following preparation:

Oil change - summer grade

30 Run the engine, on load if possible, for 15 minutes to warm up the oil before draining. This will significantly reduce the drainage time.

31 Stop the engine and drain the oil as described in Para 3.

32 Re-fill the engine with Multi-viscosity diesel engine oil - grade SAE 15W-40. The Military equivalent is OMD-113 (25 litre, NSN 9150-99-224-2540).

33 Changing the oil filter element is not essential unless the generator is due for service.

Fuel system

34 If the generator has been operating with AVTUR as the fuel, it is recommended that Dieso be used at ambient temperatures where there is no risk of waxing, ie above -5°C.

35 It is not necessary to drain any AVTUR from the fuel system. Dieso can be mixed/added so that the changeover is gradual.

36 Although there are no problems associated with operating on AVTUR at high temperatures, the engine power is slightly reduced (5%) and lubricating properties are not as good.

37 Harrington recommends operation on Dieso wherever ambient temperatures allow.

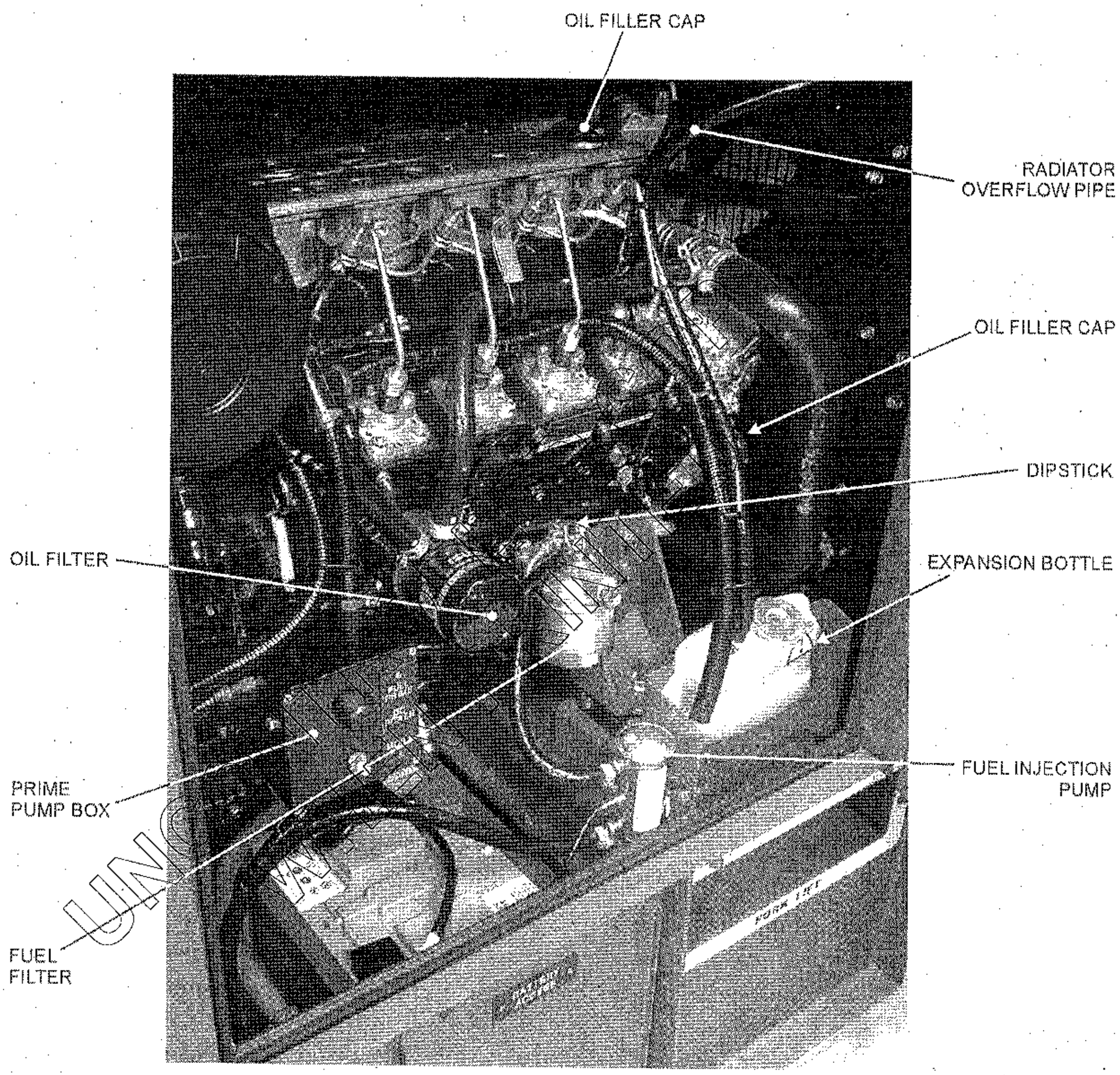


Fig 1 View through hinged canopy door

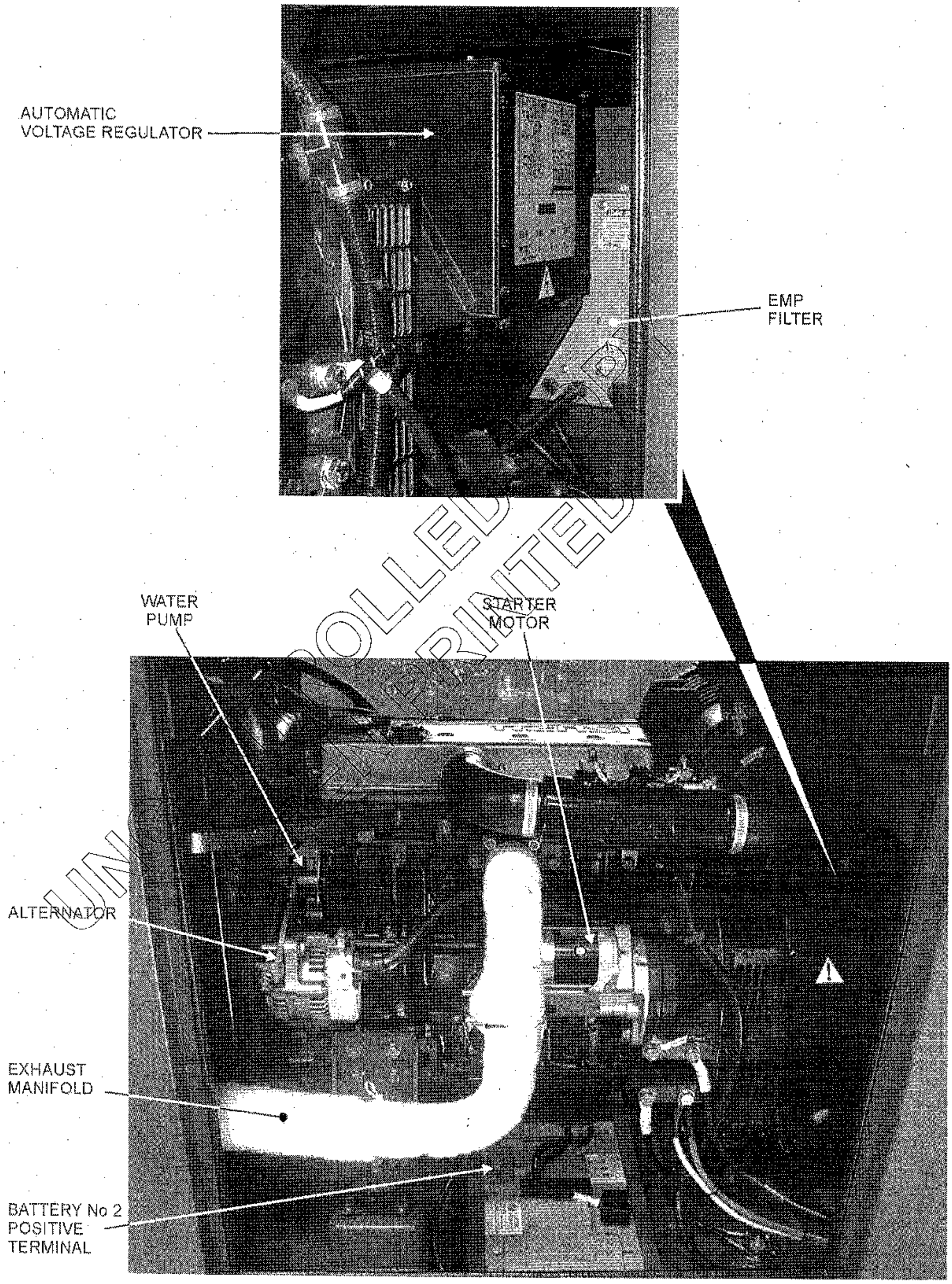


Fig 2 View through lift-off canopy door

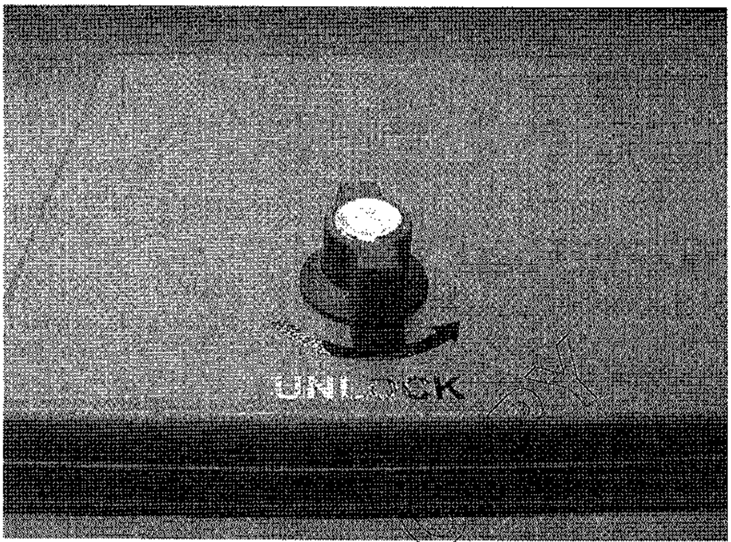


Fig 3 Radiator access flap

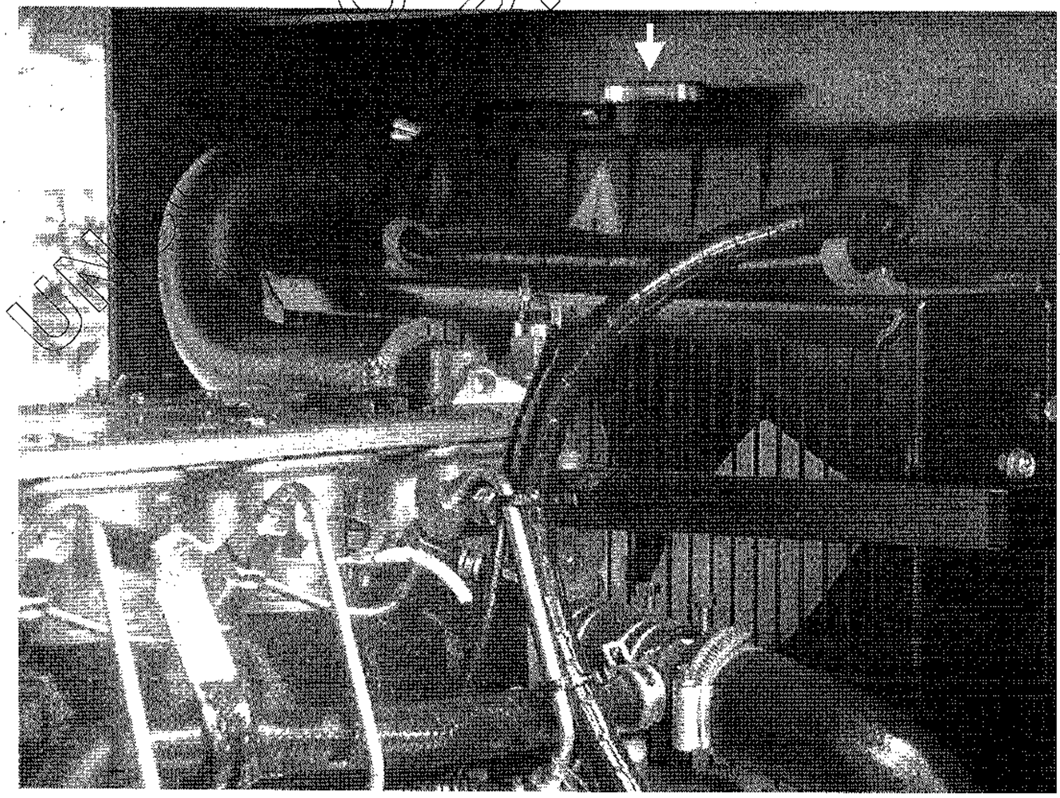


Fig 4 Radiator filler cap

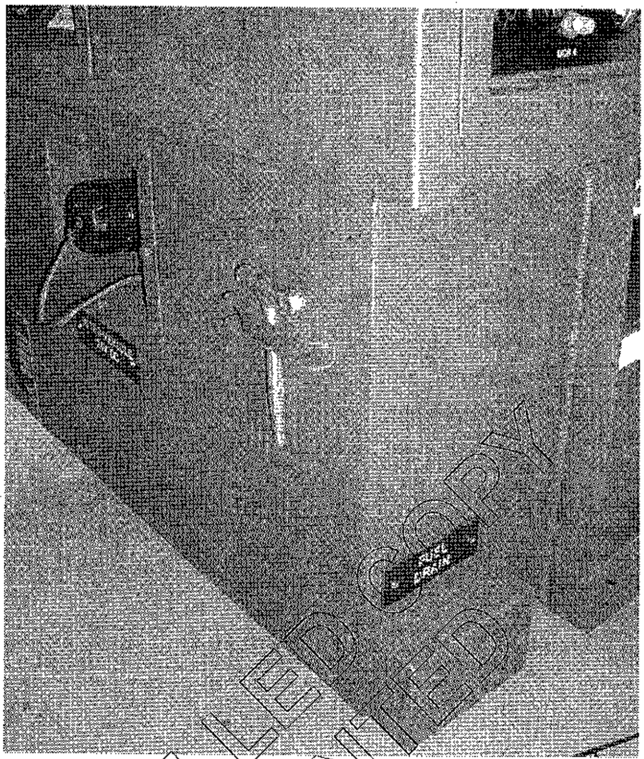


Fig 5 Fuel drain

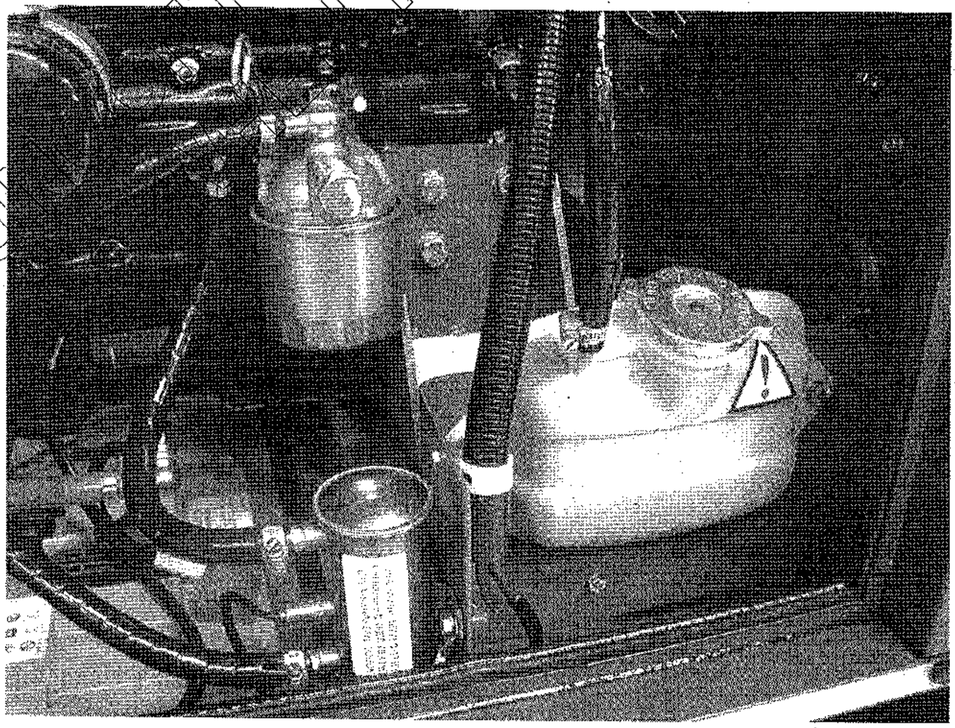


Fig 6 Expansion bottle and fuel filter

CATEGORY 7 **PARTS CATALOGUE**

SUB-CATEGORY 7.2 COMMERCIAL PARTS LISTS

SUB-CATEGORY 7.2

COMMERCIAL PARTS LISTS

CONTENTS

20kVA CORMORANT GENERATOR SPARES

ENGINE CONSUMABLE SPARES

1 Consumable spares for the Isuzu diesel engine, Model 4LE1, are detailed in Table 1.

TABLE 1 ENGINE CONSUMABLE SPARES

Description	Part No.	Qty
Oil filter element	SZ894456-7412	1
Fuel filter element	SZ894132-9471	1
Air filter element	SZ100020	1
Fan Belt	SZ897230-9390	1

ENGINE SPARE PARTS

2 Spare parts for the Isuzu diesel engine, Model 4LE1, are detailed in Table 2.

TABLE 2 ENGINE SPARE PARTS

No.	Description	Part No.	Qty
1	Blockage indicator	SZ100011-4LS	1
2	Heater plug chamber	SZ900096-4LE	1
3	Starter motor, 24V	SZ897137-4781	1
4	Alternator, 24V	SZ897112-6760	1
5	Glow plug, 24V	SZ897126-2570	4
6	Fuel control solenoid, 24V	SZ897209-1150	1
7	Manifold heater plug, 24V	SZ900095-ALS	2
8	Fuel feed pump, 24V	SZ600040-ALS	1
9	Oil pressure switch	SZ982720-0690	1
10	Water temperature switch	SZ897125-6000	1
11	Thermostat	SZ897211-2090	1
12	Joint, thermostat cover	SZ894365-6741	1
13	Water pump assembly	SZ897182-8531	1
14	Radiator assembly	SZ400001-ALS	1
15	Radiator mounts, top	SZ400046-ALS	2
16	Radiator mounts, bottom	SZ400012-ALS	2
17	Radiator hose, top	SZ400015-ALS	1
18	Radiator hose, bottom	SZ400035-ALS	1
19	Fan, cooling	SZ513660-3080	1
20	Injector nozzle	SZ894130-5320	4
21	Injector assembly	SZ897079-9760	4
22	Fuel injection pump	SZ897147-5801	4
23	Gasket set	SZ587812-8104	1
24	Jointing compound, red	SZ188440-5400	1
25	Jointing compound, black	SZ188440-1150	1
26	Oil filler cap, top cover	SZ894133-2075	1
27	Oil filler cap, front gearcase cover	SZ894425-6852	1
28	Dipstick	SZ897166-9600	1
29	Lub oil cooler assembly	SZ897102-3200	1
30	Hose, cylinder head to oil cooler	SZ897148-3430	1
31	Hose, oil cooler to tee piece	SZ897148-3450	1
32	Hose, water pump to tee piece	SZ897102-8790	1
33	Exhaust gasket	SZ897042-0280	1

ALTERNATOR SPARE PARTS

3 Spare parts for the Newage alternator, Model BCI182J, are detailed in Table 3.

TABLE 3 ALTERNATOR SPARE PARTS

No.	Description	Part No.	Qty
1	Automatic voltage regulator SX460	NE000-24602/1P	1
2	Rectifier service kit	NRSK-1101	1
3	Bearing, Non drive end	N051-01058	1

MASTER PARTS LIST

4 The master parts list for the 20kVA Cormorant Generator is provided in Table 4.

TABLE 4 MASTER PARTS LIST

No.	Description	Part No.	Qty
1	Isuzu 4LE1 24V 3000rev/min	015-264	1
2	Newage BCI182J	020-231	1
3	Canopy, base assembly	040-743/01	1
4	Canopy, battery spacer bracket	040-743/07	1
5	Canopy, battery clamp	040-743/10	1
6	Canopy, battery access cover	040-743/11	1
7	Canopy, fork pocket, eng end	040-743/12	1
8	Canopy, fork pocket, alt end	040-743/13	1
9	Canopy, fork pocket cover	040-743/17	2
10	Canopy, engine end cover	040-743/18	1
11	Canopy, alternator end cover	040-743/19	1
12	Canopy, roof panel	040-743/20	1
13	Canopy, radiator baffle	040-743/21	1
14	Canopy, lift-off door	040-743/22	1
15	Canopy, hinged door	040-743/24	1
16	Canopy, door catch bracket	040-743/28	2
17	Canopy, fuel tank	040-743/29	1
18	Canopy, e/stop, inter-vehicle pod	040-743/32	1
19	Canopy, fuel filler pod	040-743/33	1
20	Canopy, header bottle bracket	040-743/34	1
21	Canopy, roof foam retaining strip	040-743/35	2
22	Canopy, engine support bracket	040-743/36	2

(continued)

TABLE 4 MASTER PARTS LIST (continued)

No.	Description	Part No.	Qty
23	Canopy, radiator access cover	040-743/37	1
24	Canopy, output socket pod	040-743/38	1
25	Canopy, e/stop, inter-vehicle pod backplate	040-743/40	1
26	Canopy, control panel cover	040-743/41	1
27	Canopy, battery clamp top frame	040-743/44	1
28	Canopy, control panel latch bracket	040-743/45	1
29	Canopy, control panel pod	040-743/46	1
30	Canopy, control pod backplate	040-743/49	1
31	Canopy, control pod glandplate	040-743/50	1
32	Canopy, control pod CT plate	040-743/51	1
33	Canopy, hot air louvre	040-743/53	1
34	Canopy, hot air baffle	040-743/57	1
35	Canopy, cool air louvre	040-743/58	4
36	Canopy, cool air baffle - primary	040-743/62	2
37	Canopy, cool air baffle - secondary	040-743/63	1
38	Canopy, silencer support bracket	040-743/64	2
39	Canopy, battery clamp pivot rod	040-743/65	1
40	Canopy, battery clamp fixing bracket	040-743/66	1
41	Canopy, bracket - fuel transfer pump	040-743/67	1
42	Canopy, alternator end foam support	040-743/68	1
43	Canopy, fuel drain cover	040-743/69	1
44	Canopy, exhaust extension bracket	040-743/70	2
45	Canopy, transfer pump location tongue	040-743/71	1
46	Canopy, transfer pump tongue bracket	040-743/72	1
47	Canopy, transfer pump bracket	040-743/73	1
48	Canopy, exhaust extension strap clamp	040-743/74	3
49	Canopy, fork pod cover plate	040-743/76	4
50	Canopy, tee key storage bracket	040-742/65	1
51	Clamp, module interface converter	030-566	1
52	Anti vibration mount, main	070-486	4
53	Battery (OLDHAM UK6TNMF)	120-034	2
54	Battery lead, positive	120-507	1
55	Battery lead, negative	120-508	1
56	Battery lead, link	120-509	1

(continued)

TABLE 4 MASTER PARTS LIST (continued)

No.	Description	Part No.	Qty
57	Battery terminal - Positive	120-211	2
58	Battery terminal - Negative	120-212	2
59	Battery terminal cover - black	120-201	2
60	Battery terminal cover - red	120-202	2
61	Foam tape, battery clamp	160-212	1
62	Fuel pipe, tank to pump	175-001	1
63	Fuel pipe, pump to filter	175-002	1
64	Fuel pipe, filter to pump rail	175-003	1
65	Fuel pipe, leak-off	175-004	1
66	Fuel nipple 1/4in BSP with pick-up tube	170-401	1
67	Fuel nipple 5/16in BSP	170-102	1
68	Fuel nipple 1/8in BSP 5/16in hosetail	170-231	2
69	Fuel filler hose	065-604	1
70	Clamp, filler hose	170-132	2
71	Fuel filler cap	065-501	1
72	Chain, fuel cap retaining	070-930	0
73	Fuel drain elbow, 1/2in BSP	170-142	1
74	Fuel drain plug, 1/2in BSP male	170-143	1
75	Fuel drain reducer, 1in to 1/2in BSP	170-144	1
76	Fuel drain tap, 1/2in BSP	170-145	1
77	Enclosure, fuel pump switch	030-564	1
78	Fuel pump switch, pushbutton	080-051	1
79	Relay, 24V 40A 1-pole, Cold start	140-035	1
80	Relay base, 40A Cold start	140-028	1
81	Oil drain kit	655-001	1
82	Exhaust silencer, 2" ports	180-131	1
83	Exhaust manifold pipe	180-595	1
84	Flexible link pipe	180-596	1
85	Tail pipe	180-597	1
86	Silencer body clamp	180-722	2
87	Exhaust clamp 2-1/4 in	180-713	3
88	Insulation, exhaust manifold	160-301	1
89	Radiator expansion bottle	018-308	1
90	Acoustic foam kit, canopy	160-073	1

(continued)

TABLE 4 MASTER PARTS LIST (continued)

No.	Description	Part No.	Qty
91	Budget lock, universal	070-893	5
92	Key, budget lock	070-860	1
93	Escutcheon cover	070-858	5
94	Latch - wing handle, radiator access cover	070-870	1
95	Cam - wing handle	070-875	1
96	Hinge, side door	070-903	2
97	Hinge, radiator cap access cover	070-905	2
98	Hinge, control panel cover	070-904	2
99	Handle - door, recessed	070-942	3
100	Handle - roof, folding sprung loaded	070-814	2
101	Stop/buffer, door	070-945	1
102	Seal, door - side edge	160-203	2
103	Seal, cover - straight edge	160-202	2
104	Foam tape, panel inserts (10m roll)	160-209	1
105	Strap, exhaust extension stowage	151-211	3
106	Engine management module	125-043	1
107	Interface converter, engine man. module	125-074	1
108	Relay slave module	140-046	1
109	Hours counter, 24V	085-307	1
110	Mcb, 2 pole (45A), output 1 and 2	110-843	2
111	Weather cover, 2-pole mcb	110-836	2
112	Rcd detection module, EFR1	110-859	1
113	Rcd current transformer	110-864	1
114	Pilot Wire Monitor, ELM1E	110-601	2
115	Rcd Reset / Test switch	080-472	1
116	LED module, Rcd reset / test switch	080-473	1
117	Relay 24V, 2-pole	140-031	5
118	Relay 24V, 1-pole	3RS353-837	2
119	Relay base, 2-pole	3RS353-966	2
120	Relay base, 1-pole	3RS353-944	4
121	Timer, 2-pole, cold start heater	140-437	1
122	Timer, 1-pole, low fuel alarm	140-436	1

(continued)

TABLE 4 MASTER PARTS LIST (continued)

No.	Description	Part No.	Qty
123	Temperature switch, -12 deg C	110-865	1
124	Mcb, 1-pole (35A), Dc circuit	110-066	1
125	Mcb, 1-pole (10A), Fuel pump	110-063	1
126	Mcb, 1-pole (2A), Ac meters	110-067	1
127	Weather cover, 1-pole mcb	110-091	3
128	Fuel gauge, 24V	170-620	1
129	Sender, fuel gauge	085-709	1
130	Flange, fuel gauge mount	085-703	1
131	Switch, fuel/hours status (10A mom.)	080-031	1
132	Switch, sounder mute	080-004	1
133	Weather cover, toggle switch	080-005	3
134	Fuel level switch, 1 switch position	170-656	1
135	Voltmeter, 0-300V	085-057	1
136	Ammeter, 0-100A	085-255	1
137	Ammeter C.T. 100:5A	085-257	1
138	Start/stop switch - head	080-801	1
139	Start/stop switch - contact ass.	080-802	1
140	Start/stop switch - weather cover	080-803	1
141	Keyswitch, 2 position	080-479	1
142	Fixing adaptor, switch contact blocks	080-480	3
143	Contact block, keyswitch N/O	080-474	5
144	Contact block, keyswitch N/C	080-475	4
145	Keyswitch, 3 position, spring return	080-476	1
146	Key retainer/spring return, 3-pos'n switch	080-478	1
147	Sounder, audible alarm 24V	RS178-4197	1
148	Inter-vehicle connector, 24V NATO	090-601	1
149	Emergency stop switch c/w contacts	3RS318-979	1
150	Legend plate - Em. Stop switch	3RS319-253	1
151	Socket, AC power output, 50A 4 pin	090-611	2
152	Socket, remote monitor, 2A 6 pin	090-612	1
153	Cap, remote monitor socket	090-967	1
154	Gasket, remote monitor socket	090-968	1
155	Filter assembly, NEMP/LEMP	136-501	1
156	Bracket, DIN rail support	135-505	2

(continued)

TABLE 4 MASTER PARTS LIST (continued)

No.	Description	Part No.	Qty
157	Terminal 4mm WDU, DC connections	115-725	15
158	Terminal, diode, WDK2.5D	115-731	1
159	Terminal, double deck WDK2.5	115-732	1
160	End-plate, WDK terminal	115-733	2
161	Terminal 10mm WDU, AC power output	115-727	6
162	End-plate, 2.5 - 10mm terminal	115-742	1
163	End-plate, 16 - 35mm terminal	115-729	1
164	Terminal 35mm, AC power input	115-728	3
165	End stop - DIN terminal	115-730	2
166	Wiring loom, AC alternator to panel	155-001	1
167	Wiring loom, AC output 1	155-002	1
168	Wiring loom, AC output 2	155-003	1
169	Wiring loom, Pilot & remote	155-004	1
170	Wiring loom, E/stop & CT	155-005	1
171	Wiring loom, engine control	155-006	1
172	Wiring loom, Inter-vehicle	155-007	1
173	Generator Information	499-312	1
174	Mod. Strike plate - PPRF	499-511	1
175	Label, control panel fascia	499-568	1
176	Label set, output pod	499-533	1
177	Label kit, canopy	499-588	2
178	Wingnut, M12, brass	150-204	1
179	Earth stud, M12 x 50	150-205	1
180	Washer, earth point - M12, brass	150-206	2
181	Nut, earth point - M12, brass	150-207	1
182	Trailer-generator earth link cable	136-006	1
183	Exhaust extension	180-028	2
184	Pin, exhaust extension retainer	150-917	2
185	Insulation, exhaust extension	160-601	2
186	Pump, fuel transfer	170-674	1
187	Hose, inlet, fuel transfer pump	175-010	1
188	Hose, outlet, fuel transfer pump	175-011	1
189	Nipple, fuel transfer pump	170-308	1
190	Hose clamp, fuel transfer pump	170-131	1

5 For Isuzu Engine parts not listed above, refer to the Isuzu engine parts catalogue. For Newage Alternator parts not listed above, refer to the Newage alternator handbook. For Canopy and Control system parts not listed above, refer to the parts list in Table 4 of this chapter.

SERVICE AND TECHNICAL ASSISTANCE

6 Spares, service and technical assistance are available from:

HARRINGTON GENERATORS INTERNATIONAL LTD.
RAVENS TOR ROAD
WIRKSWORTH
DERBY
DE4 4FY
ENGLAND

Tel: 44 (0) 1629 824284
Fax: 44 (0) 1629 824613

NOTE

When ordering parts, the generator, alternator and engine serial numbers should be quoted where applicable.

COTS MANUALS

ANNEX A	**ISUZU DIESEL ENGINE - MODEL 4LE1 INSTRUCTION MANUAL**
ANNEX B	**ISUZU DIESEL ENGINE - MODEL 4LE1 WORKSHOP MANUAL**
ANNEX C	**ISUZU DIESEL ENGINE - L-SERIES TECHNICIAN GUIDE**
ANNEX D	**NEWAGE ALTERNATOR MANUAL**
ANNEX E	**DEEP SEA ELECTRONICS plc - ENGINE MANAGEMENT SYSTEM**

ANNEX A

ISUZU DIESEL ENGINE – MODEL 4LE1

INSTRUCTION MANUAL

ANNEX A

ISUZU DIESEL ENGINE – MODEL 4LE1 INSTRUCTION MANUAL

CONTENTS

(continued)

CONTENTS (continued)

ANNEX A

ISUZU DIESEL ENGINE - 4LE1 INSTRUCTION MANUAL

WARNING

CALIFORNIA PROPOSITION 65 WARNING. DIESEL ENGINE EXHAUST AND SOME OF ITS CONSTITUENTS ARE KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER, BIRTH DEFECTS, AND OTHER REPRODUCTIVE HARM.

FOREWORD

1 The ISUZU industrial diesel engines are a product of ISUZU's long years of experience, advanced technology. ISUZU takes great pride in the superior durability and operating economy of these engines.

2 In order to get the fullest use and benefit from your industrial engine, it is important that you operate and maintain it correctly. This manual is designed to help you do this.

3 Please read this Manual carefully and follow its operating and maintenance recommendations. This will ensure many years of trouble-free and economical engine operation.

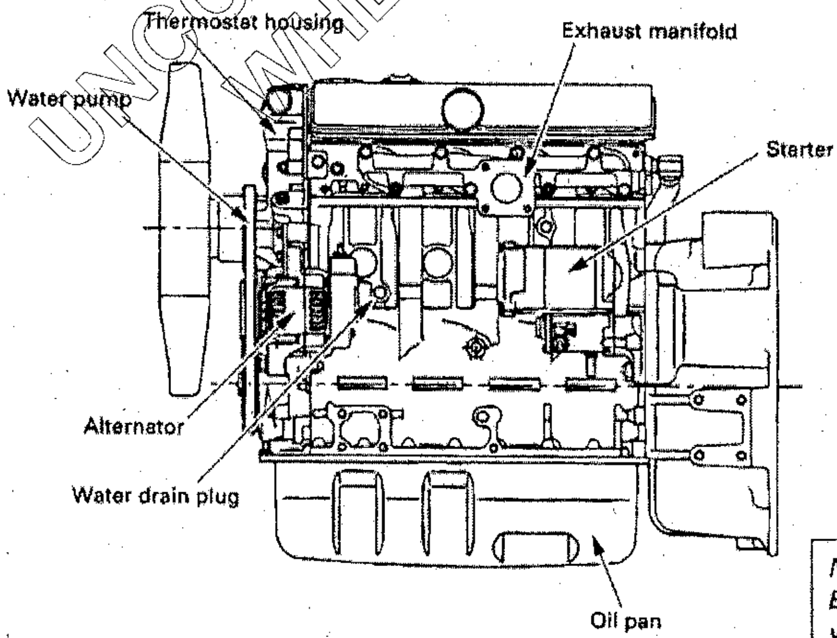
4 Should your engine require servicing, please contact your nearest ISUZU engine outlet. He knows your engine best and is ready to meet your satisfaction.

5 All information, illustrations, and specifications contained in this Manual are based on the latest product information available at the time of publication.

6 ISUZU reserves the right to make changes in this Manual at any time without prior notice.

ENGINE EXTERNAL VIEWS

7 Views of the Model 4LE1 are shown in Figs 1 and 2.



Note:
Engine details may vary depending on the specifications.

Fig 1 External view (LH)

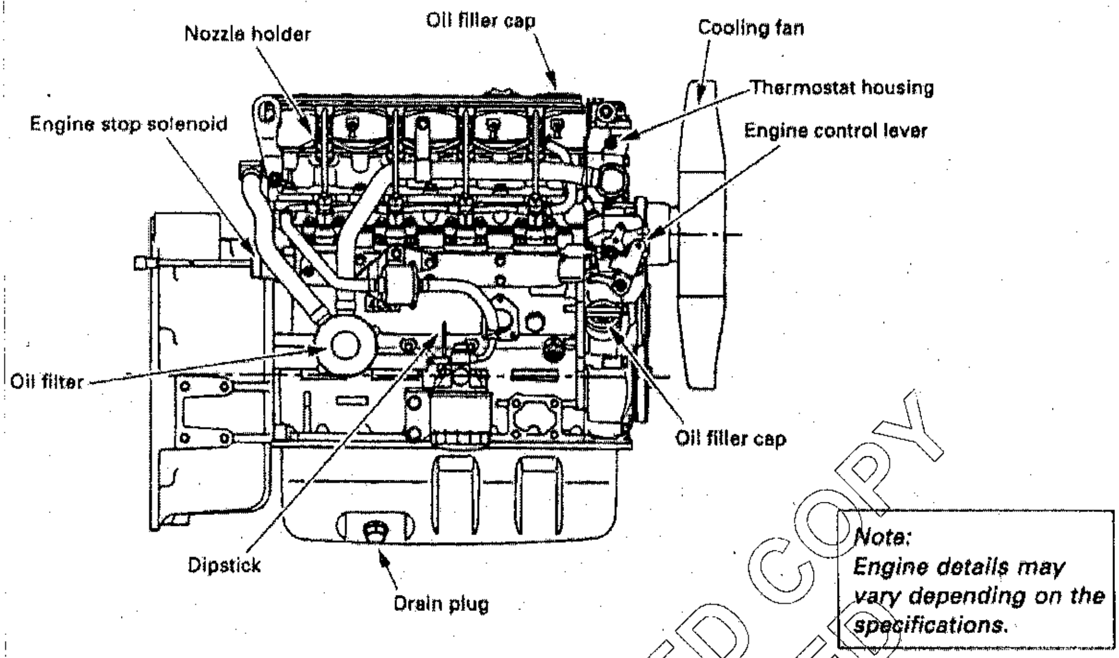


Fig 2 External view (RH)

GENERAL INFORMATION

Standard engine data and specifications

TABLE 1 4LE1 STANDARD ENGINE DATA

	Engine Type	Water-Cooled, four cycle, in-line overhead valve type
	Combustion type	In-direct Injection
	No. of cylinders - bore x stroke mm	4 - 85 x 96
	Piston displacement lit (cid)	2.179 (133)
	Compression ratio	21.5 to 1
	Firing order	1 - 3 - 4 - 2
*	Rated output; SEA GROSS kW(hp)/min^{-1}	40.5 (54.3) / 3000
*	Max. torque; SEA GROSS Nm(lbft)/min^{-1}	143 (194) / 1800
	Injection pump	Bosch, PFR type
	Governor	Mechanical type
	Injection nozzles	Throttle type
	Specified fuel	Diesel fuel (ASTM D975 No.2-D)

NOTES

(1) These specifications are based on the standard engine.

(2) Specifications for items marked with an asterisk (*) will vary according to the type of equipment in which the engine is installed. If you are unable to locate the data applicable to your engine, please contact your equipment supplier.

TABLE 2 4LE1 STANDARD ENGINE SPECIFICATIONS

* Starter		(V-kW)	12 - 1.8
* Alternator		(V-A)	12 - 35
Specified engine oil (API grade)			CC or CD
* Oil volume		lit (qts)	About 8.1 (8.6)
Coolant volume (Engine only)		lit (qts)	About 2.8 (3.0)
* Engine dry weight		kg (lb)	180 (397)
* Engine dimensions	Overall length	mm (in)	687 (27.0)
	Overall width	mm (in)	472 (18.6)
	Overall height	mm (in)	592 (23.3)
Valve clearance (cold)		mm (in)	0.40 (0.015) for exhaust and intake
Nozzle injection pressure		MPa (psi)	13.2 (1920)
* Injection timing B.T.D.C.			16°

NOTES

(1) These specifications are based on the standard engine.

(2) Specifications for items marked with an asterisk (*) will vary according to the type of equipment in which the engine is installed. If you are unable to locate the data applicable to your engine, please contact your equipment supplier.

EPA certified engine data and specifications

TABLE 3 EPA CERTIFIED ENGINE DATA

ISUZU engine model name	**4LE1**		
Engine family	XSZXL02. 2DNB	XSZXL02. 2DNC	XSZXL02. 2DNF
Engine code	22DNB	22DNC	22DNF
Engine type	Water-Cooled, four cycle, in-line overhead valve type		
Combustion type	In-direct Injection		
No. of cylinders - bore x stroke mm (in)	4 - 85 x 96 (3.35 x 3.78)		
Engine displacement lit (cid)	2.179 (133.0)		
Compression ratio	21.5 to 1		
Firing order	1 - 3 - 4 - 2		
Rated power: SAE NET kW(hp)/min^{-1}	39.0 (52.3)/3000	33.3 (44.7)/2400	35.0 (46.9)/3000
Fuel flow at max rated power (mm^3/stroke)	34.9	36.9	31.1
Max. torque: SAE NET Nm(lbft)/min^{-1}	139.8 (190)/1750	139.8 (190)/1750	139.8 (190)/1750
Fuel flow at max. torque (mm^3/stroke)	35.8	38.8	35.8
Exhaust emission control system	Engine modification		
Injection pump	Bosch, PFR type		
Governor	Variable speed, Mechanical type		
Injection nozzles	Throttle type		
Specified fuel	Diesel fuel (ASTM D975 No.2-D)		

TABLE 4 EPA CERTIFIED ENGINE SPECIFICATIONS

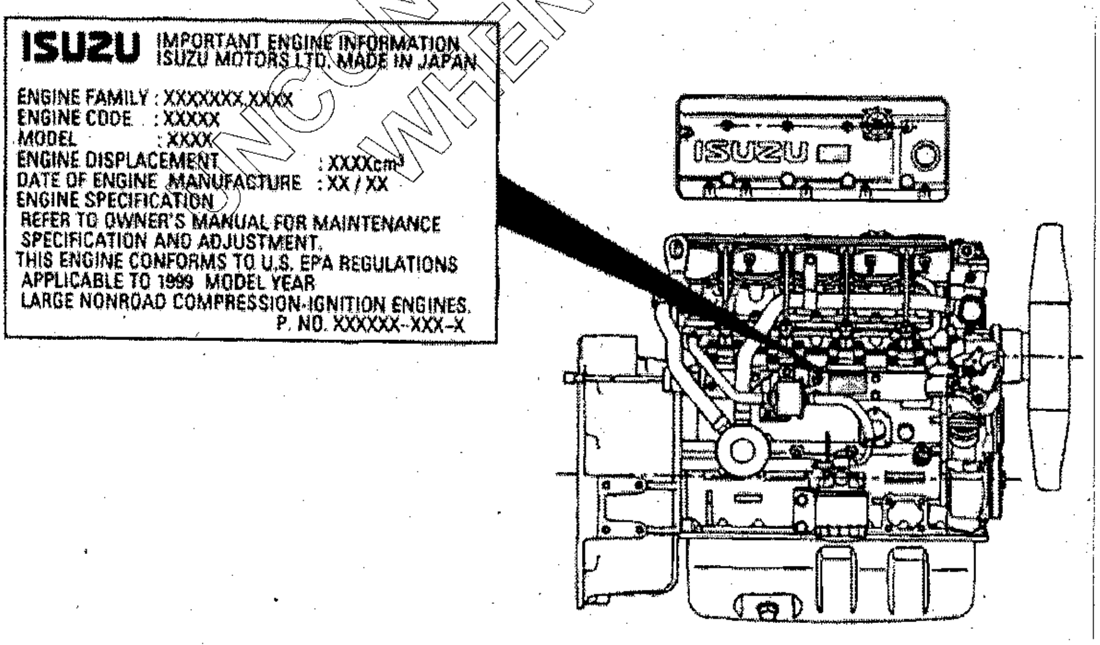
Starter		(V-kW)	12 - 1.2
Alternator		(V-A)	12 - 20
Specified engine oil (API grade)			CC or CD
Lubrication oil volume		L (qts)	6.3 (6.7)
Coolant volume (Engine only)		L (qts)	2.5 (2.6)
Engine dry weight		kg (lb)	132 (291)
Engine dimensions	Overall length	mm (in)	537 (21.1)
	Overall width	mm (in)	475 (18.7)
	Overall height	mm (in)	590 (23.2)
Valve clearance (cold)		mm (in)	0.20 (0.0078) for exhaust and intake
Nozzle injection pressure		MPa (psi)	13.2 (1920)
Injection timing B.T.D.C.			16°

EC emission control label

Emission control label: engine label (EPA)

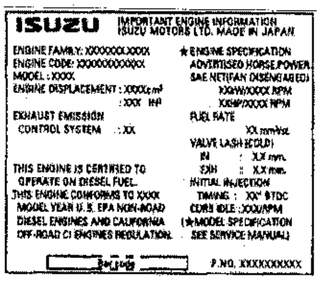
8 Emission control label is attached at the centre of injection pump cover located at the right side of cylinder body, or on the cylinder head cover. The location of emission control label attached on the engine may vary depending on the engine specification.

9 The following is a sample of the label required for engine emission control information, along with location.



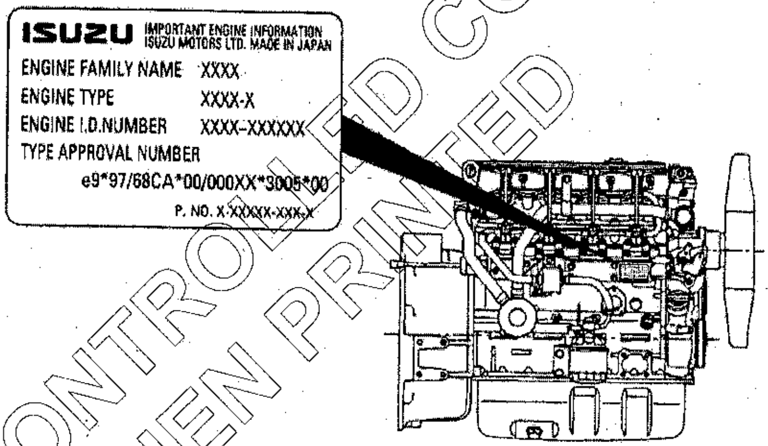
Supplemental: engine label (for EPA)

10 Emission control label is attached at a visible point on the equipment.



EC emission control label: engine label

11 Emission control label is attached at the front of injection pump cover located at the right side of cylinder body. The following is the detail of a label required for engine emission control information, along with location.



Engine identification

Position of display

12 The engine serial number is stamped on the front upper right side of the cylinder body, and the engine model is cast on the rear lower right side of the cylinder body just above the oil filter (Fig 3). Further, engine model is described also on an ID label on the top of the cylinder head cover.

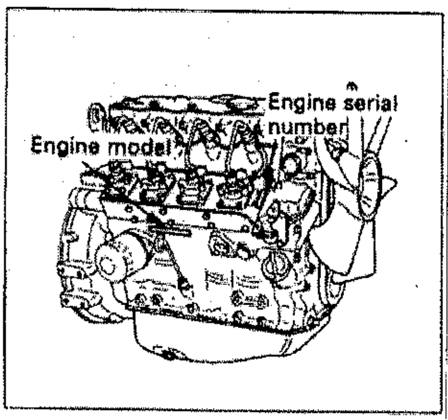


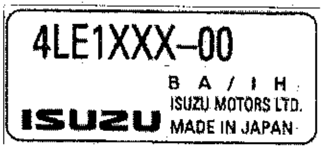
Fig 3 Engine identification

Confirmation of engine serial number

WARNING

> **PERSONAL INJURY. CONDUCT CONFIRMATION OF ENGINE SERIAL NUMBER WITH THE ENGINE STOPPED. TO AVOID BEING INJURED, DO NOT CHECK IT WHILE THE ENGINE IS STILL HOT.**

13 It is advisable to check the engine serial number, engine model name and type of machine together with the equipment manufacturer's name, as it is required when you contact the distributor for repair, service or parts ordering.



Isuzu engine after service

14 Please feel free to contact your ISUZU dealer for periodical inspection and maintenance.

Isuzu genuine parts

15 The ISUZU genuine parts are identical with those used in the engine production, and accordingly, they are warranted by ISUZU MOTORS LIMITED. The ISUZU genuine parts are supplied by the ISUZU distributors or the authorized parts suppliers. Please designate 'ISUZU Genuine Parts' when you need engine parts.

ISUZU GENUINE PARTS

FUEL, LUBRICANT AND COOLANT

Diesel Fuel

Fuel selection

16 The following specific advantages are required for the diesel fuel.

(1) Must be free from minute dust particles.

(2) Must have adequate viscosity.

(3) Must have high cetane value.

(4) Must have high fluidity at low temperature.

(5) Must have low sulphur content.

(6) Must have little residual carbon.

TABLE 5 DIESEL FUELS

Applicable Standard	Recommendation
JIS (JAPANESE INDUSTRIAL STANDARD)	No.2
DIN (DEUTSCHE INDUSTRIE NORMEN)	DIN 51601
SAE (SOCIETY OF AUTOMOTIVE ENGINEERS) Based on SAE-J-313C	No. 2-D
BS (BRITISH STANDARD) Based on BS/2869-1970	Class A-1

17 If fuel other than the specified one is used, engine function will be lowered.

Fuel requirements

CAUTIONS

EQUIPMENT DAMAGE. The fuel injection pump, injector or other parts of the fuel system and engine can be damaged if you use any fuel or fuel additive other than those specifically recommended by Isuzu. Such damage is not Isuzu's responsibility, and is not covered by the Warranty. To help avoid fuel system or engine damage, please heed the following:

(1) Some service stations mix used engine oil with diesel fuel. Some manufacturers of large diesel engines allow this, however, for your diesel engine, do not use diesel fuel which has been contaminated with engine oil. Besides causing engine damage, such fuel can also affect emission control. Before using any diesel fuel, check with service station operator to see if the fuel has been mixed with engine oil.

(2) Do not use any fuel additive (other than as recommended under 'Biocide' in this section). At the time this manual was printed, no other fuel additive was recommended. (See your authorized dealer to find out if this has changed.)

18 Your engine is designed to use either Number 1-D or Number 2-D diesel fuel. However, for better fuel economy, use Number 2-D diesel fuel whenever possible. At temperatures less than -7°C, (20°F), Number 2-D fuel may pose operating problems (see 'Cold Weather Operation' which follows). At colder temperatures, use Number 1-D fuel (if available) or use a 'winterized' Number 2-D (a blend of Number 1-D and Number 2-D). This blended fuel is usually called Number 2-D also, but can be used in colder temperatures than Number 2-D fuel which has not been 'winterized'. Check with the service station operator to be sure you get the properly blended fuel. Note that diesel fuel may foam during a fill-up. This can cause the automatic pump nozzle to shut off even though your tank is not full.

CAUTION

EQUIPMENT DAMAGE. Do not use home heating oil or gasoline in your diesel engine, either may cause engine damage.

Handling of the fuel

19 Fuel containing dust particles or water will cause engine failure. Therefore, the following notice must be observed.

(1) Take care to prevent the fuel from entry of dust particles or water when filling the fuel tank. When fuelling from an oil drum directly, keep the drum stationary over a long time so that clean fuel can be used after the dust particles or water is completely sedimented.

(2) Always fully fill the fuel tank. Drain the sedimented particles in the fuel tank frequently by opening the tank draining hole.

Water in fuel

20 During refuelling, it is possible for water (and other contaminants) to be pumped into your fuel tank along with the diesel fuel. This can happen if a service station does not regularly inspect and clean its fuel tanks, or if a service station receives contaminated fuel from its supplier(s).

21 To protect your engine from contaminated fuel, there is a fuel filter system on the engine which allows you to drain excess water.

WARNING

> **PERSONNEL INJURY. THE WATER/DIESEL FUEL MIXTURE IS FLAMMABLE, AND COULD BE HOT. TO HELP AVOID PERSONAL INJURY AND/OR PROPERTY DAMAGE, DO NOT TOUCH THE FUEL COMING FROM THE DRAIN VALVE, AND DO NOT EXPOSE THE FUEL TO OPEN FLAMES OR SPARKS. BE SURE YOU DO NOT OVERFILL THE CONTAINER. HEAT (SUCH AS FROM THE ENGINE) CAN CAUSE THE FUEL TO EXPAND. IF THE CONTAINER IS TOO FULL, FUEL COULD BE FORCED OUT OF THE CONTAINER. THIS COULD LEAD TO A FIRE AND THE RISK OF PERSONAL INJURY AND/OR VEHICLE OR EQUIPMENT DAMAGE.**

Biocides

22 In warm or humid weather, fungus and/or bacteria may form in diesel fuel if there is water in the fuel.

CAUTION

> **EQUIPMENT DAMAGE. Fungus or bacteria can cause fuel system damage by plugging the fuel lines, fuel filters or injector. They can also cause fuel system corrosion.**

23 If fungus or bacteria has caused fuel system problems, you should have your authorized dealer correct these problems. Then, use a diesel fuel biocide to sterilize the fuel system (follow the biocide manufacturer's instructions). Biocides are available from your dealer, service stations, parts stores and other automotive places. See your authorized dealer for advice on using biocides in your area and for recommendations on which biocides you should use.

Smoke suppressants

24 Because of extensive testing of treated fuel versus untreated fuel, the use of a smoke suppressant additive is not recommended because of the greater possibility of stuck rings and valve failure, resulting from excessive ash deposits.

Lubricant

25 The quality of engine oil may largely affect engine performance startability and engine life. Use of unsuitable engine oil will result in piston ring, piston and cylinder seizure and accelerate the sliding surface wear causing increased oil consumption, lowered output and, finally engine failure. To avoid this, use the specified engine oil.

Engine oil selection

26 API, CC or CD grade.

Oil viscosity

27 Engine oil viscosity largely affects engine startability, performance, oil consumption, speed of wearing and occurrence of seizure, etc. Using lubricants whose viscosity selected according to the atmospheric temperature is important (Fig 4).

CAUTIONS

(1) EQUIPMENT DAMAGE. Using a mixture of different brands or quality oils will adversely affect the original oil quality; therefore, never mix up different brand or different type oils.

(2) EQUIPMENT DAMAGE. Do not use API, CA, CB grade and reconstituted engine oil.

(3) EQUIPMENT DAMAGE. Engine damage due to improper maintenance, or using oil of the improper quality and/or viscosity, is not covered by the warranty.

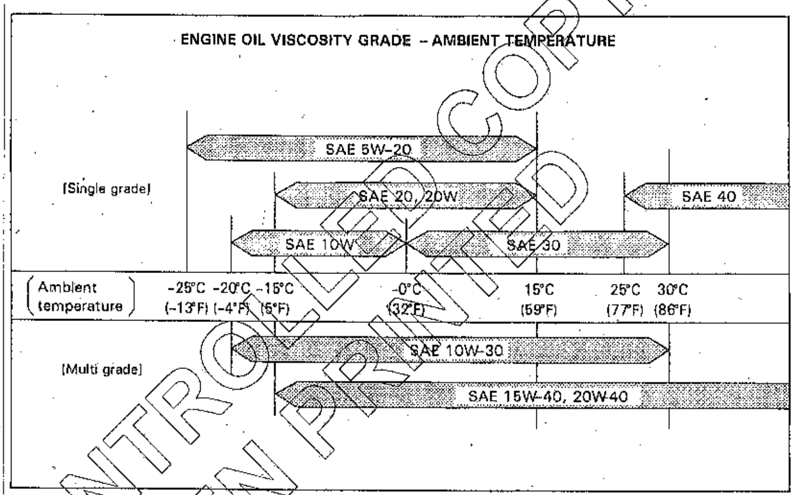


Fig 4 Engine oil viscosity chart

Coolant

28 Use drinking water for coolant and replace it periodically.

ENGINE OPERATION

WARNING

PERSONNEL INJURY. DO NOT BREATHE EXHUAST GAS AS IT CONTAINS CARBON MONOXIDE, WHICH BY ITSELF HAS NO COLOUR OR ODOUR. CARBON MONOXIDE IS A DANGEROUS GAS, IT CAN CAUSE UNCONSCIOUSNESS AND CAN BE LETHAL.

PERSONNEL INJURY. IF AT ANY TIME YOU THINK EXHAUST FUMES ARE ENTERING THE CAB, HAVE THE CAUSE DETERMINED AND CORRECTED AS SOON AS POSSIBLE. IF YOU MUST DRIVE UNDER THESE CONDITIONS, DRIVE ONLY WITH ALL WINDOWS FULLY OPEN.

PERSONNEL INJURY. PROTECT AGAINST CARBON MONOXIDE ENTRY INTO THE CAB. THE BEST WAY IS TO KEEP THE ENGINE EXHAUST SYSTEM, CAB AND CAB VENTILATION SYSTEM PROPERLY MAINTAINED. WE RECOMMEND THAT THE EXHAUST SYSTEM AND CAB BE INSPECTED BY COMPETENT TECHNICIAN:

(1) EACH TIME THE VEHICLE HAS AN OIL CHANGE.

(2) WHENEVER A CHANGE IS NOTICED IN THE SOUND OF THE EXHAUST SYSTEM.

(3) WHENEVER THE EXHAUST SYSTEM, UNDERBODY OR CAB IS DAMAGED OR BECOMES CORRODED. SEE 'MAINTENANCE SCHEDULE' OF THIS MANUAL FOR PARTS REQUIRING INSPECTION.

PERSONNEL INJURY. TO ALLOW PROPER OPERATION OF YOUR VEHICLE"S VENTILATION SYSTEM, KEEP THE AIR INLET GRILLE CLEAR OF SNOW, LEAVES OR OTHER OBSTRUCTIONS AT ALL TIMES.

PERSONNEL INJURY. DO NOT RUN THE ENGINE IN CONFINED AREAS (SUCH AS GARAGES OR NEXT TO A BUILDING) ANY MORE THAN NEEDED TO MOVE THE VEHICLE OR THE EQUIPMENT.

PERSONNEL INJURY. KEEP THE EXHAUST TAILPIPE AREA CLEAR OF SNOW AND OTHER MATERIAL TO HELP REDUCE THE BUILDUP OF EXHAUST GASES UNDER THE VEHICLE OR THE EQUIPMENT. THIS IS PARTICULARLY IMPORTANT WHEN PARKED IN BLIZZARD CONDITIONS.

Checks before operation

WARNING

PERSONNEL INJURY. FOR SAFETY'S SAKE, CONDUCT THE INSPECTION BEFORE START-UP WTH THE ENGINE STOPPED.

<u>Engine oil level</u>

29 Place the engine on a level surface.

30 Remove the dipstick (Fig 5) from the crankcase, wipe it with clothing. Insert it fully and take it out gently again. Check the oil level by the level marks on the dipstick. The oil level must be between the 'Max' and 'Min' level mark as illustrated (Fig 6).

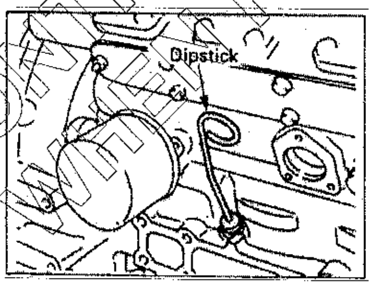


Fig 5 Dipstick

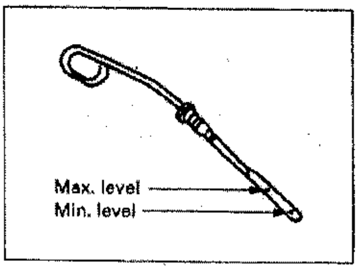


Fig 6 Oil level

31 Take care not to add too much engine oil.

(1) Drain oil to the max. oil level if oil level is above the max. level mark.

(2) Add oil to the max. oil level if oil level is below the min. level mark.

32 Also check the sample oil on the dipstick for fouling and degree of viscosity.

NOTE

Oil level check must be made ten or twenty minutes later after the engine has been stopped. When the oil level check is necessary while the engine is running, stop the engine and keep it stationary ten or twenty minutes until the oil thoroughly flows down to the crankcase.

33 Oil is poured either through the oil filler at the front of the cylinder head cover or through the oil filler on the right side of the timing gear case (Fig 7). A certain period of time is required before the engine oil completely flows down from the oil filler to the crankcase. Check the oil level ten or twenty minutes after oil replenishment.

NOTE

If the engine oil is splashed on the fan drive belt, it causes belt slippage or slackness; therefore, take care to avoid it.

WARNING

PERSONNEL INJURY. IN ADDING OIL, TAKE CARE NOT TO SPILL IT. IF YOU SPILL OIL ON THE ENGINE OR EQUIPMENT, WIPE IT PROPERLY, OR THIS COULD LEAD TO A FIRE AND THE RISK OF PERSONAL INJURY AND/OR EQUIPMENT DAMAGE.

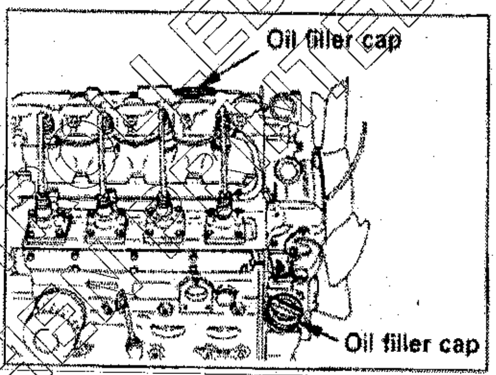


Fig 7 Oil filler caps

Fan belt check

34 Check the fan belt for tension and abnormalities (Fig 8). When the belt is depressed **about 10 mm (0.39 in)** with the thumb (about 100 N (22 lb) pressure) at midway between the fan pulley and generator pulley, the belt tension is correct.

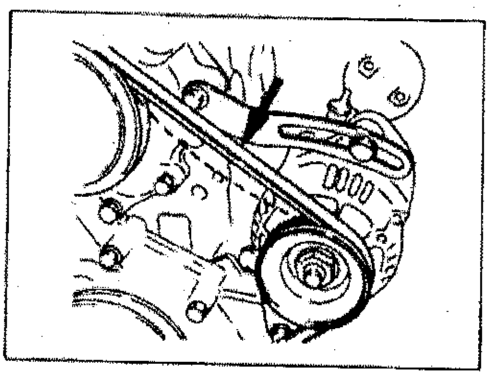


Fig 8 Fan belt tension

35 When the belt tension is too high, it will result in generator failure. Contrarily, a loose belt will cause belt slippage which may result in damaged belt and abnormal noise.

36 Check the belts. Replace them if any damage is found.

CAUTION

EQUIPMENT DAMAGE. Replace all belts as a set even when one is not usable. Single belt of similar size must not be used as a substitute for a matched belt set. Otherwise, premature belt wear would result because of uneven belt length.

Coolant level check

37 The coolant level must be between 'FULL' and 'LOW' marks on the reserve tank. Check and see that the level is correct. When the coolant level is lower than the 'LOW' mark, replenish the reserve tank by the filler port, but when the reserve tank is empty, replenish by the radiator filler port.

WARNING

PERSONNEL INJURY. WHEN REMOVING THE RADIATOR FILLER CAP WHILE THE ENGINE IS STILL HOT, COVER THE CAP WITH CLOTHING, THEN TURN IT SLOWLY TO GRADUALLY RELEASE THE INTERNAL STEAM PRESSURE. THIS WILL PREVENT YOU FROM GETTING BURNT WITH HOT STEAM SPOUTING FROM THE FILLER PORT.

38 Use clean drinking water as coolant. When an anti-freeze solution is required, keep to the specified mixing ratio.

Radiator cap condition

39 After the replenishment of the coolant, install the radiator cap. Make sure the cap is securely installed.

Battery cable condition

40 Check the battery cable connections for looseness or corrosion (Fig 9). The loosened cable connection will result in hard engine starting or insufficient battery charge. The battery cables must be tightened securely. Never reverse '+' and '-' terminals when reconnecting cables after disconnection. Even a short period of reverse connection will damage the electrical parts.

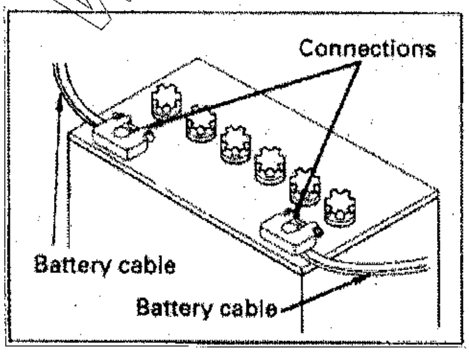


Fig 9 Battery connections

Battery electrolyte level

41 The amount of electrolyte in the batteries will be reduced after repeated discharge and recharge. Check the electrolyte for the level in the batteries (Fig 10), replenish with a commercially available electrolyte such as distilled water, if necessary. The battery electrolyte level checking procedure will vary with battery type. Follow the equipment manufacturer's instructions.

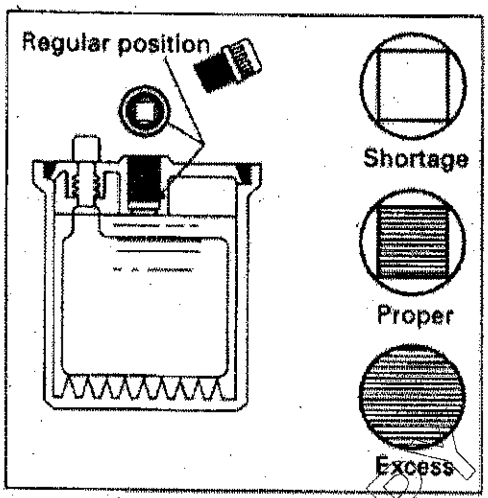


Fig 10 Battery electrolyte level

CAUTION

EQUIPMENT DAMAGE. DO NOT REPLENISH WITH DILUTE SULPHURIC ACID IN THE DAILY SERVICE.

WARNINGS

(1) PERSONNEL INJURY. WHEN INSPECTING THE BATTERIES, BE SURE TO STOP THE ENGINE.

(2) PERSONNEL INJURY. AS DILUTED SULPHURIC ACID IS USED AS ELECTROLYTE, BE CAREFUL NOT TO STAIN YOUR EYES, HANDS, CLOTHES AND METALS WITH THE ELECTROLYTE. IF IT GETS IN YOUR EYE, WASH WITH A LARGE AMOUNT OF WATER AT ONCE. THEN GO AND SEE A DOCTOR.

(3) PERSONNEL INJURY. AS A HIGHLY FLAMMABLE HYDROGEN GAS IS RISING FROM THE BATTERIES, DO NOT MAKE A SPARK OR USE FIRE IN ANY OTHER WAY NEAR THE BATTERIES.

(4) PERSONNEL INJURY. WHEN HANDLING SUCH METALLIC ARTICLES AS A TOOL NEAR THE BATTERIES, BE SURE NOT TO CONTACT '+' TERMINAL AS THE VEHICLE BODY IS '-', IT MAY CAUSE A BIG DANGER.

(5) PERSONNEL INJURY. WHEN DISCONNECTING THE TERMINALS, START WITH THE '-' TERMINAL. WHEN CONNECTING THE TERMINALS, CONNECT THE '-' TERMINAL LAST.

Engine starting

Pre-starting preparation

42

(1) Make sure that all hydraulic control levers etc. on the equipment are in the NEUTRAL position.

(2) Set the engine stop knob in the START position.

(3) Switch ON the battery switch (if so equipped).

(4) Insert the starter switch key into the switch key hole. Turn the key clockwise to the DRIVE position and make sure that the meters and warning lamps are actuated.

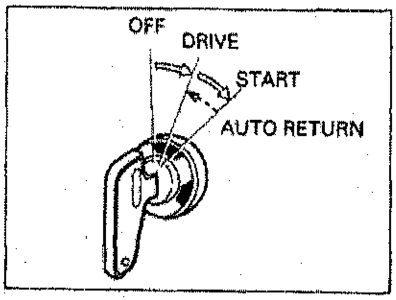


Fig 11 Starter switch (QOS system)

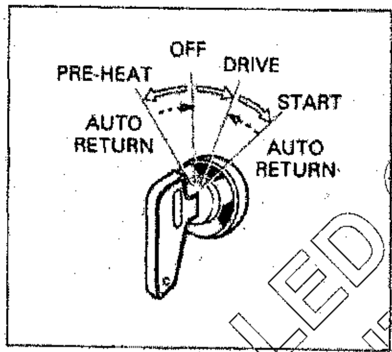


Fig 12 Starter switch (control resistance)

Pre-heating procedure

43 As an engine starting aid, pre-heating is required in cold engine starting.

44 The type with QOS system. This pre-heating uses 'QOS', a quick pre-heating system which automatically controls pre-heating time utilizing coolant temperature to conduct the irreducible minimum of pre-heating (Fig 11).

(1) Turn the key to the DRIVE position, and the glow plug built in the engine will grow red-hot to pre-heat the engine. At this time the pre-heating indicator lamp on the meterboard is actuated.

(2) When the pre-heating indicator lamp goes out, try starting the engine at once.

TABLE 6 RELATIONSHIP BETWEEN WATER TEMPERATURE AND PRE-HEATING TIME

Water Temperature	Pre-heating Time
50°C (122°F)	About 1 sec.
20°C (68°F)	About 2 sec.
0°C (32°F)	About 3.5 sec.
-15°C (5°F)	About 5 sec.

45 The type with a control resistance (Fig 12)

(1) Turn the starter switch key counter-clockwise to PRE-HEAT position in order to heat the glow plugs on the engine.

(2) Turn the starter switch key clockwise to START position as soon as the control resistance coil indicates red heat.

WARNING

PERSONNEL INJURY. DO NOT TOUCH THE RED (HOT) CONTROL RESISTANCE COIL OR ALLOW COMBUSTIBLE MATERIALS SUCH AS PAPER, CLOTH OR LEAVES ON IT. THIS COULD LEAD TO A FIRE AND THE RISK OF PERSONAL INJURY AND/OR EQUIPMENT DAMAGE.

Engine starting

46 Depress the engine throttle lever or throttle pedal and turn the starter switch key clockwise to START position. The cranking period must not exceed ten seconds. Continuous starter operation of more than ten seconds will lead to over-discharge of the batteries as well as starter seizure. If the engine cannot be started in one time attempt, keep the batteries and the starter stationary at least 30 seconds for their functional recovery, then repeat the pre-heating and the starting operations.

CAUTION

EQUIPMENT DAMAGE. Continuous re-engagement of the starter to the flywheel ring gear without giving them a break will result in the damage to the starter pinion gear and flywheel ring gear.

47 If, despite repeated operations, the engine does not start, wait for a minute or more until the functions of the batteries and starter are recovered and then repeat pre-heating and starting operations.

48 When repeating starting operation, return the key to the OFF position and then pre-heat and start the engine once again. If the engine still remains unstarted, something may be wrong with the engine. Check the repeated parts to located the cause.

CAUTION

EQUIPMENT DAMAGE. Do not use starting 'aids' in the air intake system. Such aids can cause immediate engine damage.

Check and operation after engine start-up

Warming-up operation

49 Do the warming-up operation at 1000 min^{-1} about ten minutes after the engine has started. As the lubrication for the entire engine systems will be done in this warming-up, do not speed up and load it abruptly. Particularly, observe this in cold season operation.

Check after the engine start-up

50 Check the following items in the engine warming-up operation.

(1) Engine oil pressure. Although the engine oil pressure gauge readings vary depending on ambient temperature or a type of oil, the gauge registers around 390 to 690 kPa (57 to 100 psi) in the warming-up. In the oil pressure warning lamp type, make sure that the lamp is off.

(2) Charge condition. The charge condition is normal when once the ammeter registers greatly on the plus side in the engine starting, then gradually the meter registering will be minimized. In the warning lamp type, make sure that the lamp is completely off during the warming-up.

(3) Engine noise and exhaust smoke colour. Pay attention to engine noise and, if any abnormal noise is heard, check the engine to detect the cause. Check the fuel combustion condition by the exhaust smoke colour. The exhaust smoke colour after engine warming-up and at no-load operation:

Colourless or light blue	Normal (Perfect combustion)
Black colour	Abnormal (Imperfect combustion)
White colour	Abnormal (Imperfect combustion)

NOTE

Engine noise after start-up might be noisier than that of warmed-up engine and, the exhaust smoke colour also being more blackish than the normal condition. However, it will be normalized after warming-up engine.

(4) Leakage in the system. Check the following items:

a.	Lube oil leakage	Check both sides and bottom of the engine assembly for lube oil leaks, paying particular attention to the lube oil pressure gauge pipe joint, lube oil filter and lube oil pipe joints.
b.	Fuel leakage	Check the fuel injection pump, fuel lines and fuel filter for leakage.
c.	Coolant leakage	Check the radiator and water pump hose connections also the water drain cocks on the radiator and cylinder body for leakage.
d.	Exhaust smoke or gas leakage	

(5) Checking coolant level. The coolant level could drop depending on the equipment because the mixed air is expelled in about 5 minutes after the engine started. Stop the engine, remove radiator cap, and add coolant.

WARNING

PERSONNEL INJURY. IF THE RADIATOR CAP IS REMOVED WHEN THE ENGINE IS HOT, HOT STEAM WILL RUSH OUT AND YOU COULD GET BURNT. COVER THE RADIATOR CAP WITH A THICK CLOTH AND LOOSEN THE CAP SLOWLY TO REDUCE THE PRESSURE, THEN REMOVE THE CAP.

Care in the engine operation

51 During engine operation, always pay attention to the following items if the engine indicates any sign of abnormalities.

Engine oil pressure

52 Engine oil pressure is normal when the oil pressure gauge shows 290 to 590 kPa (43 to 85 psi) in the engine warmed-up condition, although the engine oil pressure may vary depending on a type of oil or engine specification. In continuous engine operation, engine oil pressure is slightly lower than the pressure at start-up time. If, in continuous engine operation, the engine oil pressure warning lamp is off, engine oil pressure is normal.

53 When the engine oil pressure gauge shows the following abnormal conditions, stop the engine immediately and check the engine oil amount in the oil sump and oil leakage:

(1) The oil pressure gauge shows below 200 kPa (28 psi) though the engine speed is raised.

(2) The oil pressure gauge indicator oscillates greatly in the engine low speed range.

(3) When the engine oil pressure warning lamp goes on and off repeatedly.

54 When no lack of engine oil or no oil leakage is found, contact your equipment supplier to determine the cause of the abnormal reading.

Coolant temperature

55 The engine performance will be adversely affected if engine coolant temperature is too hot or too cold. The normal coolant temperature is 75 to 85°C (167 to 185°F).

WARNING

PERSONNEL INJURY. IF THE ENGINE COOLANT TEMPERATURE GAUGE SHOWS AN OVERHEAT CONDITION OR YOU HAVE OTHER REASON TO SUSPECT THE ENGINE MAY BE OVERHEATING, CONTINUED OPERATION OF THE ENGINE (OTHER THAN AS SPELLED OUT HERE) EVEN FOR A SHORT PERIOD OF TIME, MAY RESULT IN A FIRE AND THE RISK OF PERSONAL INJURY AND SEVERE VEHICLE OR EQUIPMENT DAMAGE. TAKE IMMEDIATE ACTION AS OUTLINED IN THE FOLLOWING.

56 Overheating. If you see or hear escaping steam or have other reason to suspect there is a serious overheat condition, stop and park the vehicle or equipment as soon as it is safe to do so and then turn off the engine immediately and get out of the vehicle or equipment.

57 The engine cooling system may overheat if the engine coolant level is too low, if there is a sudden loss of engine coolant (such as hose splitting), or if other problems occur. It may also temporarily overheat during severe operating conditions such as:

(1) Climbing a long hill on a hot day.

(2) Stopping after high rpm.

58 If the Engine Coolant Temperature gauge shows an overheat condition, or you have reason to suspect the engine may be overheating, take the following steps:

(1) If your air conditioner (if equipped) is on, turn it off. And turn on the heater.

(2) Do not turn off your engine.

(3) With the transmission in Neutral, increase the engine speed to about one-half full operating speed or 1200 RPM, maximum. Bring the idle speed back to normal after two or three minutes.

59 If the engine coolant temperature does not start to drop within a minute or two, let the engine run at normal idle speed for two or three minutes.:

60 If the engine coolant temperature does not start to drop, turn off the engine and get out of the vehicle or equipment then proceed as follows:

WARNING

PERSONNEL INJURY. TO HELP AVOID BEING BURNED:

(1) DO NOT OPEN THE ENGINE ACCESS COVER IF YOU SEE OR HEAR STEAM OR ENGINE COOLANT ESCAPING FROM THE ENGINE COMPARTMENT. WAIT UNTIL NO STEAM OR ENGINE COOLANT CAN BE SEEN OR HEARD BEFORE OPENING THE ENGINE COVER.

(2) DO NOT REMOVE THE RADIATOR CAP OR ENGINE COOLANT RESERVE TANK CAP IF THE ENGINE COOLANT IN THE TANK IS BOILING. ALSO DO NOT REMOVE THE RADIATOR CAP WHILE THE ENGINE AND RADIATOR ARE STILL HOT. SCALDING FLUID AND STEAM CAN BE BLOWN OUT UNDER PRESSURE IF EITHER CAP IS TAKEN OFF TOO SOON.

61 If no steam or engine coolant can be seen or heard, tilt the cab or open the engine access cover. If the engine coolant is boiling, wait until it stops before proceeding. Look at the see-through reserve tank. The engine coolant level should be between the 'MAX' and 'MIN' marks on the reserve tank. If necessary, pour engine coolant into the reserve tank only, never directly into the radiator. Also, do not check engine coolant level at the radiator.

62 Make sure the fan belts are not broken, or are off the pulleys, and that the fan turns when the engine is started.

63 If the engine coolant level in the reserve tank is low, look for leaks at the radiator hoses and connections, heater hoses and connections, radiator, and water pump. If you find major leaks, or spot other problems that may have caused the engine to overheat, do not run the engine until these problems have been corrected. If you do not find a leak or other problem, carefully add engine coolant to the reserve tank. (Engine coolant is a mixture of ethylene glycol antifreeze and water. See 'Engine Care in cold season' (Para 137) for the proper antifreeze and mixture).

WARNING

> **PERSONNEL INJURY. TO HELP AVOID BEING BURNED, DO NOT SPILL ANTIFREEZE OR ENGINE COOLANT ON THE EXHAUST SYSTEM OR HOT ENGINE PARTS. UNDER SOME CONDITIONS THE ETHYLENE GLYCOL IN ENGINE COOLANT IS COMBUSTIBLE.**

64 If the engine coolant level in the reserve tank is at the correct level but there is still an indication on the instrument panel of an overheat condition, YOU MUST LET THE ENGINE COOL FIRST. You may then add engine coolant directly to the radiator.

65 Once the Engine Coolant Temperature Gauge no longer signals an overheat condition, you can resume operating at a reduced speed. Return to normal operating after about ten minutes if the gauge pointer does not again show an overheat condition.

66 If no cause for the overheat condition was found, see a qualified service technician.

67 Overcooling. The engine operation at low coolant temperature will not only increase the oil and fuel consumption but also will lead to premature parts wear which may result in engine failure.

Engine hour meter (engine operation hour indicating) (if so equipped)

68 This meter indicates the engine operation hours. Make sure that the meter is always working during engine operation.

69 Periodical engine maintenance is scheduled on the operation hours indicated on the hour meter.

Liquid and exhaust smoke leakage

70 Be careful with lubricant, fuel, coolant and exhaust smoke leakage.

Abnormal engine noise

71 Pay attention to the noise from the engine or other related parts, checking if the noise is normal.

State of the exhaust smoke

72 Be careful with exhaust smoke colour, check if it is whitish or blackish.

Electrical system

73 Do not turn the key to OFF position during engine running. This may cause electrical parts damage.

Engine stopping

74 Make sure that all of the control levers on the equipment are in NEUTRAL position.

75 Before stopping the engine, cool down the engine by operating it at low idle speed for about three minutes. During this operation, check the engine noise and the engine oil pressure for abnormalities.

76 To stop the engine, turn the starter switch key to OFF position. Switch off the battery (if so equipped).

CAUTION

> **BATTERY DISCHARGE. Leaving the starter switch key in the DRIVE position for a long while after the engine has been stopped, will discharge the batteries wastefully.**

Operation and care of new engine

77 Your ISUZU engine is carefully tested and adjusted in the factory, however, further, thorough run-in, ie break-in operation, is necessary.

78 If the new engine is harshly operated, lubricating oil film will be reduced leading to abnormal wear or seizure. Particularly, avoid harsh engine operation within the initial 100 operation hours observing the following notice.

(1) Perform the warming-up operation continuously until the engine is warmed-up. In this operation, do not race the engine.

(2) Also do not operate the engine with rapid acceleration, rapid machine starting and continuous high speed operation.

Engine care for over-cooling

79 Engine over-cooling causes premature wear and increased fuel consumption. When the coolant temperature is not raised to 75 to 85°C (167 to 185°F) indefinitely, take action to raise the temperature using a radiator curtain or such like.

Starting the engine after being left unused for a long period of time

80 When the vehicle or equipment is left unused for 'more than three months' without running the engine (warming up), conduct a thorough inspection of the vehicle before starting the engine. After starting the engine, be sure to warm it up for more than ten minutes at 1000 min^{-1}.

PERIODICAL INSPECTION AND MAINTENANCE

Lubricating system

81 Servicing of the engine oil or the oil filter element affects the engine performance as well as the engine life.

82 Change the engine oil and the oil filter element periodically with the specified ones. (Refer to LUBRICANT at Paras 25 to 27).

Engine oil and oil filter element change

83 Engine oil change and oil filter element change must be made according to the following change schedule.

Change Interval	
Engine Oil	Initial 50 and thereafter **every 250** operating hours
Oil Filter Element	Initial 50 and thereafter **every 500** operating hours

84 Engine oil draining

WARNING

PERSONNEL INJURY. TO AVOID BEING BURNED, DO NOT DRAIN OIL WHILE THE ENGINE IS STILL HOT.

(1) Wipe clean around the oil filler cap (Fig 13) taking care that no foreign particles enter. Remove the filler cap.

(2) Remove the oil pan drain plug and drain the engine oil completely (Fig 14).

85 It is advisable that draining be done while the engine is warm, to minimize the draining time.

NOTE

Use a receptacle to receive the drained oil so that the engine and equipment may not be stained with the drained oil.

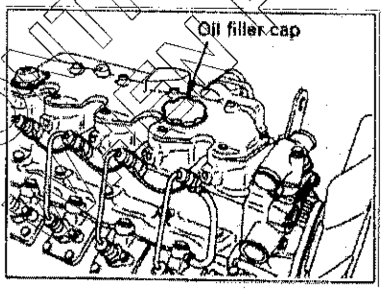


Fig 13 Oil filler cap

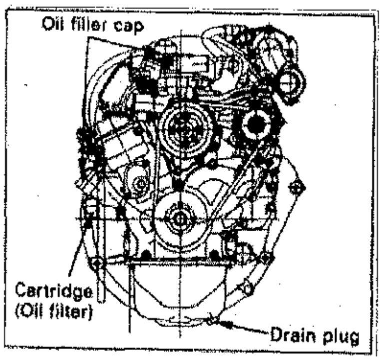


Fig 14 Oil filter and drain plug

86 Oil filter element removal. Use a filter wrench to remove the cartridge type oil filter element (Fig 15).

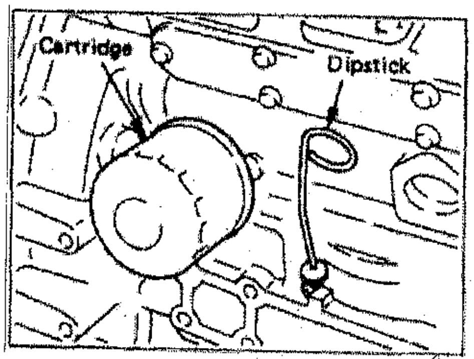


Fig 15 Oil filter removal

87 Oil filter element installation

(1) Apply light engine oil to the O-ring.

(2) Screw in new cartridge until its sealed face comes in contact with the O-ring.

(3) Use a filter wrench to further turn in the cartridge by 3/4 turn.

Used oil disposal

88 Do not dispose of used engine oil (or any other oil) in a careless manner such as pouring it on the ground, into sewers, or into streams or bodies of water. Instead, recycle it by taking it to a used oil collection facility which may be found in your community. If you have a problem disposing of your used oil, it is suggested that you contact your dealer or service station. (This also applies to diesel fuel which is contaminated with water. See 'Diesel Fuel' in Para 16.)

Used engine oil

WARNING

PERSONNEL INJURY. USED ENGINE OIL CONTAINS HARMFUL CONTAMINANTS THAT HAVE CAUSED SKIN CANCER IN LABORATORY ANIMALS. AVOID PROLONGED SKIN CONTACT. CLEAN SKIN AND NAILS THOROUGHLY USING SOAP AND WATER – NOT MINERAL OIL, FUELS, OR SOLVENTS. LAUNDER OR DISCARD CLOTHING, SHOES, OR RAGS CONTAINING USED ENGINE OIL.

89 Discard used engine oil and other oils properly.

Cooling System

Fan belt tension adjustment

90 Adjust fan belt tension when belt slackness is greater than the specified amount and when the belts are being replaced (Fig 16).

WARNING

PERSONNEL INJURY. TO HELP AVOID BEING INJURED, CHECK AND ADJUST FAN BELT TENSION WITH THE ENGINE STOPPED.

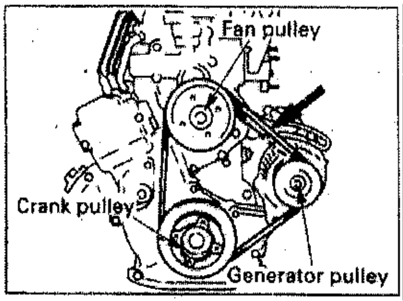


Fig 16. Fan belt

91 Belt tension. Belt tension is normal when it is depressed 10 mm (0.39 in) with the thumb at the midway between the fan pulley and generator pulley. (About 100 N (22 lb) depressing force).

Fan belt slackness : **About 10 mm (0.39 in)**

92 Adjusting procedure. Belt tension adjustment (Fig 17) is made by pivoting the generator at the generator mounting bolt.

(1) Loosen the generator adjusting plate bolt and the generator mounting bolt.

(2) Pivot the generator at the mounting bolt toward the engine left or right-hand side as required.

(3) Tighten the mounting bolt and the adjusting bolt.

NOTE

Belt tension may vary slightly after the generator is fixed. Therefore, recheck the belt tension after tightening the bolts.

(4) After the adjustment, operate the engine about five minutes at a low idle speed and recheck the belt tension. Particularly, pay attention to this matter when installing new belts. Belt tension may vary due to the initial belt conforming.

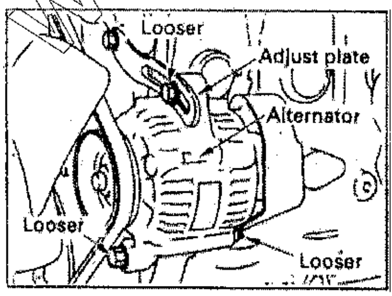


Fig 17 Fan belt tension adjustment

Fan belt change

93 Use of a fan belt of poor quality will result in premature belt wear or belt elongation leading to engine damage such as overheat. Therefore use of the ISUZU genuine fan belts is highly recommended.

Coolant change

94 The coolant must be changed at intervals of **six months**. If the coolant is being fouled greatly, it will lead to engine overheat or coolant blow-off from the radiator.

Coolant draining

95 Drain the coolant as follows:

(1) Remove the radiator cap. Open the drain cock at the radiator lower part to drain the coolant from the radiator.

WARNING

PERSONNEL INJURY. WHEN REMOVING THE RADIATOR FILLER CAP WHILE THE ENGINE IS STILL HOT, COVER THE CAP WITH A RAG, THEN TURN IT SLOWLY TO RELEASE THE INTERNAL STEAM PRESSURE. THIS WILL PREVENT A PERSON BEING SCALDING WITH HOT STEAM SPOUTING OUT FROM THE FILLER PORT.

(2) Drain away the coolant from the engine by loosening the water drain plug (Fig 18) at the rear of alternator on the left side of cylinder body.

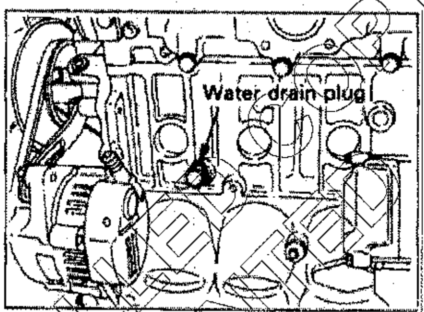


Fig 18 Water drain plug

Filling with coolant

96 Fill the system with coolant as follows:

(1) Close or tighten the coolant drain plug.

(2) Use clean drinking water as a coolant. Fill up the radiator with the coolant until the level comes up to the filler port neck. Fill gradually to prevent air entry.

Coolant volume (Engine only): Refer to 'Main Data Specifications'.

(3) With the system filled, operate the engine about five minutes at a low idle speed, then the air contained in the coolant circuit is bled. The coolant level will drop. Stop the engine to replenish the coolant.

Cleaning outside of radiator

97 Mud or dried grass caught between radiator fins will block the air flow, resulting in lower cooling efficiency. Clean the radiator fins with steam or compressed water. For the cleaning interval, refer to the instruction manual prepared by the equipment manufacturer. If the fins are stuffed, however, clean them at any time. Further, if the fins are deformed, repair or replace them.

Cooling system circuit cleaning

98 When the cooling system circuit if fouled with water scales or sludge particles, cooling efficiency will be lowered. Periodically clean the circuit interior with a cleaner.

Cooling system cleaning interval: **Every 1000** operation hours.

Fuel system

99 The fuel injection pump and fuel injection nozzles are precisely manufactured, and therefore, using the fuel which contains water or dust particles will result in either injection pump plunger seizure or injection nozzle seizure. A fuel filter element fouled with sludge or dust particles will lead to decreased engine output. In addition, a clogged filter element can cause low output or automatic air bleeding failure.

100 Perform inspection and maintenance periodically as follows:

Removal of water from the fuel

101 If water reaches the fuel filter element bottom, follow the procedure below to drain the water.

(1) Turn the fuel filter lever just above (close) until it stops, to cut off the fuel. (See Fig 19).

(2) Loosen the ring nut, remove the cup together with the element, and drain the fuel.

(3) Clean the cup, install the element and tighten to the filter body with the ring nut.

(4) Turn the fuel filter lever just below (open) until it stops, to conduct air bleeding for the fuel.

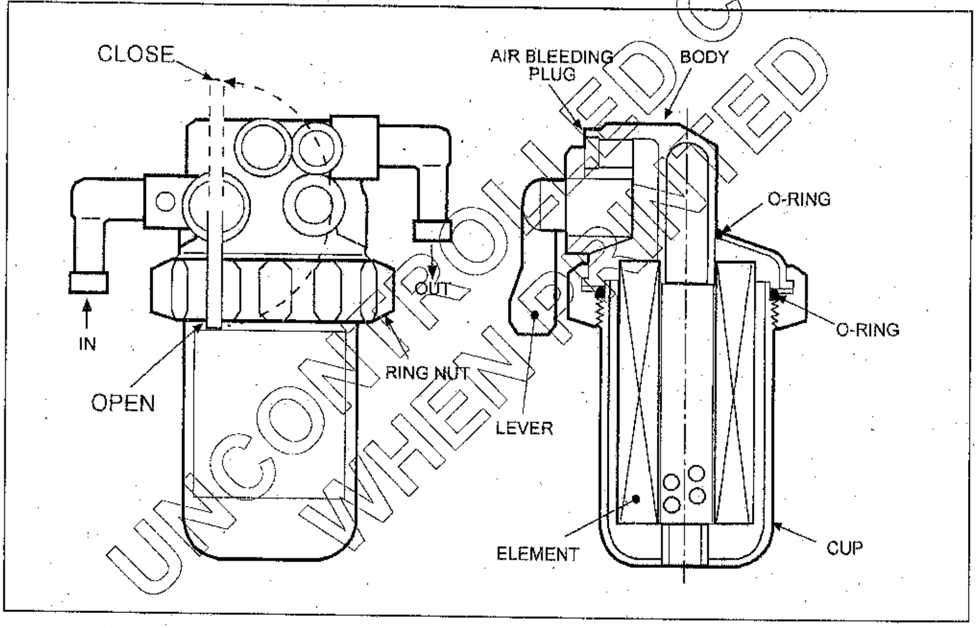


Fig 19 Draining water from the fuel

NOTES

(1) If the cup is removed without turning the fuel filter lever just above, the fuel may flow out.

(2) The cartridge and cup contain fuel. Take care not to spill it during disassembly.

(3) Perform the 'fuel system air bleeding' after the water in the fuel is drained.

Fuel system air bleeding

102 The entry of air into the fuel system will cause hard engine starting or engine malfunction. When servicing such as emptying the fuel tank, draining for the water sedimentor, and the fuel filter element change is done, be sure to conduct air bleeding. Because of the 'automatic air-bleeding system' being employed, turn the starter switch to the DRIVE position and activate the 'electromagnetic pump' to bleed the air.

103 Air bleeding procedure

(1) When the 'starter switch' is set to the DRIVE (ON) position to activate the electromagnetic pump, fuel is forcibly sent to the fuel valve of each injection pump (Fig 20) and further to the leak-off pipe of each nozzle holder, where air in the fuel leaks off automatically to the fuel tank.

(2) Start the engine and check the fuel system for fuel leak.

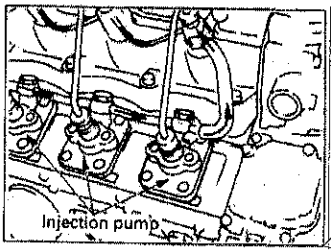


Fig 20 Injection pump

Fuel filter element change procedure

Change Interval	
Fuel Filter Element change interval	**Every 500** operating hours

104 Change the fuel filter element as follows:

(1) Turn the fuel filter lever (Fig 21) to the closed position.

NOTE

If the cup is removed without turning the lever as instructed, the fuel may flow out.

(2) Loosen the ring nut, remove the cup, and take out the element.

(3) Clean the cup, install a new element, and install new packing on the ring nut.

(4) Tighten the cut to the body securely with the ring nut.

(5) After installation, turn the fuel filter lever to the open position.

NOTES

(1) With the lever positioned just above the fuel remains off, and therefore, the engine cannot be started.

(2) During removal, be careful not to stain the parts around with the fuel in the cup.

(3) After changing the fuel filter element, conduct fuel air bleeding.

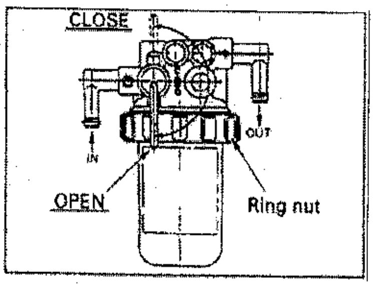


Fig 21 Fuel filter element

Change procedure with spin-on type filter

105 Change the spin-on type fuel filter element (Fig 22) as follows:

(1) Loosen the fuel filter turning it counter-clockwise with a filter wrench.

(2) With a rag wipe clean the fitting face on the upper cover, so that new fuel filter can be seated properly.

(3) Lightly oil the O-ring. To reinstall, turn the filter assembly clockwise carefully to prevent the fuel from spilling until the O-ring is fitted against the sealing face of the filter cover. Turn 2/3 turn further with the filter wrench.

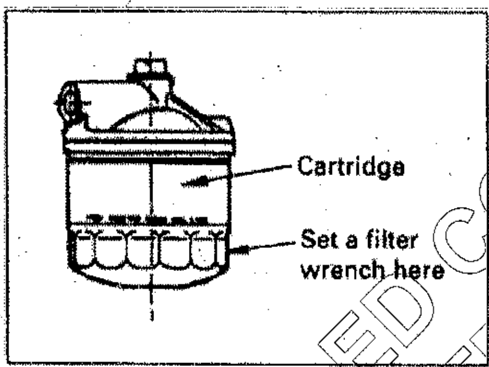


Fig 22 Spin-on type fuel filter element

Governor Control Seals

106 As the governor (timing gear case) is precisely adjusted, most of the controls are sealed, please do not break them. When the adjustment is necessary, contact your machine supply source.

NOTE

The manufacturer does not warrant the claim on the engine with the governor seals broken.

Air intake system

Air cleaner

107 Engine performance and life vary with the air intake conditions. A dirty air cleaner element reduces the amount of intake air, causing reduced engine output or disordered engine. Also, a damaged element leads to abrasion of cylinders and valves, resulting in increased oil consumption, reduced output and shortened engine life. Handling of air cleaner varies with the equipment model. Perform periodic inspection and maintenance following the equipment manufacturer's instructions.

NOTES

(1) Shorten the cleaning or change interval when the equipment is used in dusty areas.

(2) Change the element, if element damage is found during air cleaner cleaning.

(3) Take care not to cause air leakage (sucking) when reassembling the air cleaner.

Air cleaner with dust indicator

108 This indicator (Fig 23) is attached to the air cleaner. When the air cleaner element is clogged, air intake resistance becomes greater and the dust indicator signal turns into red indicating element change time. When the signal turns into red, clean the air cleaner or replace the element. Then press the dust indicator button to reset the indication.

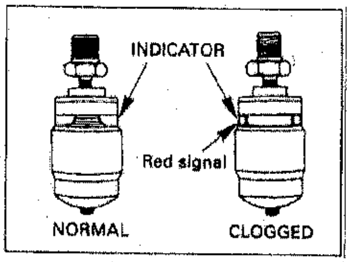


Fig 23 Dust indicator

Engine electrical

109 The ISUZU engine uses a 12 volt system and a negative grounding type for the electrical system.

Battery servicing

110 Battery maintenance schedules will vary with equipment and battery types. Follow the equipment manufacturer's instructions.

Gravity of the batteries

111 The battery charge condition is judged by the electrolyte gravity measurement. Periodically measure the electrolyte gravity of the batteries (Fig 24). For the internal check follow the equipment manufacturer's standard. The relationship between the electrolyte specific gravity and the battery conditions are as follows:

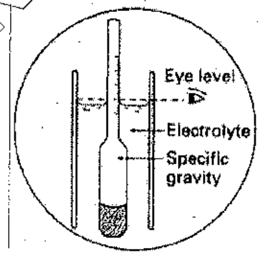


Fig 24 Electrolyte specific gravity

TABLE 7 ELECTROLYTE SPECIFIC GRAVITY

Electrolyte Specific Gravity	Battery Conditions
Over 1.300	Over 100% (Over charged)
1.290 – 1.270	100%
1.260 – 1.240	75%
Below 1.230	Below 50% (Insufficiently charged)

WARNING

PERSONNEL INJURY. THE BATTERY ELECTROLYTE IS DILUTE SULPHURIC ACID. SO, BE CAREFUL NOT TO STAIN YOUR BODY AND CLOTHES WITH IT. IF STAINED, RINSE PORTION IN CLEAN WATER.

Gravity conversion

112 The specified electrolyte temperature for the gravity measurement is 20°C (68°F). Measure the electrolyte temperature and carry out the conversion in accordance with the following formula when the temperature does not fall to the specified temperature.

$S20 \quad St + 0.0007\,(t - 20)$

Where $S20$ = gravity at 20°C
St = gravity measured
t = electrolyte temperature when measured

Battery terminal connections

113 Periodically, check the battery terminals for loose connection and corrosion.

114 For the check interval, follow the machine manufacturer's standard. Loose connections will cause hard engine starting or deficient battery charging.

115 If the terminals are excessively corroded, disconnect the battery cables and polish them with a wire brush or sandpaper.

116 Never reverse the '+' and '-' terminals when reconnecting the cables. Even a short period of reverse connection could damage the electrical parts.

Cleaning of battery

117 When the battery is fouled, clean it with clean water or tepid water and wipe them with a dry cloth to remove the water. Apply a light coat of Vaseline or grease to the battery post.

Generator Servicing

118 The polarity of the generator is negative grounding type. When an inverted circuit connection takes place, the circuit will be in short circuit instantaneously resulting in generator failure.

119 Do not put water directly on the generator. Entry of water into the generator leads to an electrolyte corrosion causing generator failure. Pay attention particularly when cleaning the engine.

120 When the battery is charged with a external electric source, be sure to disconnect the battery cables.

Wiring connections

121 Check all of the electric wiring connections for looseness and damage.

Engine assembly and others

122 To continue trouble free engine operation over a long period of time, the servicing items need a skilled maintenance technician, therefore, consult your machine supply source on the following items when necessary.

Fuel injection nozzle

123 Use an injection nozzle tester to check the static injection starting pressure and the fuel spray conditions (Fig 25).

Injection nozzle pressure test interval: **Every 1500** operation hours

124 When the injection starting pressure is too high or too low or the fuel spray pattern is improper, an abnormal fuel combustion take place in the engine leading a lowered output and blackish exhaust smoke. Further, it causes a piston seizure or piston damage etc. In such cases, the injection nozzle test or the nozzle replacement is required.

Injection starting pressure: 12.7 – 13.7 MPa (1850 – 1990 psi)

WARNING

PERSONNEL INJURY. WHILE USING A NOZZLE TESTER, HIGH PRESSURE MAY BLOW OFF THE FUEL OIL AND INJURE THE WORKER. KEEP OFF THE NOZZLE END.

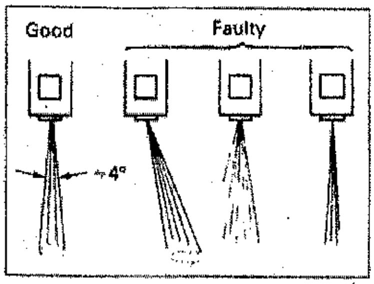


Fig 25 Fuel injection test

Valve clearance adjustment

125 The valve clearance must be adjusted **every 1000** operating hours, or whenever the valve rocker is abnormally noisy, or in an engine malfunction though the fuel system is properly working.

Valve clearance : 0.20 mm (0.0078 in) (When the engine is cold)

126 Adjustment procedure

(1) Turn the crankshaft clockwise so that the mark groove on the crank pulley is aligned with the TDC mark (cast out) on the timing gear case cover (Fig 26).

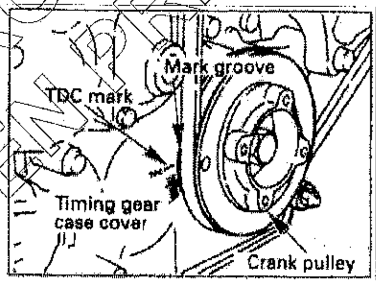


Fig 26 Valve clearance adjustment

(2) Remove the cylinder head cover and check to see if cylinder No. 1 is at TDC in the compression stroke or at TDC in the exhaust stroke. When the intake and exhaust valves are closed, the cylinder is at TDC in the compression stroke, and when only the exhaust valve is open, it is at TDC in the exhaust stroke (Fig 27).

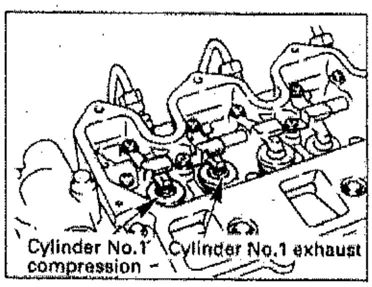


Fig 27 Exhaust and compression strokes

(3) In accordance with the conditions of cylinder No. 1, measure and adjust if required, the clearance of the valves marked with either ○ or ◎ in the table below.

TABLE 8 VALVE CLEARANCES

Cylinder No.	1		2		3		4	
Valve arrangement	I	E	I	E	I	E	I	E
When No. 1 cylinder is at TDC in the compression stroke	○	○	○			○		
When No. 4 cylinder is at TDC in the compression stroke				◎	◎		◎	◎

I : Inlet E : Exhaust

(4) On completion of the valve clearance adjustment in Sub-para (3) above, make mark alignment as in Sub-para (1) above by giving a turn to the crankshaft in normal direction. Then measure and adjust the clearance of the other valves.

NOTE

The rocker arm is made of die-cast aluminium. Therefore, be careful not to tighten the adjusting screw to excess.

Adjustment of injection timing

127 The injection timing may not be readjusted. Take care not to forget to insert a shim on the mounting surface when reassembling the injection pump after it was removed.

Cylinder compression pressure measurement

128 The cylinder compression pressure measurement must be done **every 1000** operation hours, or whenever the engine output is reduced.

Compression pressure: 3.04 MPa (441 psi)
Test condition: Cranking speed 250 min $^{-1}$
Coolant temperature 75°C (167°F)

129 Repair the engine and/or replace some parts of engine if compression pressure is lower than 2.55 MPa (370 psi).

Starter and generator servicing

130 Do the starter and the generator servicing **every 1000** operating hours on the following items.

(1) Starter commutator cleaning.

(2) Generator slip ring cleaning.

(3) Carbon brushes and the brush contact check.

Radiator pressurization valve check

131 A pressurization valve is incorporated in the radiator cap assembly. Check the valve actuating pressure with a radiator compression tester. For the pressurization valve actuating pressure and the check interval, follow the equipment manufacturer's standards.

ENGINE CARE IN COLD SEASON

Fuel

Fuel selection

132 In the cold zone, the fuel might be frozen resulting in hard engine starting; therefore, select a suitable fuel for such engine operation.

133 Use ASTM 975 No. 2-D fuel if you expect temperature above -7°C (20°F). Use Number 1-D if you expect temperatures below -7°C (20°F).

134 If Number 1-D is not available, a 'winterized' blend of 1-D and 2-D is available in some areas during the winter months. Check with the service station operator to be sure you get the properly blended fuel.

CAUTION

(1) EQUIPMENT DAMAGE. Methyl alcohol base antifreeze is not recommended because of its effect on the non-metallic components of the cooling system and because of its low boiling point.

(2) EQUIPMENT DAMAGE. High silicate antifreeze is not recommended because of causing serious silica gelation problems.

(3) EQUIPMENT DAMAGE. Usage and mixing ratio etc. should be followed to the antifreeze manufacturer's recommendations.

Engine oil

135 Engine oil viscosity largely affects engine startability, so the use of lubricant with selected viscosity according to the atmospheric temperature is important. (Refer to Fig 4.)

136 At low atmospheric temperature, engine oil viscosity will increase to cause hard engine starting.

Coolant

137 Where the atmospheric temperature falls below freezing point, the cooling system should be drained after engine operation, but to eliminate the need for repeated draining and refilling, the use of anti-freeze solution is highly recommended.

138 A 50/50 Ethylene glycol base antifreeze/water mix (which provides protection to -37°C (-34°F) is recommended for use in these ISUZU diesel engines).

139 Concentrations over 65% adversely affect freeze protection, heat transfer rates, and silicate stability which may cause water pump leakage.

140 Never exceed a 60/40 antifreeze/water mix (which provides protection to about -50°C (-58°F)).

WARNING

PERSONNEL INJURY. UNDER SOME CONDITIONS THE ETHYLENE GLYCOL IN THE ENGINE COOLANT IS COMBUSTIBLE. TO HELP AVOID BEING BURNED WHEN ADDING ENGINE COOLANT, DO NOT SPILL IT ON THE EXHAUST SYSTEM OR ENGINE PARTS THAT MAY BE HOT. IF THERE IS ANY DIFFICULTY, HAVE THIS ROUTINE PERFORMED BY A QUALIFIED TECHNICIAN.

Battery

141 Always pay attention to charging the batteries completely in the cold season. As the discharge current from the battery is large in cold engine starting, it takes a comparatively long while to recharge the batteries than when recharging after normal engine starting. Particularly, as the gravity of the insufficiently charged battery's electrolyte is low, it will easily be frozen. Pay attention to keep the batteries warm in the cold season.

142 To replenish the battery with distilled water, do it immediately before the engine operation. If the work is done after the engine has already been in operation, the distilled water replenished will not be mixed with the original electrolyte, allowing the danger of freezing, the not mixed distilled water staying in the battery cell upper part.

Engine starting

143 In cold engine starting at atmospheric temperature of below 0°C (32°F), pay attention to the following items:

(1) Do the preheating operation before cranking the engine with the starter.

(2) Set the engine throttle lever or pedal to the 1/3 position of the full lever or pedal stroke.

(3) If the engine does not start with the initial cranking, keep the batteries stationary a while to recover their power and, reattempt the preheating and the cranking operation.

(4) In order to protect the starter, one time cranking must be limited to within 10 seconds.

(5) In cranking operation, when a phenomenon that the starter pinion and the flywheel ring gear engagement is not taking place, this is a sign of weakened battery power, charge the batteries with an external electrical source.

(6) In extreme cold temperature engine starting, do the engine cranking while setting the throttle lever at no fuel position, to allow the engine rotating or travelling parts to come to an unrestricted condition from the adhesive cold lubricant. After, carry out preheating and cranking to start the engine.

CAUTION

EQUIPMENT DAMAGE. Do not use starting "aids" in the air intake system. Such aids can cause immediate engine damage.

ENGINE ELECTRICAL WIRING DIAGRAM

144 As the electrical wiring differs depending on the respective equipment, merely standard wiring is shown in the diagram (Fig 28).

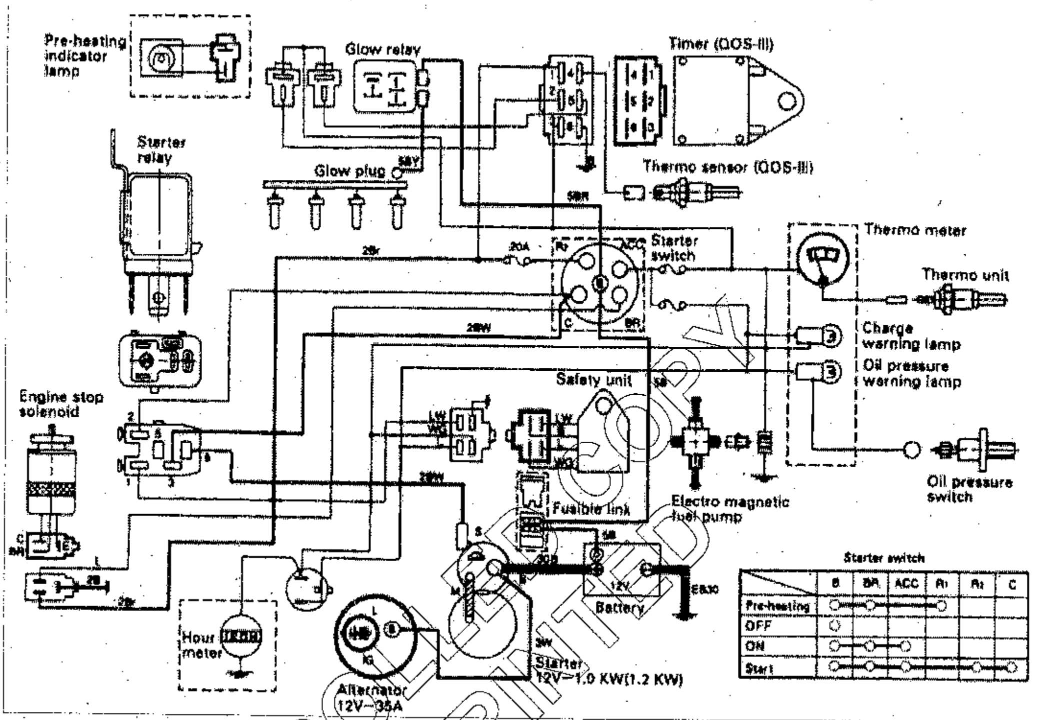


Fig 28 Engine electrical wiring diagram

ENGINE MAINTENANCE SCHEDULE

145 When performing the following items (Table 9), the daily inspection items should <u>also</u> be carried out.

TABLE 9 ENGINE MAINTENANCE SCHEDULE

No.	Description of check and maintenance	Daily	(Operation hours)							Remark
			50	250	500	750	1000	1250	1500	
1	Oil level and oil fouling	O								See 'Explanation of maintenance schedule' at Para 146.
2	Oil leakage check	O								
3	Oil pressure gauge registration	O								
4	Oil pressure warning lamp	O								
5	Engine oil replacement		(O)	O	O	O	O	O	O	
6	Oil filter element replacement		(O)		O		O		O	
7	Fuel leakage check	O								
8	Draining water in fuel filter	O								
9	Fuel filter element replacement				O		O		O	
10	Injection nozzle check (*)				O*		O*		O*	

* This is a recommended maintenance. The failure to perform this maintenance item will not nullify the emission warranty or limit recall liability prior to the completion of the engine's useful life. Isuzu, however, urges that recommended maintenance service is performed at the indicated intervals.

TABLE 9 ENGINE MAINTENANCE SCHEDULE (continued)

No.	Description of check and maintenance	Daily	(Operation hours) 50	250	500	750	1000	1250	1500	Remark
11	Coolant level and fouling check	○								See 'Explanation of maintenance schedule' at Para 146.
12	Coolant leakage check	○								
13	Radiator filler cap fitting condition	○								
14	Fan belt tension check (Replace if necessary)	○								
15	Coolant temperature registration	○								
16	Coolant replacement									
17	Radiator external face cleaning									
18	Cooling system circuit cleaning						○			
19	Radiator filler cap function check (*)									

No.	Description of check and maintenance		Daily	(Operation hours) 50	250	500	750	1000	1250	1500	Remark
20	Electrolyte level check		○								See 'Explanation of maintenance schedule' at Para 146.
21	Battery cleaning		○								
22	Battery charge condition	Ammeter registration	○								
		Charge warning lamp									
23	Electrolyte gravity check										
24	Starter and generator check and cleaning (*)							○			
25	Wiring and connection check										
26	Preheating condition check		○								
27	Air cleaner element replacement										

No.	Description of check and maintenance	Daily	(Operation hours) 50	250	500	750	1000	1250	1500	Remark
28	Engine starting conditions and noise conditions	○								See 'Explanation of maintenance schedule' at Para 146.
29	Exhaust smoke condition	○								
30	Cylinder compression pressure (*)						○			
31	Valve clearance check (*)						○			
32	Positive crankcase ventilation valve								○*	

NOTES

(1) The service intervals after 1500 operation hours should also be made every 250 operation hours in accordance with this check and maintenance schedule.

(2) When the servicing on the asterisked (*) items is necessary, consult the equipment supplier.

Explanation of maintenance schedule

146 The following is a brief explanation of the servicing listed in the preceding Engine Maintenance Schedule.

1	**Oil level and oil fouling**	Check that the oil level is between the max. level mark and the min. level mark. Drain oil to the max. level mark if oil level is above the max. level mark. Add oil to the max. level mark if oil is below the min. level mark.
2	**Oil leakage check**	Replace any damaged or malfunctioning parts which could cause leakage.
3	**Oil pressure gauge registration**	Engine oil pressure is normal at about 290 to 590 kPa in warmed-up condition. Check and repair the lubrication oil system, if it is abnormal.
4	**Oil pressure warning lamp**	Warning lamp is off while engine running. If it stays on, check and repair the lubrication system.
5	**Engine oil replacement**	Change oil every 250 hours.
6	**Oil filter element replacement**	Change element every 500 hours.
7	**Fuel leakage check**	Inspect the fuel lines for damage which could cause leakage. Replace any damaged or malfunctioning parts.
8	**Draining water in fuel filter**	Drain water in fuel filter if water has collected in the fuel element.
9	**Fuel filter element replacement**	Change element every 500 hours.
10	**Injection nozzle check**	Clean the injection nozzle tips every 1500 hours. (This is a required maintenance). Check injection opening pressure and spray condition.
11	**Coolant level and fouling check**	Check coolant level and add coolant if necessary.
12	**Coolant leakage check**	Repair part for coolant leakage.
13	**Radiator filler cap fitting condition**	The radiator cap must be installed tightly.
14	**Fan belt tension check**	Check and adjust fan belt deflection. Look for cracks, fraying and wear.
15	**Coolant temperature registration**	Coolant temperature is normal at about 75 to 85°C (167 to 185°F). Check and repair the cooling system if coolant temperature is abnormal.
16	**Coolant replacement**	Change coolant at intervals of 6 months or 12 months respectively if coolant is plain water, or long life coolant (LLC).
17	**Radiator external face cleaning**	According to the equipment manufacturer's specification.

18	**Cooling system circuit cleaning**	Clean the cooling system circuit every 1000 hours.
19	**Radiator filling cap function check**	Check radiator pressure cap periodically for proper operation according to the equipment manufacturer's specifications.
20	**Electrolyte level check**	Replenish with distilled water if necessary.
21	**Battery cleaning**	Clean the terminals.
22	**Battery charge condition**	Ammeter registration goes to plus (+) side while engine running. In the lamp type, the lamp is off while the engine is running. Check charging circuit if the lamp is not off.
23	**Electrolyte gravity check**	Check according to the equipment manufacturer's specifications.
24	**Starter and generator check and cleaning**	Check wear condition of brush and commutator.
25	**Wiring and connection check**	Check according to the equipment specifications.
26	**Preheating condition check**	Check preheating condition of the system.
27	**Air cleaner element replacement**	Change element according to the manufacturer's specifications.
28	**Engine starting condition and noise condition**	Check engine stability and noise.
29	**Exhaust smoke condition**	Check exhaust smoke colour.
30	**Cylinder compression pressure**	Check every 1000 hours.
31	**Valve clearance check**	Incorrect valve clearance will result in increased engine noise and lower engine output. Thereby adversely affecting engine performance. Check and adjust every 1000 hours.
32	**Positive crankcase ventilation valve cleaning**	Perform the adjustment, cleaning, repair or replacement every 1500 hours.

SIMPLE ENGINE TROUBLESHOOTING

147 This section contains a simple guide to troubleshooting. When a failure takes place on your ISUZU engine, diagnose the cause referring to this troubleshooting guide. If the cause of failure cannot be detected or you are unable to manage the failure, consult your machine supply source or nearest ISUZU engine service outlet.

- **Engine does not start.**
  - Starter does not turn.
    - Battery discharged.
    - Imperfect cable connections.
    - Starter or starter switch failure.
    - Safety relay failure.
  - Starter turns but engine does not ignite.
    - No fuel injection.
      - Engine stop solenoid return failure.
      - No fuel in the fuel tank.
      - Clogged fuel filter element.
      - Air in the fuel system.
      - Control rack is stuck at no fuel position.
    - Fuel is injected but engine does not ignite.
      - Unproper preheating operation.
      - Glow plug malfunction.
      - Incorrect injection timing.
      - Low cylinder compression pressure.
      - Engine stop solenoid incomplete return.
  - Engine ignite but stall immediately.
    - Air in the fuel system.
    - Improper low idling speed adjustment.
- **Unstable engine running**
  - Unstable low idling
    - Crack in injection pipe.
    - Injection nozzle failure.
    - Engine stop solenoid return failure.
    - Uneven compression pressure between cylinders.
  - Too high low idling speed.
    - Incorrect control lever adjustment.
    - Governor interior malfunction.
  - Engine hunting in medium speed range.
    - Governor spring deteriorated.
  - Malfunction in engine at high speed range.
    - Insufficient fuel supply.
      - Air in the fuel system
      - Clogged fuel filter element
      - Piping failure (squeezed, etc.)
    - Uneven fuel injection amount between plungers.
    - Deteriorated governor spring.
    - Incorrect valve clearance adjustment.
    - Deteriorated valve spring.
  - Engine speed does not be lowered.
    - Engine control restriction or seizure.

- **Engine overheat.**
  - Cooling system defect
    - Insufficient coolant amount.
    - Fan belt slippage.
    - Thermostat malfunction.
    - Radiator filler cap malfunction.
    - Cooling system interior fouled.
    - Radiator clogging.
  - Improper servicing
    - Engine over-loaded.
    - Air cleaner element clogging.
    - Insufficient ventilator.
    - Stopped coolant flow (high concentration of antifreezer, etc.)

- **Low oil pressure**
  - Lack of oil
    - Oil leakage
    - Large oil consumption.
  - Improper oil
    - Wrong selection of kind and viscosity.
  - High coolant temperature
    - Over heat
  - Clogged filter and strainer.
  - Worn bearings and oil pump.
  - Faulty relief valve.

- **Excessive oil consumption**
  - Improper oil
    - Wrong selection of kind of viscosity.
    - Too much oil quantity.
  - Oil coming up
    - Wrong selection of cylinder liner and piston ring.
  - Oil coming down
    - Faulty valve stem seal.
  - Oil leakage
    - Damaged packing.
    - Improper tightening.
    - Improper installation of filter and piping.

- **Excessive fuel consumption**
  - Fuel leakage
    - Damaged packing.
    - Improper installation or tightening.
  - Too much injection amount
    - Injection pump misadjustment.
  - Excessive mechanical loads

- **Lack engine output**
  - Incorrect injection pump adjustment.
    - Incorrect injection timing
      - Too advance
      - Too retard
    - Injection nozzle malfunction.
      - Incorrect injection pressure adjustment
      - Incorrect spray condition
    - Insufficient fuel supply to the injection pump
      - Lack of fuel in tank
      - Air mixing in injection pump
      - Fuel filter clogged
      - Overflow valve malfunction
    - Governor malfunction.
      - Incorrect engine control adjustment
      - Deteriorated governor spring
  - Poor cylinder compression pressure.
    - Cylinder compression pressure leakage.
      - Incorrect valve clearance adjustment
      - Nozzle holder misalignment
      - Cylinder bore wear
    - Insufficient air intake amount
      - Air cleaner clogging
      - Such as inferior ventilation.

- **Improper exhaust**
  - Much black smoke
    - Clogged air cleaner.
    - Nozzle damage.
    - Nozzle misadjustment.
    - Injection timing failure.
    - Injection amount misadjustment.
    - Improper fuel.
  - Much white smoke
    - Oil coming up or down.
    - Water mixing in fuel.
    - Low compression pressure.
    - Injection timing failure.
    - Low coolant temperature.

- **Battery overdischarge**
  - Low electrolyte level
    - Crack in battery body.
    - Natural consumption.
  - Charging failure
    - Loose or damaged belt.
    - Faulty generator.
    - Damaged wiring or contact failure.
    - Low speed driving.
  - Excessive electrical loads
    - Insufficient battery capacity.

INSTRUCTION MANUAL (INDUSTRIAL)

4LB1, 4LC1, 4LE1

IDE-6001

Issued by

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ANNEX B

ISUZU DIESEL ENGINE – MODEL 4LE1

WORKSHOP MANUAL

ANNEX B

ISUZU DIESEL ENGINE - MODEL 4LE1 WORKSHOP MANUAL

CONTENTS

(continued)

CONTENTS (continued)

ANNEX B

ISUZU DIESEL ENGINE - MODEL 4LE1 WORKSHOP MANUAL

FOREWORD

This Workshop Manual is designed to help you perform necessary maintenance, service, and repair procedures on applicable Isuzu industrial engines. Information contained in this Workshop Manual is the latest available at the time of publication. Isuzu reserves the right to make changes at any time without prior notice.

SECTION 1 - GENERAL INFORMATION

GENERAL REPAIR INSTRUCTIONS

1 General repair instructions for the 4LE1 engine are as follows:

(1) Before performing any service operation with the engine mounted, disconnect the grounding cable from the battery. This will reduce the chance of cable damage and burning due to short circuiting.

(2) Always use the proper tool or tools for the job at hand. Where specified, use the specially designed tool or tools.

(3) Use genuine ISUZU parts referring ISUZU PARTS CATALOG for the engines.

(4) Never reuse cotter pins, gaskets, O-rings, lock washers, and self locking nuts. Discard them as you remove them. Replace them with new ones.

(5) Always keep disassembled parts neatly in groups. This will ensure a smooth reassembly operation. It is especially important to keep fastening parts separate. These parts vary in hardness and design, depending on their installation position.

(6) All parts should be carefully cleaned before inspection or reassembly. Oil ports and other openings should be cleaned with compressed air to make sure that they are completely free of obstructions.

(7) Rotating and sliding part surfaces should be lubricated with oil or grease before reassembly.

(8) If necessary, use a sealer on gaskets to prevent leakage.

(9) Nut and bolt torque specifications should be carefully followed.

(10) Always release the air pressure from any machine-mounted air tank(s) before dismounting the engine or disconnecting pipes and hoses.

(11) Always check and recheck your work. No service operation is complete until you have done this.

2 Information contained in the "Main Data and Specifications" of the Workshop Manual and the Instruction Manual may differ. In this case, the information contained in the Instruction Manual should be considered applicable.

NOTES ON THE FORMAT OF THIS MANUAL

3 This Workshop Manual is applicable to the 4LB1, 4LC1, 4LE1 family of industrial diesel engines. Unless otherwise specified, these engines have common parts and components as well as data and specifications.

4 Illustrations used in this Workshop Manual are based on the 4LE1 engines.

(1) Find the applicable section by referring to the Table of Contents at the beginning of the Manual.

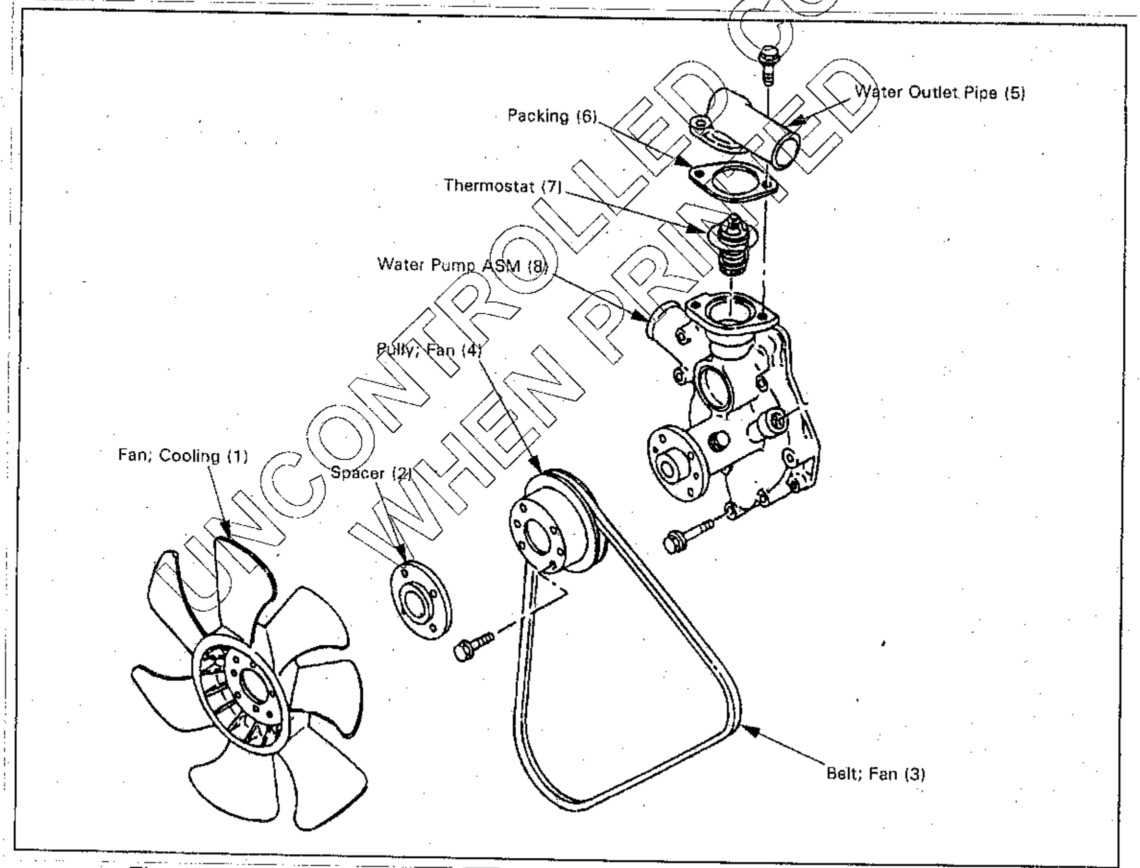
(2) Common technical data such as general maintenance items, service specifications, and tightening torques are included in the "General Information" section.

(3) Each section is divided into sub-sections dealing with disassembly, inspection and repair, and reassembly.

(4) When the same servicing operation is applicable to several different units, the manual will direct you to the appropriate page.

(5) For the sake of brevity, self-explanatory removal and installation procedures are omitted. More complex procedures are covered in detail.

(6) Each service operation section in this Workshop Manual begins with an exploded view of the applicable area.



Figures in parentheses '( )' show the order of disassembling or reassembling.

Fig 1 Typical exploded view

(7) Measurement criteria are defined by the terms "standard" and "limit". A measurement falling within the "standard" range indicates that the applicable part or parts are serviceable. "Limit" should be thought of as an absolute value. A measurement which is outside the "limit" indicates that the applicable part or parts must be either repaired or replaced.

(8) Components and parts are listed in the singular form throughout the Manual.

(9) Directions used in this manual are as follows:

Front	The cooling fan side of the engine viewed from the flywheel.
Right	The injection pump side of the engine.
Left	The exhaust manifold side of the engine.
Rear	The flywheel side of the engine.

Cylinder numbers are counted from the front of the engine.

The front most cylinder is No. 1 and rear most cylinder is No. 4.

The engine's direction of rotation is counterclockwise viewed from the flywheel.

MODEL 4LE1 APPEARANCE

5 Left and right-hand views of the Model 4LE1 engine are shown below.

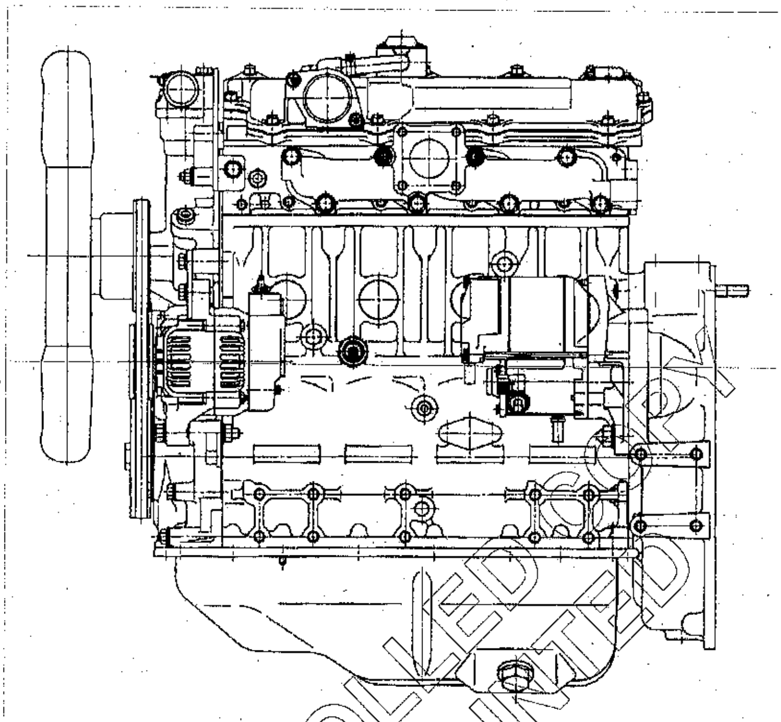


Fig 2 Left side view

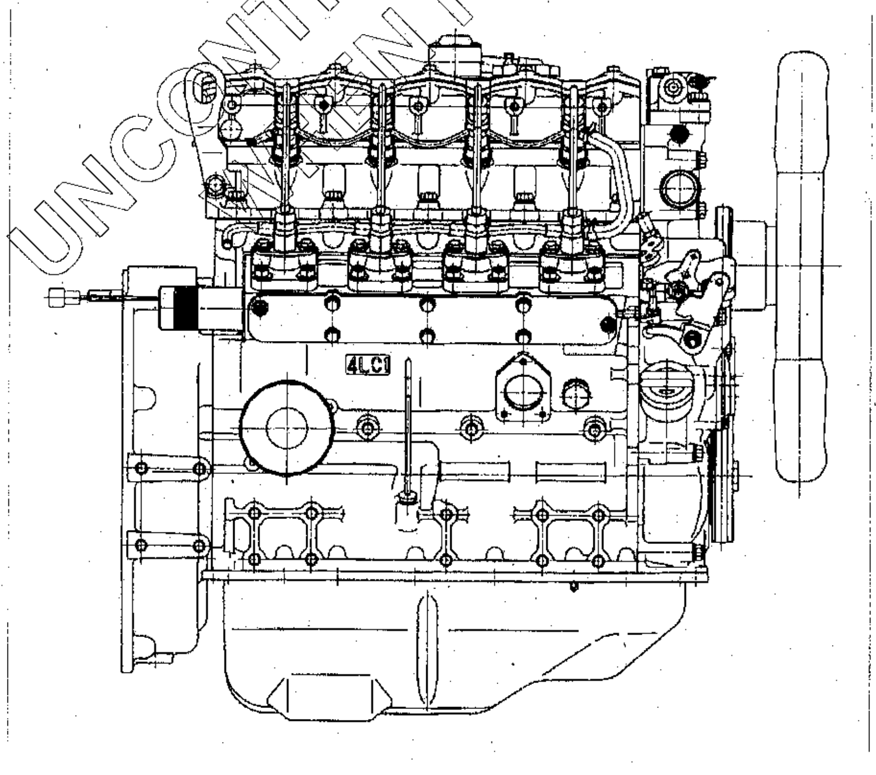


Fig 3 Right side view

MAIN DATA AND SPECIFICATIONS

6 Main data and specifications for the Model 4LE1 engine are shown below.

TABLE 1 MODEL 4LE1 SPECIFICATIONS

Item			4LE1
Type			In-line water cooled 4-cycle type, OHV: diesel engine
Timing drive system			Gear drive
Number of piston rings			Compression rings 2, and oil ring 1
No. of cylinders - Bore x Stroke		mm	4 – 85 x 92
Displacement		cc (cid)	2179 (133)
Compression ratio			21.5 : 1
Type of combustion chamber			Swirl chamber
Overall Length x Width x Height		mm	691 x 449 x 616
Dry weight kg (lb)			155 (342)
Fuel injection timing (BTDC)		(when at stop)	* 16°
Firing order			1 – 3 – 4 – 2
Fuel			Highspeed diesel fuel (SAE No.2)
Idling speed		r.p.m	* 850
Compression pressure		kg/cm² (psi/MPa)	31 (441/3) or more/250 r.p.m.
Valve clearance (cold) mm (in)		Intake	0.4 (0.0157)
		Exhaust	0.4 (0.0157)
Valve operating timing	Intake valve	Open (BTDC)	15°
		Close (ABDC)	29°
	Exhaust valve	Open (BBDC)	40°
		Close (ATDC)	16°
Injection pump			Bosch type
Governor			Mechanical type
Nozzle			Throttle type
Injection pressure		kg/cm² (psi/MPa)	* 135 (1920/13.2)
Oil pump			Trochoid type
Oil filter			Cartridge type
Lubricant capacity: In total		lit (qts)	* About 8.7 (9.2)
Generator output		(V – A)	* 12 – 20
Starter output		(V – KW)	* 12 – 1.0

NOTE

These specifications may be subject to change without notice. Figures in the column with an asterisk (*) are different for each machine. Refer to the specifications provided by the machine manufacturers.

TIGHTENING TORQUE SPECIFICATIONS

7 The tightening torque values given in the table below are applicable to the bolts unless otherwise specified.

TABLE 2 TIGHTENING TORQUE SPECIFICATIONS FOR STANDARD BOLT

kg·m (lb.ft/N·m)

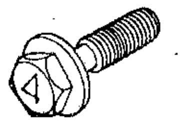
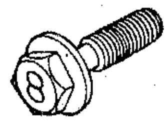
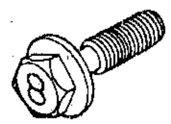
Strength Class / Bolt Identification / Bolt Diameter x Pitch (mm)	4.8 (4T)	(7T)	8.8 Refined	8.8 Non-Refined	9.8 (9T)
	4	7	8	8	9
	no mark	—			
M6 x 1.0	0.4 0.8 (2.9 5.8/3.9 17.7)	0.5 1.0 (3.6 7.2/4.9 9.8)			
M8 x 1.25	0.8 1.8 (5.8 13.0/7.8 17.7)	1.2 2.3 (8.7 16.6/11.8 22.6)			1.7 3.1 (12.3 22.4/16.7 30.4)
M10 x 1.25	2.1 3.5 (15.2 25.3/20.6 34.3)	2.8 4.7 (20.3 34.0/27.5 46.1)			3.8 6.4 (27.5 46.3/37.3 62.8)
M12 x 1.25	5.0 7.5 (36.2 54.2/49.0 73.6)	6.2 9.3 (44.8 67.3/60.8 91.2)			7.7 11.6 (55.7 83.9/75.5 113.8)
M14 x 1.5	7.8 11.7 (56.4 84.6/78.5 114.7)	9.5 14.2 (68.7 102.7/93.2 139.3)			11.6 17.4 (83.9 125.6/113.8 170.6)
M16 x 1.5	10.6 16.0 (76.7 115.7/103.0 156.9)	9.5 14.2 (68.7 102.7/93.2 139.3)			11.6 17.4 (83.9 125.6/113.8 170.6)
M18 x 1.5	15.4 23.0 (111.1 166.4/151.0 225.6)	19.9 29.9 (143.9 216.3/195.2 391.3)			23.4 35.2 (169.3 254.6/229.5 345.2)
M20 x 1.5	21.0 31.6 (151.9 288.6/205.9 307.9)	27.5 41.3 (198.9 298.7/269.7 405.0)			32.3 48.5 (233.6 350.8/316.8 475.6)
M22 x 1.5	25.6 42.2 (185.2 305.2/251.1 413.8)	37.0 55.5 (267.6 401.4/362.9 544.3)			43.3 64.9 (313.2 469.4/424.6 636.5)
M24 x 2.0	36.6 55.0 (264.7 397.8/358.9 539.4)	43.9 72.5 (317.5 523.9/430.5 711.0)			56.5 84.7 (408.7 612.6/554.1 830.6)
*M10 x 1.5	2.0 3.4 (14.5 24.6/19.6 32.4)	2.8 4.6 (20.3 33.3/27.5 45.1)			3.7 6.1 (26.8 44.1/36.3 59.8)
*M12 x 1.5	4.6 7.0 (33.3 50.6/45.1 68.7)	5.8 8.6 (42.0 62.2/56.9 84.3)			7.3 10.9 (52.8 78.8/71.6 106.9)
*M14 x 2.0	7.3 10.9 (52.8 78.8/71.6 106.9)	9.0 13.4 (65.1 96.9/88.3 131.4)			10.9 16.3 (78.8 118.9/106.9 159.9)
*M16 x 2.0	10.2 15.2 (73.8 110.0/100.0 149.1)	13.2 19.8 (95.5 143.2/129.5 194.2)			15.6 23.4 (112.8 169.3/162.8 229.5)

An asterisk (*) indicates that the bolts are used for female threaded parts that are made of soft materials such as casting. Those shown in parentheses in the Strength Class indicate the classification by the old standard.

8 The tightening torque values given in the table below are applicable to the bolts unless otherwise specified.

TABLE 3 TIGHTENING TORQUE SPECIFICATIONS FOR FLANGED HEAD BOLT

kg·m (lb.ft/N·m)

Bolt head marking / Nominal size (dia. x pitch)			
M6 x 1	0.5 0.9 (3.61 6.50/4.6 8.5)	0.6 1.2 (4.33 8.67/5.88 11.76)	-
M8 x 1.25	1.1 2.0 (7.95 14.46/10.78 19.61)	1.4 2.9 (4.33 8.67/5.88 11.76)	1.9 3.4 (13.74 24.59/18.63 33.34)
M10 x 1.25	2.3 3.9 (17.35 28.20/23.53 38.24)	3.6 6.4 (26.03 44.12/35.30 59.82)	4.3 7.2 (31.10 52.07/42.16 70.60)
*M10 x 1.5	2.3 3.8 (16.63 27.48/22.55 37.26)	3.5 5.8 (25.31 41.95/34.32 56.87)	4.1 6.8 (29.65 49.18/40.20 66.68)
M12 x 1.25	5.6 8.4 (40.50 60.75/54.91 82.37)	7.9 11.9 (57.14 86.07/77.47 116.69)	8.7 13.0 (62.92 94.02/85.31 127.48)
*M12 x 1.75	3.5 9.5 (37.61 56.41/50.99 76.49)	7.3 10.9 (52.80 78.83/71.58 106.89)	8.1 12.2 (58.58 88.24/79.43 119.64)
M14 x 1.5	8.5 12.7 (61.48 91.85/83.35 124.54)	11.7 17.6 (84.62 127.30/114.73 172.59)	12.6 18.9 (91.13 136.70/123.56 185.34)
*M14 x 2	7.6 11.5 (57.14 85.34/77.47 115.71)	11.1 16.6 (80.28 120.06/108.85 162.79)	11.8 17.7 (85.34 128.02/115.71 173.57)
M16 x 1.5	11.8 17.7 (85.34 128.02/115.71 173.57)	17.1 26.5 (125.85 189.50/170.63 256.93)	18.0 27.1 (130.19 196.01/176.52 265.76)
*M16 x 2	11.2 16.7 (81.00 120.79/109.83 163.77)	16.6 24.9 (120.06 180.10/162.79 244.18)	17.2 25.7 (124.40 186.61/168.67 253.01)

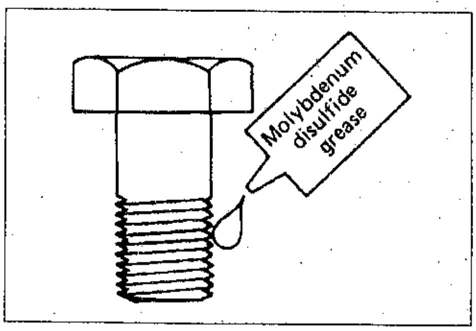
A bolt with an asterisk (*) is used for female screws of soft material such as cast iron.

ANGULAR NUT AND BOLT TIGHTENING METHOD

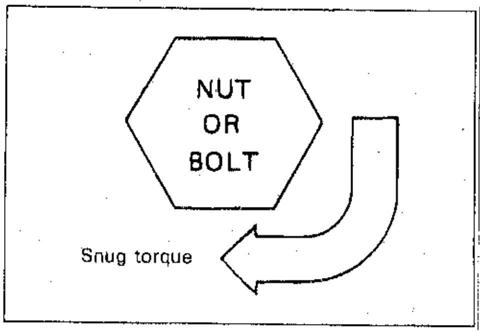
9 The method for angular nut and bolt tightening is as follows:

(1) Carefully wash the nuts and bolts to remove all oil and grease.

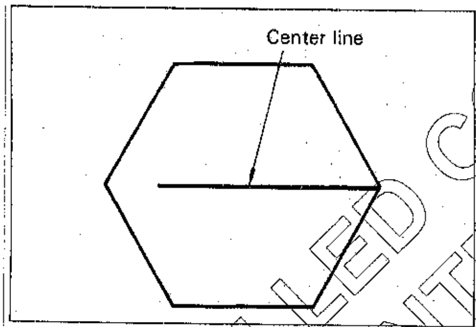
(2) Apply a coat of molybdenum disulphide grease to the threads and setting faces of the nuts and bolts.



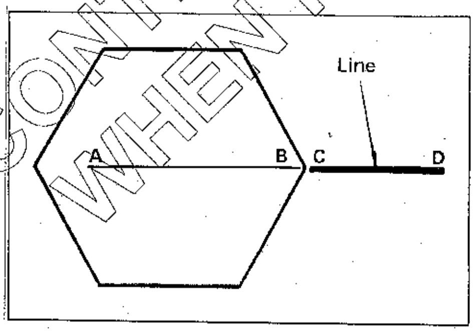
(3) Tighten the nuts and bolts to the specified torque (snug torque) with a torque wrench.



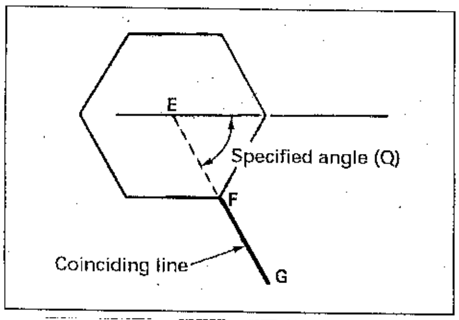
(4) Draw a line [A-B] across the centre of each bolt. Centre line



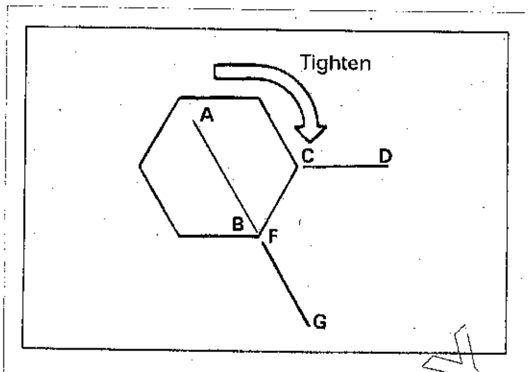
(5) Draw another line [C-D] on the face of each of the parts to be clamped. This line should be an extension of the line [A-B].



(6) Draw another line [F-G] on the face of each of the parts to be clamped. This line will be in the direction of the specified angle [Q] across the centre [E] of the nut or bolt.



(7) Use a socket wrench to tighten each nut or bolt to the point where the line [A-B] is aligned with the line [F-G].



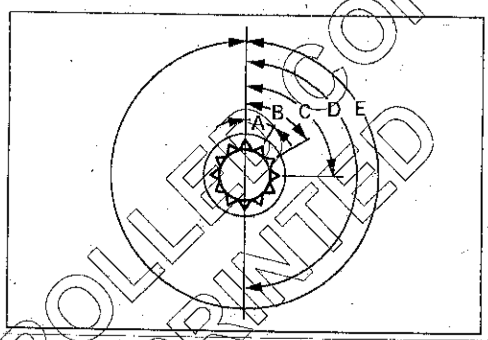


TABLE 4 SPECIFIED ANGLE AND TIGHTENING ROTATION

A	30°	1/12 of a turn
B	60°	1/6 of a turn
C	90°	1/4 of a turn
D	180°	1/2 of a turn
E	360°	One full turn

TIGHTENING TORQUE ON MAJOR COMPONENTS

10 The tightening torques on major components are shown in Figs 4 to 9.

Cooling fan and water pump

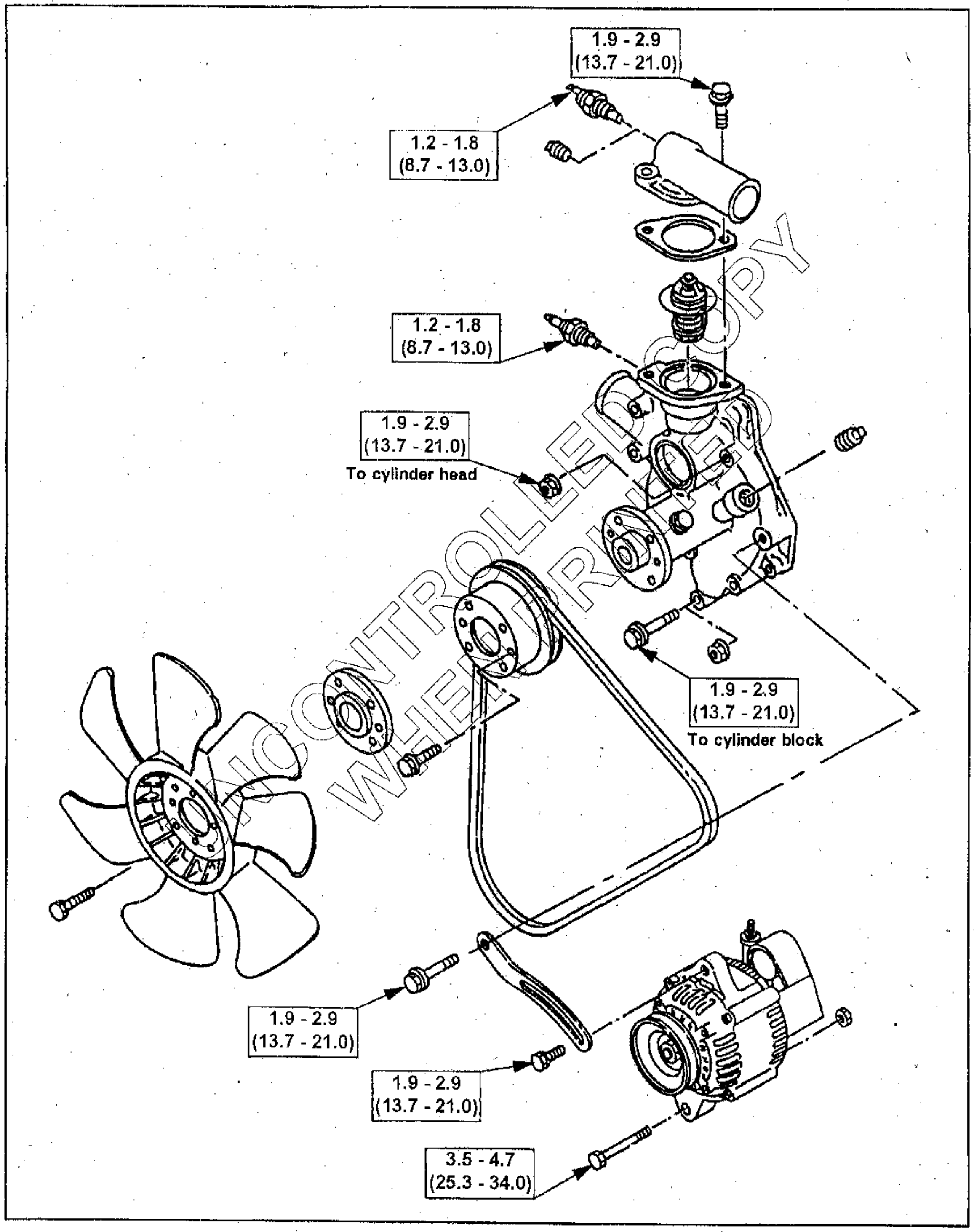


Fig 4 Cooling fan and water pump tightening torque

Cylinder head and cylinder head cover

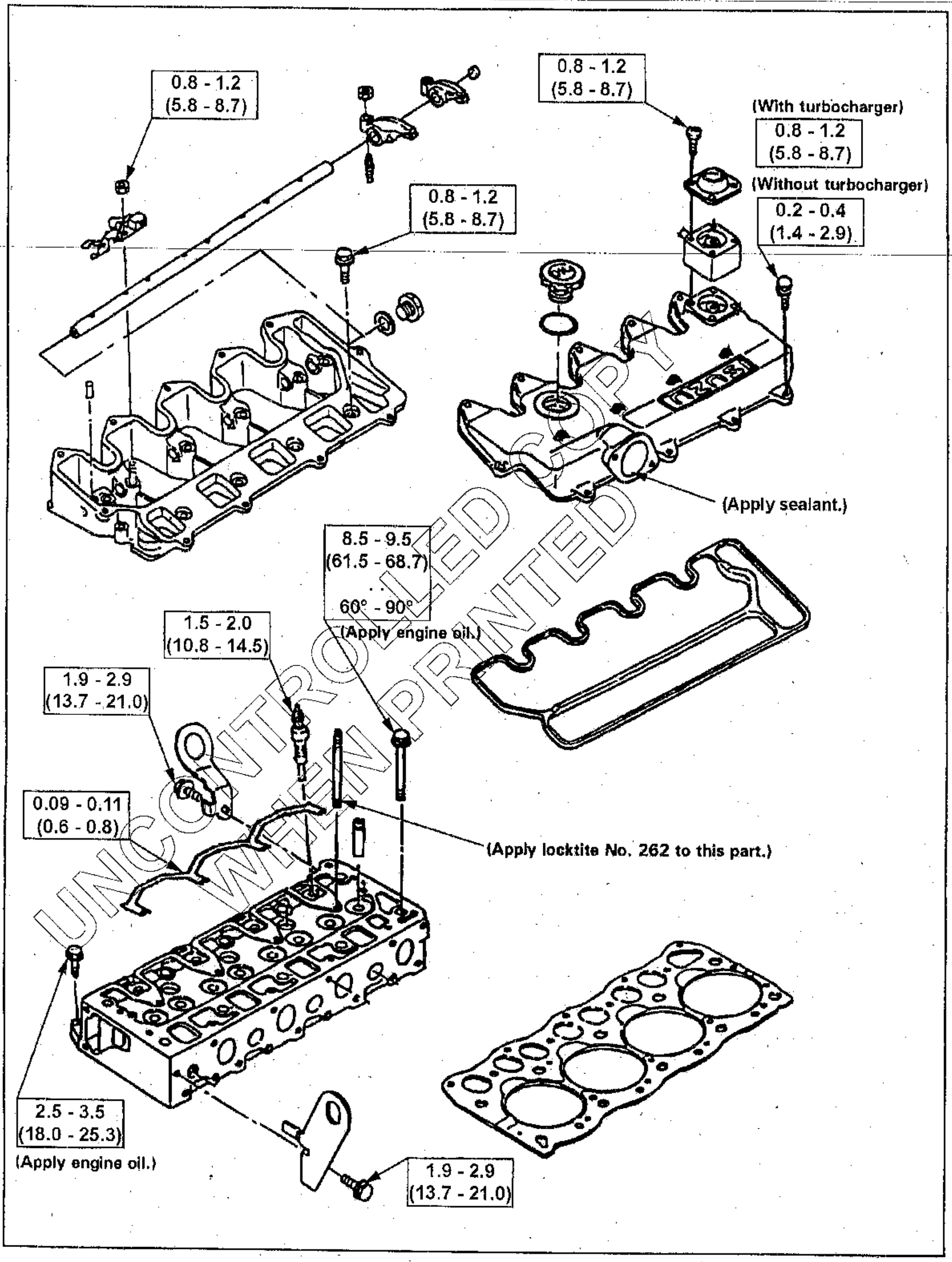


Fig 5 Cylinder head and cylinder head cover tightening torque

Cylinder block and other components

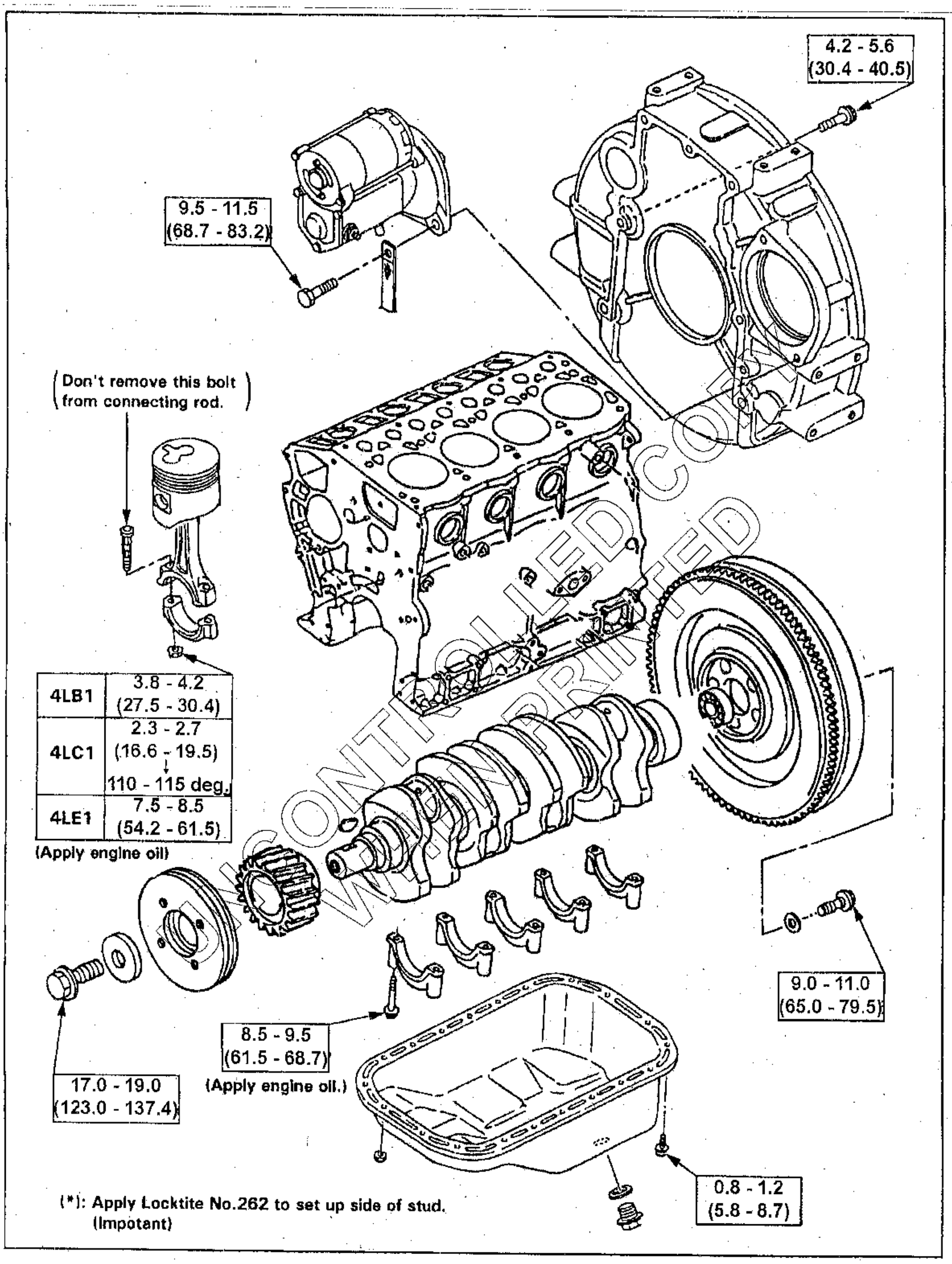


Fig 6 Cylinder block and other components tightening torque (1)

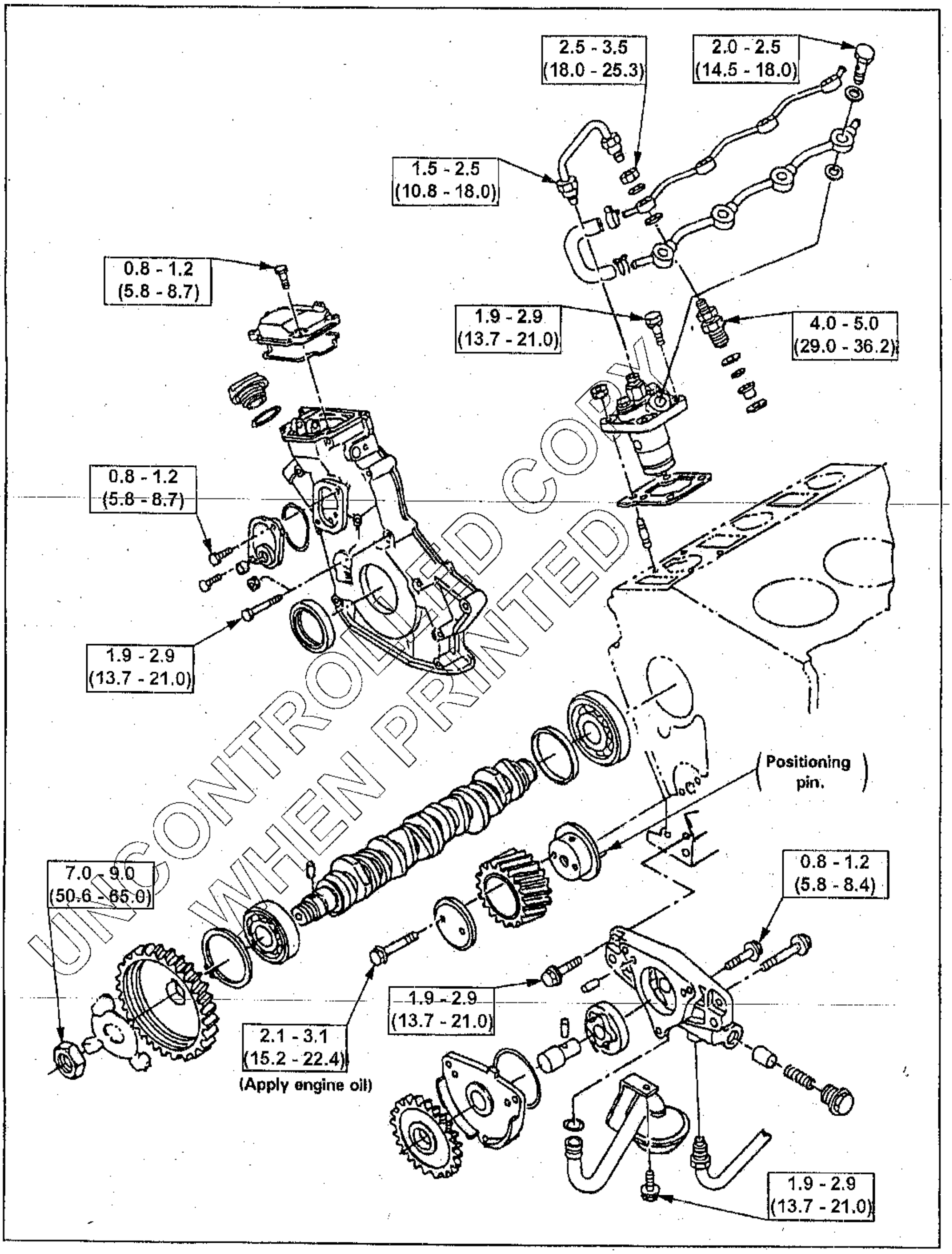


Fig 7 Cylinder block and other components tightening torque (2)

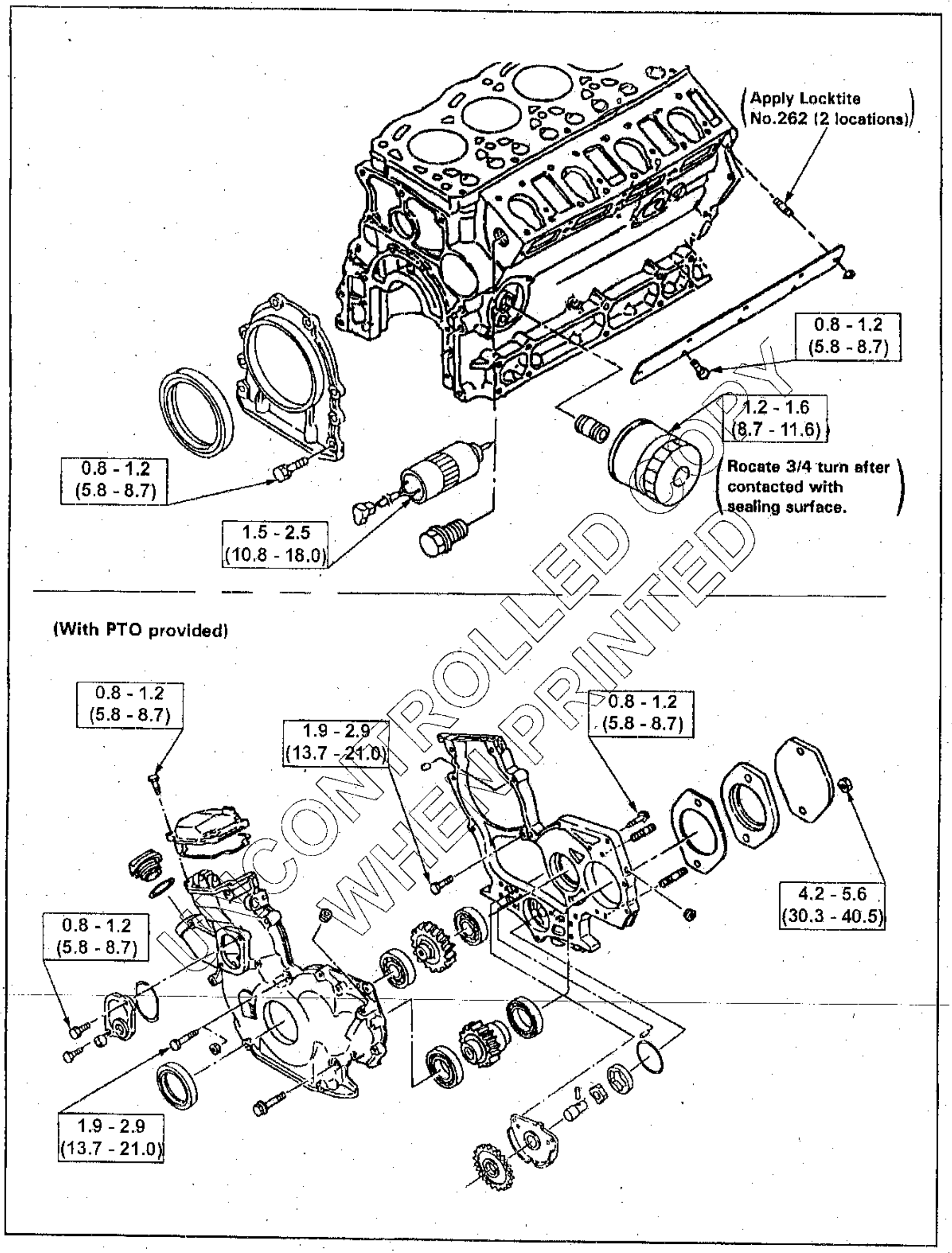


Fig 8 Cylinder block and other components tightening torque (3)

Turbocharger

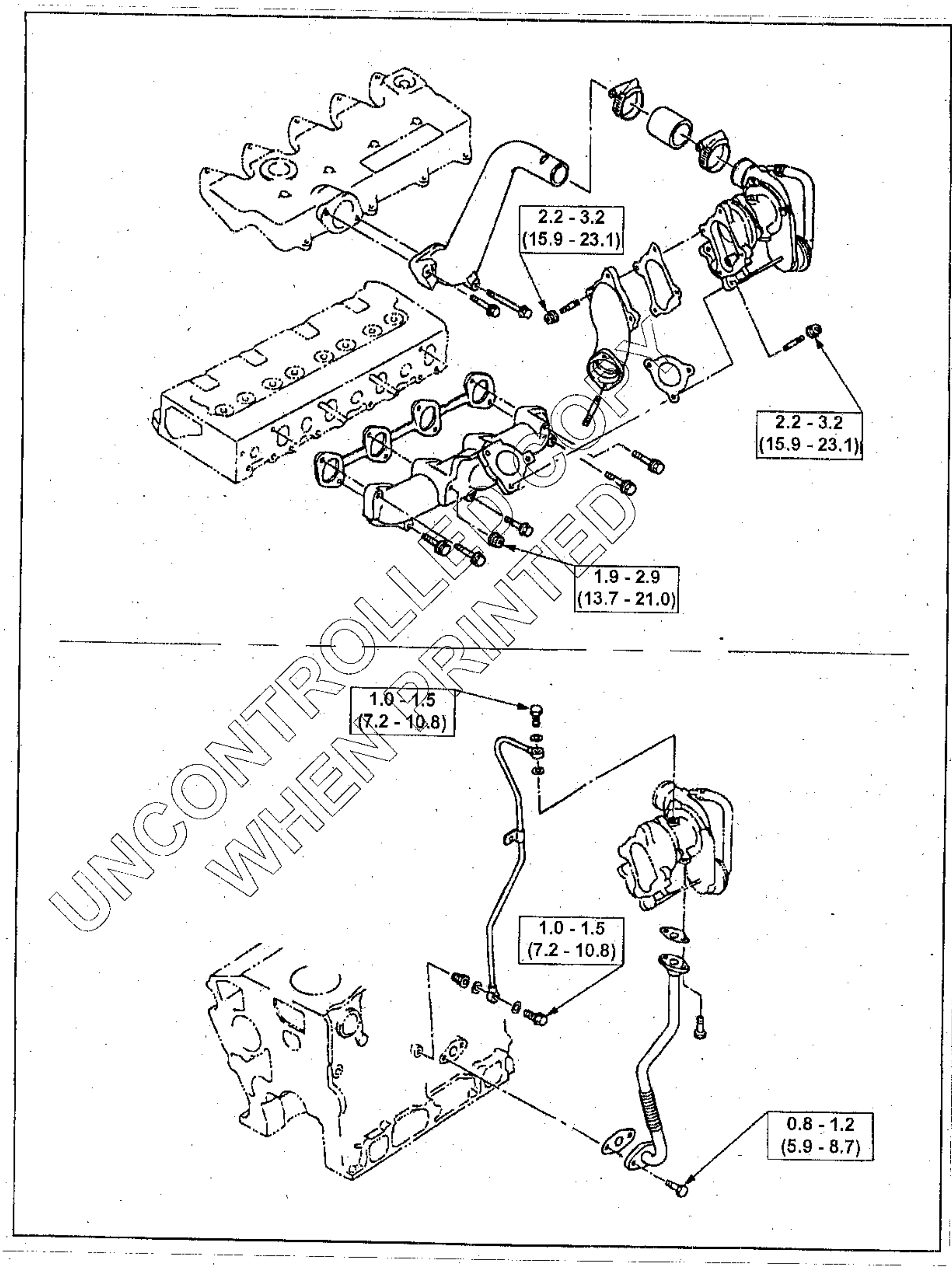


Fig 9 Turbocharger tightening torque

GASKET LOCATION

11 Locations where gaskets are used are shown in Fig 10.

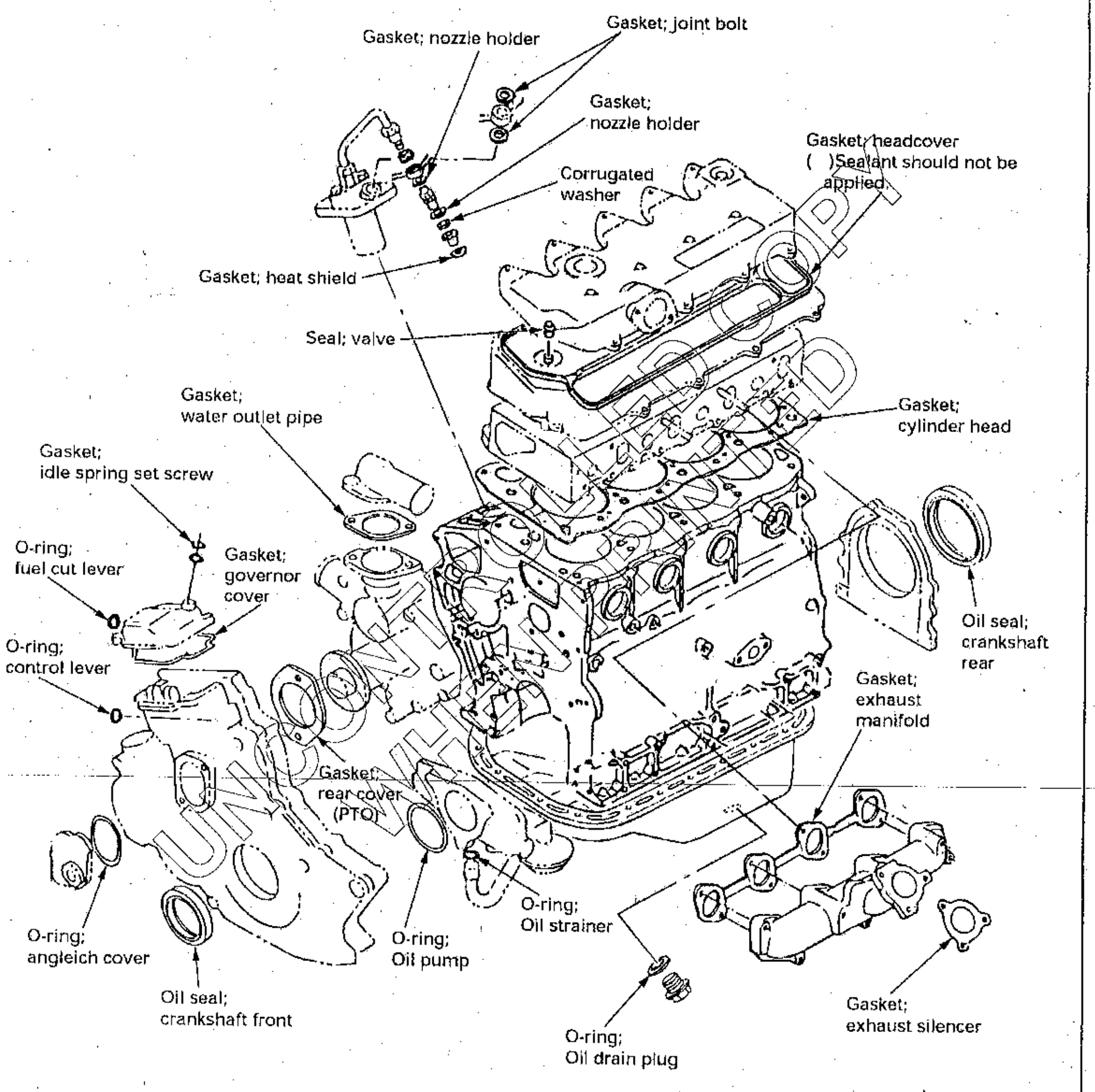


Fig 10 Locations where gaskets are used

Sealant

12 Locations where sealant is applied are given in Table 5.

TABLE 5 LOCATIONS WHERE SEALANT IS APPLIED

	Location		Condition of use		Name of sealant
	Name of part	Name of mating part	Object to be sealed	Groove to be applied	
1	Oil pan	Cylinder block	Engine oil (10W-30)	Not provided	TB1207C
2	Rocker bracket	Cylinder head	Engine oil (10W-30)	Provided	TB1207C
3	Air inlet pipe	Cylinder head cover	Air	Provided	TB1207C
4	Front plate (with PTO provided)	Cylinder block	Engine oil (10W-30)	Provided	TB1207C
5	Timing case (with PTO provided)	Front plate	Engine oil (10W-30)	Provided	TB1207C
6	Timing case (with no PTO provided)	Cylinder block	Engine oil (10W-30)	Provided	TB1207C
7	Water pump ASM	Cylinder block	Cooling water	Not provided	TB1207C
8	Rear cover; water pump	Body; water pump	Cooling water	Provided	TB1207B
9	Housing cover; injection pump	Cylinder block	Engine oil (10W-30)	Provided	TB1207C
10	Solenoid; fuel cut	Cylinder block	Engine oil (10W-30)	Provided	TB1207C
11	Retainer; oil seal	Cylinder block	Engine oil (10W-30)	Provided	TB1207C
12	Indicator; air cleaner	Air cleaner	Air	Not provided	(Sealing tape)

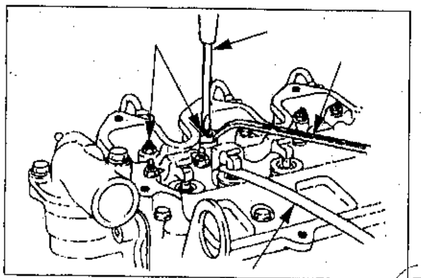
MAINTENANCE

VALVE CLEARANCE AND ADJUSTMENT

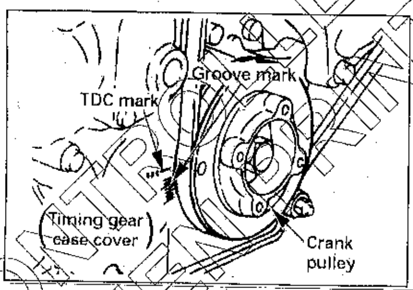
13 Maintenance procedures on the Model 4LE1 engine are set out in Paras 13 to 22.

NOTE

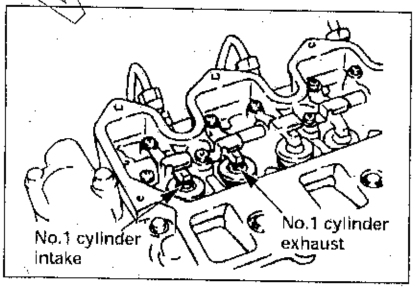
The cylinder head bolts were previously tightened with the "Angular Tightening Method". Therefore, it is not necessary to retighten the cylinder head bolts before adjusting the valve clearance.



(1) Bring the piston in either the No. 1 cylinder or the No. 3 cylinder to Top Dead Centre on the compression stroke by turning the crankshaft until the TDC mark on the front cover aligns with the groove mark on the crankshaft pulley.



(2) Check to see if there is play in the No. 1 intake and exhaust valve rocker arms.



a. If the No. 1 cylinder intake and exhaust valve rocker arms have play, the No. 1 piston is at TDC on the compression stroke.

b. If the No. 1 cylinder intake and exhaust valve rocker arms are depressed, the No. 4 piston is at TDC on the compression stroke.

c. Adjust the circle or double circle marked valves as shown in Table 6, while the No. 1 or the No. 4 cylinder is at TDC on compression stroke.

mm (in.)

Intake and Exhaust Valve Clearance (cold)	0.40 ± 0.05 (0.015 ± 0.002)

TABLE 6 VALVE CLEARANCES

Cylinder No.	1		2		3		4	
Valve arrangement	I	E	I	E	I	E	I	E
No. 1 cylinder TDC for compression	O	O	O			O		
No. 4 cylinder TDC for compression				◎	◎		◎	◎

I = Intake E = Exhaust

(3) Loosen each valve clearance adjusting screw as shown in the illustration.

(4) Insert a 0.40 mm (0.015 in) feeler gauge between the rocker arm and the valve stem end.

(5) Turn the valve clearance adjusting screw until a slight drag can be belt on the feeler gauge.

(6) Tighten the lock nut securely.

(7) Rotate the crankshaft 360°.

a. Realign the crankshaft pulley.

(8) Adjust the clearances for the remaining valves as shown in Table 6.

LUBRICATING SYSTEM

Cartridge (Spin-On) type

Removal

14 Remover and Installer: Filter Wrench.

(1) Loosen the used oil filter by turning it counterclockwise with the filter wrench.

(2) Discard the used oil filter.

Installation

15 Proceed as follows:

(1) Wipe the oil filter mounting face with a clean rag.

a. This will allow the new oil filter to seat properly.

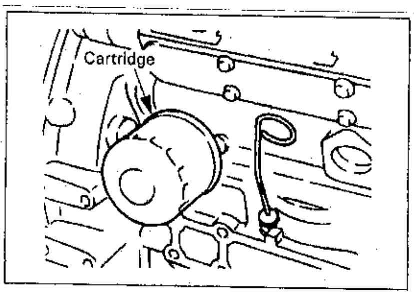
(2) Lightly oil the O-ring.

(3) Turn in the new oil filter until the sealing face is fitted against the O-ring.

(4) Use the filter wrench to turn in the oil filter an additional 3/4 of a turn or one turn.

(5) Check the engine oil level and replenish to the specified level if required.

(6) Start the engine and check for oil leakage from the oil filter.



COOLING SYSTEM

Cooling fan drive belt

Adjustment

16 Check the cooling fan drive belt adjustment as follows:

(1) Check the cooling fan drive belt for cracking and other damage.

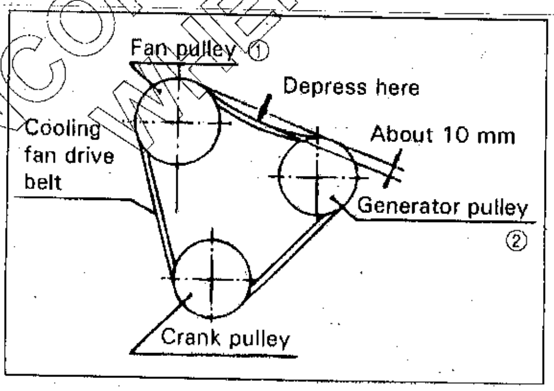
(2) Check the drive belt tension by exerting a force of 10 kg (22 lb) midway between the Fan pulley 1 and the Generator pulley 2.

(3) Adjust the belt tension by loosening the Generator mounting bolt and the Generator adjusting bolt and pivoting the Generator.

a. Be sure to retighten the bolts after adjusting the belt tension.

mm (in.)

Cooling Fan Drive Belt Deflection	8.0 – 12.0 (0.3 – 0.5)



INJECTION TIMING

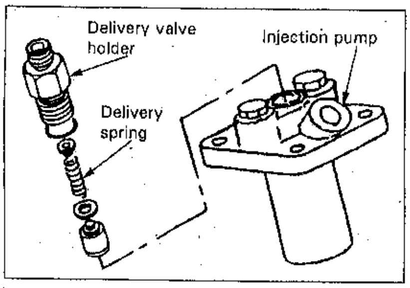
NOTE

Take care to avoid entry of dust or foreign particles into the pump interior when the timing adjustment is made.

17 Check the injection timing as follows:

(1) Remove the injection pipe of the No. 1 cylinder.

(2) Remove the delivery valve holder of the injection pump of the No. 1 cylinder, and then pull out the delivery spring.



(3) With the spring removed, install the delivery valve holder.

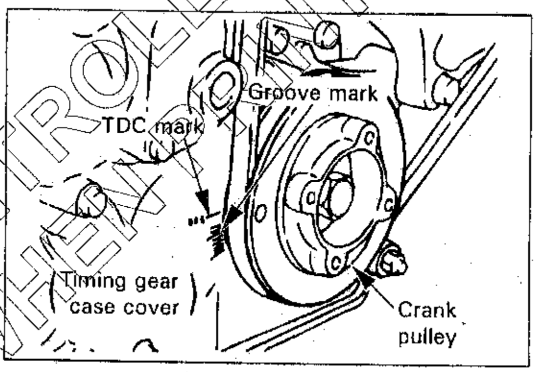
(4) Slowly turn the crankshaft pulley clockwise, at the same time, continue to feed the fuel.

a. When the fuel stop flowing out from the No. 1 delivery valve holder, stop turning the crankshaft.

b. This crank angle position is the starting point of injection.

(5) In the condition at Step (4) above, confirm what degree the "groove mark" of the crank pulley is at, when seen by the "timing mark", provided in the timing gear case.

a. When the value is out of the range of the normal injection timing, adjust it accordingly.



* Injection timing	4LE1	BTDC 16°

NOTE

The injection timing varies according to the specifications of the machine.

(6) Adjust the injection timing with a shim between the injection pump and the cylinder block.

a. Shim is available in the following 9 types, and "identification mark" is stamped (or imprinted) on the top face.

TABLE 7 IDENTIFICATION MARK OF SHIM AND ITS THICKNESS

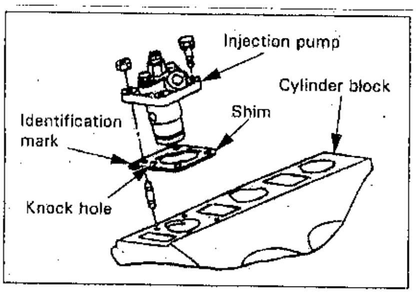
(mm)

Mark	Thickness	Mark	Thickness	Mark	Thickness
2	0.2	5	0.5	8	0.8
3	0.3	6	0.6	10	1.0
4	0.4	7	0.7	12	1.2

NOTE

(1) For each of the injection pumps of three cylinders, the shim adjustment is made at the same time.

(2) When a shim is missing while overhauling the engine and the shim thickness is unknown, assemble the engine with provisional shim inserted. After assembling the engine, check the injection timing and adjust the shim until the normal injection timing is obtained.



Reference: To add the 0.1 mm shim thickness corresponds to the 1 degree of crankshaft angle advance.

Air bleeding from fuel (automatic air-bleeding system)

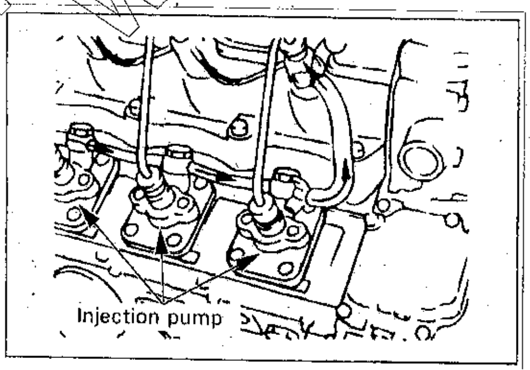
18 To bleed air from the fuel using the automatic air-bleeding system, proceed as follows:

(1) For the automatic air-bleeding system:

a. When the starter switch is set to "OPERATION", the electromagnetic pump is activated to force-feed fuel to the fuel pipe and the leak-off pipe, and air in the fuel system is automatically bled.

(2) For non-automatic air-bleeding system:

a. While sending fuel by means of the force of the electromagnetic pump, the fall from the fuel tank or the feed pump lever, bleed air out of the fuel pipe eye bolt of the No. 1 cylinder injection pump, the leak-off pipe eye bolt of the injection nozzle and the air-bleeder plug of the fuel filter, starting with the one installed the lower most and upward.



COMPRESSION PRESSURE MEASUREMENT

19 To measure the compression pressure, proceed as follows:

(1) Operate the engine to warm-up until the coolant temperature reaches to 75°C (167°F).

(2) Remove all of the glow plugs and the injection pipes.

(3) Attach a compression gauge to the No. 1 cylinder glow plug installation threads.

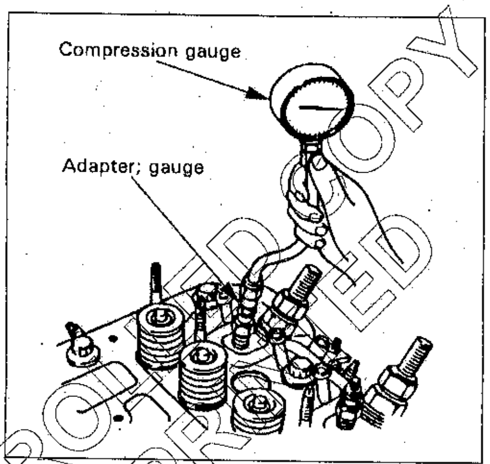
NOTE

(1) Compression pressure may be measured starting at any cylinder and in no particular cylinder order. However, it is very important that the compression pressure be measured in each cylinder.

(2) Therefore, start at the No. 1 cylinder and work back. In this way, you will be sure to measure the compression pressure in each cylinder.

Compression Gauge: 5-8840-2675-0

Compression Gauge Adaptor: 5-8840-9026-0



(4) Crank the engine with the starter motor and take the compression gauge reading.

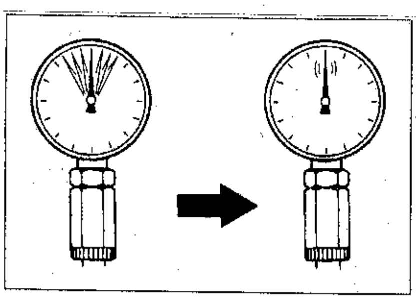
kg/cm 2 (psi) at 250 rpm

Standard	Limit
31.0 (441)	26.0 (370)

(5) Repeat the procedure (Steps 3 and 4) for the remaining cylinders.

a. Compression pressure should be approximately the same for each cylinder. A variation exceeding 2.0 kg/cm² (28 psi) is unacceptable.

b. If the measured value exceeds the specified limit, the related parts must be checked.



FUEL SYSTEM

Fuel filter replacement

Cartridge (Spin-On) Type

Removal

20 To replace the fuel filter, proceed as follows:

(1) Loosen the fuel filter by turning it counterclockwise with the filter wrench or your hand. Discard the used filter.

a. Filter Wrench.

(2) Wipe the fuel filter fitting face clean with a rag.

a. This will allow the new fuel filter to seat properly.

Installation

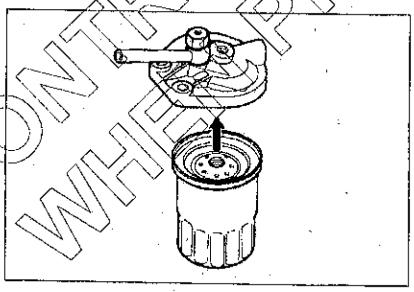
21 (1) Apply a light coat of engine oil to the O-ring.

(2) Supply fuel to the new filter.

a. This will facilitate air bleeding.

(3) Turn in the new fuel filter until the filter O-ring is fitted against the sealing face.

(4) Use the filter wrench to turn in the fuel filter an additional 2/3 of a turn.

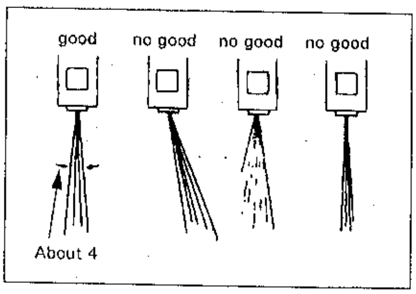


Injection nozzle

22 Check to see if the spray condition and the injection pressure are normal. Adjust them to the specified value respectively when they do not meet the standard valve.

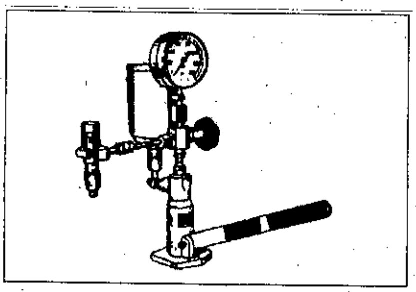
kg/cm² (psi)

Injection pressure	4LE1	135 (1920)



(1) Using a nozzle tester, adjust the injection pressure with a shim.

Special tool: Nozzle tester:



RECOMMENDED LUBRICATING OIL

23 The recommended lubricating oils for the 4LE1 engine are detailed in Fig 11.

TYPE OF LUBRICANTS (API)	DIESEL ENGINE OIL; CC OR CD GRADE

ENGINE OIL VISCOSITY CHART

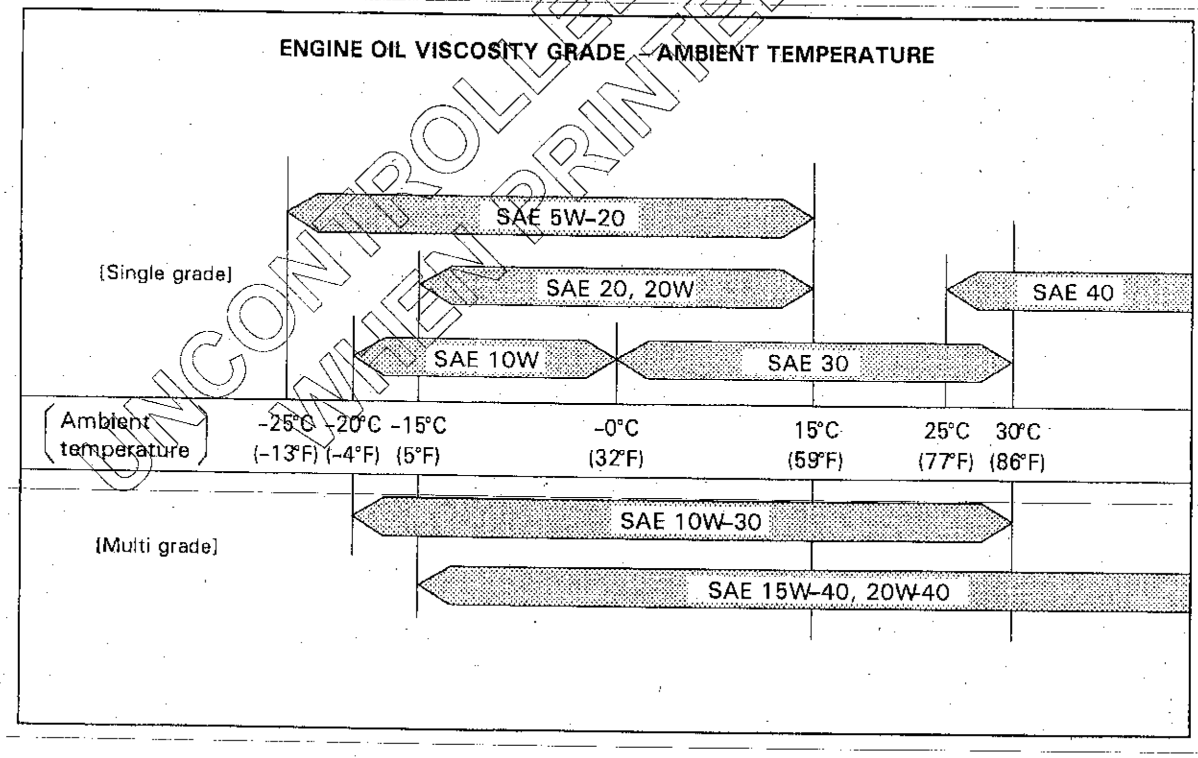


Fig 11 Engine oil viscosity chart

SECTION 2 - ENGINE

DISASSEMBLY OF EXTERNAL PARTS

External parts (left-hand side)

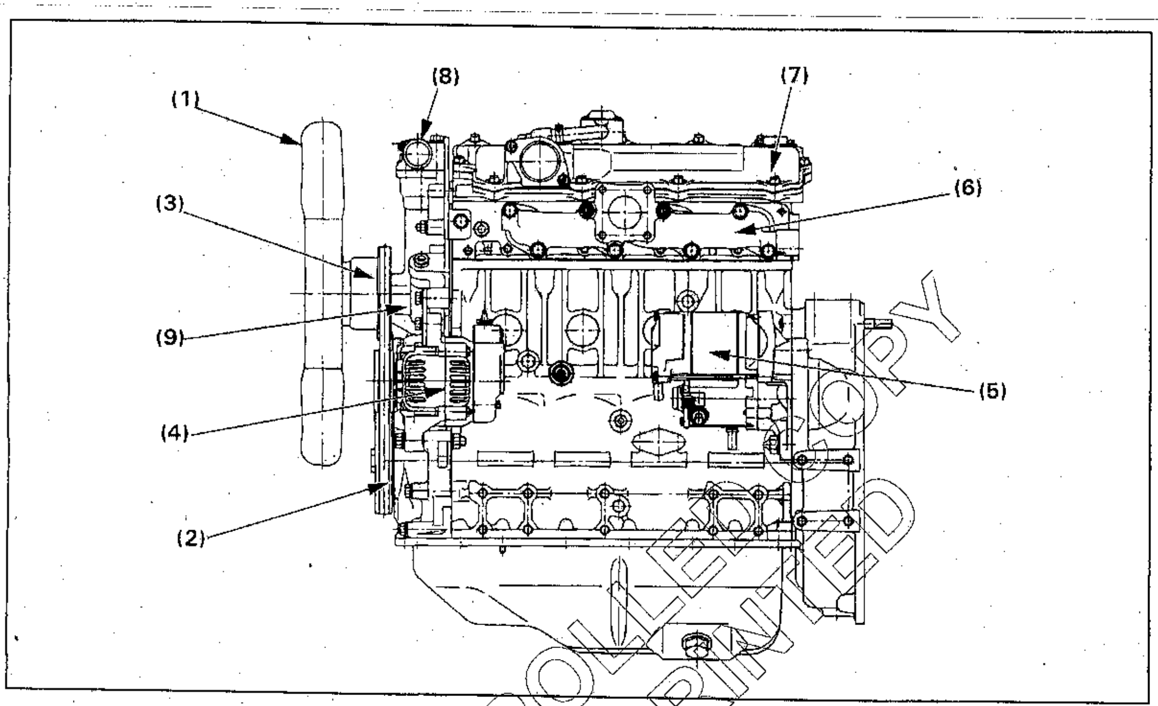


Fig 12 External parts (left-hand side)

24 The external parts on the left-hand side of the engine are shown in Fig 12.

(1) Cooling fan and spacer.

(2) Fan belt.

(3) Fan pulley.

(4) Generator.

(5) Starter.

(6) Exhaust manifold and gasket.

(7) Cylinder head cover and air intake pipe.

(8) Water outlet pipe and thermostat.

(9) Water pump assembly.

External parts (right-hand side)

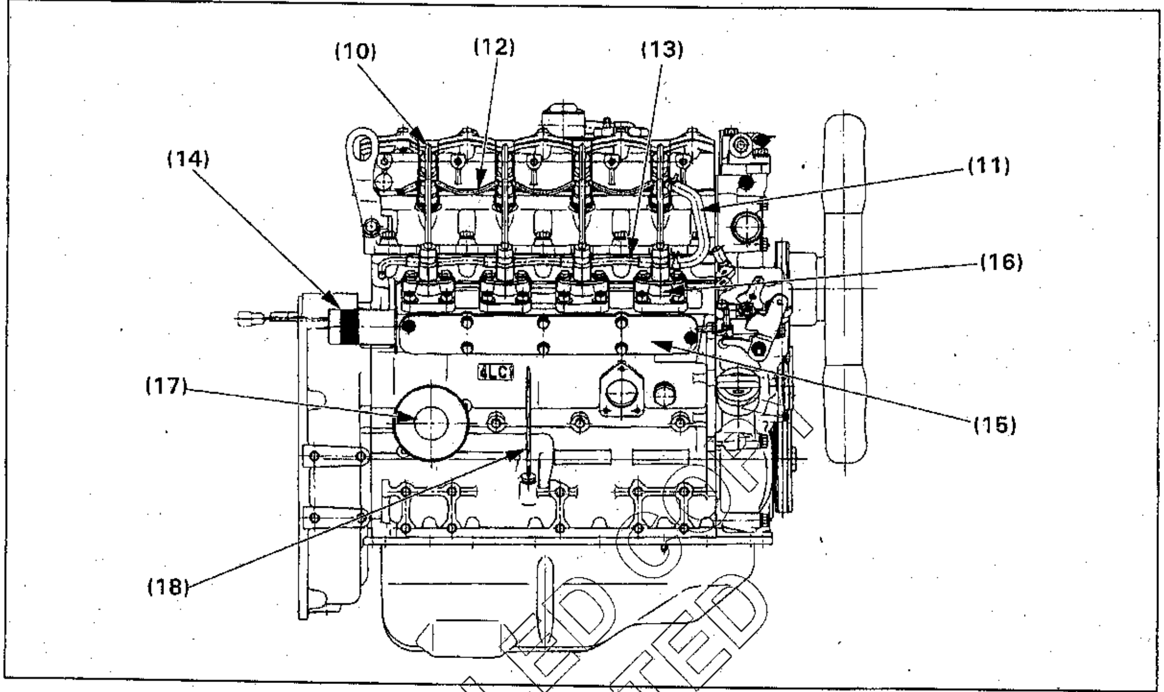


Fig 13 External parts (right-hand side)

25 The external parts on the right-hand side of the engine are shown in Fig 13.

(10) Injection pipe (4 pcs).

(11) Fuel hose.

(12) Fuel leak off pipe.

(13) Fuel pipe.

(14) Engine stop solenoid.

(15) Injection pump housing cover.

(16) Injection pump and shim (4 set).

(17) Oil filter.

(18) Oil level gauge.

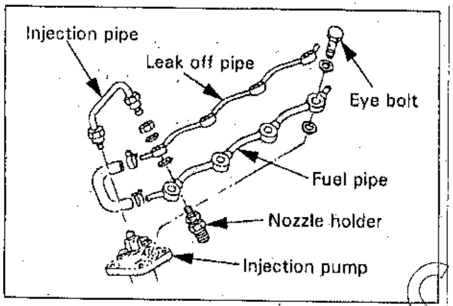
Injection pipe - Leak off pipe - Fuel pipe

26 Proceed as follows:

(1) Loosen the sleeve nuts on the nozzle holder side and on the injection pump side, and then disconnect the injection pipes.

(2) Disconnect the leak off pipe together with gaskets.

(3) Remove the eye bolt, and then disconnect the fuel pipe.



Injection pump

27 Proceed as follows:

(1) Align the hole of the fuel cut lever with the hole of the governor cover, and then insert a pin (6ø) into this hole to hold the fuel cut lever.

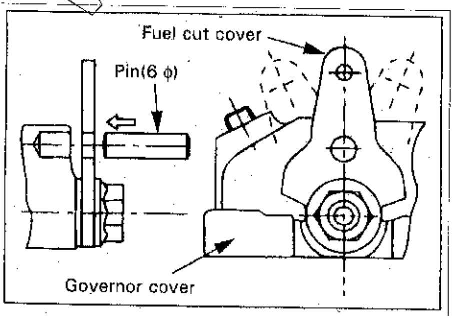
(2) Check to see if the pin groove of the control link is at the center of the injection pump.

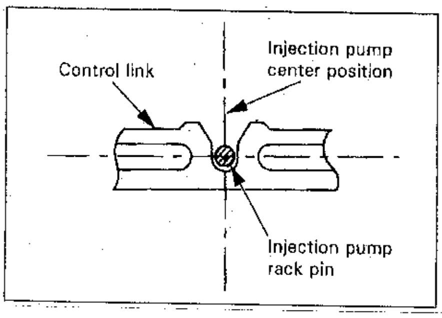
(3) Remove the injection pump, and then take out the shim.

NOTE

(1) Mark each injection pump as to which cylinder it was removed from.

(2) Do not reuse the shim, replace it with the same thickness that was removed.





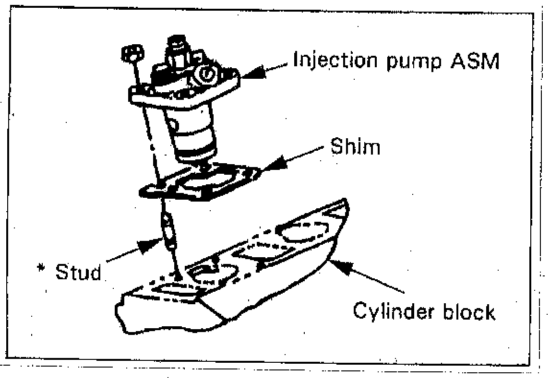


TABLE 8 BACKLASH OF TIMING GEAR

mm (in)

	Standard	Limit
Crank Gear/ Idler Gear	0.04 (0.0017)	0.2 (0.0079)
Cam Gear/ Idler Gear	0.03 (0.0012)	0.2 (0.0079)

TABLE 9 IDLER GEAR END PLAY

mm (in)

Standard	Limit
0.058 – 0.115 (0.0023 – 0.0045)	0.2 (0.0079)

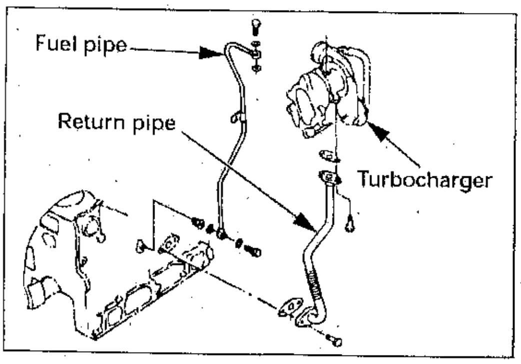
TABLE 10 CRANKSHAFT END PLAY

mm (in)

Standard	Limit
0.058 – 0.208 (0.0023 – 0.0082)	0.3 (0.0118)

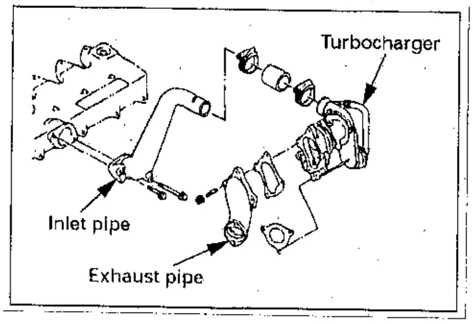
Return pipe - Feed pipe

28 Remove the return pipe and the feed pipe.



Exhaust pipe - Inlet pipe - Turbocharger

29 Remove the exhaust pipe, the inlet pipe and turbocharger.



DISASSEMBLY OF INTERNAL PARTS

30 Disassembly steps for the internal parts of the engine (Figs 14 to 16) are as follows:

(1) Rocker Bracket Assembly.

(2) Push Rods.

(3) Rear Hanger.

(4) Front Hanger.

(5) Cylinder Head Assembly.

(6) Cylinder Head Gasket.

(7) Tappets.

(8) Oil Pan.

(9) Oil Strainer.

(10) Oil Pipe.

(11) Crank Pulley.

(12) Flywheel.

(13) Flywheel Housing.

(14) Timing Gear Case (without PTO).

(15) Oil Pump Assembly.

(16) Idler Gear and Shaft.

(17) Cam Gear.

(18) Camshaft.

(19) Rear Seal Retainer.

(20) Piston Assemblies.

(21) Crankshaft.

Internal parts (1/3)

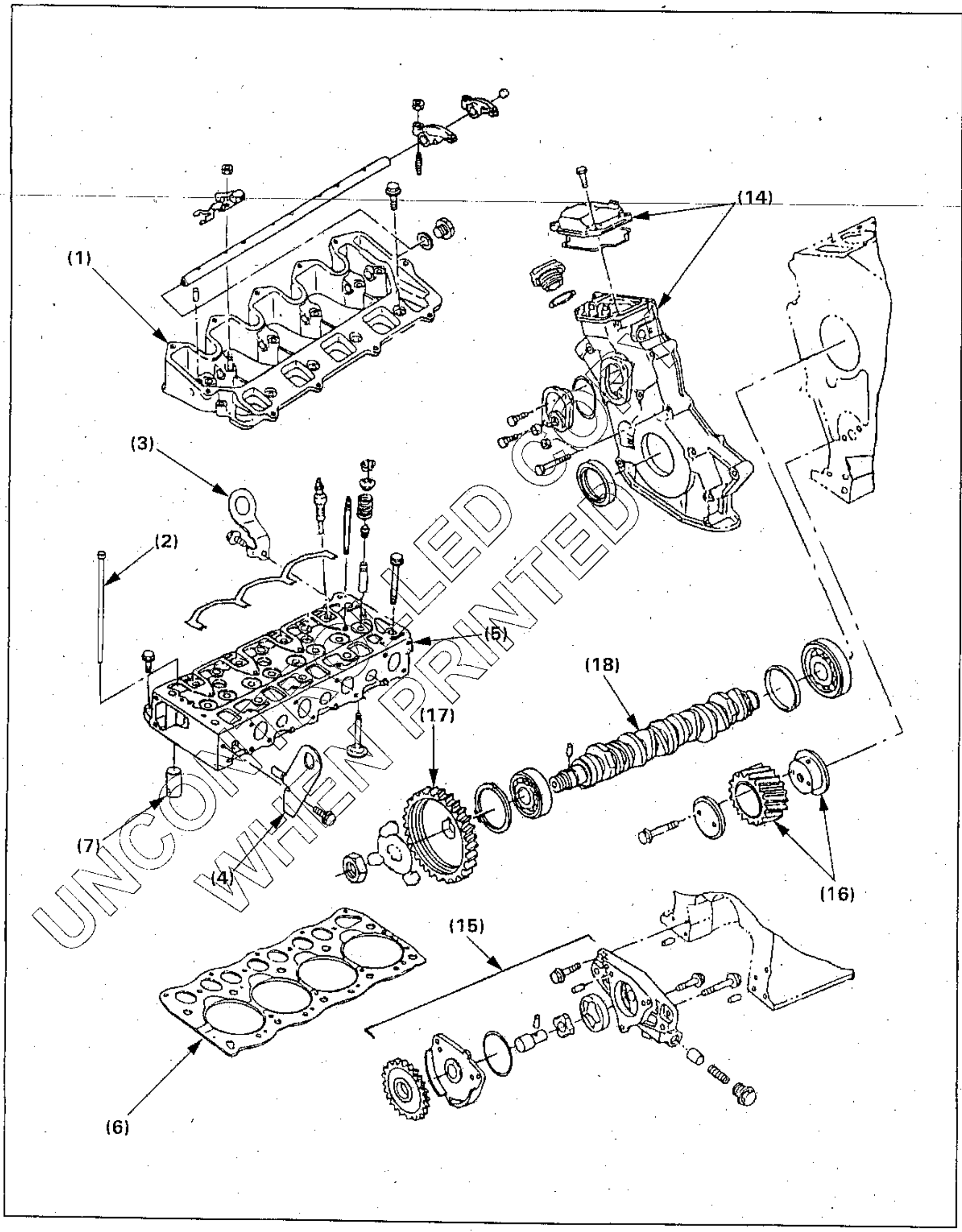


Fig 14 Disassembly internal parts (sheet 1 of 3)

Internal parts (2/3)

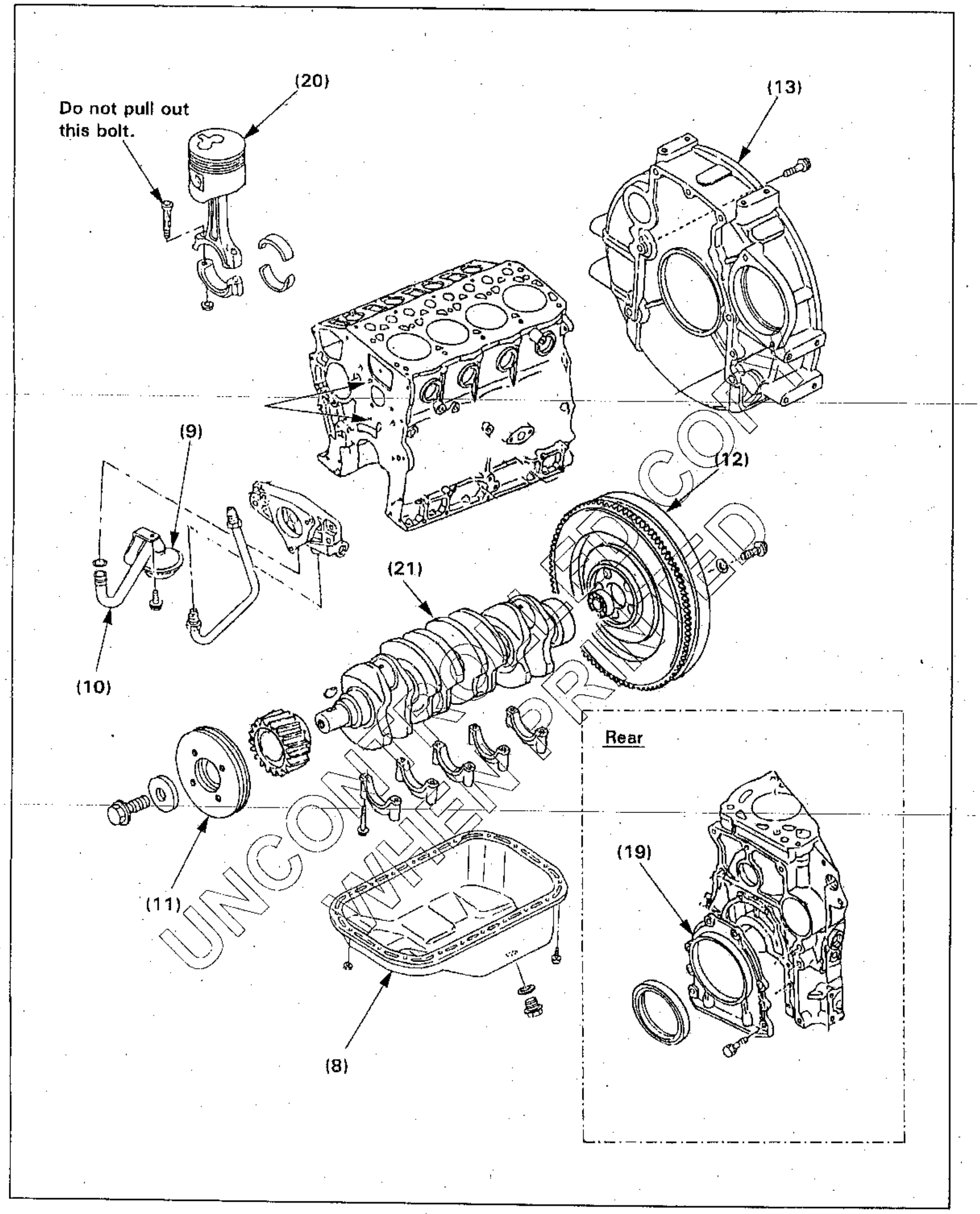


Fig 15 Disassembly internal parts (sheet 2 of 3)

Internal parts (3/3)

When provided with PTO

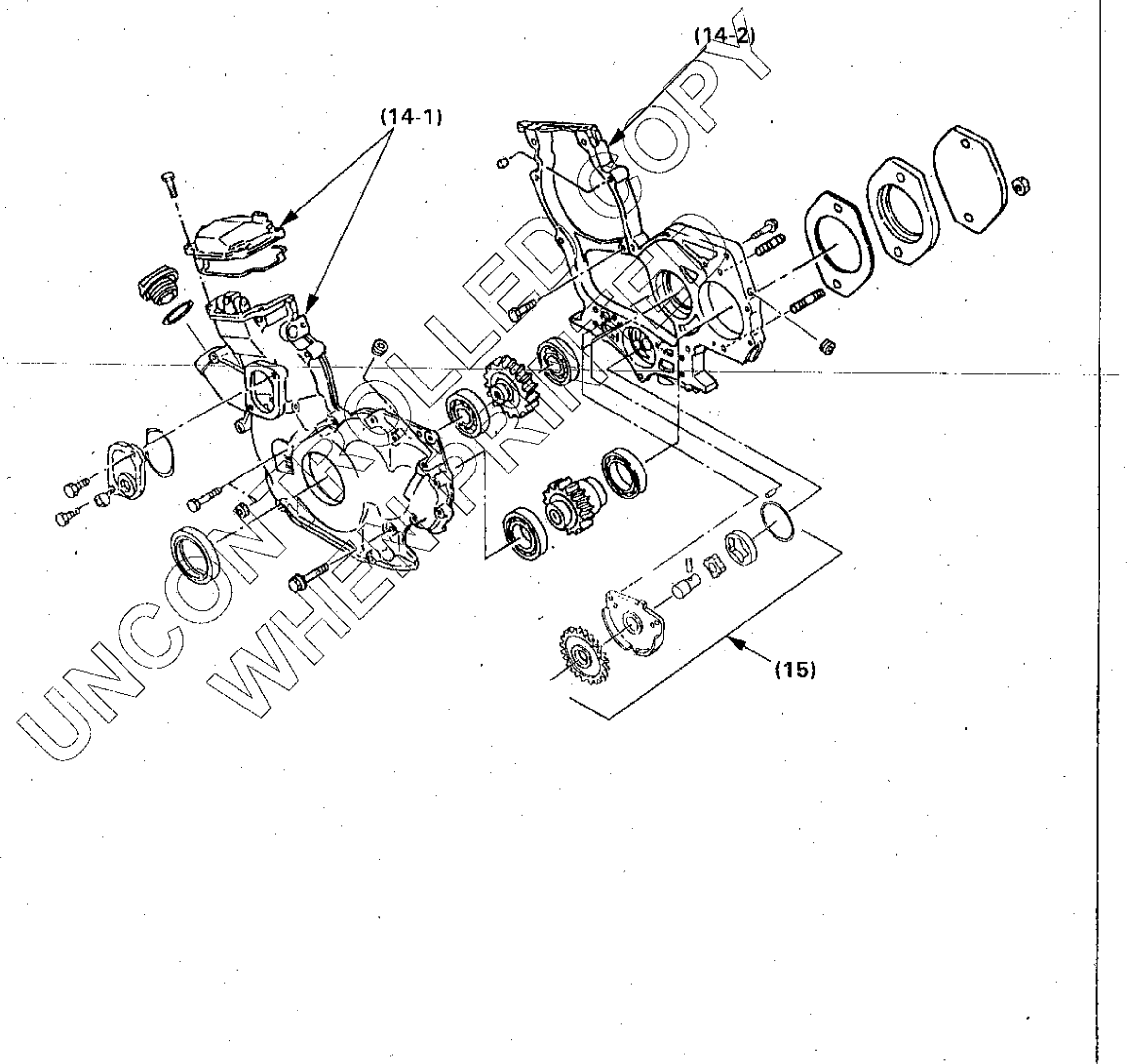


Fig 16 Disassembly internal parts (sheet 3 of 3)

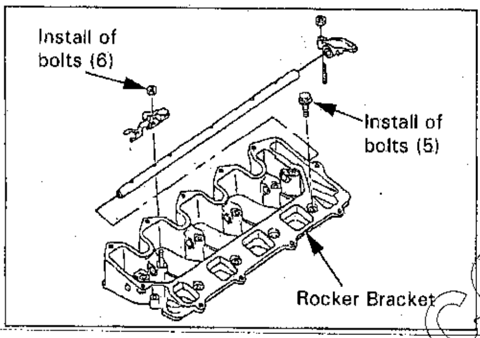
Rocker bracket

Push rod

31 Proceed as follows:

(1) Remove the rocker bracket assembly. (M6 x 1 ..... 5 bolts and 6 nuts.)

(2) Pull out the push rods (8 pcs.).



Cylinder head assembly

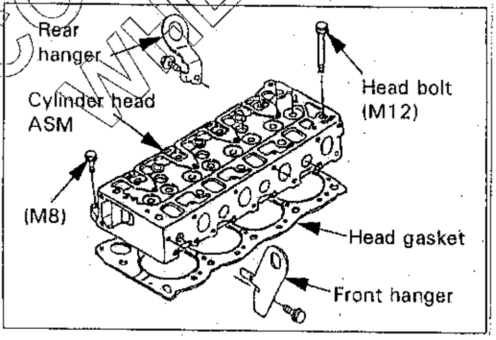
32 Proceed as follows:

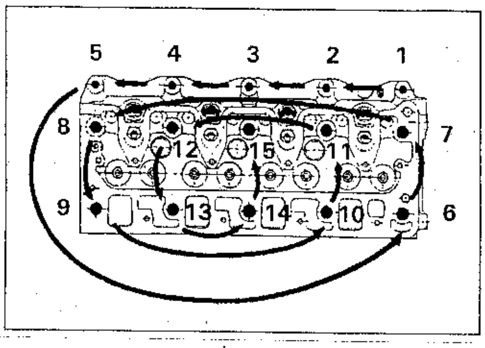
(1) Remove the rear and front hangers.

(2) When removing the cylinder head bolts, loosen them slowly, a little at a time, starting with the outside, working in a circular pattern inward.

(3) Remove the cylinder head assembly and the head gasket.

(4) Pull out the tappet from the cylinder body.





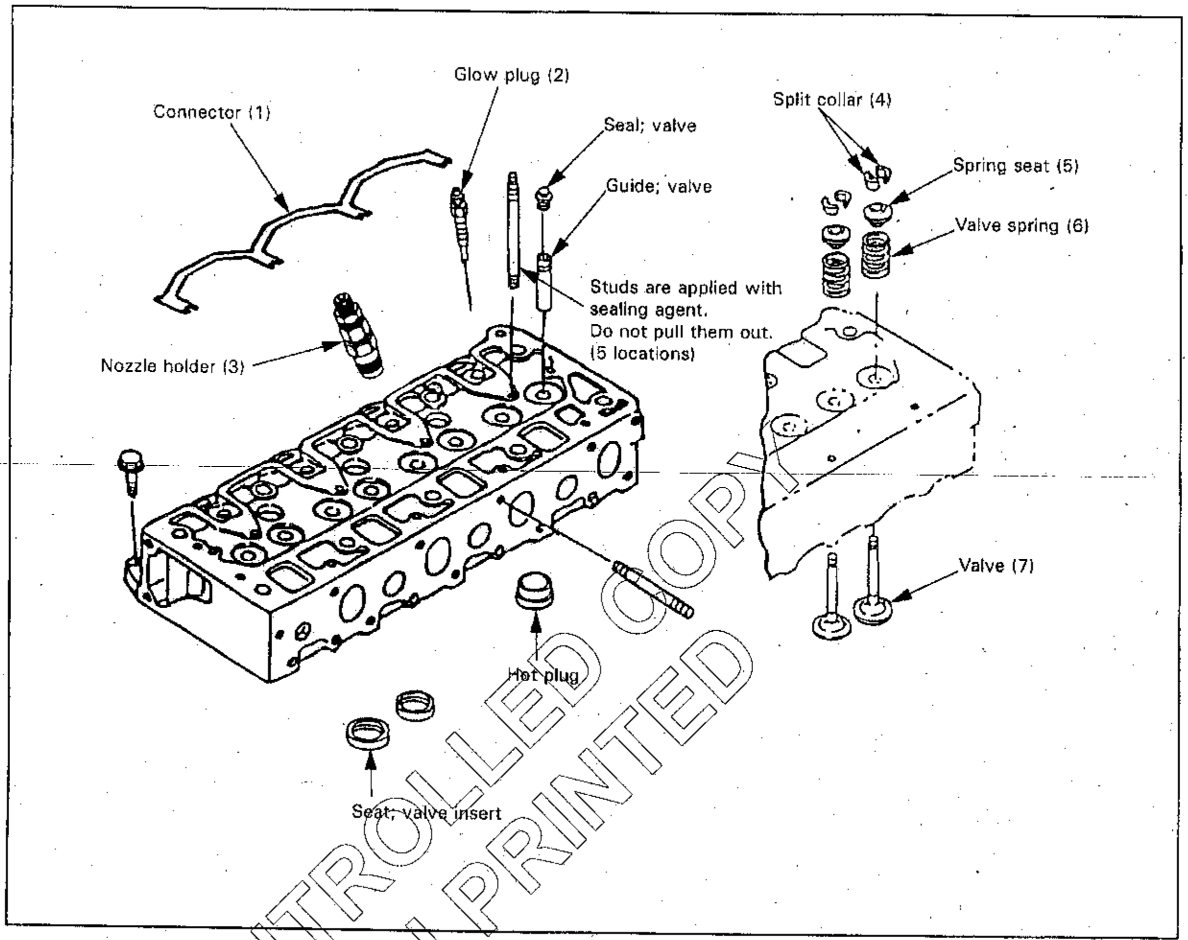


Fig 17 Cylinder head assembly

Valve mechanism

33 Proceed as follows:

(1) Before disassembling the valve mechanism, remove the connector, glow plug and nozzle holder assembly.

(2) Compressing the valve spring, remove the split collar, spring seat, valve spring and valve.

Timing gear

34 Proceed as follows:

(1) Remove the idle gear and the idle gear shaft.

(2) Pull out the sleeve from the tip end of the camshaft.

(3) Remove the lock nut of the camshaft gear, and then remove the flyweight assembly and the cam gear.

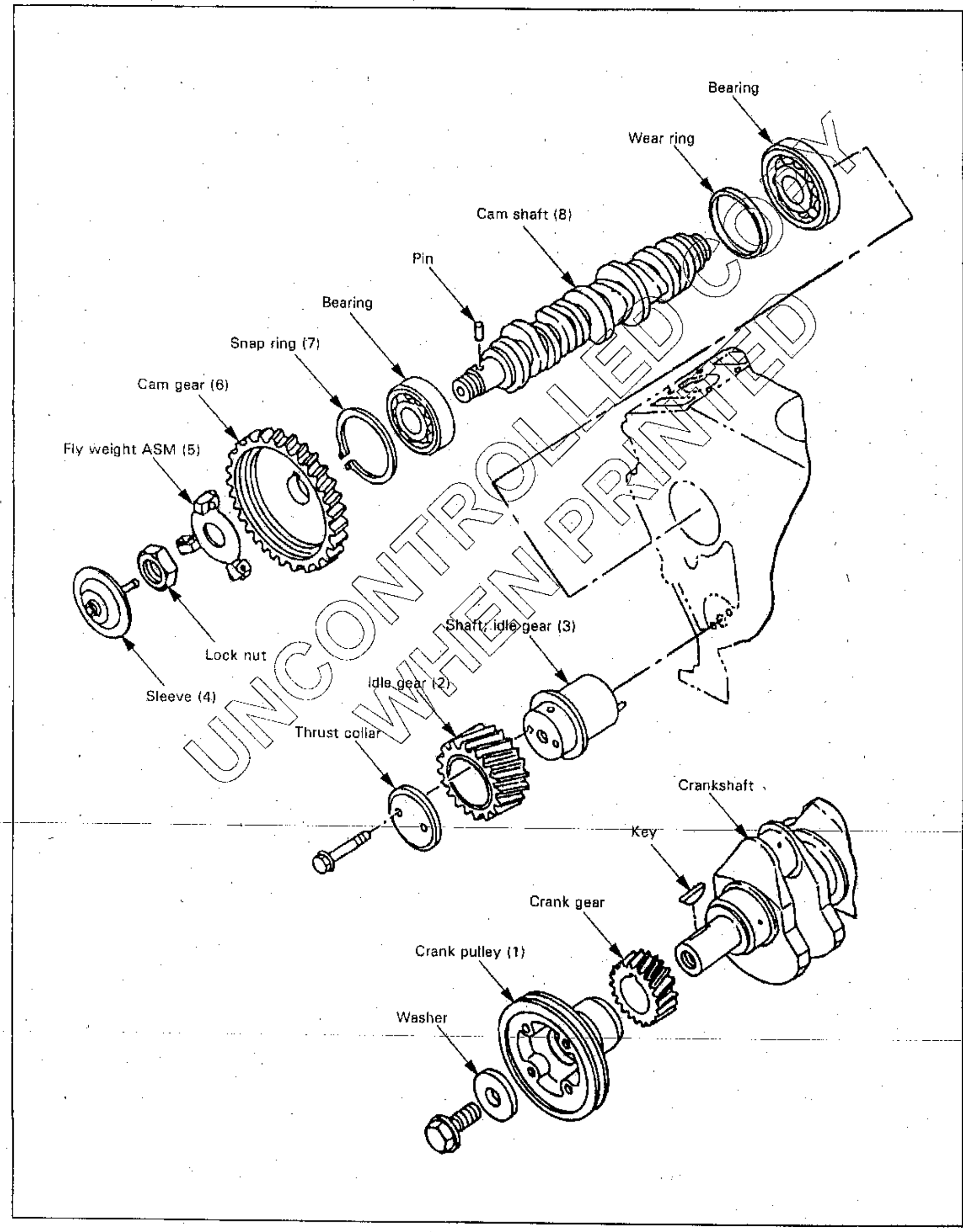


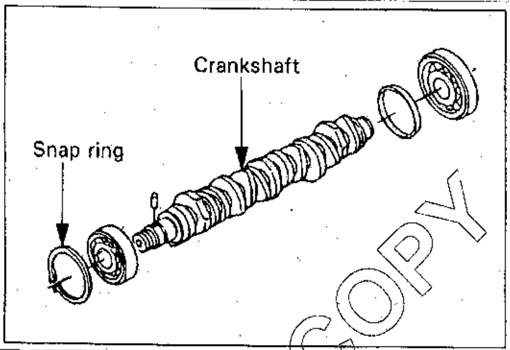
Fig 18 Timing gear

Camshaft

35 Proceed as follows:

(1) Remove the snap ring that holds down the front bearing of the camshaft from the ring groove of the cylinder block.

(2) Pull out the camshaft from the cylinder block, together with the bearing.



Piston and connecting rod

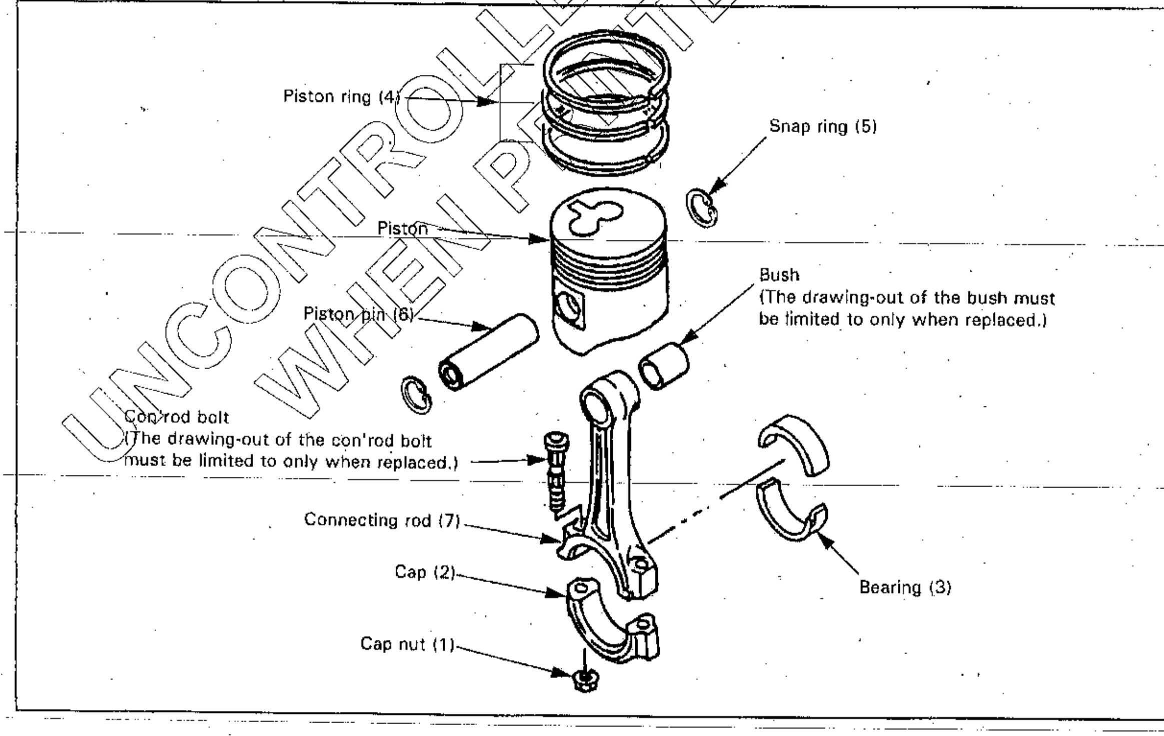


Fig 19 Piston and connecting rod

36 Proceed as follows:

(1) Turning the crankshaft, position the piston to be removed at the bottom dead centre.

(2) Loosen the cap nut of the connecting rod, and then remove it.

(3) Give another rotation to the crankshaft to position the piston at the top dead centre.

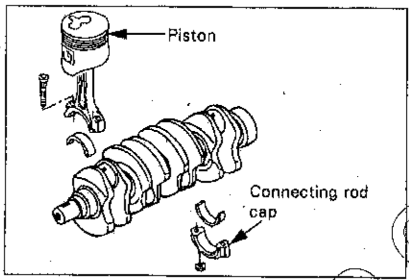
(4) With the handle of a hammer placed at the bottom of the connecting rod, push the piston assembly upward out of the cylinder block.

NOTES

(1) Before removing the piston, scrape the carbon deposit off the cylinder wall.

(2) When pushing out the piston assembly, care should be taken not to damage the cylinder wall.

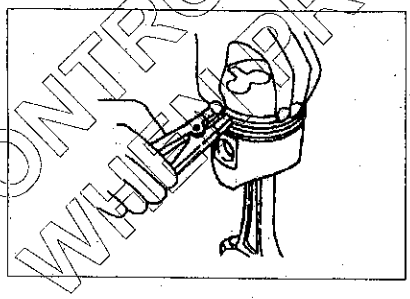
(3) Attach a tag with a cylinder number to the removed caps and bearings to keep them in order.



Piston ring

37 Proceed as follows:

(1) Remove the piston ring with ring pliers. (Pliers: piston ring: 1-85221-029-0.)



Piston pin

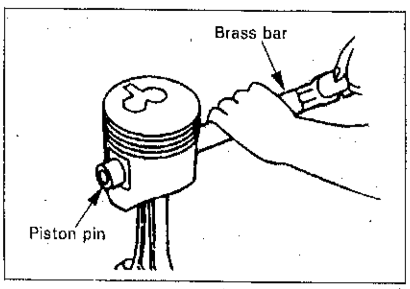
38 Proceed as follows:

(1) Remove the snap rings with a commercially available tool.

(2) With a brass bar attached to the piston pin, push it out by hammering it lightly.

NOTE

Keep the pistons, piston pins and connecting rods in order for each cylinder.



INSPECTION AND REPAIR

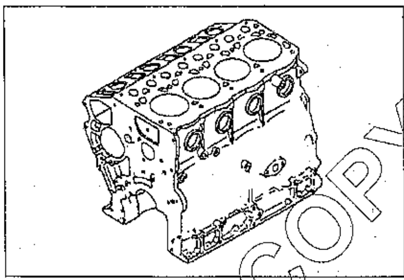
Cylinder block

39 Proceed as follows:

(1) Check the cylinder block for wear, damage or any other defects.

(2) Use the hydraulic gauge to check the water jacket water pressure.

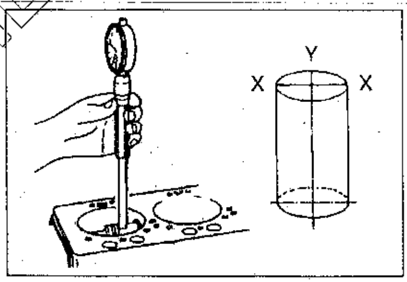
(3) Apply water pressure to the water jacket at 5 kg/cm^2 (71.1 psi) for three minutes.



Cylinder bore

Measurement position: 13 mm below the top
(Measure in X-X and Y-Y directions)
(Near the No. 1 compression ring)

Engine	Limit mm (in.)	Repair method
4LE1	0.2 (0.0079)	Perform boring and honing of the inner diameter



Cylinder bore diameter and grade mark

40 The grade mark is stamped on the top surface of the cylinder block (on the mating face with the cylinder head).

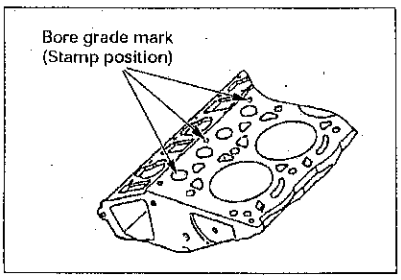


TABLE 11 CYLINDER BORE DIAMETER AND GRADE MARK

mm (in.)

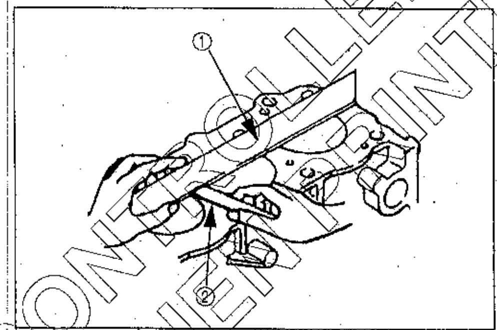
Engine	Bore Diameter mm (in.)	Grade
4LE1	85.000-85.010 (3.3464-3.3468)	A
	85.011-85.020 (3.3468-3.3472)	B
	85.021-85.030 (3.3472-3.3476)	C

Cylinder body upper face warpage

41 Proceed as follows:

(1) Use a straight edge ① and a feeler gauge ② to measure the four sides and the two diagonals of the cylinder body upper face.

(2) Regrind the cylinder body upper face if the measured values are greater than the specified limit but less than the maximum grinding allowance.

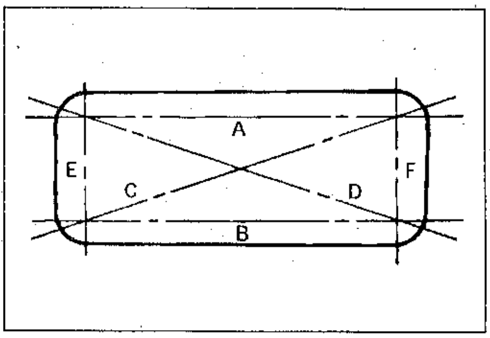


(3) If the measured values exceed the maximum grinding allowance, the cylinder body must be replaced.

Cylinder Body Upper Face Warpage mm (in.)

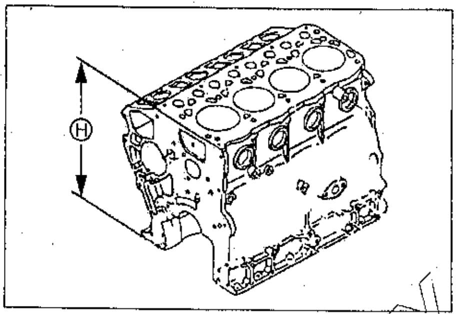
Standard	Limit mm (in.)	Maximum Grinding Allowance
0.075 (0.0029)	0.15 (0.0059)	0.3 (0.0118)

(4) If the measured value is less than the limit, the cylinder body may be reground.



Cylinder Body Height Ⓗ (Reference) mm (in.)

Engine	Standard
4LE1	307.94 – 308.06 (12.123 – 12.128)

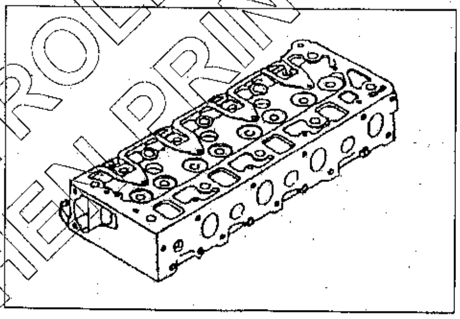


Cylinder head inspection

42 Proceed as follows:

(1) Remove carbon deposit on the bottom surface of the head with care not to damage the valve seat.

Leakage: Water pressure test 5kg/cm^2 (for 3 minutes)

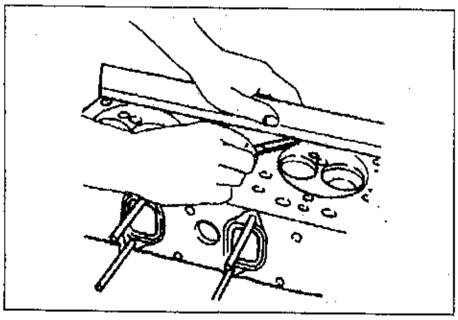


Cylinder head lower face warpage

43 Proceed as follows:

(1) Use a straight edge and a feeler gauge to measure the four sides and the two diagonals of the cylinder head lower face.

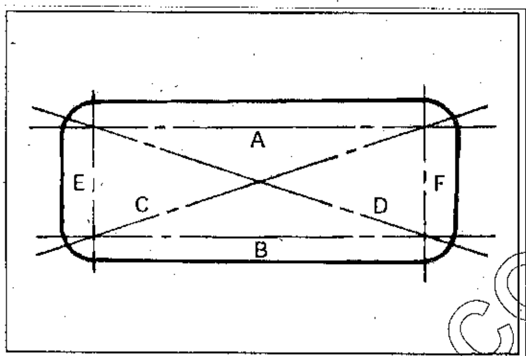
(2) Regrind the cylinder head lower face if the measured values are greater than the specified limit but less than the maximum grinding allowance.



(3) If the measured values exceed the maximum grinding allowance, the cylinder head must be replaced.

Cylinder Head Lower Face Warpage mm (in.)

Standard	Limit	Maximum Grinding Allowance
0.075 (0.0029)	0.15 (0.0059)	0.3 (0.0118)

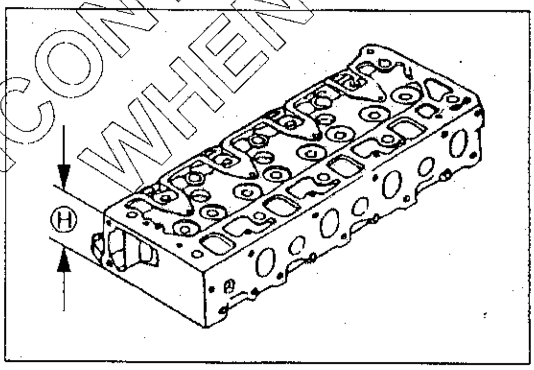


Cylinder Head Height Ⓗ(Reference) mm (in.)

Engine	Standard
4LE1	63.90 – 64.10(2.515 – 2.523)

NOTE

If the cylinder head lower face is reground, valve depression must be checked.



Hot plug

Hot plug depression

44 Proceed as follows:

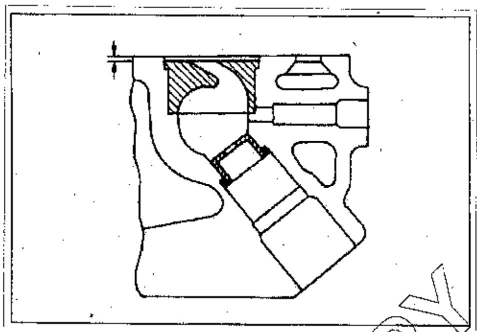
(1) Clean the cylinder head lower face, taking care not to damage the hot plug surfaces.

(2) Use a straight edge and a feeler gauge to measure the hot plug depression in a straight line from the No. 1 hot plug to the No. 3 hot plug.

(3) If the measured value exceeds the specified limit, the hot plugs must be replaced.

mm (in.)

Limit
0.05 (0.002)



Combustion chamber inspection

45 Proceed as follows:

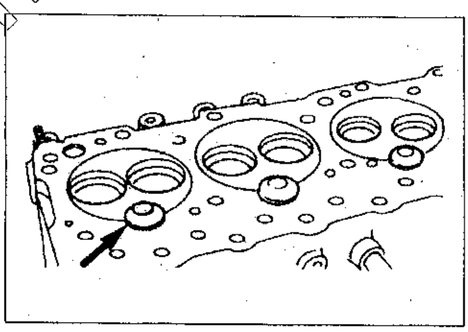
(1) Remove the carbon adhering to the inside of the combustion chamber. Take care not to damage the hot plug fitting positions.

(2) Inspect the combustion chamber, the hot plug hole, and the hot plug machined faces for cracking and other damage.

(3) If cracking or damage is present, the cylinder head must be replaced.

NOTE

Be absolutely certain that there are no scratches or protuberances on the combustion chamber surfaces which will be in contact with the hot plug after it is in-stalled. These flaws will prevent the hot plug from seating correctly.



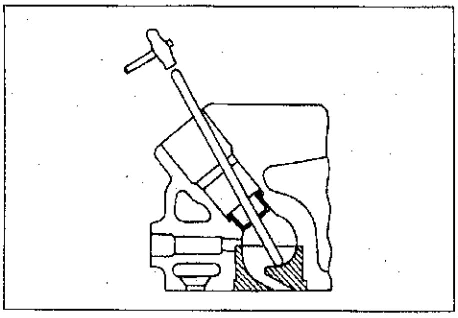
Hot plug replacement

Removal

46 Proceed as follows:

(1) Insert a 3.0 – 5.0 mm (0.12 – 0.20 in) diameter brass bar into the nozzle holder fitting hole until it makes contact with the hot plug.

(2) Lightly tap the bar with a hammer to drive the hot plug free.



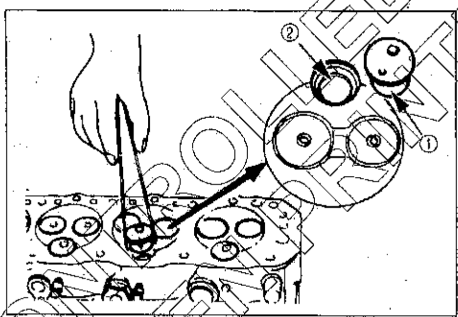
Inspection

47 Inspect the hot plugs for excessive wear and other damage. Replace the hot plugs if either of these conditions are discovered.

Installation

48 Proceed as follows:

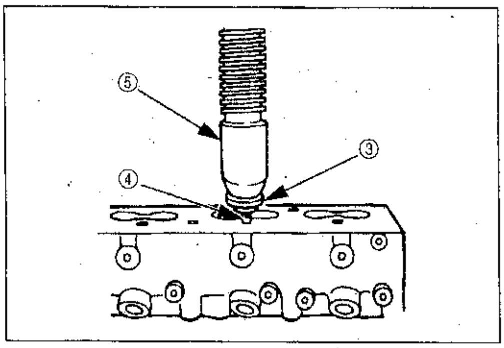
(1) Align the hot plug knock ball ← with the cylinder head groove ↑ to and tap it temporarily into position with a plastic hammer.



(2) Place a metal plate shield → approximately 25 mm (1 in) thick over the hot plug upper surface ↓.

(3) Use a bench press ° to exert a pressure of 4,000 – 5,000 kg (8,819 – 11,023 lb/39,227 – 49,033 N) on the metal plate covering the hot plug upper surface. This will drive the hot plug into position.

(4) Lightly tap the hot plug head to make sure that it is firmly seated.



(5) Repeat the procedure Steps (1) – (4) for the remaining hot plugs.

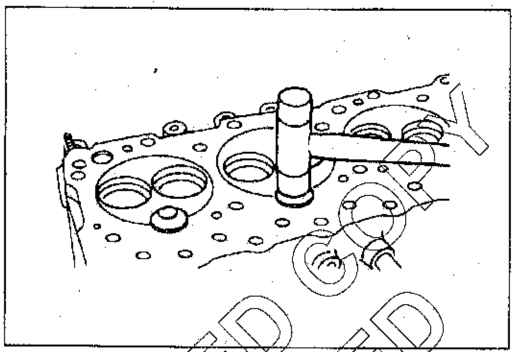
NOTE

Do not apply pressure greater than that specified. Damage to the cylinder head will result.

(6) Use a surface grinder to grind off any hot plug surface protuberances.

The hot plug surfaces must be perfectly flush with the cylinder head lower face.

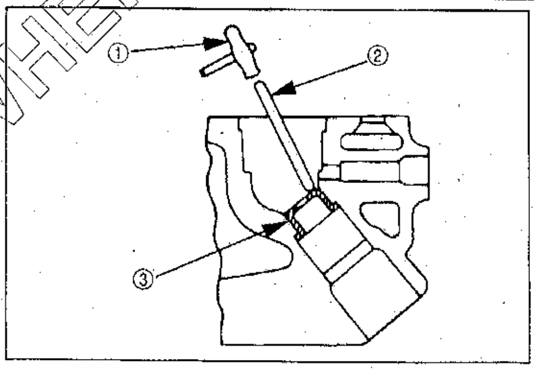
(7) After grinding, make sure that the hot plug surfaces are completely free of protuberances. The hot plug surfaces must also be free of depressions. Once again, lightly tap the hot plug heads to make sure that they are firmly seated.



Heat shield replacement

Removal

49 After removing the hot plugs, use a hammer ← and a brass bar ↑ to lightly tap the lower side of the heat shield → and drive it free.



Installation

50 Install the heat shield to the cylinder head from the nozzle holder installation hole side. Lightly tap the heat shield flange into place with a hammer and a brass bar. The heat shield flange side must be facing up.

NOTE

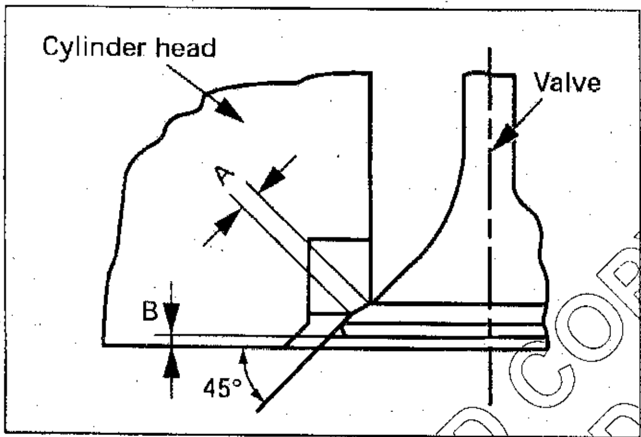
Always install a new heat shield. Never reuse the old heat shield.

VALVE, VALVE SEAT INSERT AND VALVE SEAL

Inspection of valve seat

51 A = Contact width.

B = Valve depression.



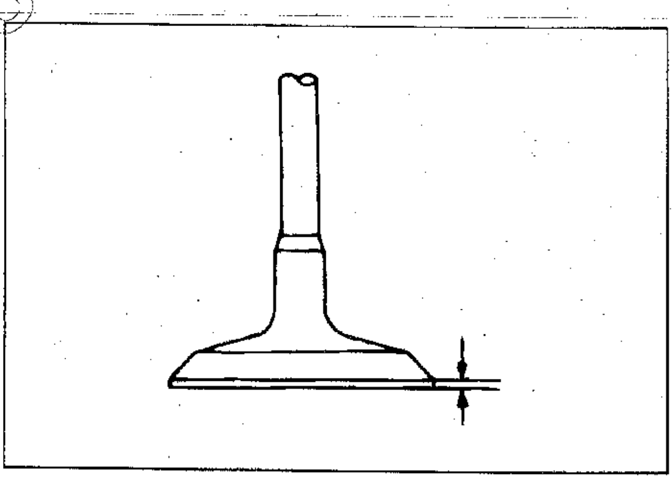
Valve Seat Limits mm (in.)

	Standard	Limit
Contact width	2.0 (0.0787)	2.5 (0.0984)
Valve depression	0.7 (0.0276)	1.2 (0.0427)

Valve thickness

Valve Thickness mm (in.)

Normal	Limit	Repair method
1.0 (0.03937)	0.7 (0.0276)	Replace

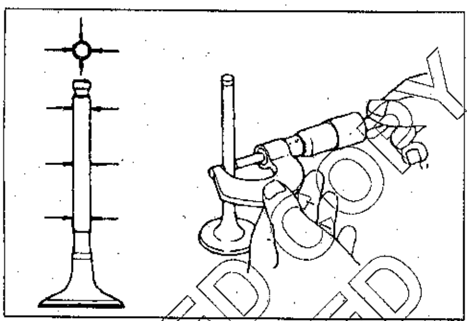


Valve stem outside diameter

52 Measure the valve stem diameter at three points. If the measured value is less than the specified limit, the valve must be replaced.

Valve Stem Outside Diameter mm (in.)

	Standard	Limit
Intake Valve	7.0 (0.2756)	6.85 (0.2697)
Exhaust Valve	7.0 (0.2756)	6.8 (0.2677)



Valve seat insert replacement

<u>Removal</u>

53 Proceed as follows:

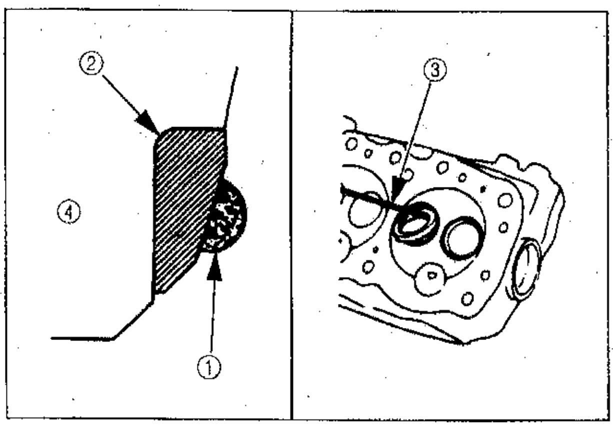
(1) Arc weld the entire inside circumference ← of the valve seat insert ↑.

(2) Allow the valve seat insert to cool for a few minutes. This will invite contraction and make removal of the valve seat insert easier.

(3) Use a screwdriver → to pry the valve seat insert free.

Take care not to damage the cylinder head ↓.

(4) Carefully remove carbon and other foreign material from the cylinder head insert bore.



Installation

54 Proceed as follows:

(1) Carefully place the attachment ← (having a smaller outside diameter than the valve seat insert) on the valve seat insert ↑.

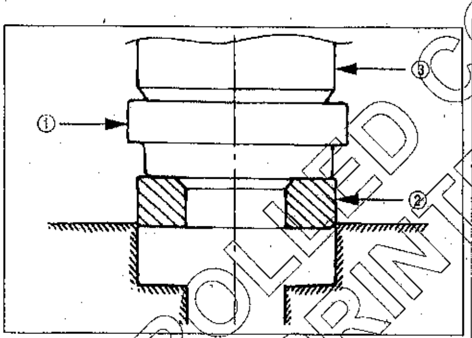
NOTE

The smooth side of the attachment must contact the valve seat insert.

(2) Use a bench press → to gradually apply pressure to the attachment and press the valve seat insert into place. 4,000 kg (8,819 lbs.)

NOTE

Do not apply an excessive amount of pressure with the bench press. Damage to the valve seat insert will result.

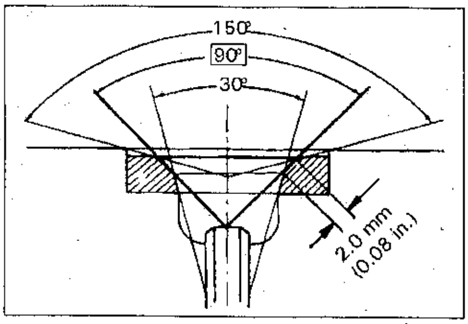


Valve seat insert correction

55 Proceed as follows:

(1) Remove the carbon from the valve seat insert surface.

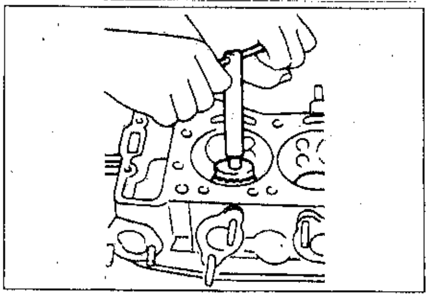
(2) Use a valve cutter (15°, 45°, and 75° blades) to minimize scratches and other rough areas. This will bring the contact width back to the standard value. Remove only the scratches and rough areas. Do not cut away too much. Take care not to cut away unblemished areas of the valve seat surface.



Valve Seat Angle (Degree)
45

NOTE

Use an adjustable valve cutter pilot. Do not allow the valve cutter pilot to wobble inside the valve guide.



(3) Apply abrasive compound to the valve seat insert surface.

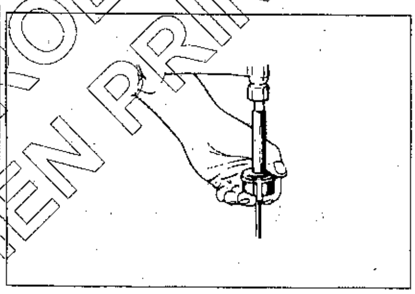
(4) Insert the valve into the valve guide.

(5) Apply light pressure to the valve while turning it to fit the valve seat insert.

(6) Check that the valve contact width is correct.

(7) Check that the valve seat insert surface is in contact with the entire circumference of the valve.

(8) Clean the head and valves to remove the abrasive compound and metal particles.



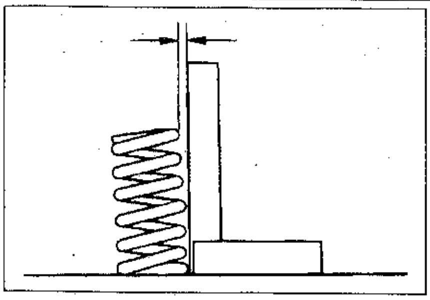
VALVE SPRING

Valve spring inclination

56 Use a surface plate and a square to measure the valve spring inclination. If the measured value exceeds the specified limit, the valve spring must be replaced.

Valve Spring Inclination mm (in.)

	Standard	Limit
Valve Spring Inclination	1.8 (0.0709)	2.5 (0.0984)

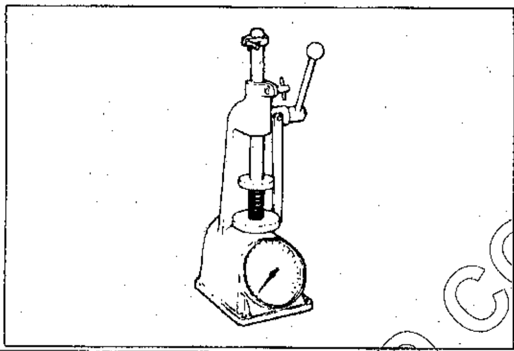


Valve spring tension

57 Use a spring tester to measure the valve spring tension. If the measured value is less than the specified limit, the valve spring must be replaced.

Valve Spring Tension kgf (lb)

	Standard	Limit
Valve Spring Tension at 29.9 mm Set Length	17.0 (37.479)	15.0 (33.069)

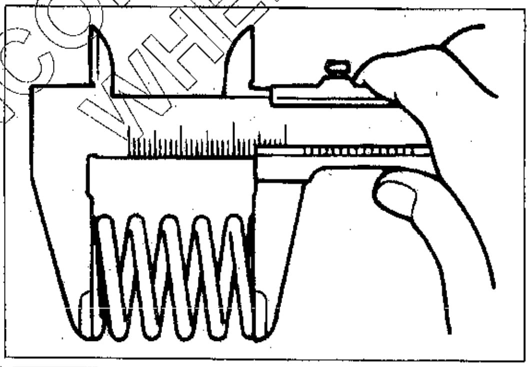


Valve spring free length

58 Use a vernier caliper to measure the valve spring free length. If the measured value is less than the specified limit, the valve spring must be replaced.

Valve Spring Free Length mm (in.)

	Standard	Limit
Exhaust and Intake Valve Spring Free Length	42.1 (1.6575)	40.0 (1.5748)

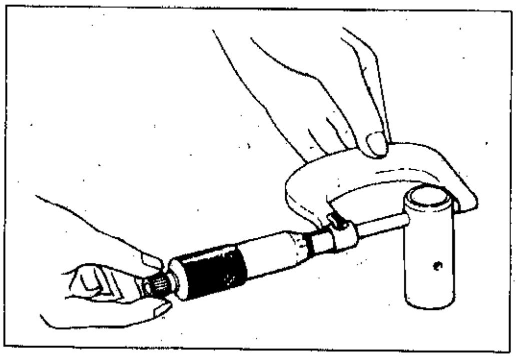


TAPPET (Cam Follower or Valve Lifter) AND PUSH ROD

59 Inspect the tappets for excessive wear, damage and any abnormalities. Use a micrometer to measure the tappet diameter.

Tappet Diameter mm (in.)

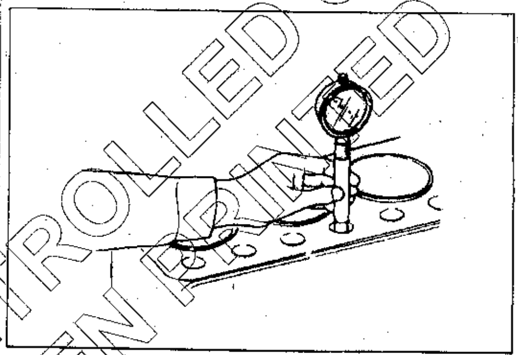
	Standard
Tappet Diameter	20.967 – 20.980 (0.82547 – 0.82598)



60 Use a dial indicator to measure the clearance between the tappet and cylinder body tappet travelling bore.

Tappet and Tappet Travelling Bore Clearance mm (in.)

	Standard	Limit
Tappet and Tappet Travelling Bore Clearance	0.020 – 0.054 (0.00079 – 0.00213)	0.08 (0.00315)

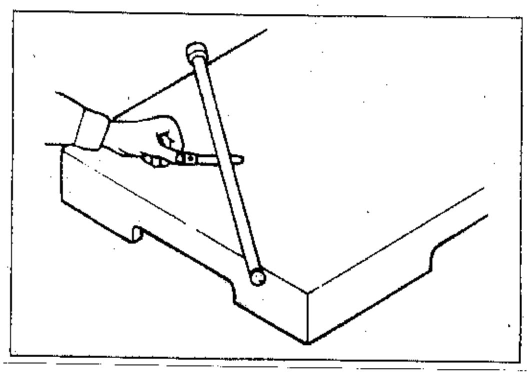


PUSH ROD

61 Use a filler gauge to measure the valve push rod runout. Roll the push rod along a smooth flat surface (illustration).

Push Rod Run-Out mm (in.)

	Limit
Push Rod Run-Out	0.3 (0.0118)



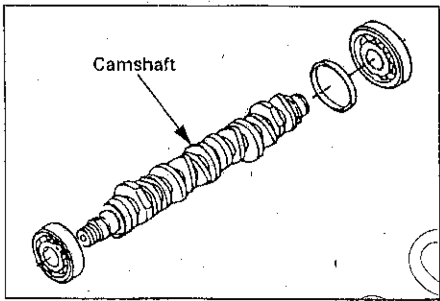
CAMSHAFT

Inspection of cam shaft

62 Check the journal and the cam for evidence of wear, damage or any other defect.

NOTE

With the front and rear parts of camshaft pressed in with ball bearings, and with the cylinder block pressed in with roller bearings as the centre bearing, check to see if the camshaft rotates smoothly with no play at each bearing.



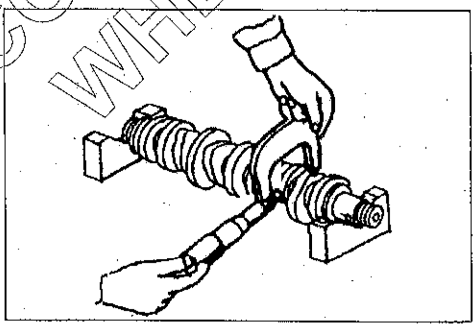
Measurement of journal and cam

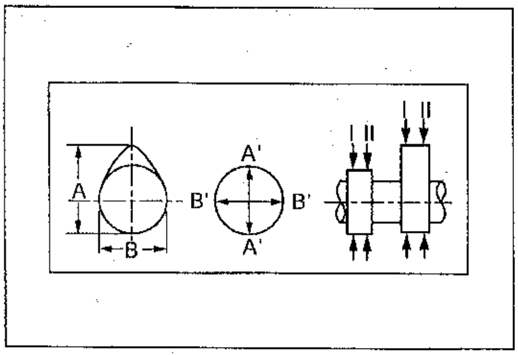
63 Proceed as follows:

(1) Cam height (A – B) mm:

Cam Height (A – B) mm (in.)

	Standard	Limit	Repair method
Intake	6.13 (0.2413)	5.83 (0.2295)	Replace
Exhaust	6.43 (0.2531)	6.13 (0.2413)	Replace





(2) Centre journal diameter:

Centre Journal Diameter mm (in.)

Nominal	Limit	Repair method
52 ø (2.0472)	51.92 ø (2.0441)	Replace

(3) Uneven wear of journal

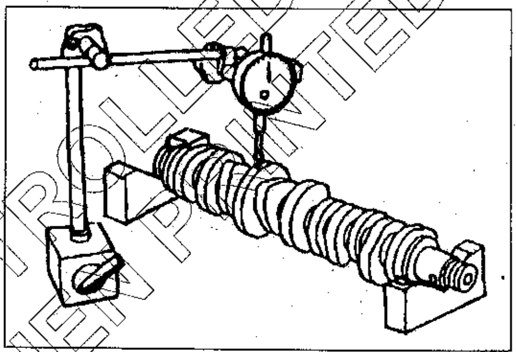
Uneven Wear of Journal mm (in.)

Nominal	Limit	Repair method
52 ø (2.0472)	0.05 (0.002)	Replace

(4) Runout of camshaft

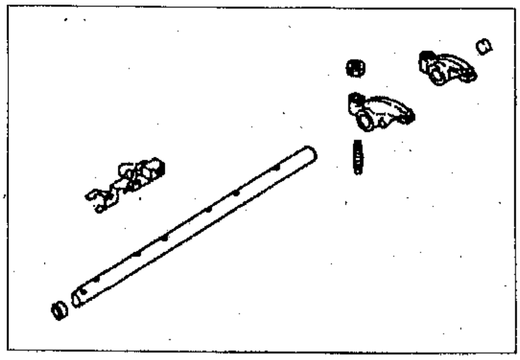
Runout of Camshaft mm (in.)

Nominal	Limit	Repair method
0.02 (0.008)	0.1 (0.004)	Replace



ROCKER ARM SHAFT AND ROCKER ARM

64 Inspect all disassembled parts for wear, damage and any abnormalities.



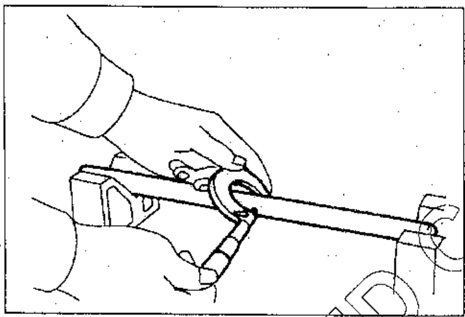
Rocker arm shaft outside diameter

65 Use a micrometer to measure the rocker arm outside diameter.

66 If the measured value is less than the specified limit, the shaft must be replaced.

Rocker Arm Shaft Diameter mm (in.)

	Standard
Rocker Arm Shaft Diameter	11.935 – 11.955 (0.4699 – 0.4707)



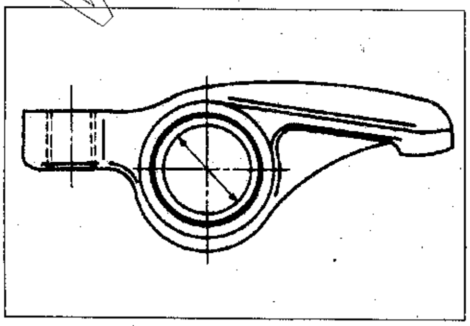
Rocker Arm Shaft and Rocker Arm Clearance

67 Proceed as follows:

(1) Use a vernier caliper to measure the rocker arm bushing inside diameter.

Rocker Arm Bushing Inside Diameter mm (in.)

	Standard
Rocker Arm Bushing Inside Diameter	11.960 – 11.980 (0.4709 – 0.4717)

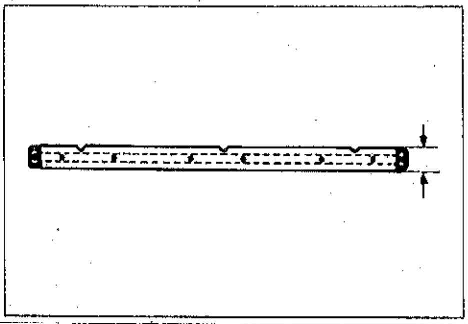


(2) Measure the rocker arm shaft outside diameter. Replace either the rocker arm or the rocker arm shaft if the clearance exceeds the specified limit.

Rocker Arm Shaft Outside Diameter mm (in.)

	Standard	Limit
Rocker Arm Bushing and Rocker Arm Shaft Clearance	0.005 – 0.045 (0.0002 – 0.0018)	0.2 (0.0079)

(3) Check that the rocker arm oil port is free of obstructions. If necessary, use compressed air to clean the rocker arm oil port.



PISTON, PISTON PIN AND PISTON RING

Clearance between piston and cylinder bore

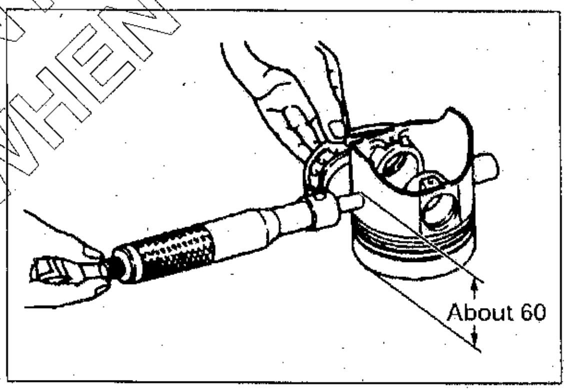
68 Proceed as follows:

(1) Measure the outside diameter of the piston at about 60 mm from the top in a right angle to the piston pin (in the unit of 1/1,000 mm).

(2) Calculate the clearance based on the measurements of the cylinder bore and the outside diameter of the piston.

mm (in.)

Clearance	0.015 – 0.035 (0.0006 – 0.0014)

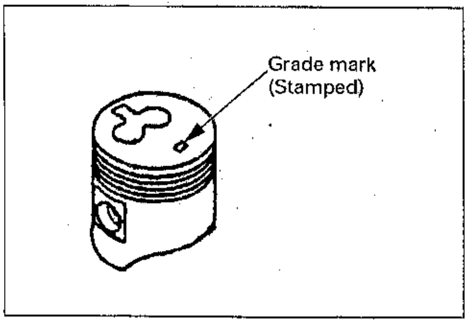


Outside diameter of piston and grade mark

69 The grade mark is stamped on the top surface of the piston.

mm (in.)

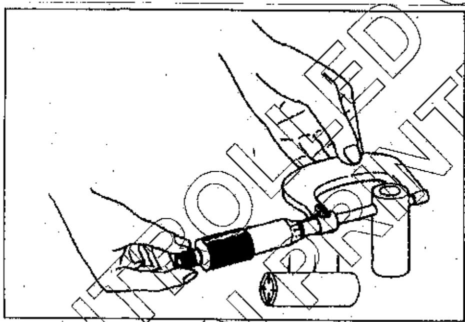
Model	Outside diameter of piston	Grade
4LE1	84.975 –84.985 (3.3454 – 3.3458)	A
	84.986 –84.995 (3.3459 – 3.3462)	B
	84.996 –85.005 (3.3463 – 3.3466)	C



Wear of piston pin (outside diameter)

Wear of Piston Pin (outside diameter) mm (in.)

Model	Nominal	Limit	Remarks
4LE1	25.0 (0.9843)	24.97 (0.9831)	



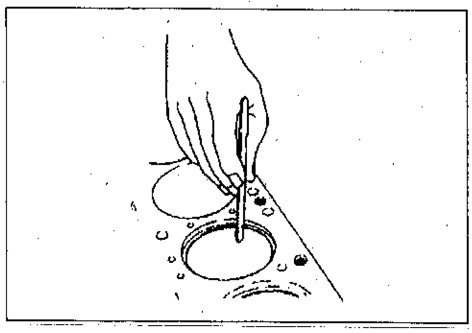
Clearance between piston pin and piston pin hole

mm (in.)

	Standard
4LE1	0.002 – 0.012 (0.00008 – 0.00047)

Piston ring gap

70 With the ring inserted into the cylinder bore, push it in with the piston head so that it becomes a right angle to the cylinder, and then measure the gap of the piston ring. If worn beyond the limit, replace the rings.



Piston Ring Gap mm (in.)

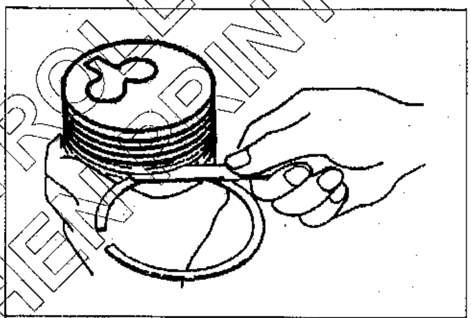
4LE1	Standard	Limit
1st compression ring	0.2 – 0.35 (0.0079 – 0.0138)	1.5 (0.0590)
2nd compression ring	0.35 – 0.5 (0.0138 – 0.0197)	
Oil ring	0.2 – 0.4 (0.0079 – 0.0157)	1.0 (0.03937)

Clearance between piston ring groove and ring

71 Measure clearance at several places on the circumference. If worn beyond the limit, replace the rings or piston.

4LE1 mm (in.)

	Standard	Limit
1st compression ring	0.085 – 0.105 (0.0033 – 0.0041)	2.0 (0.0078)
2nd compression ring	0.050 – 0.085 (0.0020 – 0.0033)	0.15 (0.0059)
Oil ring	0.030 – 0.070 (0.0011 – 0.0027)	



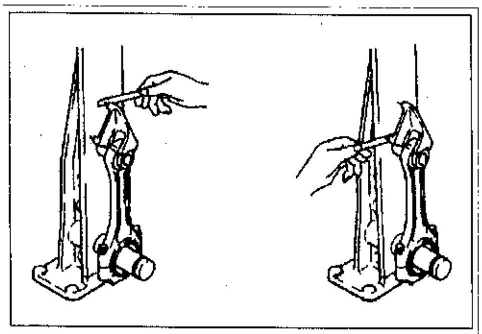
CONNECTING ROD AND CONNECTING ROD BEARING

Torsion and parallelism of connecting rod

72 If worn beyond the limit, repair or replace.

Torsion and Parallelism of Connecting Rod mm (in.)

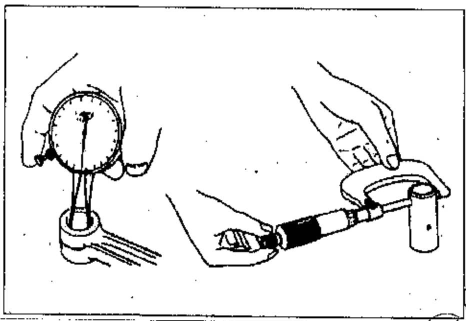
Per 100 mm (3.94)	Standard	Limit
Torsion	0.05 (0.002)	2.0 (0.0079)
Parallelism	0.05 (0.002)	0.15 (0.0059)



73 Clearance between small end pin hole of connecting rod and piston pin, inside diameter of bushing.

mm (in.)

4LE1	Standard	Limit
Clearance	0.008 – 0.020 (0.0003 – 0.0008)	0.05 (0.0020)
Inside diameter	25 (0.8268)	-



Connecting rod bearing inspection

74 Proceed as follows:

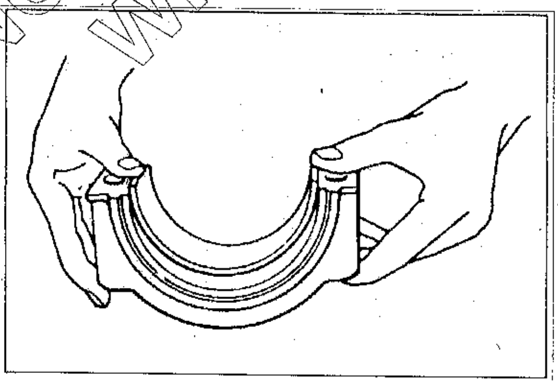
(1) Fit the connecting rod bearing lower half into the connecting rod bearing cap.

(2) Check the connecting rod bearing lower half tension. If the tension is insufficient, the bearing must be replaced.

(3) Tighten the torque and the bearing cap to the specified torque.

kg m (ft.lbs.)

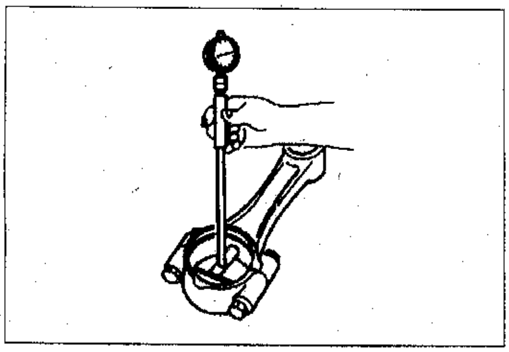
Connecting rod tightening torque	4LE1	7.5 – 8.5 (54 - 61)



75 Clearance between bearing and crank pin, inside diameter with bearing installed and without.

mm (in.)

	Standard	Limit
Clearance	0.035 – 0.073 (0.0014 – 0.0029)	0.10 (0.0039)



CRANKSHAFT AND CRANKSHAFT BEARING

Outside diameters of journal and pin

76 If worn beyond the limits, replace

Crank journal mm (in.)

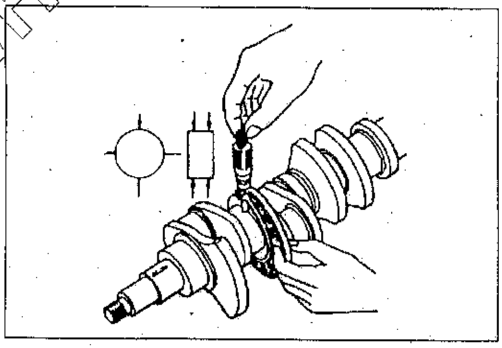
	Standard	Limit
4LE1	60.0 (2.2047)	59.86 (2.3567)

Crank pin mm (in.)

	Standard	Limit
4LE1	49.0 (1.9291)	48.87 (1.9240)

NOTE

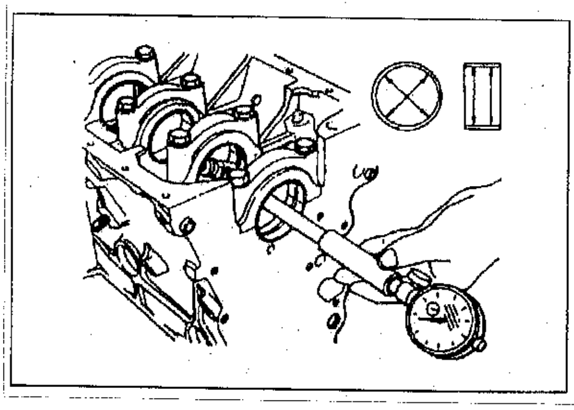
When there occurs an uneven wear to the crankshaft, replace it with a new one without grinding it for reuse.



Clearance between journal and bearing inside diameter with bearing installed and without

mm (in.)

	Standard	Limit
Clearance	0.029 – 0.072 (0.0011 – 0.0028)	0.11 (0.0043)

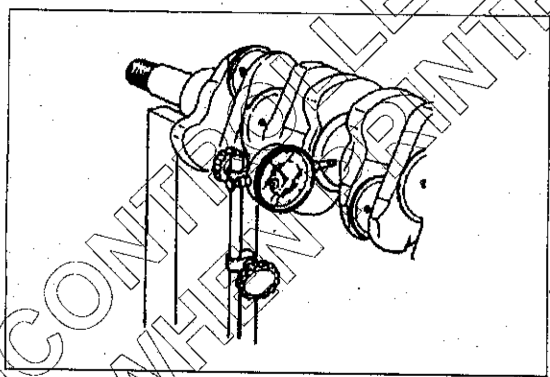


Runout of crankshaft

77 Replace if beyond limit.

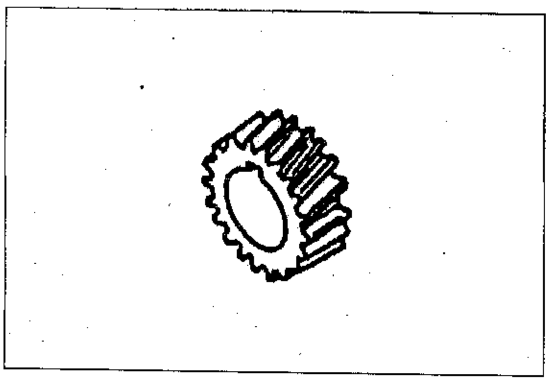
Runout of Crankshaft mm (in.)

Standard	Limit
0.025 (0.001)	0.05 (0.002)



Crankshaft gear

78 Check the crankshaft gear visually for damage and any other defects.

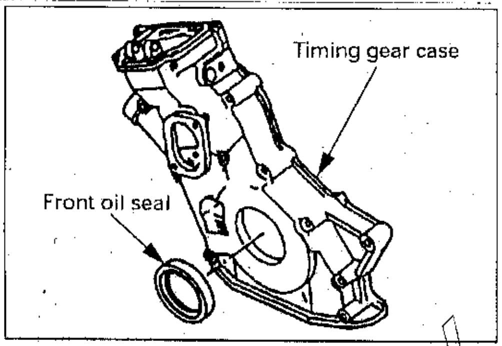


Oil seal

79 When the lip of an oil seal is found defective, replace it with a new one.

Installation

80 Use the crankshaft front oil seal installer to install the crankshaft front oil seal.



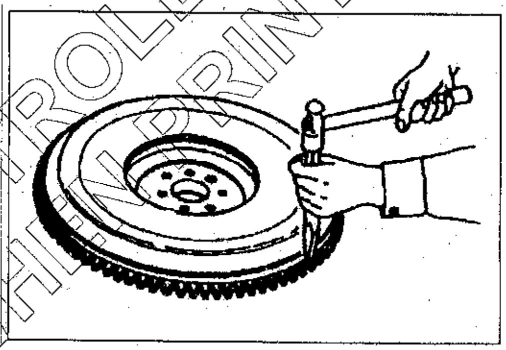
FLYWHEEL AND RING GEAR

Ring gear replacement

81 Inspect the ring gear. If the ring gear teeth are broken or excessively worn, replace the ring gear.

Removal

82 Strike around the edges of the ring gear with a hammer and chisel to remove it.

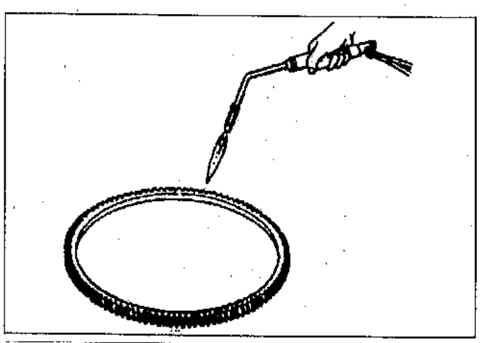


Installation

83 Proceed as follows:

(1) Heat the ring gear evenly with a gas burner to invite thermal expansion. Do not allow the temperature of the gas burner to exceed 200°C (390°F).

(2) Use a hammer to install the ring gear when it is sufficiently heated.

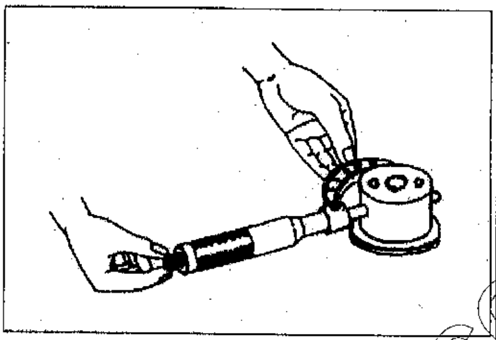


TIMING GEAR

Uneven wear of idle gear shaft

Idle gear shaft mm (in.)

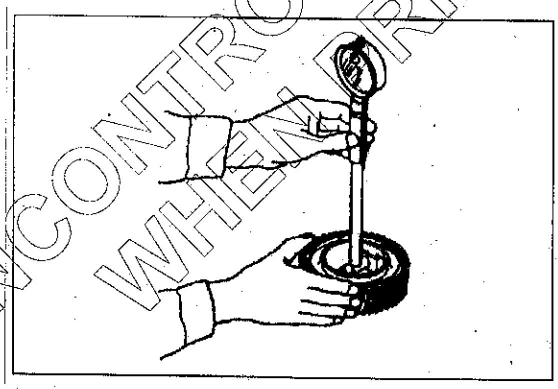
Nominal	Limit
45.0 (1.7717)	0.1 (0.0039)



Clearance between idle gear bushing and shaft

mm (in.)

Standard	Limit
0.025 – 0.085 (0.001 –0.0033)	0.2 (0.0079)



REASSEMBLY

CYLINDER HEAD ASSEMBLY

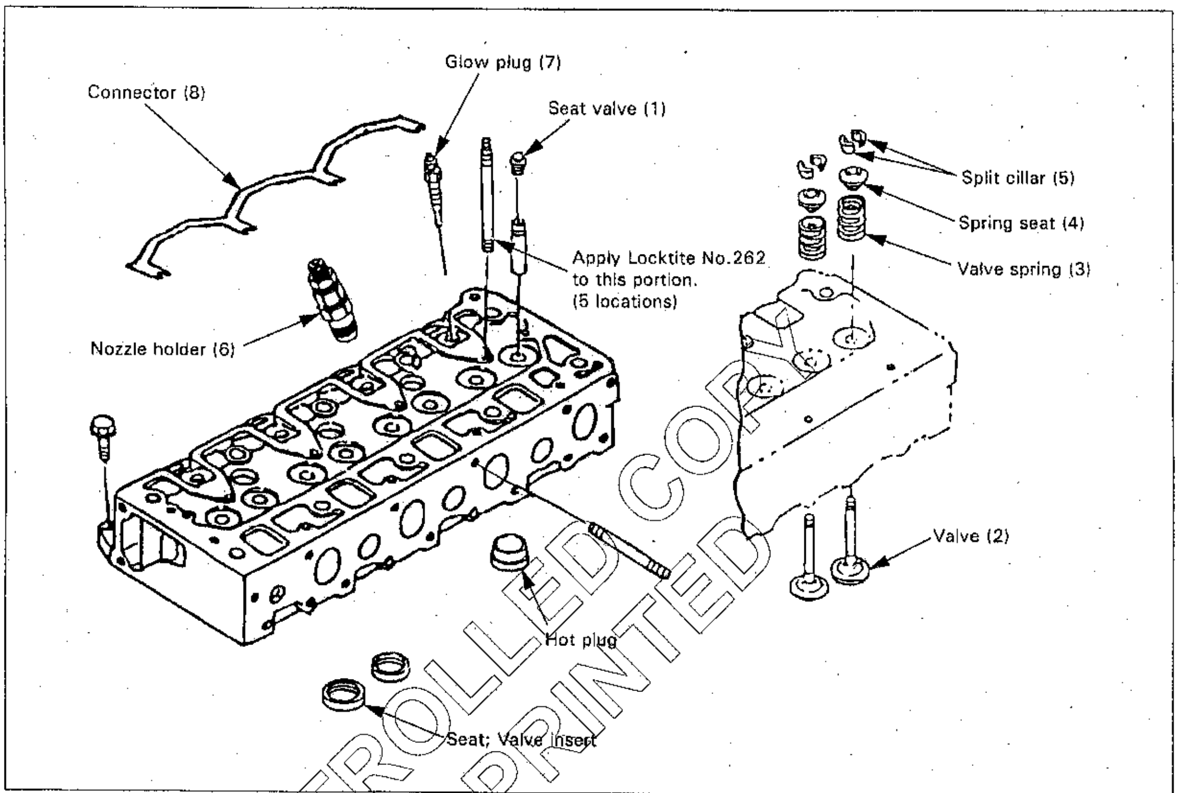


Fig 20 Cylinder head assembly

Important operations

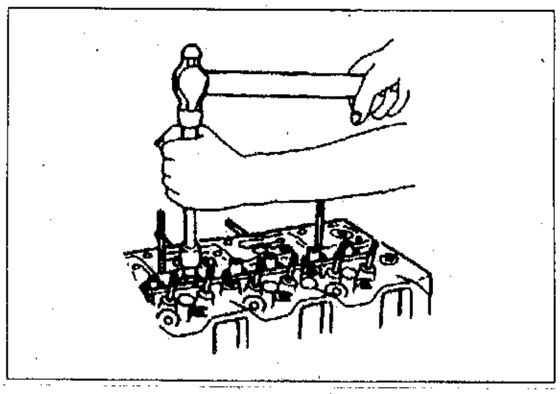
Valve stem oil seal

84 Proceed as follows:

(1) Lubricate the oil seals and valve stem sealing area with engine oil.

(2) Use a valve stem oil seal installer to install the oil seal.

Valve Stem Oil Seal Installer: 5-8840-9033-0



Intake and exhaust valves

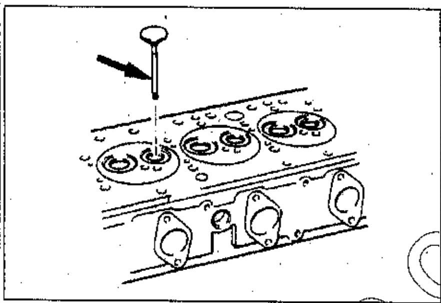
85 Proceed as follows:

(1) Place the cylinder head on a flat wooden surface.

(2) Lubricate valve stems with engine oil.

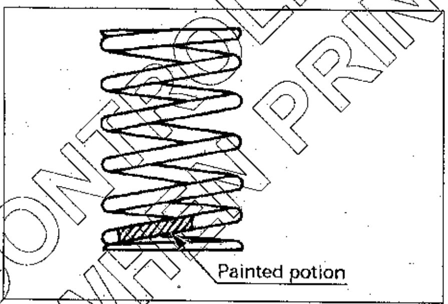
(3) Install the valves to the intake or exhaust guides.

(4) Install the valves to their original lapped valve seats.



Intake and exhaust valve springs

86 Install the valve springs with their painted end (the close pitched end) facing down.



Spring seat split collar

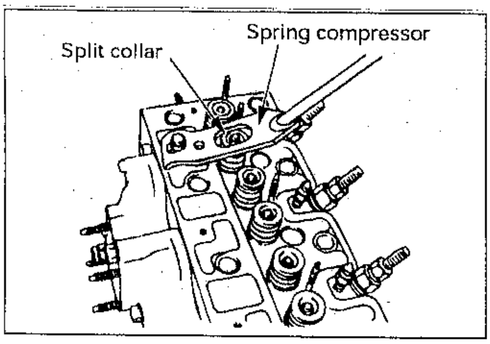
87 Proceed as follows:

(1) Use a spring compressor to push the valve spring into position.

(2) Install the spring seat split collar.

(3) Set the spring seat split collar by tapping lightly around the head of the collar with a rubber hammer.

Spring Compressor: 5-8840-9030-0



Nozzle holder assembly

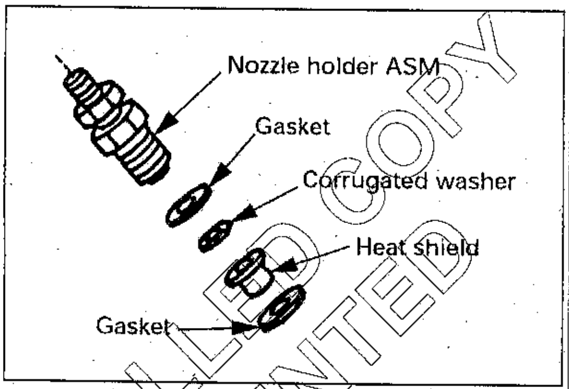
88 Before assembling the nozzle holder assembly, check to see if the spray condition and the spray pressure of the injection nozzle are appropriate, (Refer to "INSPECTION AND SERVICE.")

89 Assemble to the cylinder head the gasket (heat shield), heat shield, corrugated washer and gasket (nozzle holder) in this order.

90 Install the nozzle holder assembly, and then tighten it to the specified torque.

kg m (ft. lbs.)

Nozzle holder assembly tightening torque	4.0 – 5.0 (29.0 – 36.0)



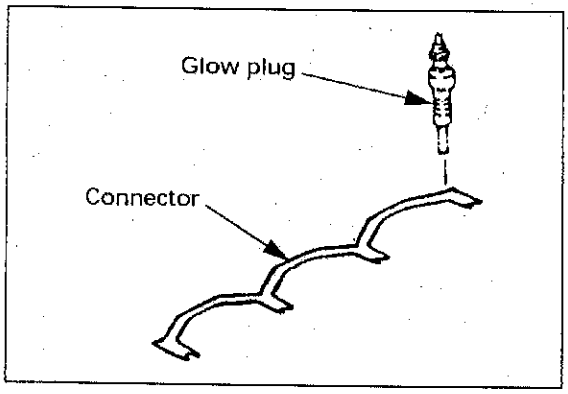
Glow plug and connector

91 Assemble the glow plug to the cylinder head, and then tighten it to the specified torque.

92 Install the connector to the glow plug, and then tighten until snug.

kg m (ft. lbs.)

Parts	Tightening torque
Glow plug	1.5 – 2.0 (11.0 – 14.0)



PISTON AND CONNECTING ROD

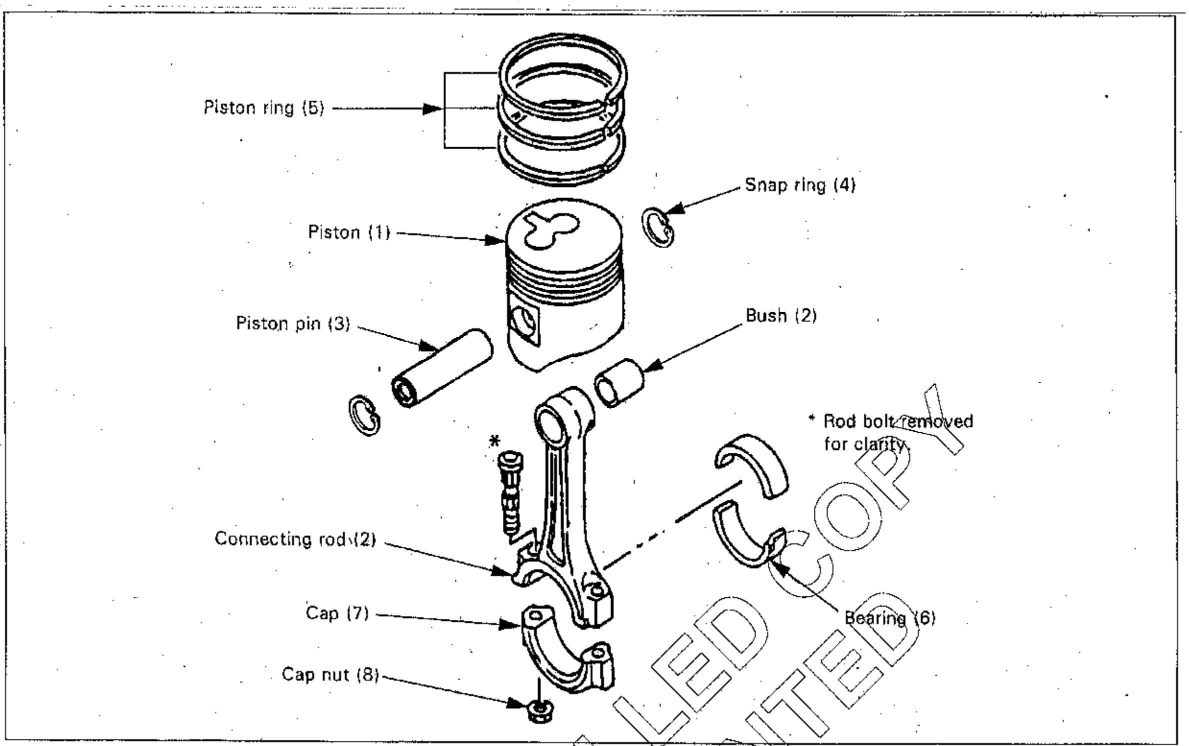
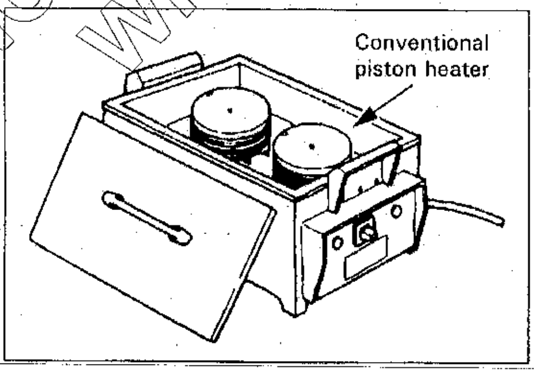


Fig 21 Piston and connecting rod

Important operations

Piston

93 Use a piston heater to heat the pistons to approximately 100°C (212°F).

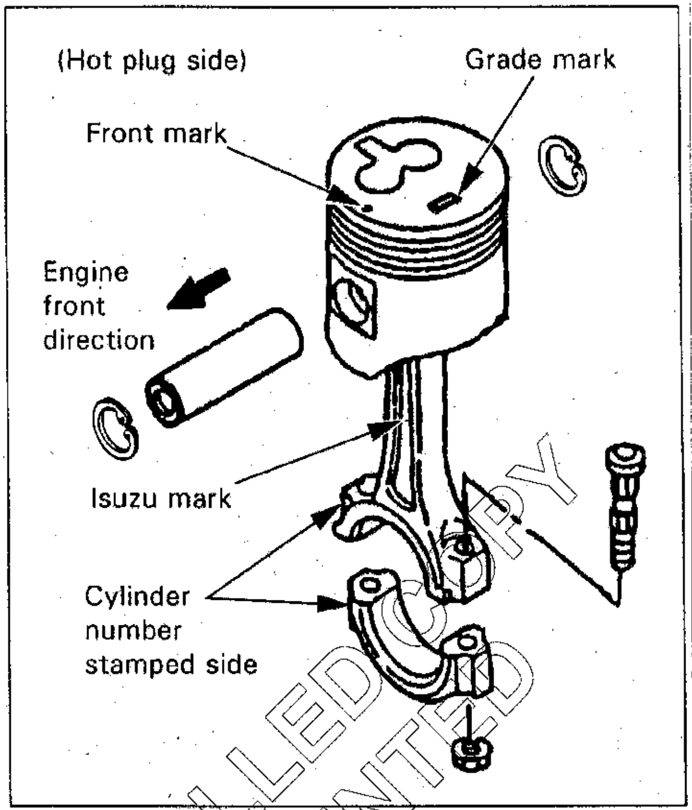


Connecting rod

94 Proceed as follows:

(1) Install the connecting rod to the piston with setting the marks as illustrated.

(2) Install the piston pin into the piston and the connecting rod bushing.

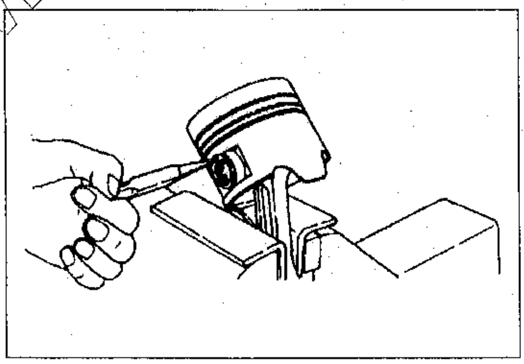


Piston pin snap ring

95 Proceed as follows:

(1) Use a pair of snap ring pliers to install the piston pin snap ring.

(2) Check that the piston moves smoothly on the piston pin.



Piston Ring

96 Proceed as follows:

(1) Use a piston ring installer to install the three piston rings.

Piston Ring Installer.

(2) Install the piston rings in the following order.

a. Oil ring.

b. 2nd compression ring.

c. 1st compression ring.

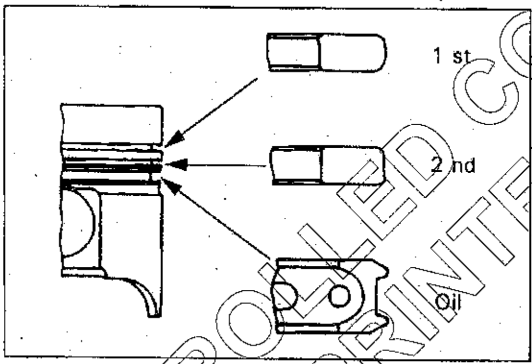
The marked side of the two compression rings must be facing up.

The undercut side of the second compression ring will be facing down.

As the oil ring has no any facing mark, it may face in either direction.

(3) Lubricate the piston ring surfaces with engine oil.

(4) Check that the piston rings rotate smoothly in the piston ring grooves.



REASSEMBLY OF INTERNAL PARTS

97 The reassembly steps for the internal parts of the engine are shown in Fig 22 to 24.

(1) Crankshaft.

(2) Piston Assembly.

(3) Rear Seal Retainer.

(4) Camshaft.

(5) Cam Gear.

(6) Idler gear and Shaft.

(7) Oil Pump Assembly.

(8) Timing Gear Case (Without PTO).

(9) Flywheel Housing.

(10) Flywheel.

(11) Crank Pulley.

(12) Oil Pipe.

(13) Oil Strainer.

(14) Oil Pan.

(15) Tappets.

(16) Cylinder Head Gasket.

(17) Cylinder Head Assembly.

(18) Push Rods.

(19) Rocker Bracket Assembly.

(20) Engine Hangers.

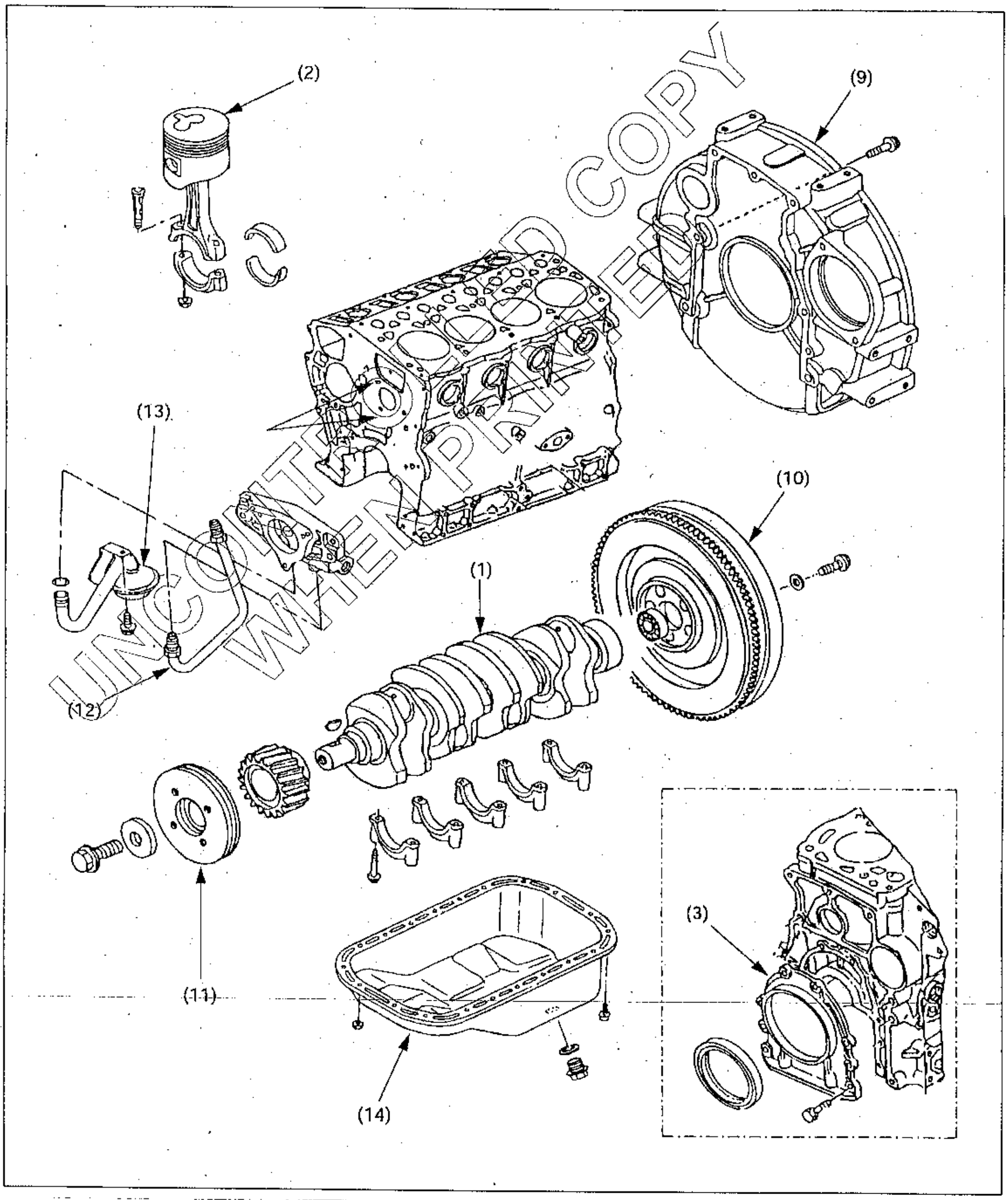


Fig 22 Reassembly internal parts (sheet 1 of 3)

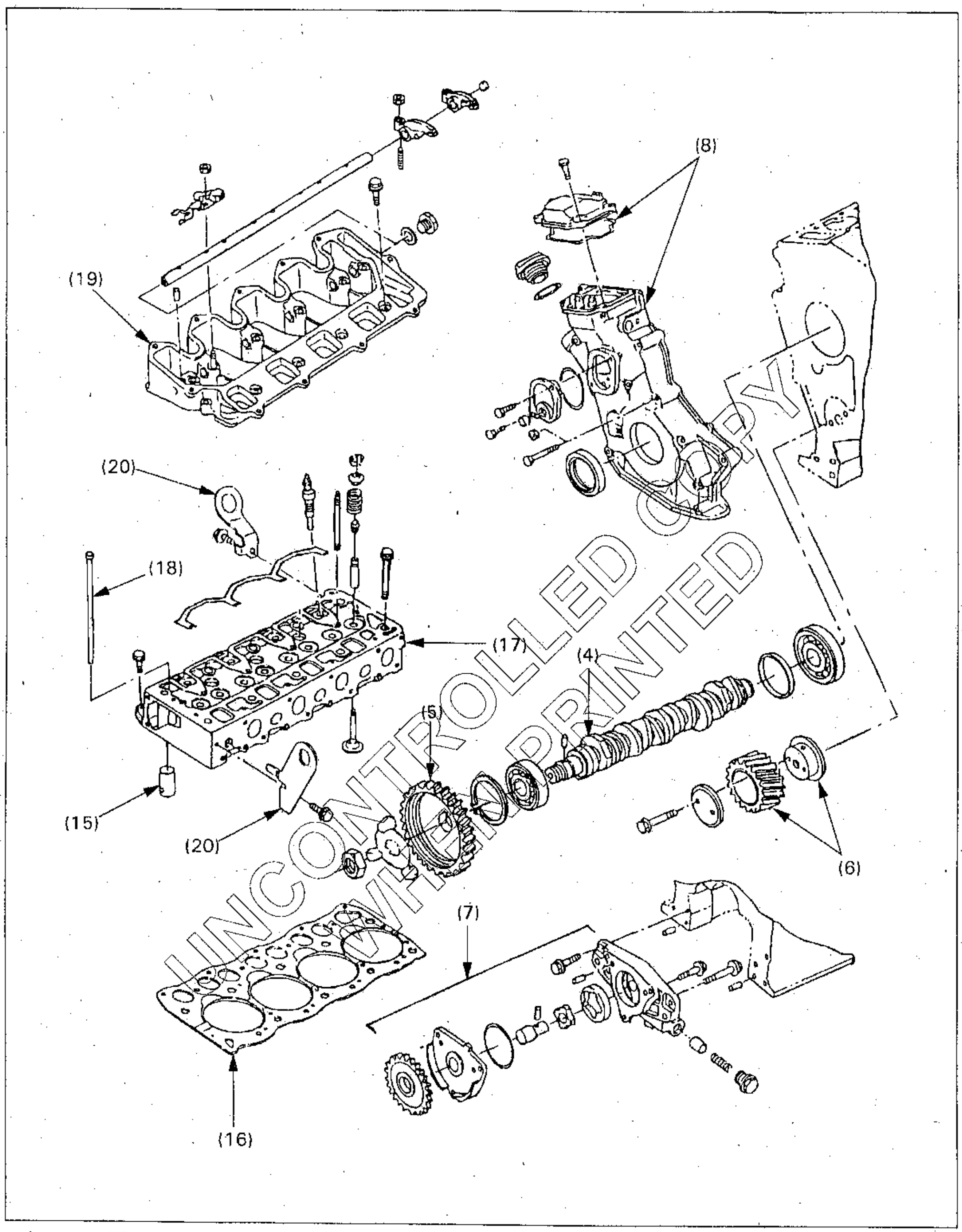


Fig 23 Reassembly internal parts (sheet 2 of 3)

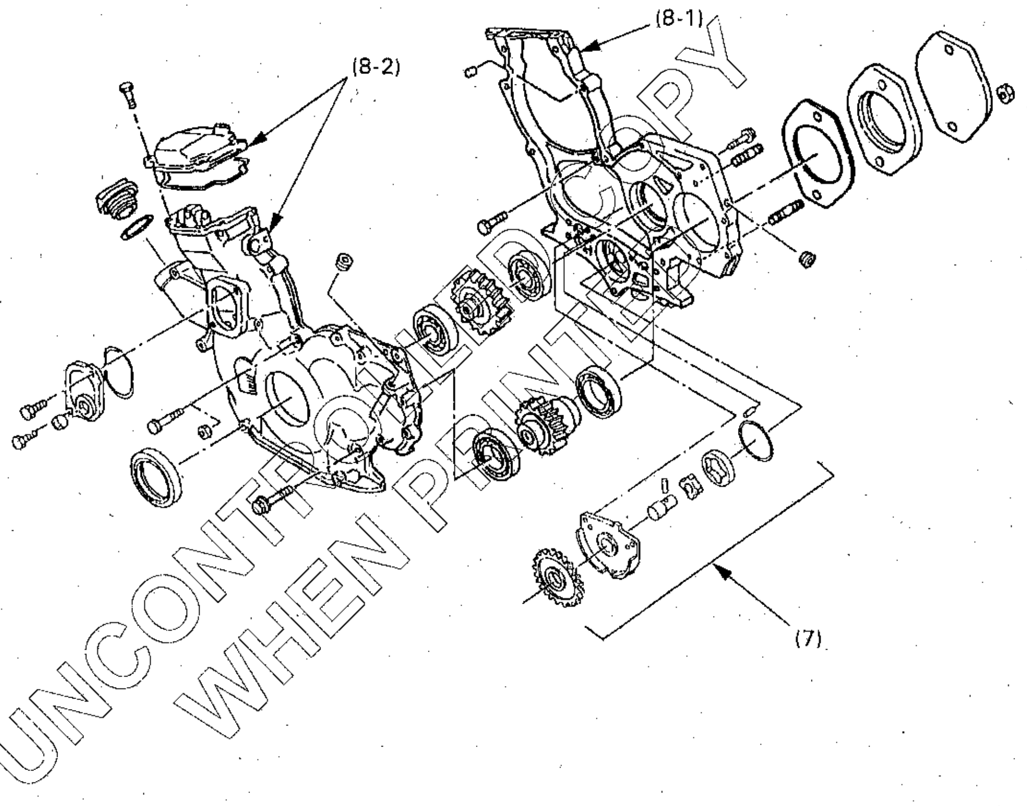
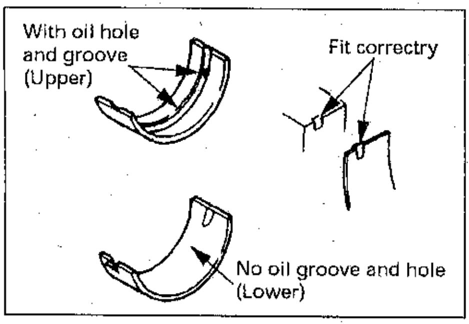


Fig 24 Reassembly internal parts (sheet 3 of 3)

Crankshaft bearing

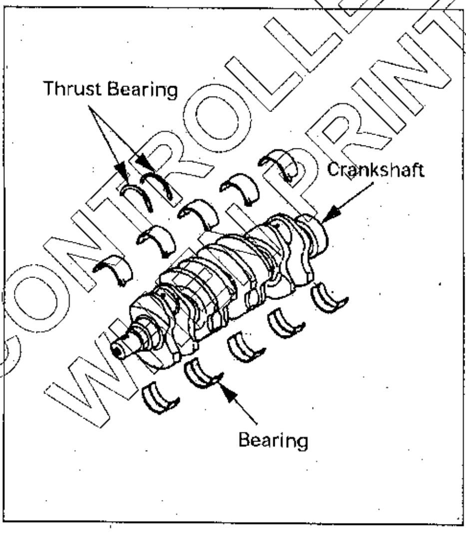
98 Note that there is an oil hole and an oil groove in the upper bearing (on the block side), but not in the lower bearing (on the bearing cap side).

99 Fit the bearing tang firmly into the slot machined on the cylinder body bearing arches.



Crankshaft and bearing

100 Lubricate the bearings with engine oil, install the crankshaft, install the thrust bearings with the groove facing the crankshaft.



Crankshaft bearing cap

101 Proceed as follows:

(1) Lubricate the bearing cap bolts with engine oil.

(2) Install the bearing caps to the crankshaft.

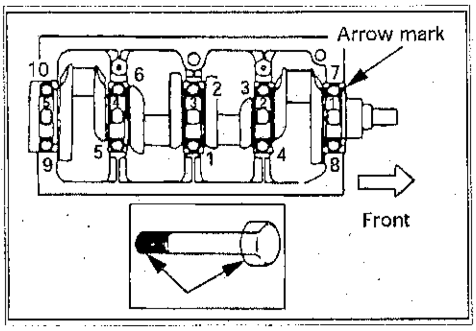
The arrow mark must be pointing to the front of the engine.

(3) Tighten the bearing cap bolts to the specified torque a little at a time in the numerical order shown in the illustration.

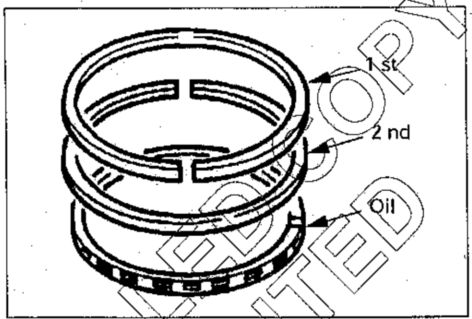
kg m (ft. lbs.)

Crankshaft bearing cap bolt tightening torque	8.5 – 9.5 (61.0 – 69.0)

(4) Check that the crankshaft turns smoothly by manually rotating it.



102 Position the rings as shown making sure the ring gaps are away from the thrust side.



Piston and connecting rod

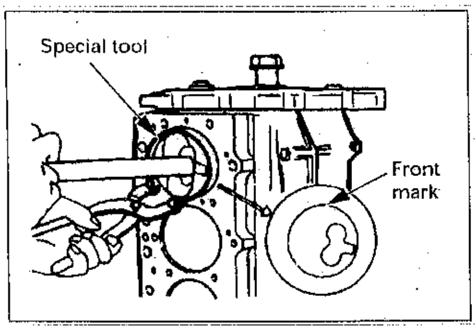
103 Lubricate the piston, the piston rings, and the connecting rod bearings with engine oil.

104 Position the piston front mark towards the front of the engine.

105 Use the piston ring compressor to compress the piston rings.

106 Use a hammer grip to push the piston in until it makes contact with the crank pin.

107 At the same time, rotate the crankshaft until the crankpin reaches its highest point.



108 Set the bearing cap cylinder number marks and the connecting rod cylinder number marks.

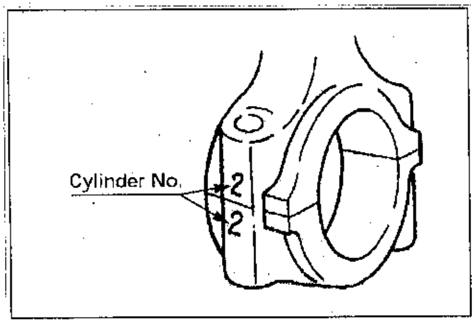
109 The marks must be facing the injection pump side.

kg m (ft.lbs.)

Tightening torque	4LE1	7.5 – 8.5 (54 - 61)

NOTE

After installation, confirm that the crankshaft rotates smoothly.



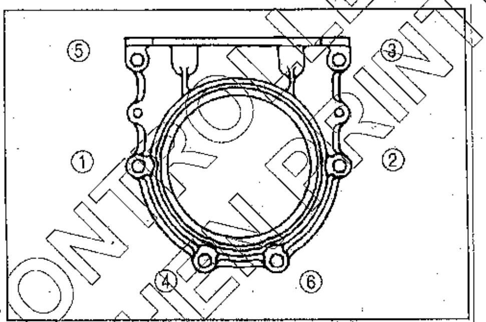
Installation of retainer

110 After applying engine oil to the lip of the oil seal, install the retainer. Apply sealant.

111 Tighten bolts on the retainer to the specified torque in the order as shown in the figure left.

kg m (ft. lbs.)

Retainer tightening torque	0.8 – 1.2 (6.0 – 9.0)



Camshaft assembly

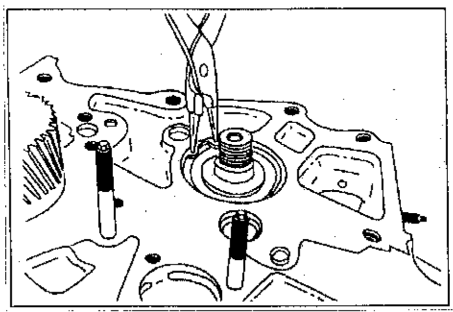
112 Proceed as follows:

(1) Apply engine oil to the inside of the bearing of the cylinder block, and then install the camshaft assembly.

NOTE

When installing the assembly, care should be taken not to damage the bearing.

(2) After installation of the snap ring to the outside of the front bearing, check to see if the camshaft rotates smoothly.



Cam gear and sleeve

113 Proceed as follows:

(1) Install the cam gear to the camshaft so that the timing point (a dot mark "·") comes to the front side.

(2) With the flyweight installed, tighten the cam gear with a lock nut.

kg m (ft. lbs.)

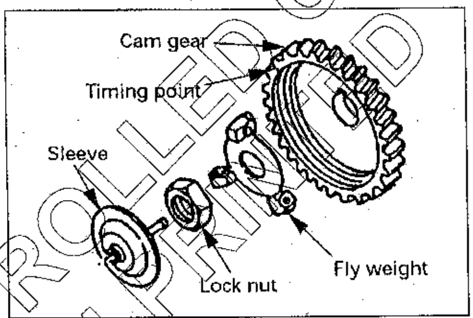
Cam gear tightening torque	7.0 – 9.0 (51.0 – 65.0)

(3) Apply engine oil to the shaft of the sleeve and the slide of the flyweight.

(4) With the lip of the sleeve placed in the cavity of the flyweight, insert the shaft of the sleeve into the tip end of the camshaft.

NOTE

Check to see if the sleeve moves smoothly.



Idle gear

114 Install the idler gear shaft with the oil hole facing up-ward.

115 Lubricate the shaft with oil.

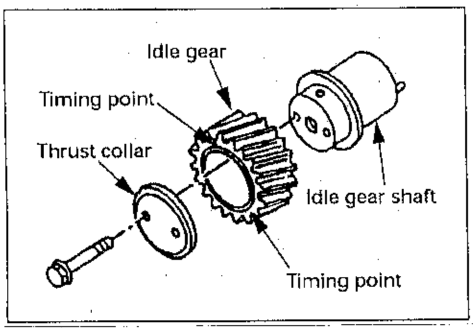
116 Install the idler gear.

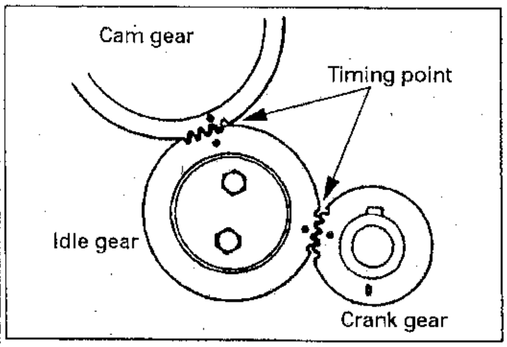
117 Align the timing marks as shown in the illustration.

118 Install the thrust collar and tighten the bolts to the specified torque.

kg m (ft. lbs.)

Thrust collar tightening torque	2.1 – 3.1 (15.2 – 22.4)





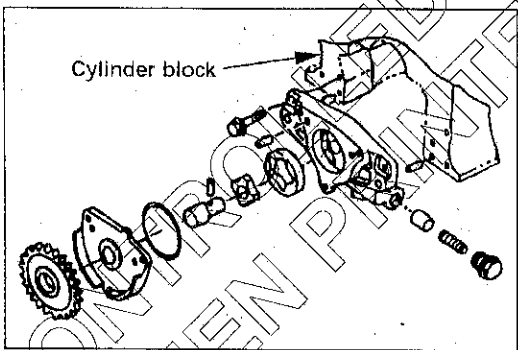
Oil pump assembly

119 Proceed as follows:

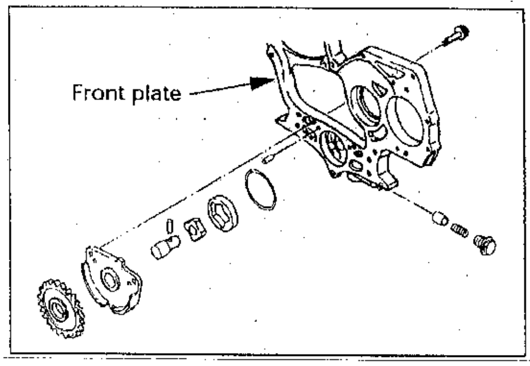
(1) When PTO is not provided, install the oil pump assembly to the cylinder block.

kg m (ft. lbs.)

Oil pump tightening torque	1.9 – 2.9 (14.0 – 21.0)



(2) When PTO is provided, install the oil pump to the front plate.



kg m (ft. lbs.)

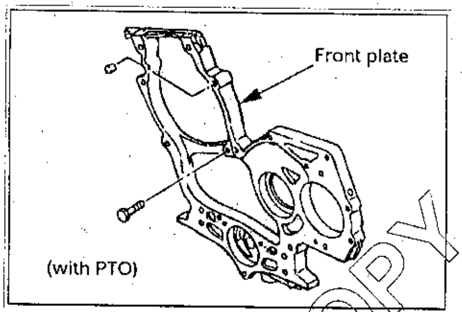
Oil pump tightening torque (PTO Provided)	0.8 – 1.2 (6.0 – 9.0)

Front plate (only for those provided with PTO)

120 Apply liquid gasket to the front plate incorporated with the oil pump before installing it to the cylinder block.

kg·m (ft. lbs.)

Front plate tightening torque	1.9 – 2.9 (14.0 – 21.0)



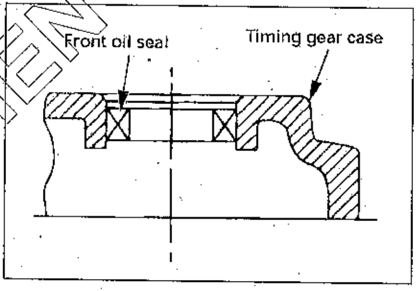
Front oil seal

121 Install the front oil seal to the timing gear case.

122 Installation is made according to the "L" dimension shown in the figure.

mm (in.)

	L dimension
PTO not provided	60.2 – 60.8 (2.370 – 2.384)
PTO provided	40.2 – 40.8 (1.582 – 1.606)



Timing gear case (with governor)

123 When not provided with PTO, install the timing gear case to the cylinder block. When provided with PTO, install it to the front plate.

(1) Put the link plate of the governor incorporated in the gear case through the connecting hole of the injection pump in advance.

(2) Apply engine oil to the bushes provided on both ends of the main spring lever of the governor.

(3) Apply sealant to the gear case, and then install it to the cylinder block or the front plate.

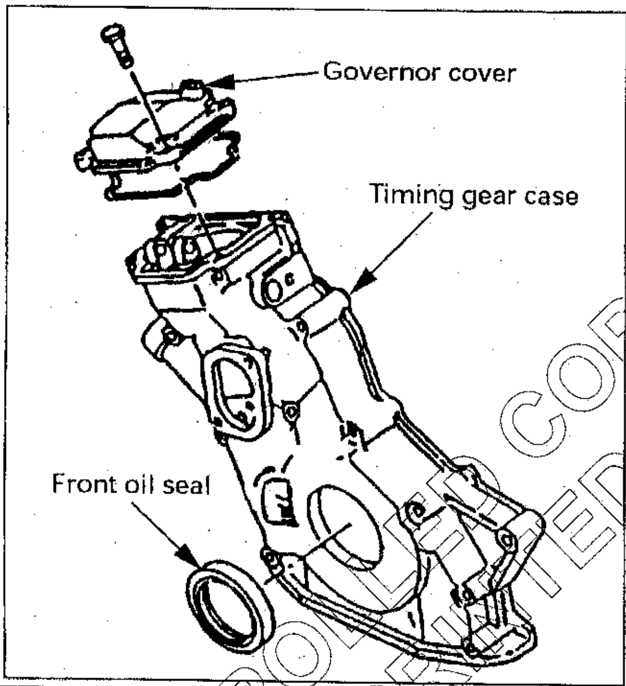
kg·m (ft. lbs.)

Case tightening torque	1.9 – 2.9 (14.0 – 21.0)

(4) Assemble the gasket and the governor cover to the top of the gear case, and then tighten them to the specified torque.

kg·m (ft. lbs.)

Cover tightening torque	0.8 – 1.2 (6.0 – 9.0)

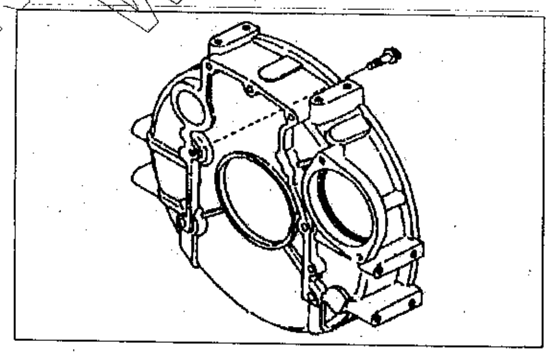


Flywheel housing

124 Install the flywheel housing to the cylinder body.

kg·m (ft. lbs.)

Flywheel housing tightening torque	4.2 – 5.6 (30.0 – 40.0)



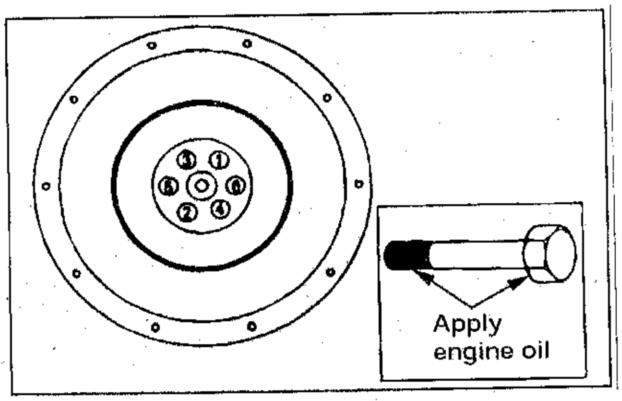
Flywheel

125 Lubricate bolts with engine oil.

126 Tighten a little at a time in the sequence shown in the illustration.

kg·m (ft. lbs.)

Flywheel tightening torque	9.0 – 11.0 (65.0 – 80.0)

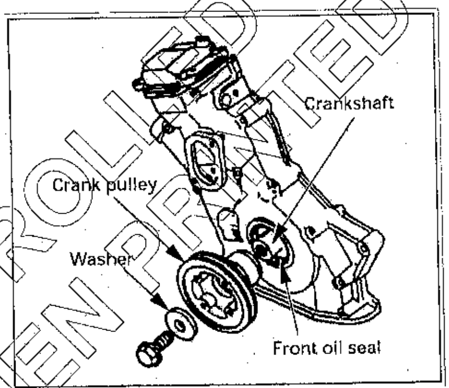


Crank pulley

127 Lubricate the lip of the front, seal with oil. Install the crank pulley, lock the crankshaft and tighten the front bolt.

kg·m (ft. lbs.)

Crank pulley tightening torque	17.0 – 19.0 (123.0 – 137.0)



Oil pipe and oil strainer

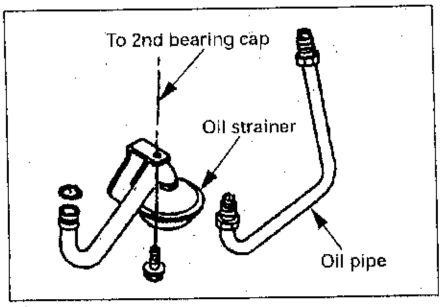
128 Proceed as follows:

(1) Install the oil pipe from the oil pump assembly to cylinder block and tighten the sleeve nuts.

(2) Install the oil strainer to the oil pump, and then tighten the bracket of the strainer to the No. 2 bearing cap.

kg·m (ft. lbs.).

Oil pipe and oil strainer tightening torque	1.9 – 2.9 (14.0 – 21.0)



Oil pan

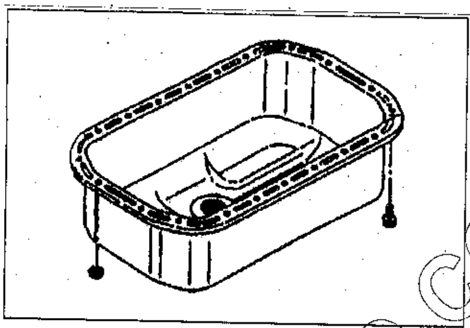
129 Proceed as follows:

(1) Apply sealant to the oil pan.

(2) Install the oil pan to the cylinder block and tighten fixing bolts evenly.

kg·m (ft. lbs.)

Oil pan tightening torque	0.8 – 1.2 (6.0 – 9.0)

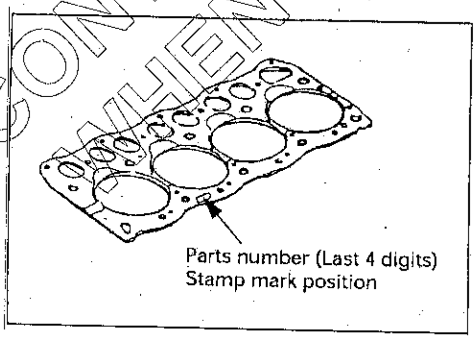


Tappet and head gasket

130 Proceed as follows:

(1) Install the tappet to the cylinder block.

(2) When installing the head gasket, turn up the stamp mark of the parts number (last 4 digits) which is between the No. 2 and No. 3 cylinders of the gasket.



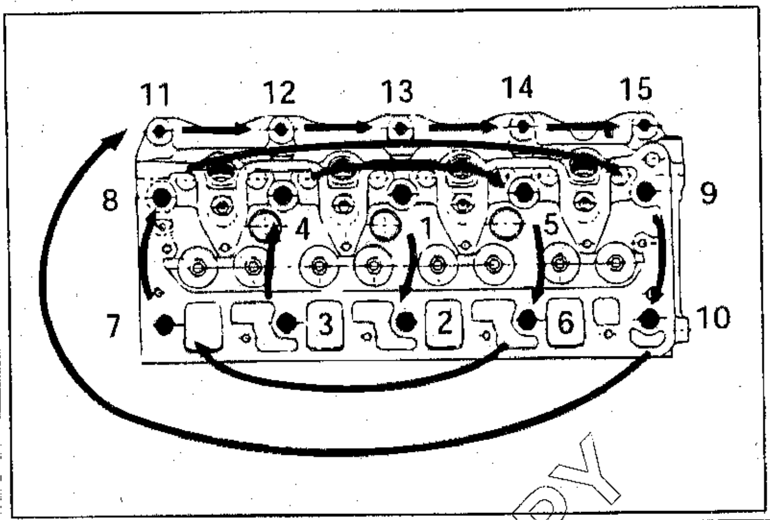
Cylinder head assembly

131 Lubricate the bolts with oil.

132 Tighten the bolts in the sequence shown in the illustration to the specified torque.

kg m (ft. lbs.)

Bolt size	Cylinder head assembly tightening torque	
M12 x 1.5 (8 each)	8.5 – 9.5 (61 - 69)	60° 90°
M8 x 1.25	2.5 – 3.5 (18 - 25)	



Push rod

133 Install the push rods.

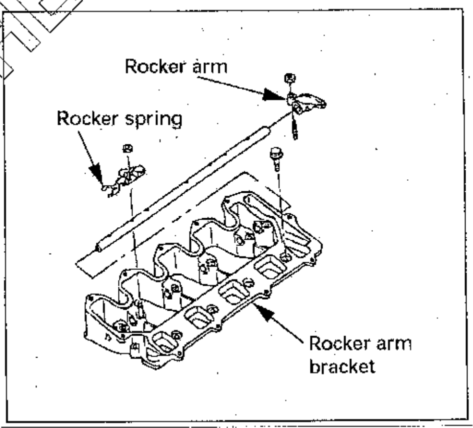
Rocker arm bracket assembly

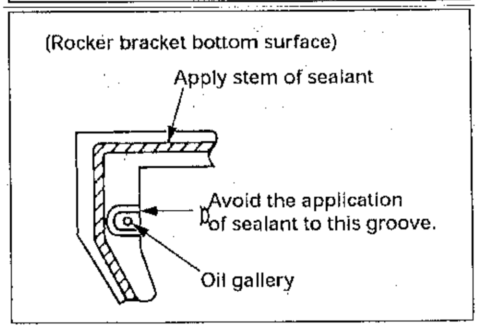
134 Apply liquid gasket to the bottom of the rocker arm bracket assembly, being careful not to get any in the groove around the oil galley as shown in the illustration.

135 Install the rocker arm bracket assembly making sure the push rods align with the rocker arms and tighten to the specified torque.

kg·m (ft. lbs.)

Rocker arm bracket assembly tightening torque	0.8 – 1.2 (6.0 – 9.0)





Adjustment of valve clearance

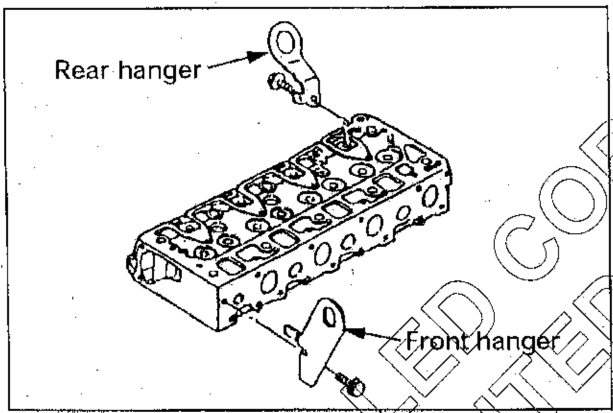
136 Refer to Page 20.

Front hanger and rear hanger

137 Tighten them to the specified torque shown below.

kg·m (ft. lbs.)

Front hanger and rear hanger tightening torque	1.9 – 2.9 (14.0 – 21.0)



REASSEMBLY OF EXTERNAL PARTS

External parts (right-hand side)

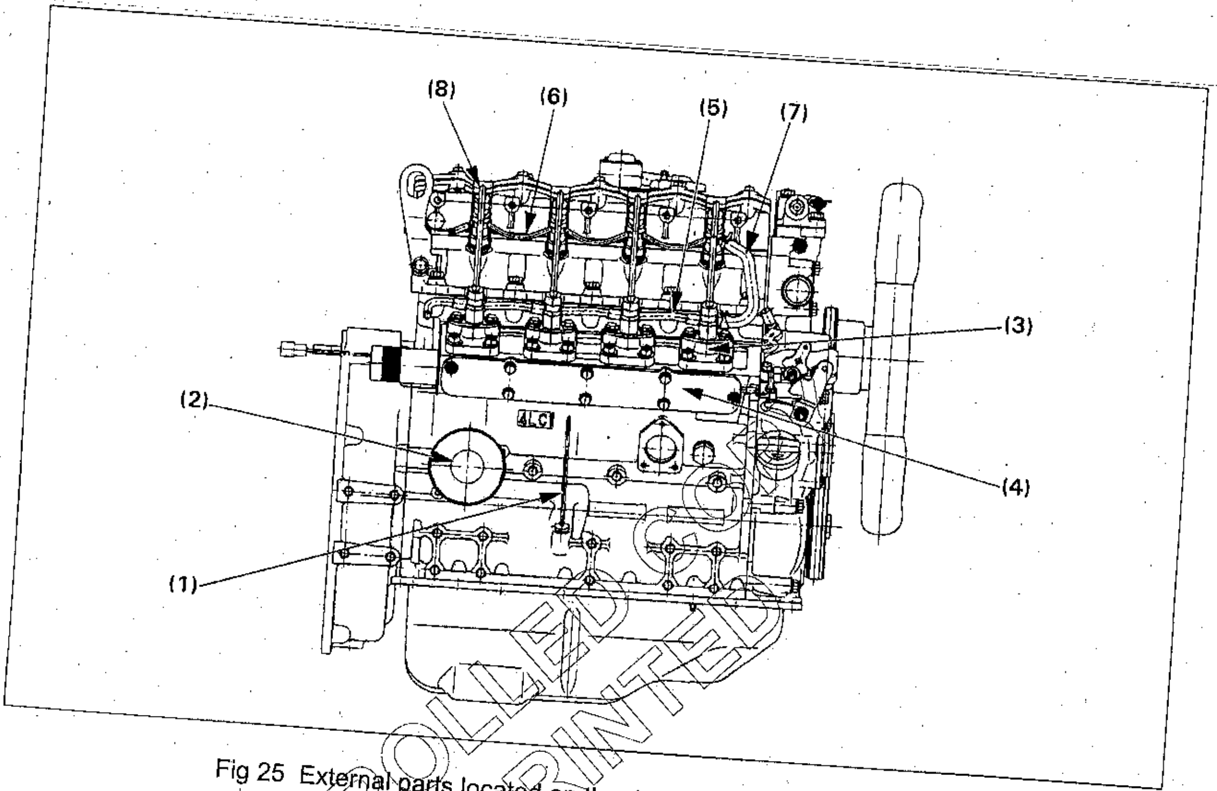


Fig 25 External parts located on the right-hand side of the engine

138 The following external parts are located on the right-hand side of the engine:

(1) Dipstick.

(2) Oil Filter.

(3) Injection Pump.

(4) Injection Pump Housing Cover.

(5) Fuel Pipe.

(6) Leak Off Pipe.

(7) Fuel Hose.

(8) Injection Pipe.

External parts (left-hand side)

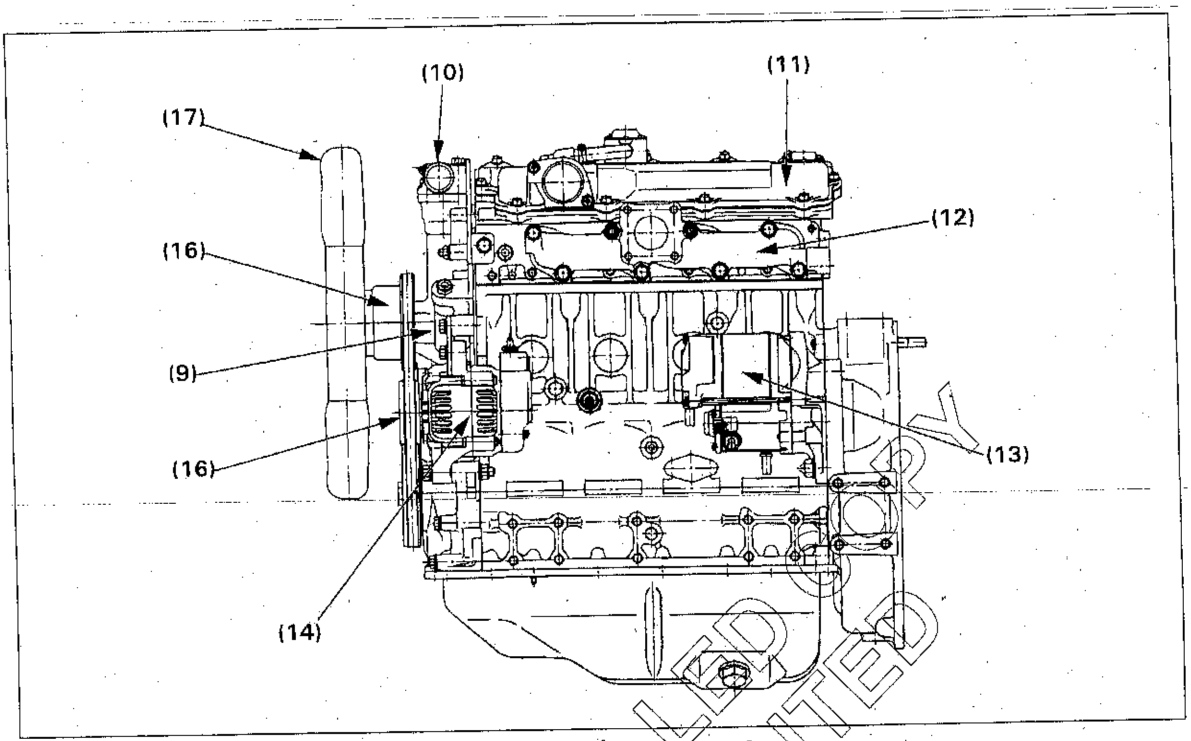


Fig 26 External parts located on the left-hand side of the engine

139 The following external parts are located on the left-hand side of the engine:

(9) Water Pump.

(10) Thermostat and Water Outlet Pipe.

(11) Cylinder Head Cover.

(12) Exhaust Manifold.

(13) Starter.

(14) Generator.

(15) Fan Pulley.

(16) Fan Belt.

(17) Cooling Fan.

Dipstick

Oil filter (cartridge)

140 Proceed as follows:

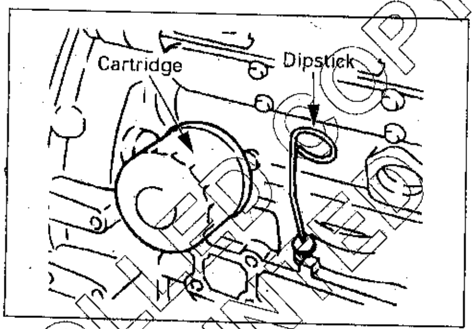
(1) Insert the dipstick.

(2) Install the cartridge with a filter wrench (commercially available).

a: Apply engine oil thinly to the gasket of the cartridge.

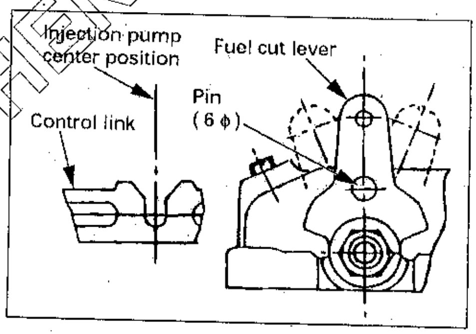
b. Screw in the cartridge until the gasket comes into contact with the seal, and then tighten it by giving it about 3/4 turns.

(Reference: Tightening torque 1.2 to 1.6 kg·m (8.6 – 11.6 ft. lbs.)

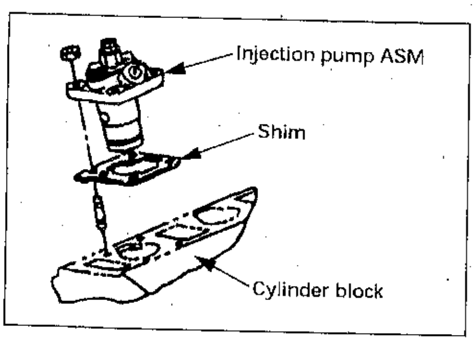


Injection pump

141 Align the two (2) holes in the fuel cut lever and the governor and lock into place with a pin. This will center and hold the control link for the installation of the injection pumps.



142 Install a new shim with the same thickness as the one that was removed. (Refer to the maintenance section on shim selection).

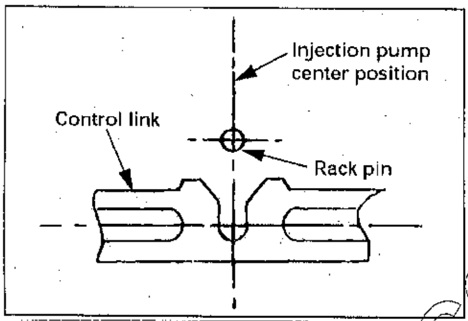


143 Install the injection pump making sure the rack pin is in the groove of the control rack before tightening the injection pump to the specified torque.

kg·m (ft. lbs.)

Injection pump tightening torque	1.9 – 2.9 (14.0 – 21.0)

144 Remove the rack pin (6ø) which is inserted into the fuel cut lever, and then confirm that the fuel cut lever moves smoothly.



Injection pump housing cover

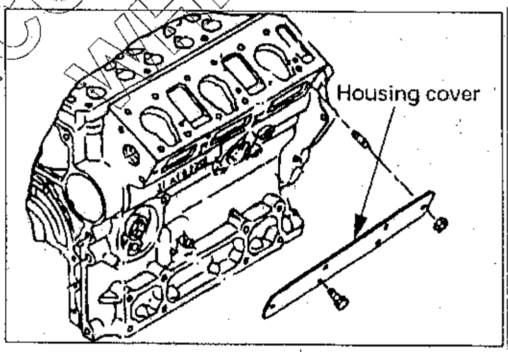
145 After applying sealant (TB1207C) to the housing cover, install it to the cylinder block by the side of the injection pump.

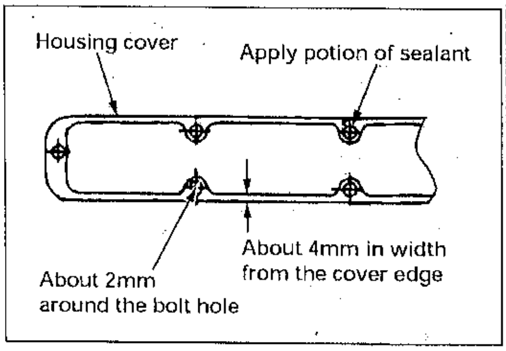
kg·m (ft. lbs.)

Injection pump housing tightening torque	0.8 – 1.2 (6.0 – 9.0)

NOTE

The areas of the housing cover to which liquid gasket is applied are about 4 mm in width from the cover edge and about 2 mm around the bolts.





Solenoid assembly

146 Proceed as follows:

(1) Apply sealant (TB1207C) to the surface (bite groove) in which the solenoid is installed.

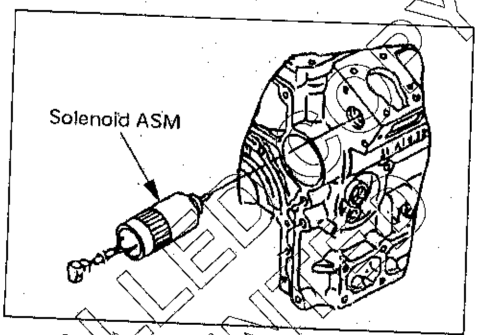
NOTE

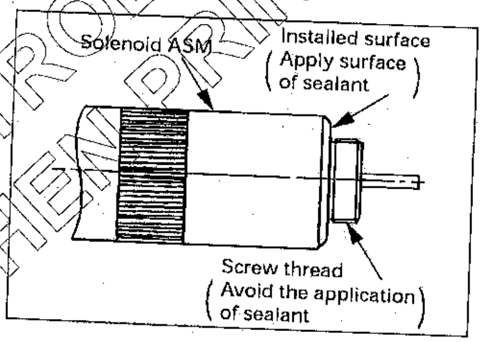
Avoid the application of sealant to the screw thread.

(2) Screw in the solenoid from the rear of the cylinder block (the rear of the No. 3 injection pump rack), and then tighten it to the specified torque.

kg·m (ft. lbs.)

Solenoid tightening torque	1.5 – 2.5 (11.0 – 18.0)





Fuel pipe

Leak off pipe

147 Proceed as follows:

(1) Install the fuel pipe to the injection pump and then tighten it to the specified torque.

(2) Install the leak off pipe to the nozzle holder and then tighten it to the specified torque.

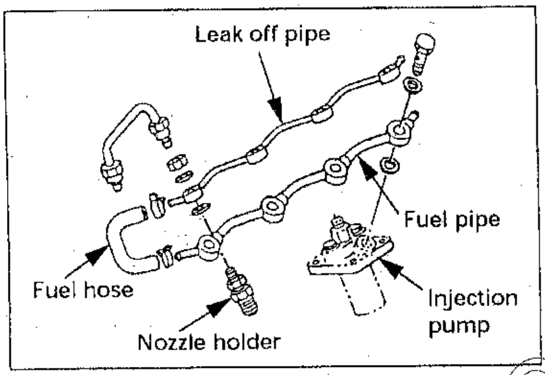
kg·m (ft. lbs.)

Fuel pipe and leak off pipe tightening torque	
Fuel pipe	2.0 – 2.5 (14.0 – 18.0)
Leak off pipe	2.5 – 3.5 (18.0 – 25.0)

NOTE

When tightening it, hold the pipe securely by hand so that it will not rotate.

(3) Connect the fuel pipe and the leak off pipe with the fuel hose and fix them with clips.



Injection pipe

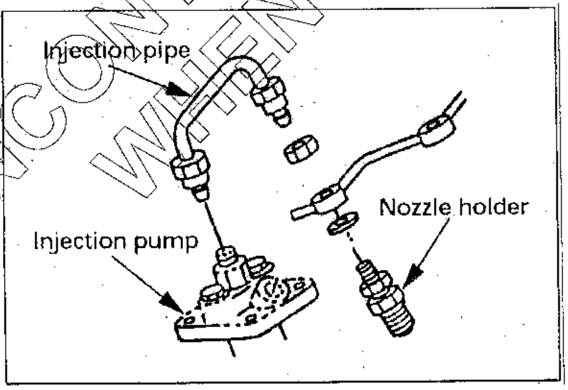
148 Install the injection pipe to the injection pump and the nozzle holder and tighten them up with sleeve nuts.

kg·m (ft. lbs.)

Injection pipe tightening torque	1.5 – 2.5 (11.0 – 18.0)

NOTE

Set the thread of the sleeve nut securely before tightening it up.



Water pump assembly

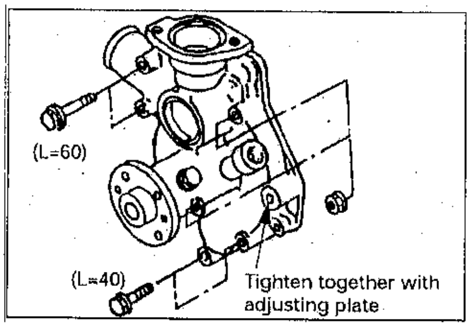
149 Proceed as follows:

(1) Put sealant on the water pump where it contacts the block and head.

(2) Tighten to the specified torque.

kg·m (ft. lbs.)

Water pump tightening torque	1.9 – 2.9 (14.0 – 21.0)



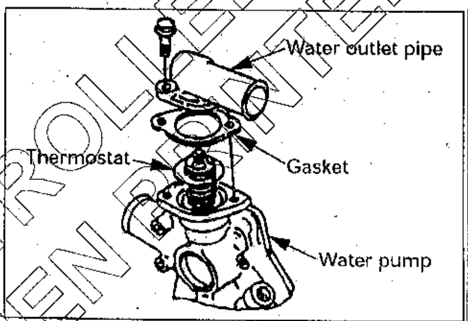
Thermostat

Water outlet pipe

150 Assemble the thermostat, install the gasket and the water outlet pipe, and then tighten it to the specified torque.

kg·m (ft. lbs.)

Water outlet pipe tightening torque	1.9 – 2.9 (14.0 – 21.0)



Adjustment of valve clearance

151 Refer to Section 1 "GENERAL INFORMATION – MAINTENANCE".

Cylinder head cover

152 Proceed as follows:

(1) Install the gasket to the cylinder head cover.

NOTES

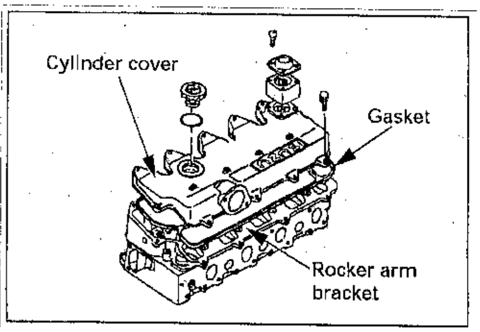
(1) Much care should be taken for the gasket not to get dislocated or twisted when installing the head cover.

(2) Avoid the application of sealant to the rubber gasket.

(2) Install the cylinder head cover to the rocker arm bracket, and tighten it to the specified torque.

kg·m (ft. lbs.)

Cylinder head cover tightening torque	0.2 – 0.4 (1.4 – 2.9)



Air inlet pipe

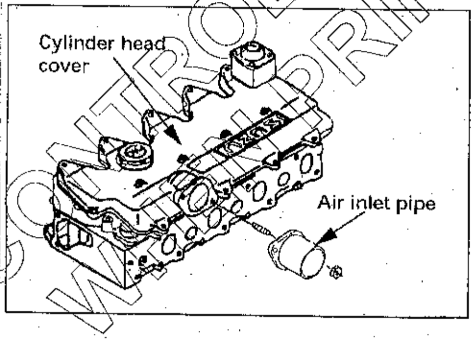
153 Proceed as follows:

(1) Apply sealant (TB1207C) to the surface in which the air inlet pipe is installed.

(2) Install the air inlet pipe to the cylinder head cover, and tighten it to the specified torque.

kg·m (ft. lbs.)

Air inlet pipe tightening torque	0.8 – 1.2 (6.0 – 9.0)

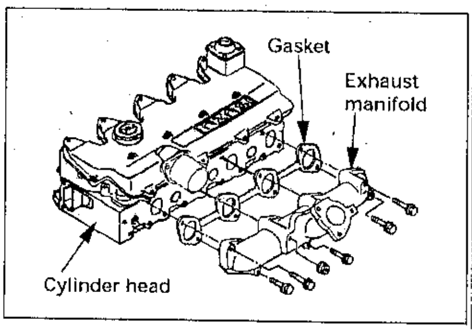


Exhaust manifold

154 Assemble the gasket to the cylinder head, install the exhaust manifold along the stud bolts and tighten it to the specified torque.

kg·m (ft. lbs.)

Exhaust manifold tightening torque	1.9 – 2.9 (14.0 – 21.0)

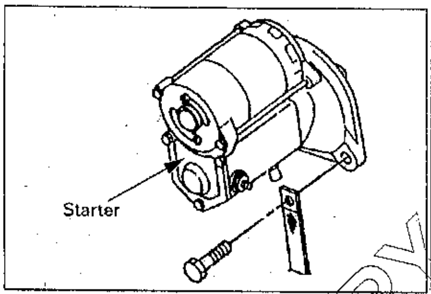


Starter

155 Install the starter to the flywheel housing, and tighten it to the specified torque.

kg·m (ft. lbs.)

Starter tightening torque	9.5 – 11.5 (68.7 – 83.2)



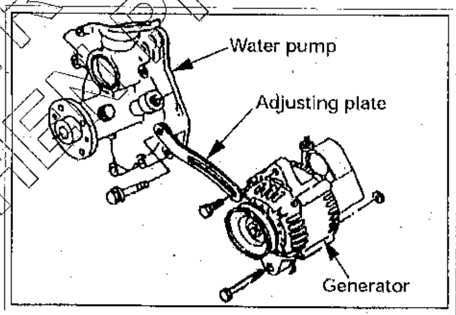
Generator

156 Proceed as follows:

(1) Tighten the adjust plate together with the water pump, and then install them temporarily.

(2) Install the bottom of the generator to the timing gear case, and then tighten it temporarily with bolts and nuts.

(3) Install the fixing bolts onto the top of the generator through the adjusting plate. (Temporary tightening.)

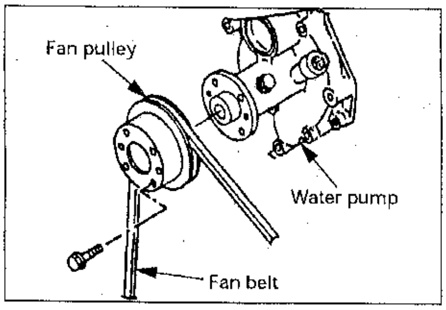


Fan pulley and fan belt

157 Proceed as follows:

(1) Install the fan pulley to the water pump and then tighten it up. (2 locations)

(2) Set the fan belt to each pulley.



Fan belt tension

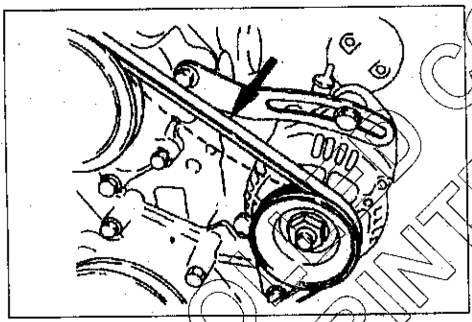
158 Adjust the alternator as specified and tighten to the specified torque.

mm (in.)

Deflection amount (Press the belt at its centre between the pulleys with 10 kg (22 lbs.) force.)	8 to 10 (0.315 – 0.3937)

kg·m (ft. lbs.)

Generator upper tightening torque	1.9 – 2.9 (14.0 – 21.0)
Generator lower tightening torque	3.5 – 4.7 (25.0 – 34.0)
Adjust plate tightening torque	1.9 – 2.9 (14.0 – 21.0)

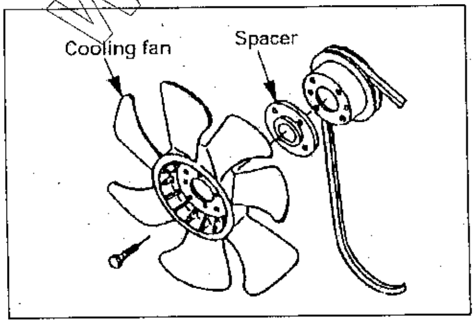


Cooling fan

159 Proceed as follows:

(1) Assemble the spacer before tightening the cooling fan.

(2) Tighten it to the specified torque. (4 locations.)



SECTION 3 - LUBRICATING SYSTEM

LUBRICATING OIL CIRCULATION DIAGRAM

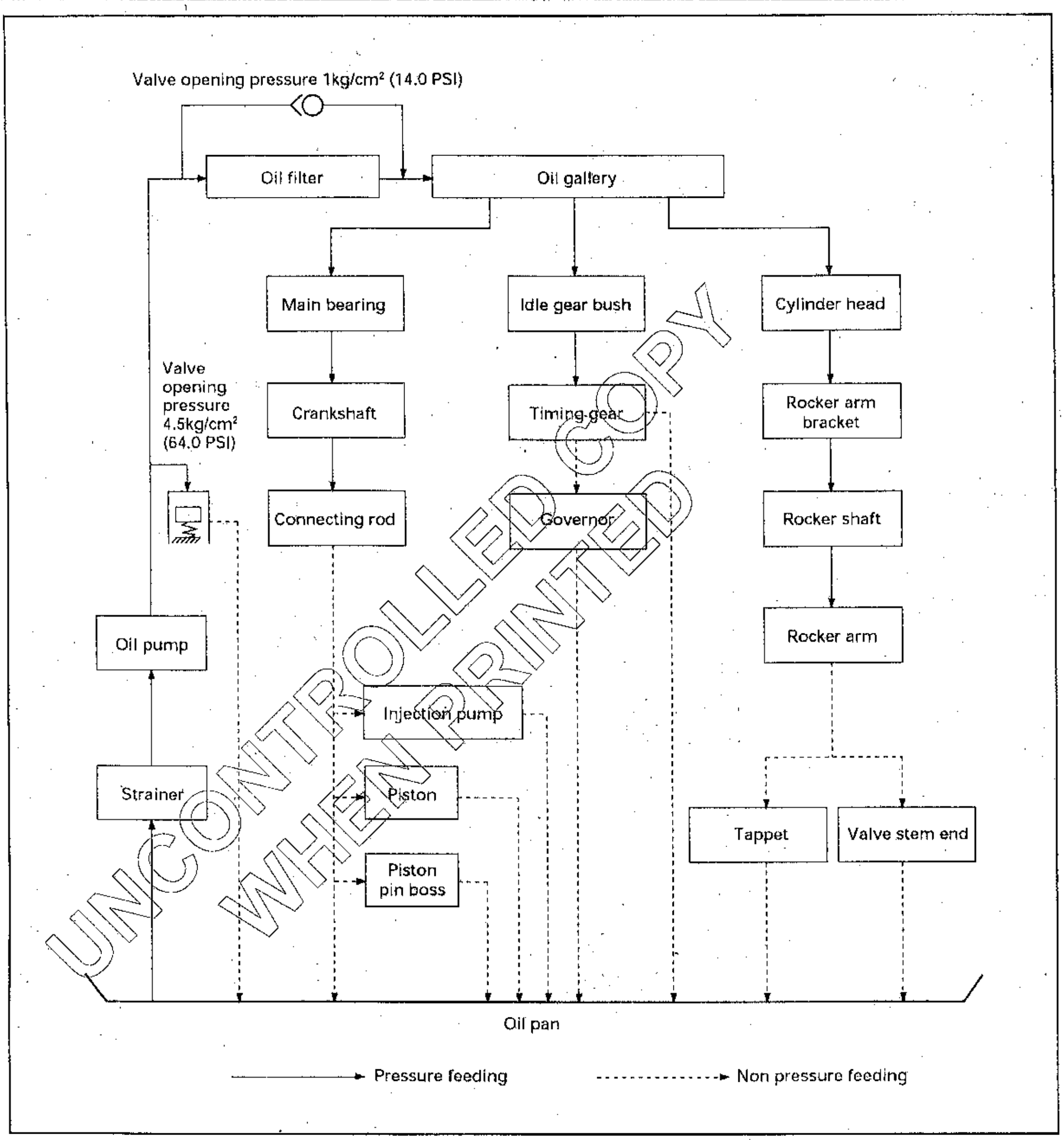


Fig 27 Lubricating oil circulation diagram

OIL PUMP

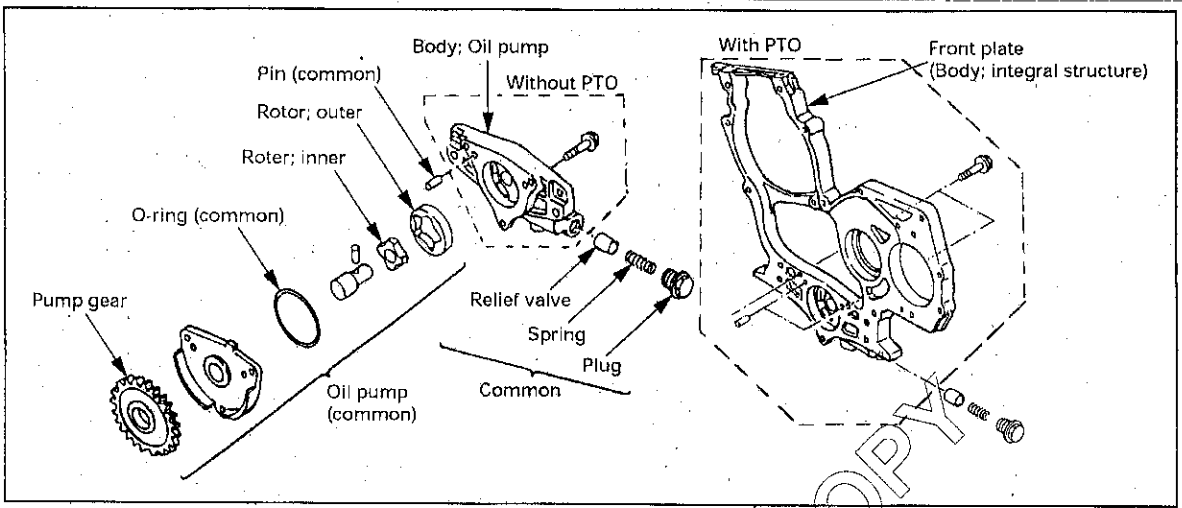


Fig 28 Oil pump exploded view

Inspection and replacement

160 When there is wear, damages or any other defects found, repair or replace the rotor.

(1) Clearance between the outer rotor or inner rotor and the pump cover:

mm (in.)

Standard	Limit
0.040 – 0.085 (0.0016 – 0.0033)	0.15 (0.0059)

(2) Clearance between the periphery of the outer rotor and the pump body:

mm (in.)

Standard	Limit
0.10 – 0.185 (0.0039 – 0.0073)	0.4 (0.0157)

(3) Clearance between the inner rotor and the outer rotor:

mm (in.)

Standard	Limit
0.17 (0.0067)	0.2 (0.0079)

SECTION 4 - COOLING SYSTEM

COOLING WATER CIRCULATION SYSTEM DIAGRAM

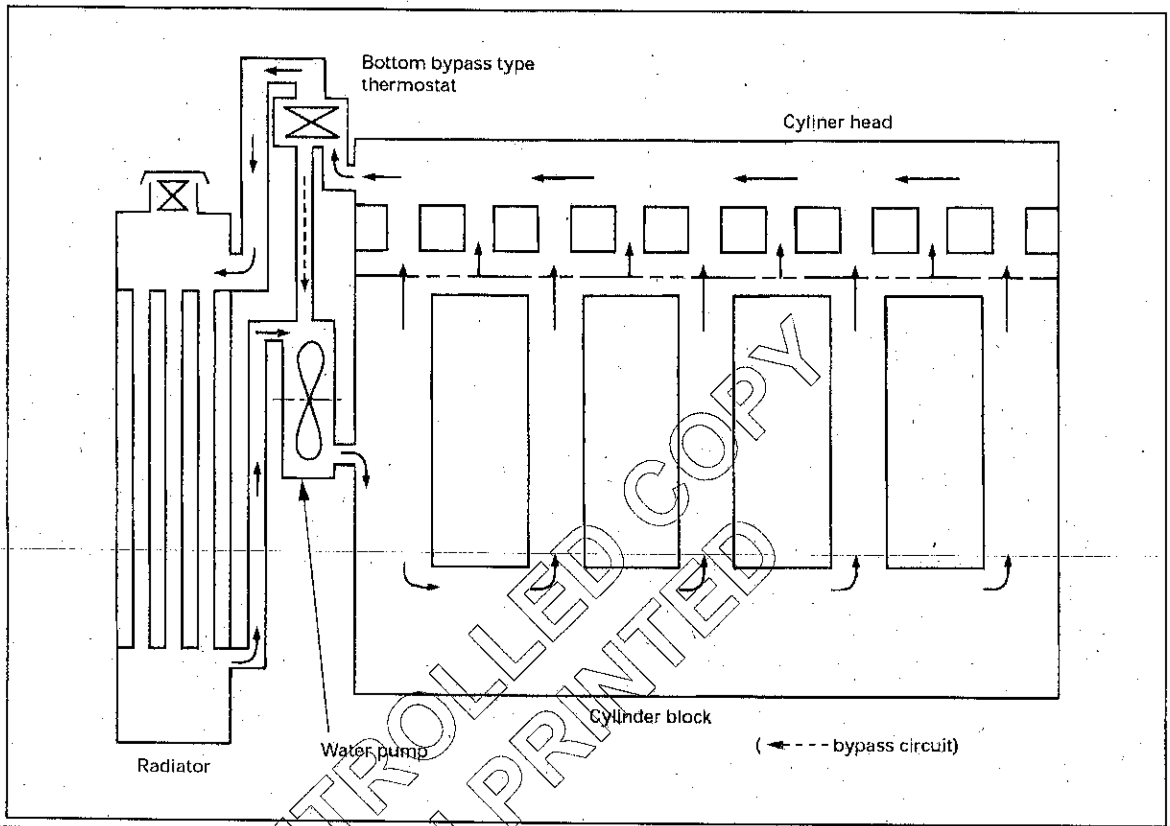


Fig 29 Cooling water circulation system diagram

WATER PUMP DISASSEMBLY

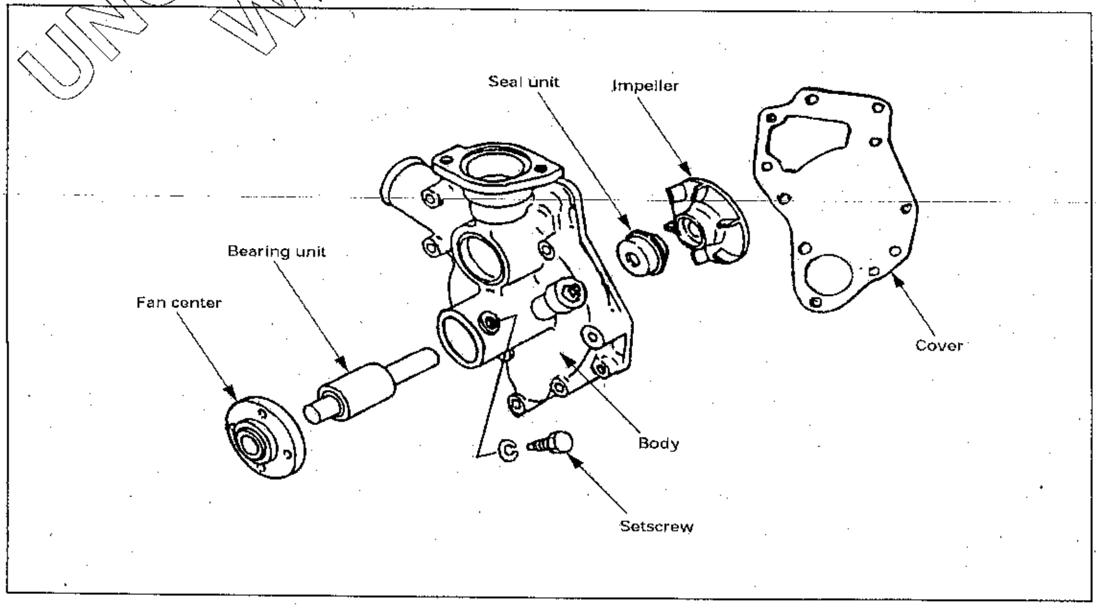


Fig 30 Water pump

Fan centre

Cover

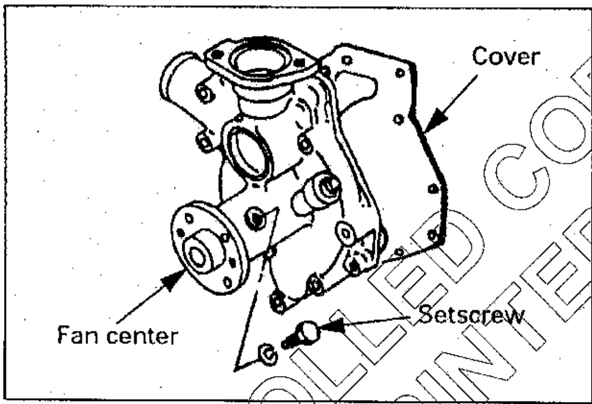
161 Proceed as follows:

(1) Loosen the set screw.

(2) Remove the cover.

NOTE

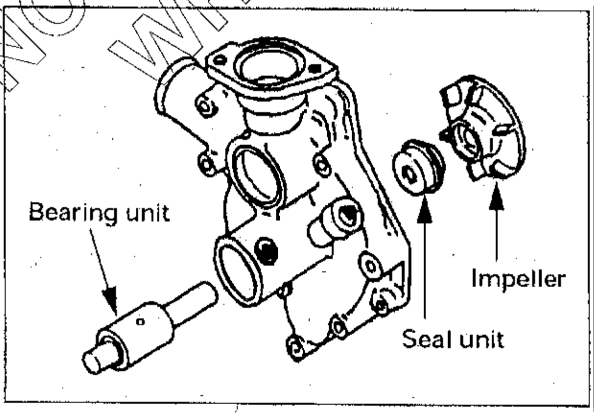
The cover is applied with sealant (TB1207B). When removing the cover, much care should be taken not to deform it by applying an excessive force to it.



Impeller

Seal unit

Bearing unit



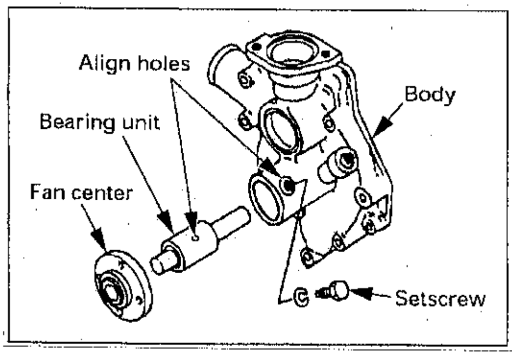
WATER PUMP REASSEMBLY

Bearing unit

162 With a hole in the bearing unit set in line with one in the body, lock the bearing unit with a setscrew.

kg·m (ft. lbs.)

Set screw tightening torque	0.8 – 1.2 (6.0 – 9.0)



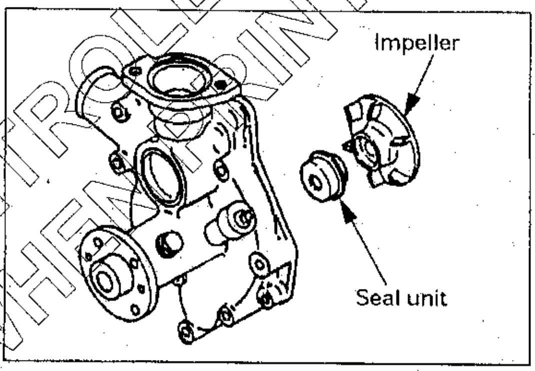
Seal unit

Impeller

163 Proceed as follows:

(1) Apply BELCO bond No. 4 to the surface where the seal unit comes into contact with the body, and then assemble the seal unit.

(2) Press in the impeller with a press until the clearance between the pump impeller and the body gets to the specified value.

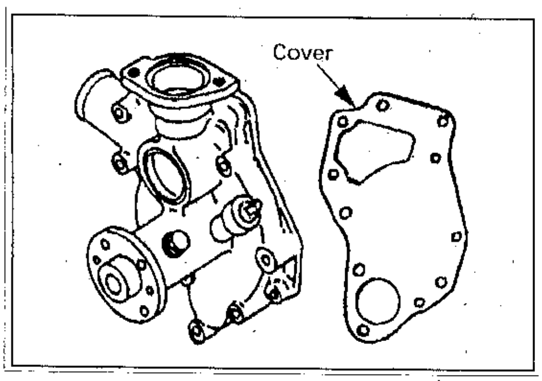


Cover

164 Proceed as follows:

(1) Apply liquid gasket to the surface to which the cover is installed, and then install the cover.

(2) Apply Screw-lock to the cover installation screws, and then tighten them.



Clearance, play and tightening allowance between parts

165 Proceed as follows:

(1) Clearance between the pump impeller and the body.

mm (in.)

Standard	0.53 – 2.17 (0.0209 – 0.0854)

(2) Play in the water pump ball bearing.

mm (in.)

Standard	Limit
0.008 – 0.010 (0.0003 – 0.0004)	0.2 (0.0079)

(3) Tightening allowance between the fan center and the bearing shaft.

mm (in.)

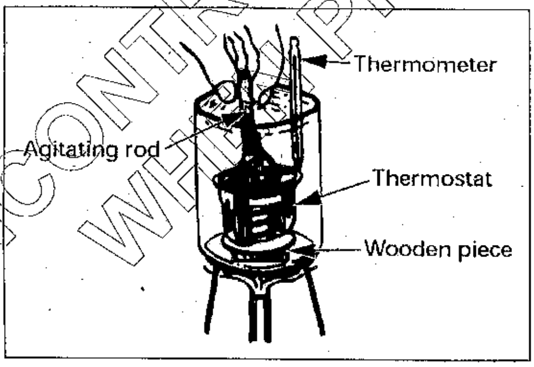
Standard	0.026 – 0.061 (0.001 – 0.0024)

THERMOSTAT

Inspection and replacement

166 Replace the thermostat when there is wear, damages or any other defects found.

Opening temp.	74.5 – 78.5°C (166 – 174°F)
Valve lift mm (in.)	8 mm or more at 90°C (0.315 inch or more at 194°F)



SECTION 5 - FUEL SYSTEM

FUEL CIRCULATION SYSTEM DIAGRAM

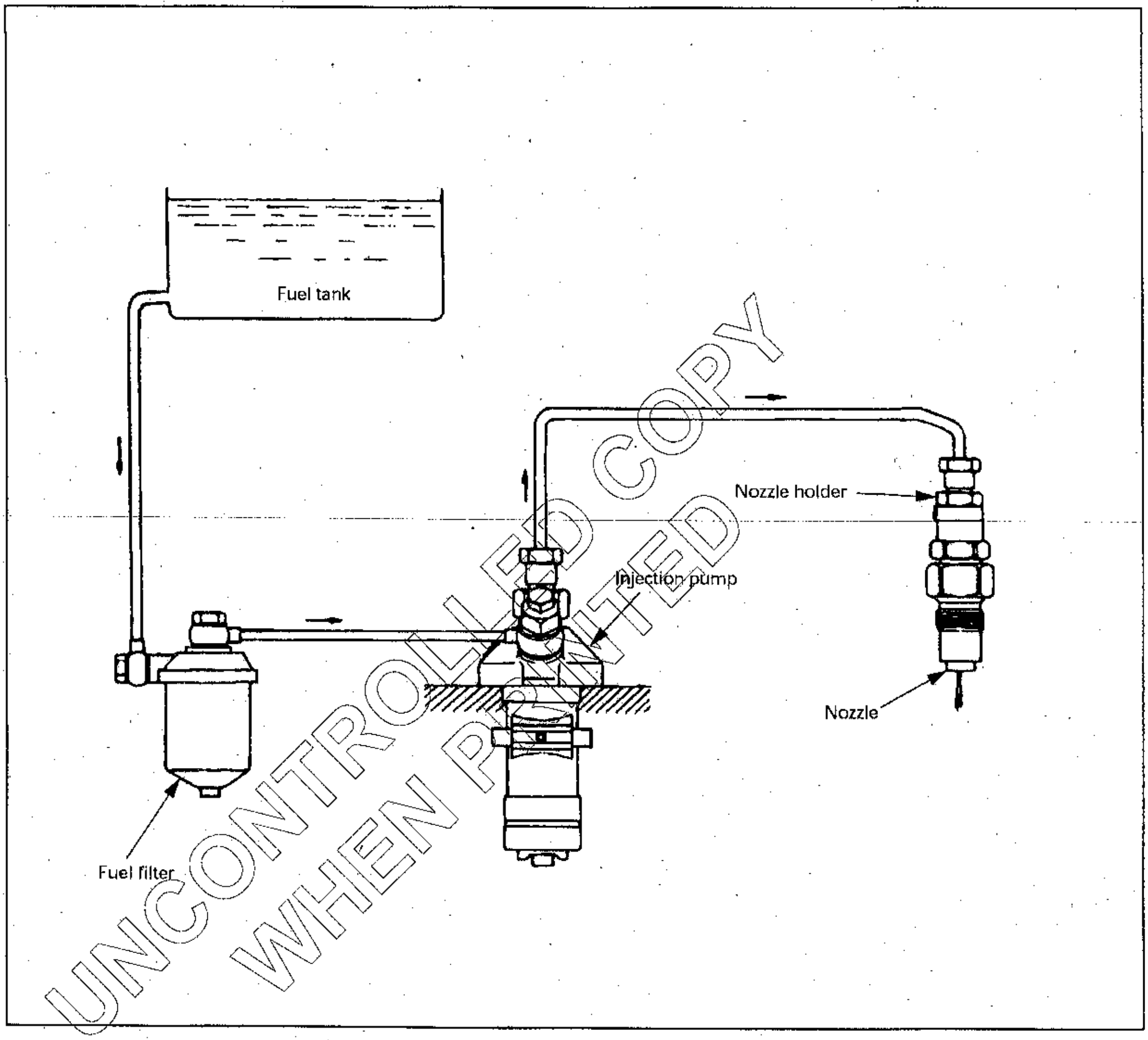


Fig 31 Fuel circulation system diagram

GOVERNOR

167 Proceed as follows:

(1) The adjustments of the governor-related parts require the engine performance test.

(2) Before disassembling the governor, measure the dimensions "A" and "B" given in the structural drawing to ensure the same dimensions in reassembly.

(3) Do not disassemble the governor when the performance test cannot be conducted after reassembly.

STRUCTURAL DRAWING OF GOVERNOR (1)

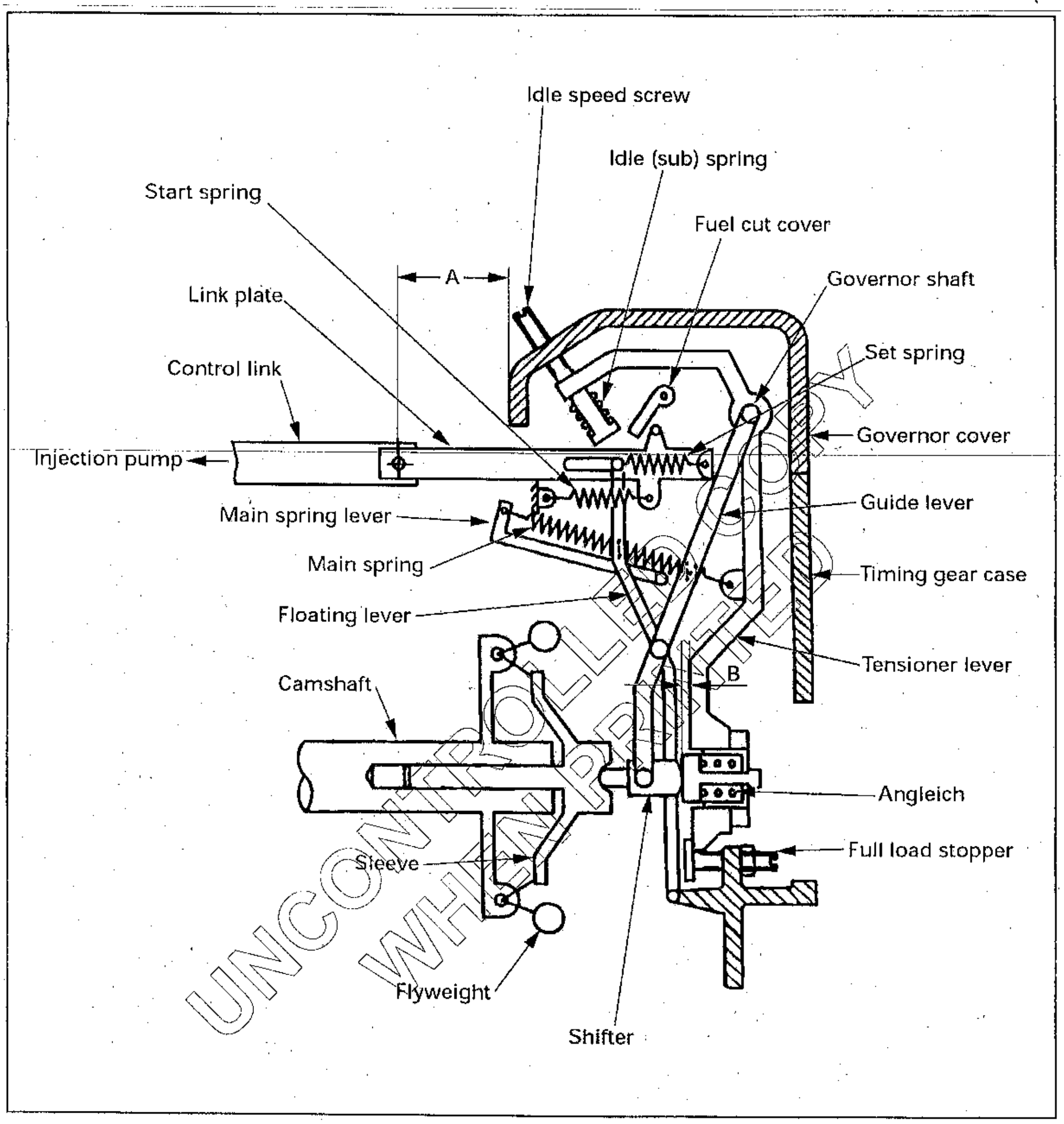


Fig 32 Structural drawing of governor (1)

STRUCTURAL DRAWING OF GOVERNOR (2)

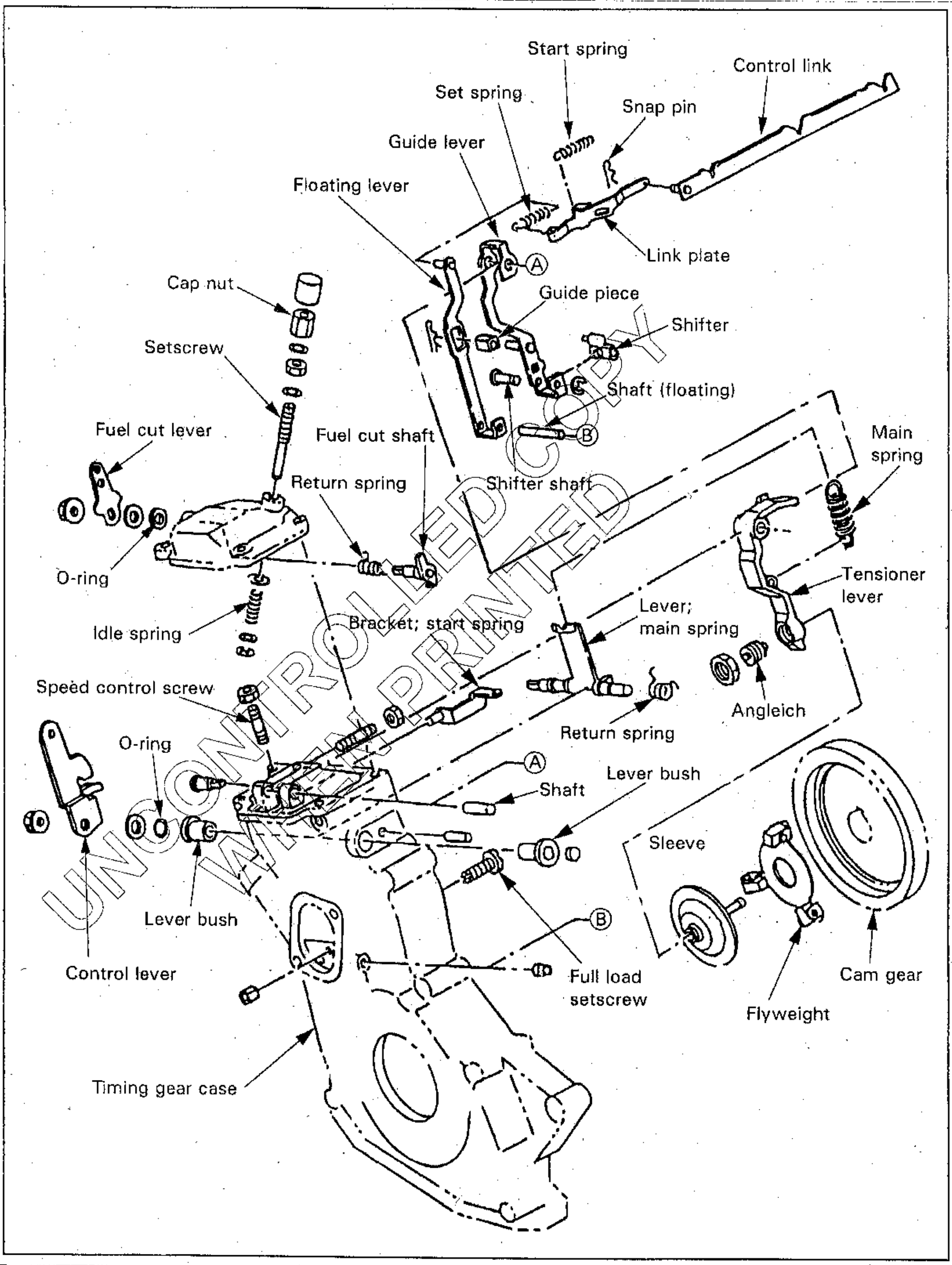


Fig 33 Structural drawing of governor (2)

REASSEMBLY OF CONTROL LEVER RELATED PARTS

168 Proceed as follows:

(1) Put the lever (main spring) through the hole of the timing gear case lever.

NOTE

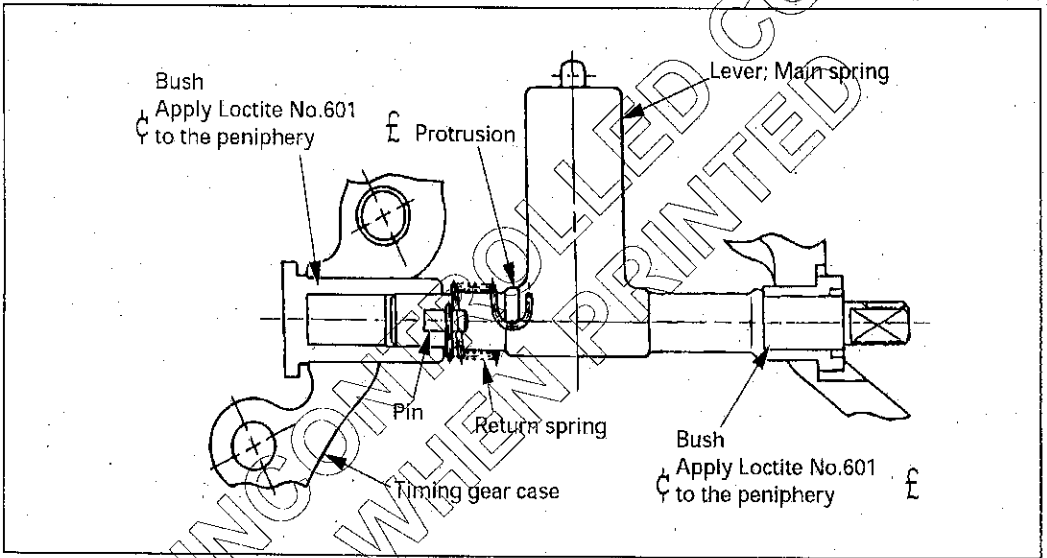
Before hammering in the bushes, put both shafts of the lever through the holes of the timing gear case lever respectively.

(2) Put the return spring of the control lever through the shaft of the lever (main spring).

(3) Assemble the bushes. Assemble the bush of the lever (main spring) first, and then the control lever bush.

NOTE

When assembling the bushes, apply Loctite (#601) to the periphery of the bushes.

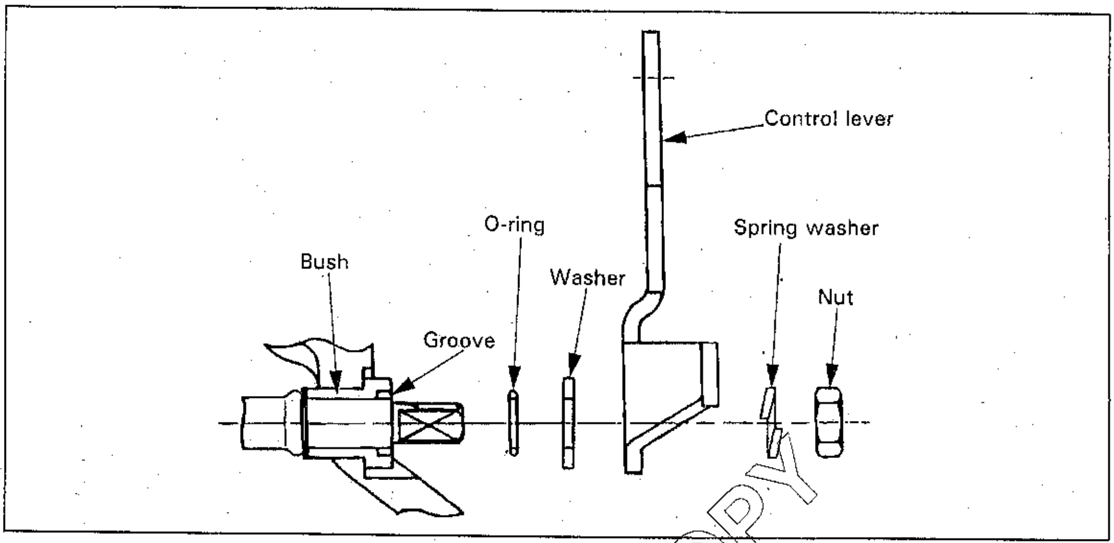


(4) Hook both ends of the return spring (control lever) securely to the protrusion and the pin of the lever (main spring) respectively.

(5) Assemble the control lever. Assemble the O-ring to the groove of the bushes (control lever) first, and then assemble the washers and the control lever before tightening up the control lever with a nut.

kg·m (ft. lbs.)

Control lever tightening torque	1.2 – 1.8 (9.0 – 13.0)



NOTES

(1) Tighten the control lever after locking the control lever firmly. (Do not tighten the control lever after locking the main spring lever.)

(2) After assembly, confirm that the control lever moves smoothly.

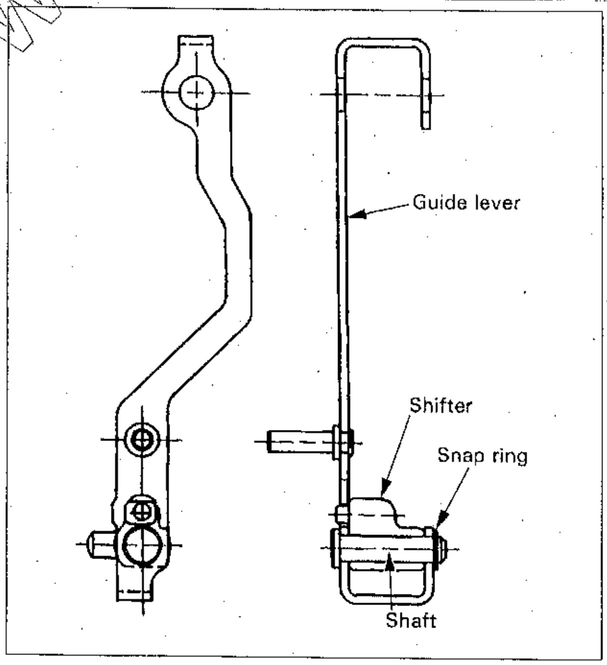
Reassembly of shifter

169 Proceed as follows:

(1) Assemble the shifter to the guide lever, put the shaft through it, and then assemble the snap ring.

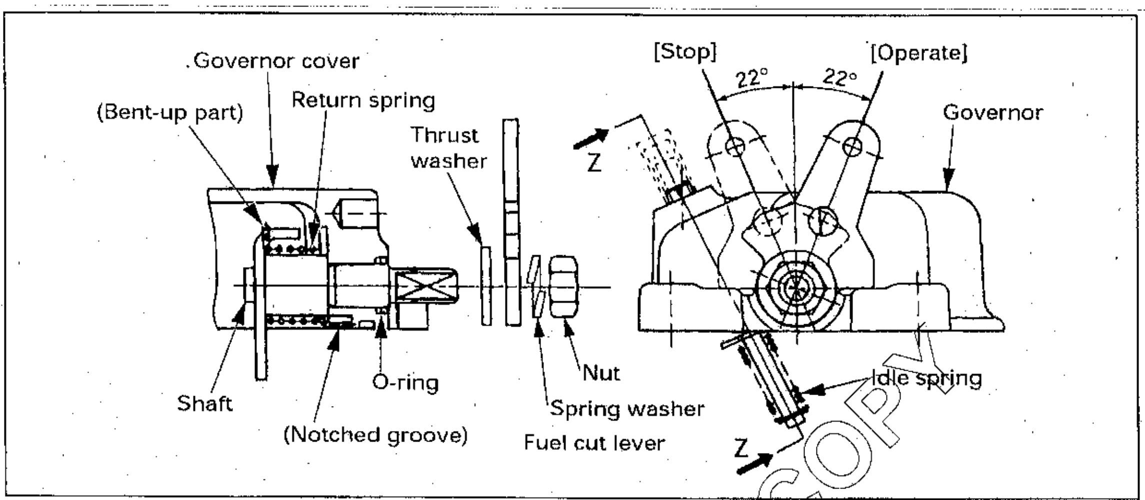
(2) After assembly, confirm that the shaft moves smoothly.

(3) Also, confirm that the shifter shakes smoothly.



Reassembly of governor cover

170 Assemble the related parts such as the fuel cut lever and the idle spring to the governor cover.



(1) When assembling the shaft, apply engine oil to the sliding portion with the governor cover.

(2) Set both ends of the return spring securely to the notched groove at the bottom of the cover and the bent-up arm of the lever respectively.

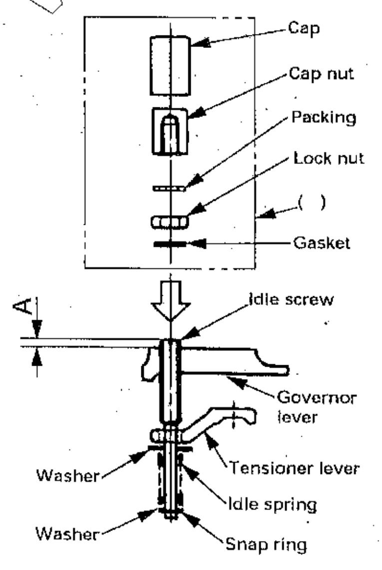
(3) After reassembling the governor cover, confirm that the governor moves smoothly.

(4) When assembling the timing gear case to the governor cover, tighten the "A" dimension shown in the illustration to 2 – 3 mm temporarily.

The parts given in the square indicated by ( ) are assembled after performance test.

mm (in.)

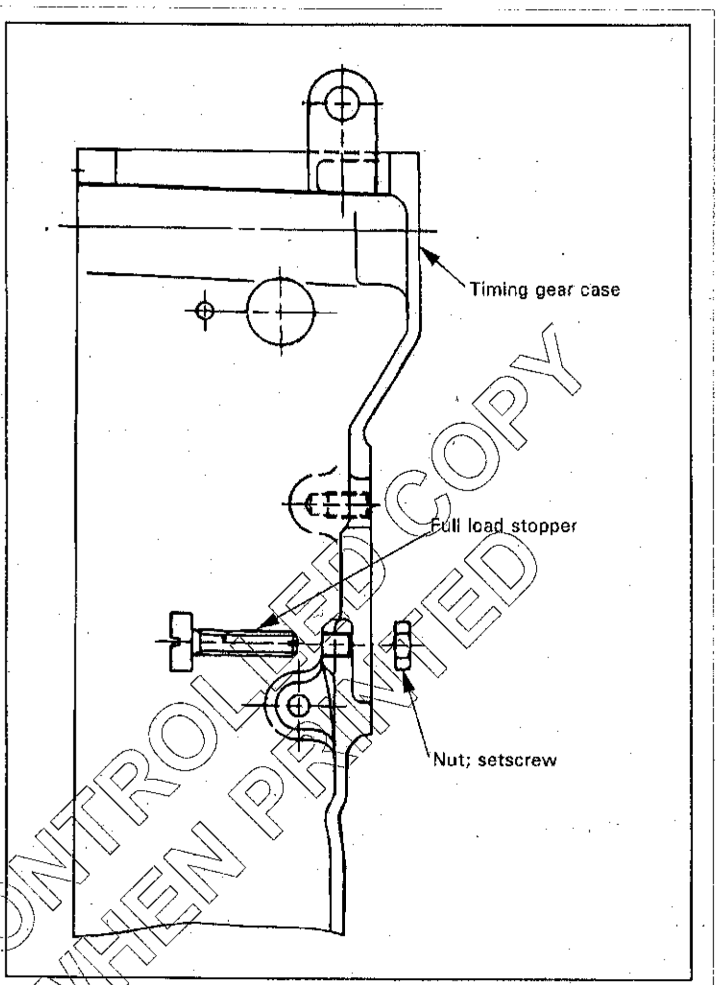
"A" dimension	(When assembling temporarily) 2 – 3 (0.0787 – 0.0118)



(Z view of the drawing above)

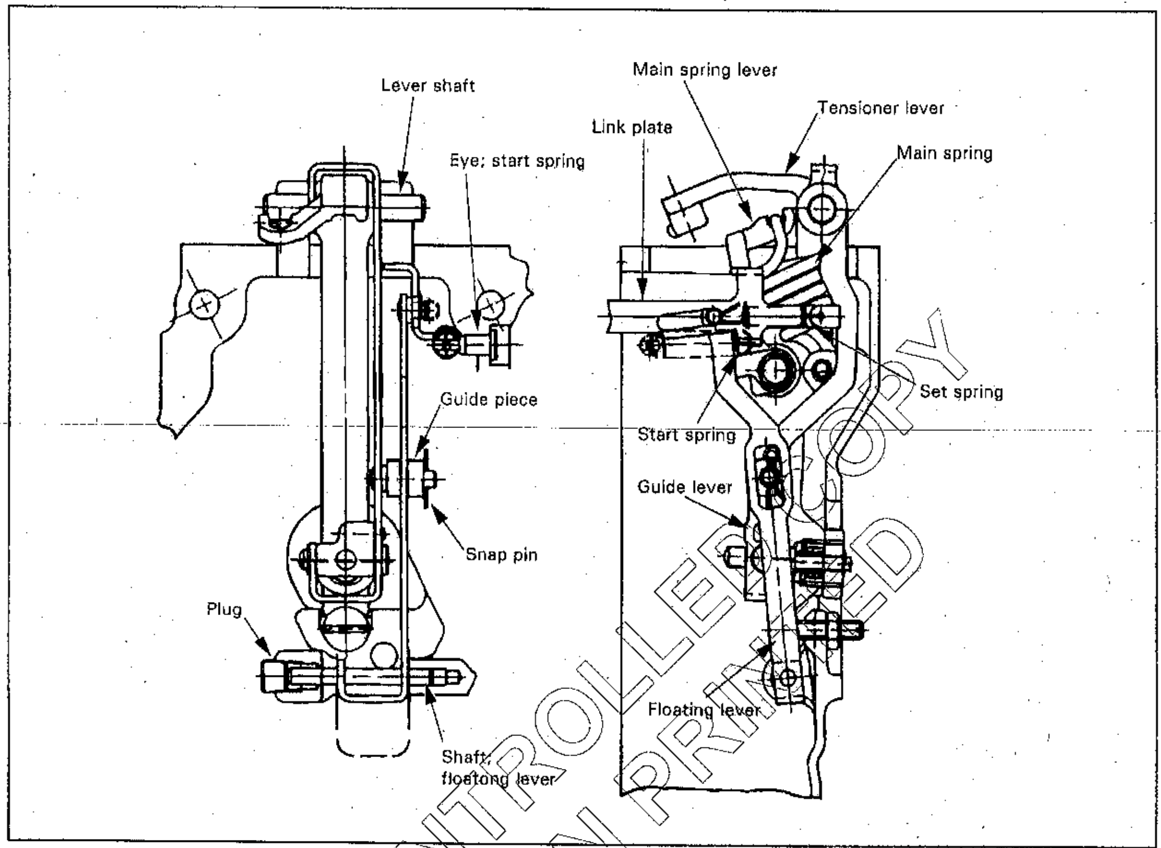
Reassembly of full-load stopper

171 Install the full-load stopper to the timing gear case, and then tighten it with a nut temporarily.



Reassembly of governor lever related components

172 Assemble each lever and spring to the timing gear case.



Notes when assembling governor related components

173 Proceed as follows:

(1) When assembling components, apply engine oil to each slide (such as the end face of the lever, the hole in the shaft, and the periphery of the shaft).

(2) Install the set spring securely to the groove of the pin connecting the floating lever, taking care with the assembling direction.

(3) Confirm that each lever moves by its dead weight before installing the start spring.

(4) After assembly, confirm that each lever moves smoothly. Also confirm that each spring operates properly.

NOZZLE HOLDER ASSEMBLY

DISASSEMBLY

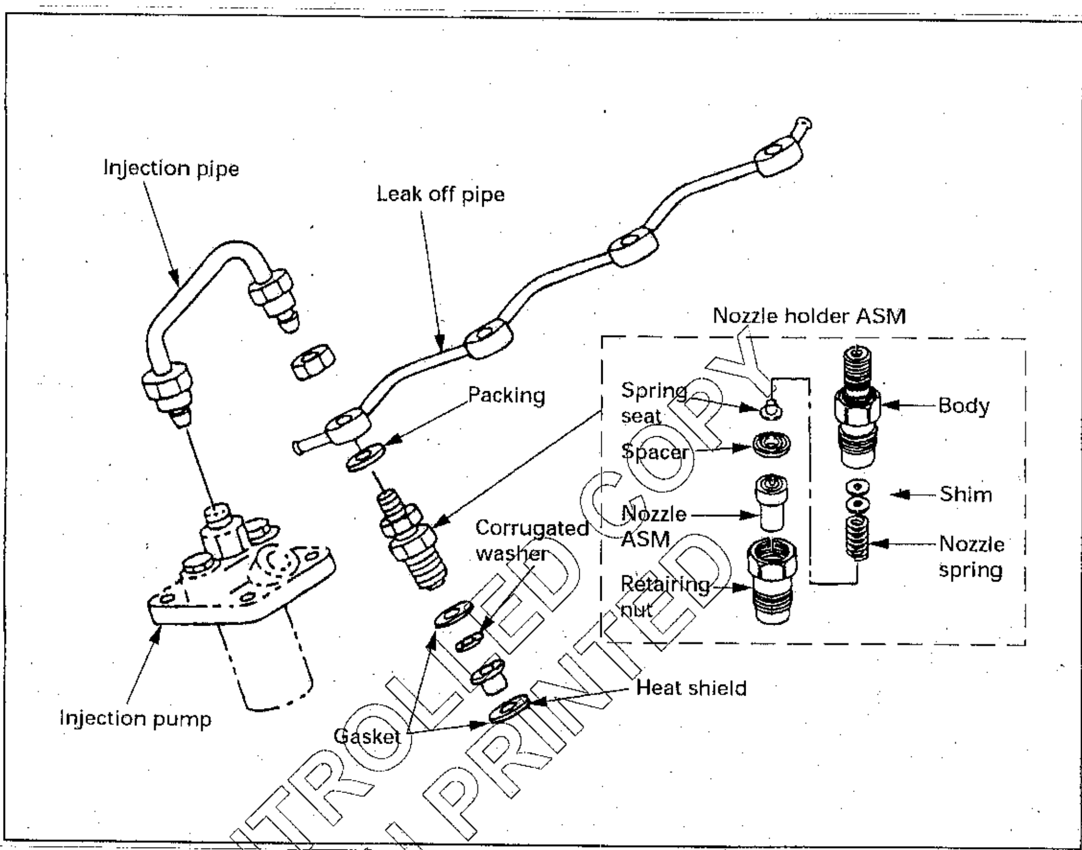


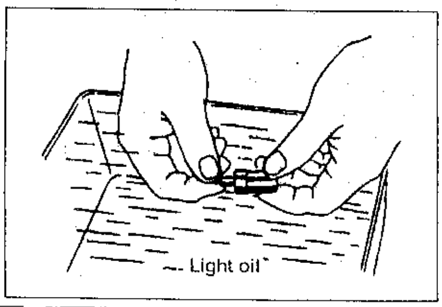
Fig 34 Nozzle holder assembly

NOZZLE ASSEMBLY

Inspection and replacement

174 Place the removed nozzle in the clean light oil, disassemble it into the nozzle body and the needle valve and clean them thoroughly. Then check to see if the valve moves smoothly in the body.

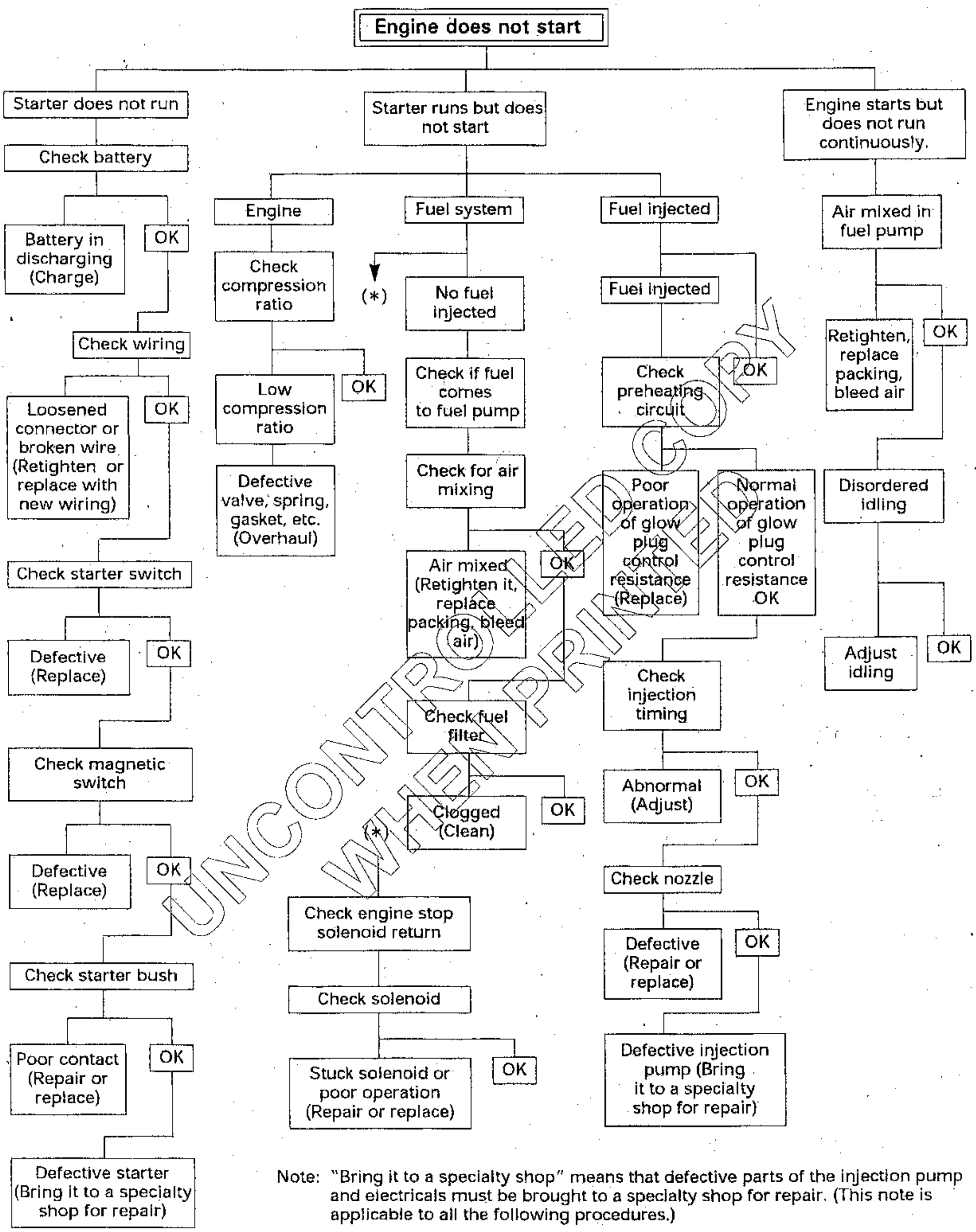
175 When it does not move smoothly, repair or replace the nozzle.



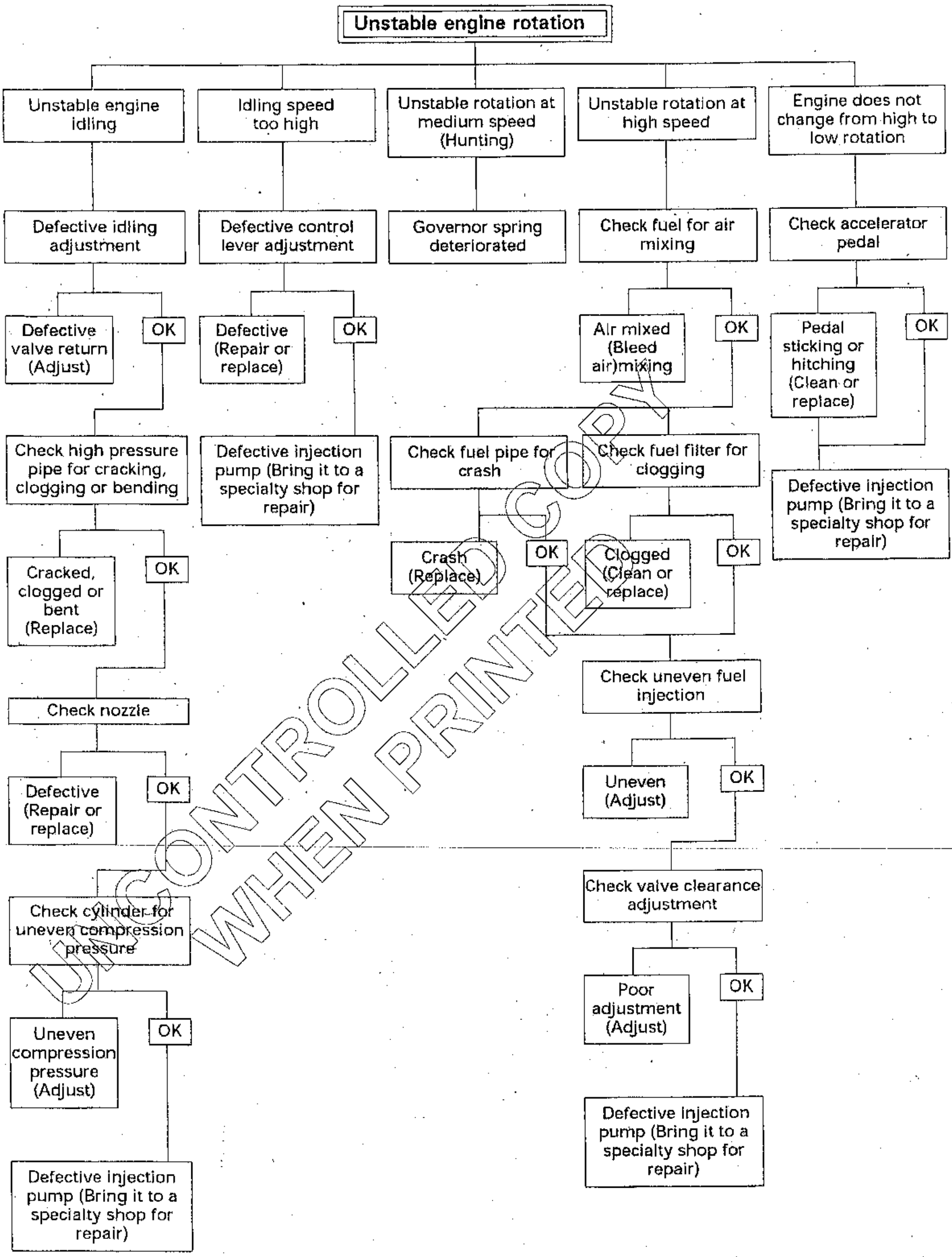
Adjustment

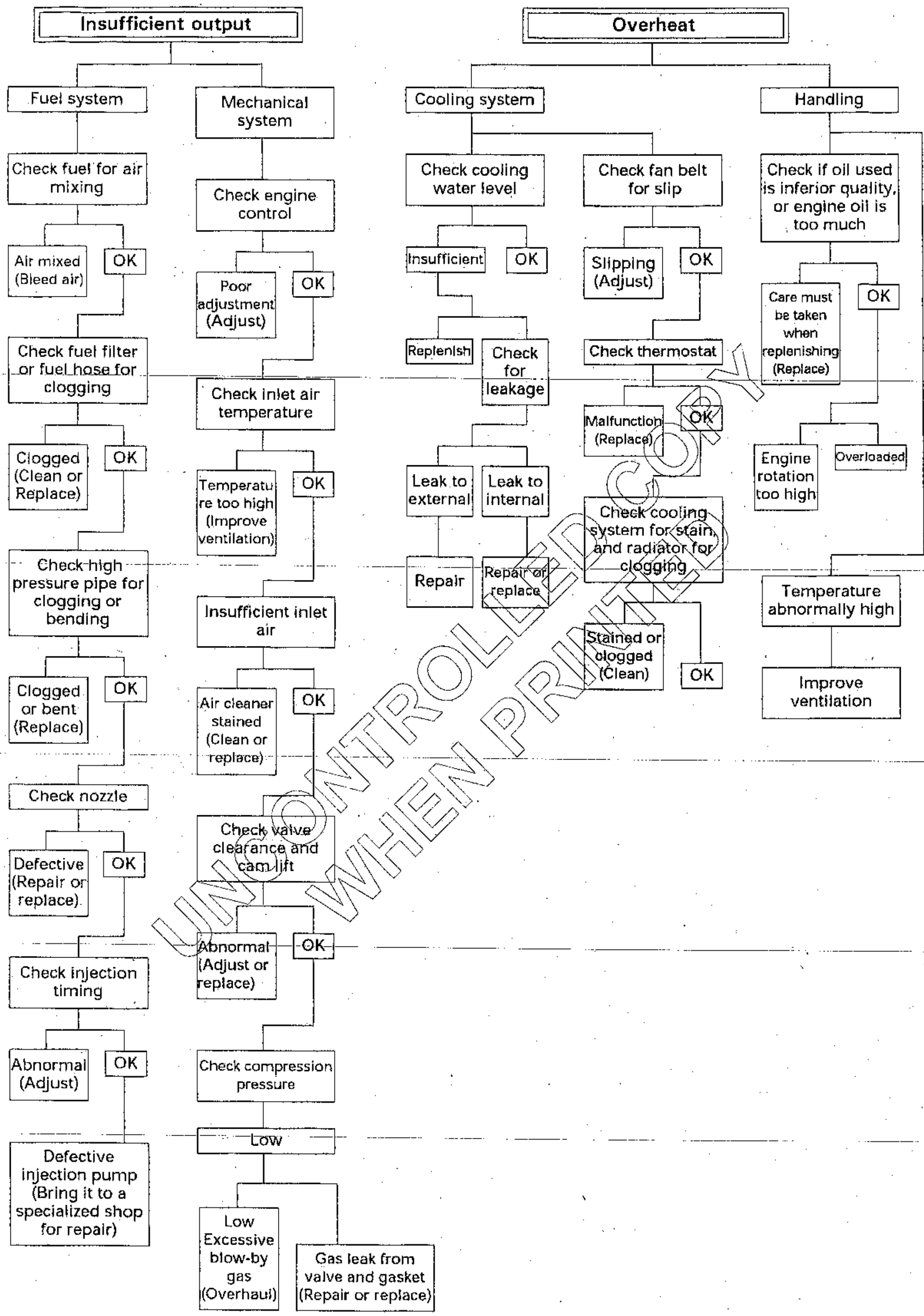
176 For the adjustment of the injection pressure and the spray condition of fuel, refer to Section 1 "INSPECTION AND SERVICE."

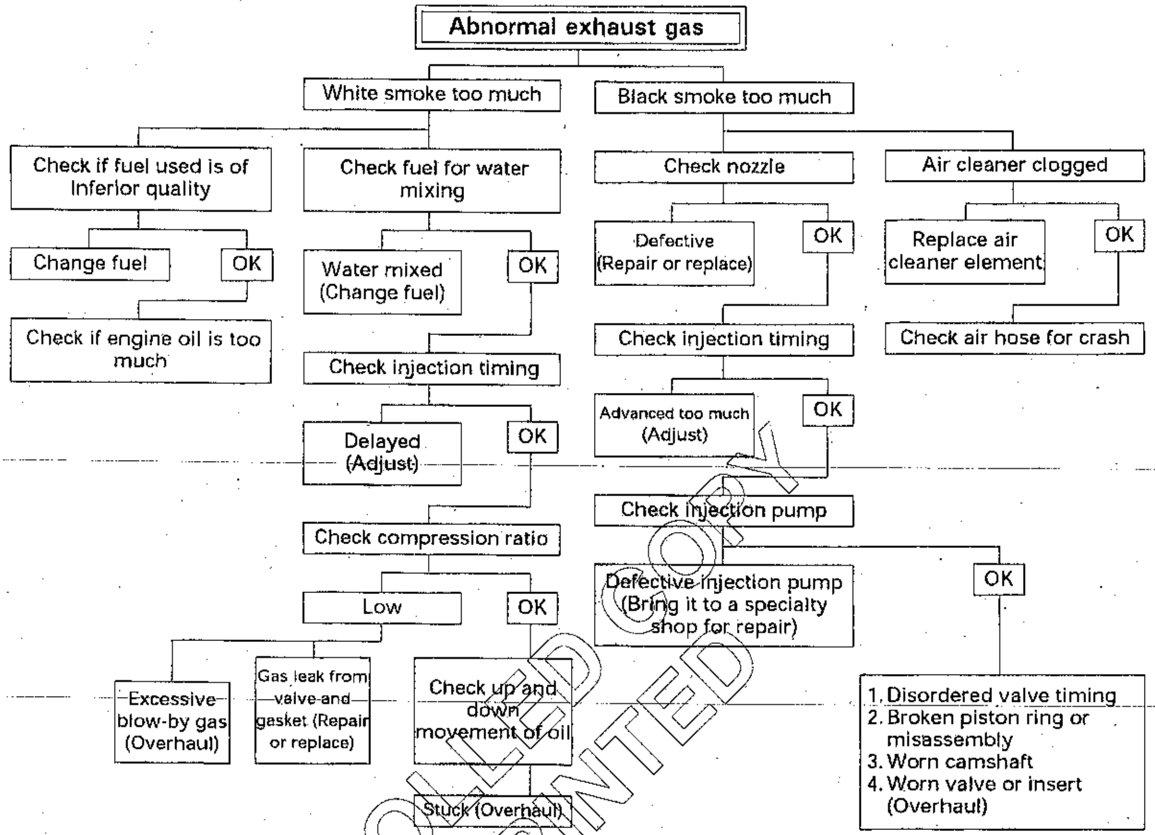
SECTION 6 - TROUBLESHOOTING

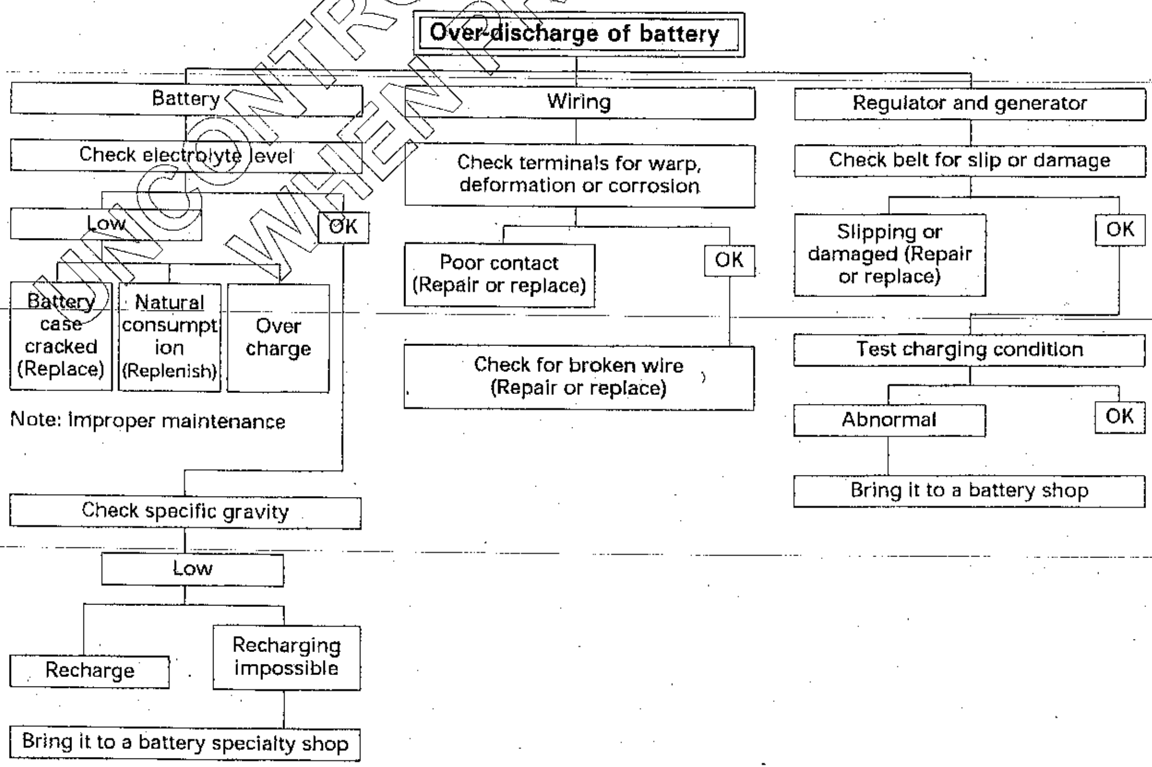


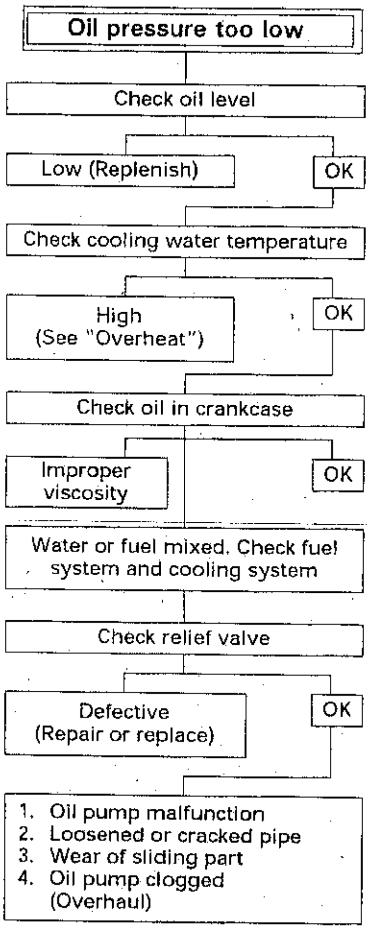
Note: "Bring it to a specialty shop" means that defective parts of the injection pump and electricals must be brought to a specialty shop for repair. (This note is applicable to all the following procedures.)

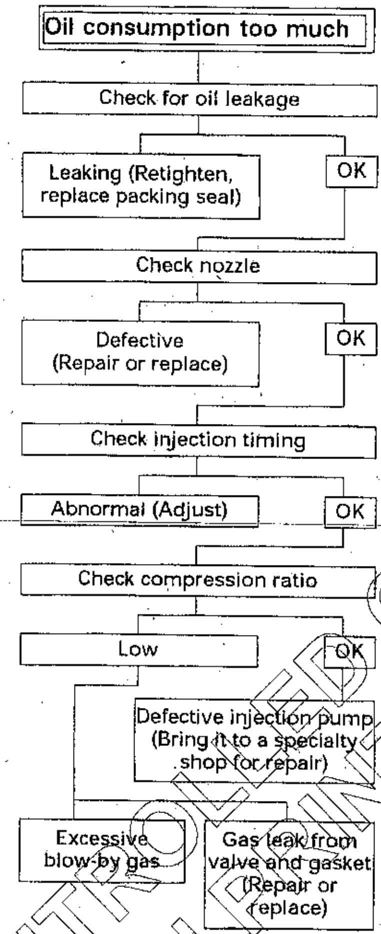

Unstable engine rotation
Unstable engine idling
Idling speed too high
Unstable rotation at medium speed (Hunting)
Unstable rotation at high speed
Engine does not change from high to low rotation
Defective idling adjustment
Defective control lever adjustment
Governor spring deteriorated
Check fuel for air mixing
Check accelerator pedal
Defective valve return (Adjust)
OK
Defective (Repair or replace)
OK
Air mixed (Bleed air)mixing
OK
Pedal sticking or hitching (Clean or replace)
OK
Check high pressure pipe for cracking, clogging or bending
Defective injection pump (Bring it to a specialty shop for repair)
Check fuel pipe for crash
Check fuel filter for clogging
Defective injection pump (Bring it to a specialty shop for repair)
Cracked, clogged or bent (Replace)
OK
Crash (Replace)
OK
Clogged (Clean or replace)
OK
Check uneven fuel injection
Check nozzle
Defective (Repair or replace)
OK
Uneven (Adjust)
OK
Check cylinder for uneven compression pressure
Check valve clearance adjustment
Uneven compression pressure (Adjust)
OK
Poor adjustment (Adjust)
OK
Defective injection pump (Bring it to a specialty shop for repair)
Defective injection pump (Bring it to a specialty shop for repair)

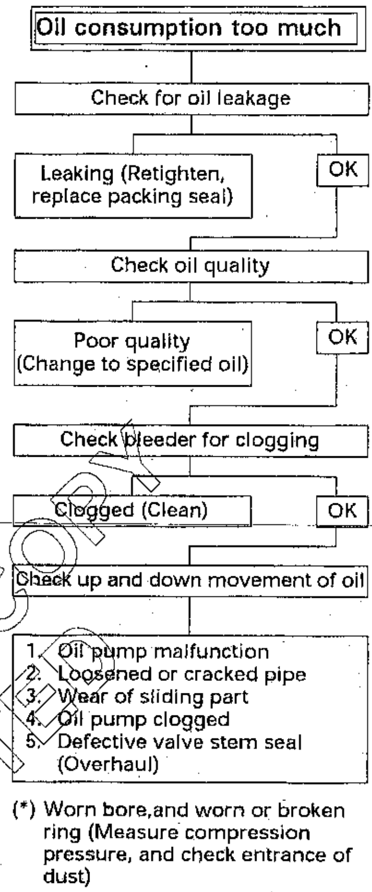

Insufficient output
Fuel system
Check fuel for air mixing
Air mixed (Bleed air)
OK
Check fuel filter or fuel hose for clogging
Clogged (Clean or Replace)
OK
Check high pressure pipe for clogging or bending
Clogged or bent (Replace)
OK
Check nozzle
Defective (Repair or replace)
OK
Check injection timing
Abnormal (Adjust)
OK
Defective injection pump (Bring it to a specialized shop for repair)
Mechanical system
Check engine control
Poor adjustment (Adjust)
OK
Check inlet air temperature
Temperature too high (Improve ventilation)
OK
Insufficient inlet air
Air cleaner stained (Clean or replace)
OK
Check valve clearance and cam lift
Abnormal (Adjust or replace)
OK
Check compression pressure
Low
Low Excessive blow-by gas (Overhaul)
Gas leak from valve and gasket (Repair or replace)
Overheat
Cooling system
Check cooling water level
Insufficient
OK
Replenish
Check for leakage
Leak to external
Leak to internal
Repair
Repair or replace
Check fan belt for slip
Slipping (Adjust)
OK
Check thermostat
Malfunction (Replace)
OK
Check cooling system for stain, and radiator for clogging
Stained or clogged (Clean)
OK
Handling
Check if oil used is inferior quality, or engine oil is too much
Care must be taken when replenishing (Replace)
OK
Engine rotation too high
Overloaded
Temperature abnormally high
Improve ventilation

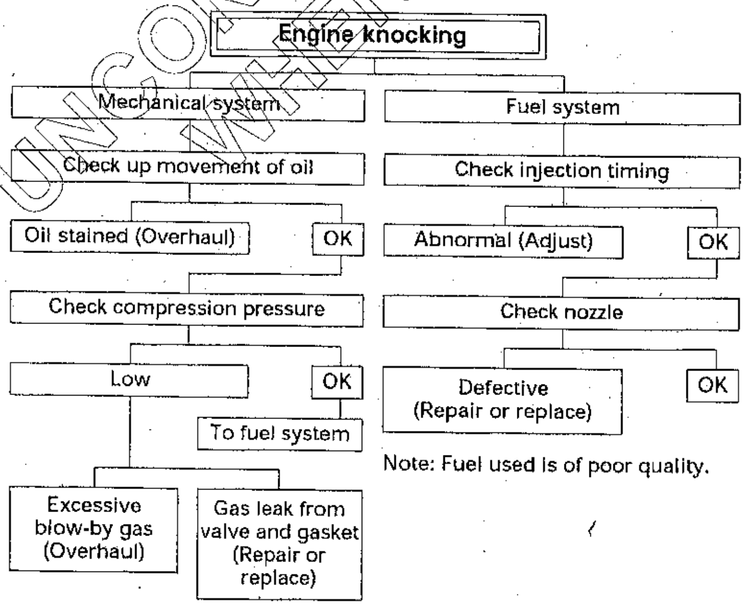

Abnormal exhaust gas
White smoke too much
Black smoke too much
Check if fuel used is of inferior quality
Check fuel for water mixing
Check nozzle
Air cleaner clogged
Change fuel
OK
Water mixed (Change fuel)
OK
Defective (Repair or replace)
OK
Replace air cleaner element
OK
Check if engine oil is too much
Check injection timing
Check injection timing
Check air hose for crash
Delayed (Adjust)
OK
Advanced too much (Adjust)
OK
Check injection pump
Check compression ratio
Defective injection pump (Bring it to a specialty shop for repair)
OK
Low
OK
Excessive blow-by gas (Overhaul)
Gas leak from valve and gasket (Repair or replace)
Check up and down movement of oil
1. Disordered valve timing
2. Broken piston ring or misassembly
3. Worn camshaft
4. Worn valve or insert
(Overhaul)
Stuck (Overhaul)


Over-discharge of battery
Battery
Wiring
Regulator and generator
Check electrolyte level
Check terminals for warp, deformation or corrosion
Check belt for slip or damage
Low
OK
Poor contact (Repair or replace)
OK
Slipping or damaged (Repair or replace)
OK
Battery case cracked (Replace)
Natural consumption (Replenish)
Over charge
Check for broken wire (Repair or replace)
Test charging condition
Note: Improper maintenance
Abnormal
OK
Bring it to a battery shop
Check specific gravity
Low
Recharge
Recharging impossible
Bring it to a battery specialty shop


Oil pressure too low
Check oil level
Low (Replenish)
OK
Check cooling water temperature
High (See "Overheat")
OK
Check oil in crankcase
Improper viscosity
OK
Water or fuel mixed. Check fuel system and cooling system
Check relief valve
Defective (Repair or replace)
OK
1. Oil pump malfunction
2. Loosened or cracked pipe
3. Wear of sliding part
4. Oil pump clogged
(Overhaul)

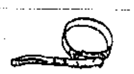
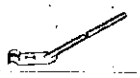
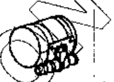
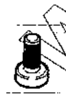
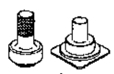
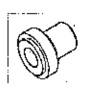
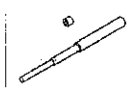
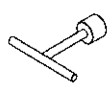

Oil consumption too much
Check for oil leakage
Leaking (Retighten, replace packing seal)
OK
Check nozzle
Defective (Repair or replace)
OK
Check injection timing
Abnormal (Adjust)
OK
Check compression ratio
Low
OK
Defective injection pump (Bring it to a specialty shop for repair)
Excessive blow-by gas
Gas leak from valve and gasket (Repair or replace)


Oil consumption too much
Check for oil leakage
Leaking (Retighten, replace packing seal)
OK
Check oil quality
Poor quality (Change to specified oil)
OK
Check bleeder for clogging
Clogged (Clean)
OK
Check up and down movement of oil
1. Oil pump malfunction
2. Loosened or cracked pipe
3. Wear of sliding part
4. Oil pump clogged
5. Defective valve stem seal
(Overhaul)
(*) Worn bore,and worn or broken ring (Measure compression pressure, and check entrance of dust)


Engine knocking
Mechanical system
Fuel system
Check up movement of oil
Oil stained (Overhaul)
OK
Check compression pressure
Low
OK
To fuel system
Excessive blow-by gas (Overhaul)
Gas leak from valve and gasket (Repair or replace)
Check injection timing
Abnormal (Adjust)
OK
Check nozzle
Defective (Repair or replace)
OK
Note: Fuel used is of poor quality.

SECTION 7 - SPECIAL TOOLS

The alphanumeric codes in parentheses ( ) are part numbers assigned by special tool manufacturers.

No.	Illustration	Part number	Part name	Page
1.		5-8840-2675-0	Compression gauge	25
2.		5-8840-9026-0	Compression gauge adaptor	25
3.		5-8840-9016-0 (J28829)	Nozzle tester	27
4.		5-8840-9015-0 (JKM-9004)	Oil filter wrench	-
5.		5-8840-9030-0	Valve spring compressor	66
6.		1-852211-029-0	Piston ring pliers	40
7.		5-8840-9018-0 (J-8037)	Piston ring compressor	-
8.		5-8840-9031-0	Front oil seal installer	-
9.		5-8840-9032-0	Rear oil seal installer	-
10.		5-8840-9034-0	Camshaft bearing installer	-
11.		5-8840-9035-0	Valve guide installer	-
12.		5-8840-9033-0	Valve stem seal installer	65

SECTION 8 - CONVERSION TABLES

LENGTH

MILLIMETERS TO INCHES

mm	in.	mm	in.	mm	in.	mm	in.
1	0.0394	35	1.3780	69	2.7165	103	4.0551
2	0.0787	36	1.4173	70	2.7559	104	4.0945
3	0.1181	37	1.4567	71	2.7953	105	4.1339
4	0.1575	38	1.4961	72	2.8346	106	4.1732
5	0.1969	39	1.5354	73	2.8740	107	4.2126
6	0.2362	40	1.5748	74	2.9134	108	4.2520
7	0.2756	41	1.6142	75	2.9528	109	4.2913
8	0.3150	42	1.6535	76	2.9921	111	4.3701
9	0.3543	43	1.6929	77	3.0315	112	4.4094
10	0.3937	44	1.7323	78	3.0709	113	4.4488
11	0.4331	45	1.7717	79	3.1102	114	4.4882
12	0.4724	46	1.8110	80	3.1496	115	4.5276
13	0.5118	47	1.8504	81	3.1890	116	4.5669
14	0.5512	48	1.8898	82	3.2283	117	4.6063
15	0.5906	49	1.9291	83	3.2677	118	4.6457
16	0.6299	50	1.9685	84	3.3071	119	4.6850
17	0.6693	51	2.0079	85	3.3465	121	4.7638
18	0.7087	52	2.0472	86	3.3858	122	4.8031
19	0.7480	53	2.0866	87	3.4252	123	4.8425
20	0.7874	54	2.1260	88	3.4646	124	4.8819
21	0.8268	55	2.1654	89	3.5039	125	4.9213
22	0.8661	56	2.2047	90	3.5433	126	4.9606
23	0.9055	57	2.2441	91	3.5827	127	5.0000
24	0.9449	58	2.2835	92	3.6220	128	5.0394
25	0.9843	59	2.3228	93	3.6614	129	5.0787
26	1.0236	60	2.3622	94	3.7008	131	5.1575
27	1.0630	61	2.4016	95	3.7402	132	5.1969
28	1.1024	62	2.4409	96	3.7795	133	5.2362
29	1.1417	63	2.4803	97	3.8189	134	5.2756
30	1.1811	64	2.5197	98	3.8583	135	5.3150
31	1.2205	65	2.5591	99	3.8976	136	5.3543
32	1.2598	66	2.5984	100	3.9370	137	5.3937
33	1.2992	67	2.6378	101	3.9764	138	5.4331
34	1.3386	68	2.6772	102	4.0157	139	5.4724

INCHES TO MILLIMETERS

in.	mm.	in.	mm.
1/64	0.3969	33/64	13.0969
1/32	0.7938	17/32	13.4938
3/64	1.1906	35/64	13.8906
1/16	1.5875	9/16	14.2875
5/64	1.9844	37/64	14.6844
3/32	2.3813	19/32	15.0813
7/64	2.7781	39/64	15.4781
1/8	3.1750	5/8	15.8750
9/64	3.5719	41/64	16.2719
5/32	3.9688	21/32	16.6688
11/64	4.3656	43/64	17.0656
3/16	4.7625	11/16	17.4625
13/64	5.1594	45/64	17.8594
7/32	5.5563	23/32	18.2563
15/64	5.9531	47/64	18.6531
1/4	6.3500	3/4	19.0500
17/64	6.7469	49/64	19.4469
9/32	7.1438	25/32	19.8438
19/64	7.5406	51/64	20.2406
5/16	7.9375	13/16	20.6375
21/64	8.3344	53/64	21.0344
11/32	8.7313	27/32	21.4313
23/64	9.1281	55/64	21.8281
3/8	9.5250	7/8	22.2250
25/64	9.9219	57/64	22.6219
13/32	10.3188	29/32	23.0188
27/64	10.7156	59/64	23.4156
7/16	11.1125	15/16	23.8125
29/64	11.5094	61/64	24.2094
15/32	11.9063	31/32	24.6063
31/64	12.3031	63/64	25.0031
1/2	12.7000	1	25.4000

LENGTH

FEET TO METERS

ft.	0	1	2	3	4	5	6	7	8	9	ft.
	m	m	m	m	m	m	m	m	m	m	
---	---	0.305	0.610	0.914	1.219	1.524	1.829	2.134	2.438	2.743	---
10	3.048	3.353	3.658	3.962	4.267	4.572	4.877	5.182	5.486	5.791	10
20	6.096	6.401	6.706	7.010	7.315	7.620	7.925	8.230	8.534	8.839	20
30	9.144	9.449	9.754	10.058	10.363	10.668	10.973	11.278	11.582	11.887	30
40	12.192	12.497	12.802	13.106	13.411	13.716	14.021	14.326	14.630	14.935	40
50	15.240	15.545	15.850	16.154	16.459	16.764	17.069	17.374	17.678	17.983	50
60	18.288	18.593	18.898	19.202	19.507	19.812	20.117	20.422	20.726	21.031	60
70	21.336	21.641	21.946	22.250	22.555	22.860	23.165	23.470	23.774	24.079	70
80	24.384	24.689	24.994	25.298	25.603	25.908	26.213	26.518	26.822	27.127	80
90	27.432	27.737	28.042	28.346	28.651	28.956	29.261	29.566	29.870	30.175	90
100	30.480	30.785	31.090	31.394	31.699	32.004	32.309	32.614	32.918	33.223	100

METERS TO FEET

m	0	1	2	3	4	5	6	7	8	9	
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	
---	---	3.2808	6.5617	9.8425	13.1234	16.4042	19.6850	22.9659	26.2467	29.5276	---
10	32.8084	36.0892	39.3701	42.6509	45.9318	49.2126	52.4934	55.7743	59.0551	62.3360	10
20	65.6168	68.8976	72.1785	75.4593	78.7402	82.0210	85.3018	88.5827	91.8635	95.1444	20
30	98.4252	101.7060	104.9869	108.2677	111.5486	114.8294	118.1102	121.3911	124.6719	127.9528	30
40	131.2336	134.5144	137.7953	141.0761	144.3570	147.6378	150.9186	154.1995	157.4803	160.7612	40
50	164.0420	167.3228	170.6037	173.8845	177.1654	180.4462	183.7270	187.0079	190.2887	193.5696	50
60	196.8504	200.1312	203.4121	206.6929	209.9738	213.2546	216.5354	219.8163	223.0971	226.3780	60
70	229.6588	232.9396	236.2205	239.5013	242.7822	246.0630	249.3438	252.6247	255.9055	259.1864	70
80	262.4672	265.7480	269.0289	272.3097	275.5906	278.8714	282.1522	285.4331	288.7139	291.9948	80
90	295.2756	298.5564	301.8373	305.1181	308.3990	311.6798	314.9606	318.2415	321.5223	324.8032	90
100	328.0840	331.3648	334.6457	337.9265	341.2074	344.4882	347.7690	351.0499	354.3307	357.6116	100

MILES TO KILOMETERS

miles	0	1	2	3	4	5	6	7	8	9	
	km	km	km	km	km	km	km	km	km	km	
---	---	1.609	3.219	4.828	6.437	8.047	9.656	11.265	12.875	14.484	---
10	16.093	17.703	19.312	20.921	22.531	24.140	25.749	27.359	28.968	30.577	10
20	32.187	33.796	35.405	37.015	38.624	40.234	41.843	43.452	45.062	46.671	20
30	48.280	49.890	51.499	53.108	54.718	56.327	57.936	59.546	61.155	62.764	30
40	64.374	65.983	67.592	69.202	70.811	72.420	74.030	75.639	77.248	78.858	40
50	80.467	82.076	83.686	85.295	86.904	88.514	90.123	91.732	93.342	94.951	50
60	96.560	98.170	99.779	101.388	102.998	104.607	106.216	107.826	109.435	111.044	60
70	112.654	114.263	115.872	117.482	119.091	120.701	122.310	123.919	125.529	127.138	70
80	128.747	130.357	131.966	133.575	135.185	136.794	138.403	140.013	141.622	143.231	80
90	144.841	146.450	148.059	149.669	151.278	152.887	154.497	156.106	157.715	159.325	90
100	160934	162.543	164.153	165.762	167.371	168.981	170.590	172.199	173.809	175.418	100

KILOMETERS TO MILES

km	0	1	2	3	4	5	6	7	8	9	
	miles	miles	miles	miles	miles	miles	miles	miles	miles	miles	
---	---	0.621	1.243	1.864	2.485	3.107	3.728	4.350	4.971	5.592	---
10	6.214	6.835	7.456	8.078	8.699	9.321	9.942	10.563	11.185	11.806	10
20	12.427	13.049	13.670	14.292	14.913	15.534	16.156	16.777	17.398	18.020	20
30	18.641	19.262	19.884	20.505	21.127	21.748	22.369	22.991	23.612	24.233	30
40	24.855	25.476	26.098	26.719	27.340	27.962	28.583	29.204	29.826	30.447	40
50	31.069	31.690	32.311	32.933	33.554	34.175	34.797	35.418	36.039	36.661	50
60	37.282	37.904	38.525	39.146	39.768	40.389	41.010	41.632	42.253	42.875	60
70	43.496	44.117	44.739	45.360	45.981	46.603	47.224	47.845	48.467	49.088	70
80	49.710	50.331	50.952	51.574	52.195	52.816	53.438	54.059	54.681	55.302	80
90	55.923	56.545	57.166	57.787	58.409	59.030	59.652	60.273	60.894	61.516	90
100	62.137	62.758	63.380	64.001	64.622	65.244	65.865	66.487	67.108	67.729	100

Connecting rod

36 A forged steel I-beam connecting rod is used for all L-series engines. They are full floating design with bushed wrist pin ends (Fig 24).

NOTE

When removing and replacing the connecting rod assemblies, be sure to install the connecting rod with the Isuzu Logo facing the same direction as the piston's forward notch.

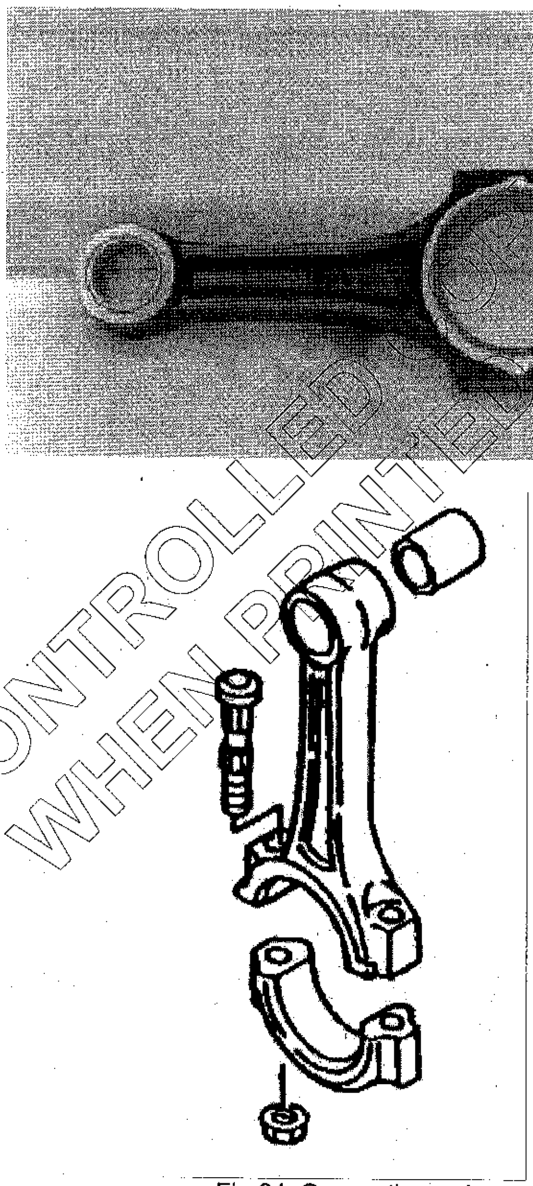


Fig 24 Connecting rod

IMPORTANT: The rod cap bolts are not to be removed. It is shown only for clarity, but is not a standard rod cap bolt. These bolts have serrations (to prevent the bolts from turning) and are pressed onto the rod. When servicing, the entire rod must be replaced.

Cylinder head gasket

37 The L-series engines use a three-layer ultra thin laminated steel head gasket that requires no re-torqueing after the engine break-in period. Holes for coolant are drilled between the valve seats for effective cooling of the combustion area.

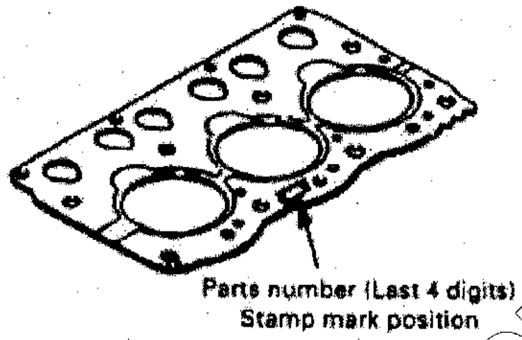


Fig 25 Cylinder head gasket

IMPORTANT: The head gasket must be installed with the flat side of the sealing bead facing up. Also the large flat end of the gasket must face forward.

38 The sealing bead surrounding the cylinders of the gasket is stainless steel. It protects the head gasket from the high cylinder pressures. The sealing bead also protects the gasket from the high temperatures released by the hot plugs.

39 The gasket comes pre-coated with a silicon material. Therefore, no additional application of sealers or gasket adhesives is necessary, and no re-torqueing of the head bolts is required if the prescribed angular tightening method is used.

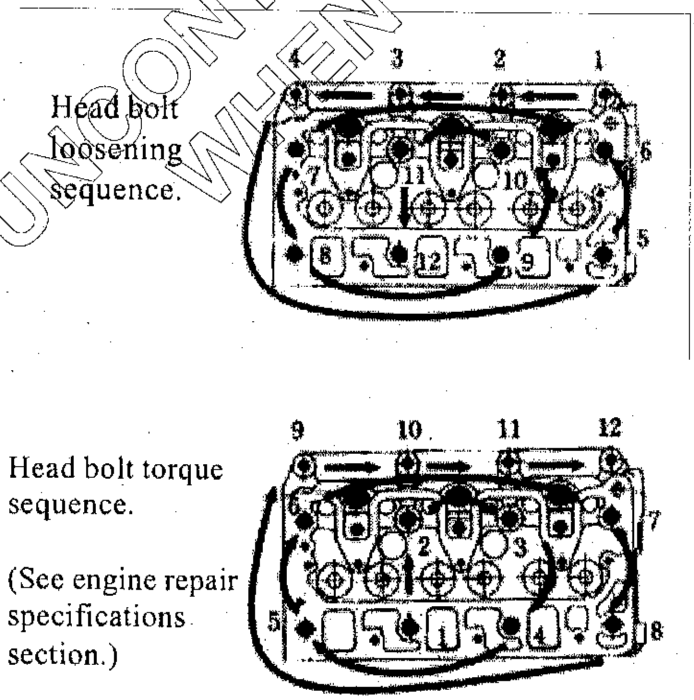
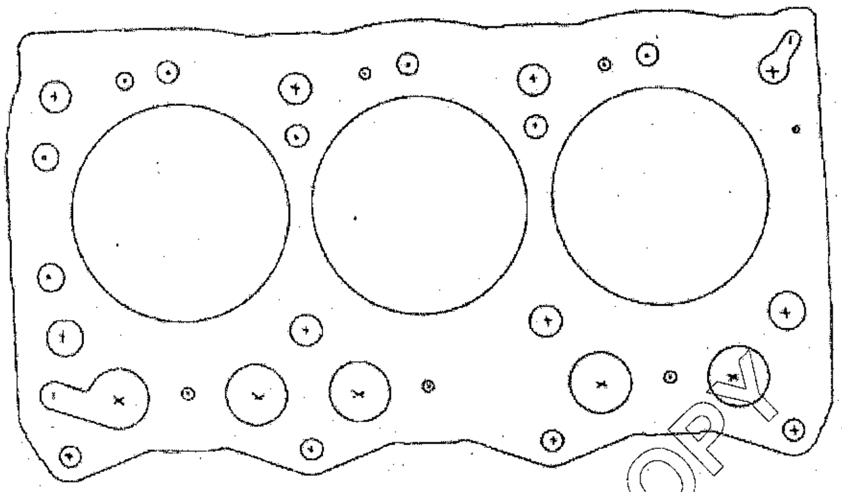


Fig 26 Head bolt loosening and torque sequences

40 To identify the gallies, use Fig 27 and the legend below.



Legend

- **o Coolant**
- **- Oil**
- **+ Bolt**
- **x Push Rod**

Fig 27 Gasket detail

Cylinder head

41 The L-series cylinder heads are cast iron with replaceable valve guides and valve seats. The head casting number is embossed at the front of the head's casting just below the injector nozzle bore (Fig 28).

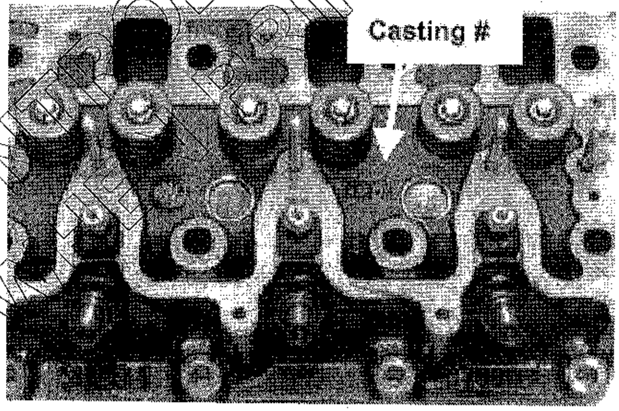


Fig 28 Head casting number

42 Compression tests are conducted using a compression gauge adaptor used as a glow plug insert, special tool number 5-88402-656-0. Refer to the workshop manual for procedure.

43 The service limit for this engine is 370 psi (26.0 kg/cm^2). Standard pressure is 441 psi (31.0 kg/cm^2). Isuzu allows an 8% variance between cylinders on compression tests, but there can be no more than a 15% difference between any two cylinders.

44 Letters A - F represent the different measurements that need to be taken to determine head warpage. See Fig 29.

Upper and Lower face warpage specifications:

Standard:	0.075 mm. (0.0029 in.)
Limit:	0.15 mm. (0.0059 in.)
Max Grinding Allowance:	0.3 mm. (0.0118 in.)

Head Height:

Standard: 64 mm. (2.5197 in.)
Limit: 63.7 mm. (2.5079 in.)

IMPORTANT: Valve depression must be checked to ensure that it is still within specification.

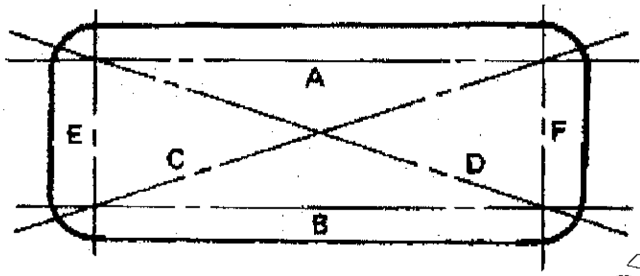


Fig 29 Head warpage measurements

LUBRICATION

45 Lubrication is achieved with a conventional wet sump oiling system. Internally, the trochoid oil pump uses a set of rotors instead of spur gears. Refer to Fig 30.

46 It is a very efficient and smooth operating pump. Compared with the spur gear type pump, the trochoid pump gives practically continuous flow, due to less leakage on the discharge side of the pump.

47 The pump is mounted to the front of the engine block and driven by the crankshaft.

48 On the pump's exterior housing, there are two lugs machined for dowel pins. This enables the pump to be repositioned in exactly the same location without having to set pump gear backlash.

49 The pump is a serviceable unit. Internal components are interchangeable between PTO (Fig 31) and non-PTO versions.

TIP: Always remove the pump's pressure relief valve during a rebuild. Look for a cocked pressure spring, burred relief valve or burred pump housing that would cause the pressure valve to fail. (If housing is burred, it must be replaced.)

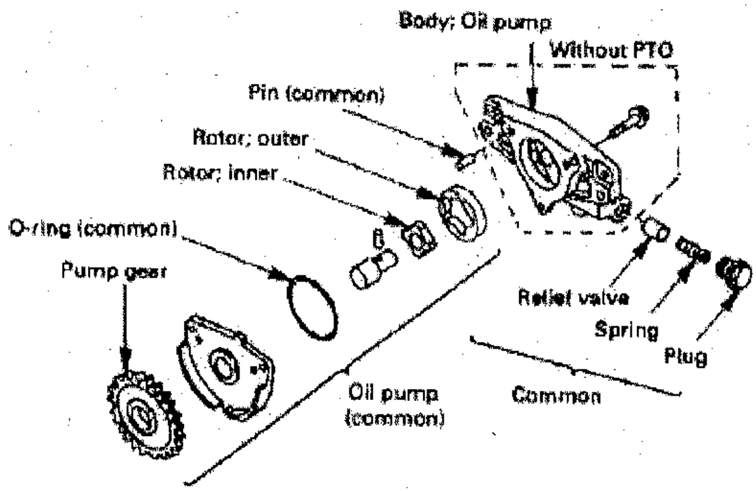


Fig 30 Oil pump

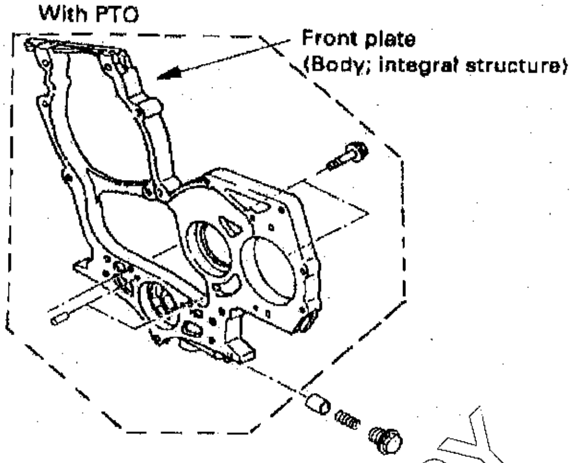


Fig 31 Oil pump housing

50 Below is the oil full flow diagram (Fig 32). Note the valve opening pressure for the oil filter bypass valve (14 PSI) is where the valve begins to open. The same is true for the oil pump relief valve, which begins to open at 64 PSI.

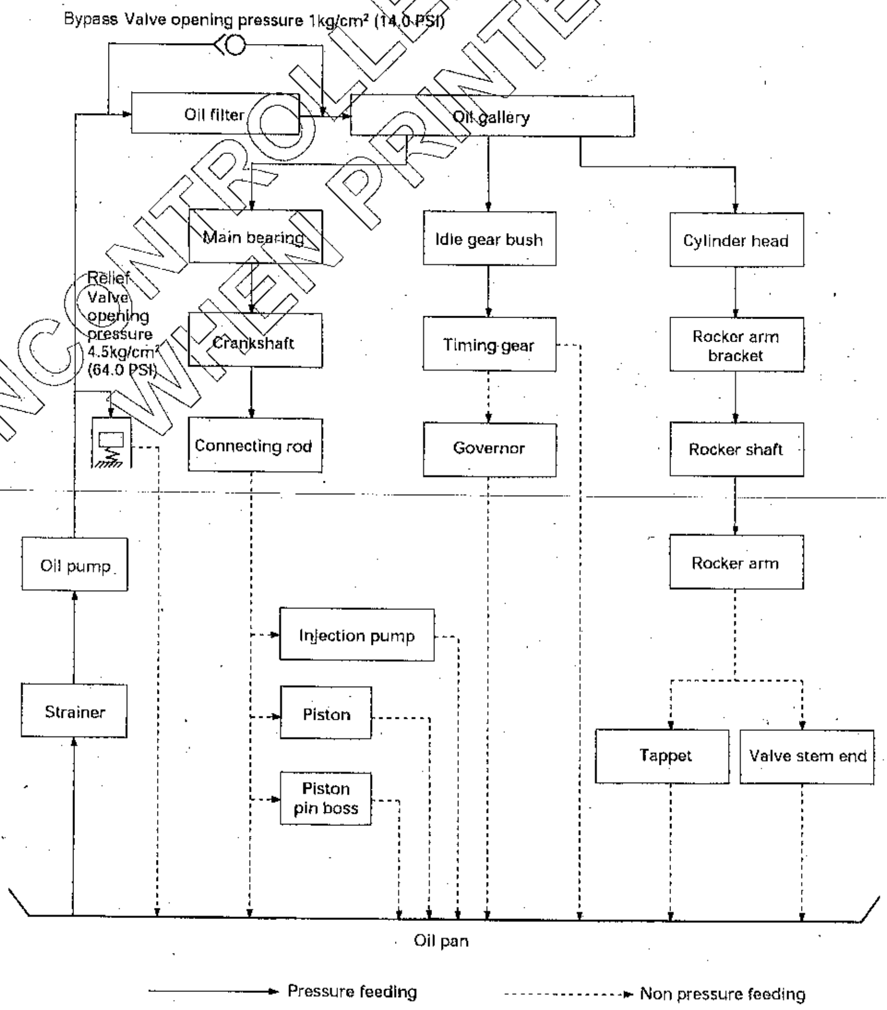


Fig 32 Oil flow diagram

COOLING SYSTEM

51 Below is the coolant flow diagram (Fig 33). Good coolant circulation is ensured by utilizing water jackets formed with a one-piece casting core, which eliminates burrs in the water passage.

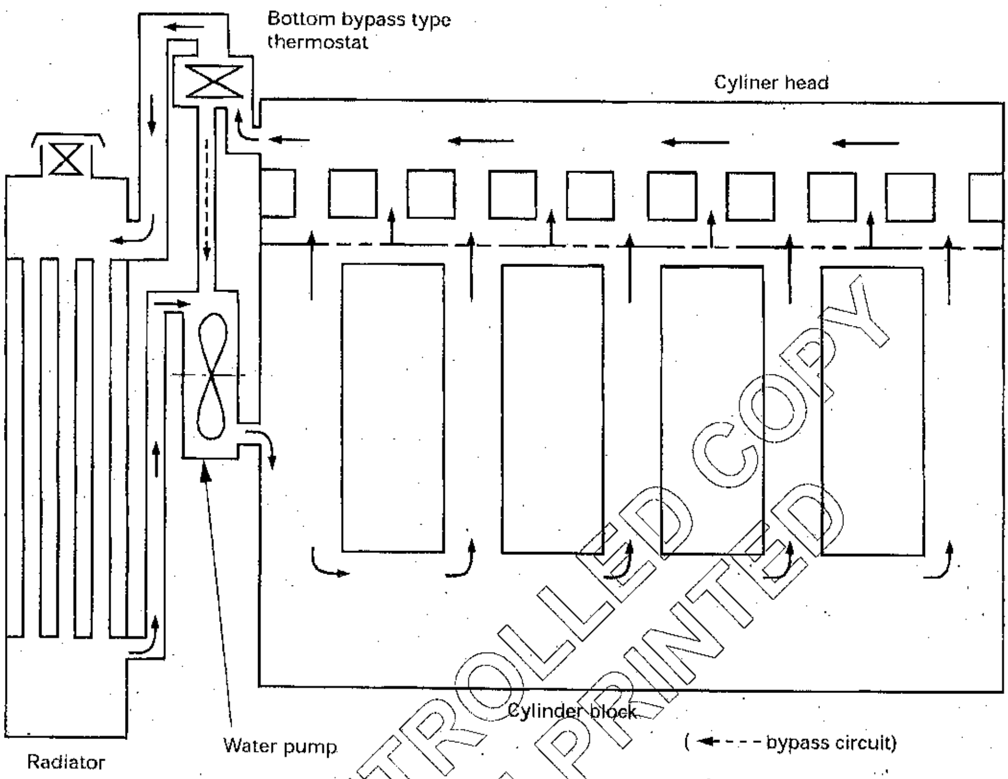


Fig 33 Coolant flow diagram

52 Maintain a coolant/water solution concentration ratio of 50 /50. Use only de-mineralized (soft) water, since hard water tends to neutralize the corrosion inhibitors in the antifreeze and add scale (particularly in hot spots) to the cooling system. It is absolutely **required** that you use a low-silicate formula anti-freeze. Do not add any additional water pump lubricants to the cooling system. Refer to the Workshop Manual for radiator cap and cooling system testing and specifications.

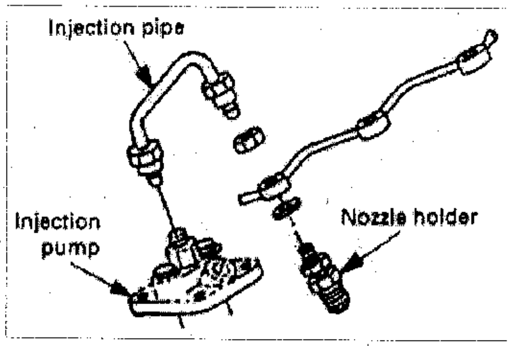
53 Use a commercially available antifreeze tester when testing for coolant/water mixture. Testing for pH is essential, as too high an acidity or alkalinity can cause severe damage to the engine and cooling systems. The pH readings should be 7.5-8.5 (SAE J1034 allows for 7.5-11.0). Litmus test paper is available from most commercial tool suppliers and product distributors.

SECTION 3 - ENGINE SERVICING PROCEDURES

SPILL-PORT TIMING

54 Spill-port timing is a precise method of measuring the initial injection of fuel by the pump and the duration of injection. It is a standard procedure used by Isuzu when timing Zexel pumps. This procedure is a very precise method of timing fuel because it shuts off fuel to the high-pressure chambers relative to the position of the piston.

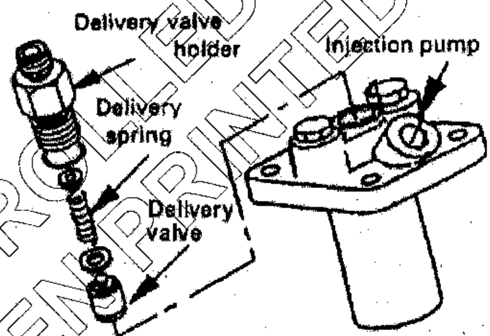
(1) Disconnect the injection pipe from the nozzle holder.



(2) Remove the nozzle delivery valve holder from the pump. Reinstall the holder without the delivery spring and delivery valve. Pressurize the pump. Then rotate the engine clockwise until fuel quits flowing out of the holder. (This is the beginning of the injection).

NOTE

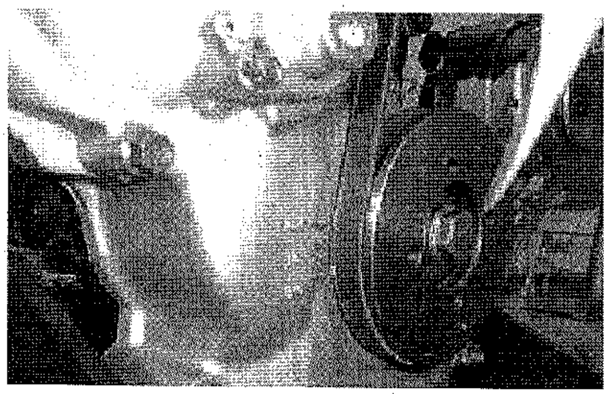
Remember that the injection pump uses shims to advance or retard injection. Thicker retards the timing, thinner advances it).



(3) Observe the reading on the crank pulley in relation to the timing marks on the gear case cover. If this value is out of range, change the thickness of the shims from underneath the pump. Each shim varies in thickness by .1mm (.004"), creating a 1° change in timing (thicker=retard, thinner=advance). The shims are a "crush" design and must not be reused.

NOTE

Refer to the proper specification sheet for timing adjustment information.



55 After spill port is performed, be sure to reassemble all components and install correctly for proper operation.

VALVE ADJUSTMENT

56 Bring the engine up on number one compression stroke. Verify the position by checking for clearance in-between the valve stem tip and the rocker arm.

NOTE

Valves can be adjusted beginning with #1 or #4 (4L). This adjustment can only be made with a cold engine.

TABLE 3 VALVE ADJUSTMENT - COMPRESSION STROKE

4L Engines								
Cylinder Number	1		2		3		4	
Valve Arrangement	I	E	I	E	I	E	I	E
Valve Numbers	4	4	4	---------	---------	4	---------	---------

57 Loosen the adjuster jam nut; insert a 0.40 mm (0.016") feeler gauge in-between the rocker tips and the valve stems to adjust the valves.

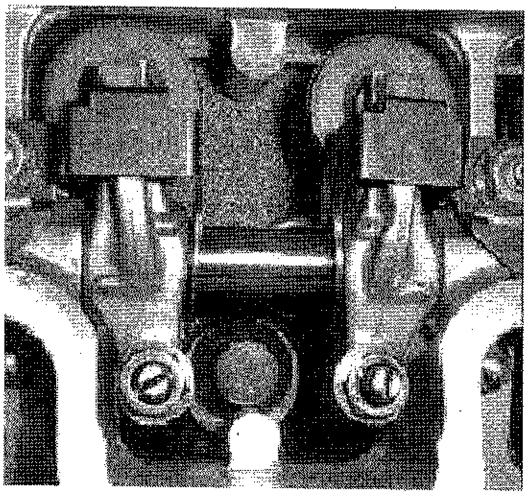
NOTE

Proper adjustment is obtained when there is a slight drag against the feeler gauge. Jam nut torque is 5.8-8.7 lbs. ft (0.8-1.2 kg m)

58 Rotate the crankshaft 360° (so that the opposing piston is now on its exhaust stroke) and adjust the remaining valves.

TABLE 4 VALVE ADJUSTMENT - EXHAUST STROKE

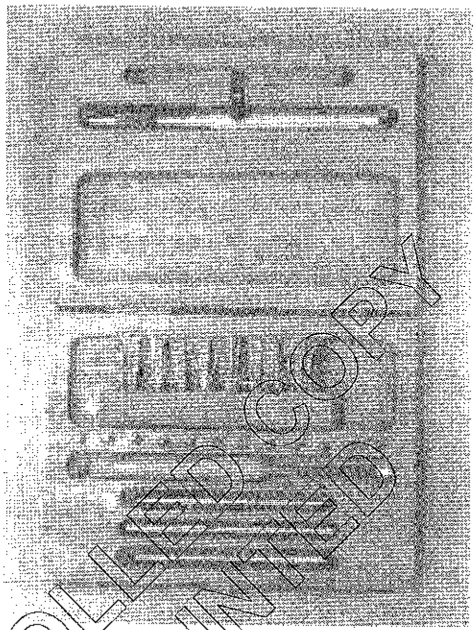
4L Engines								
Cylinder Number	1		2		3		4	
Valve Arrangement	I	E	I	E	I	E	I	E
Valve Numbers	---------	---------	---------	4	4	---------	4	4



INJECTOR SERVICE

59 The following procedures are service recommendations from Zexel:

(1) Thoroughly clean all carbon residue and carbon build–up on the surface of the nozzle using Zexel cleaning kit #1057790010.

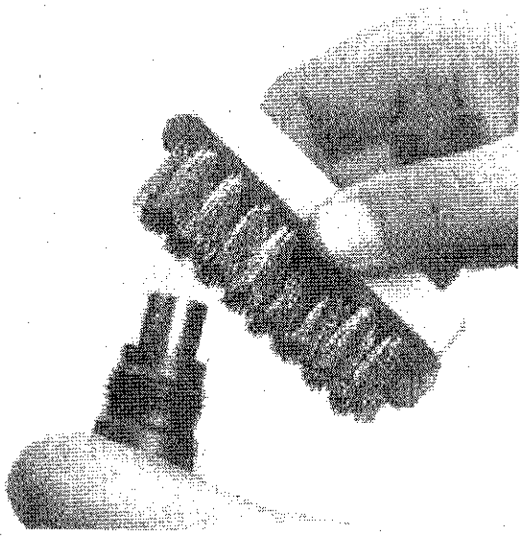


(2) Soak all parts other than the nozzle in cleaning oil.

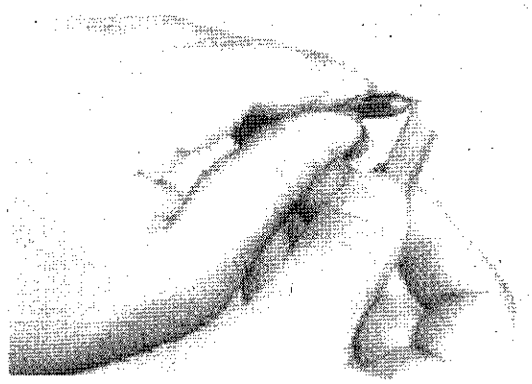
(3) Use a soft wire brush to clean excessively dirty parts.

CAUTION

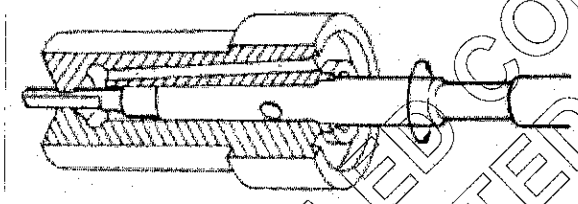
EQUIPMENT DAMAGE: Do not use metal or abrasive cleaning media to clean the nozzle holder. Their abrasive nature will leave scars on the ground surface and may cause fuel leaks



(4) Remove the needle valve from the nozzle. Clean the seat's surface and shaft section using the piece of hardwood from the cleaning kit or a clean soft cloth dipped in oil.

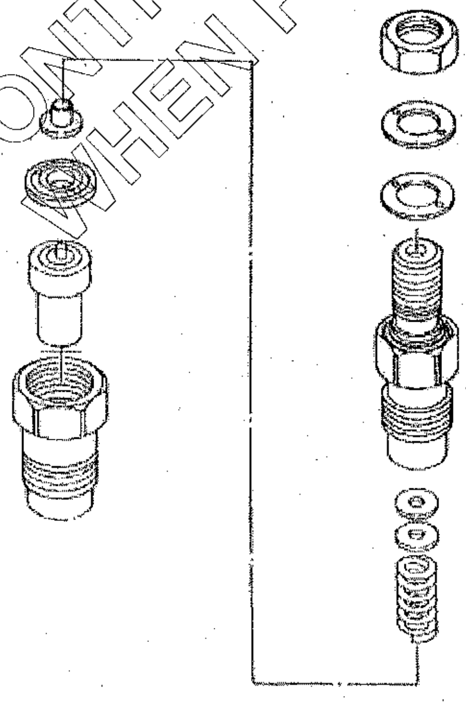


(5) Likewise, clean the spray hole with the special needle also supplied with the cleaning kit.



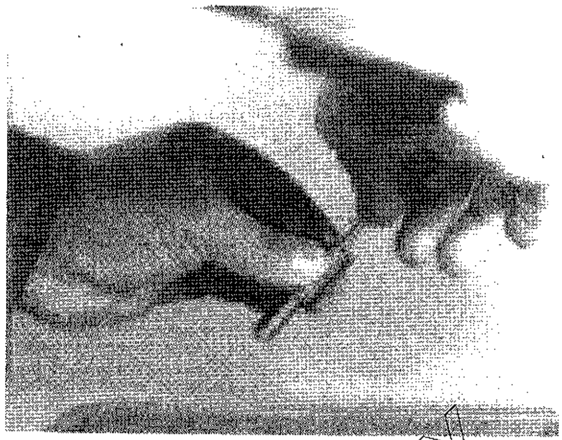
(6) Re-wash the injector components to remove any final debris.

(7) Reassemble the injector.



NOTE

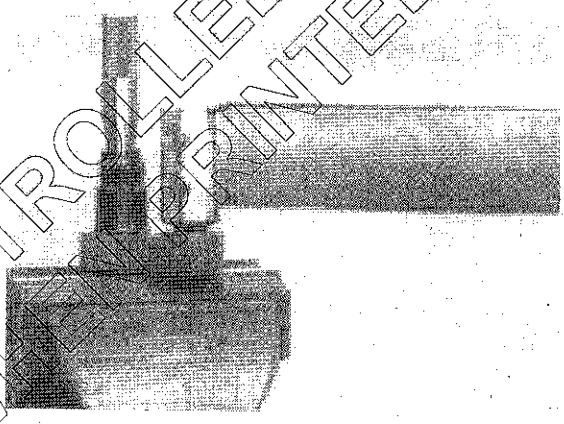
Before assembling the injector, perform a needle slide test to ensure that there is no obstruction that could cause a fuel leak.



(8) Insert the body nozzle holder to center the nozzle in the retaining nut. For reassembly torque specifications, see Appendix 1 'Nozzle Holder Tightening Standards'.

NOTE

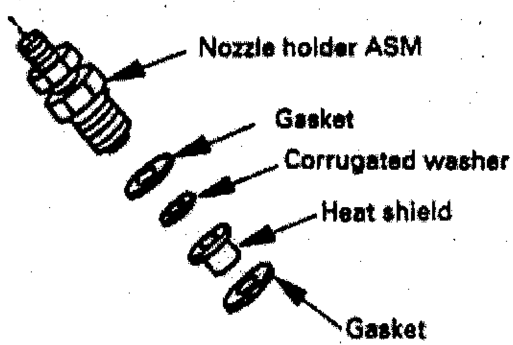
Use a flare nut/crowfoot socket on the torque wrench.



(9) When installing nozzle assembly into the cylinder head, be sure to replace the gaskets and washers, as they can only be used once.

NOTE

The <u>blue</u> side on the corrugated washer faces the nozzle.



(10) Tighten the retaining nut with a torque wrench to 29-36 lb. ft. (39-49 Nm).

INJECTOR POP-OFF TEST

WARNING

PERSONNEL INJURY. FLUID FROM THE NOZZLE TESTER WILL SPRAY OUT UNDER GREAT PRESSURE. IT CAN EASILY PUNCTURE A PERSON'S SKIN. KEEP YOUR HANDS AWAY FROM THE NOZZLE TESTER AT ALL TIMES.

60 Use the following procedure to check nozzle opening pressure, spray pattern, chatter and leakage:

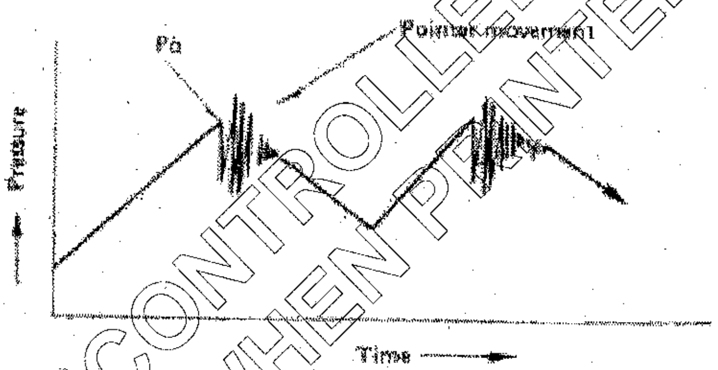
(1) Mount the nozzle and holder assembly to the gauge (J28829) and bleed the system of air.

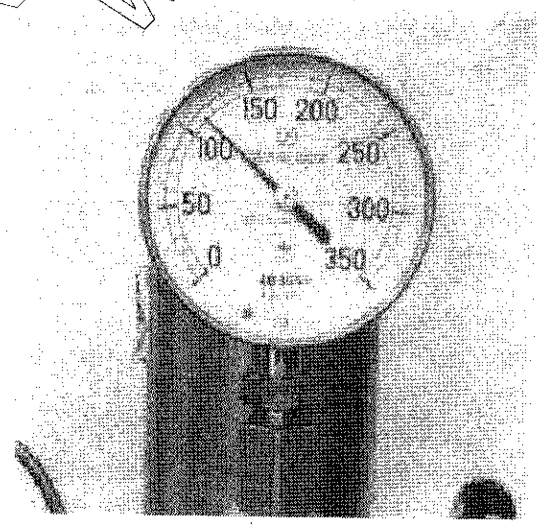
(2) Open the pressure gauge valve and pump the lever at a rate of one stroke per second.

(3) Then check the opening pressure. When the pressure gauge pointer decreases rapidly, read pop-off value. (Refer to engine's specification sheet for values. An Indirect Injection will have lower readings than a Direct Injection engine.)

NOTE

If the nozzle opening pressure is not steady or cannot be checked, the trouble is with the nozzle assembling procedure.





61 If the nozzle 'pop-off' pressure does not meet factory pressures, disassemble the nozzle and make a shim adjustment. The following size shims are available through AIPDN.

Shim Part Number	Shim Size (mm)
894176-9620	0.10
894176-9630	0.20
894176-9640	0.30
894176-9650	0.40
894176-9660	0.50
894176-9670	0.52
894176-9680	0.54
894176-9690	0.56
894176-9700	0.58
894176-9710	0.80

INJECTOR LEAK TEST

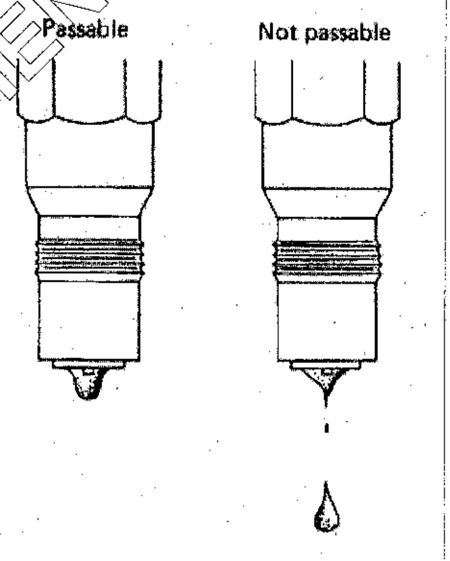
62 The leak test should be conducted immediately following the nozzle opening pressure adjustment check.

(1) Wipe the nozzle with a clean shop towel.

(2) Decrease the tester pressure about 20 kg/cm^2 less than the pop-off pressure and maintain the position.

(3) There should be no fuel discharge from the nozzle for at least 10 seconds.

(4) Re-clean or replace any nozzle that does not meet the criteria.

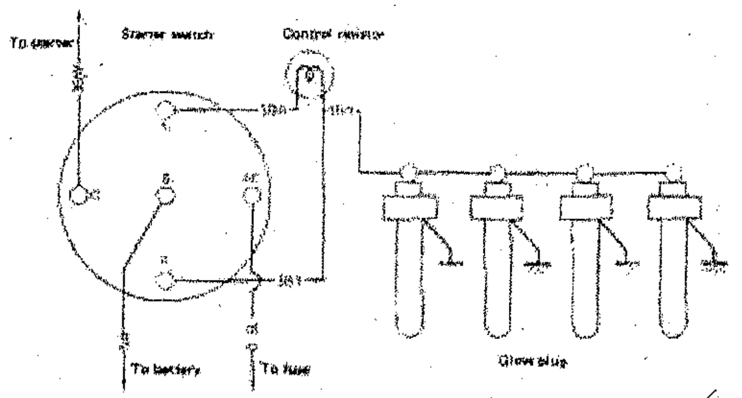


GLOW PLUG INSPECTION

63 The following procedure tests the resistance value of the glow plug.

NOTE

The test can be performed on or off the engine.



64 Total glow plug resistance value should be ≤ 0.9 ohms.

On engine service:

(1) Remove the buss bar from the glow plug.

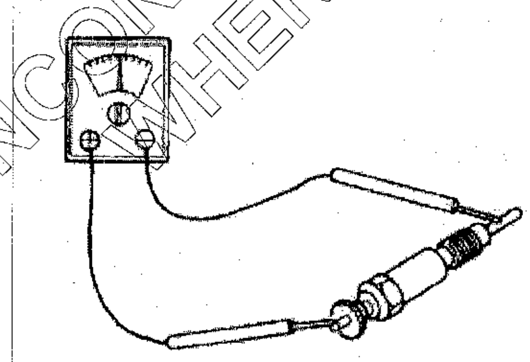
(2) Attach the DVOM red lead to the to the tip of the glow plug.

(3) Attach the DVOM black lead to a good ground source. Verify the ground integrity by testing it with the DVOM.

Off engine service:

(1) Disconnect and remove glow plug.

(2) Place DVOM leads across glow plug (one lead at each end) to obtain resistance reading

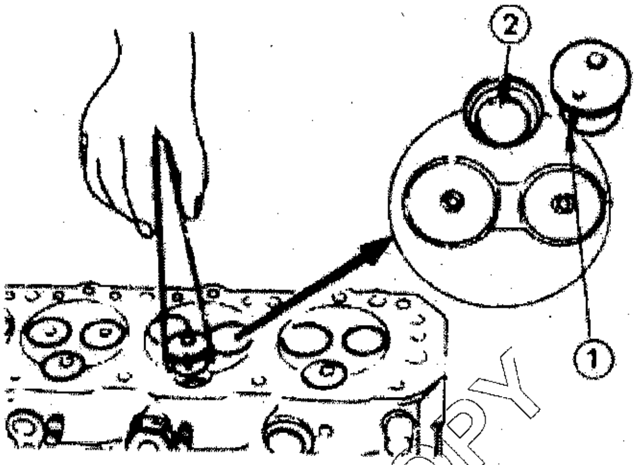


HOT PLUG REPLACEMENT

65 Hot plugs for the L-series are similar to other Isuzu diesel engines.

66 If the plug needs to be replaced, knock out the old plug from behind, though the injector nozzle hole.

67 Always remember that the plug groove in the cylinder head needs to be clean and free of any burrs that would prevent proper seating. With reference to the figure overpage, align the hot plug knock ball (1) with the cylinder head groove (2) and tap it temporarily into position with a plastic hammer.



NOTE

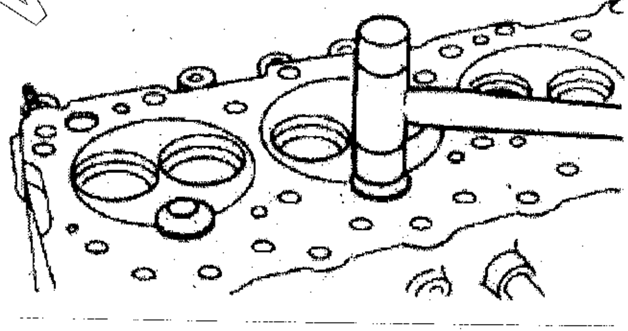
Illustration is generic and does not precisely represent the L-Series hot plugs.

68 New plug. Place a 1" thick metal plate over the top of the hot plug and press fit the plug using 4 to 5 tons of force on the metal plate.

69 Old plug. When re-using plugs, be sure to place the plug in the same hole that it came out of originally. Tap the plug head into place and ensure that the plug is firmly seated. Grind off any surface protrusions so that it is completely flush with the surface of the head.

NOTE

Most current/newer model surfacing machines do not require hot plug removal before head refinishing. Consult your particular equipment manual.



SECTION 4 - ENGINE REPAIR SPECIFICATIONS - 4L

MAINTENANCE SPECIFICATIONS

70 Maintenance specifications are as follows:

TABLE 5 4L MAINTENANCE SPECIFICATIONS

Item	Metric Measure	US Measure
Engine Oil Capacity (see Note 1) 4LB1/LC1 4LE1	 7.3 Litres 8.7 Litres	 7.7 quarts 9.2 quarts
Engine Oil Pressure (see Note 5)	4-5 Kg/cm^2	43-51 lbs
Compression Pressure (see Note 2)	31 Kg/cm^2	441 psi
Valve Adjustment	.40 ±0.05 mm	0.015 ± .002 in
Coolant Capacity (see Note 3) 4LB1 4LC1 4LD1	 2.5 Litres 2.7 Litres 2.8 Litres	 2.6 quarts 2.8 quarts 3.0 quarts
Injection Starting Pressure	12.7-13.7 Mpa	1850-1990 psi
Injection Timing (see Note 4)	16° BTDC	
Fan Belt Deflection Tension	8.0 mm-12 mm	0.3-0.5 in
Glow Plug Resistance	0.7-0.9 Ω	

NOTES

(1) These specifications vary depending upon the type of equipment in which the engine is being installed. Only use API class CC or CD. On 4LB1 with turbocharger, use only API grade <u>CD</u>.

(2) First warm up the engine until coolant temperature reaches 167° F (75° C). Measured at 250 rpm. Service Limit is 26 Kg/cm^2 (370 psi).

(3) Use only an Ethylene glycol based anti-freeze/water mixture. A 50/50 concentration ratio provides maximum protection to -37° C or -34° F. Never exceed a 60/40 concentration ratio, which provides protection to ≈ -50° C or -58° F.

(4) Timing may vary depending on engine specification.

(5) Pressure may be lower at engine idle.

MECHANICAL SPECIFICATIONS

71 Mechanical specifications are as follows:

TABLE 6 4L MECHANICAL SPECIFICATIONS - CYLINDER HEAD/VALVE TRAIN

Cylinder Head/Valve Train	Standard	Service Limit
Valve Clearance (see Note 1)	0.40 mm/0.01575 in	------------------------------------
Cylinder Head Warpage (see Note 2)	0.075 mm/0.0029 in	0.15 mm/0.0059 in
Cylinder Head Height (see Note 3)	63.9 mm/2.515 in	64.1 mm/2.523 in
Valve Depression (see Note 4)	0.7 mm/0.0276 in	1.2 mm/0.0427 in
Hot Plug Description	0.05 mm/0.002 in	0.05 mm/0.002 in

Valve Margin Thickness (see Note 5)	1.0 mm/0.3937 in	.7 mm/ .0276 in
Valve Stem Diameter	7.0 mm/ .2756 in (Int) 7.0 mm/ .2756 in (Exh.)	6.85 mm/ .2697 in (Int) 6.80 mm/ .2677 in (Exh.)
Valve Spring Installed Height	29.9 mm	------------------------------------
Valve Seat Angle	45°	

NOTES

(1) Valve adjustment clearances are established cold.

(2) Maximum grinding allowance is 0.3 mm/0.0118 in.

(3) Measurement is established by measuring from the head's sealing surface to the rocker bracket surface area.

(4) Dimension taken from the cylinder head surface to the top of the valves.

(5) Specification is for both intake and exhaust valves.

TABLE 7 4L MECHANICAL SPECIFICATIONS - SHORT BLOCK SPECIFICATIONS

Short Block Specifications	Standard	Service Limit
Main Bearing Bore Diameter	55.98 mm/2.2039 in	56.0 mm/2.2047 in
Cylinder Block Height 4LB1 4LC1/4LD1	280394 mm/11.060 in 307.94 mm/12.123 in	281.06 mm/11.065 in 308.06 mm/12.128 in
Main Bearing Journal Diameter 4LB1/4LC1 4LD1	56.0 mm/2.2047 in 60.0 mm/2.3622 in	55.86 mm/2.1992 in 59.86 mm/2.3567 in
Crank Pin Diameter 4LB1 4LC1 4LE1	43.0 mm/1.6929 in 46.0 mm/1.8110 in 49.0 mm/1.9291 in	42.87 mm/1.6878 in 45.87 mm/1.8059 in 48.87 mm/1.9240 in
Piston Protrusion	.400 mm/ .0158 in	------------------------------------
Piston to Cylinder Clearance	0.015-.035 mm/0.0006-.0014 in	
Main Bearing Clearance	0.029-0.072 mm/ 0.0011-0.0028 in	.0127 mm/0.005 in
Connecting Rod Bearing Clearance	0.035-0.073 mm/ 0.0014-0.0029 in	0.10 mm/0.0039 in
Crank Gear/Idler Gear Backlash	0.04 mm/0.0017 in	0.2 mm/0.0079 in
Cam Gear/Idler Backlash	0.03 mm/0.0012 in	0.2 mm/0.0079 in
Crankshaft End Play	0.058-.208 mm (0.0023-0.0082 in)	0.30 mm/0.0118 in

TORQUE SPECIFICATIONS

72 Torque specifications are as follows:

TABLE 8 4L TORQUE SPECIFICATIONS - CYLINDER HEAD/VALVE TRAIN

Cylinder Head/Valve Train	kg m	lb/ft
Cylinder Head Torque (see Notes 1 and 2) M12 x 1.5 M8 x 1.25	8.5-9.5 + 60°~90° (see Note 3) 2.5-3.5	61-69 + 60°~90° (see Note 3) 18-25
Valve lash adjusting jamb nut	0.8-1.2	5.8-8.7
Valve cover bolts	0.2-0.4	1.4-2.9
Exhaust Manifold	1.9-2.9	13.7-21.0
Rocker Arm Bracket Assembly	0.8-1.2	5.8-8.7
Exhaust Manifold	1.9-2.9	13.7-21.0
Nozzle Holder Assembly	4.0-5.0	29.0-36.2
Glow Plug	1.5-2.0	10.8-14.5

NOTES

(1) Torque using the following sequence.

(2) Bolts must not be reused. New bolts only.

(3) Clarification: On the second step, turn 60° to 90°.

TABLE 9 4L TORQUE SPECIFICATIONS - SHORT BLOCK SPECIFICATIONS

Short Block Specifications	kg m	lb/ft
Crankshaft Bearing Cap	8.5-9.5	61.0-69.0
Rod Bearing Cap 4LB1 4LC1 4LE1	 3.8-4.2 2.3-2.7 + 100°-115° 7.5-8.5	 27-30 17-20 + 100°-115° 54-61
Camshaft Gear Nut	7.0-9.0	50.6-65.0
Idler Gear	2.7-3.5	19.5-25.3
Oil Pump w/o PTO w PTO	1.9-2.9 0.8-1.2 (see Note)	13.7-21.0 5.8-8.7 (see Note)
Front Plate	1.9-2.9	13.7-21.0
Timing Gear Case	2.1-3.1	15.2-22.4
Starter	9.5-11.5	68.7-83.2
Flywheel Housing	4.2-5.6	30.4-40.5
Flywheel	9.0-11.0	65.0-79.5
Crank Pulley	17.0-19.0	123.0-137.4
Oil Strainer Bolt	1.9-2.9	13.7-21.0

NOTE: When PTO is provided, install the oil pump to the front plate.

LUBRICATION AND SEALANT SPECIFICATIONS

73 Lubrication and sealant specifications are as follows:

TABLE 10 4L LUBRICATION AND SEALANT SPECIFICATIONS

Application	Thread Lockers	Lubricants	Sealant
Flywheel Bolts	------------------------	Engine Oil	------------------------
Oil Pan	------------------------	------------------------	TB1207C
Rocker Bracket (see Note)	------------------------	------------------------	TB1207C
Air Inlet Pipe	------------------------	------------------------	TB1207C
Front Plate (PTO only)	------------------------	------------------------	TB1207C
Timing Case w/wo PTO	------------------------	------------------------	TB1207C
Water Pump	------------------------	------------------------	TB1207C
Core Plugs	------------------------	------------------------	TB1207C
Injection Pump Housing Cover	------------------------	------------------------	TB1207C
Fuel Cut Solenoid	------------------------	------------------------	TB1207C
Oil Seal Retainer	------------------------	------------------------	TB1207C
Connecting Rod Bolts	------------------------	Engine Oil	------------------------
Cylinder Head Bolts	------------------------	Engine Oil	------------------------
Main Cap Bolts	------------------------	Engine Oil	------------------------
Head Gasket	------------------------	------------------------	------------------------
Exhaust Gasket	------------------------	------------------------	------------------------
Oil Pump O-ring	------------------------	Engine Oil	------------------------
Oil Strainer O-ring	------------------------	Engine Oil	------------------------
Drain Plug O-ring	------------------------	Engine Oil	------------------------
Head Cover Gasket	------------------------	------------------------	------------------------
Oil Pump Back Cover	------------------------	------------------------	------------------------
Camshaft	------------------------	Extreme Pressure Lubricant	------------------------
Lifters	------------------------	Extreme Pressure Lubricant	------------------------
Engine Bearings	------------------------	Engine Oil	------------------------
Piston Pin	------------------------	Engine Oil	------------------------
Pistons	------------------------	Engine Oil	------------------------
Piston Rings	------------------------	Engine Oil	------------------------
Valve Guides	------------------------	Engine Oil	------------------------
Valves	------------------------	Engine Oil	------------------------

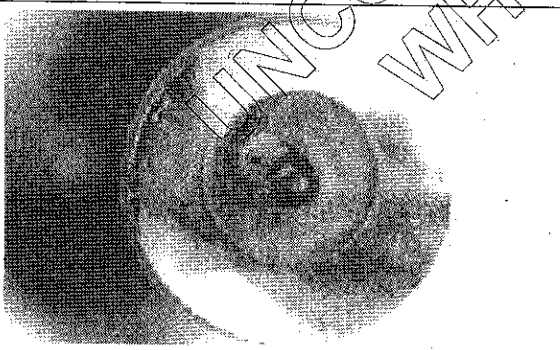
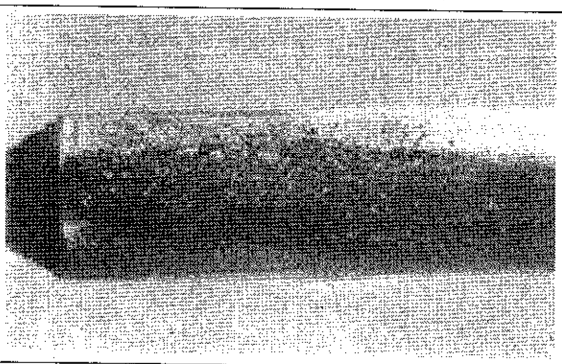
NOTE

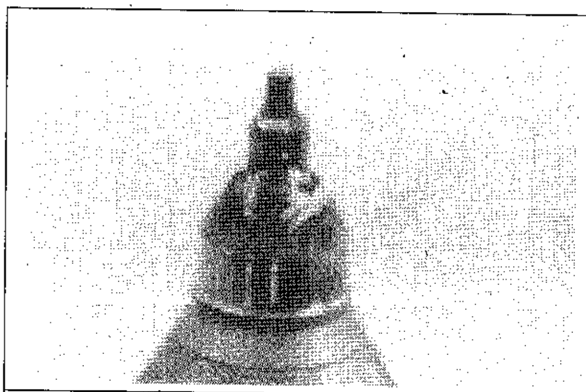
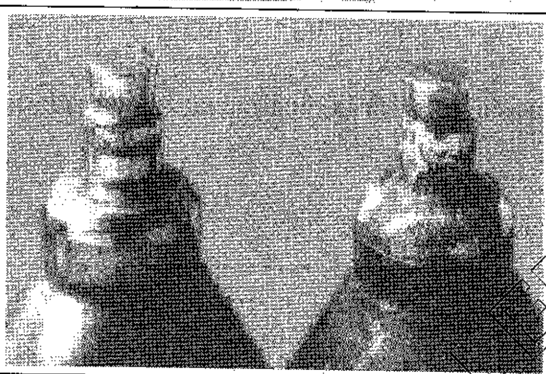
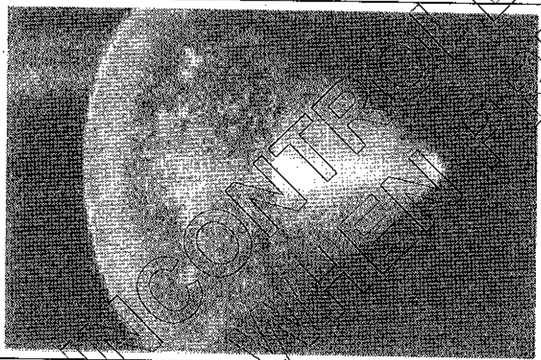
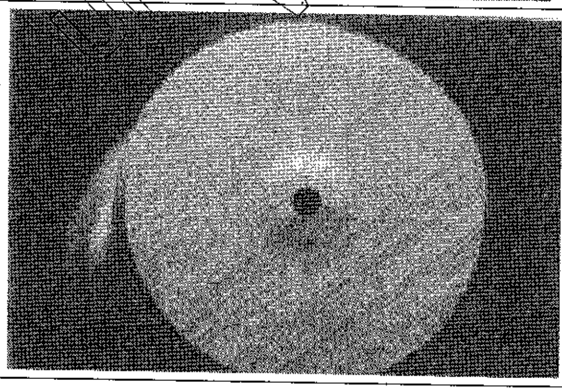
During Installation of the rocker arm bracket, be sure not to cover the rocker shaft oil galley.

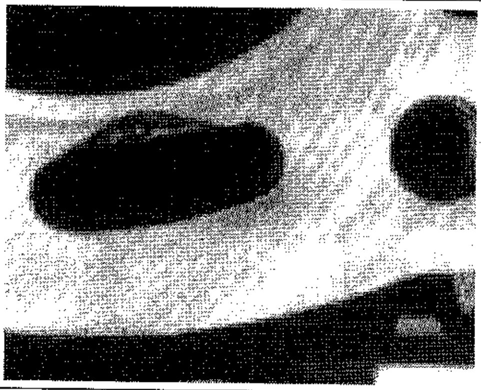
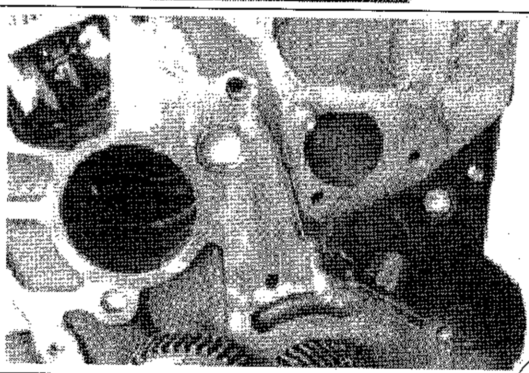
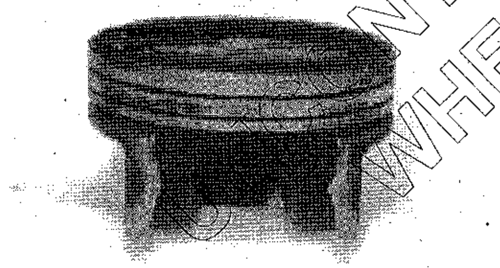
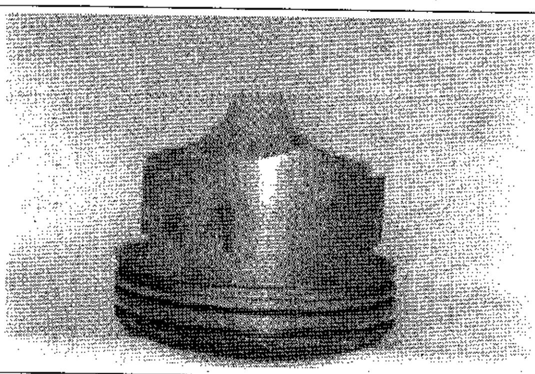
SECTION 5 - COMPONENT FAILURE ANALYSIS

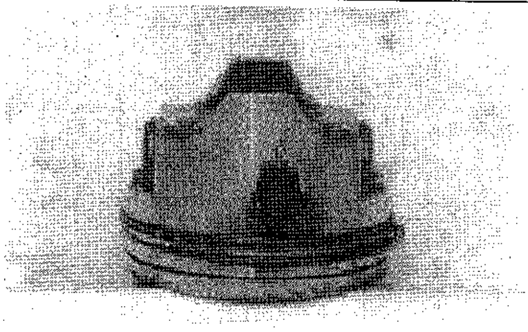
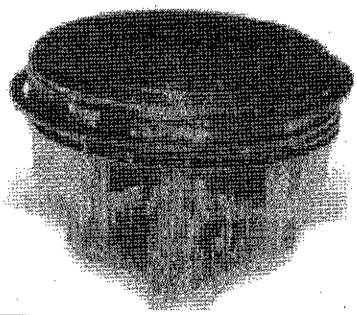
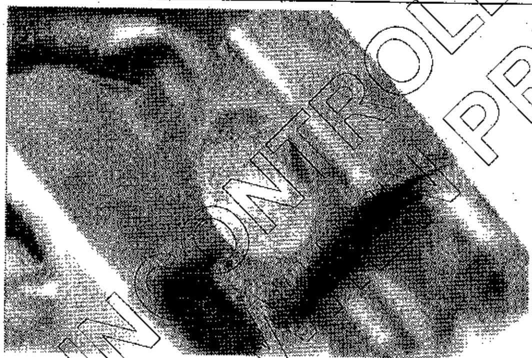
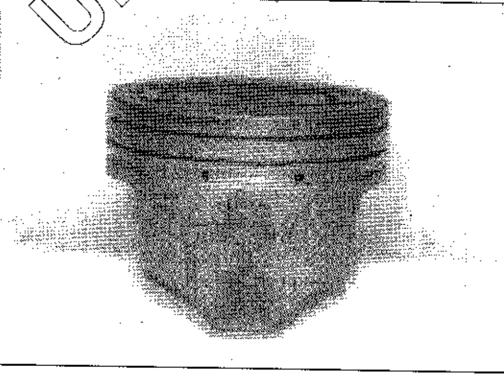
74 Table 11 illustrates examples of component failure.

TABLE 11 COMPONENT FAILURE ANALYSIS

Example	Description
FUEL SYSTEM – Nozzle holder component failure	
	Broken coil on the holder spring directly related to large amounts of carbon build-up on the nozzle spring. Carbon build-up can also be seen on the push rod. This condition is directly related to combustion gases passing through the nozzle holder spring chamber. Problems can be avoided by routine inspection of the nozzles.
	Broken coil due to oxidation caused by moisture or high sulphur content in the fuel. Condition can be prevented through routine inspection of the fuel and filter.
	Sulphuric acid corrosion at the pintal caused by high sulphur content in the fuel. This is a result of water reacting with the sulphur to form sulphuric acid.
	Corrosive abrasion of the pintal nozzle edge caused by direct contact with blow-by of the combustion gases in the combustion chamber.

	Nozzle seat damage caused by metal contaminants in the fuel that pressed onto the seat area. The condition can cause leaks or distorted spray patterns from improper nozzle seating.
	Pintal valve abrasion caused by sulfuric acid. This condition will cause the nozzle to stop functioning.
	Foreign material build-up on the nozzle seat surface. This condition will cause an injector leak.
	Damage to the nozzle seat and spray hole sections when the nozzle holder is over tightened.

CYLINDER BLOCK	
	Damaged head gasket, cylinder head, pistons, connecting rods and crankshaft caused by poor cylinder block casting, cooling system cavitation, or cooling system electrolysis.
	Low oil pressure readings or premature engine bearing wear due to missing internal oil galley plugs.
PISTON	
	Piston failure due to reusing a previously cracked piston skirt.
	Broken piston skirt tang due to excessive piston to wall clearance. (Creates piston slap sound).

	Seized piston skirt due to insufficient piston to wall clearance. (aka piston galling).
	Failed piston due to lack of oil in the engine at the time of the failure. (Heat failure can be identified by '4 point' scoring resulting in vertical scoring on the sides of the pin boss on both sides of the piston.)
PISTON FAILURE	
	A wrist pin seized in this bore due to a previously used bent wrist pin or damaged piston pin bore.
	(Normal piston skirt wear)

APPENDIX 1

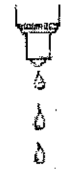
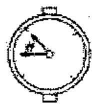
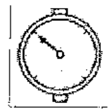
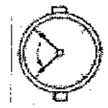
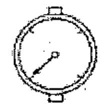
MISCELLANEOUS SERVICE INFORMATION

NOZZLE TROUBLESHOOTING GUIDE

Nozzle opening pressure too low	Nozzle opening pressure too high	Unsatisfactory chatter	Oil leak from nozzle seat	Improper spray pattern	Excessive pressure drop	External oil leak	Cause
X	X						Improper adjustment of nozzle opening pressure
	X	X		X			Clogged pintle nozzle hole and spray hole (carbon residue, foreign matter)
	X	X	X	X	X		Needle valve sticking
X		X	X	X	X		Abrasion, damage or accumulation of foreign matter at seat section
		X		X			Damage to pintle section of needle valve (pintle type nozzle)
X		X		X			Broken needle valve holding shaft
		X			X		Corrosion of sliding section
X		X					Damage to nozzle spring
X		X					Damage to push rod
					X	X	Scars or wear to nozzle's high pressure surface
					X	X	Scars or wear to spacer's high pressure surface
					X	X	Scars or wear to holder's high pressure surface
					X	X	Foreign matter accumulation in each mating surface of nozzle, spacer and holder
					X	X	Insufficient tightening of inlet connector
					X	X	Defective gasket of each seal section
				X			Damage or excessive wear to nozzle hole area
		X		X		X	Defective retaining nut (deformation caused by corrosion or insufficient cleaning)

NOZZLE PERFORMANCE AND DIAGNOSIS

PERFORMANCE EXAMPLES OF USED NOZZLES

Judgement Rank	A	B	C	D	E
Spray pattern example					
Pressure gauge pointer movement	 Continuously moves in the neighbourhood of nozzle opening pressure	 The same as "A"	 Stabilizes and does not move in the neighborhood of nozzle opening pressure.	 Rises to nozzle opening pressure, but the pressure markedly drops.	 Pressure does not rise even when the tester handle is operated.
Spray pattern	Almost uniform	Extremely non-uniform	Atomizes, but no pulsation of needle.	Incorrect atomization with extreme after-drip.	Dripping.
Possible cause of malfunction	(Normal)	(1) The common cause is carbon residue sticking to the nozzle edge. (2) Occasionally the needle edge is damaged or broken.	(1) A large quantity of carbon residue is sticking to the nozzle edge. (2) Occasionally caused by foreign materials caught in the spray hole.	(1) Damage to the seat section. (2) Fine foreign matter caught in the seat section. (3) The seat section has worn excessively.	(1) Needle stick. (2) The seat section has been damaged or worn excessively. (3) Foreign matter caught in the seat section. (4) Damage to nozzle holder internal parts.
Judgement after nozzle cleaning (removal of carbon residue and foreign matter, etc.)	Useable as is.	Replace with a new nozzle if the "A" performance is not restored after cleaning.	The same as "B"	The same as "B"	The same as "B" NOTE Replace with a new nozzle holder or parts (in the case of Item 4 above).

NOZZLE HOLDER TIGHTENING STANDARDS

NOZZLE HOLDER TIGHTENING STANDARDS

Unit: kg-m

Parts / Type	Retaining Nut	Nozzle holder plug	Adjusting screw lock nut	Cap nut	Leak off pipe joint bolt	Eye lock nut	Inlet connector
KB-S	M20x1.5 ZMC2 6-8 " Br 8-10 3/4-16UNF ZMC2 6-8 " ZMC2 8-10 M22x15 ZMC2 6-8 " Br 8-10 M24x1.5 Br 9-11	M22x1.5 Br 5-6	M8x0.75 Br 2.5	M22x1.5 ZMC2 4-5 " Br 5-6	M8x1 ZMC2 1-1.5 " Br 1-1.5 M8x1.25 ZMC2 1-1.5 " Br 1-1.5 M10x1 ZMC2 1.5-2 " Br 1.5-2		M12x1.5 ZMC2 5-6 " Br 6-7 M14x1.5 ZMC2 6-7 " Br 7-8 M16x1.5 Br 8-10 M18x1.5 Br 10-12
KBA . . S	M22x1.5 Br 10-12				M8x1 Br 1-1.5		M14x1.5 Br 7-8
KBL . . S	M20x1.5 ZMC2 6-8 " Br 8-10 3/4-16UNF ZMC2 6-8 " Br 8-10 M22x15 ZMC2 6-8 " Br 8-10 M24x1.5 Br 9-11			M14x1 ZMC2 3-4 " Br 4-5 M20x1 ZMC2 4-5 " Br 5-6 M22x1 ZMC2 4-5 M22x1.5 ZMC2 4-5 " Br 5-6	M8x1 Br 1-1.5 M8x1.25 ZMC2 1-1.5 " Br 1-1.5 M10x1 ZMC2 1.5-2 " Br 1.5-2		M12x1.5 ZMC2 5-6 " Br 6-7 M14x1.5 ZMC2 6-7 " Br 7-8 M16x1.5 Br 8-10 M18x1.5 Br 10-12
KB . . . T	M24 x1.5 Br 18-20	M22x1.5 Br 5-6	M8x0.75 Br 2.5-3.5	M22x1.5 Br 4-5	M10x1 Br 1.5-2.0		029301-0090 M18x1.5 Br 10-12 029300-4030 M18x1.5 Br 1.5-17 150604-1420 M18x1.5 Br 150604-3820 M20 x1.5 1.5-17
KB . . . U	M36x3 Br 24-27	M36x3 Br 12-14	M12x1.5 Br 2.5-3.5	M36x3 Br 10-12	M14x15 Br 5-6		M22x1.5 B4 20-23

NOTE

ZMC2 Galvanizing and chrome treatment
Br Black oxide coating

(continued)

NOZZLE HOLDER TIGHTENING STANDARDS (continued)

Unit: kg-m

Parts / Type	Retaining Nut	Nozzle holder plug	Adjusting screw lock nut	Cap nut	Leak off pipe joint bolt	Eye lock nut	Inlet connector
KBF . . T	M24x1.5 Br 18-20	M22x1.5 Br 5-6	M8x0.75 Br 2.5-3.5	M22x1.5 Br 4-5	M10x1 Br 1.5-2.0		029301-0090 M18x1.5 Br 10-12 029300-4030 M18x1.5 Br 1.5-17 150604-1420 M18x1.5 Br 150604-3820 M20 x1.5 1.5-17
KBF . . U	M36x3 Br 24-27	M36x3 Br 12-14	M12x1.5 Br 2.5-3.5	M36x3 Br 10-12	M14x15 Br 5-6		M22x1.5 Br 20-23
KCA . . S	M22x1.5 ZMC2 8-10 " Br 10-12					M12x1.5 ZMC2 4- 5 " Br 4-5 M14z1.5 ZMC2 5-6 " Br 5-6	
KCA SD	M22x1.5 ZMC2 8-10 " Br 10-12					M12x1.5 ZMC2 4- 5 " Br 4-5 M14z1.5 ZMC2 5-6 " Br 5-6	
KD . . . S	M20x1.5 ZMC2 6-8 " Br 8-10 3/4-16UNF ZMC2 6-8 " Br 8-10 M22x1.5 ZMC2 6-8 " Br 8-10 M24x1.5 Br 9-11		M22x1 ZMC2 5-6 M22x1 Br 6-7	M22x1 ZMC2 5-6 " Br 5-6	M8x1 ZMC2 1-1.5 M8x1.25 ZMC2 1-1.5 " Br 1-1.5 M10x1 ZMC2 1.5-2 " Br 1.5-2		M12x1.5 ZMC2 5-6 " Br 6-7 M14x1.5 ZMC2 6-7 " Br 7-8 M16x1.5 Br 8-10 M18x1.5 Br 10-12
KD L . S	M20x1.5 ZMC2 6-8 " Br 8-10 3/4-16UNF ZMC2 6-8 " Br 8-10 M22x1.5 ZMC2 6-8 " Br 8-10 M24x1.5 Br 9-11		M22x1 ZMC2 5-6 M22x1 Br 6-7	M22x1 ZMC2 5-6 " Br 5-6	M8x1 ZMC2 1-1.5 M8x1.25 ZMC2 1-1.5 " Br 1-1.5 M10x1 ZMC2 1.5-2 " Br 1.5-2		M12x1.5 ZMC2 5-6 " Br 6-7 M14x1.5 ZMC2 6-7 " Br 7-8 M16x1.5 Br 8-10 M18x1.5 Br 10-12

NOTE

ZMC2 Galvanizing and chrome treatment
Br Black oxide coating

TURBOCHARGER BOOST PRESSURE DIAGNOSIS

1 Listed below are suggested checks for determining the cause of lowered turbo boost pressure (in the sequence they should be performed). To obtain maximum boost pressure, the engine must be operated at rated RPM under a full load condition. Boost pressure is measured with a mercury manometer. A pressure gauge may be substituted.

2 One of the following checks will uncover the reason for low boost pressure. (Normal pressure is 11-16 psi.)

(1) Check the throttle linkage for travel to full fuel position.

(2) Measure the maximum no load engine RPM. Adjust if necessary.

(3) Inspect the manifolds and turbo for cracks, loosened mounting bolts or leaking gaskets.

(4) Check the intake and exhaust systems for restriction, ie dirty air cleaner, collapsed hose or crushed exhaust pipe.

(5) Check the fuel system, ie air in the fuel, dirty fuel inlet screen (rock stopper), dirty fuel filter, contaminated fuel or reduce fuel delivery to the injection pump.

(6) Check the valve clearance adjustment.

(7) Check the injection nozzles, ie popping pressure, spray pattern or leakage.

(8) While the injection nozzles are removed, check the compression pressure.

(9) With the turbo mounted to the manifold inspect the following:

It is necessary to remove the intake and exhaust piping from the turbo.

a. The wastegate (if used) does not close completely.

b. Check the compressor wheel for damage.

c. Check the turbine side for heavy carbon deposits or damage.

d. Measure the wheel shaft end play and bearing clearance.

(10) Have the injection pump tested by an authorized Zexel dealer for proper calibration.

EXHAUST TEMPERATURE TEST

3 Exhaust temperature is measured with a pyrometer, thermo coupler, or infrared meter.

4 The temperature probe is installed in a straight section of the exhaust pipe approximately 6 inches from the turbo flange or manifold flange for naturally aspirated engines.

5 The reading is taken with the engine operating at rated output.

6 When the exhaust temperature is high, check the following:

(1) Retarded timing.

(2) Air intake system restriction.

(3) Excessive exhaust system back pressure.

7 When exhaust temperature is low, check the following:

(1) Low compression.

(2) Inadequate fuel delivery from injection pump.

CRANKCASE PRESSURE TEST

8 Crankcase pressure is measured with a water manometer.

NOTE

2 in. of water (or less) is normal. Pressure should never measure more than 2 in.

9 The manometer pickup tube is inserted into the oil level gauge tube, from which the level gauge has been removed. Do not insert the tube into the oil. Do not attempt to seal engine openings.

10 The reading is taken with the engine operating at rated output.

INLET MANIFOLD PRESSURE (BOOST PRESSURE) TEST

11 Boost pressure is to be measured with a mercury manometer. A pressure gauge may be used when a manometer is not available. 1 inch of mercury =.49 PSI

12 The measuring device is to be installed in or straight run of the inlet air pipe. The most desirable location is 6 inches from the inlet manifold flange.

13 The reading is taken with the engine operating at its peak rated output.

SPECIFICATIONS FOR THESE TESTS

14 The results of all three of these tests will vary between engine models and between specifications of the same model. To find specifications for your particular engine, reference American Isuzu Motors Inc. Engine & Components Operations Publication #SV-5013-00 ('Engine Service Specifications Manual').

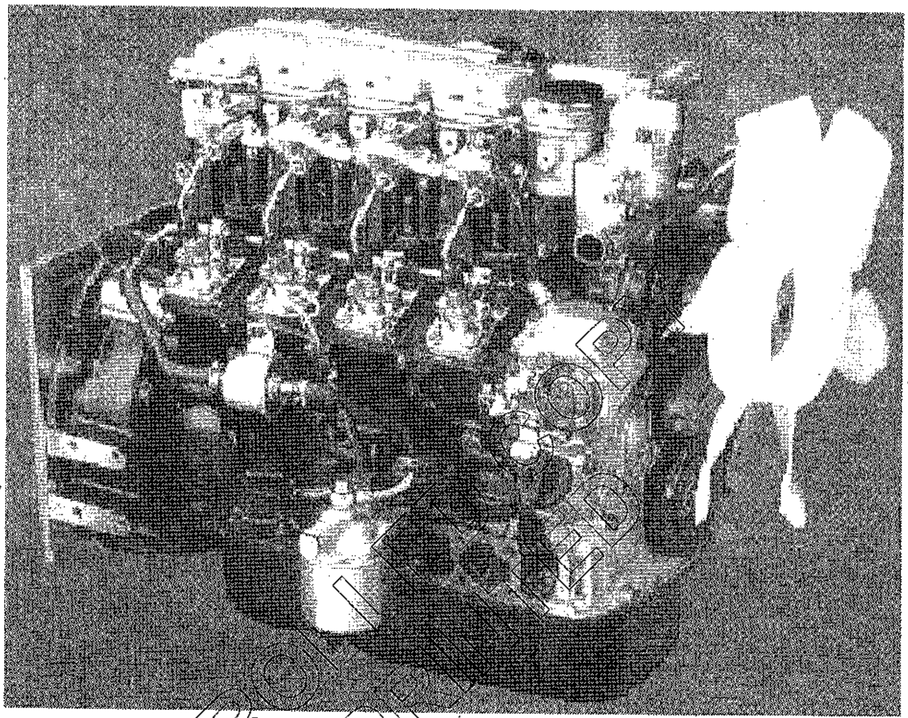
USED OIL SAMPLE DATA (LIMITS)

Item	Unit of Measurement	Limit
Kinematic Viscosity	(@98.9°C (CST)/210°F	-20 to 50% of new oil
Total Base No.	KOH mG/G	1 (min.)
Total Acid No.	KOH mG/G	3 (max.)
B-Heptane Insoluble	Wt%	3 (max.)
Resin Insoluble	Wt%	Reference [1 (max.)]
Ash Sulphate	Wt%	Reference [0.5 (max.)]
Diesel Fuel Content	Wt%	5 (max.)
Water Content	Wt%	.5 (max.)
Worn Metal particle: Fe	PPM	150
Worn Metal particle: Cu	PPM	50
Worn Metal particle: PB	PPM	50
Worn Metal particle: Cr	PPM	20 (or 80..Cr-plated liner)
Worn Metal particle: Al	PPM	20-40
Worn Metal particle: Si	PPM	20

Based on testing a new oil sample of exact same kind as used oil.

APPENDIX 2

ISUZU TECHNOLOGY: L-SERIES DIRECT INJECTION



1 Re-engineering equipment for a new engine model is typically an expensive proposition and stepping up to EPA's Tier 2 regulations in 2004 for off-highway engines in the 25 to 100 hp range will mean just that, but not if the envelope of the replacement engine is identical with the present engine. Current and prospective users of Isuzu's L-Series engines will be pleased to learn that the new direct-injection (DI) versions have the same physical footprint as the current IDI models.

2 The industrial engines are developed from the technology of well-proven automotive engines. It is certainly the automotive sector that represents the leading edge in gaseous emissions, but that is also true of customer expectations with respect to noise, vibration and ease of use. Isuzu produces more than 800,000 diesel engines per year and plans to produce 1.8 million by 2005.

3 The L-Series diesels will still be in the picture at that time and that was always the plan from the time they were introduced by American Isuzu to the U.S. market back in 1993, replacing the well-known K-Series. The three cylinder L-Series engines were joined by four cylinder versions in 1995. These engines were conceived to be among the quietest, most compact, lightweight, water-cooled engines in their class and the plan was that this basic platform would meet CARB, EPA and other applicable emission standards well into the future.

4 If one looks at the global automotive picture, it is estimated that fully 90 percent of the vehicular diesel engines will be direct injected after 2000 and the percentage would be even higher were it not for Third World production. The main motivations are the reduction of CO, and particulate matter emissions and the improvement of fuel economy.

5 So this is the battleground and direct injection appears to be the weapon of choice. And from this massive automotive capital base flows the technology base that will then be applied to other engine applications. Virtually all automotive diesel engines above 3.5 L displacement already use DI technology and many smaller automotive engines are also DI.

6 Many of Isuzu's engines were developed for automotive as well as industrial use. Included would be the J-Series and the B-Series in the under 100 hp range. The L-Series, however, was developed strictly for industrial use, yet it too makes use of the tools of automotive engine design.

7 With the new DI three cylinder model 3LD2 displacing 1499 cc and the four cylinder 4LE2 displacing 2179 cc, the L-Series is the smallest series that Isuzu manufactures today. The 3LD2 has a bore and stroke of 83.1 x 92 mm and a maximum output of 34.8 hp at 3000 rpm, with peak torque of 73.5 lb.ft. at 1800 rpm. The 4LE2 has a bore and stroke of 85 x 96 mm and a maximum output of 54.4 hp at 3000 rpm, with peak torque of 113.4 lb.ft. at 1800 rpm. All ratings are SAE J1995 gross hp. Dry weight of the 3LD2 and 4LE2 is given at 290 and 396 lb. respectively.

8 Despite the very small differences in bore and stroke, the engines are virtually identical in other respects. Isuzu insists new DI L-Series still offers OEMs a single engine family with high component commonality in both three and four cylinder configurations.

9 The compact and lightweight L-Series feature one-piece, cast iron blocks and heads, and overhead valve design with two valves per cylinder. The block is deep skirted for strength, rigidity and durability. Unit injection pump housings are cast into the blocks. The engine water jacket is formed with a one-piece casting core to eliminate irregular cooling passages.

10 The ductile iron crankshaft is underslung to the block with five main bearings for the 4LE2 and four main bearings for the 3LD2. The flame-hardened, chilled casting camshaft is mid-mounted in the block and it is gear driven. The camshaft is a one-piece design.

11 Low noise and vibration were very active design themes for the L-Series. A single camshaft actuates unit pump injectors as well as intake and exhaust valves. Valves are actuated through forged steel push rods and aluminum die cast rocker arms. Gears are helical and the number of gears in the gear train is only three and this permits a smaller gear cover with a lower profile and reduced forward noise emissions.

12 Finite element analysis (FEA), modal analysis and acoustic intensity techniques were used to evaluate every engine component and determine the contribution to the overall noise level. FEM was used to develop spherical cylinder block sidewalls and to optimize bulkhead ribs. Integral camshaft journal bearings featured on the L-Series had a tendency to lower rigidity of the engine block but this was overcome by numerous FEMJ iterations.

13 Other L-Series noise reduction features include the use of auto thermatic type pistons, an oil pan constructed of vibration damped steel sheet on the 3LD2, crankshaft balancers and an optimized fuel injection system. There is no difference in noise level comparing the DI and IDI at no load and only a 2 dB(A) difference at full load. Fuel injection lines from the unit pumps to the injectors are short and all the same length. Additionally, the fan or blower speed can also be lowered for an extra measure of noise reduction. Isuzu feels it has accomplished something with respect to sound quality as well as sound level.

14 Both the 3LD2 and the 4LE2 direct injected diesels are naturally aspirated and feature Isuzu's new 'Cobra' combustion chamber, which uses an interesting high swirl conservation strategy. The aim is twofold. First, reduce the peak temperature in the premixed combustion stage to lower combustion noise and NOx emissions. A two-spring injector is vital to achieving this part of the rate shaping. Second, promote vigorous, fast mixing in the diffusion combustion stage - after top dead center - to lower smoke and particulate matter emission and to improve fuel consumption.

15 The unit injection pump is driven by the camshaft lobes that have a concave-shaped cam profile and this determines rate shaping throughout the combustion cycle. A lower initial injection rate in the premix stage and a higher rate in the diffusion stage provides a more complete and efficient burn.

16 So most of the fuel is actually injected during the combustion diffusion stage via a high-pressure nozzle with small holes to minimize fuel particle size and new combustion chamber design optimized through the use of computational fluid dynamics (CFD) analysis. The entire combustion cycle is reduced in length, but it is characterized by relatively higher swirl in the later stages.

17 Tier 2 compliance is the real driving force here, but fuel consumption should be lower 10 to 15 percent. The overall efficiency of the DI L-Series engines is demonstrated by a heat rejection rate that is 20 to 25 percent lower than the comparable IDI engines. Users may be less interested in fuel consumption lately, but the overall improvement in efficiency cannot be overlooked.

18 The engine lube oil filler and level gauge, oil filter cartridge, unit injection pumps, and injection nozzles are all located on the right side of the engines. The L-Series reputation for leak-free operation should be continued, always a strong point for Isuzu. The fuel system is also self-bleeding and self-priming, meaning that should the operator run out of fuel, he can just add fuel and restart the engine.

19 Summing up features of the new DI L-Series, high engine performance and efficiency, compliant with Tier 2 regulations; low noise and pleasant sound quality, low fuel consumption, low heat rejection, compact envelope size, one side service access, high reliability. And don't forget, the same footprint as the IDI versions.

ANNEX D

NEWAGE ALTERNATOR MANUAL

ANNEX D

NEWAGE ALTERNATOR MANUAL

CONTENTS

(continued)

CONTENTS (continued)

STAMFORD
AC GENERATORS FROM
NEWAGE INTERNATIONAL

Installation, Service and Maintenance Manual

For the BC Range of Generators (BCI182J)

SAFETY PRECAUTIONS

Before operating the generating set, read the generating set operation manual and this generator manual and become familiar with it and the equipment.

SAFE AND EFFICIENT OPERATION CAN ONLY BE ACHIEVED IF THE EQUIPMENT IS CORRECTLY OPERATED AND MAINTAINED.

Many accidents occur because of failure to follow fundamental rules and precautions.

ELECTRICAL SHOCK CAN CAUSE SEVERE PERSONAL INJURY OR DEATH.

- Ensure installation meets all applicable safety and local electrical codes. Have all installations performed by a qualified electrician.
- Do not operate the generator with protective covers, access covers or terminal box covers removed.
- Disable engine starting circuits before carrying out maintenance.
- Disable closing circuits and/or place warning notices on any circuit breakers normally used for connection to the mains or other generators, to avoid accidental closure.

Observe all **IMPORTANT, CAUTION, WARNING, and DANGER** notices, defined as:

IMPORTANT!

Important refers to hazard or unsafe method or practice which can result in product damage or related equipment damage.

CAUTION!

Caution refers to hazard or unsafe method or practice which can result in product damage or personal injury.

WARNING!

WARNING REFERS TO A HAZARD OR UNSAFE METHOD OR PRACTICE WHICH CAN RESULT IN SEVERE PERSONAL INJURY OR POSSIBLE DEATH.

DANGER!

Danger refers to immediate hazards which will result in severe personal injury or death.

Due to our policy of continuous improvement, details in this manual which were correct at time of printing may now be due for amendment. Information included must therefore not be regarded as binding.

FOREWORD

The function of this book is to provide the user of the Stamford generator with an understanding of the principles of operation, the criteria for which the generator has been designed, and the installation and maintenance procedures. Specific areas where the lack of care or use of incorrect procedures could lead to equipment damage and/or personal injury are highlighted, with WARNING and/or CAUTION notes, and it is IMPORTANT that the contents of this book are read and understood before proceeding to fit or use the generator.

The Service, Sales and technical staff of Newage international are always ready to assist and reference to the company for advice is welcomed.

WARNING

PERSONNEL INJURY. INCORRECT INSTALLATION, SERVICE OR REPLACEMENT OF PARTS CAN RESULT IN SEVERE PERSONAL INJURY OR DEATH, AND/OR EQUIPMENT DAMAGE. SERVICE PERSONNEL MUST BE QUALIFIED TO PERFORM ELECTRICAL AND MECHANICAL SERVICE.

EC DECLARATION OF INCORPORATION

All Stamford generators are supplied with a declaration of incorporation for the relevant EC legislation, typically in the form of a label as below.

EC DECLARATION OF INCORPORATION

IN ACCORDANCE WITH THE SUPPLY OF MACHINERY (SAFETY) REGULATIONS 1992 AND THE SUPPLY OF MACHINERY (SAFETY) (AMENDMENT) REGULATIONS 1994 IMPLEMENTING THE EC MACHINERY DIRECTIVE 89/392/EEC AS AMENDED BY 91/368/EEC.

THIS STAMFORD A.C. GENERATOR WAS MANUFACTURED BY OR ON BEHALF OF NEWAGE INTERNATIONAL LTD BARNACK ROAD STAMFORD LINCOLNSHIRE ENGLAND.

THIS COMPONENT MACHINERY MUST NOT BE PUT INTO SERVICE UNTIL THE MACHINERY INTO WHICH IT IS TO BE INCORPORATED HAS BEEN DECLARED IN CONFORMITY WITH THE PROVISIONS OF THE SUPPLY OF MACHINERY (SAFETY) REGULATIONS 1995/MACHINERY DIRECTIVE.

FOR AND ON BEHALF OF NEWAGE INTERNATIONAL LIMITED

NAME: LAWRENCE HAYDOCK
POSITION: TECHNICAL DIRECTOR
SIGNATURE:

THIS COMPONENT MACHINERY CARRIES THE CE MARK FOR COMPLIANCE WITH THE STATUTORY REQUIREMENTS FOR THE IMPLEMENTATION OF THE FOLLOWING DIRECTIVES

The EMC Directive 89/336/EEC
WARNING! This Component Machinery shall not be used in the Residential, Commercial and Light Industrial environment unless it also conforms to the relevant standard (EN 50081 - 1) REFER TO FACTORY FOR DETAILS

ii) The Low Voltage Directive 73/23/EEC as amended by 93/68/EEC

When this manual is supplied to support a specific generator at point of sale, the generator identity is clearly displayed on the front cover of this book.

ELECTROMAGNETIC COMPATIBILITY

Additional information

European Union Council Directive 89/336/EEC

For installations within the European Union, electrical products must meet the requirements of the above directive, and Newage ac generators are supplied on the basis that:

- They are to be used for power-generation or related function.
- They are to be applied in one of the following environments:

  Portable (open construction - temporary site supply)

  Portable (enclosed - temporary site supply)

  Containerised (temporary or permanent site supply)

  Ship-borne below decks (marine auxiliary power)

  Commercial vehicle (road transport/refrigeration etc)

  Rail transport (auxiliary power)

  Industrial vehicle (earthmoving, cranes etc)

  Fixed installation (industrial - factory/process plant)

  Fixed installation (residential, commercial and light industrial home/office/health)

  Energy management (Combined heat and power and/or peak lopping)

  Alternative energy schemes

- The standard generators are designed to meet the 'industrial' emissions and immunity standards. Where the generator is required to meet the residential, commercial and light industrial emissions and immunity standards reference should be made to Newage document reference N4/X/011, as additional equipment may be required.
- The installation earthing scheme involves connection of the generator frame to the site protective earth conductor using a minimum practical lead length.
- Maintenance and servicing with anything other than factory supplied or authorized parts will invalidate any Newage liability for EMC compliance.
- Adequately trained personnel fully aware of the requirements of the relevant EC directives carry out installation, maintenance and servicing.

INTRODUCTION

1 The BC16/18 range of generators is of brushless rotating field design, available up to 660V/50Hz (1500 rpm, 4 pole and 3000 rpm, 2 pole) or 60Hz (1800 rpm, 4 pole and 3600 rpm, 2 pole), and built to meet B.S. 5000 Part 3 and international standards.

2 The BC16/18 range are self-excited with excitation power derived from the main output windings, using either the **SX460**/SA465 AVR or transformer controlled excitation system.

3 The BC184 may be supplied fitted with an auxiliary winding in the main stator, using the SA465 AVR.

4 Detailed specification sheets are available on request.

DESIGNATION

5 To provide standardisation of systems with minimal change to customers.

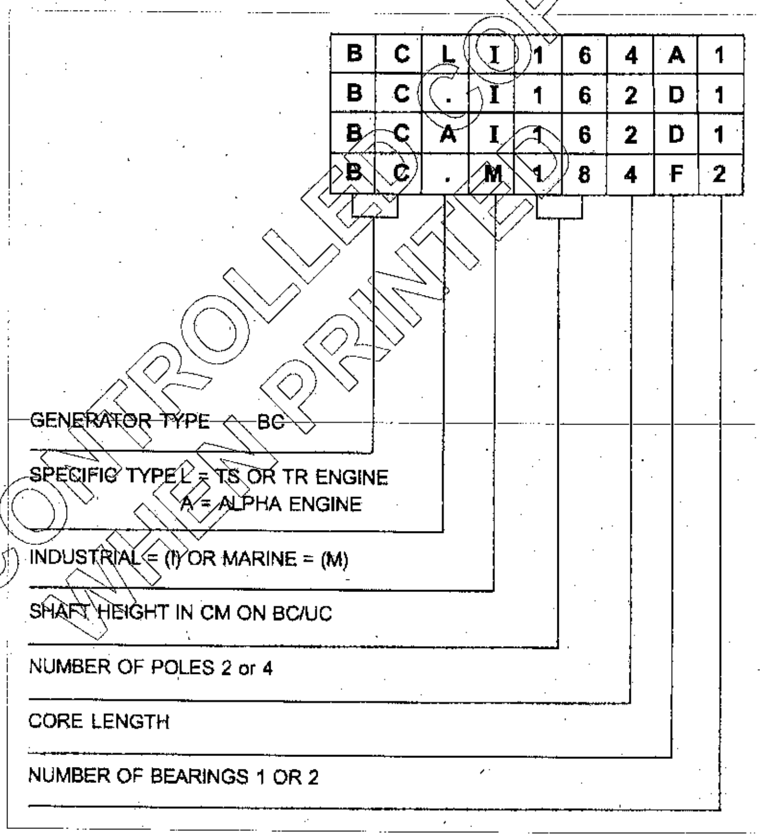


Fig 1 Designation

PACKAGED LOOSE ADAPTOR HARDWARE

6 Several adaptors are only partially fitted to generators to simplify removal prior to engine-generator assembly. The remaining hardware is contained within a plastic bag located in the terminal box.

Adaptor types

7 SAE2
SAE3
SAE5 Spacer Rings
SAE6
Coupling Plate Dowel Pins

SERIAL NUMBER LOCATION

8 Each generator has its unique serial number stamped into the upper section of the non-drive end frame.

9 Inside the terminal box two adhesive rectangular labels have been fixed, each carrying the generator's unique identity number. One to the inside of the terminal box sheet metal work, and the second label fixed to the main frame of the generator.

RATING PLATE AND CE MARK

10 The generator has been supplied with a self-adhesive rating plate label to enable fitting after final assembly and painting. It is intended that this label will be stuck to the outside of the terminal box on the left-hand side when viewed from the drive-end. To assist with squarely positioning the label, location protrusions have been made in the sheet metalwork.

11 A CE Mark label is also supplied loose for fitment after final assembly and painting. This should be attached to an external surface of the Generator at a suitable location where it will not be obscured by the customer's wiring or other fittings. Before fitting the CE Mark label the genset builder must address the requirements of the relevant EC legislation to ensure the compliance of the genset as a whole. CE compliance will also need to be addressed when installed on site.

12 The surface on the area where a label is to be stuck must be flat, clean and any paint finish must be fully dry before attempting to attach label. Recommended method for attaching label is peel and fold back sufficient of the backing paper to expose some 20mm of label adhesive along the edge which is to be located against the sheet metal protrusions. Once this first section of label has been carefully located and stuck into position the backing paper can be progressively removed, as the label is pressed down into position. The adhesive will achieve a permanent bond in 24 hours.

PRINCIPLE OF OPERATION

SELF-EXCITED AVR CONTROLLED GENERATORS

Main stator powered AVR

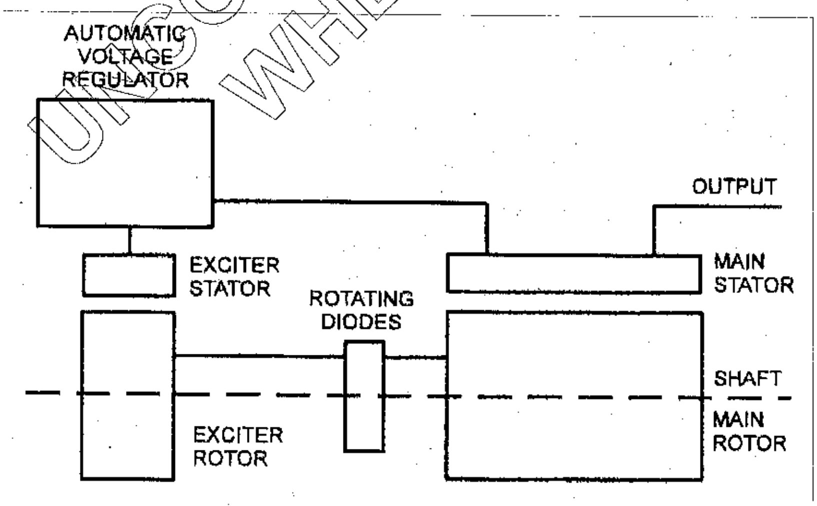


Fig 2 Main stator powered AVR

13 The main stator provides power for excitation of the exciter field via the SX460 (SA465) AVR which is the controlling device governing the level of excitation provided to the exciter field. The AVR responds to a voltage sensing signal derived from the main stator winding. By controlling the low power of the exciter field, control of the high power requirement of the main field is achieved through the rectified output of the exciter armature.

14 The AVR senses average voltage on two phases ensuring close regulation. In addition it detects engine speed and provides voltage fall off with speed, below a pre-selected speed (Hz) setting, preventing over-excitation at low engine speeds and softening the effect of load switching to relieve the burden on the engine.

15 The detailed function of the AVR circuits and their adjustment are covered in the load testing section.

16 In addition the SA465 AVR incorporates circuits which, when used in conjunction with accessories, can provide for parallel operation either with 'droop' or 'astatic' control and VAR/PF control.

17 Function and adjustment of the accessories which can be fitted inside the generator terminal box are covered in the accessories section of this book.

18 Separate instructions are provided with other accessories available for control panel mounting.

Auxiliary winding powered AVR

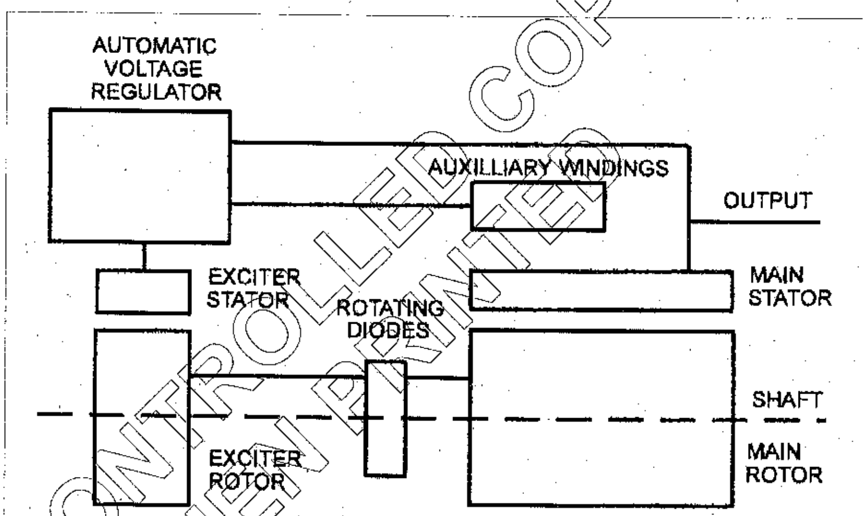


Fig 3 Auxiliary winding powered AVR

19 The auxiliary winding provides power for excitation of the exciter field via the SA465 AVR which is the controlling device governing the level of excitation provided to the exciter field. The AVR responds to a voltage sensing signal derived from the main stator winding. By controlling the low power of the exciter field, control of the high power requirement of the main field is achieved through the rectified output of the exciter armature. The AVR senses average voltage on two phases ensuring close regulation. In addition, it detects engine speed and provides voltage fall off with speed, below a pre-selected speed (Hz) setting, preventing over-excitation at low engine speeds and softening the effect of load switching to relieve the burden on the engine.

20 Under fault conditions on the main stator output the auxiliary winding continues to generate voltage from the harmonic content of the magnetic field in the main stator core providing the necessary power via the SA465 AVR, to maintain short circuit fault currents.

21 The detailed function of the AVR circuits and their adjustment are covered in the load testing section.

22 Function and adjustment of the accessories which can be fitted inside the generator terminal box are covered in the accessories section of this book.

23 Separate instructions are provided with other accessories available for control panel mounting.

Transformer controlled generators

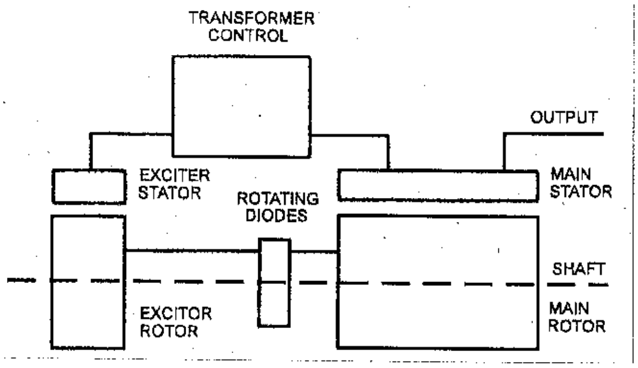


Fig 4 Transformer controlled generators

24 The main stator provides power for excitation of the exciter field via a transformer rectifier unit. The transformer combines voltage and current elements derived from the main stator output to form the basis of an open-loop control system, which is self regulating in nature. The system inherently compensates for load current magnitude and power factor and provides short circuit maintenance in addition to a good motor starting performance.

25 Three-phase generators normally have a three-phase transformer control for improved performance with unbalanced loads but a single-phase transformer option is available.

26 No accessories can be provided with this control system.

APPLICATION OF THE GENERATOR

27 The generator is supplied as a component part for installation in a generating set. It is not, therefore, practicable to fit all the necessary warning/hazard labels during generator manufacture. The additional labels required are packaged with this manual, together with a drawing identifying their locations.

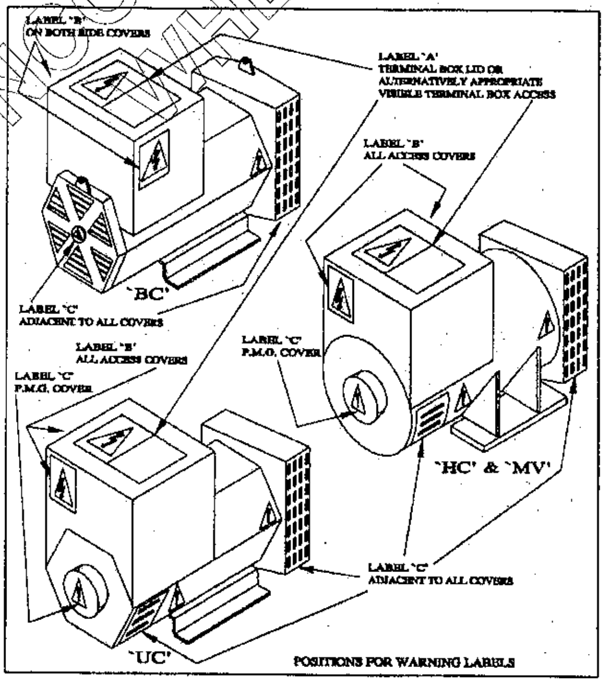


Fig 5 Warning/hazard label locations

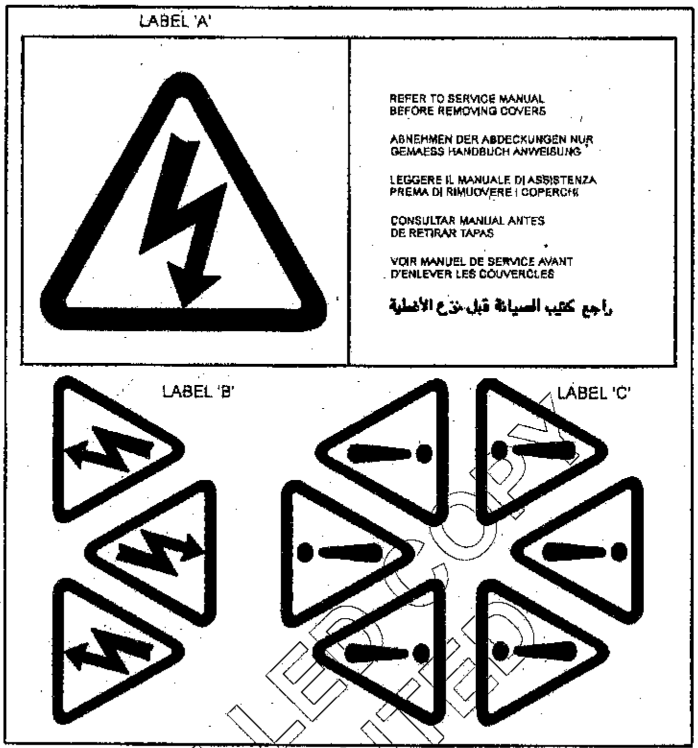


Fig 6 Warning/hazard labels

28 It is the responsibility of the generating set manufacturer to ensure that the correct labels are fitted, and are clearly visible.

29 The generators have been designed for use in a maximum ambient temperature of 40°C and altitude less than 1000 metres above sea level in accordance with BS 5000.

30 Ambients in excess of 40°C and altitudes above 1000 metres can be tolerated with reduced ratings - refer to the generator nameplate for rating and ambient. In the event that the generator is required to operate in an ambient in excess of the nameplate value or at altitudes in excess of 1000 metres above sea level, refer to the factory.

31 The generators are of air-ventilated screen protected drip-proof design and are not suitable for mounting outdoors unless adequately protected by the use of canopies. Anti-condensation heaters are recommended during storage and for standby duty to ensure winding insulation is maintained in good condition.

32 When installed in a closed canopy it must be ensured that the ambient temperature of the cooling air to the generator does not exceed that for which the generator has been rated.

33 The canopy should be designed such that the engine air intake to the canopy is separated from the generator intake, particularly where the radiator cooling fan is required to draw air into the canopy. In addition the generator air intake to the canopy should be designed such that the ingress of moisture is prohibited, preferably by use of a 2 stage filter.

34 The generator air intake is through the non-drive end cover and the generating set and canopy design must be such that the intake is not restricted. It is recommended that a minimum clearance of 50mm is allowed between the generator air intake and any vertical flat surface.

35 The air intake/outlet must be suitable for the air flow given in the following table with additional pressure drops less than or equal to those given below:

TABLE 1 AIR FLOW

Frame	Air flow 50 Hz	Air flow 60 Hz	Additional (intake/outlet) Pressure drop
BC164	0.071 m³/sec	0.09 m³/sec	3mm water gauge (0.1")
	150 cfm	190 cfm	
BC184 EFG	0.095 m³/sec	0.119 m³/sec	
	200 cfm	250 cfm	
BC184 HJ	0.15 m³/sec	0.19 m³/sec	
	318 cfm	403 cfm	
BC162	0.19 m³/sec	0.23 m³/sec	
	403 cfm	487 cfm	
BC182	**0.254 m³/sec**	**0.304 m³/sec**	
	538 cfm	**644 cfm**	

36 If specified at the time of ordering, the generator itself may be fitted with air filters.

37 The BCL construction has no fan fitted to the generator. The engine flywheel fan draws air through the generator and additional restrictions on air flow such as filters on the generator or canopies are not permissible.

CAUTION

EQUIPMENT DAMAGE. Reduction in cooling air flow or inadequate protection to the generator can result in damage and/or failure of windings.

38 Dynamic balancing of the generator rotor assembly has been carried out during manufacture in accordance with BS 6861 Part 1 Grade 2.5 to ensure vibration limits of the generator are in accordance with BS 4999 Part 142.

39 The main vibration frequencies produced by the component generator are as follows:

4 pole 1500 r.p.m. 25 Hz

4 pole 1800 r.p.m. 30 Hz

2 pole 3000 r.p.m. 50 Hz

2 pole 3600 r.p.m. 60 Hz

40 However, vibrations induced by the engine are complex and contain frequencies of 1, 3, 5 or more times the fundamental frequency of vibration. These induced vibrations can result in generator vibration levels higher than those derived from the generator itself. It is the responsibility of the generating set designer to ensure that the alignment and stiffness of the bedplate and mountings are such that the vibration limits of BS 5000 Part 3 are not exceeded.

41 In standby applications where the running time is limited and reduced life expectancy is accepted, higher levels than specified in BS 5000 can be tolerated, up to a maximum of 18mm/sec.

42 Two bearing generators require a substantial bedplate with engine/generator mounting pads to ensure a good base for accurate alignment. Close coupling of engine to generator can increase the overall rigidity of the set. For the purposes of establishing set design the bending moment at the engine flywheel housing to generator adaptor interface should not exceed 125 ft.lb (17 kgm). A flexible coupling, designed to suit the specific engine/generator combination, is recommended to minimise torsional effects.

43 Belt driven applications of two bearing generators require the pulley diameter and design to be such that the side load or force applied to the shaft is central to the extension and does not exceed the values given in the table below:

TABLE 2 SIDE LOAD

Frame 2/4 Pole	Side Load		Shaft extension mm
	kgf	N	
BC16	92	900	82
BC18	**173**	**1700**	**82**

44 In instances where shaft extensions greater than specified in the table have been supplied, reference must be made to the factory for appropriate loadings.

45 Alignment of single bearing generators is critical and vibration can occur due to the flexing of the flanges between the engine and generator. As far as the generator is concerned the maximum bending moment at this point must not exceed 125 ft.lb (17 kgm).

46 Single bearing generators require a substantial bedplate with engine/generator mounting pads to ensure a good base for accurate alignment.

47 It is expected that the generator will be incorporated into a generating set operating in an environment, where the maximum shock load experienced by the generator will not exceed 3g in any plane. If shock loads in excess of 3g are to be encountered, anti-vibration mountings must be incorporated into the generating set to ensure they absorb the excess.

48 The maximum bending moment of the engine flange must be checked with the engine manufacturer.

CAUTION

EQUIPMENT DAMAGE. Single bearing drive end brackets are designed to be bolted to the engine flywheel housing using cap head screws.

49 Torsional vibrations occur in all engine-driven shaft systems and may be of a magnitude to cause damage at certain critical speeds. It is therefore necessary to consider the torsional vibration effect on the generator shaft and couplings.

50 It is the responsibility of the generator set manufacturer to ensure compatibility, and for this purpose drawings showing the shaft dimensions and rotor inertias are available for customers to forward to the engine supplier. In the case of single bearing generators coupling details are included.

CAUTION

EQUIPMENT DAMAGE. Torsional incompatibility and/or excessive vibration levels can cause damage or failure of generator and/or engine components.

51 The terminal box is constructed with removable panels for easy adaptation to suit specific glanding requirements. Within the terminal box there are insulated terminals for line and neutral connections and provision for earthing. A hole is provided on the generator foot which may be tapped to give an additional earthing point.

52 The neutral is NOT connected to the frame.

53 The main stator winding has 12 leads brought out to the terminals in the terminal box.

WARNING

PERSONNEL INJURY. NO EARTH CONNECTIONS ARE MADE ON THE GENERATOR AND REFERENCE TO SITE REGULATIONS FOR EARTHING MUST BE MADE. INCORRECT EARTHING OR PROTECTION ARRANGEMENTS CAN RESULT IN PERSONAL INJURY OR DEATH.

WARNING

PERSONNEL INJURY. INCORRECT INSTALLATION AND/OR PROTECTIVE SYSTEMS CAN RESULT IN PERSONAL INJURY AND/OR EQUIPMENT DAMAGE. INSTALLERS MUST BE QUALIFIED TO PERFORM ELECTRICAL INSTALLATION WORK.

54 Fault current curves (decrement curves), together with generator reactance data, are available on request to assist the system designer to select circuit breakers, calculate fault currents and ensure discrimination within the load network.

INSTALLATION – PART 1

LIFTING

WARNING

PERSONNEL INJURY. INCORRECT LIFTING OR INADEQUATE LIFTING CAPACITY CAN RESULT IN SEVERE PERSONAL INJURY OR EQUIPMENT DAMAGE. MINIMUM LIFTING CAPACITY REQUIRED IS 250kg. GENERATOR LIFTING LUGS SHOULD NOT BE USED FOR LIFTING THE COMPLETE GENERATOR SET.

55 Lifting lugs are provided at each end of the generator for use with a shackle and pin type lifting aid or lifting hooks. Chains of suitable length and lifting capacity, with spreader bar to avoid damage to the terminal box, must be used.

56 The correct lifting arrangement is shown on a label attached to the generator. A typical example is shown below.

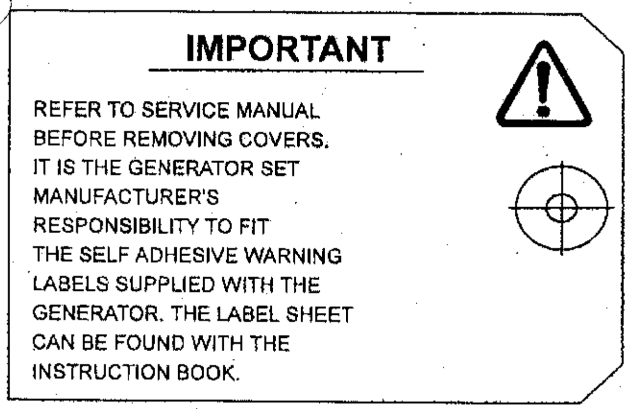


Fig 7 Typical lifting warning label

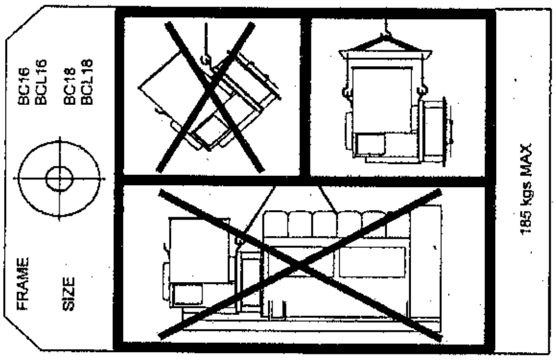


Fig 8 Lifting warning label

57 BCL generators have no fan to support the drive end and are supplied fitted with a transit strap clamping the coupling hub to the drive end adaptor ring.

58 Once the transit strap is removed the rotor is free to move in the frame, and care is needed during coupling and alignment to ensure the frame is kept in the horizontal plane.

ASSEMBLY TO ENGINE

Engine to generator coupling assembly

59 During the assembly of the Generator to the Engine it will be necessary to firstly carefully align, then rotate, the combined Generator rotor - Engine crankshaft assembly, as part of the construction process, to allow location, insertion and tightening of the coupling bolts. This requirement to rotate the combined assemblies exists for both single and two bearing units. During the assembly of single bearing units it is necessary to align the generator's coupling holes with the engine flywheel holes: it is suggested that two diametrically opposite location dowel pins are fitted to the engine flywheel, over which the generator coupling can slide into final location into the engine flywheel spigot recess. The dowels must be removed and replaced by coupling bolts before the final bolt tightening sequence.

60 While fitting and tightening the coupling bolts it will be necessary to rotate the Engine crankshaft - Generator rotor assembly. Care should be taken to ensure that rotation is carried out in an approved manner that ensures safe working practice when reaching inside the machine to insert or tighten coupling bolts, and that no component of the assembly is damaged by non-approved methods of assembly rotation.

61 Engine Manufacturers have available a proprietary tool designed to enable manual rotation of the crankshaft assembly. This tool must always be used, having been engineered as an approved method of assembly rotation, by engaging the manually driven pinion with the engine flywheel starter ring-gear.

UNDER NO CIRCUMSTANCES SHOULD A LEVER BE USED AGAINST THE FAN BLADES OR BAFFLE TO ROTATE THE GENERATOR ROTOR/ENGINE CRANKSHAFT ASSEMBLY.

WARNING

PERSONNEL INJURY. BEFORE WORKING INSIDE THE GENERATOR, DURING THE ALIGNING AND FITTING OF COUPLING BOLTS, CARE SHOULD BE TAKEN TO LOCK THE ASSEMBLY TO ENSURE THERE IS NO POSSIBILITY OF ASSEMBLY ROTATIONAL MOVEMENT. INCORRECT GUARDING AND/OR GENERATOR ALIGNMENT CAN RESULT IN PERSONAL INJURY AND/OR EQUIPMENT DAMAGE.

Single bearing generators

62 Alignment of single bearing generators is critical. If necessary shim the generator feet to ensure alignment of the machined surfaces.

63 For transit and storage purposes the generator frame spigot and rotor coupling plates have been coated with a rust preventative. This MUST BE removed before assembly to engine.

64 A practical method for removal of this coating is to clean the mating surface areas with a degreasing agent based on a petroleum solvent.

WARNING

PERSONNEL INJURY. CARE SHOULD BE TAKEN NOT TO ALLOW ANY CLEANING AGENT TO COME INTO PROLONGED CONTACT WITH SKIN.

65 For coupling to the various engine flywheel housings, the generators can be supplied with an end bracket-adaptor arrangement as outlined below.

End bracket/adaptor

SAE5
SAE4
SAE3
SAE2
SAE5 Plus SAE6 Adaptor Ring

CAUTION

EQUIPMENT DAMAGE. Drive end adaptors are designed for use with cap head screws. BC18 generators fitted with an SAE 5 drive end adaptor must also be fitted with a reduced diameter fan and must be operated at reduced output. Fan securing screws should be tightened to 0.59kgm (6Nm 4.4lb. ft.)

66 The sequence of assembly to the engine should generally be as follows:

(1) On the engine check the distance from the coupling mating face on the flywheel to the flywheel housing mating face. This should be within 0.5mm of nominal dimension. This is necessary to ensure that a thrust is not applied to the ac generator bearing or engine bearing.

(2) Check that the bolts securing the coupling disc to the coupling hub are tight and locked into position. Torque tightening is 7.6kgm (75Nm; 55 lb ft).

(3) Remove covers from the drive end of the generator to gain access to coupling disc and adaptor bolts.

(4) Check that coupling disc is concentric with adaptor spigot. This can be adjusted by suspending the rotor by means of a rope sling through the adaptor opening.

(5) Offer the ac generator to engine and engage both coupling disc and housing spigots at the same time, finally pulling home by using the housing and coupling bolts. Use heavy gauge washers between bolt head and discs on disc to flywheel bolts.

(6) Tighten coupling disc to flywheel. Refer to engine manual for torque setting of disc to flywheel bolts.

CAUTION

EQUIPMENT DAMAGE. When fitting drive disc ensure that flywheel fixing bolt holes fall between fan blades to allow access for flywheel bolts. Use engine pulley to turn rotor.

Single bearing 4-pole and 2-pole generators

67 Generators offered in the BCA range can be specified to suit different engine build configurations of specific flywheel and flywheel housing combinations.

CAUTION

EQUIPMENT DAMAGE. It is most important that the appropriate generator build is ordered with prior knowledge of the intended engine flywheel/housing arrangement.

CAUTION

EQUIPMENT DAMAGE. During assembly, loss of residual voltage may occur. Refer to Para 188 for field flashing.

Generator to engine assembly instructions

68 Generator to engine assembly instructions:

(1) Remove louvered cover 'A' from non-drive end bracket 'B'.

(2) Assemble locating bar 'E' (Newage No AF1609) by screwing into shaft.

(3) Remove transit bar 'K'.

(4) Remove side screens 'G'.

(5) If the adaptor ring is an individual item, as indicated 'F', bolted to the generator DE bracket, remove from generator and fit to engine flywheel housing.

(6) Thread two locating pins 'H' into two top flywheel holes.

(7) Fit two locating pins 'J' into two top holes of the engine flywheel housing/adaptor location holes.

(8) Pick up generator by the cast lifting lugs on both ends with 1/2 ton shackles (TO BS3032) or lifting hooks (Newage No.LE130) using suitable lifting equipment.

(9) Rotate generator rotor such that two top holes of coupling disc are in close axial alignment.

(10) Push the generator rotor forward only half (50mm) the available movement provided by locating bar 'E'. It may be necessary to tap bar E' with a hide mallet to ease the bearing out of housing.

CAUTION

EQUIPMENT DAMAGE. Do not push the rotor forward too far. There is a risk that the rotor will rest on the stator winding outhang resulting in winding damage especially if any rotational movement occurs during alignment with pins 'H'.

(11) Support the weight of the rotor at the coupling end whilst sliding the rotor forward to locate coupling disc holes over support pins 'H'. Locating bar 'E' will allow the rotor to move forward a further 50mm, the total movement bar 'E' allows being 100mm. With coupling discs positioned against flywheel location fit securing screws and washers. Remove pins 'H' and fit two final securing screws and washers.

(12) Push generator onto engine guiding adaptor over locating pins 'J' and onto engine flywheel housing location, or ring 'F', secure with screws and washers. Remove pins and replace with two screws and washers.

(13) Remove locating bar 'E'. Replace M10 screw 'C' for barring purposes.

(14) Remove lifting tackle and replace side screens 'G' and louvred cover 'A'.

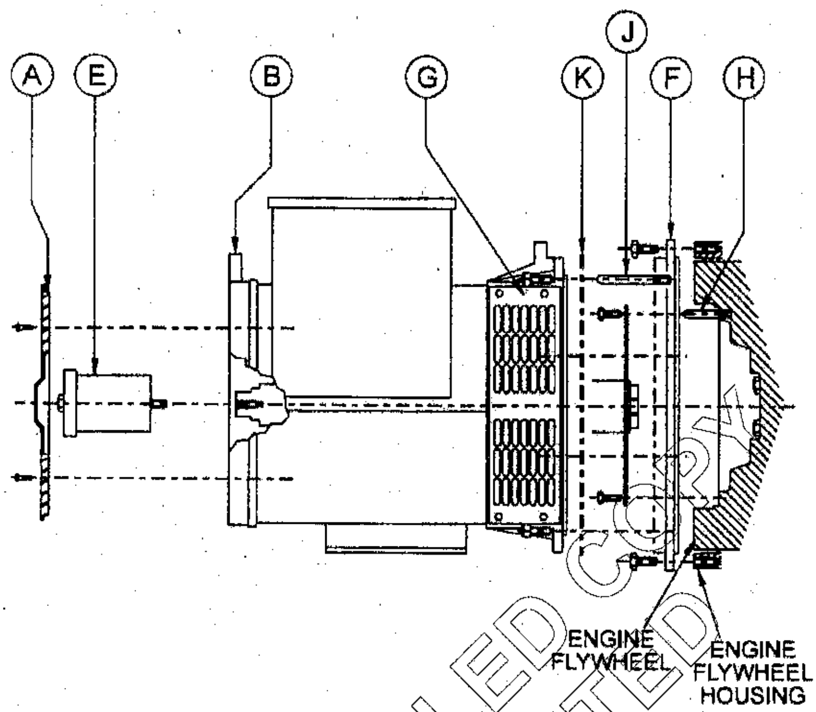


Fig 9 Generator to engine assembly

<u>Single bearing 2-pole generator to engine assembly instructions (with doweled flywheels)</u>

69 Follow Para 68 steps 1 to 5 from the 4-pole instruction procedure.

(1) Fit the two location dowels pins into appropriate diametrically opposite holes in engine flywheel, leaving sufficient parallel diameter exposed to allow for positive location of the disc-spacer-ring and coupling discs.

(2) Fit the disc-spacer-ring over the two dowel pins and position firmly against the flywheel face.

(3) Follow Para 68 steps 6 to 8 from the 4-pole instruction procedure.

(4) Rotate generator rotor such that the two coupling disc dowel holes align with flywheel dowel pins, and two top holes of coupling discs are in close axial alignment with the two flywheel location pins 'H'.

(5) Follow Para 68 step 10 from the 4-pole instruction procedure.

(6) Support the weight of the rotor at the coupling end whilst sliding the rotor forward to locate coupling disc holes over support pins 'H'.

CAUTION

EQUIPMENT DAMAGE. Ensure coupling disc dowel pin holes are in correct alignment.

a. With the coupling disc positioned against flywheel location fit securing screws and washers.

b. Remove pins 'H' and fit two final securing screws and washers.

(7) Follow Para 68 steps 12 to 14 from 4-pole instruction procedure.

Taper shaft arrangements

70 This arrangement is used on the BCL style generators.

71 As with single bearing generators alignment is critical. If necessary shim the generator feet to ensure alignment of the machined surfaces.

72 The following procedure should be adopted to assemble the generator to the engine:

(1) Remove louvred end cover 'G' from non-drive end bracket 'H' and M10 Hex Nut 'D' from shaft securing stud 'AA'. Remove transit bar 'E' and withdraw stub shaft/shaft securing stud 'A/B' from rotor.

(2) Ensure alternator, engine flywheel and flywheel housing locating spigots, faces and recesses are free from paint or preservatives.

(3) Locate stub shaft/shaft securing stud assembly 'A'/'B' on engine flywheel spigot and secure with studs 'J', M12 hex nut 'L' or bolts. Refer to engine manual for torque settings.

(4) Ensure both tapers are clean and free of burrs, oil or grease. Slide alternator complete with rotor towards engine, ensuring that shaft securing stud 'A' enters central hole in rotor shaft. Refer to engine manual for torque settings.

(5) Secure alternator adaptor 'F' to engine flywheel housing. Tap adaptor into place before tightening. Refer to engine manufacturer for torque setting.

(6) Fit M10 Binx nut 'D'" to protruding shaft securing stud 'AA'. M10 Binx nut tightening torque 45.0Nm (33.0 lbs.ft).

(7) Fit louvred end cover 'G' to non-drive end bracket 'H'.

(8) Check for excessive vibration at time of initial run-up.

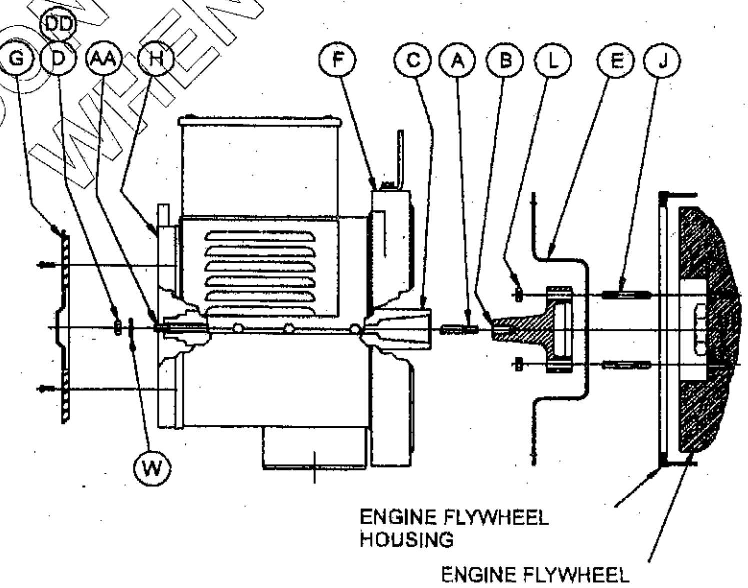


Fig 10 Taper shaft arrangements

CAUTION

EQUIPMENT DAMAGE. Incorrect guarding and/or generator alignment can result in personal injury and/or equipment damage.

EARTHING

73 The generator frame should be solidly bonded to the generating set bedplate. If anti vibration mounts are fitted between the generator frame and its bedplate a suitably rated earth conductor (normally one half of the cross sectional area of the main line cables) should bridge across the anti vibration mount.

WARNING

> **PERSONNEL INJURY. REFER TO LOCAL REGULATIONS TO ENSURE THAT THE CORRECT EARTHING PROCEDURE HAS BEEN FOLLOWED.**

PRE-RUNNING CHECKS

Insulation check

74 Before starting the generating set, both after completing assembly and after installation of the set, test the insulation resistance of windings.

75 The AVR should be disconnected during this test.

76 A 500V Megger or similar instrument should be used. Disconnect any earthing conductor connected between neutral and earth and megger an output lead terminal U, V or W to earth. The insulation resistance reading should be in excess of 5MΩ to earth. Should the insulation resistance be less than 5MΩ the winding must be dried out as detailed in the Service and Maintenance section of this manual (Para 134).

CAUTION

> **EQUIPMENT DAMAGE. The windings have been H.V tested during manufacture and further H.V testing may degrade the insulation with consequent reduction in operating life. Should it be necessary to demonstrate H.V testing, for customer acceptance, the tests must be carried out at reduced voltage levels, ie Test Voltage = 0.8 (2 x Rated Voltage + 1000).**

Direction of rotation and phase rotation

77 BC generators can rotate efficiently in either direction. However phase rotation is fixed for clockwise rotation as viewed from the drive end. If the generator is to be rotated in a counter-clockwise direction it will be necessary for the customers to adjust their cabling to the output terminals accordingly. Refer to the factory for a reverse wiring diagram.

Voltage and frequency

78 Check that the voltage and frequency levels required for the generating set application are as indicated on the generator nameplate.

79 Three-phase generators normally have a 12 ends out reconnectable winding. If it is necessary to reconnect the stator for the voltage required, refer to diagrams in the back of this manual.

AVR initial settings

80 To make AVR selections remove the AVR cover and refer to the following sections depending upon type of AVR fitted.

81 Reference to the generator nameplate will indicate AVR type.

AVR type SX460 - Refer to Para 83

82 Most of the AVR adjustments are factory set in positions which will give satisfactory performance during initial running test. Subsequent adjustment may be required to achieve optimum performance of the set under operating conditions. Refer to Para 92 for details.

Type SX460 AVR

83 The following 'jumper' connections on the AVR should be checked to ensure they are correctly set for the generating set application.

84 Refer to Figure 11 for location of selection links.

(1) Frequency selection

50Hz operation LINK C-50
60Hz operation LINK C-60

(2) External hand trimmer selection

No external hand trimmer	-	LINK 1-2
External hand trimmer required	-	REMOVE LINK 1-2 and connect trimmer across terminals 1 and 2.

(3) AVR Input Selection

High Voltage	**(220/240V)**	**INPUT**	**No Link**
Low Voltage	(110/120V)	INPUT	LINK 3-4

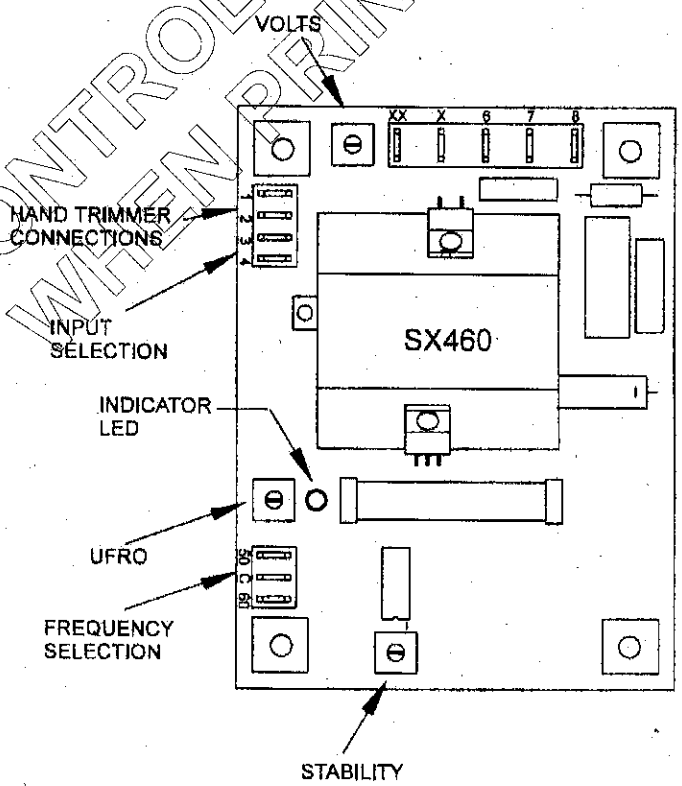


Fig 11 Type SX460 AVR

GENERATOR SET TESTING

WARNING

PERSONNEL INJURY. DURING TESTING IT MAY NE NECESSARY TO REMOVE COVERS TO ADJUST CONTROLS EXPOSING 'LIVE' TERMINALS OR COMPONENTS. ONLY PERSONNEL QUALIFIED TO PERFORM ELECTRICAL SERVICE SHOULD CARRY OUT TESTING AND/OR ADJUSTMENT.

Test metering/cabling

85 Connect any instrument wiring and cabling required for initial test purposes with permanent or spring-clip type connectors.

86 Minimum instrumentation for testing should be line - line or line to neutral voltmeter, Hz meter, load current metering and kW meter. If reactive load is used a power factor meter is desirable.

CAUTION

(1) EQUIPMENT DAMAGE. Check that all wiring terminations for internal or external wiring are secure, and fit all terminal box covers and guards. Failure to secure wiring and/or covers may result in personal injury and/or equipment failure.

(2) EQUIPMENT DAMAGE. When fitting power cables for load testing purposes, ensure cable voltage rating is at least equal to the generator rated voltage. The load cable termination should be placed on top of the winding lead termination and clamped with the nut provided.

INITIAL START-UP

WARNING

PERSONNEL INJURY. DURING TESTING IT MAY BE NECESSARY TO REMOVE COVERS TO ADJUST CONTROLS EXPOSING 'LIVE' TERMINALS OR COMPONENTS. ONLY PERSONNEL QUALIFIED TO PERFORM ELECTRICAL SERVICE SHOULD CARRY OUT TESTING AND/OR ADJUSTMENTS. REFIT ALL ACCESS COVERS AFTER ADJUSTMENTS ARE COMPLETED.

87 On completion of generating set assembly and before starting the generating set ensure that all engine manufacturer's pre-running procedures have been completed, and that adjustment of the engine governor is such that the generator will not be subjected to speeds in excess of 125% of the rated speed.

CAUTION

EQUIPMENT DAMAGE. Overspeeding of the generator during initial setting of the speed governor can result in damage to the generator rotating components.

88 In addition remove the AVR access cover (on AVR controlled generators) and turn VOLTS control fully anti-clockwise. Start the generating set and run on no-load at nominal frequency. Slowly turn VOLTS control potentiometer clockwise until rated voltage is reached. Refer to Fig. 11 for control potentiometer location.

CAUTION

EQUIPMENT DAMAGE. Do not increase the voltage above the rated generator voltage shown on the generator nameplate.

89 The STABILITY control potentiometer should be set to the midway position (refer to Fig 11 for its location) and with the stability selection correctly set should not normally require adjustment. Should adjustment be required, usually identified by oscillation of the voltmeter proceed as follows:

90 On SA465 major adjustment of the stability can be made by selection on switch SW2.

91 Switch position 8 will give SLOW AVR response
Switch position 0 will give FAST AVR response

(1) Run the generating set on no-load and check that speed is correct and stable.

(2) Turn the STABILITY control potentiometer clockwise, then turn slowly anti-clockwise until the generator voltage starts to become unstable. The correct setting is slightly clockwise from this position (ie where the machine volts are stable but close to the unstable region).

LOAD TESTING

WARNING

PERSONNEL INJURY. DURING TESTING IT MAY BE NECESSARY TO REMOVE COVERS TO ADJUST CONTROLS EXPOSING 'LIVE' TERMINALS OR COMPONENTS. ONLY PERSONNEL QUALIFIED TO PERFORM ELECTRICAL SERVICE SHOULD CARRY OUT TESTING AND/OR ADJUSTMENTS. REFIT ALL ACCESS COVERS AFTER ADJUSTMENTS ARE COMPLETED.

AVR controlled generators - AVR adjustments

92 Refer to Figure 11 for control potentiometer locations.

93 Having adjusted VOLTS and STABILITY during the initial start-up procedure, the AVR control function UFRO should not normally need adjustment.

94 If however, poor voltage regulation on-load is experienced, refer to the following paragraph to check that the symptoms observed do indicate adjustment is necessary, and also to make the adjustment correctly.

UFRO (under frequency roll off)

95 The AVR incorporates an underspeed protection circuit which gives a voltage/speed (Hz) characteristic as shown:

96 The UFRO control potentiometer sets the 'knee point'.

97 Symptoms of incorrect setting are that the light emitting diode (LED) indicator, adjacent to the UFRO Control potentiometer, being permanently lit when the generator is on load, and poor voltage regulation on load, ie operation on the sloping part of the characteristic.

98 Clockwise adjustment lowers the frequency (speed) setting of the 'knee point' and extinguishes the LED. For Optimum setting the LED should illuminate as the frequency falls just below nominal frequency, ie 47Hz on a 50Hz generator or 57Hz on a 60Hz generator.

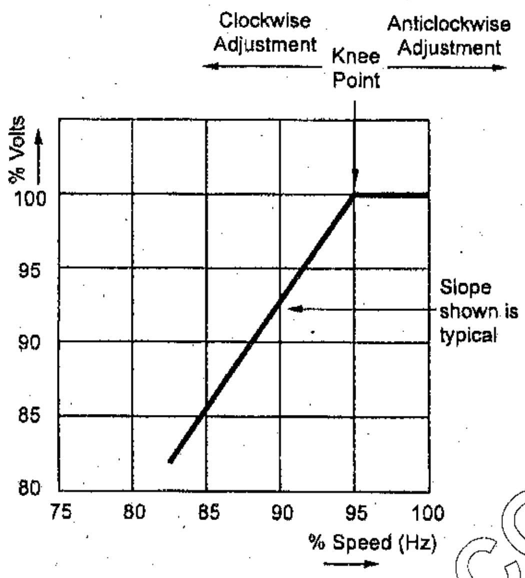


Fig 12 Under frequency roll off (UFRO)

Accessories

99 Refer to the Para 114 accessories for setting up procedures related to generator mounted accessories.

100 If there are accessories for control panel mounting supplied with the generator, refer to the specific accessory fitting procedures inserted inside the back cover of this book.

INSTALLATION – PART 2

GENERAL

101 The extent of site installation will depend upon the generating set build, eg if the generator is installed in a canopied set with integral switchboards and circuit breaker, on site installation will be limited to connecting up the site load to the generating set output terminals. In this case reference should be made to the generating set manufacturer's instruction book and any pertinent local regulations.

102 If the generator has been installed on a set without switchboard or circuit breaker the following points relating to connecting up the generator should be noted.

GLANDING

103 The terminal box will normally be supplied with the right hand side panel, viewed from the non-drive end, available for cable exit. The side panel is removable for drilling/punching to suit glands or glanding boxes. Should the cable exit be required from the left-hand side of the generator when viewed from the non-drive end, the left and right-hand panels may be interchanged. Sufficient length of wiring to the AVR has been provided for this purpose.

104 Incoming cables should be supported from either below or above the box level and at a sufficient distance from the centre line of the generating set so as to avoid a tight radius at the point of entry into the terminal box panel, and allow movement of the generator set on its anti-vibration mountings without excessive stress on the cable.

105 Before making final connections, test the insulation resistance of the windings. The AVR should be disconnected during this test.

106 A 500V Megger or similar instrument should be used. Should the insulation resistance be less than 5MW the windings must be dried out as detailed in the Service and Maintenance section of this manual.

107 When making connections to the terminals the incoming cable termination should be placed on top of the winding lead termination(s) and clamped with the nut provided.

CAUTION

EQUIPMENT DAMAGE. To avoid the possibility of swarf entering any electrical components in the terminal box, panels must be removed for drilling.

EARTHING

108 The neutral of the generator is not bonded to the generator frame as supplied from the factory. An earth terminal is provided inside the terminal box adjacent to the main terminals. Should it be required to operate with the neutral earthed a substantial earth conductor (normally equivalent to one half of the section of the line conductors) must be connected between the neutral and the earth terminal inside the terminal box. A hole is provided on the generator foot which may be tapped to give an additional earthing point. The feet should be already bonded to the generating set bedplate by the generating set builder, but will normally be required to be connected to the site earth system.

CAUTION

EQUIPMENT DAMAGE. Reference to local electricity regulations or safety rules should be made to ensure correct earthing procedures have been followed.

PROTECTION

109 It is the responsibility of the end user and his contractors/ sub-contractors to ensure that the overall system protection meets the needs of any inspectorate, local electricity authority or safety rules, pertaining to the site location.

110 To enable the system designer to achieve the necessary protection and/or discrimination, fault current curves are available on request from the factory, together with generator reactance values to enable fault current calculations to be made.

WARNING

PERSONNEL INJURY. INCORRECT INSTALLATION AND/OR PROTECTIVE SYSTEMS CAN RESULT IN PERSONAL INJURY AND/OR EQUIPMENT DAMAGE. INSTALLERS MUST BE QUALIFIED TO PERFORM ELECTRICAL INSTALLATION WORK.

COMMISSIONING

111 Ensure that all external cabling is correct and that all the generating set manufacturer's pre-running checks have been carried out before starting the set.

112 The generator AVR controls will have been adjusted during the generating set manufacturer's tests and should normally not require further adjustment. Should adjustment on site be necessary refer to Para 80 for AVR details and/or Para 118 for paralleling adjustments.

113 Should malfunction occur during commissioning refer to the Service and Maintenance section 'Fault Finding' procedure at Para 187.

ACCESSORIES

114 Generator control accessories may be fitted, as an option, in the generator terminal box. If fitted at the time of supply, the wiring diagram(s) in the back of this book shows the connections. When the options are supplied separately, fitting instructions are provided with the accessory.

115 Accessories available are droop transformer for parallel operation applicable to generators with SA465 AVR, and remote voltage adjust (hand trimmer). The latter being available for all AVR types but not fitted on the generator.

NOTE

None of the accessories can be fitted with a transformer controlled generator.

REMOTE VOLTAGE ADJUST (all AVR types)

116 A remote voltage adjust can be fitted to the control panel.

117 Remove link 1-2 on the AVR and connect adjuster to terminals 1 and 2.

PARALLEL OPERATION

118 Understanding of the following notes on parallel operation is useful before attempting the fitting or setting of the droop kit accessory. When operating in parallel with other generators or the mains, it is essential that the phase sequence of the incoming generator matches that of the busbar and also that all of the following conditions are met before the circuit breaker of the incoming generator is closed on to the busbar (or operational generator).

(1) Frequency must match within close limits.

(2) Voltages must match within close limits.

(3) Phase angle of voltages must match within close limits.

119 A variety of techniques, varying from simple synchronising lamps to fully automatic synchronisers, can be used to ensure these conditions are met.

CAUTION

EQUIPMENT DAMAGE. Failure to meet conditions (1), (2) and (3) when closing the circuit breaker, will generate excessive mechanical and electrical stresses, resulting in equipment damage.

120 Once connected in parallel a minimum instrumentation level per generator of voltmeter, ammeter, watt meter (measuring total power per generator), and frequency meter is required in order to adjust the engine and generator controls to share kW in relation to engine ratings and kVAr in relation to generator ratings.

121 It is important to recognise that:

(1) kW are derived from the engine, and speed governor characteristics determine the kW sharing between sets.

(2) kVAr are derived from the generator, and excitation control characteristics determine the kVAr sharing. Reference should be made to the generating set manufacturer's instructions for setting the governor controls.

Droop

122 The most commonly used method of kVAr sharing is to create a generator voltage characteristic which falls with decreasing power factor (increasing kVAr). This is achieved with a current transformer (CT) which provides a signal dependent on current phase angle (ie power factor) to the AVR. The current transformer has a burden resistor on the AVR board, and a percentage of the burden resistor voltage is summed into the AVR circuit. Increasing droop is obtained by turning the DROOP control potentiometer clockwise.

123 The diagrams below indicate the effect of droop in a simple two-generator system:

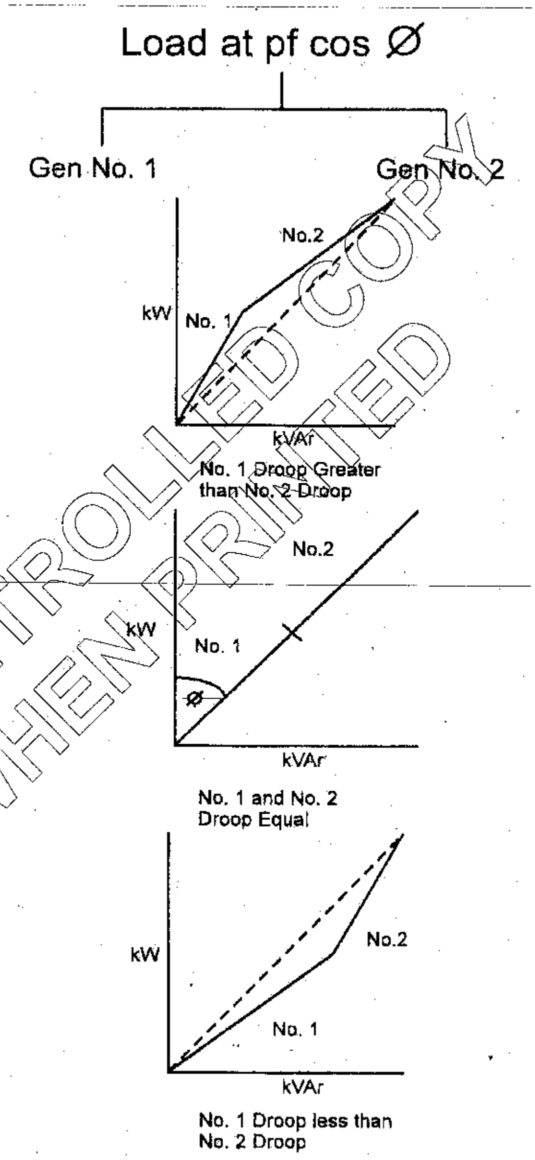


Fig 13 Droop in a simple two-generator system

124 Generally 5% droop at full load current zero pf is sufficient to ensure kVAr sharing.

125 If the droop accessory has been supplied with the generator it will have been tested to ensure correct polarity and set to a nominal level of droop. The final level of droop will be set during generating set commissioning.

126 The following setting procedure will be found to be helpful.

Setting procedure

127 Depending upon available load the following settings should be used - all are based on rated current level.

0.8 P.F. LOAD	(at full load current)	SET DROOP TO 3%
0 P.F. LOAD	(at full load current)	SET DROOP TO 5%

128 Setting the droop with low power factor load is the most accurate.

129 Run each generator as a single unit at rated frequency or rated frequency + 4% depending upon type of governor and nominal voltage. Apply available load to rated current of the generator. Adjust 'DROOP' control potentiometer to give droop in line with above table. Clockwise rotation increases amount of droop. Refer to Fig 11 for potentiometer location. After adjustment check NO LOAD voltage level and adjust if necessary.

NOTES

(1) Reverse polarity of the CT will raise the generator voltage with load. The polarities S1-S2 shown on the wiring diagrams are correct for clockwise rotation of the generator looking at the drive end. Reversed rotation requires S1-S2 to be reversed.

(2) The most important aspect is to set all generators equal. The precise level of droop is less critical.

(3) A generator operated as a single unit with a droop circuit set at rated load 0.8 power factor is unable to maintain the usual % regulation. A shorting switch can be connected across S1-S2 to restore regulation for single running.

CAUTION

EQUIPMENT DAMAGE. LOSS OF FUEL to an engine can cause its generator to motor with consequent damage to the generator windings. Reverse power relays should be fitted to trip main circuit breaker. LOSS OF EXCITATION to the generator can result in large current oscillations with consequent damage to generator windings. Excitation loss detection equipment should be fitted to trip main circuit breaker.

Astatic control

130 The 'droop' current transformer can be used in a connection arrangement which enables the normal regulation of the generator to be maintained when operating in parallel.

131 This feature is only supplied from the factory as a fitted droop kit, however, if requested at the time of order, the diagrams inside the back cover of this book will give the necessary site connections. The end user is required to provide a shorting switch for the droop current transformer secondary.

132 Should the generator be required to be converted from standard droop to 'astatic' control, diagrams are available on request.

133 The setting procedure is exactly the same as for DROOP (Para 127).

CAUTION

EQUIPMENT DAMAGE. When using this connection arrangement a shorting switch is required across each CT burden (terminals S1 and S2). The switch must be closed when a generating set is not running <u>and</u> when a generating set is selected for single running.

SERVICE AND MAINTENANCE

WINDING CONDITION

WARNING

PERSONNEL INJURY. SERVICE AND FAULT FINDING PROCEDURES PRESENT HAZARDS THAT CAN RESULT IN SEVERE PERSONAL INJURY OR DEATH. ONLY PERSONAL INJURY OR DEATH. ONLY PERSONNEL QUALIFIED TO PERFORM ELECTRICAL AND MECHANICAL SERVICE SHOULD CARRY OUT THESE PROCEDURES. ENSURE ENGINE STARTING CIRCUITS ARE DISABLED BEFORE COMMENCING SERVICE OR MAINTENANCE PROCEDURES. ISOLATE ANY ANTI-CONDENSATION HEATER SUPPLY.

Guidance of typical insulation resistance [IR] values

134 The following is offered as general information about IR values and is aimed at providing guidance about the typical IR values for generators from new through to the point of refurbishment.

New machines

135 The generators Insulation Resistance, along with many other critical factors, will have been measured during the alternator manufacturing process. The generator will have been transported with an appropriate packaging suitable for the method of delivery to the Generating Set assemblers works. Where we expect it to be stored in a suitable location protected from adverse environmental conditions.

136 However, absolute assurance that the generator will arrive at the Gen-set production line with IR values still at the factory test levels of above 100 MΩ cannot be guaranteed.

At generating set manufacturers works

137 The generator should have been transported and stored such that it will be delivered to the assembly area in a clean dry condition. If held in appropriate storage conditions the generator IR value should typically be 25 MΩ.

138 If the unused/new generators IR values fall below 10 MΩ then a drying out procedure should be implemented by one of the processes outlined below before being despatched to the end customer's site. Some investigation should be undertaken into the storage conditions of the generator while on site.

Generators in service

139 Whilst it is known that a generator will give reliable service with an IR value of just 1.0 MΩ. For a relatively new generator to be so low it must have been subjected to inappropriate operating or storage conditions.

140 Any temporarily reduction in IR values can be restored to expected values by following one of the drying out procedures.

Winding condition assessment

CAUTION

EQUIPMENT DAMAGE. The AVR should be disconnected and the Resistance Temperature Detector (RTD) leads grounded during this test.

141 The condition of the windings can be assessed by measurement of insulation resistance [IR] between phase to phase, and phase to earth.

142 Measurement of winding insulation should be carried out:

(1) As part of a periodic maintenance plan.

(2) After prolonged periods of shutdown.

(3) When low insulation is suspected, eg damp or wet windings.

143 Care should be taken when dealing with windings that are suspected of being excessively damp or dirty. The initial measurement of the [IR] Insulation Resistance should be established using a low voltage (500V) megger type instrument. If manually powered the handle should initially be turned slowly so that the full test voltage will not be applied, and only applied for long enough to very quickly assess the situation if low values are suspected or immediately indicated.

144 Full megger tests or any other form of high voltage test should not be applied until the windings have been dried out and if necessary cleaned.

Procedure for insulation testing

145 Disconnect all electronic components, AVR, electronic protection equipment etc. Ground the [RTDs] Resistance Temperature Detection devices if fitted. Short out the diodes on the rotating diode assembly. Be aware of all components connected to the system under test that could cause false readings or be damaged by the test voltage.

146 Carry out the insulation test in accordance with the operating instructions for the test equipment.

147 The measured value of insulation resistance for all windings to earth and phase to phase should be compared with the guidance given above for the various 'life stages' of a generator. The minimum acceptable value must be greater than 1.0 MΩ.

148 If low winding insulation is confirmed, use one or more of the methods given below for drying the winding.

Methods of drying out generators

Cold run

149 Consider a good condition generator that has not been run for some time, and has been standing in damp, humid conditions. It is possible that simply running the gen set unexcited (AVR terminals K1 K2 open circuit) for a period of say 10 minutes will sufficiently dry the surface of the windings and raise the IR sufficiently, to greater than 1.0 MΩ, and so allow the unit to be put into service.

Blown air drying

150 Remove the covers from all apertures to allow the escape of the water-laden air. During drying, air must be able to flow freely through the generator in order to carry off the moisture.

151 Direct hot air from two electrical fan heaters of around 1 – 3 kW into the generator air inlet apertures. Ensure the heat source is at least 300mm away from the windings to avoid overheating and damage to the insulation.

152 Apply the heat and plot the insulation value at half hourly intervals. The process is complete when the parameters covered in the section entitled, 'Typical Drying Out Curve', are met.

153 Remove the heaters, replace all covers and re-commission as appropriate.

154 If the set is not to be run immediately ensure that the anti-condensation heaters are energised, and retest prior to running.

Short circuit method

NOTE

This process should only be performed by a competent engineer familiar with safe operating practices within and around generator sets of the type in question.

155 Ensure the generator is safe to work on. Initiate all mechanical and electrical safety procedures pertaining to the gen set and the site.

156 Bolt a short circuit of adequate current carrying capacity, across the main terminals of the generator. The shorting link should be capable of taking full load current.

157 Disconnect the cables from terminals 'X' and 'XX' of the AVR.

158 Connect a variable dc supply to the 'X' (positive) and 'XX' (negative) field cables. The dc supply must be able to provide a current up to 2.0 Amp at 0 - 24 Volts.

159 Position a suitable ac ammeter to measure the shorting link current.

160 Set the dc supply voltage to zero and start the generating set. Slowly increase the dc voltage to pass current through the exciter field winding. As the excitation current increases, so the stator current in the shorting link will increase. This stator output current level must be monitored, and not allowed to exceed 80% of the generators rated output current.

161 After every 30 minutes of this exercise:

(1) Stop the generator and switch off the separate excitation supply, and measure and record the stator winding IR values, and plot the results. The resulting graph should be compared with the classic shaped graph. This drying out procedure is complete when the parameters covered in the section entitled 'Typical Drying Out Curve' are met.

162 Once the Insulation Resistance is raised to an acceptable level - minimum value 1.0MΩ, the dc supply may be removed and the exciter field leads 'X' and 'XX' re-connected to their terminals on the AVR.

163 Rebuild the gen set, replace all covers and re-commission as appropriate.

164 If the set is not to be run immediately ensure that the anti-condensation heaters are energised, and retest the generator prior to running.

Typical drying out curve

165 Whichever method is used to dry out the generator the resistance should be measured every half-hour and a curve plotted as shown in Fig 14.

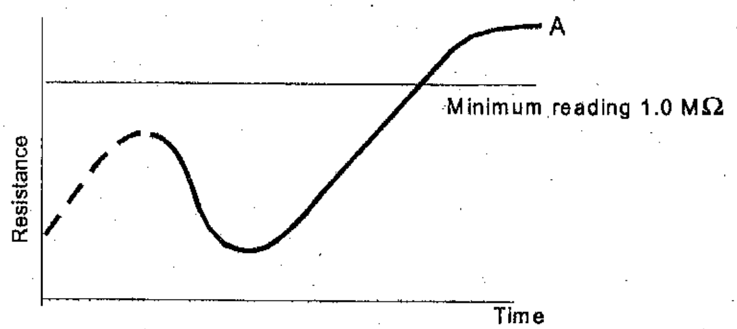


Fig 14 Drying time/resistance plot

166 The illustration shows a typical curve for a machine that has absorbed a considerable amount of moisture. The curve indicates a temporary increase in resistance, a fall and then a gradual rise to a steady state. Point 'A', the steady state, must be greater than 1.0 MΩ. (If the windings are only slightly damp the dotted portion of the curve may not appear.)

167 For general guidance expect that the typical time to reach point 'A' will be:

1 hour for a BC16/18,
2 hours for a UC22/27
3 hours for an HC4, 5, 6 and 7

Drying should be continued after point 'A' has been reached for at least one hour.

168 It should be noted that as winding temperature increases, values of insulation resistance may significantly reduce. Therefore, the reference values for insulation resistance can only be established with windings at a temperature of approximately 20°C.

169 If the IR value remains below 1.0 MΩ, even after the above drying methods have been properly conducted, then a Polarisation Index test [PI] should be carried out.

170 If the minimum value of 1.0 MΩ for all components cannot be achieved rewinding or refurbishment of the generator will be necessary.

171 The generator must not be put into service until the minimum values can be achieved.

CAUTION

EQUIPMENT DAMAGE. The short circuit must not be applied with the AVR connected in circuit. Current in excess of the rated generator current will cause damage to the windings.

172 After drying out, the insulation resistances should be rechecked to verify minimum resistances quoted above are achieved. On re-testing it is recommended that the main stator insulation resistance is checked as follows:

173 Separate the neutral leads; Ground V and W phase and megger U phase to ground.

Ground U and W phase and megger V phase to ground.

Ground U and V phase and megger W phase to ground.

174 If the minimum value of 1.0 MΩ is not obtained, drying out must be continued and the test repeated.

BEARINGS

175 All bearings are supplied sealed for life and are, therefore, not regreasable.

CAUTION

(1) EQUIPMENT DAMAGE. The life of a bearing in service is subject to the working conditions and the environment.

(2) EQUIPMENT DAMAGE. Long stationary periods in an environment where there is vibration can cause false brinnelling, which puts flats on the ball, and grooves on the races. Very humid atmospheres or wet conditions can emulsify the grease and cause corrosion.

(3) EQUIPMENT DAMAGE. High axial vibration from the engine or misalignment of the set will stress the bearing.

176 The bearing, in service, is affected by a variety of factors that together will determine the bearing life. We recommend that the health of the bearings be monitored, using 'spike energy' vibration monitoring equipment. This will allow the timely replacement of bearings that exhibit a deteriorating trend, during a major engine overhaul.

177 If excessive heat, noise or vibration is detected, change the bearing as soon as practicable. Failure to do so could result in bearing failure.

178 In the event that 'spike energy' vibration monitoring equipment is not available, it is strongly recommend that consideration be given to changing the bearing during each 'major engine overhaul'.

179 Belt driven application will impose an additional load on bearings. The bearing life will therefore be significantly affected. It is important that the side load limits (given in Table 2) are not exceeded and the health of the bearing is monitored more closely.

AIR FILTERS

WARNING

PERSONNEL INJURY. REMOVAL OF FILTER ELEMENTS ENABLES ACCESS TO LIVE PARTS. ONLY REMOVE ELEMENTS WITH THE GENERATOR OUT OF SERVICE.

180 The frequency of filter maintenance will depend upon the severity of the site conditions. Regular inspection of the elements will be required to establish when cleaning is necessary.

Cleaning procedure

181 Remove the filter elements from the filter frames. Immerse or flush the element with a suitable degreasing agent until the element is clean.

182 Alternatively, after removing the filter elements a high-pressure water hose with a flat nozzle can be used. Sweep the water spray back and forth across the element from the clean side (fine mesh side of element) holding the nozzle firmly against the element surface. Cold water may be adequate depending upon type of contamination although hot water is preferable.

183 The element can be inspected for cleanliness by looking through the filter towards the light. When thoroughly clean, no cloudy areas will be seen.

184 Dry elements thoroughly before attempting to carry out the recharging procedure.

Recharging (charging)

185 Charging is best done by totally immersing the dry element into a dip tank containing 'Filterkote Type K' or commercial lubricating oil SAE 20/50. Oils of higher or lower viscosity are not recommended.

186 Allow elements to completely drain before refitting the elements into the frames and putting into service.

FAULT FINDING

CAUTION

EQUIPMENT DAMAGE. Before commencing any fault finding procedures examine all wiring for broken or loose connections.

187 Three excitation control systems can be fitted to the range of generators covered by this manual, identified by the last digit of the generator frame size designation. Refer to the nameplate then proceed to the appropriate sub-section as indicated below:

SERIES	EXCITATION CONTROL	PARA
4	SA465 AVR	
5	Transformer control	
6	**SX460 AVR**	**13**

All AVR types - fault finding

TABLE 3 FAULT FINDING

Symptom	Actions
No voltage build-up when starting set	1 Check speed. 2 Check residual voltage. Refer to Para 188. 3 Follow separate excitation test procedure to check generator and AVR. Refer to Para 192.
Unstable voltage either on no-load or with load	1 Check speed stability. 2. Check stability setting. Refer to Para 87.
High voltage either on no-load or with load	1 Check speed. 2 Check that generator load is not capacitive (leading power factor).
Low voltage no-load	1 Check speed. 2 Check link 1-2 or external hand trimmer leads for continuity.
Low voltage on-load	1 Check speed. 2 Check UFRO setting. Refer to Para 95. 3 Follow separate excitation procedure to check generator and AVR. Refer to Para 192.

Residual voltage check (field flashing)

188 This procedure applies to all generators fitted with AVR control. With the generator set stationary remove AVR access cover and leads F1 and F2 from the AVR.

189 Start the set and measure voltage across AVR terminals 7-8. A minimum level of 5 Volts is required at these terminals. If the voltage is less than 5 Volts stop the set, because it will be necessary to carry out the following Field Flashing procedure. Replace leads F1 and F2 on the AVR terminals. Using a 12 Volt dc battery as a supply, clip leads from battery negative to AVR terminal F2, and from battery positive through a diode to AVR terminal F1. See Fig 15.

CAUTION

EQUIPMENT DAMAGE. A diode must be used as shown below to ensure the AVR is not damaged.

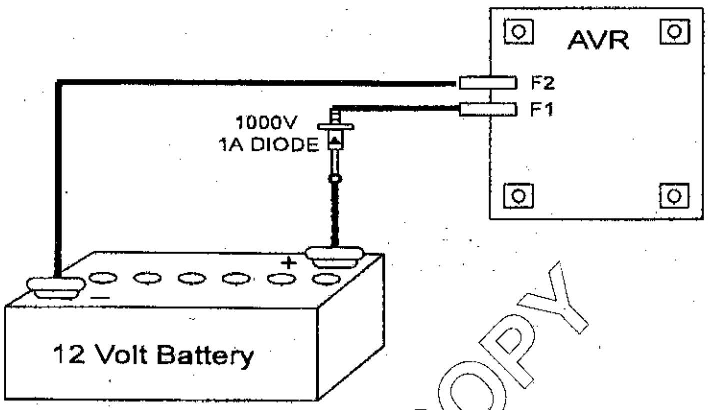


Fig 15 Residual voltage check

CAUTION

EQUIPMENT DAMAGE. If the generating set battery is used for field flashing, the generator main stator neutral must be disconnected from earth.

190 Restart the set and note output voltage from the main stator, which should be approximately nominal voltage, or voltage at AVR terminals 7 and 8, which should be between 170 and 250 Volts.

191 Stop the set and unclip battery supply from terminals F1 and F2. Restart the set. The generator should now operate normally. If no voltage build-up is obtained it can be assumed a fault exists in either the generator or the AVR circuits. Follow the Separate Excitation Procedure to check generator windings, rotating diodes and AVR. Refer to Para 192.

SEPARATE EXCITATION TEST PROCEDURE

192 The generator windings, diode assembly and AVR can be checked using this procedure.

(1) With the generating set stationary remove AVR access cover and leads F1 and F2 from the AVR. On transformer controlled generators remove the terminal box lid for access and remove leads F1 and F2 from the control rectifier bridge.

(2) Connect a 60W 240 Volt household lamp (or two 120V lamps in series) to AVR terminals F1 and F2. (Only required for Para 209.)

(3) Connect a 0-12 volt, 1.0 Amp dc supply to leads F1 and F2. The positive of the dc supply is connected to the lead marked F1 and the negative to the lead marked F2.

193 The procedure is simplified by dividing into two sections:

(1) Generator windings and rotating diodes and excitation control test.

(2) Excitation control test.

Generator windings and rotating diodes

CAUTION

> **EQUIPMENT DAMAGE. The resistances quoted apply to a standard winding. For generators having windings or voltages other than those specified refer to factory for details. Ensure all disconnected leads are isolated and free from earth.**

194 This procedure is carried out with leads F1 and F2 disconnected at the AVR or transformer control rectifier bridge and using a 12 Volt dc supply to leads F1 and F2.

195 Start the set and run at rated speed, on no-load.

196 Measure the voltages at the main output terminals U, V and W. These should be balanced and within 10% of the generator nominal voltage.

197 On generators fitted with an auxiliary winding in the main stator, applicable only with the SA665 AVR, the voltage at AVR terminals 8 and Z2 should be approximately 150 Volts ac.

Balanced main terminal voltages

198 If all voltages are balanced within 1% at the main terminals, it can be assumed that all exciter windings, main windings and main rotating diodes are in good order, and the fault is in the AVR or transformer control. Refer to Para 209 for test procedure.

199 If voltages are balanced but low, there is a fault in the main excitation windings or rotating diode assembly. Proceed as follows to identify:

Rectifier diodes

200 The diodes on the main rectifier assembly can be checked with a multimeter. The flexible leads connected to each diode should be disconnected at the terminal end, and the forward and reverse resistance checked. A healthy diode will indicate a very high resistance (infinity) in the reverse direction, and a low resistance in the forward direction. A faulty diode will give a full deflection reading in both directions with the test meter on the 10,000 ohms scale, or an infinity reading in both directions.

Replacement of faulty diodes

201 The rectifier assembly is split into two plates, the positive and negative, and the main rotor is connected across these plates. Each plate carries three diodes, the negative plate carrying negative biased diodes and the positive plate carrying positive biased diodes. Care must be taken to ensure that the correct polarity diodes are fitted to each respective plate. When fitting the diodes to the plates they must be tight enough to ensure a good mechanical and electrical contact, but should not be overtightened. The recommended torque tightening is 4.06 - 4.74Nm (36-42lb in).

Surge suppressor

202 The surge suppressor is a metal-oxide varistor connected across the two rectifier plates to prevent high transient reverse voltages in the field winding from damaging the diodes. This device is not polarised and will show a virtually infinite reading in both directions with an ordinary resistance meter. If defective this will be visible by inspection, since it will normally fail to short circuit and show signs of disintegration. Replace if faulty.

Main excitation windings

203 If after establishing and correcting any fault on the rectifier assembly the output is still low when separately excited, then the main rotor, exciter stator and exciter rotor winding resistances should be checked (see Table 4), as the fault must be in one of these windings. The exciter stator resistance is measured across leads F1 and F2. The exciter rotor is connected to six studs which also carry the diode lead terminals. The main rotor winding is connected across the two rectifier plates. The respective leads must be disconnected before taking the readings.

204 Resistance values should be within 10% of the values given in Table 4 below:

TABLE 4 MAIN EXCITATION WINDINGS

Frame size	Main rotor	Exciter stator			Exciter rotor
		Type 1	Type 2 *	Type 3**	
BC164A	0.44	19	26	110	0.26
BC164B	0.48	19	26	110	0.26
BC164C	0.52	19	26	110	0.26
BC164D	0.56	19	26	110	0.26
BC184E	0.64	20	27	115	0.21
BC184F	0.74	22	30	127	0.23
BC184G	0.83	22	30	127	0.23
BC184H	0.89	24	-	-	0.24
BC184J	0.96	24	-	-	0.24
BC162D	0.81	18	-	-	0.26
BC162E	0.89	18	-	-	0.26
BC162F	0.95	18	-	-	0.26
BC162G	1.09	19	-	-	0.27
BC182H	1.17	20	-	-	0.21
BC182J	**1.28**	**20**	**-**	**-**	**0.21**
BC182K	1.4	20	-	-	0.21
BCA162L	1.55	20	-	-	0.21

* Used with 1-phase transformer controlled 3-phase or 1-phase generators

** Used with 3-phase transformer controlled 3-phase generators.

Unbalanced main terminal voltages

205 If voltages are unbalanced, this indicates a fault on the main stator winding or main cables to the circuit breaker.

NOTE

Faults on the stator winding or cables may also cause noticeable load increase on the engine when excitation is applied. Disconnect the main cables and separate the winding leads U1-U2, U5-U6, V1-V2, V5-V6, W1-W2, W5-W6 to isolate each winding section.

206 Measure each section resistance - values should be balanced and within 10% of the value given in Table 5 below:

TABLE 5 AVR CONTROLLED GENERATORS

Frame size	**Section resistances**		
	Winging 311	**Winging 05**	**Winging 06**
BC164A	0.81	0.41	0.31
BC164B	0.51	0.30	0.19
BC164C	0.36	0.21	0.13
BC164D	0.3	0.32	0.21
BC184E	0.20	0.20	0.13
BC184F	0.13	0.14	0.09
BC184G	0.11	0.11	0.07
BC184H	0.085	0.041	0.029
BC184J	0.074	0.034	0.024
BC162D	0.68	0.30	0.25
BC162E	0.42	0.21	0.15
BC162F	0.31	0.17	0.11
BC162G	0.21	0.10	0.095
BC182H	0.16	0.075	0.055
BC182J	**0.13**	**0.06**	**0.042**
BC182K	0.10	0.047	0.030
BCA162L	0.65	0.03	0.02

207 Measure insulation resistance between sections and each section to earth.

208 Unbalanced or incorrect winding resistances and/or low insulation resistances to earth indicate rewinding of the stator will be necessary. Refer to removal and replacement of component assemblies commencing at Para 213.

EXCITATION CONTROL TEST

AVR function test

209 All types of AVR can be tested with this procedure:

(1) Remove exciter field leads X and XX (F1 and F2) from the AVR terminals X and XX (F1 and F2).

(2) Connect a 60W 240V household lamp to AVR terminals X and XX (F1 and F2).

(3) Set the AVR VOLTS control potentiometer fully clockwise.

(4) Connect a 12V, 1.0A dc supply to the exciter field leads X and XX (F1 and F2) with (F1) to the positive.

(5) Start the generating set and run at rated speed.

(6) Check that the generator output voltage is within +/- 10% of rated voltage.

210 Voltages at AVR terminals 7-8 on SX460 AVR or P2-P3 on SX421 AVR SHOULD BE BETWEEN 170 AND 250 VOLTS. If the generator output voltage is correct but the voltage on 7-8 (or P2-P3) is low, check auxiliary leads and connections to main terminals.

211 The lamp connected across X-XX should glow. In the case of the SX460 and SA465 AVRs the lamp should glow continuously. Failure to turn off indicates faulty protection circuit and the AVR should be replaced. Turning the 'VOLTS' control potentiometer fully anti-clockwise should turn off the lamp with all AVR types.

212 Should the lamp fail to light the AVR is faulty and must be replaced.

CAUTION

EQUIPMENT DAMAGE. After this test turn the VOLTS control potentiometer fully anti-clockwise.

REMOVAL AND REPLACEMENT OF COMPONENT ASSEMBLIES

CAUTION

(1) EQUIPMENT DAMAGE. The following procedures assume that the generator has been removed from the generating set. On single bearing generators before removal from the engine, position the rotor such that a full pole face is at bottom dead centre. Use engine pulley to turn rotor. Metric threads are used throughout.

(2) EQUIPMENT DAMAGE. When lifting single bearing generators, care is needed to ensure the generator frame is kept in the horizontal plane. The rotor is free to move in the frame and can slide out if not correctly lifted. Incorrect lifting can cause serious personal injury.

Removal of bearings

CAUTION

EQUIPMENT DAMAGE. Position the main rotor so that a full pole face of the main rotor core is at the bottom of the stator bore.

213 Removal of bearings may be effected either after the rotor assembly has been removed or simply by removal of end bracket(s).

214 Refer to main rotor assembly at Para 218.

215 The bearings are pre-packed with grease and sealed for life.

(1) The bearing(s) are a press fit on the shaft and can be removed with standard tooling, ie 2 or 3 legged manual or hydraulic bearing pullers.

(2) Remove circlip from shaft at non-drive end (only fitted on single bearing machines).

216 When fitting new bearings use a bearing heater to expand the bearing before fitting to the shaft. Tap the bearing into place ensuring that it contacts the shoulder on the shaft.

217 Refit the retaining circlip on single bearing generators.

Main rotor assembly

Single bearing generator

218 (1) Remove four screws securing louvred cover at non-drive end and remove cover.

(2) Remove the screws and covers on each side of adaptor.

(3) Ensure that rotor is supported at DE on a sling.

(4) Tap the rotor from non-drive end bearing housing to push the bearing clear of the end bracket and its retaining 'O' ring.

(5) Continue to push rotor through stator bore, gradually moving sling along rotor as it is withdrawn, to ensure full support at all times.

CAUTION

EQUIPMENT DAMAGE. When re-assembling position the rotor such that full pole face is at bottom dead centre.

219 This may make removal of shaft securing stud 'AA' difficult.

220 Replacement of rotor assemblies is a reversal of the procedures above.

Re-assembly of generator engine

221 Before commencing re-assembly, components should be checked for damage and bearing(s) examined for loss of grease.

222 Fitting of new bearing(s) is recommended during major overhaul.

223 Before re-assembling to the engine drive shafts and couplings or drive disc should be checked for damage or wear.

224 Where fitted the drive disc should be examined for cracks, signs of fatigue or elongation of fixing holes.

225 Ensure that the disc to shaft end fixing bolts are fitted with the pressure plate and are torque tightened to 7.6kgm (75Nm 55lbs.ft).

226 Taper shaft drive end arrangements should be checked for damage to the taper on both shaft and coupling hub. Ensure both tapers are free from oil before refitting.

227 Refer to Para 69 for assembly to engine.

NOTE

The M10 'BINX' nut should always be renewed. Tightening torque 4.6kgm, (45Nm; 33lbs.ft).

228 Damaged or worn components must be replaced.

RETURNING TO SERVICE

229 After rectification of any faults found, remove all test connections and reconnect all control system leads.

230 Restart the set and adjust VOLTS control potentiometer on AVR by slowly turning clockwise until rated voltage is obtained.

231 Refit all terminal box covers/access covers and reconnect heater supply.

CAUTION

EQUIPMENT DAMAGE. Failure to refit all guards, access covers and terminal box covers can result in personal injury or death.

SPARES AND AFTER SALES SERVICE

RECOMMENDED SPARES

232 Service parts are conveniently packaged for easy identification. Genuine parts may be recognised by the Nupart name.

233 We recommend the following for Service and Maintenance. In critical applications a set of these service spares should be held with the generator.

AVR controlled generators

234	(1)	Diode set (6 diodes with surge suppressor)	RSK	1101
	(2)	SA465 AVR	E000	24650
		SX460 AVR	**E000**	**24602**
	(3)	Non-drive end bearing	051	01058
	(4)	BC16 and BC18 Drive end bearing	051	01032

235 When ordering parts the machine serial number or machine identity number and type should be quoted, together with the part description. For location of these numbers see Para 8.

236 Orders and enquiries for parts should be addressed to:

Newage International Limited
Nupart Department
PO Box 17, Barnack Road
STAMFORD
Lincolnshire
PE9 2NB
ENGLAND

Telephone: 44 (0) 1780 484000
Fax: 44 (0) 1780 766074

Or any of our subsidiary companies listed on the back cover.

Assembly tools

237 Locating bar (Single bearing) AF1609.

8mm ratchet box wrench (for M10 socket screws) AF1599.

AFTER SALES SERVICE

238 A full technical advice and on-site service facility is available from our Service Department at Stamford or through our Subsidiary Companies. A repair facility is also available at our Stamford Works.

TABLE 6 PARTS LIST TYPICAL SINGLE BEARING GENERATOR

Fig 16 Ref.	Description
1	Stator
2	Rotor
3	Exciter Rotor
4	Exciter Stator
5	NDE End bracket
6	Cover NDE.
7	Bearing 'O' Ring NDE
8	Bearing NDE
9	DE Adaptor
10	DE Screen
11	Coupling Hub
12	Pressure Plate
13	Coupling Bolt
14	Foot
15	Frame Cover Bottom
16	Frame Cover Top
17	Terminal Box Lid
18	End Panel DE
19	End Panel NDE
20	Side Panel (AVR)
21	Side Panel
22	Main Terminal Panel
23	Terminal Link
24	Main Rectifier Assembly - Forward
25	Main Rectifier Assembly - Reverse
26	Varistor
27	Diode Reverse Polarity
28	Diode Forward Polarity
29	AVR
30	AVR Mounting Plate
31	AVR Mounting Bracket
32	AVM
33	Fan Hub
34	Fan
35	Fan Securing Screw

NDE Non-Drive End
DE Drive End
AVR Automatic Voltage Regulator
AVM Anti-Vibration Mount

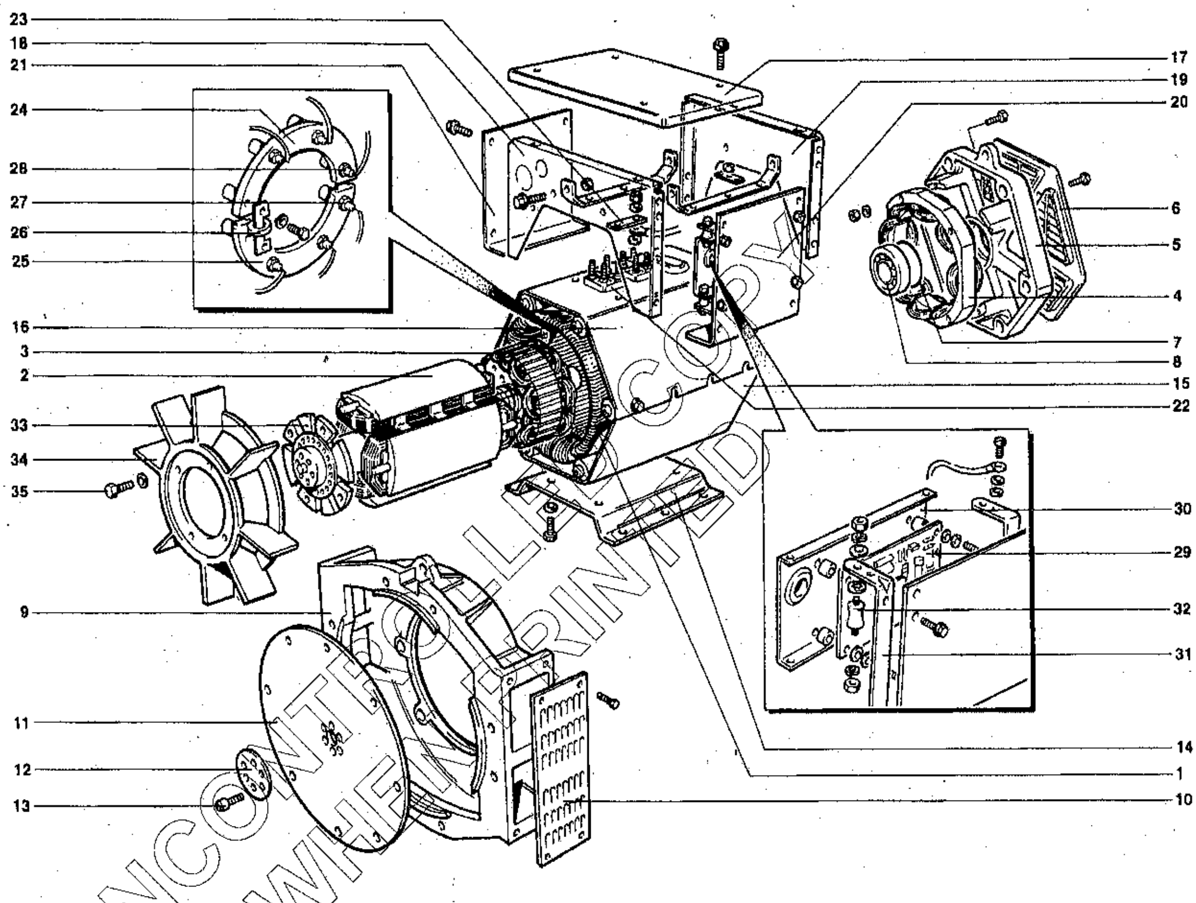


Fig 16 Typical single bearing generator

AC GENERATOR WARRANTY

WARRANTY PERIOD

AC Generators

In respect of ac generators the Warranty Period is eighteen months from the date when the goods have been notified as ready for despatch by NI or twelve months from the date of first commissioning (whichever is the shorter period).

DEFECTS AFTER DELIVERY

We will make good by repair or, at our option, by the supply of a replacement, any fault which under proper use appears in the goods within the period specified on Clause 12, and is found on examination by us to be solely due to defective material and workmanship; provided that the defective part is promptly returned, carriage paid, with all identification numbers and marks intact, or our works or, if appropriate to the Dealer who supplied the goods.

Any part repaired or replaced, under warranty, will be returned by NI free of charge (via sea freight if outside the UK).

We shall not be liable for any expenses which may be incurred in removing or replacing any part sent to us for inspection or in fitting any replacement supplied by us. We shall be under no liability for defects in any goods which have not been properly installed in accordance with NI recommended installation practices as detailed in the publications 'NI Installation, Service and Maintenance Manual' and 'NI Application Guidelines', or which have been improperly stored or which have been repaired, adjusted or altered by any person except ourselves or our authorised agents, or in any second-hand goods, proprietary articles or goods not of our own manufacture although supplied by us, such articles and goods being covered by the warranty (if any) given by the separate manufacturers.

Any claim under this clause must contain fully particulars of the alleged defect, the description of the goods, the date of purchase, and the name and address of the Vendor, the Serial Number (as shown on the manufacturers identification plate) or for Spares the order reference under which the goods were supplied.

Our judgement in all cases of claims shall be final and conclusive and the claimant shall accept our decision on all questions as to defects and the exchange of a part or parts.

Our liability shall be fully discharged by either repair or replacement as above, and in any event shall not exceed the current list price of the defective goods.

Our liability under this clause shall be in lieu of any warranty or condition implied by law as to the quality or fitness for any particular purpose of the goods, and save as expressly provided in this clause we shall not be under any liability, whether in contract, tort or otherwise, in respect of defects in goods delivered or for any injury, damages or loss resulting from such defects or from any work undone in connection therewith.

MACHINE SERIAL NUMBER	

NEWAGE INTERNATIONAL LIMITED

REGISTERED OFFICE AND ADDRESS:
PO BOX 17
BARNACK ROAD
STAMFORD
LINCOLNSHIRE
PE9 2NB ENGLAND

Telephone: 44 (0) 1780 484000
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Web site: www.newagestamford.com

ANNEX E

DEEP SEA ELECTRONICS plc

ENGINE MANAGEMENT SYSTEM

ANNEX E

DEEP SEA ELECTRONICS plc - ENGINE MANAGEMENT SYSTEM

CONTENTS

ANNEX E

ENGINE MANAGEMENT SYSTEM

INTRODUCTION

1 The DSE **520** Remote Start Module has been designed to allow the OEM to meet most of the industry's complex specifications. It has been primarily designed to start a generator when a remote start signal from a remote transfer switch or other monitoring system applies an earthing signal to the remote start input of the **520**. Transfer the load to the generator when the operating criteria have been met, then shutdown the engine on removal of the remote start signal.

2 Once activated the **520** module carries out all the start and stop procedures of the engine, indicating the operational status and fault conditions; automatically shutting down the engine and giving a true first up fault condition of an engine failure by a flashing LED and other simultaneous faults by a steady LED. This information is indicated by the LEDs on the front panel.

3 Selective operational sequences, timers and alarm trips can be altered by the customer. Alterations to the system are made by using a PC with the **808** interface.

4 Access to critical operational sequences and settings for use by qualified engineers, are barred by a security code. Timers are protected by a separated code allowing operator changes to be made.

5 The module is housed in a robust plastic case for the front panel mounting. Connections to the module are via locking plug and sockets.

Clarification of notation used within this publication

NOTE	Highlights an essential element of a procedure to ensure correctness.
CAUTION	Indicates a procedure or practice that, if not strictly observed, could result in damage or destruction of equipment.
WARNING	Indicates a procedure or practice that could result in injury to personnel or loss of life if not followed correctly.
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OPERATION

6 On connection of the dc power supply to the module, the module becomes active.

CONTROL

7 Control of the **520** module is by a three position rotary switch or key-switch (specified on ordering), mounted on the front of the module with OFF, AUTO and MANUAL positions.

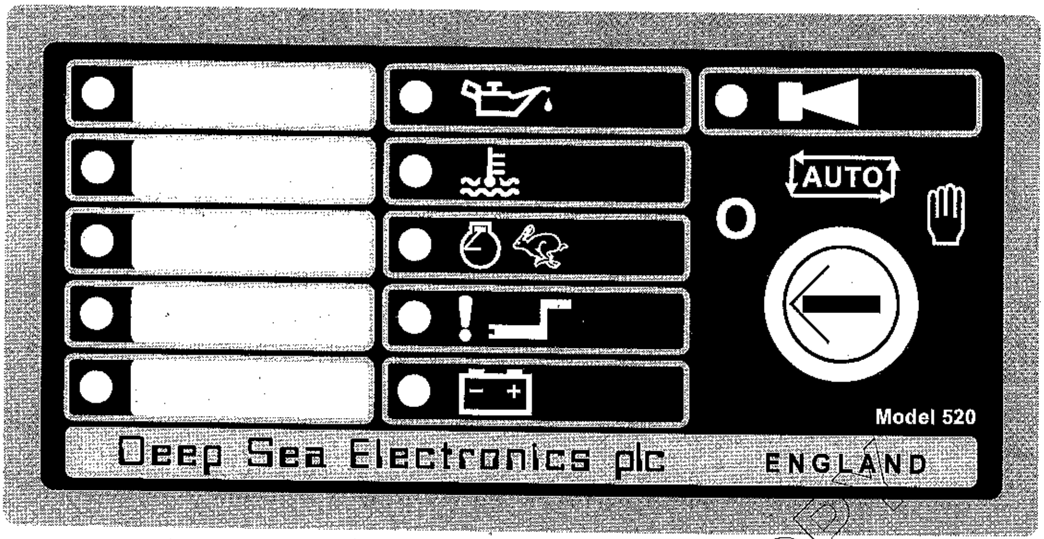


Fig 1 DSE 520 remote start module front panel

AUTOMATIC MODE OF OPERATION

8 The module is activated by turning the selector switch to the AUTO position.

(1) When a Remote Start signal is applied to the remote start input, the following sequence is initiated:

(2) The Remote Start Present LED illuminates.

(3) To allow for false signals the Start Delay timer is initiated, after this delay, if the pre-heat output option is selected this timer is then initiated, and the corresponding auxiliary output that is selected energises.

NOTE

If the Remote Start signal is removed during the Start Delay timer, the unit will return to a stand-by state.

(4) After the above delays, the Fuel Solenoid is energised and the Starter Motor is engaged.

(5) The engine is cranked for a pre-set time period. If the engine fails to fire during this cranking attempt then the starter motor is disengaged for the pre-set rest period. Should this sequence continue beyond the set number of attempts, the start sequence will be terminated and Fail to Start fault will be displayed by a flashing LED.

(6) When the engine fires, the starter motor is disengaged and locked out at a pre-set frequency from the Alternator output. Alternatively, a Magnetic Pickup mounted on the flywheel housing can be used for speed detection. (This is selected by PC using the **808** interface.) The warning lamp output of the charge alternator can also be used to disconnect the starter motor, however it cannot be used for underspeed or overspeed. This is explained in the calibration section.

(7) After the starter motor has disengaged, the Safety On timer is activated, allowing Oil Pressure, High Engine Temperature, Underspeed, Charge Fail and any delayed Auxiliary fault inputs to stabilise without triggering the fault.

(8) Once the engine is running, the Warm Up timer if selected is initiated, allowing the engine to stabilise before accepting the load.

(9) If an auxiliary output has been selected to give a load transfer signal, this would then activate.

NOTE

A load transfer will not be initiated until the Oil Pressure has risen and the Oil Pressure switch has operated. This prevents excessive wear on the engine.

(10) On removal of the Remote Start signal, the Stop delay timer is initiated, once it times out the Load Transfer signal is de-energised, removing the load. The Cooling timer is then initiated, allowing the engine a cooling down period off load before shutting down. Once the Cooling timer expires, the Fuel Solenoid is de-energised, bringing the generator to a stop.

(11) Should the Remote Start signal be re-activated during the cooling down period, the set will return on load after the Warming timer has expired.

MANUAL OPERATION

NOTE

The following sequence is only applicable to controllers not using external start/stop pushbutton control.

9 To initiate a start sequence in MANUAL, turn the selector switch to MANUAL.

NOTE

There is no Start Delay in this mode of operation.

(1) If the pre-heat output option is selected, this timer is then initiated and the auxiliary output selected is energised.

(2) After the above delay, the Fuel Solenoid is energised and the Starter Motor is engaged.

(3) The engine is cranked for a pre-set time period. If the engine fails to fire during this cranking attempt then the starter motor is disengaged for the pre-set rest period. Should this sequence continue beyond the set number of attempts, the start sequence will be terminated and Fail to Start fault will be displayed by a flashing LED.

(4) When the engine fires, the starter motor is disengaged and locked out at a pre-set frequency from the Alternator output. Alternatively, a Magnetic Pickup mounted on the flywheel housing can be used for speed detection. (This is selected by PC using the **808** interface.) The warning lamp output of the charge alternator can also be used to disconnect the starter motor, however it cannot be used for underspeed or overspeed.

(5) After the starter motor has disengaged, the Safety On timer is activated, allowing Oil Pressure, High Engine Temperature, Underspeed, Charge Fail and any delayed Auxiliary fault inputs to stabilise without triggering the fault.

(6) Once the engine is running, the Warm Up timer if selected is initiated, allowing the engine to stabilise before it can be loaded.

(7) The generator will run off load, unless a Remote Start signal is applied, and if Load Transfer has been selected as a control source, the appropriate auxiliary output selected will activate.

(8) If the Remote Start signal is removed, the generator will continue to run On load until the selector switch is turned to Auto. The Remote Stop Delay timer will time out, the load is then disconnected. The generator will then run Off load allowing the engine a cooling down period.

(9) Turning the selector to STOP de-energises the FUEL SOLENOID, bringing the generator to a stop.

MANUAL OPERATION WITH EXTERNAL START AND STOP PUSHBUTTONS

10 If the module has been configured to use external Start and Stop pushbuttons, the normal 'Manual' mode of operation is over-ridden and the following sequence is observed:

(1) Turn the selector switch to MANUAL.

(2) To start the set operate the 'Start' pushbutton, the pre-heat output (if selected) will energise and the timer is initiated.

(3) Once the above delay has expired, the Fuel Solenoid is energised and the Starter Motor is engaged.

(4) The engine is cranked for a pre-set time period. If the engine fails to fire during this cranking attempt then the starter motor is disengaged for the pre-set rest period. Should this sequence continue beyond the set number of attempts, the start sequence will be terminated and Fail to Start fault will be displayed by a flashing LED.

(5) When the engine fires, the starter motor is disengaged and locked out at a pre-set frequency from the Alternator output. Alternatively, a Magnetic Pickup mounted on the flywheel housing can be used for speed detection. (This is selected by PC using the **808** interface.) The warning lamp output of the charge alternator can also be used to disconnect the starter motor, however it cannot be used for underspeed or overspeed.

(6) After the starter motor has disengaged, the Safety On timer is activated, allowing Oil Pressure, High Engine Temperature, Underspeed, Charge Fail and any delayed Auxiliary fault inputs to stabilise without triggering the fault.

(7) Once the engine is running, the Warm Up timer if selected is initiated, allowing the engine to stabilise before it can be loaded.

(8) The generator will run off load, unless a Remote Start signal is applied, and if Load Transfer has been selected as a control source, the appropriate auxiliary output selected will activate.

(9) If the Remote Start signal is removed, the generator will continue to run On load until the selector switch is turned to Auto. The Stop Delay timer will time out, the load is then disconnected. The generator will then run Off load allowing the engine a cooling down period.

(10) Turning the selector to STOP or pressing the 'Stop' Pushbutton de-energises the FUEL SOLENOID, bringing the generator to a stop.

PROTECTIONS

11 The LEDs will indicate the fault condition and one of the auxiliary outputs, if selected to be a common alarm output, will activate. First up fault is indicated by a flashing LED, subsequent faults which happen simultaneously are indicated by a steady LED. Warnings are also indicated by a steady LED. Indications are fed directly from the appropriate input and are indicated by a steady LED, which will be present for as long as the input is active, this feature can be used to allow the module to operate as an Annunciator.

NOTES

(1) An auxiliary output may be configured as one of three alarm options, Shutdown, Warning or Common Alarm (Shutdown and Warnings). This is in addition to the list of other control sources from which it may be driven.

(2) There is a Common alarm LED on the front panel which illuminates to indicate all Shutdown and Warning faults. This is mainly used to indicate fault conditions such as Emergency Stop, Fail to Stop, Underspeed, Sensor Fail and Oil Pressure Switch which do not have their own individual LED to indicate the fault. A warning indication is illuminated steady, while shutdown indications flash.

(3) A corrupt configuration is indicated by all the LEDs flashing. The module must then be re-configured.

WARNINGS

12 Warnings are self-resetting, once the fault has been removed the input is reset.

(1) **CHARGE FAIL**, if charge alternator voltage falls below the pre-set trip voltage after the end of Safety On timer, the Charge Fail LED is illuminated.

(2) **AUXILIARY INPUTS**, if an auxiliary input has been configured as a warning the appropriate **LED** will illuminate.

(3) **OIL PRESSURE SWITCH,** the **520** will only attempt to crank the engine if the Oil Pressure is initially low, (engine at rest, not running). It is also possible that this could indicate that the Oil Pressure switch is faulty if engine not running. The Common Alarm LED will illuminate.

SHUTDOWNS

13 Shutdowns are latching and stop the Generator. The selector switch must be turned to Stop Reset and the fault removed to reset the module.

(1) **EMERGENCY STOP**, removal of the +ve dc supply from the Emergency Stop input initiates the following sequence. Firstly it will initiate a controlled shutdown of the Generator and prevent any attempt to restart the Generator until the Emergency Stop pushbutton has been reset. Secondly, it removes the +ve dc supply from both the Fuel Solenoid and Starter Solenoid. This input is always active when AUTO or MANUAL is selected.

NOTE

The Emergency Stop signal must be present otherwise the unit will shutdown.

(2) **LOW OIL PRESSURE**, activation of the Low Oil Pressure input after the Safety On timer has expired, initiates a shutdown. The Low Oil Pressure LED will flash.

(3) **HIGH ENGINE TEMPERATURE**, activation of the High Engine Temperature input after the Safety On timer has expired, initiates a shutdown. The High Engine Temperature LED will flash.

(4) **OVERSPEED**, if the engine speed exceeds the pre-set trip a shutdown is initiated. The Overspeed LED will flash. Overspeed is not delayed, it is an immediate shutdown.

(5) **FAIL TO START**, if the engine fails to fire after the pre-set number of attempts to crank, the start sequence is terminated. The Fail to Start LED will flash.

(6) **FAIL TO STOP**, if the generator fails to stop after the pre-set time, the Common Alarm LED will flash. Two conditions must be met to signal that the generator has stopped, Oil Pressure has gone low, and that no speed is sensed from either Magnetic Pickup or Alternator speed sensing sources.

(7) **UNDERSPEED**, if the engine speed falls below the pre-set trip after the Safety On timer has expired a shutdown is initiated. The Common Alarm LED will flash.

(8) **SENSOR FAIL**, if the speed-sensing signal is lost during cranking, the Generator will shutdown and the Common Alarm LED will flash.

NOTE

This will only occur if the speed-sensing signal is lost during cranking or during the safety on timer. If the signal is lost during normal operation, the Generator will shutdown with an Underspeed alarm.

(9) **AUXILIARY INPUTS**, if an auxiliary input has been configured as a shutdown the appropriate LED will illuminate.

NOTE

It is possible for the LEDs to be configured to indicate any of the 32 different control sources in addition to the shutdowns and warnings detail above. Please refer to the **808** Software Manual for detail on how to achieve this.

INSTALLATION INSTRUCTIONS

14 The model **520** Remote Start Module has been designed for front panel mounting. Fixing is by two spring loaded clips for easy assembly.

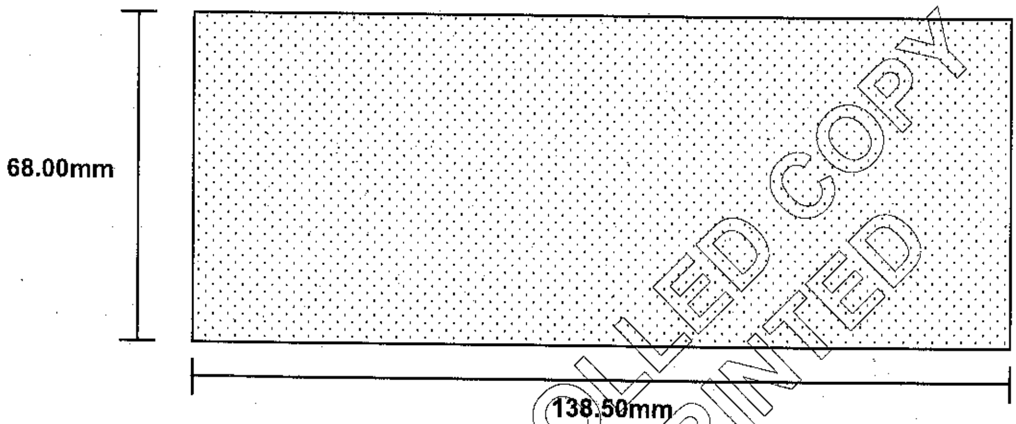


Fig 2 Panel cut-out

15 In conditions of excessive vibration the module should be mounted on suitable anti-vibration mountings.

COOLING

16 The module has been designed to operate over a wide temperature range -30° C to +55° C. However allowances should be made for the temperature rise within the control panel enclosure. Care should be taken <u>NOT</u> to mount possible heat sources near the module unless adequate ventilation is provided. The relative humidity inside the control panel enclosure should not exceed 85%.

UNIT DIMENSIONS

17 All dimensions are in mm.

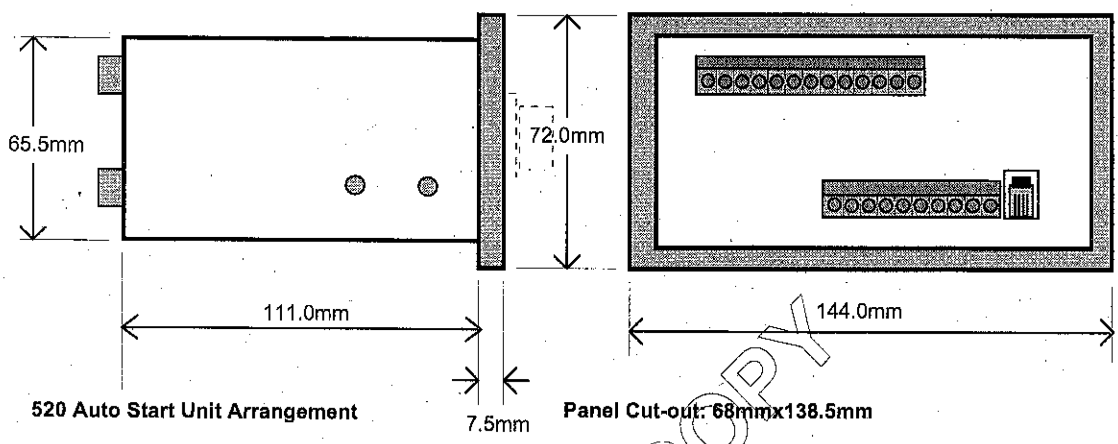


Fig 3 Unit dimensions

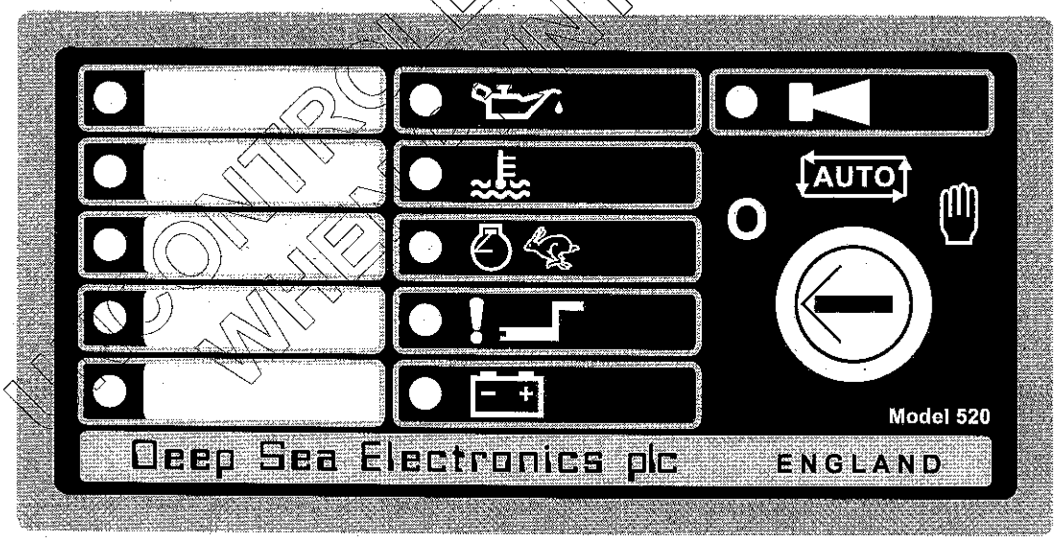


Fig 4 Front panel layout

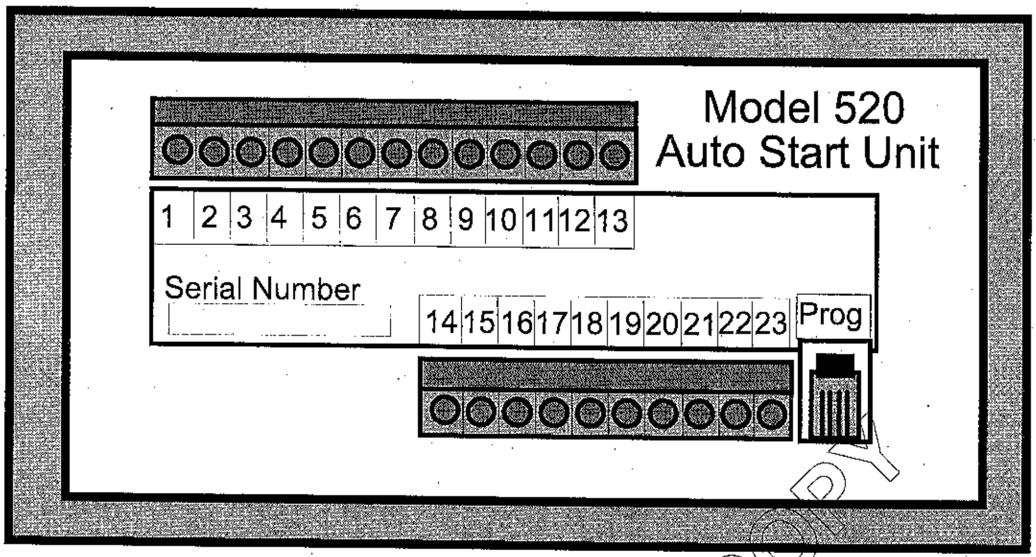


Fig 5 Rear panel layout

ELECTRICAL CONNECTIONS

18 Connections to the **520** Module are via plug and sockets.

CONNECTION DETAILS

19 The following describes the connections and recommended cable sizes to the two plugs and sockets on the rear of the **520** Module. See rear panel layout Fig 5.

TABLE 1 PLUG A 13 WAY

Pin No.	Description	Cable Size	Notes
1	dc Plant Supply Input (-ve)	2.5mm	
2	dc Plant Supply Input (+ve)	2.5mm	(Recommended Fuse 16A)
3	Emergency Stop Input	2.5mm	Plant Supply +ve. Also supplies fuel and start outputs. (Recommended Fuse 32A)
4	Fuel relay Output	2.5mm	Plant Supply +ve from Pin 3. 16 Amp rated.
5	Start relay Output	2.5mm	Plant Supply +ve from Pin 3. 16 Amp rated.
6	Auxiliary Output Relay 1	1.0mm	Plant Supply +ve. 5 Amp rated.
7	Auxiliary Output Relay 2	1.0mm	Plant Supply +ve. 5 Amp rated.
8	Charge Fail Input/ Excitation Output	1.0mm	Must NOT be connected to plant supply -ve if not used.
9	Low Oil Pressure Input	0.5mm	Switch to -ve
10	High Engine Temp Input	0.5mm	Switch to -ve
11	Auxiliary Input 1	0.5mm	Switch to -ve
12	Auxiliary Input 2	0.5mm	Switch to -ve
13	Remote Start Input	0.5mm	Switch to -ve

TABLE 2 PLUG B 10 WAY

Pin No.	Description	Cable Size	Notes
14	Alternator Input L1	1.0mm	Do not connect if not used. (2A Fuse)
15	Alternator Input N	1.0mm	Do not connect if not used.
16	DO NOT USE		Ensure no connection is made to this pin.
17	Auxiliary Output 3	1.0mm	Plant Supply +ve. 5 Amp rated.
18	Auxiliary Input 3	0.5mm	Switch to -ve
19	Auxiliary Input 4	0.5mm	Switch to -ve
20	Magnetic Pickup Input (+ve)	0.5mm	Connect to Magnetic Pickup device.
21	Magnetic Pickup Input (-ve)	0.5mm	Connect to Magnetic Pickup device.
22	Tachometer Output (+ve)	0.5mm	Optional, specified on ordering. Tachometer must be completely isolated.
23	Tachometer Output (-ve)	0.5mm	Optional, specified on ordering. Tachometer must be completely isolated.

NOTE

Screened cable must be used for connecting the Magnetic Pickup, ensuring that the screen is earthed at one end ONLY.

CONNECTOR FUNCTION DETAILS

20 The following describes the functions of the two connectors on the rear of the module. See rear panel layout Fig 5.

TABLE 3 PLUG A FUNCTIONS

Pin No.	Description
1	dc Supply -ve. System dc negative input. (Battery Negative).
2	dc Supply +ve. System dc positive input. (Battery Positive).
3	Emergency Stop input. Internally linked to Starter and Fuel outputs. If this input is not connected to positive the module will be locked out, and if the engine is running will shutdown immediately. Positive Supply also removed from Starter and Fuel therefore only a single-pole Emergency Shutdown button is required.
4	Fuel Relay output. Plant Supply +ve from Pin 3. Used to control the fuel solenoid.
5	Starter Relay output. Plant Supply +ve from Pin 3. Used to control the Starter Motor.
6	Auxiliary Relay output 1. Plant Supply +ve. Configurable output, see Calibration Manual for options available.
7	Auxiliary Relay output 2. As for Auxiliary output 1 (Pin No 6).
8	Charge Fail input/Excitation output. Supplies excitation to the Plant Battery Charging Alternator, also an input for the Charge Fail detection circuitry.

(continued)

TABLE 3 PLUG A FUNCTIONS (continued)

Pin No.	Description
9	Low Oil Pressure input. This is a negative switched input, it is possible to calibrate the input to be a normally closed signal or a normally open signal. This input is used to signal to the module that the oil pressure is low.
10	High Engine Temperature input. This is a negative switched input, it is possible to calibrate the input to be a normally closed signal or a normally open signal. This input is used to signal to the module that the engine temperature is high.
11	Auxiliary input 1. This is a negative switched configurable input, see Calibration Manual for options available. It is possible to configure the input to be a normally closed signal or a normally open signal.
12	Auxiliary input 2. As for Auxiliary input 1 (Pin 11).
13	Remote Start input. This is a negative switched input that will start the generator when Auto is selected. It is possible to configure the input to be a normally open signal or a normally closed signal.

TABLE 4 PLUG B FUNCTIONS

Pin No.	Description
14	Alternator Input L1. Used for Alternator speed sensing.
15	Alternator Input N. Used for Alternator speed sensing.
16	DO NOT USE
17	Auxiliary Relay output 3. Plant Supply +ve. Configurable output, see Calibration Manual for options available.
18	Auxiliary input 3. This is a negative switched configurable input, see Calibration Manual for options available. It is possible to configure the input to be a normally closed signal or a normally open signal.
19	Auxiliary input 4. As for Auxiliary input 3 (Pin 18).
20	Magnetic Input +ve. An AC signal from the magnetic pickup +ve for speed sensing.
21	Magnetic Input -ve. An AC signal from the magnetic pickup -ve for speed sensing.
22	Tachometer output +ve. 0.5 or 1.0 mA Tachometer can be used.
23	Tachometer output -ve. --------------------- " --------------------------

TABLE 5 CALIBRATION SOCKET

Pin No.	Description
1	Ground
2	Transmit Data
3	Receive Data
4	+5 Supply

CAUTION

EQUIPMENT DAMAGE. This socket is for the connection of appropriate products manufactured by Deep Sea Electronics plc only. Connection of any other device may cause damage and will invalidate the warranty.

SPECIFICATION

21	dc Supply	-	8.0 to 35 V Continuous.
	Cranking Dropouts	-	Able to survive 0 V for 50 mS, providing supply was at least 10 V before dropout and supply recovers to 5 V.
	Max. Operating Current	-	290 mA at 12 V. 210 mA at 24 V.
	Max. Standby Current	-	50 mA at 12 V. 30 mA at 24 V.
	Alternator Input Range	-	15 - 300 V ac RMS.
	Alternator Input Frequency	-	50 - 60 Hz at rated engine speed.
	Magnetic Input Range	-	0.5 V to +/- 70 V (Clamped by transient suppressors)
	Magnetic Input Frequency	-	10Hz to 10,000 Hz at rated engine speed.
	Start Relay Output	-	16 Amp DC at supply voltage.
	Fuel Relay Output	-	16 Amp DC at supply voltage.
	Auxiliary Relay Outputs	-	5 Amp DC at supply voltage.
	Dimensions	-	144 x 72 x 118.5 (Excluding Key-switch or Knob)
	Charge Fail / Excitation Range	-	0 V to 35 V.
	Operating Temperature Range	-	-30 to +55°C.

COMMISSIONING

Pre-commissioning

22 Before the system is started, it is recommended that the following checks are made:

(1) The unit is adequately cooled and all the wiring to the module is of a standard and rating compatible with the system.

(2) The unit dc supply is fused and connected direct to the battery, and is of correct polarity.

(3) The Emergency Stop input is wired to an external normally closed switch connected to dc positive.

NOTE

If Emergency Stop feature is not required, link this input to the dc positive.

(4) To check the start cycle, take appropriate measures to prevent the engine from starting (disable the operation of the fuel solenoid). After a visual inspection to ensure it is safe to proceed, connect the battery supply. Turn the selector switch to MANUAL. The unit start sequence will commence.

(5) The starter will engage and operate for the pre-set crank period. After the starter motor has attempted to start the engine for the pre-set number of attempts, the FAIL TO START LED will be illuminated. Turn to OFF to reset the unit.

(6) Restore the engine to operational status (reconnect the fuel solenoid), again select MANUAL and this time the engine should start and the starter motor should disengage automatically. If not then check that the engine is fully operational (fuel available, etc.) and that the fuel solenoid is operating. The engine should now run up to operating speed. If not, and an alarm is present, check the alarm condition for validity, then check the input wiring. The engine should continue to run for an indefinite period.

(7) Select AUTO on the front panel, the engine will run for the pre-set cooling down period, then shutdown. The generator should stay in the standby mode. If not check that there is not a signal present on the Remote Start input.

(8) Initiate a remote start by grounding the Remote Start input. The start sequence will start and the engine will run up to operational speed. If one of the Auxiliary Outputs has been configured for Load Transfer, the Generator will accept the load. If not, check the wiring to the Generator Contactor Coil. Check the Warming timer has timed out.

(9) Remove the Remote Start signal, the return sequence will start. After the pre-set time period, the load will be removed from the generator. The generator will then run for the pre-set cooling down period, then shutdown.

(10) All internal timers and selections should now be adjusted to the customer's specifications or to the engine and alternator manufacturers recommendations.

(11) If despite repeated checking of the connections between the **520** and the customer's system, satisfactory operation cannot be achieved, then the customer is requested to contact the factory for further advice on:

INTERNATIONAL TEL: 44 (0) 1723 377566
INTERNATIONAL FAX: 44 (0) 1723 354453
E-mail: Support@Deepseaplc.com

FAULT FINDING

23 Management system fault symptoms and possible remedies are shown below:

TABLE 6 FAULT FINDING

Symptom	Possible remedy
Unit is inoperative	Select AUTO on the front panel. Check the battery and wiring to the unit. Check the DC supply. Check the DC fuse.
Unit shuts down	Check DC supply voltage is not above 35 Volts or below 8 Volts Check the operating temperature is not above 55°C. Check the dc fuse.
Unit locks out on Emergency Stop	If an Emergency Stop Switch is not fitted, ensure that a positive is connected to the Emergency Stop input. Check emergency stop switch is functioning correctly. Check wiring is not open circuit.
Intermittent sensor fault	Ensure that Magnetic pickup screen is only connected at one end, if connected at both ends this enables the screen to act as an aerial and will pick up random voltages.
Low oil pressure fault operates after engine has fired	Check engine oil pressure. Check oil pressure switch and wiring. Check configured polarity is correct.

(continued)

TABLE 6 FAULT FINDING (continued)

Symptom	Possible remedy
High engine temperature fault operates after engine has fired.	Check engine temperature. Check switch and wiring. Check configuration of input, ie Normally Open or Normally Closed.
Shutdown fault operates	Check relevant switch and wiring of illuminated fault LED. Check configuration of input. If only common alarm LED illuminated, please refer to Para 11, Note 2.
Warning fault operates	Check relevant switch and wiring of illuminated fault LED. Check configuration of input. If only common alarm LED illuminated, please refer to Para 11, Note 2.
Fail to Start is activated after pre-set number of multi attempts to start	Check wiring of fuel solenoid. Check fuel. Check battery supply. Check battery supply is present on the Fuel output of the module. Check the speed-sensing signal is present on the **520** inputs. Refer to engine manual.
Continuous starting of generator when in AUTO	Check that there is no signal present on the Remote Start input. Check configured polarity is correct.
Generator fails to start on receipt of Remote Start signal	Check Start Delay timer has timed out. Check signal is on Remote Start input.
Pre-heat inoperative	Check wiring to engine heater plugs. Check battery supply. Check battery supply is present on the Pre-heat output of module. Check pre-heat has been selected in the configuration menu.
Starter motor inoperative	Check wiring to starter solenoid. Check battery supply. Check battery supply is present on the Starter output of module. Ensure that the Emergency Stop input is at +Ve.
Engine runs but generator will not take load	Check Warm up timer has timed out. Check configuration to ensure output has been selected to give Load Transfer.

NOTE

Fault finding can be assisted greatly by utilising the Diagnostic feature available from the PC Interface. This will display the module state, any alarm conditions present and the state of all inputs and outputs. It is recommended that diagnostics are used to aid fault finding wherever possible.

TYPICAL WIRING DIAGRAM

24 A typical wiring diagram of the Model 520 module is shown in Fig 6.

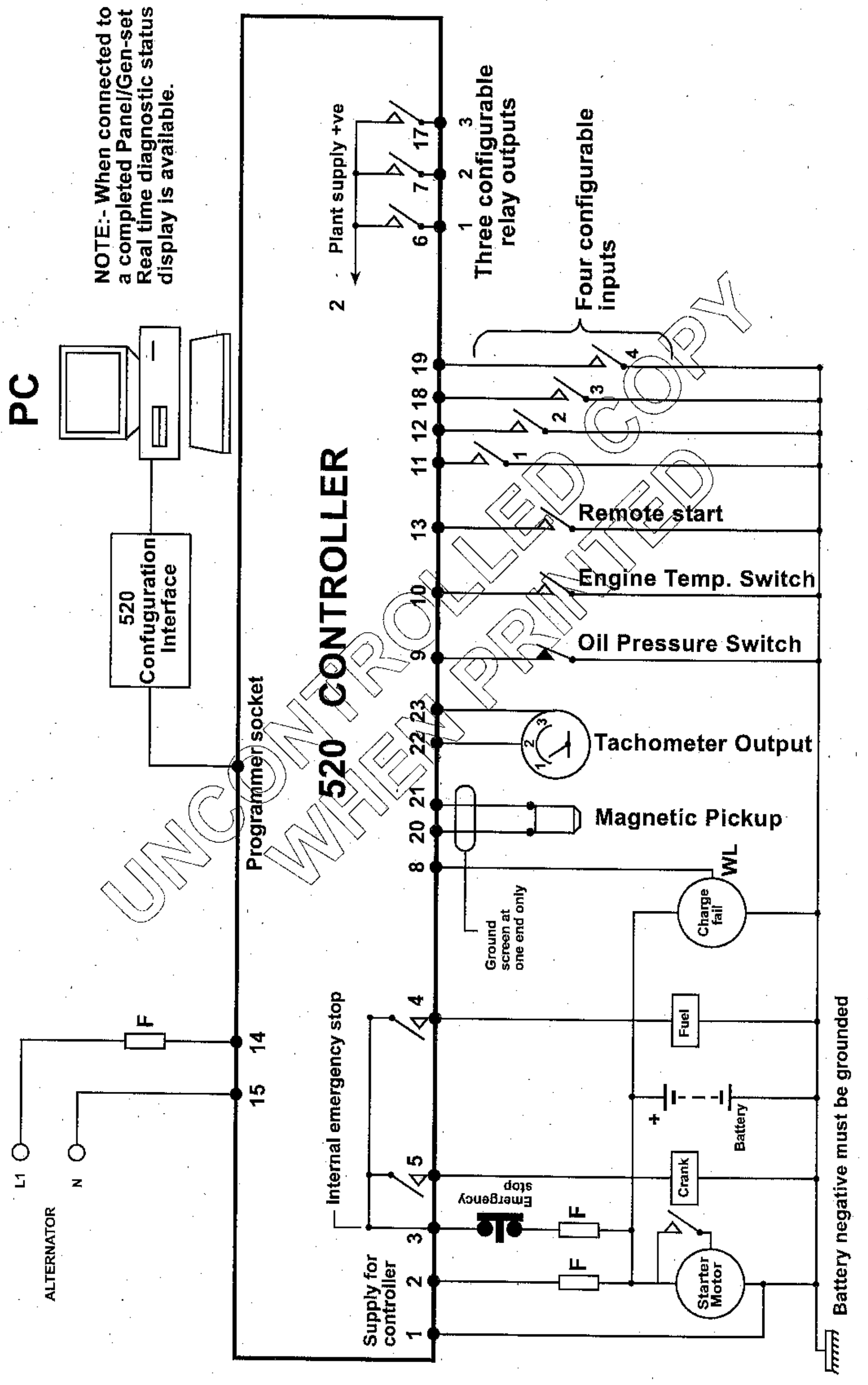


Fig 6 Typical wiring diagram

CALIBRATION

25 The **520** module can be calibrated by using a PC with the Interface Module **808**.

PC INTERFACE MODULE 808

26 The PC interface **808** kit comprises the following:

(1) **808** Interface module.

(2) 25 to 9 way adaptor.

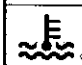
(3) FCC 68 (4 Pin) connecting lead.

(4) Floppy disk with configuration software.

ICON DESCRIPTIONS

27 The **DSE P520** module is available with graphical icons instead of text. This is for use where text in the English language may cause problems and also allows for a standard module for all world markets to be used.

TABLE 7 ICONS

Symbol	Meaning	Description
	Stop/Reset	Stop the generator and reset any alarm conditions. Refer to the Operation section of this Manual.
	Auto	The controller will automatically start the generator when given a remote start command. Refer to Para 8 of this Manual.
	Manual	The controller will start the generator under manual control. Refer to Para 9 of this Manual.
	Low Oil Pressure	A low oil pressure shutdown has occurred. Refer to Para 13 of this Manual.
	High Engine Temperature	A High Engine Temperature shutdown has occurred. Refer to Para 13 of the Manual.
	Overspeed	An overspeed shutdown has occurred. Refer to Para 13 of this Manual.
	Fail to start/Over-crank	The engine has failed to start after the pre-set number of attempts. Refer to Para 13 of this Manual.
	Charge Fail	The charge alternator on the engine is not giving sufficient output. Refer to Para 12 of this Manual.
	Common Alarm	An alarm condition has been detected. Refer to Para 11 of this Manual. (Warning = Steady, Shutdown = *Flashing*)
	Remote Start Active	The remote start signal is being applied to the module.
	dc Power On	The module is being supplied with a suitable dc supply.

APPENDIX 1

FACTORY DEFAULT CONFIGURATION

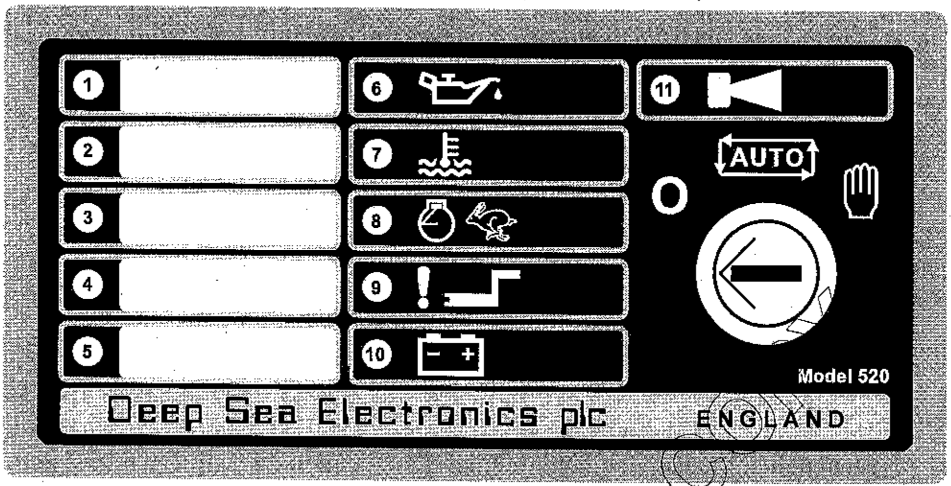


Fig 7 LED identification diagram

NOTE

The software disk supplied with the Calibration Interface **(808)** contains a Microsoft Word document for the automatic creation of suitable label inserts for the Auxiliary LEDs.

FACTORY DEFAULT CONFIGURATION

1 The **520** module when shipped contains the following configuration, allowing it to be used as a standard module if no configuration interface is available.

MISCELLANEOUS ITEMS

Item	Value
Start attempts	3
Alternator frequency input present	Yes
Nominal frequency	50Hz
Alternator poles	4
Magnetic pickup input present	No
Flywheel teeth	118
Nominal RPM	1500
Lamp test enabled	No
Start button	None
Stop button	None
Safety on delay time termination	Premature
Load transfer mode	Normal
Pre-heat mode	Normal
Tachometer full scale current	0.5mA
Tachometer full scale RPM	2500
Electrical trip enabled	No

CONFIGURABLE INPUTS

Input channel	Polarity	Type	Activation time
Remote start	Close to activate		
Low oil pressure	Close to activate	Shutdown	Active from safety on
High engine temp.	Close to activate	Shutdown	Active from safety on
Auxiliary input 1	Close to activate	Warning	Always active
Auxiliary input 2	Close to activate	Warning	Active from safety on
Auxiliary input 3	Close to activate	Shutdown	Active from safety on
Auxiliary input 4	Close to activate	Indication	Always active

RELAY OUTPUTS

Output channel	Polarity	Control source
Auxiliary output 1	Energize	1 Pre-heat
Auxiliary output 2	Energize	18 Common alarm
Auxiliary output 3	Energize	4 Load transfer

FRONT PANEL LEDs

LED	Polarity	Control source
LED 1	Lit	29 Auxiliary IP 1 active
LED 2	Lit	30 Auxiliary IP 2 active
LED 3	Lit	31 Auxiliary IP 3 active
LED 4	Lit	32 Auxiliary IP 4 active
LED 5	Lit	25 Remote start present
LED 6	Lit	27 Low oil pressure alarm
LED 7	Lit	28 High engine temp. alarm
LED 8	Lit	20 Overspeed alarm
LED 9	Lit	7 Fail to start alarm
LED 10	Lit	21 Charge fail alarm
LED 11	Lit	18 Common alarm

SYSTEM TIMERS

Timer	Mins:Secs
Remote start delay time	0:05
Remote stop delay time	0:30
Cranking time	0:10
Crank rest time	0:10
Safety on delay time	0:10
Warm up time	0:05
Cooling time	0:30
Fail to stop time	0:30
ETS hold time	0:00
Pre-heat time	0:00
Sensor fail delay time	0:02
Smoke limiting time	0:00
Smoke limiting ramp time	0:00

ANALOGUE LEVELS

Level	Value
Overspeed on alternator frequency	57.0 Hz
Overspeed on magnetic pickup	1750 RPM
Overspeed overshoot during safety on delay	0 %
Underspeed on alternator frequency	30.0 Hz
Underspeed on magnetic pickup	1250 RPM
Crank disconnect on alternator frequency	21.0 Hz
Crank disconnect on magnetic pickup	600 RPM
Crank disconnect charge alternator voltage	30.0 V
Charge fail voltage	8.0 V

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