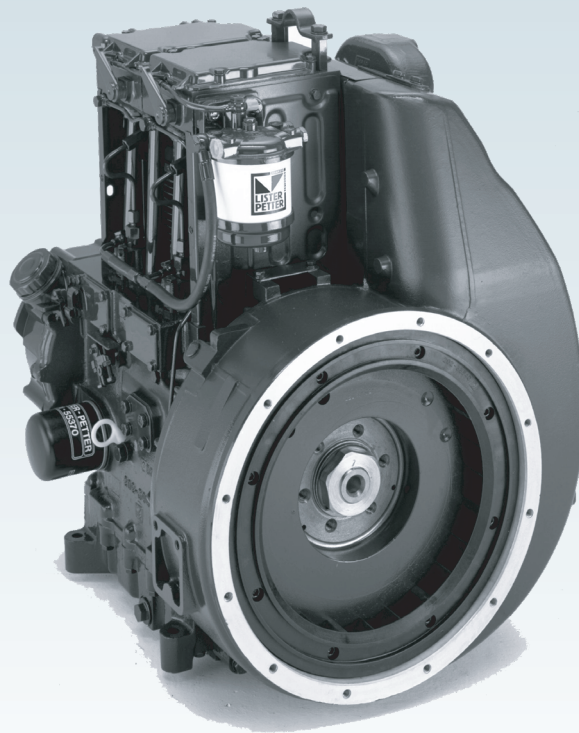




T SERIES

TS, TR, TX ENGINES WORKSHOP MANUAL



Associated Publications

Operators Handbook.....	P027-08185
TS, TR Master Parts Manual.....	P027-08030
TX Master Parts Manual.....	P027-08929
Technical Handbook.....	P027-09212

Disclaimer

The information, specifications, illustrations, instructions and statements contained within this publication are given with Lister Petter Power Systems' best intentions and are believed to be correct at the time of going to press.

Our policy is one of continued development and we reserve the right to amend any technical information with or without prior notice. Whilst every effort is made to ensure the accuracy of the particulars contained within this publication neither the Manufacturer, the Distributor nor the Dealer shall in any circumstances be held liable for any

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INTRODUCTION

The purpose of this manual is to give information, operating, maintenance and repair procedures for the 'T' Series of engines.

The manual is designed primarily for use by qualified technicians with electrical and mechanical experience.

This work can only be carried out if the necessary hand and service tools are available. When the user has insufficient tools, experience or ability to carry out adjustments, maintenance and repairs then this work should not be attempted.

Where accurate measurements, or torque values, are required they can only be made using calibrated instruments.

Under no circumstances should makeshift tools or equipment be used, as their use may adversely affect safe working procedures and engine operation.

The specification details given apply to a range of engines and not to any one particular engine. In cases of difficulty the user should consult the local Lister Petter Power Systems Distributor or Dealer for further advice and technical assistance.

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Parts that have not been approved by the Lister Petter Power Systems organisation cannot be relied upon for correct material, dimensions or finish. This Company cannot therefore, be responsible for any damage arising from the use of such parts and the guarantee will be invalidated.

When purchasing parts or giving instructions for repairs users should, in their own interests, always specify Genuine Lister Petter Parts and quote the Description of the Part and the Engine Serial Number.

Training

Comprehensive training in the correct operation, service and overhaul procedures of engines is

available at the Lister Petter Power Systems International Product Training Centre. Please contact Lister Petter Power Systems for details.

If Problems Occur

If problems occur with your engine, or any of the Lister Petter Power Systems approved accessories fitted to it, your local Lister Petter Power Systems Distributor should be consulted.

There are Lister Petter Power Systems Distributors in most countries of the world and details for these can be obtained from any one of the companies listed on the back cover.

Using this Workshop Manual

Each section title is given at the top of the relevant pages and each section has its own 'Contents' page. A full cross reference 'Index' appears at the back of the manual.

It is recommended the individual steps contained in the various maintenance or repair operations are followed in the sequence in which they appear.

At times it may be necessary to refer to other parts of the section, or to a different section, for more specific or detailed information.

Caution and Warning Symbols

When an engine is operating or being overhauled there are a number of associated practices which may lead to personal injury or product damage.

Your attention is drawn to the symbols shown and described below which are applied throughout this manual.

CAUTION

This caution symbol draws attention to special instructions or procedures which, if not correctly followed, may result in damage to, or destruction of, equipment.

WARNING

This warning symbol draws attention to special instructions or procedures which, if not strictly observed, may result in personal injury.

WARNING

A WARNING SYMBOL WITH THIS TYPE OF TEXT DRAWS ATTENTION TO SPECIAL INSTRUCTIONS OR PROCEDURES WHICH, IF NOT STRICTLY OBSERVED, MAY RESULT IN SEVERE PERSONAL INJURY, OR LOSS OF LIFE.

Note:

A note is used to draw your attention to additional or important information.

1. GENERAL INFORMATION

1.1 SAFETY PRECAUTIONS AND SAFE WORKING PRACTICES

At all times follow the recommended precautions and safe operating and working practices. The following are of a general nature and more specific information appears where it is relevant.

Caution and Warning Symbols

CAUTION

This caution symbol draws attention to special instructions or procedures which, if not correctly followed, may result in damage to, or destruction of, equipment.

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Follow All Safety Instructions

- Carefully read all safety messages in this manual and the safety and informative symbols on your engine and plant.
- Starting any diesel engine can be dangerous in the hands of inexperienced people. Engine operators must be instructed in the correct procedures before attempting to start any engine.
- Do not make any unauthorised modifications as these may affect the safe operation of the engine and put the operator at risk.
- Ensure all starting devices are removed, or isolated, before commencing any work on the engine or plant.

Emergency Considerations

- Be prepared with suitable equipment, and knowledge, in case a fire starts.
- Know where to make calls to the emergency services from.
- Ensure a third party knows where you are working and when you leave the working area.

Handling Fluids Safely

- When working with fuel or batteries do not smoke or work near to heaters or other fire hazards.

- Store flammable liquids away from fire hazards.
- Do not expose pressurised containers to heat and do not incinerate or puncture them.
- Handle fuel with care and always stop the engine before refuelling. Do not overfill the fuel tank.
- Thoroughly clean any lubricating or fuel oil from the skin as soon as possible.
- Rectify all fuel, coolant and oil leaks as soon as practicable and clean any spills when they occur.
- Remove any build-up of grease, oil or debris.
- Batteries contain sulphuric acid - if the acid has been splashed on the skin, eyes or clothes flush it away with copious amounts of fresh water and seek medical aid.

Personal Safety

- Tie long hair close to your head.
- Do not wear a necktie, scarf, loose clothing or necklace when working close to a running engine.
- It is advisable to remove rings and other jewellery to prevent possible entanglement in moving parts. These items could also cause an electric short circuit if any part of the electrical system is being worked on.
- Ensure any lifting equipment to be used has the correct capacity to lift the engine.
- Lifting equipment must be designed to give two vertical lifts from directly above the engine lifting eyes.
- The engine lifting eyes fitted to the engine are suitable for lifting the engine and accessory assemblies originally fitted by Lister Petter. They must not be used to lift the complete plant.
- Do not work under any plant that is only held by overhead lifting equipment.

Personal Protective Clothing & Equipment

- Wear close fitting clothing and personal protective clothing and safety equipment appropriate to the work being done.
- Wear suitable ear protection to protect against objectionable or uncomfortable loud noise. Prolonged exposure to loud noise can cause impairment, or loss of hearing.
- The use of music or radio headphones could cause a loss of concentration.

Handling Chemical Products Safely

- Direct exposure to hazardous chemicals can cause serious injury.
- Potentially hazardous chemicals include such items as lubricants, fuel, coolant concentrate,

battery acid, paint and adhesives.

- c. Manufacturers Safety Data Sheets will provide specific details of the physical and health hazards, safety and emergency procedures and any necessary personal protection equipment required while working with hazardous materials.

Rotating Machinery

- a. Entanglement with any rotating equipment can cause serious injury or death.
b. If unprotected skin comes into contact with rotating equipment severe burns can result.

Safe Maintenance Considerations

- a. Understand the service procedures before commencing any work.
b. Ensure the work area is clean, dry, well ventilated and has adequate lighting.
c. Isolate the engine starting system before commencing any work on the plant.
d. All persons using equipment or processes in connection with the maintenance of plant and machinery must have received adequate and suitable training.

High Pressure Fluids

- a. Never allow any part of the body to come into contact with high pressure hydraulic oil, compressed air or fuel oil, for example when testing fuel injection equipment.
b. Both digested and ingested fluids can lead to serious injury, possibly with fatal results in a very short period of time.

Electrical System Considerations

- a. Ensure that the battery is of sufficient capacity to start the engine down to its minimum operating temperature taking into account any drag that may be imposed on the engine by the type of transmission that is attached to it.
b. Ensure the battery and all engine wiring cables are of sufficient size to carry the currents required.
c. Check that the engine mounted alternator is of sufficient output to cope with the total electrical load required by the machine to which it is fitted.
d. Ensure engine wiring cables are:
Bound together in a loom and adequately supported. Routed to avoid any hot surfaces, particularly the exhaust system. Not in contact with any rough surfaces or sharp corners so as to avoid any possibility of chaffing taking place.

Alternator/Charge Windings Precautions

- a. Never remove any electrical cable while the battery is connected in the circuit.

- b. Only disconnect the battery with the engine stopped and all switches in the OFF position.
c. Ensure cables are fitted to their correct terminals. A short circuit or reversal of polarity will ruin diodes and transistors. Never connect a battery into the system without checking that the voltage and polarity are correct.
d. Never flash any connection to check the current flow or experiment with any adjustments or repairs to the system.
e. The battery and alternator/charge windings must be disconnected before commencing any electric welding when a pole strap is directly or indirectly connected to the engine.
f. Starting engines that are fitted with charge windings which have been disconnected from the battery will cause irreparable damage unless the stator leads from the rectifier/regulator have been removed.

Starter Battery Precautions

WARNING

Sulphuric acid in battery electrolyte is poisonous, is strong enough to burn skin, eat holes in clothing and cause blindness if splashed into the eyes.

- a. Do not smoke near the batteries and keep sparks and flames away from them.
b. Batteries contain sulphuric acid - if the acid has been splashed on the skin, eyes or clothes flush it away with copious amounts of fresh water and seek immediate medical aid.
c. Keep the top of the battery well ventilated during charging. Switch off the battery charger before connecting or disconnecting the charger leads.
d. Disconnect the battery negative (earth) lead first and reconnect last.
e. Never 'flash' connections to check current flow.
f. A damaged or unserviceable battery must never be used.
g. Do not attempt to charge a frozen battery; it may explode; warm the battery to 16°C (60°F).

Asbestos Dust

- a. Avoid breathing dust that may be generated when handling components containing asbestos fibres. Inhaled asbestos fibres may cause lung cancer.
b. Components that may contain asbestos include brake pads, brake band and lining assemblies, clutch plates and some gaskets.
The asbestos in these products is usually found in a resin or it is sealed.
Normal handling is not hazardous as long as airborne dust containing asbestos is not generated.

Oil Seals Containing Viton

Some engines may be fitted with seals or 'O' rings manufactured from 'Viton' or a similar material.

When exposed to abnormally high temperatures, in excess of 400°C (752°F), an extremely corrosive acid is produced which cannot be removed from the skin. If signs of decomposition are evident, or if in doubt, always wear disposable heavy duty gloves.

Fuel System Precautions

- a. When priming or checking the fuel injection pump timing, care must be taken to wipe spilled fuel from the outside of the engine.
- b. Always fit a new joint when a union has been disturbed.
- c. Special care must be taken to see that there is no leakage from the joints of the fuel pipe connection to the pump.
- d. When tightening or loosening the fuel injection pump delivery connections, use two spanners to prevent the un-sealing of the fuel pump delivery valve holders.
- e. When refitting the fuel pipe from the pump to injector, the connection to the injector must be tightened before the connection to the fuel pump. This procedure will ensure that there is no leakage from these joints.
- f. It is most important that all fuel joints are tight and leak proof.
- g. Always fill the fuel tank through a fine strainer, preferably at the end of the engine work period. If any sediment is stirred up during the process this has time to settle before the engine is used again, this will minimise the risk of condensation

contaminating the fuel. If cans are used, avoid tipping out the last few drops.

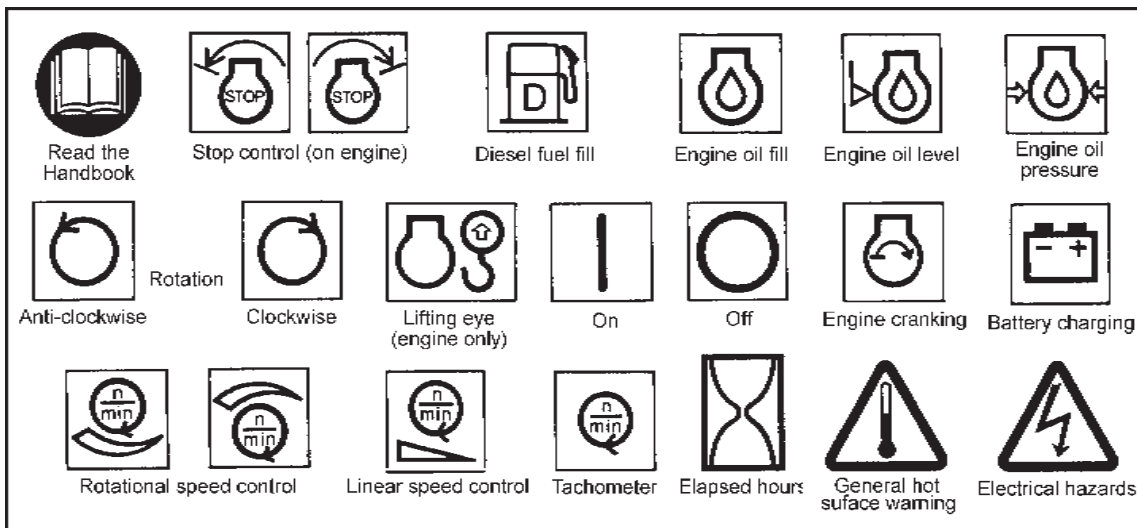
- h. Funnels are very difficult to keep clean in dusty conditions. Wash them before and after use and wrap them up when not required, or fill the tank direct from a small mouthed screw capped fuel can.
- i. The fuel injection equipment is manufactured to very accurate limits and the smallest particle of dirt will destroy its efficiency. Fuel free from water and contaminants is of the utmost importance.

Precautions for Oil, Filters and Elements

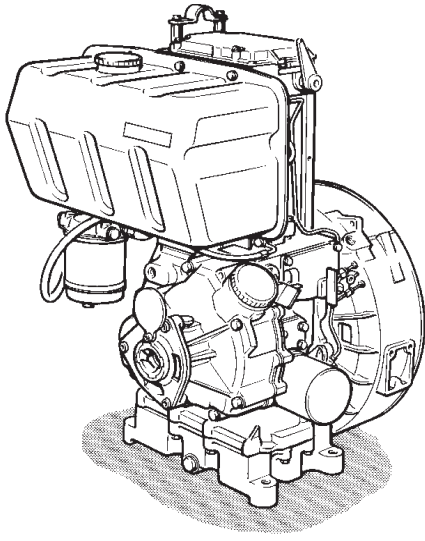
- a. Used liquid filters and elements contain some of the filtered liquid and should be handled and disposed of with care.
- b. After handling new or used elements the users hands should be thoroughly washed, particularly before eating.
- c. Fuel and new or used lubricating oil may cause skin irritation. Contact with used lubricating oil can cause cancer, birth defects or other reproductive harm.
- d. The materials used in the manufacture and treatment of some filters and elements may cause irritation or discomfort if they come into contact with the eyes or mouth and they may give off toxic gasses if they are burnt.
- e. Extreme care must be taken to ensure that waste oil, filter elements, solvents or other toxic wastes are disposed of in accordance with local regulations to prevent contamination.
- f. As a direct result of combustion the lubricating oil may contain harmful acids and therefore it should not be left in the sump if it is known that the engine will not be used for extended periods.

1.2 SAFETY SYMBOLS

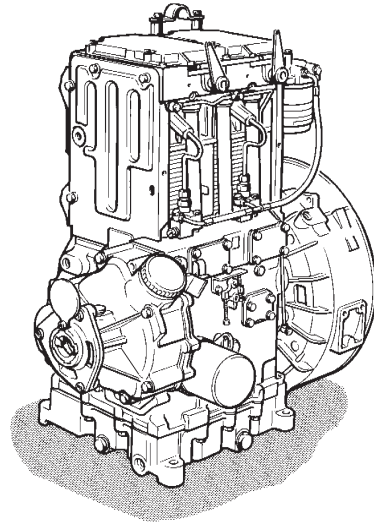
This section identifies the ISO 8999 symbols currently used by Lister Petter Power Systems.



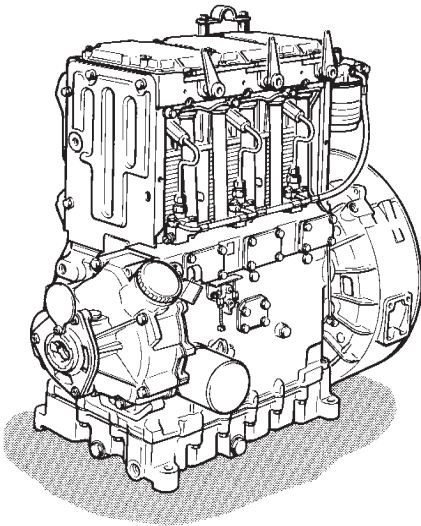
1.3 ENGINE FEATURES



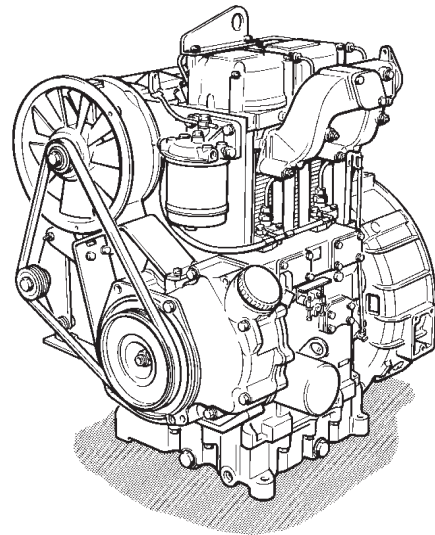
TS/TR1



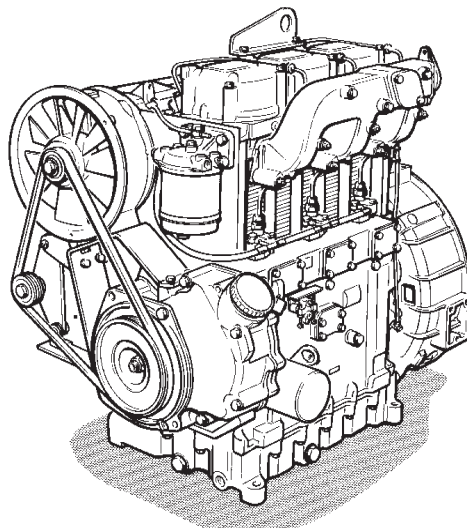
TS/TR2



TS/TR3



TX2



TX3

1.4 ENGINE IDENTIFICATION

Nomenclature

TS and TR - one, two and three cylinder, direct injection, naturally aspirated flywheel fan air cooled diesel engines.

TX - two and three cylinder, direct injection, naturally aspirated, axial fan air cooled diesel engines.

Engine Serial Number

The engine serial number is stamped on a plate attached to the engine.

It is necessary to identify the type and build of each engine to enable the correct maintenance procedures, as described later in this publication, to be carried out.

An example number is shown below.

03 001234 TS3 A 01

03..... Year code (03 = 2003)
001234..... Unique engine number
TS3..... Engine series
A..... Anti clockwise rotation
01..... Build number

1.5 BATTERY DETAILS

⚠ WARNING

Battery posts, terminals and related accessories contain lead and lead compounds, chemicals known to the State of California to cause cancer and reproductive harm. Wash hands after handling.

⚠ WARNING

Sulphuric acid in battery electrolyte is poisonous, is strong enough to burn skin, eat holes in clothing and cause blindness if splashed into the eyes.

Battery Polarity

All electric start engines have a 12 or 24 Volt negative earth system and a 12 Volt flywheel mounted charging system is available for some TS and TR engine builds.

Recommended Battery Type

Heavy Duty Batteries to BS3911:982 or IEC95-1 are recommended for all engine applications.

For temperatures below -18°C (0°F), high discharge, low resistance Arctic or Alkaline batteries must be used.

Lister Petter Power Systems recommend that a battery should provide a minimum cranking period

of 60 seconds from a 70% charged 12 volt battery, with a minimum voltage at the end of the cranking period of 8.4 volts (16.8 volts on a 24 volt system).

Preparing a Battery for Use

The following procedure should be used to prepare a battery with factory sealed charge.

1. Where necessary remove the flash seal in each vent plug hole.
2. Fill with battery grade sulphuric acid of specific gravity 1.260 (1.200 for tropical climates - see Note). The temperature of this acid should not be above 30°C (90°F) before filling. The correct level is 6mm (0.25in) above the separator guards.
3. Stand the filled battery for one hour and adjust the acid to the correct level by adding more acid where necessary.
4. Charge the battery at 6-12 amps for a minimum period of 4 hours.
5. At the end of this charge period the specific gravity of the acid in any cell should not be less than 1.260 (1.200 for tropical climates).

If the specific gravity readings are uneven or the specific gravity low, continue charging until two consecutive half hourly readings of specific gravity and charge voltage are approximately the same. Discontinue charging and allow the battery to cool if the temperature rises above 40°C (110°F).

Note:

Tropical climates apply to those countries or areas where the average temperature of any month of the year exceeds 27°C (80°F).

Connecting Batteries

It is most important to ensure that the starter battery, or batteries, are properly connected and all connections are tight.

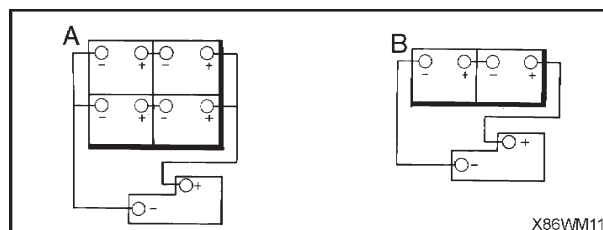


Figure 1.5.1 Battery Connections

A - 12 volt system using four 6 volt batteries connected in series-parallel; B - 12 volt system using two 6 volt batteries connected in series.

Connecting a Slave Battery

A slave, or booster battery can be connected in parallel with the existing battery to aid starting in cold weather conditions.

⚠ WARNING

Heavy duty jumper leads must always be used and no attempt must be made to use any others.

⚠ WARNING

Do not allow the jumper lead free ends to directly, or indirectly touch the engine at any time.

1. Connect one end of the jumper lead to the positive (+) post of the slave battery.
2. Connect the other end of the jumper lead to the positive (+) post of the battery connected to the starter motor.
3. Connect one end of the jumper lead to the negative (-) post of the slave battery.
4. Make the final connection of the negative (-) cable to a good earth on the engine frame and away from all the batteries.

Disconnecting a Slave Battery

1. Start the engine.
2. Disconnect the slave battery negative (-) jumper lead first.
3. Disconnect the remaining jumper leads.

Servicing a Battery

In freezing weather conditions, run the engine for at least 30 minutes to ensure thorough mixing after adding distilled water to the battery.

The battery electrolyte level should be checked every 500 hours and distilled water added, if necessary, to bring the level to the bottom of each filler neck.

Keep the battery clean by wiping it with a damp cloth. If the terminals or battery posts are corroded wash them with a solution of 1 part baking soda to 4 parts of water.

To help reduce corrosion coat the battery terminals or posts with petroleum jelly and baking soda.

Battery Cold Cranking Performance

The cold cranking battery performance rating figures given relate to the cranking current required from a starter battery when tested at -18°C (0°F) and not the current available from the battery at the engine operating ambient temperature stated. This is in accordance with BS3911 Part 2 and IEC95-1.

To use the table:

1. Select the system voltage and ambient temperature range.
2. Read off the value in Amps.
3. Refer to a battery catalogue for the battery required.

	Ambient Temperature Range				
	Volts	Above 27°C (80°F)	26° to 1°C (79°-34°F)	0° to -8°C (32°-18°F)	-9° to -18°C (16°-0°F)
TS1	12	120A	135A	180A	285A
	24	65A	75A	115A	185A
TS2	12	122A	157A	220A	365A
	24	122A	150A	205A	320A
TS3	12	142A	187A	265A	445A
	24	135A	165A	238A	385A
TR1	12	120A	135A	180A	300A
	24	68A	82A	120A	195A
TR2	12	135A	165A	238A	385A
	24	125A	155A	210A	335A
TR3	12	150A	187A	265A	485A
	24	140A	172A	238A	400A
TX2	12	102A	150A	228A	420A
TX3	12	142A	187A	295A	540A
	24	108A	127A	170A	315A

Notes:

The recommendations made assume that the engine is filled with the recommended type and grade of lubricating oil and is not required to start against high inertia loads such as concrete mixers, tar boilers, hydraulic pumps, screw pumps and similar. In these

applications, wherever possible, means should be provided to overcome such loads by the inclusion of clutches and unloading valves, etc. Heavy Duty Batteries are recommended for all applications and for temperatures below -18°C (0°F). high discharge, low resistance Arctic or Alkaline batteries must be used.

Battery Charging

Battery charging is by means of the alternator, flywheel mounted charge windings or a remote mounted charger.

Before attempting to charge the starter battery, on engines fitted with charge windings or an alternator, the regulator/rectifier, or alternator, must be disconnected from the starter battery.

Failure to do this will result in discharge of the

starter battery and/or damage to the regulator/rectifier.

Too little charging can be indicated by the specific gravity being frequently below 1230.

Too much charging is indicated by the specific gravity of the acid being generally at the fully charged value of 1270 to 1290 and by unusually frequent topping-up being necessary.

2. ENGINE SERVICING & ADJUSTMENTS

2.1 PRELIMINARY INSTRUCTIONS

⚠ WARNING

Maintenance must be performed by qualified persons who are conversant with the hazards of fuels, electricity and machinery.

⚠ WARNING

BEFORE COMMENCING ANY WORK ON THE ENGINE, PARTICULARLY WHEN WORKING WITH ENGINE FLUIDS, READ 1.1 SAFETY PRECAUTIONS AND SAFE WORKING PRACTICES.

Dismantling and Rebuilding

When the engine is being dismantled all items must be identified and retained in their respective cylinder orientation and all related components must be treated similarly.

The instructions given deal with individual components and it may be necessary to remove others before the relevant instructions can be carried out.

- a. Disconnect or isolate any non-electric starting systems.
- b. Disconnect and remove the battery.
- c. Drain the diesel fuel and lubricating oil.
- d. Disconnect all services.
- e. Remove any accessories or components that may be susceptible to damage when the engine is turned out of its normal plane.

Because of the various engine configurations, and installations in which the engine can be fitted, it is not possible to give detailed instruction for each one.

When assembling the engine, use the same type of lubricating oil as used in the engine to spray all moving parts during assembly. All bearings and bushes must be well lubricated during assembly. Renew all joints, gaskets, connecting rod nuts and bolts and the cylinder head bolts.

2.2 THE AIR CLEANER

Inlet Manifold Loading

A conventional air cleaner may be mounted direct on the manifold, or on a light extension which must be no more than 152mm (6ins) long.

Heavy air cleaners must be remotely mounted, or mounted on the engine using a special bracket, and connected by means of flexible pipe or hose, with no solid extensions between the manifold and

the flexible element.

Care must be taken to ensure all joints are kept air tight.

The standard air cleaner is fitted to the air manifold adaptor by a jubilee clip. Access to the paper element is gained by undoing the cruciform headed screw in the centre of the main body of the the filter casing. If the element is found to be dirty it must be replaced.

The Cyclonic Air Cleaner

The air cleaner can be engine or remote mounted. It should be cleaned daily under very dusty operating conditions and as specified in "5.4 Routine Maintenance - schedule hours".

The air cleaner mounting bracket bolts are torqued to 21.0Nm (15.5lbf ft).

1. Release the cover clips and remove the end cap.

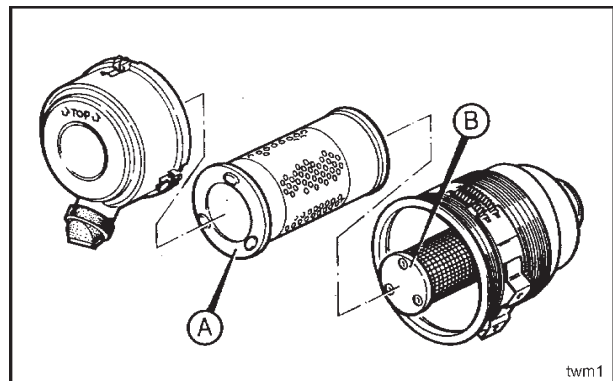


Figure 2.2.1 Cyclonic Type Air Cleaner

2. Remove the outer element (A) and clean or replace it as necessary.
3. Replace the element.
4. Replace the cover with the inlet facing downwards.

Note:

After the outer element (A) has been cleaned three times the inner element (B) must be replaced. No attempt must be made to clean the inner element.

2.3 THE COLD START AID

TS and TR Engines

The cold starting aid may be fitted to the combustion air intake ports and is used when the ambient temperature is below -10°C (14°F).

1. With the fuel turned on, turn the engine for up to

20 revolutions to prime the fuel and lubrication systems.

2. Withdraw the plunger (A) and fill one third of the cup (B) with the same type of lubricating oil as used in the engine.

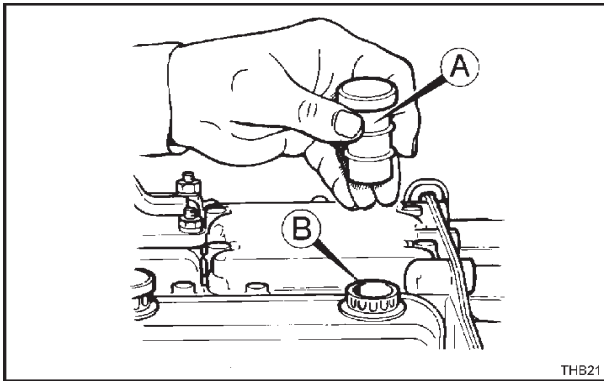


Figure 2.3.1 Cold Start

3. Replace the plunger and inject the oil just before starting the engine.

CAUTION

The device must not be used more than three times in succession during the same attempt to start the engine.

TX Engines

The TX inlet manifold may have a cold weather glowplug fitted and care must be taken to ensure the battery is isolated and the cable removed before attempting to remove the manifold from the engine.

The glowplug is energised during the starting sequence by the start key.

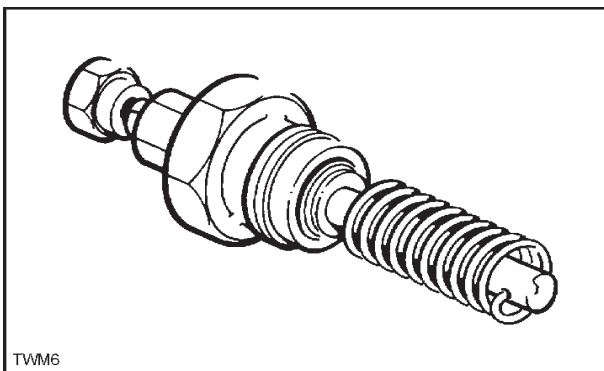


Figure 2.3.2 TX Glowplug

2.4 THE MANIFOLDS

Manifold Loading

A small, light exhaust silencer may be mounted direct on the manifold, or on a light extension which must be no more than 152mm (6ins) long.

Heavy exhaust silencers and air cleaners must be remotely mounted, or mounted on the engine using a special bracket, and connected by means of flexible pipe or hose, with no solid extensions between the manifold and the flexible element. All joints must be gas tight.

WARNING

EXHAUST GASSES CONTAIN CARBON MONOXIDE WHICH IS A COLOURLESS, ODOURLESS AND POISONOUS GAS THAT CAN CAUSE UNCONSCIOUSNESS AND DEATH.

CAUTION

Detrimental damage to the engine, or loss of performance, may be caused if exhaust gasses are sucked in by the air cleaner or the fan.

The exhaust manifold is made of cast iron and the inlet manifold of light alloy, both are secured to the cylinder head on studs and nuts which are torque loaded.

Bolted to the side of the exhaust manifold is the standard exhaust silencer which has provision for fitting a tail pipe or a lightweight extension; the outlet of the silencer tail pipe must face away from the engine.

Removing the Manifolds - TS/TR

1. Remove the air cleaner and exhaust silencer.
2. Remove the nuts, spring washers and distance pieces.
3. Unscrew and remove the cold start pots, if fitted.
4. Remove the manifolds.

Refitting the Manifolds - TS/TR

1. Fit new gaskets if necessary.
2. Refit the manifolds and torque the nuts to:
 - Top nuts - 21.0Nm (15.5lbf ft).
 - Bottom nuts - 9.0Nm (6.5lbf ft).

Removing the Manifolds - TX

1. Remove the air cleaner and silencer
2. Remove the nuts and spring washers retaining the exhaust manifold and lift it off.
3. Remove the axial fan air cowling.
4. If a glowplug is fitted remove the cable.
5. Remove the nuts and spring washers retaining the inlet manifold and lift it off.

Refitting the Manifolds - TX

1. Fit new inlet and exhaust manifold gaskets.
2. Refit the inlet and exhaust manifolds and torque the nuts to:
 - Inlet - 13.5Nm (10.0lbf ft).
 - Exhaust - 21.0Nm (15.5lbf ft).

3. Replace the glowplug cable.
4. Replace the axial fan air cowling.

2.5 THE AIR COWLING

Three sides of the engine are encased in an air cowl and two sides shields, which together with the air baffle(s) direct cooling air from the flywheel fan around the cylinders.

Removing the Air Cowling - TS/TR

1. Remove the cold start pots if fitted.
2. Drain the fuel and remove the engine mounted fuel tank, if fitted.
3. Remove the gear end air shield by removing the setscrews, spring washers and plain washers in the top plate and air cowling.

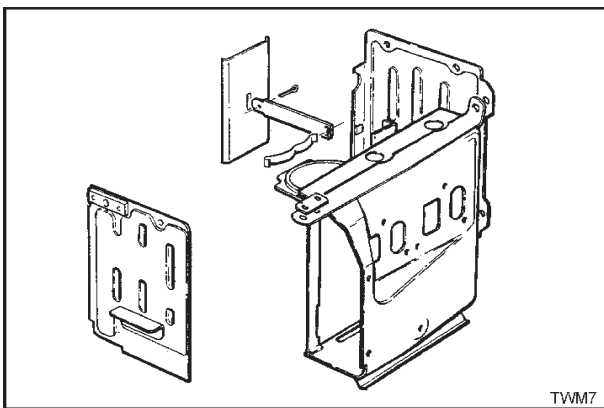
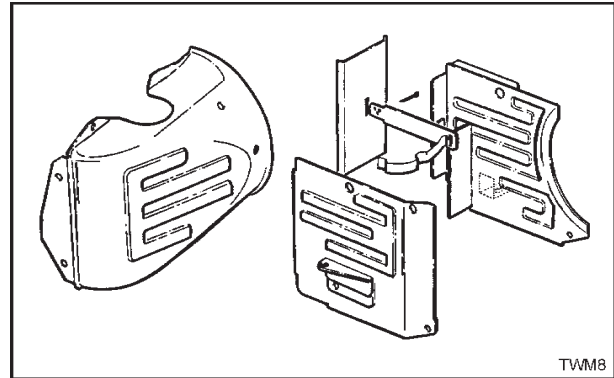


Figure 2.5.1 Air Cowling - TS/TR

4. Remove the manifolds.
 5. Remove the air cowl by removing the setscrew in the fanshroud and setscrews, spring and plain washers in the cowl.
 6. If a fuel filter is fitted to the flywheel end shield, isolate or drain the fuel before disconnecting the fuel feed to the fuel pumps and remove the nuts and spring washers securing the fuel filter.
 7. Remove the setscrews, spring washers and plain washers securing the flywheel end shield to the cylinder head top plate.
- A setscrew is fitted in the middle of the filter mounting block.
8. Remove the shield.

Removing the Air Cowling - TX

1. Remove the air cleaner if necessary.
2. Remove the flywheel end air shield.
3. Remove the axial fan cowling.
4. Isolate or drain the fuel before disconnecting the fuel pipes to and from the fuel filter.
5. Remove the fuel filter.



6. Remove the gear end air shield; it may be necessary to slacken the axial fan before the shield can be removed.

The Air Baffles

The air baffles are fitted between the cylinder barrels and extreme care must be taken to ensure they do not totally block the air flow when they are refitted.

The baffles can be removed for cylinder fin cleaning by removing the split pin; it is not necessary to remove the cylinder heads.

2.06 THE CYLINDER COOLING FIN

The cylinder barrel, head, crankcase and cooling fan fins must be kept reasonably clean otherwise seizure of various components can occur because of overheating.

Cleaning frequency will depend on the nature and concentration of the substances contained in the cooling air; fluff hair, vegetable fibre and other such items have a greater clogging effect than dry dust. The cooling fins should always be cleaned when the engine is decarbonised and as necessary. With the engine stopped, and immobilised, the contaminants can be raked off the fins by using a suitable hooked piece of wire or low pressure compressed air.

⚠ WARNING

If compressed air is used extreme care must be taken to prevent personal injury by the jet or debris.

2.07 THE AXIAL FAN - TX

A single stage axial flow fan, belt driven from the gear end forces cooling air to the cylinder heads, barrel and crankcase external cooling fins.

⚠ WARNING

The axial fan belt must be changed every 2000 hours, irrespective of its condition.

Removing the Fan

- 1.Remove the drive guards.
- 2.Slacken the alternator mounting bolts and move the alternator as far as it will go towards the crankcase.
- 3.Remove the drive belt.
- 4.Remove the fan from the mounting bracket; it will be necessary to slacken the fan cowling.

Refitting the Fan

⚠ CAUTION

The drive belt must not be levered or wound on and care must be taken to ensure it is correctly fitted onto the pulley grooves.

The above removal procedure is reversed when the fan is replaced and after the drive belt has been fitted it must be correctly tensioned.

2.08 DRIVE BELT TENSION

It is important that the tension of the drive belt is checked after the first 50 hours, after an overhaul, after a new belt has been fitted and as specified in "Maintenance Schedule".

The measurements shown in the table are taken in the centre of the longest span after the belt has been turned through 360° to equalise the tension. After adjustment turn the belt through 360° and re-check the deflection.

	Belt Tension Force		Deflection	
	N	lbf	mm	in
New Belt	31.0 - 33.0	7.0 - 7.5	3.5	0.14
Used Belt	22.0 - 24.0	5.0 - 5.4		

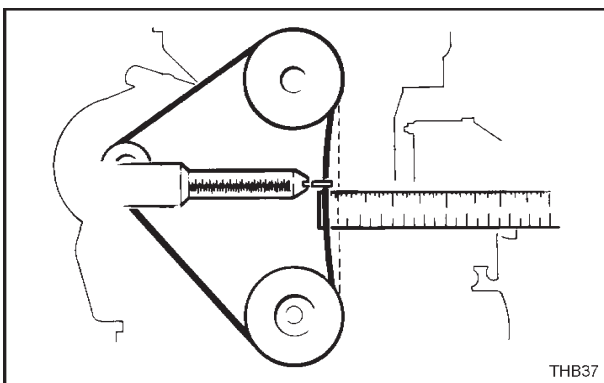


Figure 2.8.1 Belt Tension

2.09 AXIAL FAN DRIVE GUARD - TX

A polypropylene replaces the earlier, welded steel guards. If a later guard is being fitted in place of a metal type the end cover must be modified. Drawing SK2204/91 is available from Lister Petter Power Systems for this purpose.

2.10 THE CYLINDER HEAD COVER

The light alloy cylinder head cover, which is bolted to the top of the cylinder head, gives access to the breather box, decompressors, injector and valve gear.

The TS/TR engine mounted fuel tank is secured to the side of the cylinder head cover at the gear end by three setscrews (two on early engines) and by two setscrews in the side shield.

The Crankcase Breather

On the majority of TS and TR engines a plate locates over the breather tube and forms an oil separator box in the cylinder head cover which connects with the inlet manifold port via a copper pipe brazed to the plate. The breather plate has a metal contact with the cylinder head cover and is secured with three self tapping screws. A felt washer is fitted around the top of the tube between the cylinder head and breather plate and care must be taken to ensure the washer is refitted on re-assembly. The breather tube forms an interference fit in the cylinder head.

Removing the Cylinder Head Cover

- 1.Remove the lifting eye and fuel tank securing bolts if necessary.
- 2.Remove the four bolts securing the cover.
- 3.Lift off the cover being careful not to damage the joint or leak-off pipe.

Refitting the Cylinder Head Cover

- 1.On TS/TR engines ensure the breather plate is securely retained in position and that the felt washer is fitted round the breather tube.
- 2.Clean the cover and cylinder head joint area.
- 3.Place the joint on the cylinder head.
- 4.Move the decompressor lever, if fitted, into the vertical position.
- 5.Replace the cylinder head cover ensuring the decompressor lever, if fitted, is located between the two stops and the fuel injector leak-off pipe is located snugly in the recess provided.
- 6.Fit the four bolts with new washers.

2.11 THE CYLINDER HEAD

On and after the TX engine serial numbers shown, two spring disc washers were fitted under each cylinder bolt head instead of one plain washer.

- 38 00138 TX2
- 38 00206 TX3

Removal of a Cylinder Head

1. Remove the cylinder head cover.
2. Remove the valve rocker lubricating oil feed pipe by removing the oil swivel plugs from the cylinder head and crankcase.
3. Remove the fuel pump to injector pipe.
4. Slacken the injector clamp.
5. If more than one head is being removed mark each one with chalk to identify their respective cylinders.
6. Remove the cylinder head securing nuts diagonally and lift off the head.
7. Ensure the TS/TR cylinder head clearance shims and gaskets from each cylinder are placed with their respective cylinder heads for correct re-assembly.
8. Remove the air baffle/s taking careful note of their position for re-assembly.
With the cylinder head in position the air baffle/s may be removed by removing the split pin.
9. Remove the push rods and tubes and place them with their respective cylinder head if further dismantling is anticipated.
10. To prevent movement of the barrel if the crankshaft is turned place a suitable length of tube over one holding down stud of the cylinder secured by fitting a cylinder head nut finger tight.

Refitting a Cylinder Head

The TS and TR cylinder head nuts, top threads of the studs and the area of the top plate in contact with the nuts should be lightly coated with Wellseal. All cylinder head nuts should be fitted with the machined grade symbol facing upwards to ensure a good seal between the nut and the head. It is strongly recommended that cylinder head nuts and push rod seals are replaced at every major overhaul.

1. Renew or replace the push rod seals in the cylinder head and crankcase.
2. Lightly coat both ends of the push rod tubes with Hellerine rubber lubricant and replace them taking care to ensure they are centralised in their rubber seals.
3. Replace the push rods in their original positions.
4. Replace the cylinder head.

Great care must be taken not to trap the TS or TR shims on the cylinder barrel spigot.

5. Replace the head nuts finger tight only.

The inlet and exhaust flanges of all cylinder heads must be lined up with a straight edge and any gap along the straight edge must not exceed 0.2mm (0.008in).

Alternatively fit a manifold before tightening down the cylinder heads.

6. Tighten down the cylinder head nuts diagonally and evenly to a final torque of:
TS/TR - 68.ONm (50.0lbf ft).
TX - 61.ONm (45.0lbf ft).
7. On TX engines ensure the valve stem caps are in position.
8. Replace the injector and the injector clamp.
9. Check and adjust the valve rocker clearances.
10. Check and adjust the decompressor, if fitted.
11. Replace the cylinder head cover and lifting eye.
12. Replace the baffle between the cylinder barrels with the spring clip on the manifold side.
13. Replace the air cowling and manifolds.
14. Replace the valve rocker lubricating oil feed pipe, fitting a new union and two washers to the cylinder head.

2.12 CYLINDER HEAD CLEARANCE

TS and TR Engines

1. With the head removed smear a very small amount of high melting point grease in the recess on the head where the shims seat and also the side of the recess.
2. Lightly grease both sides of each shim in turn and place them in the recess.
3. Place the gasket in the recess on top of the shims.
4. From two 50mm x 1.6mm (2.00 x 0.063in) diameter pieces of lead wire or soft, but not multicore, solder form two 'U' shaped symmetrical loops.
5. Twist the open tails of each loop to form four or five coils.
6. Refer to 'Figure 2.12.1' and using a very small amount of grease place the two pieces of wire on the piston crown.
The wires must be at each side of the gudgeon pin axis and 90° to the centre line and just touching the cylinder bore.
Care must be taken to ensure the wires are not placed over any markings on the piston crown.

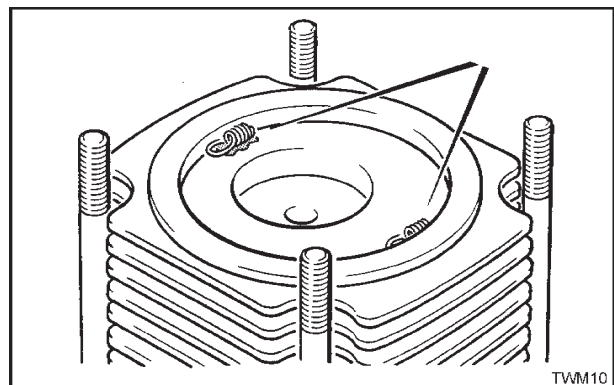


Figure 2.12.1 Cylinder Head Clearance

7. Replace the cylinder head.
8. Replace and torque the cylinder head nuts to 68.0Nm (50.0lbf ft).
9. Turn the piston twice past TDC.
10. Remove the cylinder head and measure the thickness of the lead, this should be:
 - TS - 0.813-0.889mm (0.032-0.035in).
 - TR - 0.889-0.965mm (0.035-0.038in).
 If this measurement is not correct it can be adjusted by adding or removing 0.07mm or 0.25mm (0.003 or 0.010in) thick shims placed between the cylinder head and the gasket.
11. Replace the cylinder head.
12. Re-check the head clearance.

TX Engines

The cylinder head clearance is maintained by 0.07mm, 0.13mm or 0.38mm (0.003in, 0.005in, 0.015in) metal shims placed between the cylinder barrel and crankcase.

1. From two 50mm x 1.6mm (2.00 x 0.063in) diameter pieces of lead wire or soft, but not multicore, solder form two 'U' shaped symmetrical loops.
2. Twist the open tails of each loop to form four or five coils.
3. Refer to 'Figure 2.12.1' and using a very small amount of grease place the two pieces of wire on the piston crown.

The wires must be at each side of the gudgeon pin axis and 90° to the centre line and just touching the cylinder bore.

Care must be taken to ensure the wires are not placed over any markings on the piston crown.
4. Replace the cylinder head.
5. Replace and torque the cylinder head bolts to 61.0Nm (45.0lbf ft).
6. Turn the piston twice past T.D.C.
7. Remove the cylinder head and measure the thickness of the lead, this should be:
 - 0.81-0.95mm (0.032-0.037in).
8. If it is necessary to change the shims:
 - a. Remove the cylinder barrel.
 - b. Place the necessary shims, dry, onto the crankcase end of the cylinder barrel.
9. Replace the cylinder barrel and head.

2.13 THE VALVE ROCKER STUB SHAFTS - TS/TR

The removal of the stub shafts is necessary when it is required to examine or change the valves, valve seats, rocker arms or rocker arm bushes.

Removing Stub Shafts

⚠ WARNING

Care must be taken to ensure that any part of the hand is not likely to become trapped between the two parts of the tool while it is being used.

1. Screw the small end of the adapter (A) into the screw thread of the stub shaft and tighten.

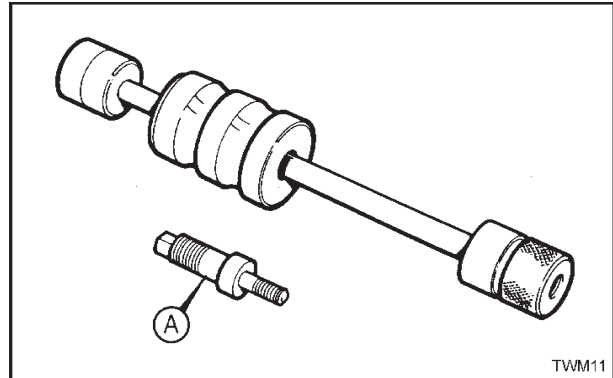


Figure 2.13.1 Stub Shaft Tool

2. Preferably place the cylinder head into a vice, and screw the slide hammer tool onto the adapter.
3. Grip the slide hammer in one hand and strike the sleeve in the required direction until the stub shaft has been removed.
4. Lift out the rocker arm.

Refitting the Stub Shaft

Before fitting check the oil holes are clear, fit a new 'O' ring to the recess on the inside face of the stub shaft and coat the sealing groove nearest to the bolt hole with Wellseal or Hylomar PL32/M.

When refitting, the mark 'TOP' on the outside face of the stub shaft must be positioned towards the top of the cylinder head.

⚠ WARNING

Care must be taken to ensure that any part of the hand is not likely to become trapped between the two parts of the tool while it is being used.

⚠ CAUTION

When refitting the stub shafts using the slide hammer, great care must be taken not to dislodge the 'O' ring on the inside face recess of the shaft.

1. Fit the small end of the adapter (A) into the screw thread of the stub shaft and tighten.

Ensure 'TOP' is correctly positioned.
2. Place the cylinder on its side on a bench and place the rocker arm into position for refitting the stub shaft.

3. Fit the slide hammer tool on to adaptor.
4. Align the stub shaft with the stub shaft hole.
5. Grasp the slide hammer with one hand while positioning the rocker arm with the other and refit the stub shaft by striking the end of the tool nearest the cylinder head with the slide hammer. If the rocker lever bush is not correctly lined up and is preventing the stub shaft being refitted gently strike either end of the tool with the slide hammer while repositioning the rocker arm.

Note:

Ideally, after fitting, the stub shaft hole and internal hole of the rocker arm bush will be perfectly aligned. Small 'G' clamps or a second pair of hands may be required.

2.14 THE VALVE ROCKERS - TX

The removal of the valve rocker assembly is necessary when it is required to examine or change the valves, valve seats, rocker arms or rocker arm bushes.

Removing an Individual Rocker Arm

Individual rocker arms can be removed without removing the rocker assembly.

1. Remove the rocker cover.
2. With the piston at TDC on the firing stroke screw the rocker adjusting screw (A) anti-clockwise until the valve spring is not tensioned.

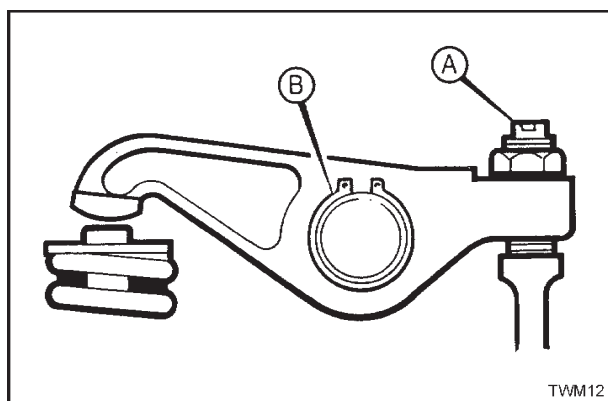


Figure 2.14.1 Valve Rocker

3. Using suitable circlip pliers remove the circlip (B) and slide the rocker lever off the stub shaft.
4. With the piston at TDC on the firing stroke and the adjusting screw turned fully anti-clockwise slide the rocker lever onto the stub shaft.
5. Using suitable circlip pliers replace the circlip and check that it is fully seated in the groove.
6. Check and reset the valve clearance.
7. Replace the valve rocker cover.

2.15 THE VALVES

Removing the Valves

1. Remove the cylinder head.
2. Remove the TS/TR valve rockers.
3. Remove the TX valve rocker assembly and oil restrictor plate.
4. Lay the cylinder head upright on a bench and place a circular block of wood under the head of the valve.
5. Place the adapter (A) onto the valve spring carrier with the two indentations facing outwards.

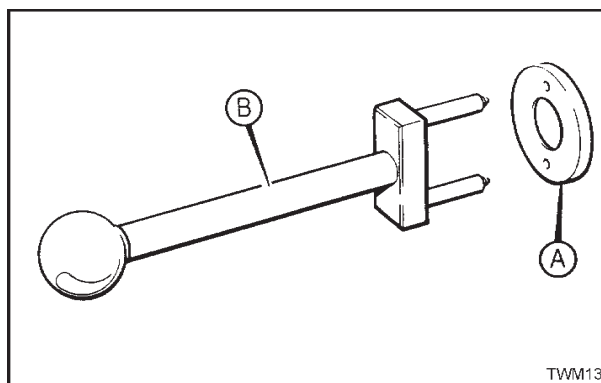


Figure 2.15.1 Valve Spring Compressor

6. Fit the tool (B) into the two plate indentations.
7. Push down on the tool until the collets can be removed.
8. Gently release the tool and remove the carrier, valve cap, valve spring and the valve stem shields. TS/TR1 engines are not fitted with an exhaust valve stem shield.
9. Turn the cylinder head over and remove the valve.

Refitting the Valves

1. Assemble the valves in the reverse order ensuring the collets are securely in position with their tops slightly sunk in the valve spring carrier.
2. Fit the valve stem caps
3. Replace the TS/TR valve rocker and stub shaft.
4. Replace the TX oil restrictor plate and the valve rocker assembly.
5. Replace the cylinder head and set the valve clearance.
6. Replace the valve rocker cover.

2.16 THE VALVE GUIDES

It is recommended that valve guides are removed and refitted with the aid of the Service Tool to ensure the correct protrusion is obtained.

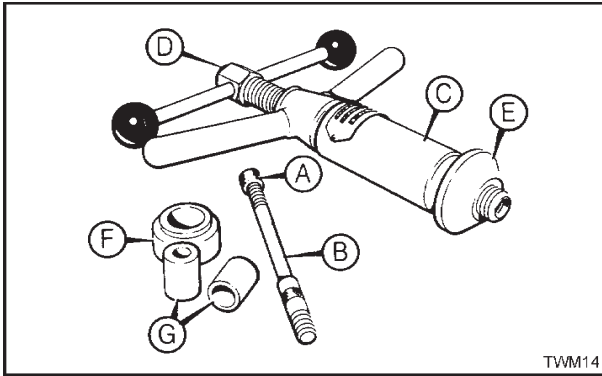


Figure 2.16.1 Valve Guide Tool

Valve Guides - TS/TR

The guides are marked 'IN TOP' and 'EX TOP' (inlet or exhaust valve guide, top position) and are a press fit into the two halves of the cylinder head assembly. A rubber ring and a retaining plate are located around the top of the inlet guide on early engines; later engines have sealing caps on both valves.

The rubber sealing ring must be inserted in the top plate recess before pressing in the inlet valve guide to prevent damage to the ring as there is no lead-chamfer to the recess.

After coating the outside of the valve guides with Wellseal they should be pressed into their correct positions with the markings uppermost and pointing towards the opposite guide. The projections of the valve guides above the top plate surface are:

Exhaust: 17.40-17.90mm (0.685-0.704in).

Inlet: 12.40-12.90mm (0.488-0.507in).

These projections will be correct if the Service Tool is used.

After assembly a gauge 8.707mm (0.343in) diameter must pass through the exhaust valve guide. If the gauge does not pass through, the guide must be reamed square to 8.707-8.727mm (0.343-0.3436in) diameter.

These measurements also apply to cylinder heads fitted with pre-finished valve guides that have been obtained from Lister Petter Power Systems.

Valve Guides - TX

After the outside of the valve guides have been coated with Wellseal they are pressed into the cylinder head.

The projection of the valve guide above the top plate surface must be 12.45-12.95mm (0.489-0.509in).

After fitting the internal measurement should be 7.910-7.965mm (0.311-0.313in).

Removing Valve Guides

1. Remove the cylinder head.
2. Remove the valves.
3. Remove the valve guide oil seal.
4. Preferably place the cylinder head on its side in a soft jawed vice.
5. Screw the correct mandrel (B) into the tool (D).
6. Place the sleeve (C) onto the tool.
7. Fit the bevelled adapter (E) into the sleeve (C) and locate the bevel into the valve seat; it may be necessary to fit the spacer (F) into the sleeve.
8. Locate the mandrel through the guide.
9. Screw the small threaded sleeve (A) onto the mandrel.
10. Holding the sliding handle firmly to prevent rotation, turn the double handled lever clockwise until the guide is withdrawn through the head. If it is found difficult to start moving the guides a sharp tap with a copper hammer should break the seal.

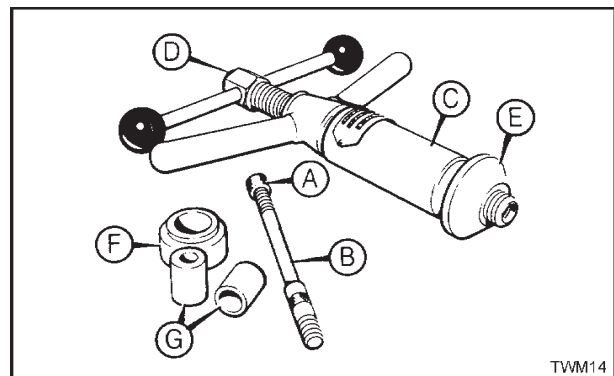


Figure 2.16.2 Valve Guide Tool

Refitting Valve Guides

1. Fit the correct mandrel into the valve guide hole from the valve rocker end.
2. Place the valve guide over the mandrel in the top plate.
3. Place the correct depth stop (G) over the mandrel and screw on the threaded sleeve (A).
4. Fit the tool complete with the bevelled adapter (E) onto the mandrel.
5. Hold the sliding handle firmly, to prevent it rotating, and turn the double handled lever clockwise until the depth stop prevents any further movement. At this point the guide will protrude the correct distance above the cylinder head.
6. Fit a new valve guide oil seal.

2.17 THE VALVE SEATS

The valve seats are cast iron inserts which are pressed into position to ensure they bed on the bottom of the recess in the cylinder head. Before

pressing in the inserts, at ambient temperature the head should be heated to 100°-150°C (212°-302°F) for a minimum of 45 minutes and the insert chilled to -65° to -75°C (-85° to -103°F) for a minimum of 30 minutes.

The width of the TS/TR seatings must be:

Inlet: 1.65-2.29mm (0.065-0.090in).

Exhaust: 1.35-1.78mm (0.053-0.070in).

If necessary metal must be ground or cut from the top of the insert or recess. The valves are pre-finished and no lapping or further processing is required.

All seats are precision ground to allow the valves to lay below the combustion surface of the head.

Up to the TS/TR serial numbers shown the measurements were:

Inlet valves: 1.02-1.27mm (0.040-0.050in).

Exhaust valves: 0.89-1.14mm (0.035-0.045in).

36 00199 TS1 36 00025 TR1

36 00480 TS2 36 00020 TR2

36 00307 TS3 36 00043 TR3

On later TS/TR engines the measurements are:

Inlet valves: 0.63-0.94mm (0.025-0.037in).

Exhaust valves: 0.51-0.82mm (0.020-0.032in).

On TX engines the measurement for both valves is 1.020-1.550mm (0.040-0.061in).

Valve Recess and Seat Cutting

1. Fit the correct adjustable mandrel (A) into the valve guide and turn the adjuster until the flutes just bind onto the guide.
2. Select the necessary cutting tool (B) and assemble it to the handle (C).

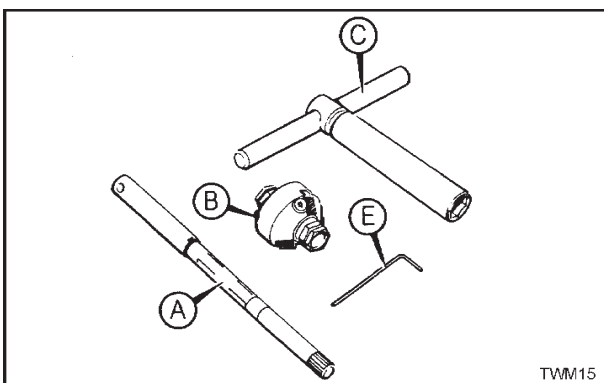


Figure 2.17.1 Recess and Seat Cutting Tool

3. Place the cutter over the mandrel and adjust the three individual blades by using the Allen Key (E).
4. Rotate the tool in a clockwise direction until the valve seat or recess finish is satisfactory.

⚠ WARNING

The valve guide will be damaged if the mandrel is adjusted too much when it is located in the guide and care must be taken to ensure an even, gentle downward pressure is applied when using the cutter to prevent the removal of too much metal.

2.18 VALVE CLEARANCE

The valve clearance must be measured and adjusted when the engine is cold. It is important that the clearances are maintained correct to prevent serious damage to the valve gear. With new engines, or engines which have just been overhauled, the valve gear beds down rapidly during the first 500 hours running and it is essential that the clearance is checked every 25 hours until it is found that the clearances remain constant. The periods between adjustments may then be increased to 1000 hours.

Adjusting the Valve Clearance

		GO	NOT GO
TS/TR	mm	0.15	0.20
	in	0.006	0.008
TX	mm	0.10	0.15
	in	0.004	0.006

1. Ensure the decompressor is clear of the exhaust valve rocker.
2. With the cylinder head cover removed, turn the engine until the relevant piston is at the TDC position on the firing stroke - both valves will be closed.
3. Hold the adjusting screw (A) with a screwdriver and slacken the locknut (B).
Turn the screw until the correct clearance has been obtained.

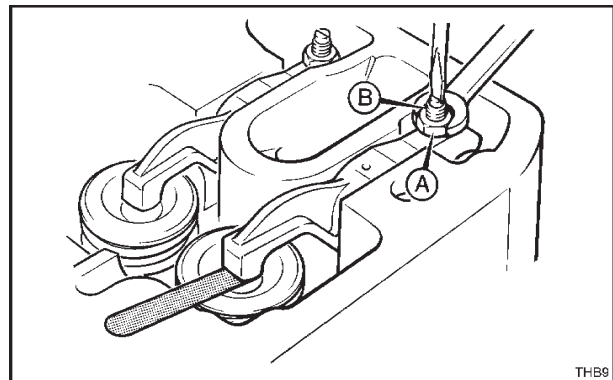


Figure 2.18.1 Valve Clearance

4. Torque the locknut, while continuing to hold the adjusting screw, to 21.0Nm (15.5lbf ft).
5. Re-check to ensure the clearance is correct.
6. Repeat the procedure for both valves in all cylinders.

2.19 THE DECOMPRESSOR

The decompressor is fitted to the exhaust valve on some engines. When the cylinder head cover is being replaced care must be taken to ensure the lever is vertical between the two stops.

The decompressor lever is spring loaded towards the cylinder head and is located by a plain washer and a split pin or circlip fitted through the decompressor shaft. A seal, fitted on the outside of the cylinder head, prevents oil seepage along the spindle. On engine builds not fitted with a decompressor the drilling in the cylinder head is plugged with a dowel.

Removing the Decompressor

Remove the cylinder head cover.

Remove the split pin or circlip, washer, spring and adjusting screw.

Withdraw the decompressor lever from the cylinder head.

Decompressor Adjustment

This adjustment should only be made when the valve clearance is correctly adjusted.

After the decompressor has been set on TX engines the maximum valve lift must not exceed 0.76mm (0.030in).

1. Remove the cylinder head cover.
2. Turn the engine until the piston is at TDC. firing stroke, for the cylinder being worked on.

TS and TR Engines

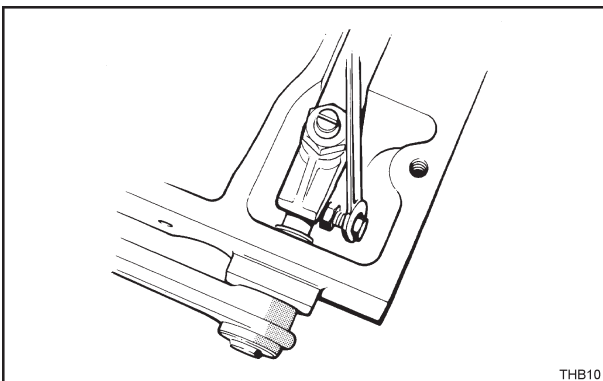


Figure 2.19.1 Decompressor Lever

3. Slacken the locknut (A) and adjust the screw (B) until it just touches the exhaust valve rocker

when the lever is vertical.

4. Turn the screw half a turn clockwise so that it travels towards the rocker.
5. Tighten the locknut whilst restraining the adjusting screw.

TX Engines

6. Place the decompressor lever in the vertical position.
7. Slacken the decompressor pin locknut and adjust the pin to take up the valve clearance.
8. Turn the pin a further half a turn and tighten the locknut.

All Engines

9. Replace the rocker cover taking care to ensure the decompressor lever is vertical.

2.20 THE CRANKSHAFT PULLEY - TX

The pulley is secured by a torque loaded left hand thread nut.

Removing the Pulley

1. Slacken the alternator mounting bolts and move the alternator as far as it will go towards the crankcase.
2. Remove the drive belt.
3. Fit the flywheel locking tool into the tapped hole in the flywheel housing - check that the flywheel will not turn.

If the flywheel locking tool is not available wedge the crankshaft with a suitable piece of wood to prevent it turning.

The pulley is secured by a torque loaded left hand thread nut.

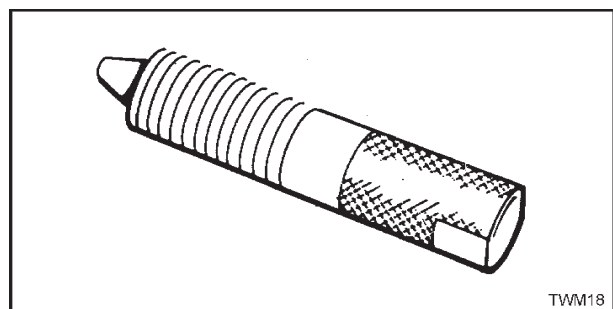


Figure 2.20.1 Flywheel Locking Tool

4. Remove the pulley retaining nut by turning it clockwise.
5. Pull off the crankshaft pulley.
6. Remove the locking tool.

Refitting the Pulley

1. Fit the flywheel locking tool into the tapped hole in the flywheel housing - check that the flywheel

will not turn.

2. Replace the crankshaft pulley.
3. Replace the pulley retaining nut and torque it anti-clockwise to 197.0Nm (145.0lbf ft).
4. Remove the flywheel locking tool.
5. Replace the drive belt and tension it following the instructions given in "02.20 Drive Belt Tension".

2.21 THE GEAR END COVER

The light alloy end cover is located on two dowels and is secured to the crankcase by seven setscrews and washers. The end cover contains an oil filler neck and filler cap, and a bucket plug is secured in position with Hylomar PL32M over the crankshaft pinion. A joint is fitted between the end cover and the crankcase face.

The Service Tool 317-50063 (TS/TR) or 317-50065 (TX), is used to protect the oil seal when the end cover is either removed or replaced and it can also be used to remove and replace the seal in the end cover.

On TX engines a bracket supporting the axial fan and alternator is fitted to the cover.

Removing the End Cover - TS/TR

1. Remove the plastic dustcap in the end cover boss.

On early engines:

- a. Turn the crankshaft until the spring pin (A) of the starting handle catch pin (B), in the camshaft is visible through the hole in the cover boss.
- b. Tap out the pin (A) with a suitable punch.
- c. Turn the engine through 90° and drift out the starting handle catch pin (B).

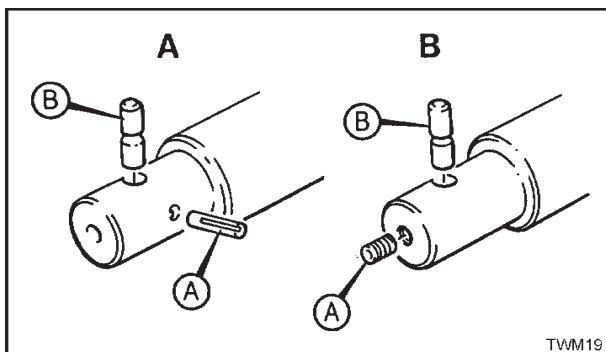


Figure 2.21.1 Starting Handle Pin
A - Early Engines
B - Later Engines

On later engines:

- d. Remove the grub screw (A) from the end of the camshaft.
- e. Drift out the pin (B).

2. Insert the oil seal tool into the end cover to protect the seal.
3. Remove the retaining bolts.
On hydraulic pump build engines a retaining bolt is fitted behind the pump mounting flange and it must be removed before attempting to remove the end cover.
4. Remove the end cover.
5. Clean all traces of the old joint from the crankcase and cover.
6. If necessary push out the oil seal by using the oil seal tool, or a suitable plug press.

Removing the End Cover - TX

1. Remove the drive belt and crankshaft pulley.
2. If necessary remove the alternator and axial fan.
3. Insert the oil seal tool into the end cover to protect the seal.
4. Remove the seven end cover bolts.
5. Remove the end cover.
6. Clean all traces of the joint from the crankcase and cover.
7. If necessary push out the oil seal by using the oil seal tool or a suitable plug press.

Refitting the End Cover

1. With the crankcase and end cover joint faces clean and dry fit a new joint.
2. Fit the oil seal tool into the outside face of the oil seal.
3. Replace the end cover, taking care to ensure the new joint is not damaged and the cover is correctly fitted over the dowels.

TS/TR Engines

4. Replace the catch pin and spring pin or grub screw.

TX Engines

5. Replace the crankshaft pulley and drive belt.
6. Replace the alternator and axial fan.

All Engines

7. Check the camshaft end float.

The End Cover Oil Seal

The camshaft oil seal is of the lip variety and a plain bush fitted to the outside of the end cover sleeve is to support the starting handle when in use.

The Service Tool, 317-50063 (TS/TR) or 317-50065 (TX), is used to protect the oil seal when the end cover is either removed or replaced and it can also be used to remove and replace the seal in the end cover.

1. Place a new seal into the outside neck of the end cover, lip side first, and position it squarely on the

shoulder of the seal boss.

- Using the oil seal tool press the seal into position within the oil seal housing' boss until it is flush with the inside face of the boss.

In an emergency, if the tool is not available a suitable plug, preferably hard wood, can be used.

2.22 THE FUEL TANK

Various sizes of engine mounted fuel tanks are available as shown in the table below.

TS/TR tanks are fitted to the gear end of the engine and TX are fitted at the flywheel end.

	litres	pints	US qts
TS/TR1	8.2	14.5	8.7
	13.5	23.7	14.2
TS/TR/TX2	13.5	23.7	14.2
TS/TR/TX3	25.0	43.9	26.3

Tank Maintenance

- Drain the tank.
- Remove any sediment.
- Flush the tank with clean kerosene and allow it to drain dry.
- Refill the tank and prime the fuel system if it is not self-priming.

Removing the Fuel Tank - TS/TR

- Drain the fuel tank into a clean receptacle.
- Disconnect the fuel pipe at either the fuel pumps or fuel tank.
- Pull out the leak-off pipe from top of the tank.
- Remove the nuts securing the base of the tank to the air shield and end cover bracket.
- Remove the bolts securing the top of the tank to the cylinder head cover and air cowl bracket.

Replacing the Fuel Tank - TS/TR

- Support the tank and replace the bolts securing the top of the tank to the cylinder head cover and air cowl bracket.
- Replace the two nuts securing the base of the tank to the air shield and end cover bracket.
- Reconnect the fuel pipe at either the fuel pumps or fuel tank.
- Push the leak-off pipe into the top of the tank.

Removing the Fuel Tank - TX

- Drain the fuel into a clean receptacle.
- Disconnect the fuel pipe from tank.
- Pull off the leak-off pipe from the top of the tank.

- Remove the four nuts securing the tank flexible mountings to the mounting plate.
- Lift off the tank.

Replacing the Fuel Tank - TX

- Support the tank and replace the four flexible mounting studs into the mounting plate and replace the washers and nuts.
- Reconnect the fuel pipe to the tank.
- Push the leak-off pipe onto the union at the top of the tank.
- Refill the tank and prime the fuel system if it is not self-priming.

2.23 THE FUEL FILTER

One of three types of filter will be fitted and a combined filter and agglomerator is available when no tank is fitted.

The filter is an essential part of a diesel engine and the engine must never be run without a fuel filter element. The element should be renewed every 500 hours, or more frequently if for any reason the fuel is known to be dirty.

The Fuel Tank Filter

The fuel filter is an essential part of the engine and it must never be run without a filter and the element should be renewed every 500 hours, or more frequently if for any reason the fuel is known to be dirty.

- Remove the retaining plug (A).
- Remove the old element (B) and the joints (C).

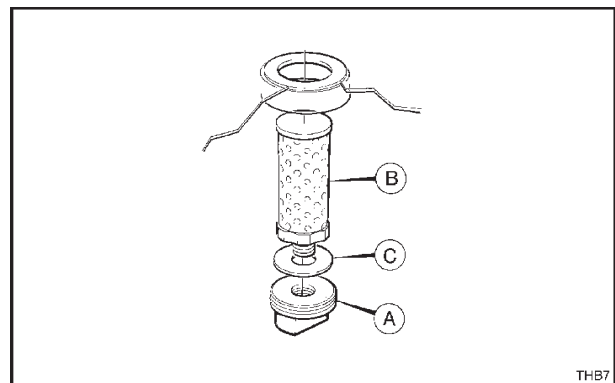


Figure 2.23.1 Fuel Tank Internal Filter

- Fit a new element and new joints.
- Replace and tighten the retaining plug (A).
- Prime the fuel system.

The Fuel Filter - TS/TR2, 3

1. Unscrew and remove the retaining bolt (A) from the element bowl.

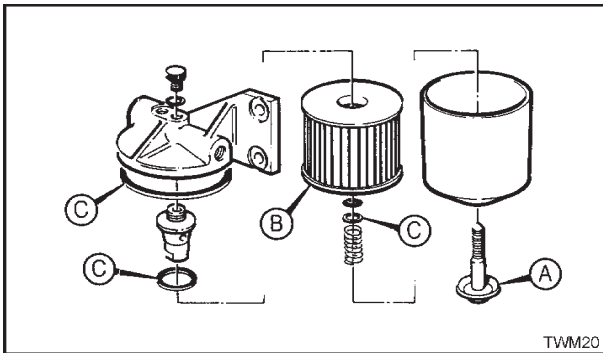


Figure 2.23.2 Fuel Filter

2. Remove the element (B) and discard it.
3. Discard the three joints (C).
4. Fit a new joint to the element adapter, the retaining bolt and the filter head.
5. Place the new element onto the adapter.
6. Replace the element bowl and retaining bolt.
7. Fill the fuel tank and prime the fuel system.

The Cartridge Agglomerator

Several types of filter/agglomerator have been used but the following instructions are valid for all types.

The cartridge agglomerator is an essential part of the engine and should be renewed every 500 hours, or more frequently if for any reason the fuel is known to be dirty. Water is drained from the agglomerator by unscrewing the drain tap (C) sufficiently to allow the water to drain.

A strap wrench is required to remove the agglomerator from the engine but it must not be used to fit a replacement.

1. Using a suitable strap wrench unscrew the cartridge (A) from the head (B).
2. Screw a new cartridge onto the head and hand tighten it.

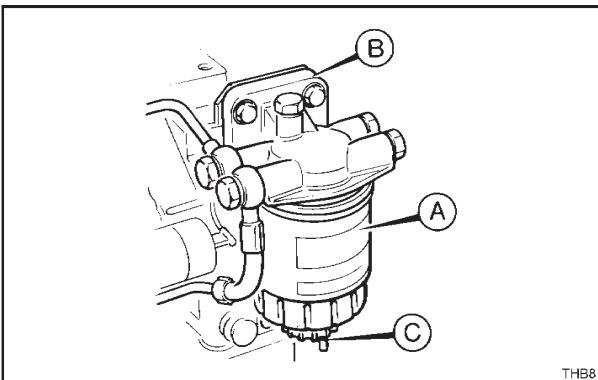


Figure 2.23.3 The Cartridge Agglomerator

2.24 PRIMING THE FUEL SYSTEM

If the fuel system is self venting it should not be necessary to manually prime it.

1. Fill the tank with fuel.
2. Vent the fuel filter through the bleed screw (A) until a full air free flow of fuel is obtained.
3. Vent the fuel at each pump in turn through the bleed screws (B) starting with the pump nearest to the fuel tank.

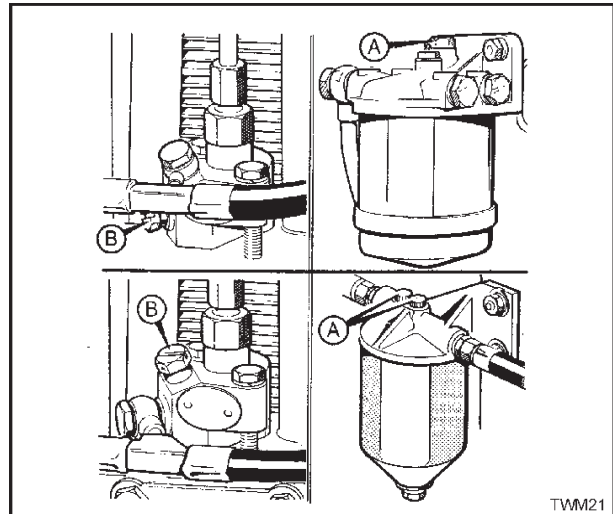


Figure 2.24.1 Priming the Fuel System

2.25 THE FUEL LIFT PUMP

A Pienne (B) fuel lift pump was first fitted from the engines below and differs from the older AC Delco (A) type.

- 38 02253 TS1
- 38 00287 TS2
- 38 00262 TS3
- 38 00754 TR1
- 38 00003 TR2
- 38 00094 TR3
- 38 00244 TX2
- 38 00242 TX3

With the introduction of the Pienne pump a new fuel control solenoid arrangement and a new speed control cable anchor bracket (366-07912) were introduced.

The Pienne pump has since been replaced by a Corona (C) lift pump.

The pump push rod and joint are interchangeable for all types of pump.

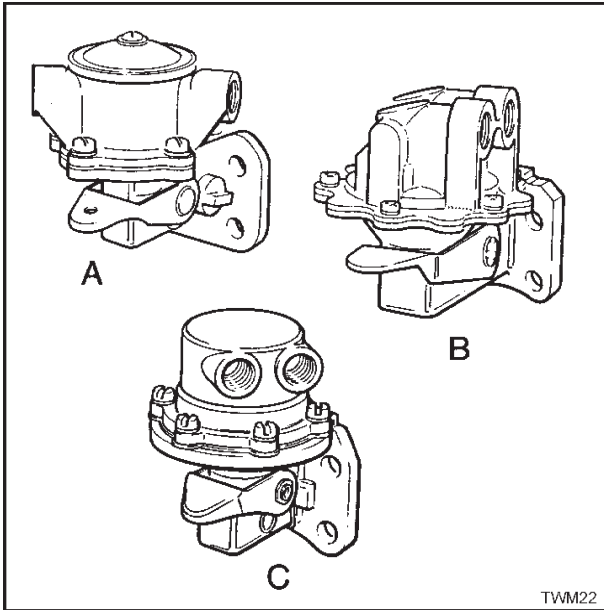


Figure 2.25.1 Fuel Lift Pumps
 A - AC Delco
 B - Piemme
 C - Corona

2.26 THE FUEL INJECTOR

The fuel injection equipment and all of the pipes and unions between the fuel filter and the injector must be absolutely clean. A minute particle of dirt can easily block one hole in the injector nozzle and this will give rise to a dirty exhaust and starting and running problems.

Lucas Dizel fuel injectors are currently fitted to the engines and they must not be mixed with any earlier types on an engine. It is recommended that injectors are changed as a set rather than individually. For further information please contact any Lister Petter Power Systems distributor.

Removing an Injector - TS/TR

1. Remove the cylinder head cover.
2. Remove the fuel pipe between the fuel pump and injector; hold the fuel pump delivery valve holder with a spanner to prevent it turning.
3. Remove the leak-off pipe and union from the injector.
4. Unscrew the Allen screw and remove the injector clamp; the clamp is located in position by a hole in the side of the cylinder head assembly.
 Either:
 - a. Screw the adaptor (A) into the slide hammer and tighten the screw (C) into the injector leak-off hole; see Note.
 Or:
 - b. Screw the adaptor (A) into the slide hammer.

- c. Fit the adaptor nylon bush over the high pressure pipe connection.

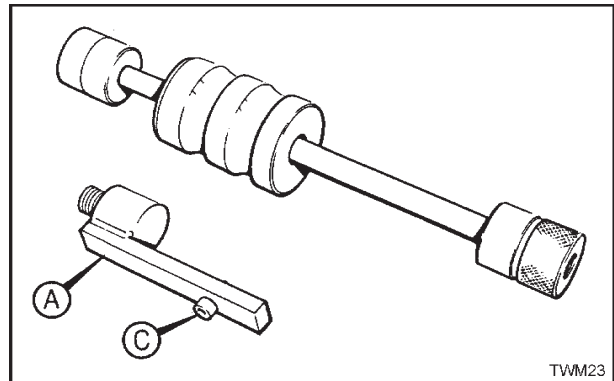


Figure 2.26.1 Injector Removal Tool with Early Type Adaptor

6. Use the slide hammer to remove the injector.

⚠ WARNING

Care must be taken to ensure that any part of the hand is not likely to become trapped between the two parts of the slide hammer while it is being used.

Note:

The tool design has changed and now incorporates a larger hole with a nylon insert which fits over the high pressure pipe connection on the injector. No screw is required.

Removing an Injector - TX

1. Remove the cylinder head cover.
2. Remove the fuel pipe between the fuel pump and injector; hold the fuel pump delivery valve holder with a spanner to prevent it turning.
3. Remove the leak-off pipe from the injector.
4. Remove the two clamp retaining nuts and lift the clamp off.
5. Fit the adapter (A) into adapter (B) and screw them onto the injector.

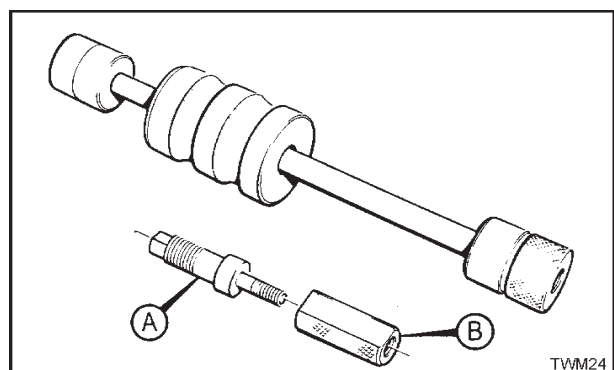


Figure 2.26.2 Injector Removal Tool

6. Fit the slide hammer to the adapter and remove the injector.

⚠ WARNING

Care must be taken to ensure that any part of the hand is not likely to become trapped between the two parts of the slide hammer while it is being used.

Cleaning an Injector

- A thoroughly cleaned container holding a supply of clean, fresh fuel oil should be available for washing dismantled parts.
- The components of each individual injector should be kept together at all times.
- Never use paraffin or woven cloths; it is permissible to use non-fluffing paper during the cleaning process.
- Components should be assembled wet.

Setting the Injector

To ascertain if the injector is in good condition, it is removed from the engine and connected to a fuel injector test rig, similar to the one shown.

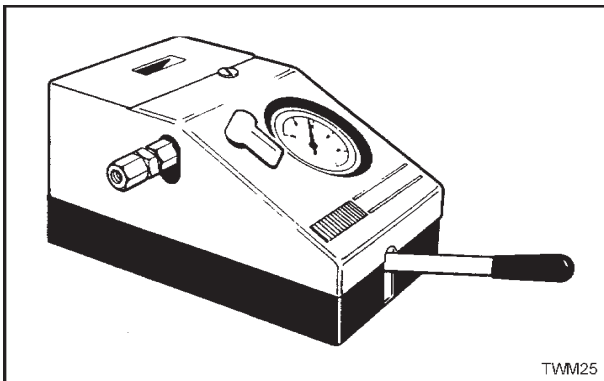


Figure 2.26.3 Typical Injector Test Rig

If a rig is not available it becomes necessary to replace the complete injector by a new or serviced one which has a clean nozzle and has been correctly set.

All sprays should have the same appearance and the same length of penetration in the air. If one spray is shorter or weaker than the others this means that the corresponding hole is partially blocked and best results will not be obtained. If one hole is totally blocked or the nozzle dribbles it must be replaced.

When a new nozzle is fitted the injector must be reset on a test rig. After testing and resetting the injector top plug must be torque loaded to 27.1 Nm (20.0lbf ft).

Note:

Injector setting pressures can be found in "Technical Data" in the relevant engine section.

⚠ WARNING

Under no circumstances allow unprotected skin to come into contact with the spray as the fuel may enter the blood stream with fatal results.

Injector Back Pressure

The leak-off rate is 6-27 seconds between 172-142bars (170-140atmos) on an injector tester using Calibration C fluid, at a temperature of 15.5°C (60°F).

Replacing an Injector

If the injector sealing washer has been used more than once it will become compressed and may adversely affect combustion. Care should be taken to ensure two washers are not fitted.

1. Examine the oil seal ring for damage or cuts, replace if necessary.
2. Ensure the injector sealing washer has been removed and the seating in the cylinder head is clean and smooth.
3. Lightly smear a very small amount of high melting point grease to one side of a new injector sealing washer and place it over the injector nozzle, greased side first.
4. Replace the leak-off pipe to the injector.
5. Fit the injector into the cylinder head.

TS/TR Engines:

6. Replace the clamp and leave the Alien screw finger tight.
7. Replace the fuel pump to injector pipe - do not tighten.
8. Replace the leak-off pipe into the fuel tank.
9. Torque the clamp screw to 21.0Nm (15.5lbf ft).
10. Torque all fuel pipe nuts to 28.5Nm (21.0lbf ft) and the leak-off pipe swivel union to 4.0Nm (3.0lbf ft).
11. Replace the cylinder head covers.
12. After the initial run following an injector replacement re-torque the injector clamp screw.

TX Engines:

13. Replace the clamp and leave the nuts finger tight.
14. Replace the fuel pump to injector pipe - do not tighten.
15. Push the leak-off pipe onto the injector.
16. Torque the clamp screw to 8.0Nm (6.0lbf ft).
17. Torque all fuel pipe nuts to 28.5Nm (21.0lbf ft).
18. Replace the leak-off pipe into the fuel tank.

2.27 THE FUEL PUMP

The individual fuel pumps are located at the side of the engine between the push rods and are secured to the crankcase by two bolts. Early TS engines were fitted with a long headed bolt fitted to the inside hole in the pump mounting flange.

Removing the Fuel Pumps

1. Drain the fuel tank or isolate the fuel supply.
2. Disconnect the fuel feed pipes at the pumps.
3. Remove the fuel pipes from the pumps to injectors taking care to hold the fuel pump delivery valve holder with a spanner to prevent it turning.
4. Remove the fuel pump inspection doors.
5. Release the spring tension of the speeder spring by unscrewing the speed adjusting screws on the side of the crankcase.
6. Using long nose pliers disconnect the speeder spring from its spigot.
It may be necessary to turn the spigot until the hole axis is parallel to the camshaft before removing the spring.
7. Disconnect the governor and pump interconnecting linkage at the pumps.

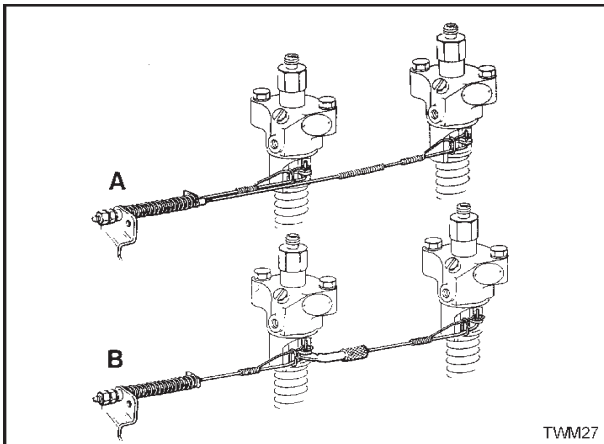


Figure 2.27.1 Fuel Pump Linkage
A - Early TS/TR
B - Later TS/TR and all TX

8. Move the rack operating lever on the pump to the central position.
9. Remove the fuel pump holding down bolts.
10. Gently lift out the pump taking care to retain the timing shims which are between the pump flange and crankcase.

⚠ CAUTION

If more than one pump is being removed care must be taken to retain the timing shims with their respective pump.

Fuel Pump Maintenance

It is recommended that the work of servicing the fuel pump is carried out by accredited Service Depots. For operators wishing to carry out their own maintenance, reference should be made to the relevant Master Parts Manual.

Timing Shims

To improve the accuracy of fuel pump timing the 'sickle' type shims (A) have been replaced by full form 'ring' types (B). The two types of shim should not be mixed on the same pump.

The 'ring' type can only be fitted with the pump removed from the engine.

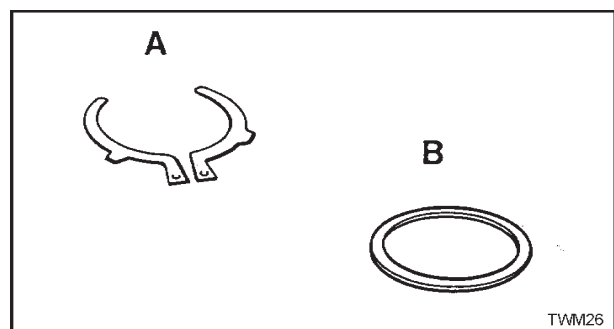


Figure 2.27.2 Timing Shims

The 'ring' type are available in 0.127, 0.762, 1.016 and 1.276mm sizes and were first fitted on:

40 00213 TS1	40 00113 TR1
40 00297 TS2	40 00135 TR2
40 00223 TS2	40 00039 TR3

In all instances it is recommended that the thickest shim is fitted next to the crankcase and it is advisable to fit the minimum number of thinner shims as possible.

Refitting the Fuel Pumps

1. If 'ring' type shims are being fitted place them onto the fuel pump taking care not to damage the pump sealing ring.
2. Place the pumps into the crankcase and fit the retaining bolts finger tight only.
3. If 'sickle' type shims are being fitted place the pumps into the crankcase and fit the retaining bolts finger tight only: the pumps should be slightly above the face of the crankcase.
Replace the shims between the pump and crankcase taking care to ensure that the same thickness of shims are on each side of the pump.
4. Evenly tighten the retaining bolts to a torque of 9.0Nm (6.6lbf ft).
5. Connect the governor link and the fuel pump interconnecting linkage as shown.

When re-fitting the new type of linkage to the fuel pumps it is important to ensure that the radiused shackles follow the pump radius.

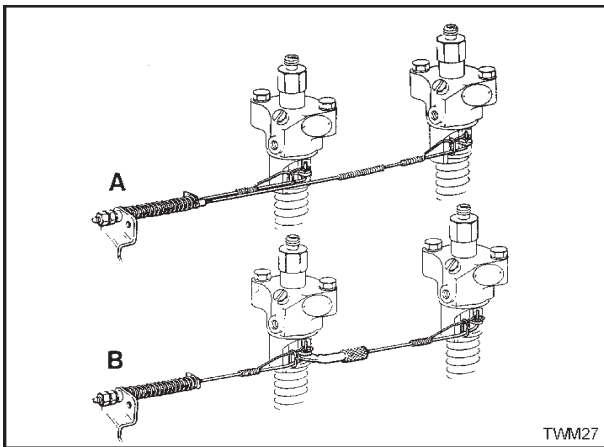


Figure 2.27.3 Fuel Pump Linkage
A - Early TS/TR
B - Later TS/TR and all TX

- Re-connect the speeder spring to the spigot. If the spigot was turned when the pumps were removed it must be turned until the hole axis is at 90° to the camshaft before refitting the spring when the speeder spring spigot is upright.

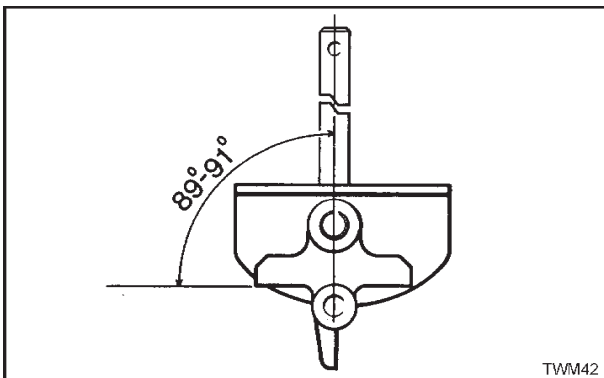


Figure 2.27.4 Speed Control Lever

- Check the governor setting; refer to "02.31 Setting the Governor".
- Fit new joints to the fuel pump inspection doors and replace the doors.
- Replace the fuel pipes.
- Prime the fuel system if it is not self-priming.
- Check and adjust the pump timing.

2.28 FUEL PUMP TIMING

Fuel pump components are manufactured to exacting limits and care must be taken to ensure they are returned to their respective pumps if more than one pump is dismantled at a time. The fuel pump timing gauge, 317-50518, can

be used to check the timing without the need to dismantle the pump.

Spill Timing

- Isolate the fuel supply.
- Remove the fuel pipe from the pump to the injector.
- Unscrew the fuel pump delivery union body (A) and remove it.
- Lift out the delivery valve spring seat (B) and spring (C).

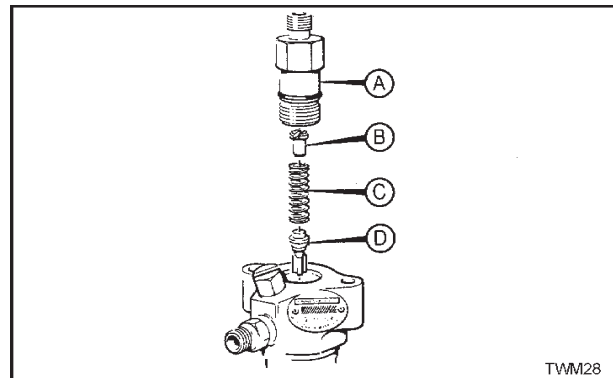


Figure 02.28.1 Fuel Pump Components

- Carefully lift out the delivery valve (D) taking care not to disturb the valve seat.
- Place these components in a suitable container of clean fuel.
- Replace the delivery union body (A).
- Fit a suitable spill pipe.
- Ensure the fuel pump rack is in the run position by removing a cylinder fuel pump housing door and manually moving the fuel pump rack towards the gear end.
- Turn the flywheel, in the direction of rotation, until the piston for the cylinder being timed is at 'FP' on the compression stroke. At this position both the inlet and exhaust valves will be closed.
- Connect the fuel supply and bleed the fuel filter and pump.
- Carefully turn the flywheel against rotation until fuel is flowing from the spill pipe.
- Turn the flywheel very slowly in the direction of rotation until the fuel flow from the spill pipe just stops dripping this is known as the 'Spill Point'.
- Check the flywheel timing mark. The flywheel timing mark (FP), which can be seen through an aperture in the fanshroud, should align with the arrow on the fanshroud.
- If the flywheel mark is not correct, see 'Figure 2.28.2', the shims under the fuel pump must be adjusted, see "Timing Shims".

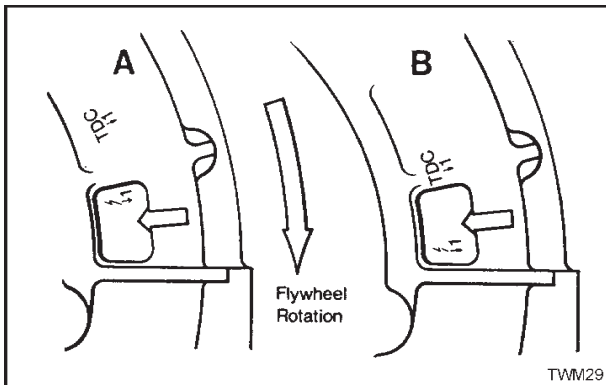


Figure 2.28.2 Flywheel Timing Marks

If the timing is:

Advanced - Add Shims

Retarded - Remove Shims.

Approximately 1° of flywheel movement can be obtained with a 0.127mm (0.005in) shim.

16. Re-check the timing.
17. When the correct timing has been obtained remove the spill pipe and delivery union body.
18. Replace the delivery valve, delivery valve spring and spring seat.
19. Refit the delivery union body and torque it to 35.0/45.0Nm (26.0/33.0lbf ft).
20. Check that the fuel pump calibration marks are still aligned.
21. Repeat this procedure for the remaining fuel pumps.
22. Connect all fuel pipes and torque the pump to injector pipe nuts to:
 - TS/TR - 29.0Nm (21.0lbf ft).
 - TX - 22.0Nm (16.0lbf ft).
23. Bleed the entire fuel system.

Fuel Pump Timing Gauge

1. Assemble the pipe (A) to the gauge ensuring that the pipe nuts are tight.

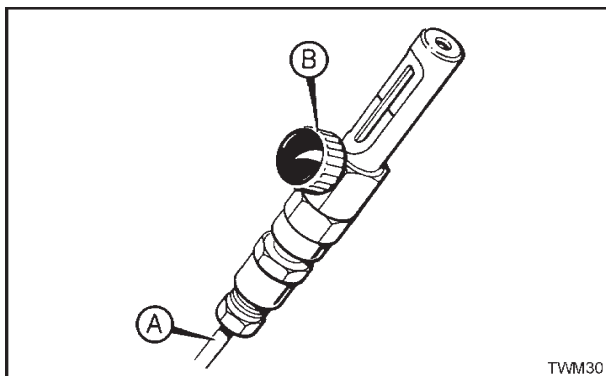


Figure 2.28.3 Fuel Pump Timing Gauge - 317-50518

2. Remove the fuel pipe from the pump to the

injector.

3. Connect the gauge and pipe to the fuel pump delivery valve union for the cylinder being timed.
4. Bleed the filter and pump.
5. Ensure the fuel pump rack is in the run position by removing a cylinder fuel pump housing door and manually moving the fuel pump rack towards the gear end.
6. Turn the flywheel, in the direction of rotation, to prime the gauge.
7. Turn the flywheel, in the direction of rotation, until the flywheel 'FP' timing mark is in line with the arrow.

At this position both the inlet and exhaust valves will be closed.

8. Turn the flywheel against rotation for 50.8mm (2.00in).
9. Slowly release the gauge knob (B) until the fuel level is in line with the calibration mark on the gauge sight glass.
10. Turn the flywheel in the direction of rotation, extremely slowly, until the fuel in the sight glass just moves.
11. Check the flywheel timing mark.
 - The flywheel timing mark (FP), which can be seen through an aperture in the fanshroud, should align with the arrow on the fanshroud.
12. If the flywheel mark is not correct, the shims under the fuel pump must be adjusted, see "Timing Shims".

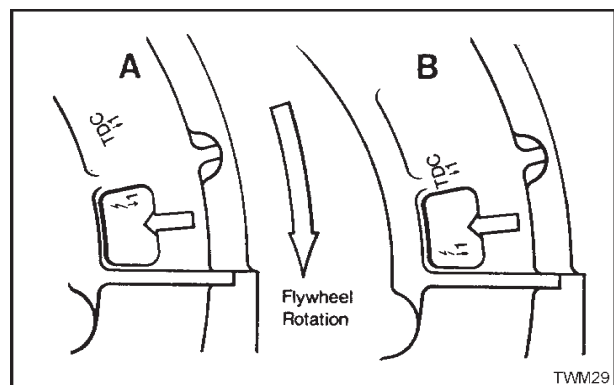


Figure 2.28.3 Flywheel Timing Marks

If the timing is:

Advanced - Add Shims

Retarded - Remove Shims.

Approximately 1 of flywheel movement can be obtained with a 0.127mm (0.005in) shim.

13. Remove the gauge and replace the pump to injector pipe and torque the pipe nuts to:
 - TS/TR - 29.0Nm (21.0lbf ft).
 - TX - 22.0Nm (16.0lbf ft).

Fuel Pump Timing Tables

The values given in the first table apply to early TS/TR engines with serial numbers up to those shown.

36 00489 TS1	36 03079 TR1
36 00314 TS2	36 05126 TR2
36 00467 TS2	36 03520 TR3

Early TS/TR

r/min	BTDC				
	1500	1800	2500 ¹	3000 ¹	3000
TS1	20°	20°	-	22°	25°
TS2	20°	20°	-	23°	23°
TS3	20°	20°	-	23°	23°
TR1	20°	20°	23°	-	26°
TR2	20°	20°	23°	-	26°
TR3	20°	20°	23°	-	26°

Note:

The value given is for variable speed engines running at any speed up to the maximum shown.

Later Engines - TS/TR and all TX

All TX engines and TS and TR engines with serial numbers after those given above have values as given in "02.32 Governor 'G' Setting and Timing Tables".

2.29 GOVERNOR MODIFICATIONS

There have been alterations to the TS/TR governor assembly and the two types are not totally interchangeable.

A one-piece 'Nylatron' sleeve has been introduced to replace the original sleeve assembly.

The new type is interchangeable with the original if the following changes are made:

The governor lever shoes are removed.
 The governor weight shoes are removed.
 The governor sleeve setting 'A' is set at 9.5mm.
 Re-designed support blocks and return springs are now fitted with the springs not being interchangeable; if the pivot blocks are changed the return springs must also be changed.
 All of the above changes were introduced on the following engines, and in later text, dealing with the governor, these changes will be referred to as being applicable to early engines or later engines.

35 01614 TS1	36 00001 TR1
35 07495 TS2	36 00011 TR2
35 06047 TS3	36 00141 TR3

The Governor Linkage

The fuel pump governor linkage has also been modified.

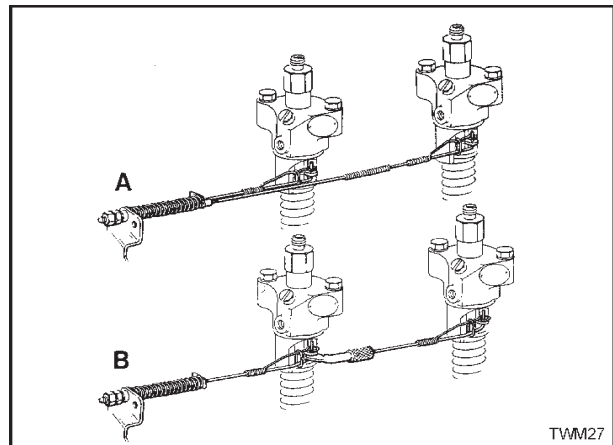


Figure 2.29.1 Fuel Pump Linkage
 A - Early TS/TR
 B - Later TS/TR and all TX

When re-fitting the new type of linkage to the fuel pumps it is important to ensure that the radiused shackles follow the pump radius.

If the shackle radius does not follow the pump radius the shackle will become wedged against the fuel pump body and the pumps will be prevented from closing correctly.

2.30 THE GOVERNOR

Governing Ranges to BS5514

Build Number			r/min Ranges to BS5514				
TS1	TS2	TS3	Full Load Class A1	Full Load Class B1	Outside 10%	Idling Limits	Governor Code
01, 02, 03, 04, 06, 07, 14, 15, 17, 40, 60, 61	01, 02, 03, 04, 05, 06, 07, 14, 15, 40, 42, 60, 61	01, 02, 03, 04, 05, 06, 07, 40, 42, 60, 61	2700-3000	2100-3000	1300-2099 ¹	850-950	QW2 18W2 ²
16	41	41				850-950	LW2
08, 09, 10, 11, 62, 63, 64, 65	08, 09, 10, 11, 43, 62, 63	08, 09, 10, 11, 62, 63	1200-2000				LWS4 13WS4 ²
	12, 13	12, 13	2050-3000	1300-3000 ¹			LY2 13Y2 ²
12, 13							SY2 20Y2 ²
TR1	TR2	TR3					
01, 02, 03, 04, 06, 07, 14, 15, 16	01, 02, 03, 06, 07, 14, 15	01, 02, 03, 04, 06, 07	2700-3000	2100-3000	1300-2099 ¹	850-950	QW2 18W2 ²
08, 09, 10, 11	08, 09	08, 09	1200-2000				LWS4 13WS4 ²
	12, 13	12, 13					LY2
	TX2	TX3					
	01, 02, 03, 04, 05, 06, 07, 08, 12, 13, 20, 21, 52	01, 02, 03, 04, 05, 06, 07, 08, 12, 13, 14, 52	2700-3000	1800-3000	1500-1799	850-950	SU2
	09, 10, 11		1200-2000				LUS4

Notes:

The speed ranges given in the table do not necessarily relate to the full load build speeds due to flywheel limitations.

1. The minimum full load speed must not be less than 1500r/min.

2. These codes are for earlier TS/TR engines, see "02.29 Governor Modifications - TS/TR", that are fitted with a metal thrust washer assembly and shoes on the governor lever and weights.

Governor Combination Code

First letter or number - weight code.

Second letter - spring colour code

(W = white, B = black, U = blue, Y = yellow)

Letter 'S' - Inner speeder spring, if fitted.

End figure - number of weights.

Dismantling the Governor

1. Remove the gear end cover.
 2. Remove the fuel pump inspection door/s.
 3. Disconnect the fuel pump and governor linkage at the fuel pump using long nosed pliers.
 4. Slacken off the speed control screw and then disconnect the speeder spring.
 5. Remove both fulcrum pins from the pivot support blocks using a 1.5mm rod, punch or suitable piece of stiff wire.
- Take care not to lose the shims.
6. Remove the governor lever assembly complete with the speeder spring and fuel pump linkage.
 7. Remove the governor sleeve assembly

Assembling the Governor

Assemble the governor and fuel pump linkage in the reverse order to dismantling, taking care to note the following points:

- a. The fulcrum pins are drilled at one end only and these holes must be fitted at the outer end.
- b. Ensure the governor sleeve is fitted the correct way.
- c. The speed control spring is correctly hooked into its spigot.
- d. The small return spring, which is only fitted to variable speed engines, must be fitted to the fuel pump side end of the lever assembly with the short tail wound backwards and held captive under the pivot support block.

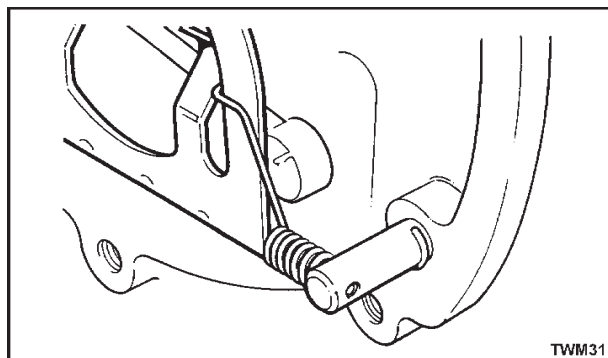


Figure 2.30.1 Variable Speed Return Spring

- e. Check that the governor lever assembly is perfectly free to move.

Changing Governor Weights

A table of governor weight and spring combinations is given in "Governing Ranges to BS5514". Current engines are fitted with an improved camshaft gearwheel design, the weights remain the same although on current engines they are retained in position by sintered retaining plates with cast slots

which locate over the weight pins. Both types are shown in 'Figure 2.30.2' and they are not interchangeable.

1. Remove the gear end cover.
2. Remove the governor lever and sleeve assemblies.
3. Disconnect the speeder spring from its spigot and fit a new spring if necessary.
4. Turn the engine until one of the governor weight retaining plate bolts is accessible.
5. Remove the bolt and plate.
6. Turn the engine until the adjacent retaining plate bolt is accessible.
7. Remove the governor weight.
8. Repeat items 4. to 7. for the remaining weights.

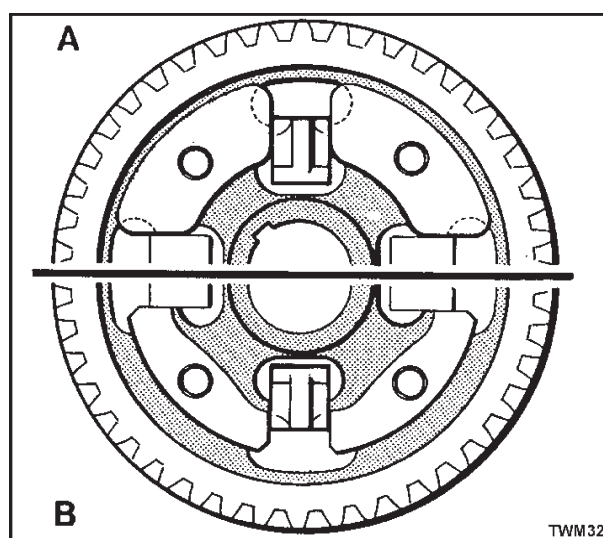


Figure 2.30.2 Governor Weights - TS/TR
A - Early TS/TR
B - Later TS/TR and TX

9. Fit the new weights and retaining plate; take care to ensure the weight pins are correctly seated in their respective slots.
10. Torque the retaining plate bolts to 9.0Nm (6.5lbf ft).
11. Replace the governor sleeve and governor lever assemblies.
12. Check the governor settings.
13. Replace the fuel pump inspection door and the end cover.

2.31 SETTING THE GOVERNOR

Before setting the governor refer to "Governing Ranges to BS5514" and "Governor Modifications - TS/TR".

To adjust or check the settings, it is necessary to remove the fuel pump inspection doors and the end cover. The engine control must be in the start position and the end of the camshaft gently tapped towards the flywheel to take up any end play.

⚠ CAUTION

Extreme care must be taken to ensure that the governor is correctly set for the engine type and build.

Governor 'E' Setting

Adjustment 'E', as shown below, should be checked and if necessary shims added or removed to obtain a clearance of 0.12-0.25mm (0.005-0.010in).

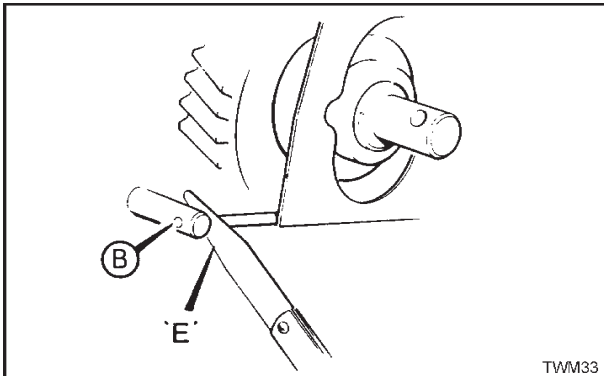


Figure 2.31.1 Governor 'E' Setting

The pivot pins (B) can be withdrawn with a 1.5mm punch or stiff wire, they are drilled at one end only therefore care must be taken on re-assembly to ensure they are fitted with the holes facing outwards. Take care to retain the endfloat shims and check that the governor lever assembly is perfectly free to move.

The small return spring, which is only fitted to variable speed engines, is fitted to the fuel pump side end of the lever assembly and the short tail is wound backwards and held captive under the pivot support block.

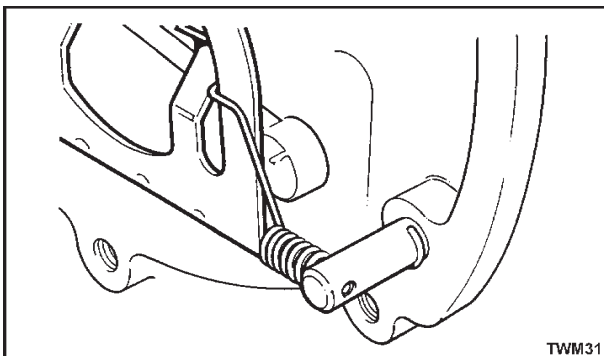


Figure 2.31.2 Variable Speed Return Spring

Governor 'Q' Setting

1. Gently move the governor plate forward sufficiently to ensure the chamfered spacers behind the locknuts on the speeder spring and governor linkages are seated.

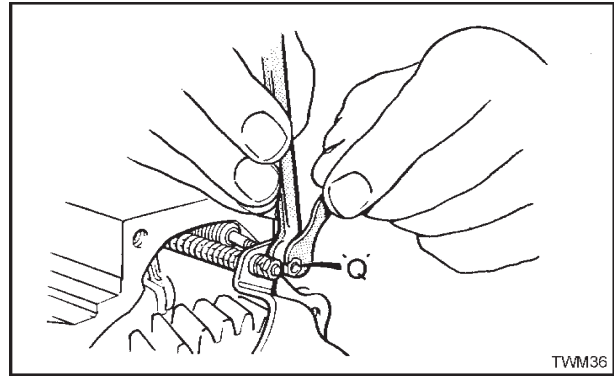


Figure 2.31.3 Governor 'Q' Setting

2. Adjust the two locknuts on the speeder spring link until the ends of both links are flush.

Governor 'A' Setting

1. Set the distance 'A', between the end of the thrust sleeve and the shoulder on the camshaft gear hub, to 5.0mm (0.197in) on early TS/TR engines and 9.5mm (0.374in) on later TS/TR and all TX engines by marking a scribed line the required distance from the shoulder and then moving the thrust sleeve forward to this scribed mark. With care, an engineers screwdriver can be fitted behind the governor sleeve to hold it in the correct position while the next stages are carried out.

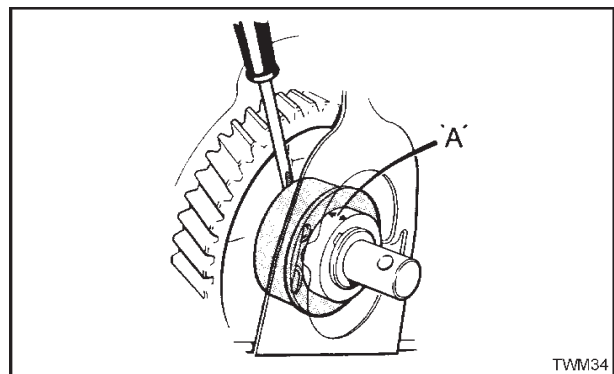


Figure 2.31.4 Governor 'A' Setting

2. Disconnect the fuel pump linkage, for the remaining fuel pumps from No.1 pump by:
 a. Sliding the oval split ring towards the gear end.
 b. Lifting the spring tail from the end of the governor link.
 c. Removing the governor link from the fuel pump rack.

3. Check that the calibration mark (X) on No.1 fuel pump is in line with the mark on the centre of the fuel pump body, as shown below, while the correct distance 'A' is maintained.

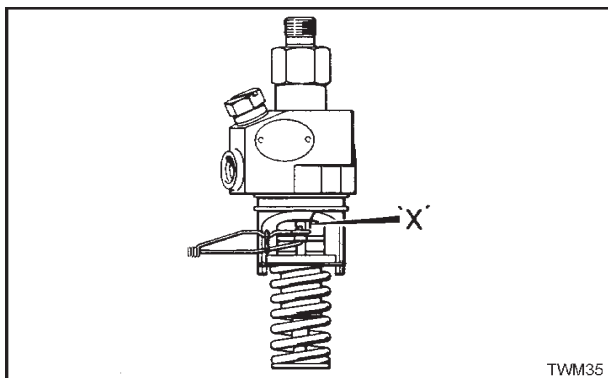


Figure 2.31.5 Fuel Pump Calibration Marks

4.If the two calibration marks are not in line they can be adjusted by altering the effective length of the governor link through the two locknuts on the outside of the governor lever.

Ensure the chamfered spacer is seated when making this adjustment.

- 5.Replace the linkage to No.1 pump.
- 6.The length of the links from No.1 to No.2, and between No.2 and No.3 pumps are then adjusted individually by removing the relevant linkage from the pump and rotating the link as necessary until the calibration marks (X) on all pumps are in line simultaneously while the distance 'A', is maintained.
- 7.Release the governor lever assembly and check that all parts of the governor move freely.

Governor 'G' Setting

The 'G' setting is used to ensure that the fuel pumps deliver the correct amount of fuel as dictated by the engine build number.

The various settings are given in "02.32 Governor 'G' Setting and Timing Tables". For intermediate speeds not given in the tables use the setting for the nearest higher speed.

All TS and TR engines built from January 1999 have been fitted with fuel pump 201-31305 (Mk II Pump). These can be fitted individually as spares to replace the earlier pumps, but improved engine idling characteristics can only be gained by changing all pumps in the engine to the new type. This fuel pump supersedes earlier pumps although the fuel pump element remains unchanged.

- 1.Turn the engine control to the stop position and release it.
- 2.Gently move the governor assembly lever away from the camshaft until the excess fuel device is heard to 'click' into the run position.
- 3.With a feeler gauge of the correct thickness for the build inserted between the control lever and the lever stop, loosen the control plate retaining

screw (A) and rotate the plate (B) until the fuel pump calibration marks are aligned. On some engines a tamperproof setscrew is fitted.

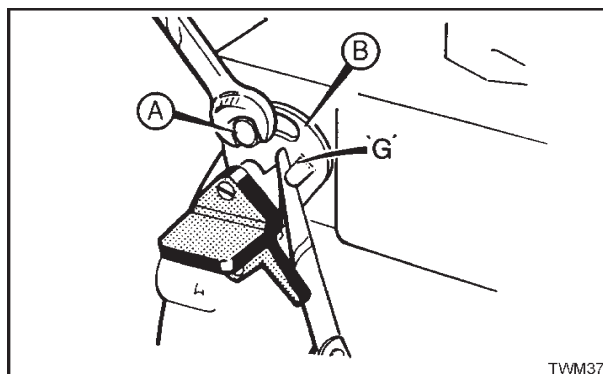


Figure 2.31.6 Governor 'G' Setting

- 4.Tighten the plate retaining screw.
- 5.After all the settings have been carried out, ensure the fuel pump rack and all moving parts move freely.

CAUTION

Extreme care must be taken when inserting the feeler gauge or rotating the plate to ensure that the governor does not move into the start position.

Limited Excess Fuel Trip - TX

This device may be fitted to some TX2 Build 20 engines.

Adjusting the Trip

Care must be taken to ensure the governor 'G' and 'Q' settings are correct before attempting to adjust the trip.

- 1.Adjust the two locknuts (A) to a nominal position on the adjusting screw (B).
- 2.Adjust the speed control, if necessary, to ensure the speeder spring (C) is tensioned with the stop control against the overload stop.

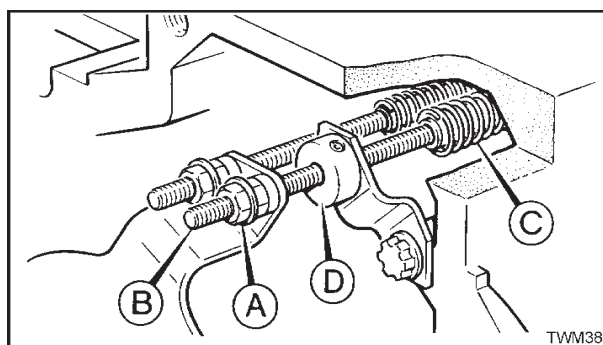


Figure 2.31.6 Excess Fuel Trip - TX

3. Slacken the collar grub screw sufficiently and screw the collar along the adjusting screw (B) until it just touches the plate (E).
4. Turn the collar back half a turn and tighten the collar grub screw.
5. Move the stop control fully anti-clockwise and release it, checking that the engine goes freely into the excess fuel position.
6. Gently move the governor assembly lever away from the camshaft until the excess fuel device is heard to 'click' into the run position.
7. Ensure that when the stop control contacts the overload stop the clearance between the collar (D) and plate (E) is 0.3-0.4mm (0.12-0.16in).

2.32 GOVERNOR 'G' SETTING AND TIMING TABLES

TS1

Builds	Timing BTDC	Speed/ Class	Load Rating	'G' Setting
01, 02	20°	2500 B1	90/100%	0.045"
03, 04	23°	3000 B1	90/100%	0.055"
06, 07	20°	2500 B1	100%	0.060"
08, 09	20°	1500 A1	100%	0.045"
10	20°	1800 A1	100%	0.045"
16	20°	2000 B1	90/100%	0.045"
17	20°	2500 B1	90/100%	0.045"
18	20°	2200 A1	90/100%	0.045"
62	20°	1500 A1	100%	0.045"
101	20°	1500 A1	100%	0.045"
102, 103	20°	2500 B1	90/100%	0.045"
106	20°	2500 B1	90/100%	0.045"

TS2,3

01, 02	20°	2500 B1	90/100%	0.045"
03, 04	23°	3000 B1	90/100%	0.055"
06, 07	20°	2500 B1	100%	0.060"
08, 09	20°	1500 A1	100%	0.045"
10	20°	1800 A1	100%	0.045"
16	20°	2000 B1	90/100%	0.045"
17	20°	2500 B1	90/100%	0.045"
18	20°	2200 A1	90/100%	0.045"
62	20°	1500 A1	100%	0.045"
101	20°	1500 A1	100%	0.045"
102, 103	20°	2500 B1	90/100%	0.045"
106	20°	2500 B1	90/100%	0.045"

TR1

Builds	Timing BTDC	Speed/ Class	Load Rating	'G' Setting
01, 02	20°	2500 B1	90/100%	0.040"
03	23°	3000 B1	90/100%	0.055"
06, 07	20°	2500 B1	100%	0.040"
08, 09	20°	1500 A1	100%	0.053"
10, 11	20°	1800 A1	100%	0.053"
14, 16	20°	2500 B1	100%	0.040"
78	20°	1500 A1	100%	0.053"
100	20°	2500 B1	90/100%	0.040"
105, 106	20°	2500 B1	90/100%	0.040"

TR2

01, 02	20°	2500 B1	90/100%	0.040"
04	23°	3000 B1	90/100%	0.055"
06, 07	20°	2500 B1	90/100%	0.040"
08, 09	20°	1500 A1 1800 A1	100%	0.050"
101	20°	1500 A1 1500 A1	100%	0.050"

TR3

01, 02	20°	2500 B1	90/100%	0.040"
03	23°	3000 B1	90/100%	0.055"
08, 09	20°	1500 A1 1800 A1	100%	0.045"
78	20°	1500 A1	100%	0.045"

TX2,3

Builds	Timing BTDC	Speed/ Class	Load Rating	'G' Setting
1	20°	2500 B1	90/100%	0.045"
02	22°	2500 B1	100%	0.069"
03	24°	3000 B1	90/100%	0.043"
04	24°	2800 B1	100%	0.071"
05	22°	2500 B1	100%	0.069"
09	20°	1500 A1	90/100%	0.042"
10	20°	1800 A1 1800 A1	100%	0.056"
13	24°	2900 B1	90/100%	0.043"
14	22°	2500 B1	100%	0.069"
16, 17	22°	2500 B1	90/100%	0.069"
52	22°	2000 B1	90/100%	0.045"

2.33 SPEED ADJUSTMENT

The speed of the engine is controlled by the tension of the speeder spring which is internally attached to the speed control. The control has two adjustable screws which are adjusted and locked to give the rated full on-load or variable speed as determined by the engine Build.

Fixed Speed Adjustment

The two screws are adjusted and locked against the speed control lever to give the full on-load speed. The right hand side adjusting screw (A) increases the speed when it is turned clockwise.

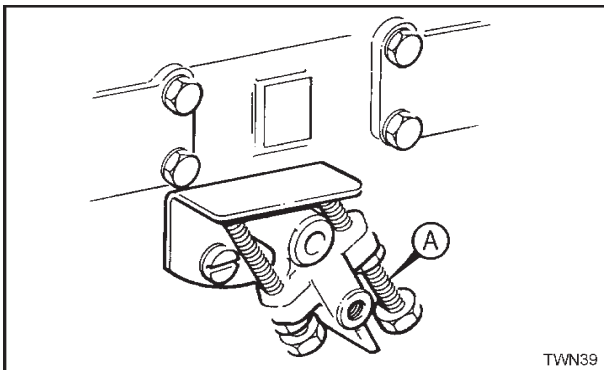


Figure 2.33.1 Fixed Speed Adjustment

Variable Speed Adjustment

The speed of the engine is controlled by the tension of the speeder spring which is internally attached to the speed control which in turn can be operated either by a cable or rod.

The idling speed must not be set below 850r/min.

1. Move the speed control until it is against the adjusting screw (A).
2. Turn the adjusting screw (A) anti-clockwise until it has no further effect on reducing the engine speed.
3. Turn (A) clockwise until the no-load speed is 850r/min.

The adjuster can be turned further clockwise if a higher idling speed is required.

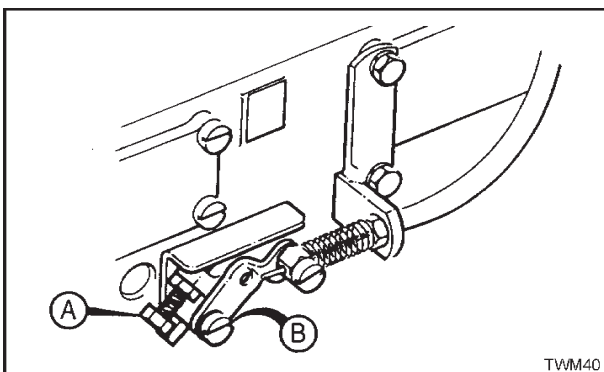


Figure 2.33.2 Variable Speed Adjustment

4. Tighten the locknut.
5. Move the speed control until it is against the adjusting screw (B).
If the speed is not correct turn the adjusting screw (B) clockwise to reduce the speed and anti-clockwise to increase it.

2.34 THE ENGINE CONTROLS

The Engine Control

The control knob, spindle and plate assembly was modified on and after the following TS engines:

- 35 01203 TS1
- 35 06483 TS2
- 35 05021 TS3

On later TS and all TR and TX engines the knob and spindle are one assembly and the location plate is a separate item.

Note:

The current assembly cannot be used with an early type of unmodified locating plate.

Removing the Assembly

1. Remove the gear end cover.
2. Remove No.1 cylinder fuel pump inspection door.
3. Move the automatic excess fuel lever (B) along the shaft towards the outside of the crankcase and hold it in this position.
4. Remove the small dowel pin (C).

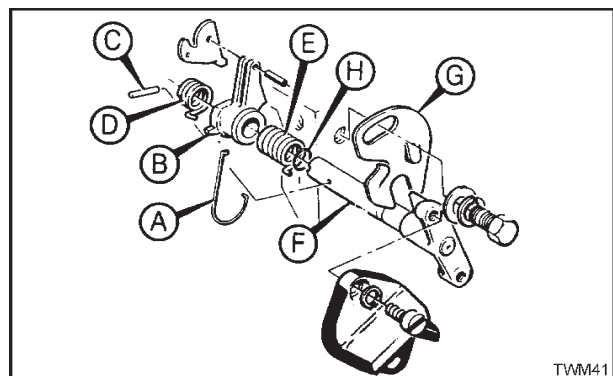


Figure 2.34.1 Engine Control

5. Remove the spring (D) from its location on the excess fuel lever.
6. Remove the excess fuel lever assembly (B) and spring (E) while withdrawing the control lever (F) and plate assembly (G).
7. Examine and renew the 'O' ring (H) if necessary.
8. Replace the cam spring (A), if removed, to the lever assembly (B).
9. Replace the control lever (F) and plate assembly (G) through the crankcase into the spring (E) and

- the excess fuel lever assembly (B).
10. Relocate the spring (D) on the excess fuel lever.
 11. Move the automatic excess fuel lever (B) along the shaft towards the outside of the crankcase and hold it in this position.
 12. Replace the dowel (C).
 13. Replace the gear end cover.
 14. Replace No.1 cylinder fuel pump inspection door.

The Speed Control Lever

To ensure the speed control is correctly re-fitted, care must be taken to ensure the angle is 89°-91° when the speeder spring spigot is upright. When the lever is assembled it must be free to rotate.

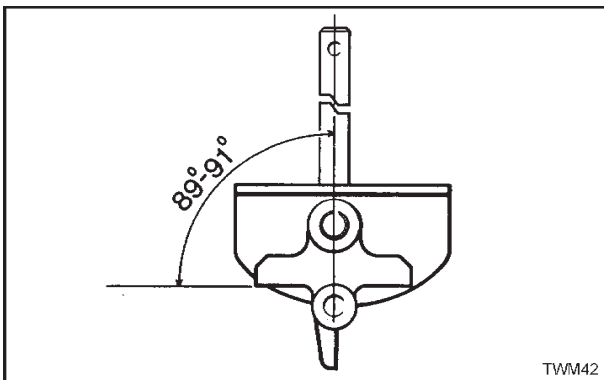


Figure 2.34.2 Speed Control Lever

2.35 THE FUEL PUMP TAPPET

Removing a Tappet

1. Remove the fuel pump.
2. With the fuel pump removed use long nosed pliers to remove the tappet insert (A) from the top of the tappet assembly (B).

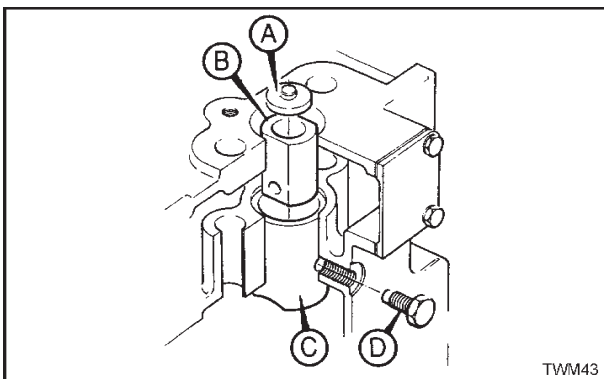


Figure 2.35.1 Fuel Pump Tappet

3. Lift out the fuel pump tappet assembly from the guide (C).
4. Remove the guide locating bolt (D) from the fuel

- pump side of the crankcase.
5. Remove the tappet guide.

Replacing a Tappet

1. Replace the guide into the crankcase taking extreme care to ensure the end with the two flats enters first and the locating holes in the crankcase and guide are correctly aligned.
2. Replace the guide locating bolt and a new copper washer.
3. Replace the tappet.
4. Replace the tappet insert with the smaller section on the outside.

⚠ CAUTION

Failure to fit a new washer to the guide locating bolt may allow the bolt to touch the tappet and prevent it operating.

2.36 THE CAMSHAFT

The steel camshaft is carried in plain bearings in the crankcase at both the flywheel end and in the centre web(s). A ball bearing attached to the camshaft and fitted behind the camshaft gear provides the bearing for the gear end. The camshaft gear carries the governor weights. Cams on the camshaft operate the valve tappets, oil pump, fuel pumps and the fuel lift pump.

Removing the Camshaft

1. Remove the sump.
2. Remove the oil pump.
3. Remove the end cover.
4. Remove the governor and fuel pumps.
5. If the engine is in its normal plane hold the cam followers clear of the camshaft using suitable clips or magnets.
6. Gently ease the camshaft out of the crankcase keeping it square at all times.
7. Remove the cam followers.

Inspecting the Camshaft

- a. Examine the camshaft bush for scars or wear.
- b. Examine the ball race bearing for wear and freedom of movement.
- c. Check the camshaft gearwheel and crankshaft pinion teeth for wear.
- d. Ensure the cams are not damaged.
- e. Check the tappets for scars or damage to the contact face.
- f. Examine the oil seal in the end cover for damage or wear.

Replacing the Camshaft

1. Replace the cam followers and secure them in their highest positions.
2. Carefully replace the camshaft into the crankcase keeping it square at all times; take care to line up the '0' timing marks on the crankshaft and camshaft gears exactly.

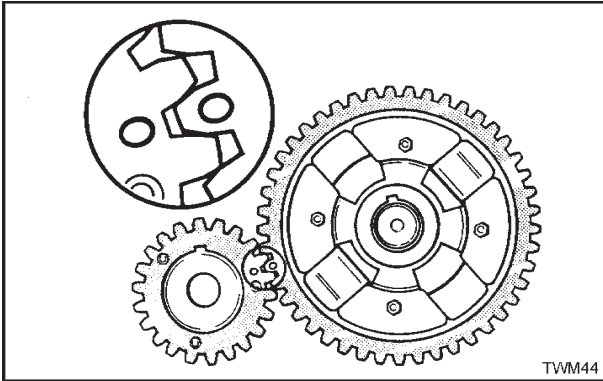


Figure 2.36.1 Gear Timing Marks

3. Release the cam followers.
4. Replace the oil pump, sump, fuel pumps, governor and end cover.

Camshaft Endfloat

The end float, maintained with a single metal shim between the camshaft thrust washer and the camshaft gearwheel hub, is 0.08-0.2mm (0.003-0.008in).

In engines where the camshaft does not extend through the end cover the end float can be measured through the top right hand tapped hole of the gear cover SAE flange.

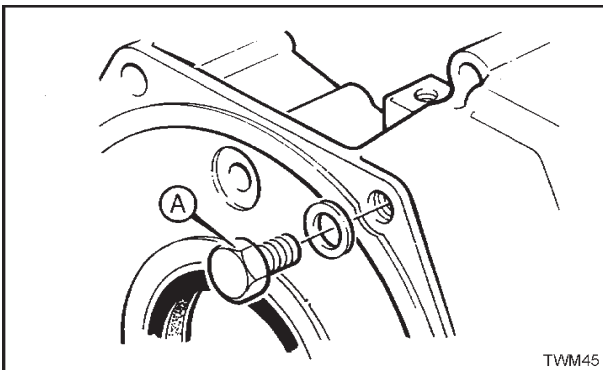


Figure 2.36.2 Camshaft End Float Access

1. Remove the setscrew (A) from the end cover.
2. Use a suitable rod through the hole to push the camshaft gearwheel as far as it will go towards the flywheel end.
3. Insert a clock gauge extension through the hole until it rests against the gearwheel and zero the gauge.

4. Push the camshaft gearwheel towards the gear end by inserting a suitably cranked rod through the fuel pump inspection door and check the gauge reading.

This endfloat should be 0.08-0.2mm (0.003-0.008in).

CAUTION

Excessive cam shaft end float affects the governing and can cause uneven firing. Some early engines were fitted with a paper gear end cover joint and if this is replaced with a new type thicker joint the end float must be checked and adjusted as necessary.

2.37 THE CAMSHAFT GEARWHEEL

Removing the Gearwheel

1. Drift pin (A) into the camshaft (B) until it clears the gearwheel (C).

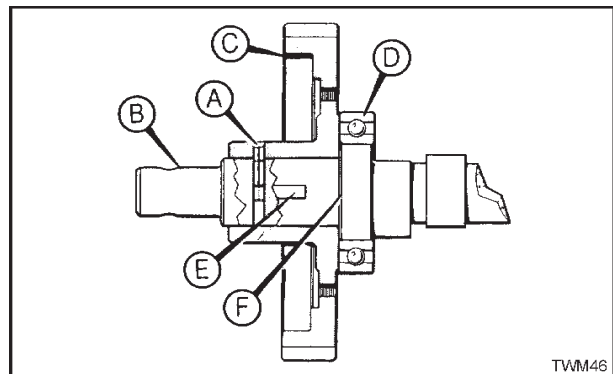


Figure 2.37.1 Camshaft Gearwheel

2. Press off the gearwheel sufficiently to allow a thin metal washer to be placed between the bearing (D) and the gearwheel to prevent dirt entering the bearing.

Continue to press off the bearing.

3. Remove the Woodruff key (E).
4. Drift pin (A) out of the camshaft (B) using a small drift.

Refitting the Gearwheel

On re-assembly the dowel pin must be carefully pressed in to 1mm below the diameter of the gearwheel hub and any sharp edges around the hole must be removed - any burrs will affect the operation of the governor thrust sleeve.

Fit the camshaft gearwheel in the reverse order to dismantling ensuring the thin flat washer is removed and that the gearwheel abuts against the shoulder (F).

⚠ CAUTION

Ensure no pressure is applied to the outer ring of the gear at any time.

Changing the Camshaft Ball Race

1. Remove the retaining pin from the gearwheel hub.
2. Support the camshaft assembly on the hub of the ball race and push the camshaft through the gearwheel and bearing.
3. Push the new bearing on to the camshaft and apply pressure to the gearwheel hub.
4. Push on the gearwheel and key.
5. Refit the retaining pin.

2.38 THE CAMSHAFT BUSHES

A new bush should be immersed in clean engine lubricating oil for four hours before fitting. A small identification dot is on one outside edge of the bush and on assembly this dot must be towards the top of the crankcase. It is recommended that bushes are replaced as a set.

To gain access to the flywheel end expansion plug and bush it will be necessary to remove the flywheel, fanshroud and main bearing housing.

Camshaft Bush Tool 393235**Notes:**

The camshaft bush tool, 393235, replaces 317-50006 ; both are described and either can be used. The legend numbers referred to in the illustration and text are also marked on the individual tool items.

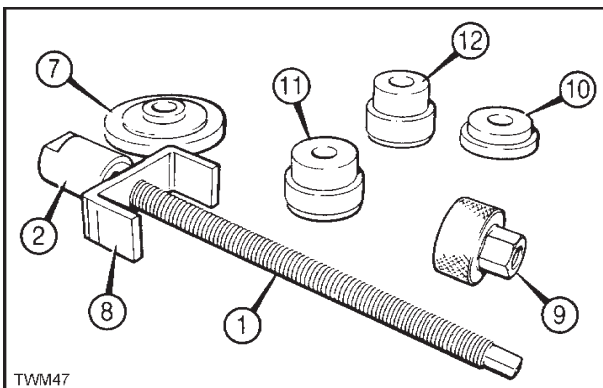


Figure 2.38.1 Camshaft Bush Tool 393235

Flywheel End Bush Removal

1. Remove the flywheel end main bearing housing.
2. Fit the nut (2) onto the screw (1).
3. Fit the small dolly (11) into the bush from inside the crankcase.

4. Place the screw through the dolly from the gear end.
5. Assemble the bridge (8) and thrust nut (9) to the screw.
6. Using the correct size of spanner tighten the thrust nut until the bush is removed.
7. Remove the tool.

Flywheel End Bush Replacement

1. Fit the new lubricated bush to the small dolly (11).
2. With the dot on the bush at the top, place the dolly and bush into the crankcase from the inside and line up the bush with its location.
3. Fit the nut (2) onto the screw (1).
4. Place the screw through the dolly from the gear end.
5. Place the guide (10) over the screw to align the bush in the housing.
6. Fit the bridge (8) and thrust nut (9).
7. Using the correct size of spanner and checking the tool and bush alignment very carefully, tighten the thrust nut until the bush is central across its housing.
8. Remove the tool.

Centre Bush Removal

1. Fit the nut (2) onto the screw (1).
2. Fit the large dolly (12) into the bush, on three cylinder engines the flange must be facing the direction in which the bush will be removed.
3. Place the screw through the dolly from the end giving the maximum protrusion of the screw outside the crankcase.
4. Fit the bridge (8), for the flywheel end centre bush or the depth plate (7) for the gear end centre bush.
5. Fit the thrust nut (9) to the screw.
6. Using the correct size of spanner tighten the thrust nut until the bush is removed.
7. Remove the tool.

Centre Bush Replacement

1. Fit the new lubricated bush to the large dolly (12).
2. Fit the nut (2) onto the screw (1).
3. With the dot on the bush at the top, place the dolly and bush into the appropriate centre web housing and align the bush by using guide (10).
4. Place the screw through the dolly and place the guide (10) over the screw to align the bush in the housing.
5. Assemble the bridge (8), for the flywheel end centre bush, or the depth plate (7) for the gear

- end centre bush.
- Fit the thrust nut (9) to the screw.
 - Using the correct size of spanner and checking the tool and bush alignment very carefully, tighten the thrust nut until the bush is central across its housing.
 - Remove the tool.

Camshaft Bush Tool 317-50006

Notes:

The camshaft bush tool, 317-50006, has been replaced by 393235; both are described and either can be used. The legend numbers referred to in the illustration and text are also marked on the individual tool items.

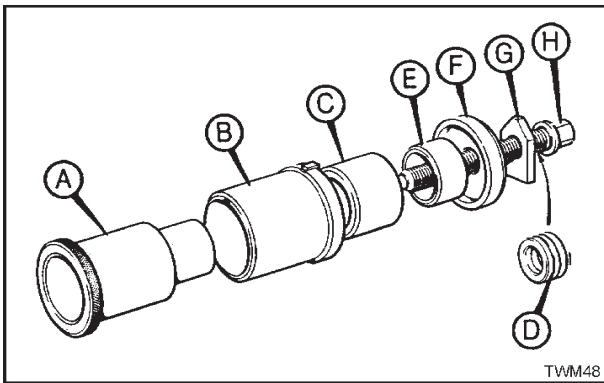


Figure 2.38.2 Camshaft Bush Tool 317-50006

Centre Bush Removal

- Place sleeve (B) over the plug (A) with the locating lug towards the plug head.
- Place the sleeve and plug into the gear end camshaft bush hole. The chamfer on the sleeve will assist in aligning the tool.
- Insert the bolt (H) through the flywheel end camshaft bearing hole.
- Place the washer (E), which must be the same diameter as the centre bearing bush, over the bolt with the flat face towards the bolt head and screw it into the plug until the washer abuts the centre camshaft bush.
- Checking carefully for tool alignment, tighten the bolt to push the washer and bush through the centre web of the crankcase.
- Remove the tool complete with bush.

Centre Bush Replacement

- Place the sleeve over the plug with the locating lug towards the plug head.
- Place the sleeve and plug into the gear end camshaft bush hole.

- The chamfer on the sleeve will assist in aligning the tool.
- Insert the bolt through the flywheel end camshaft hole, place the washer and bush over the bolt with the flat face towards bolt head and screw it into the plug until the bush and washer abuts the centre camshaft bearing hole.
- Checking the tool and bush alignment very carefully, gently screw the bolt until the centre bearing is fully located in the centre web bearing housing.
- Remove the complete tool.

Flywheel End Bush Removal

- Place the plug (A) against the bush.
- Insert the bolt (H) with plate (G) through gear end camshaft bearing housing and screw it into the plug.
- Place the plate in correct position on the centre web and tighten the bolt.
- Ensure the tool is correctly lined up and tighten the bolt until the bush is fully removed.
- Unscrew the plug and remove the tool and bush.

Flywheel End Bush Replacement

- Start the bush by gently tapping it into the housing using a copper or hide faced hammer.
- Place the plug against the bush.
- Insert the bolt with the plate through the gear end camshaft bearing hole and screw it into the plug.
- Place the plate into the correct position on the centre web and tighten the bolt.
- Ensure the tool is correctly lined up and tighten the bolt until the bush is correctly located.
- Unscrew the plug and remove the tool.

2.39 THE CYLINDER BARREL

Before removing any cylinder barrel it should be marked to ensure it is replace to its original orientation.

Cylinder Barrel Removal

- Remove the cylinder head and sump.
- Place a retaining tube, secured by a hand tight cylinder head nut, over one stud of each cylinder from which the head was removed. This will prevent the cylinder rising as the crankshaft is turned.
- With the engine turned over and standing on the flywheel, rotate the crankcase until one connecting rod big end is at BDC.
- Remove the big end bearing cap.

5. To protect the crankshaft journal from possible damage, fit a suitable tube over each connecting rod bolt and secure it with a hand tight nut.
6. Rotate the crankcase until the same piston is at TDC.
7. Mark the cylinder for position and number.
8. Remove the tube securing the barrel.
9. Lift off the barrel, piston and connecting rod as a complete assembly.
10. Remove the tubes from the big end.
11. Replace the big end bearing cap.
12. Remove the piston from the cylinder barrel.
13. Thoroughly clean the cylinder barrel and check for scoring and wear.

Cylinder Barrel Replacement

1. Fit the piston to the connecting rod.
On TS/TR engines ensure the wording 'CAMSHAFT SIDE' on the piston crown is the same side as the identification marks on the connecting rod big end.
2. Insert the gudgeon pin and two circlips; ensure the circlips are correctly located in the grooves.
3. Fit the piston rings in the order as shown in 'Figure 2.40.1'
4. Ensure the piston ring gaps are staggered and fit the piston into the cylinder barrel while compressing the rings.
5. If necessary, fit new big end bearing shells ensuring they are correctly located in both the connecting rod and cap.
6. On TS/TR engines:
Coat the bottom jointing face surface of the cylinder barrel with Hylomar PL32M.
Fit a new joint and coat it with Hylomar PL32M.
7. On TX engines:
Clean and dry the cylinder head clearance shims, the cylinder barrel and crankcase mating surfaces.
Place the shims, dry, onto the bottom of the cylinder barrel.
8. Turn the crankshaft crankpin to TDC.
9. To protect the crankshaft journal from possible damage, fit a suitable tube over each connecting rod bolt and secure it with a hand tight nut.
10. On TS/TR engines:
Ensure the deeper cylinder barrel fins will be facing towards the manifold side and 'CAMSHAFT SIDE' on the piston crown will face towards the camshaft.
- 10a. On TX engines:
Ensure the connecting rod identification marks will face towards the camshaft.
11. Lower the cylinder and piston assembly into

- position.
12. Push down on the top of the piston as the crankcase is rotated until the crankshaft crankpin is at BDC.
13. Remove the protective tubes.
14. Ensure the connecting rod cap bolt head is correctly located against the shoulder on the connecting rod as shown below.
15. Fit the big end bearing cap ensuring the identification numbers are on the same side and identical.

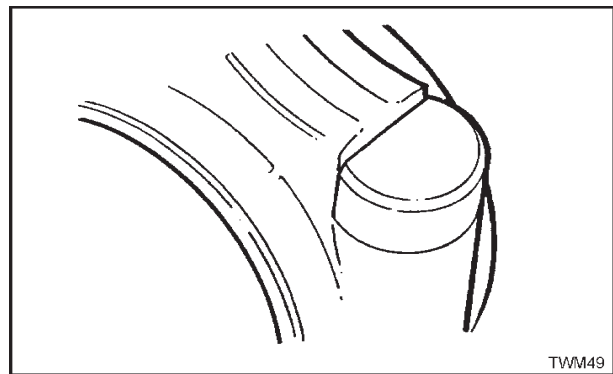


Figure 2.39.1 Bearing Cap Bolt Head Location

16. Replace the connecting rod nuts and torque them to 43.5Nm (32.0lbf ft).
It is recommended that connecting rod bolts and nuts are replaced at every major overhaul.

2.40 THE PISTON AND CONNECTING ROD

The piston is manufactured from low expansion alloy and has a machined recessed combustion chamber in the crown. All pistons are fitted with three cast iron rings except certain TS builds which have five rings.

The gudgeon pin is retained by two circlips and runs in a bush in the small end of the connecting rod.

The forged steel connecting rod is connected to the crankpin by a conventional big end bearing, the cap being held in position by two bolts and nuts. The two halves of the big end bearing are steel backed copper lead and are precision finished and should not be scraped or touched up in any way.

The gudgeon pin is a clearance fit in the small end bush.

The Piston Rings Firing Ring

A barrel lapped chrome ring is situated at the top of the piston and is tapered on the sides to prevent sticking in the groove.

Compression Ring

Two compression rings are fitted to the five ring piston and one on the three ring piston. They have a tapered face in contact with the barrel, one surface on each is marked 'TOP' and the rings must be fitted the correct way up with 'TOP' towards the piston crown.

Oil Control Ring

One conformable type, with a spring expander, is fitted above the gudgeon pin and a slotted scraper ring is fitted below the gudgeon pin on five ring pistons. On a three ring piston only one ring is fitted above the gudgeon pin.

Removing a Piston

1. Remove the cylinder barrel together with the piston.
2. Withdraw the piston from the barrel.
3. Release the circlip from one end of the gudgeon pin.
4. Push out the gudgeon pin.

If the pin is tight, place the piston in hot water until it can be removed; it may be necessary to protect the hands.

5. Using a suitable piston ring expander remove the piston rings.

Inspection and Servicing

- a. Clean the piston, removing all traces of carbon from the crown, ring grooves and oil holes.
- b. Check all the piston rings in the cylinder barrel for the correct gap clearance.
- c. Clean the connecting rod and examine for bending and twisting.
- d. Examine the small end bush for wear.
- e. If the big end has been dismantled because of metal failure the oil passages in the crankshaft must also be examined for obstruction and fragments of metal.

Refitting a Piston

1. Fit the piston to the connecting rod.
On TS/TR engines ensure the wording 'CAMSHAFT SIDE' on the piston crown is the same side as the identification marks on the connecting rod big end.
2. Insert the gudgeon pin and replace the circlips.
3. Using a suitable piston ring expander replace the piston rings in the order as shown below.

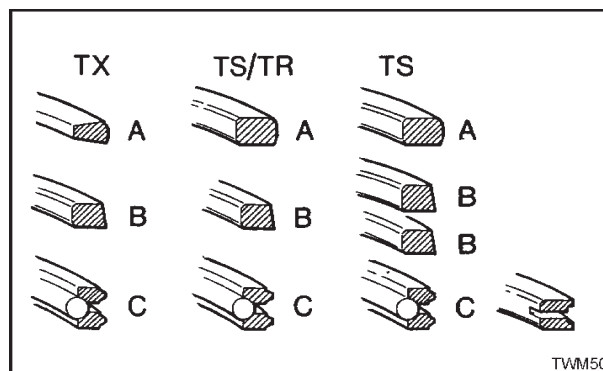


Figure 2.40.1 Piston Rings

A - Firing Ring
B - Compression Ring
C - Oil Control Ring

4. Distribute the piston ring gaps around the piston circumference so that the gaps are not in line.
5. Lightly lubricate the piston and rings with new engine oil.
6. Using a suitable piston ring clamp compress the rings and fit the piston and connecting rod assembly into the cylinder barrel.

2.41 THE FLYWHEEL

The flywheel rotates within the flywheel housing and the type fitted depends on engine, speed, application and build. All flywheels can be fitted with ring gears for electric starting.

The TS/TR cooling air fan is fitted to the outside face and is made of either polypropylene or cast iron depending on the Build; the two types are not interchangeable.

The flywheel is keyed on to the crankshaft and held in position with a setscrew or nut. Early TS and TR engines, up to the serial numbers given, were fitted with a flywheel retaining setscrew and locking washer. Later engines are fitted with a locking washer and nut.

35 00630 TS1	36 00255 TR1
35 06716 TS2	36 00073 TR2
35 05963 TS3	36 00112 TR3

The retaining screw or nut should be torque loaded to 475.0Nm (350.0lbf ft). All flywheels have tapped holes for attaching couplings, shaft extensions, pulleys etc.

The tolerance for bore and face run-out must be within 0.25mm (0.010in) TIR.

Marks showing the firing point (FP) and the TDC position for each cylinder can be viewed through an aperture in the rear of the fanshroud.

The magnetic rotor for the TS and TR charge windings is pressed into the rear face of the flywheel.

⚠ WARNING

The flywheel, without gear ring or fan, weighs in excess of 54kg (1191bs) therefore it is important to bear this point in mind when removing, handling or replacing it. To prevent damaging the TS or TR stator of the flywheel mounted charge windings the free length of studs or bolts entering the flywheel must not exceed 20.0mm (0.79in).

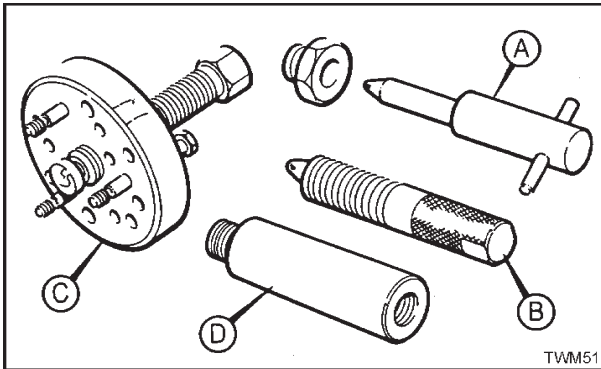


Figure 2.41.1 Flywheel Tools:
A - Early Locking Tool
B - Current Locking Tool
C - Puller
D - Mandrel

Flywheel Removal

1. Remove the starter motor.
2. Fit the flywheel locking tool into the tapped hole in the fanshroud.
3. If the flywheel locking tool is not available wedge the crankshaft with a suitable piece of wood to prevent it turning.
4. Slacken the flywheel retaining screw or nut two turns with a 65mm socket spanner.
5. Fit the flywheel puller tool by screwing three bolts through the 'B' holes into the flywheel.
6. Turn the tool centre bolt sufficiently to loosen the flywheel.
7. Remove the puller and locking tools.
8. Remove the flywheel screw or nut and fit the correct flywheel mandrel to prevent damaging the stator and for personal safety.
9. Support the flywheel at all times and keeping it square, slide it over the mandrel and lift it off.
10. Remove the Woodruff key.

Refitting the Flywheel

The shaft and the bore of the flywheel must be perfectly clean and should be smeared with clean lubricating oil before assembly.

1. Fit a new Woodruff key.

2. Fit the correct flywheel mandrel to prevent damaging stator and for personal safety.
3. Support the flywheel at all times and keeping it square, slide it over the mandrel and into the fanshroud.
Check that the key has remained in position in the shaft.
4. Remove the mandrel.
5. Fit a new tabwasher and replace the setscrew/nut.
6. Either fit the flywheel locking tool or wedge the crankshaft with a suitable piece of wood to prevent it turning.
7. Torque the retaining screw or nut to 475.0Nm (350.0lbf ft).
8. Remove the locking tool.

2.42 THE FANSHROUD - TS/TR

An aluminium fanshroud is fitted to all engines except Build 16 which has one of sheet metal.

Removing the Fanshroud

1. Remove the flywheel.
2. Remove the two nuts and then remove the rectifier/regulator cover.
3. Carefully noting the position of the electrical cables, disconnect all four cables.
4. Remove the two nuts, washers and distance pieces and remove the rectifier/regulator unit from the fanshroud.
The unit will be fitted to either, the manifold side of the shroud or above the starter motor.
5. Remove the cable clip securing the cable inside the fanshroud.
6. Remove the six screws securing the stator and remove it, gently easing the cable through the fanshroud.
7. Remove the two bolts that are fitted through the lower end of the fanshroud securing it to the sump.
8. Remove the self-lock bolts.
 - a. On older engines ease back the tab washers and remove the bolts.
9. Lift off the housing.

Refitting the Fanshroud

Refitting is carried out in the reverse order and it is recommended that new tabwashers are fitted and correctly locked after the bolts have been torque loaded to 43.5Nm (32.0lbf ft).

The tabwashers and bolts can be replaced with the current self-locking setscrews which must be torque loaded to 88.0Nm (65.0lbf ft).

⚠ CAUTION

If the sump has been removed, the procedure detailed in "Replacing the Oil Sump" must be followed when refitting the fanshroud to prevent the possibility of distorting it resulting in excessive flywheel to shroud run-out. This is particularly important on Build 16 engines.

2.43 FLYWHEEL HOUSING - TX**Removing the Flywheel Housing**

1. Remove the flywheel.
2. Remove the six self-locking setscrews.
3. Remove the fanshroud, noting that it is secured to the sump by two bolts.

Refitting the Flywheel Housing

Refitting is carried out in the reverse order with the self-locking setscrews torque loaded to 88.0Nm (65.0lbf ft).

⚠ CAUTION

If the sump has been removed, the procedure detailed in "Replacing the Oil Sump" must be followed when refitting the fanshroud to prevent the possibility of distorting it resulting in excessive flywheel to shroud run-out.

2.43 MAIN BEARING HOUSING

The main bearing housing is secured to the crankcase at the flywheel end and has an oil drain which must be located towards the bottom of the crankcase when the housing is refitted. Shims are fitted between the housing and the crankcase to maintain the crankshaft end float. An oil seal is fitted to the centre bore of the housing and an 'O' ring is fitted in the side of the bearing housing to provide a seal between the housing and bearing oil feed drilling in the crankcase.

On engines fitted with battery charging equipment the stator is secured to the main bearing housing with screws.

If the crankshaft is moved towards the flywheel end after the housing has been removed the thrust washer at the gear end could become detached from its recess. This can be avoided by removing the gear end cover and placing two suitable thin strips of metal between the crankshaft pinion and the crankcase.

To prevent the thrust washer at the flywheel end becoming detached from the main bearing housing while removing the housing, turn the engine until No. 1 cylinder piston is at the BDC position.

Removing the Main Bearing Housing

1. Remove the centre bearing locating dowel securing screw (A) from the fuel pump side of the engine.

⚠ CAUTION

Failure to remove the dowel may result in distorting it making it difficult to remove at a later stage.

2. Using a fuel pump securing bolt remove the centre bearing dowel (B); leave the bolt in the dowel until it is refitted to ensure the dowel is fitted the correct way round.

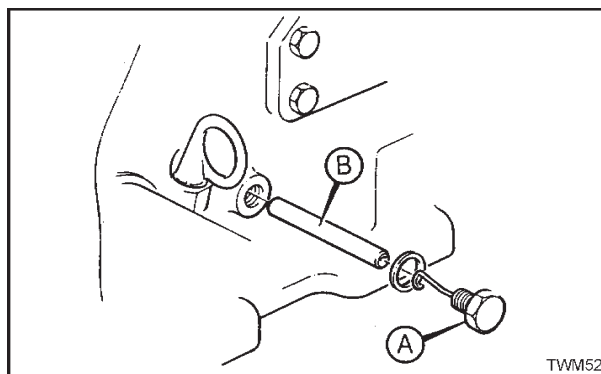


Figure 2.43.1 Centre Bearing Dowel

3. Remove the bolts securing the main bearing housing.
4. On early TS engines remove the charge winding adaptor adapter.
5. Remove the bearing housing: if it is tight use two M8 setscrews through the threaded holes provided and jack it off.
6. Drift out the oil seal taking care not to damage the bearings.

Refitting the Main Bearing Housing

When refitting the housing ensure that the oil supply holes line up and the grooved bearing shell is fitted at the top.

1. Lightly grease the steel back of the thrust washers and position them in the housing, ensure they are correctly located and the copper face will be towards the crankshaft.
2. Remove the oil seal from the main bearing housing.
3. Coat the bearing housing face with Loctite 221, fit a shim and coat the outside face of the shim. Continue adding and coating the remaining shims.
4. Replace the housing and charge winding adaptor, if fitted, and torque the bolts to 27.0Nm (20.0lbf ft).
5. Check the crankshaft endfloat.

6. Replace the oil lip seal.
7. Replace the centre bearing locating dowel/s with the tapped end facing outwards.
8. Replace the locating dowel securing screw and torque it to 20.5Nm (15.0lbf ft).

⚠ CAUTION

Striking the crankshaft may displace the thrustwashers and damage the bearing locating dowel.

The Main Bearing Oil Lip Seal

1. Place the new seal squarely into the housing; do not use any jointing compound.
2. Hold the oil seal tool onto the outside face of the seal and using the oil seal tool, drive in the seal until the tool shoulder is against the bearing housing.

2.44 THE CRANKSHAFT

The crankshaft is a steel forging and is carried in steel backed copper faced main bearings which are located in the crankcase at the gear end, the flywheel end and the central web/s of the crankcase.

End thrust is taken on steel backed copper faced split thrust washers fitted at the gear end of the crankcase and in the flywheel end main bearing housing.

The main bearings are in two halves which are not interchangeable; the top half has an oil groove and an oil hole which must be correctly located.

An interference fit pinion is keyed onto the end of the crankshaft and engages with the camshaft gear.

Early crankshaft balance weights were secured with only one retaining bolt up to the following engines:

35 00630 TS1	36 00255 TR1
35 06716 TS2	36 00073 TR2
35 05963 TS3	36 00112 TR3

After these and on all TX engines the weights were secured by two capscrews; the later weights and capscrews are not interchangeable with the original items.

Crankshaft Removal

1. Remove the cylinder barrels and pistons, main bearing housing and the sump.
2. Using the Service Tool 393175 remove the crankshaft pinion.

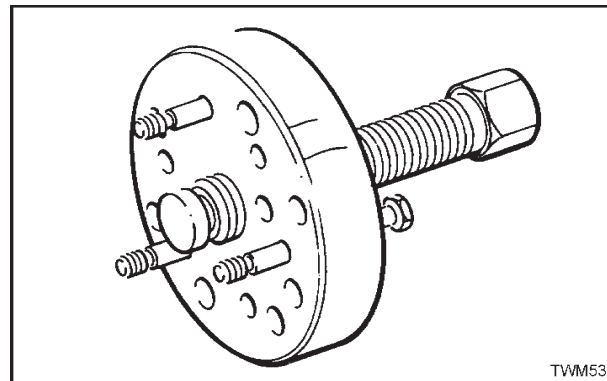


Figure 2.44.1 Crankshaft Gear Removal Tool

3. Remove the pinion gear Woodruff key if necessary.
4. Remove each centre bearing locating dowels securing screw (A).

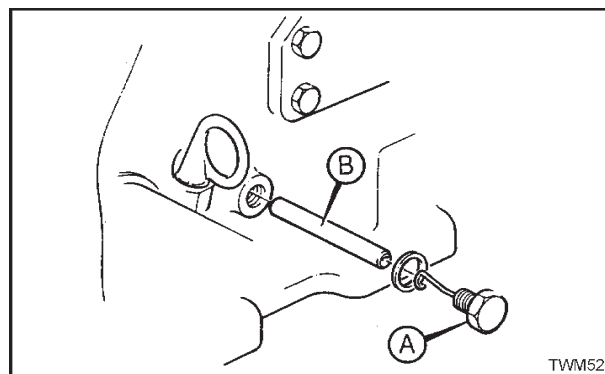


Figure 2.44.2 Centre Bearing Dowel

5. Using a fuel pump securing bolt remove each centre bearing dowel (B). Leave the bolt in the dowel until it is refitted to ensure the dowel is fitted the correct way round.
6. Remove the crankshaft balance weights.
7. Gently withdraw the crankshaft through the flywheel end of the crankcase.
8. Remove the two socket screws and dismantle the centre bearing housing/s.
9. Remove the gear end thrust washers.

Servicing the Crankshaft

- a. Inspect the main bearings for scoring or wear. If necessary, the bearings can be removed and replaced using either Service Tool 393235 or 317-50006 as described in "02.47 Crankshaft Main Bearings".
- b. If the connecting rod big end has been dismantled because of failure of the bearing, the oil passages in the crankshaft must also be examined for obstruction and fragments of metal.
- c. Check the clearance between the crankshaft and journals, the main bearings and crankpins and

- also the connecting rod bearings.
- d. Examine all bearing surfaces for scoring and wear.
- e. Renew the split thrust washers if they are damaged or worn.

Refitting the Crankshaft

1. If necessary fit new bearing shells to the main bearing housing, centre bearing housing/s and the gear end crankcase main bearing.

The grooved bearing shell must be to the top and the oil holes must be lined up.

2. Re-assemble the centre main bearing housing/s around the crankshaft ensuring the socket screws are tightened.

Ensure 'Flywheel End' on the housing halves is correctly located before assembly.

3. Apply grease to the steel side of the thrust washers and place them in the gear end of the crankcase with the tab correctly located and the copper face towards the crankshaft.

4. Offer up the crankshaft, lining up the centre bearing to ensure each dowel hole is in the correct position.

Take special care when passing the crankshaft through the gear end bearing as it is quite easy to score the bearing shell with the crankshaft.

5. With the fuel pump bolt inserted in the centre bearing dowel (B), insert the dowel through the crankcase wall and into the centre bearing housing.

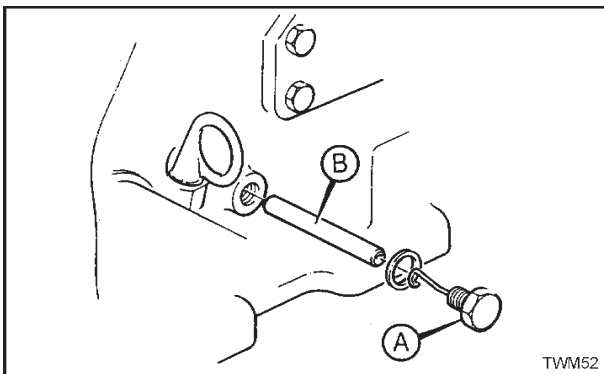


Figure 2.44.3 Centre Bearing Dowel

⚠ CAUTION

Ensure the dowel has gone fully home and that it is not abutting the main bearing housing shoulder or capscrew recess.

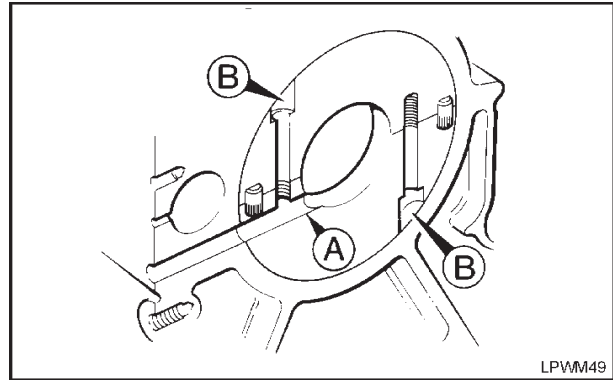


Figure 2.44.4 Dowel Hole Alignment

A - Dowel Hole

B - Capscrew Head Recess

6. Replace the locating dowel securing screw and torque load it to 20.5Nm (15.0lbf ft).
 7. Remove the fuel pump bolt from the dowel.
 8. Refit the crankshaft balance weights, with the stamped part numbers facing each other, and torque load to 57.0Nm (42.0lbf ft).
- Early balance weights only have one retaining screw.
9. Lock the bolts by preening them with a centre punch.
 10. Replace the rear main bearing housing.
 11. Check that the crankshaft is free to rotate.
 12. Fit the Woodruff key at the gear end.
 13. Heat the crankshaft pinion to straw yellow and fit it to the crankshaft without delay ensuring the '0' mark is facing outwards.
- Insufficient heat or delay in fitting could well cause the pinion to become jammed on the crankshaft, whereas overheating may cause softening of the pinion.
14. Check the crankshaft end float.

2.45 CRANKSHAFT END FLOAT

1. Set a dial test indicator so that the actuating plunger makes contact with the flywheel end face of the crankshaft.
 2. Push the crankshaft firmly towards the gear end of the engine and zero the indicator.
 3. Push the crankshaft firmly towards the flywheel end of the engine and check the end float; this should be:
 - TS/TR1: 0.178-0.305mm (0.007-0.012in)
 - TS/TR/TX2,3: 0.229-0.356mm (0.009-0.014in).
 4. If the end float is incorrect adjust by the addition or removal of 0.127 or 0.254mm (0.005 or 0.010in) shims.
- Shims are fitted to the flywheel end main bearing housing.

Notes:

On current engines 0.127 and 0.254mm (0.005 and 0.010in) aluminium shims control the endfloat and are assembled as given in "02.43 Main Bearing Housing".

Early TS and TR engines may have paper and 0.076mm (0.003in) metal shims assembled dry, or with Wellseal.

5. After the bearing housing has been replaced the housing bolts are torqued to 27.0Nm (20.0lbf ft).

2.46 CHECKING BEARING CLEARANCE

1. Place a piece of the correct size 'Plastigauge' approximately 6.35mm (0.25in) off-centre across the full width of one bearing shell.

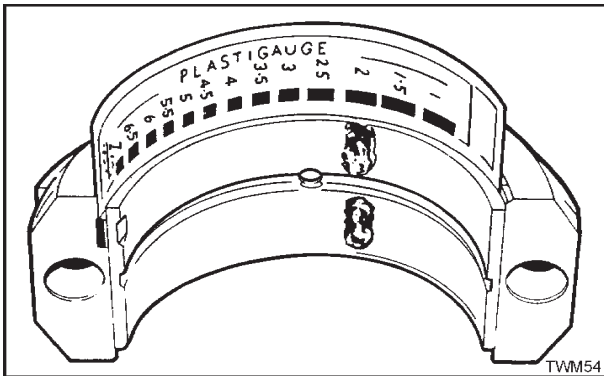


Figure 2.46.1 Checking Bearing Clearance

2. Replace the bearing and torque the nuts.
3. Remove the bearing shell and use the scale to check the width of the flattened 'Plastigauge'; the width at the widest point establishes the minimum clearance and at the narrowest point the maximum clearance.
The difference between the two readings is the journal to bearing clearance.

CAUTION

Care must be taken to ensure the crankshaft is not turned when the Plastigauge is in place, and all traces of it must be removed before final assembly of the bearing.

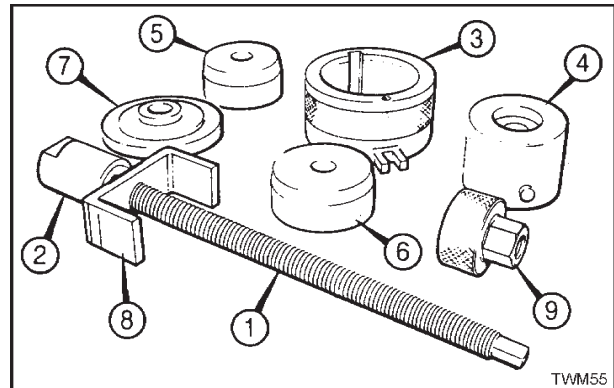
2.47 CRANKSHAFT MAIN BEARINGS**Main Bearing Tool 393235**

Figure 2.47.1 Main Bearing Tool

Note:

This tool replaces 317-50006; both are described and either can be used. The legend numbers referred to in the illustration and text are also marked on the individual tool components.

Gear End Main Bearing Removal

1. Fit the nut (2) onto the screw (1).
2. Place both dollies (5, 6) onto the screw with the tapered ends outwards and the large dolly (6) next to the nut (2).
3. Insert the assembly into the main bearing from inside the crankcase.
4. Fit the bridge (8) followed by the thrust nut (9) onto the screw (1).
5. Locate the bridge against the outside of the crankcase.
6. Using the correct size of spanner tighten the thrust nut (9) until the main bearing shells are removed from the crankcase.

Gear End Main Bearing Replacement

1. Remove the thrustwashers from the crankcase.
2. Fit the nut (2) and bridge (8) onto the screw (1). Ensure the tang on the nut is correctly located into the slot on the bridge.
3. Place both halves of the new bearing into the sleeve (3) from the end opposite the locating spigots.
Align the ends of the new bearings with the letter 'G' on the sleeve and ensure the bearing oil hole is correctly lined up with the '0' mark on the sleeve face.
4. Place the dolly (6) with the taper outwards into the spigot end of the sleeve (3).
5. Fit the driver (4) into the other end of the sleeve,

ensuring the guide dowel is positively located in the slot in the sleeve.

6. Fit the assembly onto the crankcase from the outside making sure the forked sleeve spigot is fully located on the crankcase lower end cover dowel.
7. Place the screw assembly inside the crankcase and fit it to the sleeve assembly.
8. Place the depth plate (7) onto the screw with the 'G' face next to the driver (4).
9. Fit the thrust nut (9).
10. Using the correct size of spanner tighten the thrust nut (9) until the depth plate is tight to the sleeve.
When the plate is tight to the sleeve the bearing shells are correctly located in the crankcase.
11. Remove the tool taking care to prevent it dropping onto the new bearing.
12. Check that the oil holes in the crankcase and bearings align.

Flywheel End Main Bearing Removal

1. Remove the thrustwashers and the oil seal from the bearing housing.
2. Fit the nut (2) onto the screw (1).
3. Hold the nut firmly across its flats in a vice.
4. Place both dollies (5, 6) onto the screw with the tapered ends outwards and the large dolly (6) next to the nut (2).
5. Fit the bearing housing on the screw with the thrust face uppermost.
6. Fit the bridge (8) followed by the thrust nut (9) onto the screw (1).
7. Using the correct size of spanner tighten the thrust nut (9) until the main bearing shells are removed from the bearing housing.
8. Remove the tool.

Flywheel End Main Bearing Replacement

The top half of the plain bearing in the main bearing housing has a locating tongue which locates into its recess in the main bearing housing when fully fitted.

1. Fit the nut (2) onto the screw (1).
2. Hold the nut firmly across its flats in a vice.
3. Place both halves of the new bearing into the sleeve (3) from the end opposite the locating spigots.
Ensure the tag on the top half of the new bearings faces outwards and is correctly located in the slot in the sleeve and check that the ends of the bearings line up with the 'F' mark on the sleeve.
4. Place the dolly (6) with the taper outwards into the spigot end of the sleeve (3).

5. Fit the driver (4) into the other end of the sleeve, ensuring the guide dowel is positively located in the slot in the sleeve.
6. Place the depth plate (7) onto the screw (1) with the face marked 'F' uppermost.
7. Place the sleeve assembly onto the screw with the driver (4) next to the depth plate (7).
8. Place the bearing housing onto the screw with the thrust face downwards.
Ensure the sleeve spigot is located in the recess in the bearing housing.
9. Fit the bridge (8) followed by the thrust nut (9) onto the screw (1).
10. Using the correct size of spanner tighten the thrust nut (9) until the depth plate (7) is against the sleeve.
When the depth plate is against the sleeve the main bearing shells are correctly located in the housing.
11. Remove the tool taking care to prevent it dropping onto the new bearing.
12. Check that the oil holes in the housing and bearings align.

Intermediate Main Bearing

The grooved bearing shell must be fitted to the top half of the bearing housing with the oil holes aligned.

Re-assemble the centre main bearing housings around the crankshaft ensuring the socket screws are tightened.

Ensure the 'Flywheel End' identification marks on the housing halves are correctly located before assembly.

Main Bearing Tool 317-50006

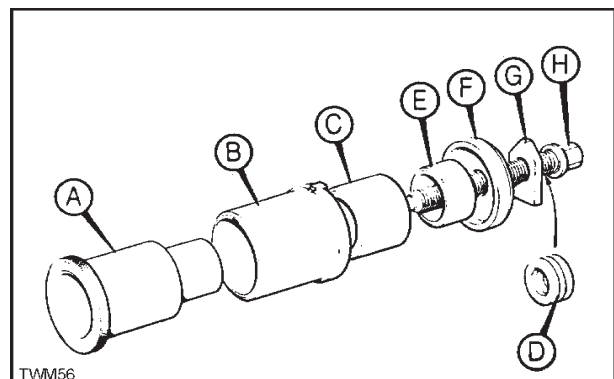


Figure 2.47.2 Main Bearing Tool 317-50006

Note:

This tool has been replaced by 393235; both are described and either can be used.

Gear End Main Bearing

1. Fit the correct bearing locating ring (C) onto the plug (A).
Four bearing rings are available for standard and undersize bearings.
2. Insert the plug and bearing ring into the main bearing shells until the bearing ring is located completely in the bearing shells.
3. Fit the sleeve (B) inside the crankcase with the locating lug on the sleeve positioned in the thrust washer locating groove in the crankcase.
4. Push the bolt (H) through the ball bearing, if used, and through centre of the spacer (F) with the recessed face of the spacer nearest the bolt head.
5. Fit the bolt from inside the crankcase through the sleeve and screw it into the plug (A).
6. Maintain a firm grip on the flange of the plug and tighten the bolt until main bearing shells are pushed fully into the sleeve of the tool.

Gear End Main Bearing Replacement

The top section of the gear end main bearing shell has an oil groove but no locating lug. When fitting new shells extreme care must be taken to ensure that the oil ways in the shells and crankcase are aligned. If not correctly aligned oil restriction or starvation may occur.

1. Position the sleeve (B) on a flat surface with the locating lug facing downwards.
2. Slide the two halves of the new bearing into the top of the sleeve together, ensure the ends of the new bearings are at 90° to the locating lug.
3. Fit the correct bearing locating ring (C) onto the plug (A).
Four bearing rings are available for standard and undersize bearings.
4. Fit the plug into the sleeve (B) with the bearing ring located completely in the bearing shells.
5. Place the assembly into the crankcase with the locating lug on the sleeve positioned in the thrust washer locating groove in the crankcase.
6. Place the ball bearing, if used, onto the bolt (H) followed by the spacer (F) with plain face towards the bolt head.
7. Push the bolt into the crankcase, locating the spacer squarely against the outside of the crankcase and screw the bolt into the plug.
8. Tighten the bolt until the bearing shells are drawn into position.

Flywheel End Main Bearing Removal/Replacement

The removal and fitting of bearing shells in the main

bearing housing is carried out by the same method. The bearing housing should be held securely in a vice or refitted to the engine.

The oil seal assembly should first be pushed out from the centre of the housing.

The top half of the plain bearing in the main bearing housing has a locating tongue which must be fitted into the groove of the sleeve to ensure the tongue locates into its recess in the main bearing housing when fully fitted.

Intermediate Main Bearings

The grooved bearing shell must be fitted to the top half of the bearing housing and the oil holes must be aligned. Re-assemble the centre main bearing housings around the crankshaft ensuring the socket screws are tightened.

Ensure the 'Flywheel End' identification marks on the housing halves are correctly located before assembly.

2.48 GEAR END DRIVES

These must be correctly torque loaded to 362.0Nm (267.0lbf ft).

Where it is not possible to torque direct at the gear end:

1. Apply torque to the flywheel screw or nut with the engine decompressed.
2. With the flywheel locked re-torque the flywheel retainer to 474.5Nm (350.0lbf ft).

Crankshaft Extension Spanner 317-50060

The tool is used when it is not possible to torque direct at the gear end with the flywheel locked.

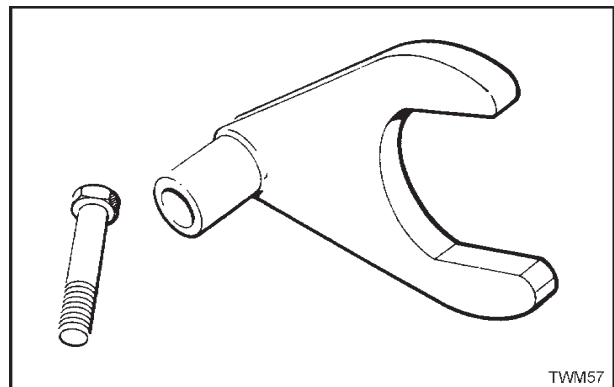


Figure 2.48.1 Extension Spanner 317-50060

1. Fit the open ended section behind the pinion or onto the shaft.
2. Place the bolt through the boss and into the crankcase.
3. With the engine decompressed turn the

- flywheel using a 65mm socket (317-50052).
4. Remove the tool.
 5. Fit the flywheel locking tool.
 6. Re-torque the flywheel screw or nut to 474.5Nm (350.0lbf ft).

2.49 THE OIL FILTER

The standard full flow oil filter is a spin-on cartridge type located on the side of the crankcase and remote mounted oil filters are available for all engines.

Genuine Lister Petter Power Systems approved filters should be used as these have the correct bypass valve pressure to match the self regulating oil pump, high temperature joints, adequate filter paper characteristics and a rigid case. The fact that a proprietary filter may have the same external dimensions and thread as the genuine one is no guarantee that it will not fail in service.

Changing the Oil Filter

A readily available strap wrench is required to remove the filter from the engine but must not be used to fit a replacement.

1. Using a suitable strap wrench, unscrew and remove the old filter.
2. Thoroughly clean the crankcase filter housing face.
3. Apply a small amount of clean engine oil to the oil filter sealing joint.
4. Screw on the new oil filter, by hand, until the sealing joint is just touching the crankcase and tighten a further half turn.

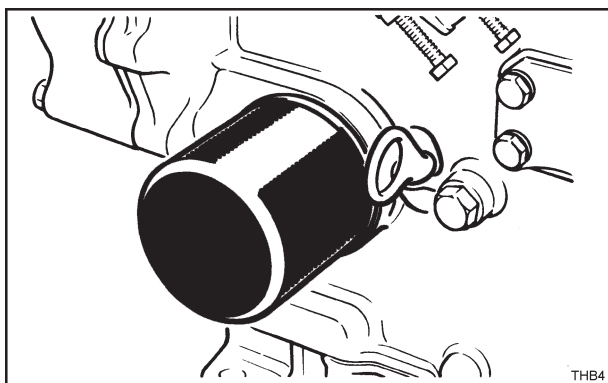


Figure 2.49.1 Changing the Oil Filter

5. Run the engine and check for any oil leaks.
6. Stop the engine, allow the oil to settle and check the level on the dipstick.
7. Add more oil if necessary.

2.50 THE OIL DIPSTICK

Nylon handled dipsticks have been fitted to all TR and TX engines and were introduced on TS engines from:

- 35 01426 TS1
- 35 06750 TS2
- 35 05365 TS3

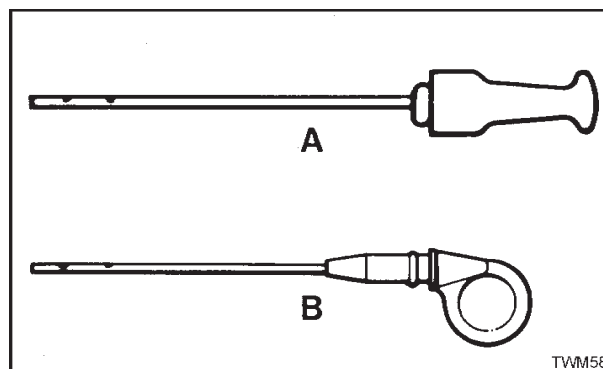


Figure 2.50.1 Dipsticks:
A - Early TS
B - Later TS, all TR and TX

CAUTION

The new type dipsticks are not fitted with a crankcase adapter and an existing adapter must not be removed to allow the new type of dipstick to be used as the adapter bore has no lead-in chamfer. If the adapter is removed damage to the 'O' ring may lead to loss of crankcase vacuum and ingress of dirt.

2.51 THE OIL SUMP

The sump is manufactured from cast iron and is secured to the crankcase by bolts and spring washers; the four corner bolts are longer than the remainder.

The integral engine mounting bolt drillings are located on each corner of the sump.

An oil strainer is fitted inside the sump and a drilling in the casting carries oil from the sump through the strainer to the oil pump.

An anti-surge plate, fitted to the oil strainer lays alongside the crankcase web when the sump is fitted.

Draining and Filling the Sump

1. If possible run the engine immediately before draining the oil.
2. Place a suitable container under the drain plug.
3. Remove the plug.

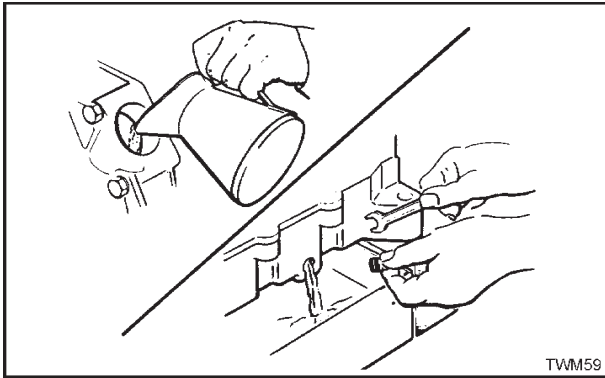


Figure 2.51.1 Oil Filler and Drain

4. Clean and coat the threads of the drain plug with Hylomar PL32/M or Three Bond 1110B.
5. Replace the drain plug taking care not to overtighten it.
6. Fill the sump to the correct level with the correct grade and type of lubricating oil.
7. Start the engine and run it for a few minutes to circulate the oil and check the drain plug does not leak.
8. Stop the engine and allow time for the oil to settle and re-check the level on the dipstick.
9. Add more oil if necessary.

Oil Sump Capacity

	litres	pints	US qts
TS/TR1	2.7	4.7	2.8
TS/TR/TX2	4.0	7.0	4.2
TS/TR/TX3	6.0	10.5	6.3

Removing the Sump

1. Remove the drain plug from the sump and drain the oil into a suitable receptacle.
2. Remove the oil level dipstick.
A polypropylene handled dipstick is currently fitted; refer to "02.50 The Oil Dipstick".
3. Stand the engine on its flywheel using a suitable piece of wood or similar material on which to rest the flywheel but not the fanshroud; this will enable the engine to be rotated and ease subsequent dismantling.
4. Remove the sump bolts and spring washers noting that two bolts pass through the fanshroud into the sump.
As the bolts are removed from the sump the oil pump will move it away from the crankcase.
5. Remove the sump taking care not to damage the oil pump.

Replacing the Oil Sump

1. Using a new joint, replace the sump with the recess corner adjacent to the oil pump.
2. Replace the four long corner bolts finger tight.
3. Replace the two bolts through the fanshroud into the sump and torque them to 43.5Nm (32.0lbf ft).
4. Replace and torque the remaining sump bolts to 27.0Nm (20.0lbf ft).
5. Coat the threads of the drain plug with Hylomar PL32/M or Three Bond 1110B and refit.
6. Return the engine to its normal position.
7. Fill the sump to the correct level with the correct grade and type of lubricating oil.
8. Start the engine and run it for a few minutes to circulate the oil and check the drain plug does not leak.
9. Stop the engine and allow time for the oil to settle and re-check the level on the dipstick.
10. Add more oil if necessary.

⚠ CAUTION

If the procedure in items 2. and 4. is not correctly carried out there is a possibility of distorting the fanshroud resulting in excessive flywheel to fanshroud run-out. The tolerances for bore and face run-out must be within 0.25mm (0.010in) TIR.

2.52 THE OIL STRAINER AND PUMP

The Oil Strainer

The engines are fitted with a coarse lubricating oil strainer on the suction side of the oil pump; access to the strainer is gained by removing the sump.

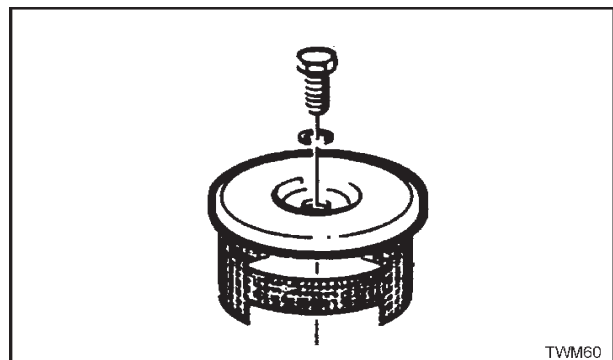


Figure 2.52.1 Oil Strainer

Care must be taken to ensure that rags are not used to wipe the inside of the crankcase during overhauls to eliminate the possibility of fluff entering the strainer and causing a restricted oil flow.

Note - Early TS Engines:

On re-assembly take care to replace the distance piece under the top plate and ensure that the anti-surge plate on the strainer is parallel to the crankcase web.

Oil Pump

The camshaft operated oil pumps are the self-regulating, plunger type and they are not interchangeable across the ranges.

Removing the Oil Pump

1. Drain the oil.
2. Remove the dipstick and sump.
3. Lift out the oil pump.
4. Using long nosed pliers remove the oil pump push rod from the crankcase.
5. Dismantle the oil pump making a careful note of the component positions and the two different sized ball valves.

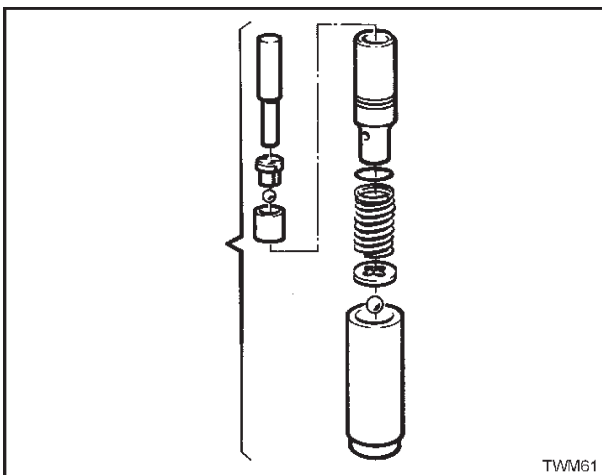


Figure 2.52.2 The Oil Pump

Refitting the Oil Pump

1. Check that the oil pump is correctly assembled as shown.
2. Check that the pump is working freely by compressing it between the palms of the hands.
3. Replace the oil pump push rod with the larger diameter towards the camshaft.
4. Replace the oil pump with the plunger end towards the push rod.
5. Replace the sump, drain plug and the dipstick.
6. Refill the sump with oil.

2.53 THE OIL SEALS

Lip type seals are fitted to all TR and current TS engines although two other types have been fitted to early TS engines:

- Rotary type - very early TS2, 3.
- Screw type - early TS2, 3.

A lip seal is fitted to the gear end cover with a rotary, screw or lip type fitted in the flywheel end main-bearing housing.

Lip Seals

The seals used must be the approved type as supplied by Lister Petter Power Systems and they are fitted without any jointing compound being applied.

Lip type seals will not seal if the shaft is scratched or bruised within 5mm (0.20in) either side of the path of the lip of the seal.

A finely and accurately ground shaft without chatter marks and with a surface finish of 0.4 microns Ra (16 micro inches CLA) maximum is advisable.

Emery cloth of any grade must not be used in the area of the lip. Very fine scratches should be corrected by polishing the working surface with a wet mixture of metal polish and optical aluminium oxide powder, failing this domestic scouring powder may be used. Fold a strip of rag some 400mm long by 50mm wide lengthwise into a 10mm belt and wet it with the abrasive mixture, wrap the belt once around the shaft and use it with a reciprocating motion.

The End Cover Lip Seal

1. Remove the end cover and press out the old seal.
2. Place a new seal into the outside neck of the end cover, lip side first, and position it squarely on the shoulder of the seal boss; do not use any jointing compound.
3. Using the oil seal tool, 317-50065 press the seal into position within the oil seal housing boss until it is flush with the inside face of the boss.
In an emergency if the tool is not available a suitable plug, preferably hard wood, can be used.

The Main Bearing Housing Lip Seal

1. Remove the bearing housing and press out the old seal.
2. Place the new seal squarely into the housing; do not use any jointing compound.
3. Hold the oil seal tool, 317-50065, onto the outside face of the seal and drive in the seal until the tool shoulder is against the bearing housing.
In an emergency if the tool is not available a suitable plug, preferably hard wood, can be used.

The Rotary Oil Seal

If a rotary seal requires changing on a very early engine it can be replaced by the current lip type.

The three components of the rotary seal are:

- a. A rotating impeller which is an interference fit on the crankshaft and has an oil sealing thread machined on the outside diameter.

b.A felt ring, held in place by a stationary retaining cap, which acts as a dust seal.

c.A retaining cap which is an interference fit in the bearing housing.

Special tools are required to assemble the seal to achieve the correct spacing between the impeller and the inner edge of the retaining cap and to ensure the components are square to the crankshaft.

The impeller must not be allowed to touch the retaining cap otherwise damage will result.

Special care must be taken when fitting the impeller not to damage the oil sealing thread or oil leaks will occur.

The Screw Type Seal

The crankcase may be sealed at the crankshaft by a screw type oil seal and a felt ring. The seals are marked with an arrow to show the engine rotation for which they are intended.

The seal must be concentric with the crankshaft, with the maximum permissible variation of gap being 0.075mm (0.005in).

A ring type oil thrower is fitted over the crankshaft at the flywheel end before the main bearing housing is replaced.

- 1.Apply a small amount of Hylomar PL32/M to the outside diameter of the seal
- 2.Before inserting the felt, the inside of the grooves should be coated with Wellseal.
- 3.Lightly oil the felt sealing surface.
- 4.Assemble the seal to the crankshaft.

WARNING

Under no circumstances must the felt seal be distorted or damaged in any way before or during fitting.

3. ENGINE FLUIDS

3.1 ENGINE FLUIDS - LUBRICATING OIL

European Oil Specifications

ACEA specifies the following:

Gasolene engines: A1-96, A2-96, A3-96.

Light duty diesel engine operation:

B1-96, B2-96, B3-96.

Heavy duty and commercial vehicle diesel engine operation: E1-96, E2-96, E3-96.

The Oil Classification System

The information contained in this section has been extracted from "Lubricant and Fuel Performance", with the permission of 'The Lubrizol Corporation.

⚠ CAUTION

Some of the following classifications may not be available in your country. In cases of difficulty, it is suggested contact be made with a reputable oil supplier or any Lister Petter Distributor.

Note:

US 'S' grade oils are for gasolene engines and are not recommended for Lister Petter Power Systems diesel engines.

Past and Current US API Grade Oils

API Service Category CA:

Service typical of diesel engines operated in mild to moderate duty with high-quality fuels; occasionally has included gasoline engines in mild service.

Oils designed for this service provide protection from bearing corrosion and ring-belt deposits in some naturally aspirated diesel engines when using fuels of such quality that they impose no unusual requirements for wear and deposit protection.

They were widely used in the 1940's and 1950's but should not be used in any engine unless specifically recommended by the equipment manufacturer.

API Service Category CB:

Service typical of diesel engines operated in mild to moderate duty, but with lower quality fuels, which necessitate more protection from wear and deposits; occasionally has included gasoline engines in mild service.

Oils designed for this service were introduced in 1949. They provide necessary protection from bearing corrosion and from high temperature deposits in naturally aspirated diesel engines with higher sulphur fuels.

API Service Category CC:

Service typical of certain naturally aspirated diesel engines operated in moderate to severe duty service, and certain heavy duty gasoline engines. Oils designed for this service provide protection from high temperature deposits and bearing corrosion in diesel engines, and also from rust, corrosion, and low temperature deposits in gasoline engines. These oils were introduced in 1961.

API Service Category CD:

Service typical of certain naturally aspirated, turbocharged or supercharged diesel engines where highly effective control of wear and deposits is vital, or when using fuels with a wide quality range (including high-sulphur fuels).

Oils designed for this service were introduced in 1955 and provide protection from high-temperature deposits and bearing corrosion in these diesel engines.

API Service Category CD-11:

Severe duty two-stroke

Service typical of two-stroke cycle diesel engines requiring highly effective control of wear and deposits.

Oils designed for this service meet all performance requirements of API Service Category CD.

API Service Category CE - 1983:

Service typical of certain turbocharged or supercharged heavy duty diesel engines, manufactured since 1983 and operated under both low speed, high load and high speed, high load conditions.

Oils designated for this service may also be used when API Service Category CD is recommended for diesel engines.

API Service Category CF-4 -1990:

Service typical of high-speed, four-stroke cycle diesel engines.

API CF-4 oils exceed the requirements for the API CE category, providing improved control of oil consumption and piston deposits.

These oils should be used in place of API CE oils. They are particularly suited for on-highway, heavy duty truck applications. When combined with the appropriate 'S' category, they can also be used in gasoline and diesel powered personal vehicles - i.e., passenger cars, light trucks, and vans - when recommended by the vehicle or engine manufacturer.

API Service Category CF:

Indirect injection

Service typical of indirect-injected diesel engines and other diesel engines that use a broad range of fuel types, including those using fuel with high sulphur content; for example, over 0.5% weight.

Effective control of piston deposits, wear and copper-containing bearing corrosion is essential for these engines, which may be naturally aspirated, turbocharged or supercharged.

Oils designated for this service have been in existence since 1994 and may be used when API Service Category CD is recommended.

API Service Category CF-2:

Severe duty, two-stroke cycle

Service typical of two-stroke cycle diesel engines requiring highly effective control over cylinder and ring-face scuffing and deposits.

Oils designed for this service have been in existence since 1994 and may also be used when API Engine Service Category CD-11 is recommended.

These oils do not necessarily meet the requirements of API CF or CF-4 unless they pass the test requirements for these categories.

API Service Category CG-4 - 1994:

Severe duty

API Service Category CG-4 describes oils for use in high-speed four-stroke-cycle diesel engines used in both heavy-duty on-highway (0.05% weight sulphur fuel) and off-highway (less than 0.5% weight sulphur fuel) applications.

CG-4 oils provide effective control over high-temperature piston deposits, wear, corrosion, foaming, oxidation stability, and soot accumulation.

These oils are especially effective in engines designed to meet 1994 exhaust emission standards and may also be used in engines requiring API Service Categories CD, CE, and CF-4. Oils designed for this service have been in existence since 1994.

The Oil Specification

To help assist engine running-in, all engines are despatched with an initial fill lubricating oil which must be changed after 100 hours.

1. The temperatures mentioned in the table are the ambient temperatures at the time when the engine is started. However, if monograde oils are used and running ambient temperatures are significantly higher than starting temperatures, a higher viscosity oil should be selected subject to

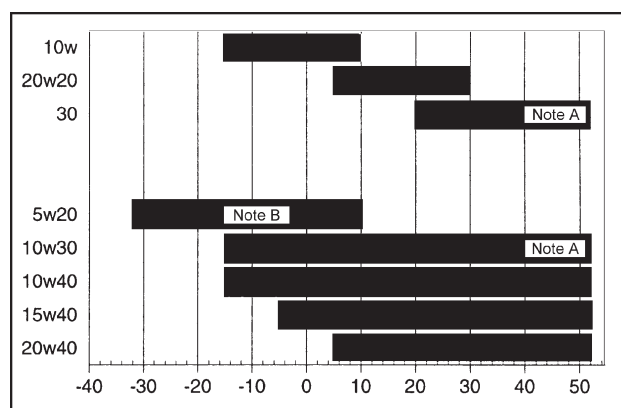
satisfactory starting performance. Multigrade oils may be used to overcome the problem.

- Where it is not practical to continually change oils to suit varying ambient temperatures a suitable multigrade oil is recommended to ensure adequate starting performance at the lowest temperature likely to be encountered.
- The engines must be run on heavy duty lubricating oils. Straight mineral oils are not suitable, neither are oils of less detergency than specified.
- API CF-4, API CG-4, API CH or API CI oils are recommended for heavy duty load applications, with API CC or API CD for light duty load applications.
- For engines in long running installations Lister Petter Power Systems should be consulted.

⚠ CAUTION

Lister Petter Power Systems recommend that oils of different brands or types are not mixed together.

Oil Viscosity



Notes:

A. Intermittent running.

B. Synthetic oils only.

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32.$$

1. SAE 5W-20 oils are recommended on the basis that they are fully synthetic, and are technically suitable for use up to 25°C (77°F). Non synthetic oils at very low temperatures will suffer from wax crystallisation.

Monograde SAE 5W is not normally available as a synthetic oil and therefore is not quoted.

2. In order to maintain the cold starting characteristics of any recommended grade it is essential that oil changes are made within the Lister Petter Power Systems recommendations.

An oil change is recommended immediately if the engine fails to reach its normal cold start cranking speed due to excessive oil viscosity.

Fuel dilution of the lubricating oil will adversely affect cold starting and oil consumption.

3.SAE 30 and 10W-30 oils may be used at up to 52°C (126°F) but oil consumption may be affected.

10W-40, 15W-40 and 20W-40 multigrades are recommended for continuous full load operation at this temperature.

4.Monograde SAE 40 oils are not recommended.

3.2 ENGINE FLUIDS - FUEL

The Fuel Specification

The engine must only be used with diesel fuel oil which conforms to one of the following:

- a.BS 2869:1988 Class A2.
- b.BS EN590:1995 Class A1.
- c.USA Specification ASTM D-975-77 Grades No.1-D and 2-D.
- d.BSMA 100 Class M1 for marine use.

The fuel must be a distillate, and not a residual oil or blend.

Vaporising oils are not suitable as fuels for Lister Petter Power Systems engines.

The user is cautioned that although the engines may operate on fuels outside the above specifications, such operation may well result in excessive wear and damage.

The engine must only be used with diesel fuel oil

which conforms to one of the following:

- a.BS 2869:1988 Class A2.
- b.BS EN590:1995 Class A1.
- c.USA Specification ASTM D-975-77 Grades No.1-D and 2-D.
- d.BSMA 100 Class M1 for marine use.

The fuel must be a distillate, and not a residual oil or blend.

Vaporising oils are not suitable as fuels for Lister Petter Power Systems engines.

The user is cautioned that although the engines may operate on fuels outside the above specifications, such operation may well result in excessive wear and damage.

⚠ CAUTION

The fuel injection equipment is manufactured to very accurate limits and the smallest particle of dirt will destroy its efficiency. Fuel free from water and contaminants is of the utmost importance.

Low Temperature Fuels

Special winter fuels are often available for use at ambient temperatures below 0°C (32°F).

These fuels have a lower viscosity and limit the formation of wax at low ambient temperatures.

⚠ CAUTION

Wax formation can rapidly reduce the flow of fuel through the fuel filter element.

4. OPERATING INSTRUCTIONS

4.1 PRELIMINARY INSTRUCTIONS

The following information is of a general nature and should be read in conjunction with, or substituted by, the equipment manufacturers instructions.

⚠ WARNING

Starting any diesel engine can be dangerous in the hands of inexperienced people. Before attempting to start any engine the operator should read the "Safety Precautions and Safe Working Practices" and be conversant with the use of the engine controls and the correct starting procedures.

⚠ CAUTION

ETHER BASED COLD START AIDS IN AEROSOL CANS MUST NOT BE USED UNDER ANY CIRCUMSTANCES.

Systems may be fitted, except on TX engines, to allow a measured quantity to be injected into the inlet manifold, but these must be used in accordance with the manufacturers instructions.

⚠ WARNING

DO NOT BREATHE EXHAUST GASES AS THEY CONTAIN CARBON MONOXIDE, A COLOURLESS, ODOURLESS AND POISONOUS GAS THAT CAN CAUSE UNCONSCIOUSNESS AND DEATH.

Starting Handle Precautions

A non-limited kick-back handle (A) or limited kick-back handle (B) system may be fitted to the engine.

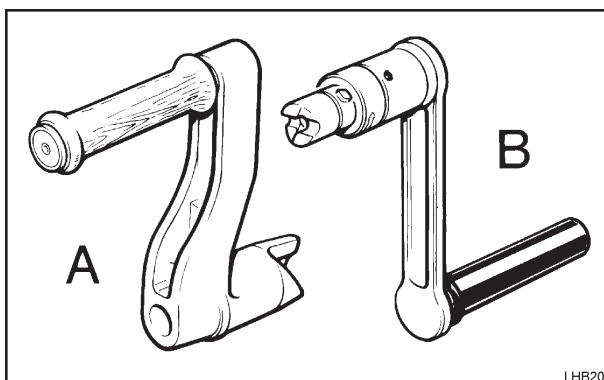


Figure 4.1.1 The Starting Handle

⚠ WARNING

Do not attempt to use a handle if it is damaged in any way.

- The two types of handle are not interchangeable and care must be taken to ensure the correct type is retained with the engine.
- Always use the correct starting handle which has been designed for the engine.
- Ensure there are no burrs on that part of the handle which fits onto the engine.
- Ensure the handle grip is clean, dry and free to turn on its shaft.
- Clean and lightly oil that part of the handle which fits onto the engine.
- Firmly hold the handle grip, **with the thumb on top of the grip**, during the starting procedure.

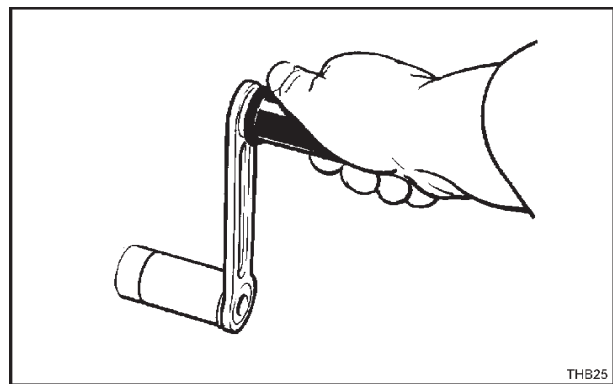


Figure 4.1.2 Holding the Starting Handle

Automatic Excess Fuel Device

'T Series' engines are fitted with an automatic excess fuel device which becomes operative, ready for the next start, when the engine is stopped. If the engine stops other than by the operation of the engine control, the control must be turned anti-clockwise to the 'STOP' position and released before the device can operate.

As the engine runs up to speed the excess fuel device will automatically reset to the normal running position.

Cold Starting Aid - TS/TR

The cold starting aid may be fitted to the combustion air intake ports and is used when the ambient temperature is below -10°C (14°F).

1. With the fuel turned on, turn the engine for up to 20 revolutions to prime the fuel and lubrication systems.
2. Withdraw the plunger (A) and fill one third of the cup (B) with the same type of lubricating oil as used in the engine.

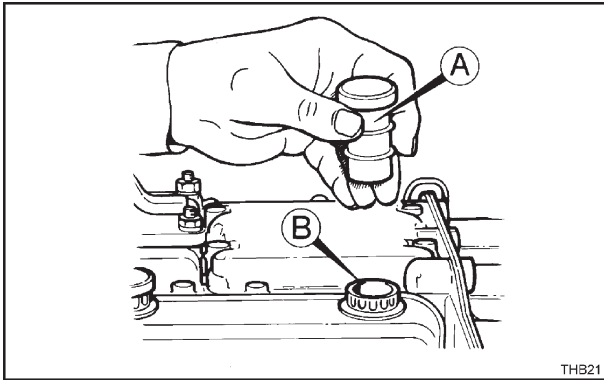


Figure 4.1.3 Cold Start

3. Replace the plunger and inject the oil just before starting the engine.

CAUTION

The device must not be used more than three times in succession during the same attempt to start the engine.

4.2 HAND STARTING

Before attempting to start the engine refer to "Starting Handle Precautions".

1. Select the excess fuel position by turning the engine control lever anti-clockwise to the 'STOP' position and releasing it.

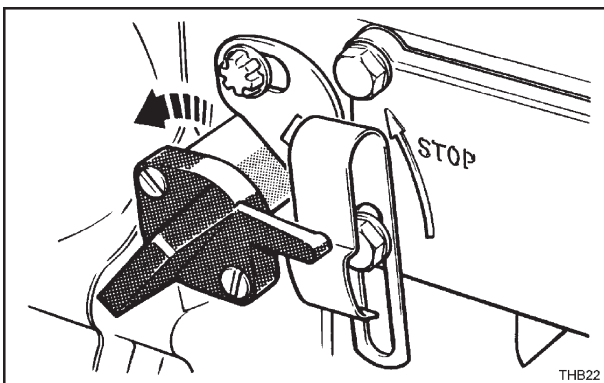


Figure 4.2.1 The Engine Control

2. If a variable speed control lever is fitted move it to the fast position.

3. Move the decompressor lever towards the flywheel.

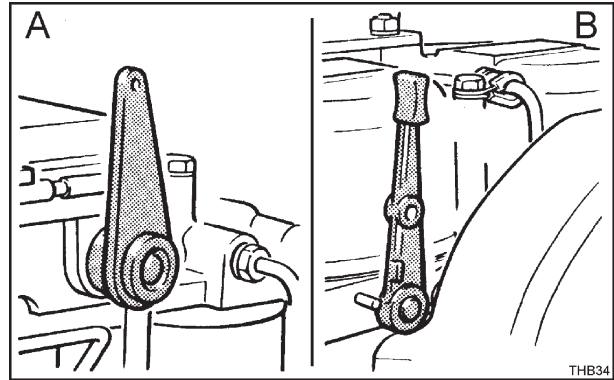


Figure 4.2.3 Decompressor Lever
A - TS/TR; B - TX

4. If the ambient temperature is below -10°C (14°F) refer to "Cold Starting Aid - TS/TR".

5a. **If using a non-limited kick-back handle:**

Insert the correct handle, refer to 'A' in 'Figure 4.1.1', into the starting housing.

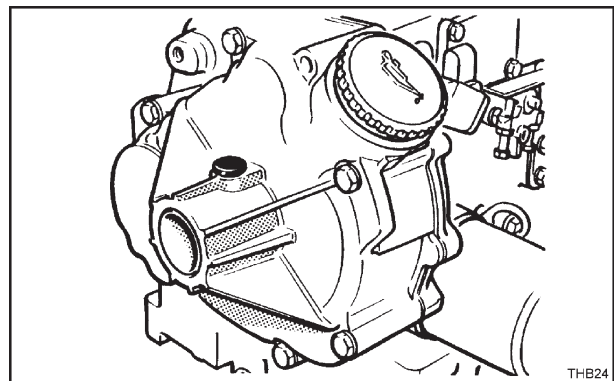


Figure 4.2.3 Starting Handle Housing

Slowly rotate the handle in the direction of cranking until it fully engages.

5b. **If using a limited kick-back handle:**

Swivel the starting handle housing cover (A) to one side and insert the correct handle, refer to 'B' in 'Figure 4.1.1', into the housing.

Slowly rotate the handle in the direction of cranking until it fully engages.

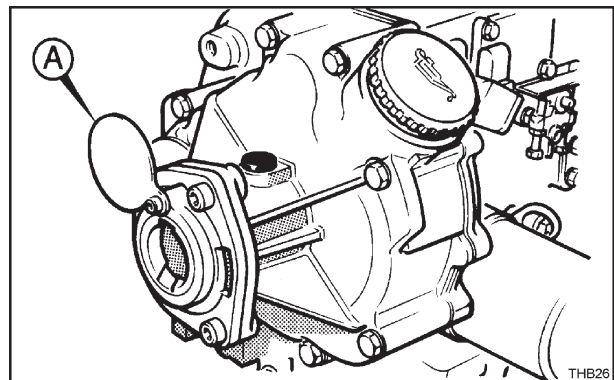


Figure 4.2.4 Starting Handle Housing

6. If the cold starting aid was not used turn the engine slowly for up to 20 turns to prime the combustion chamber and lubricating oil system.
7. Firmly hold the handle grip, with the thumb on top of the grip as shown in 'Figure 4.1.2', and crank the engine really fast, when sufficient speed is obtained move the decompressor lever towards the gear end and continue to crank until the engine fires.
Retaining a firm grip on the handle remove the handle from the housing.

⚠ WARNING

Do not pull the starting handle away from the engine while cranking.

8. If a variable speed control is fitted reduce the speed as required.

4.3 ELECTRIC STARTING

If an oil pressure switch bypass button is fitted it must be depressed during engine cranking and until the engine attains full speed.

If the engine fails to start within 30 seconds, release the key, or start button, and attempt to restart after allowing sufficient time for all moving parts to stop.

1. Check that the decompressor lever, if fitted, is towards the gear end.

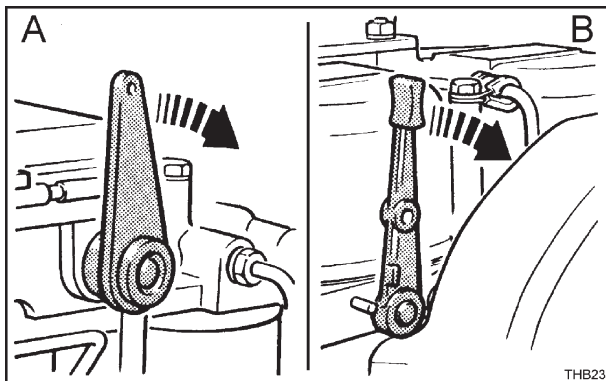


Figure 4.3.1 Decompressor Lever
A - TS/TR; B - TX

2. Turn the engine control lever anti-clockwise to the 'STOP' position and release it.

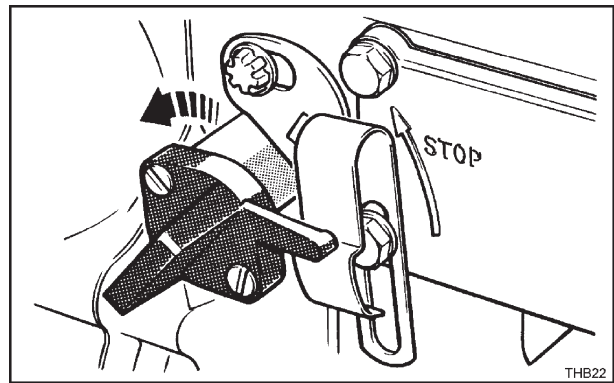


Figure 4.3.2 The Engine Control

3. If a variable speed control lever is fitted move it to the fast position.
4. If the ambient temperature is below -10°C (14°F) refer to items 2. and 3. in "Cold Starting Aid - TS/TR".
- 5a. **If a start key is being used:**
Turn the start key clockwise and hold it at position '3', until the engine fires and then release it immediately.

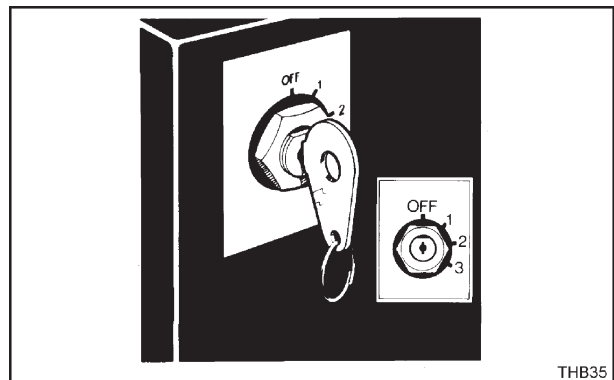


Figure 4.3.3 Start Key

- 5b. **If a starter button is being used:**
Press the starter button until the engine fires and then release it immediately.
6. Turn the engine control lever anti-clockwise to the 'RUN' position.
7. If a variable speed control is fitted reduce the speed as required.

4.4 STOPPING THE ENGINE

1. On engines not fitted with a fuel control solenoid, turn the engine control anti-clockwise to the 'STOP' position and hold it there until the engine comes to rest.

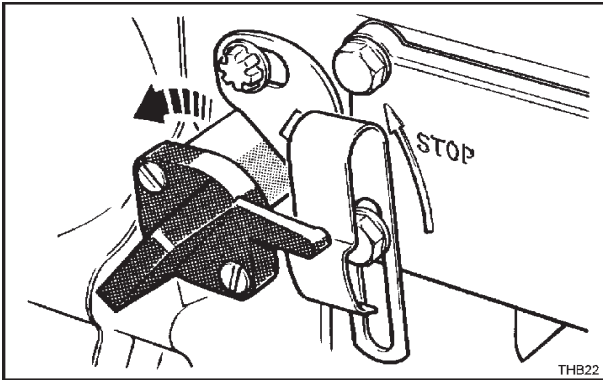


Figure 2.7.1 The Engine Control

After the engine has stopped turn the start key, if fitted, to the OFF position.

⚠ CAUTION

Turning the start key to the 'OFF' position will not stop the engine unless an optional fuel control solenoid is fitted.

2. On engines fitted with a fuel control solenoid turn the key to the 'OFF' position.

⚠ CAUTION

Never stop the engine by operating the decompressor lever or valve damage may occur.

5. ROUTINE MAINTENANCE

5.1 PRELIMINARY INSTRUCTIONS

⚠ WARNING

Routine maintenance must be performed by qualified persons who are conversant with the hazards of oil, fuel, electricity and machinery.

⚠ CAUTION

Before commencing any work on the engine read the "Safety Precautions and Safe Working Practices" at the front of this manual.

This routine maintenance section is designed primarily for use by trained technicians but it does contain sufficient information, illustrations and detail to allow the operator to perform basic maintenance work.

This work can only be carried out if the necessary hand and service tools are available. When the user has insufficient tools, experience or ability to carry out adjustments, maintenance and repairs this work should not be attempted.

Where accurate measurements or torque values are required they can only be made using calibrated instruments.

Under no circumstances should makeshift tools or equipment be used as their use may adversely affect safe working procedures and engine operation.

These recommendations and instructions cover several engine models therefore they are of a general nature.

The engine may include optional equipment not specifically covered in this book.

- Long periods of light or 'no load' running early in the engine's life may lead to cylinder bore glazing and high oil consumption.
- The instructions given in "05. Maintenance - schedule hours" are based on average operating conditions and cover the minimum requirements

to keep an engine running at peak performance with trouble free operation.

- Under very dusty conditions, air cleaners, lubricating oil and fuel filters will require more frequent attention
- Decarbonising may be required more often if the engine has been running on light loads for long periods.
- Before carrying out any maintenance work on an engine it is advisable to remove the battery. The battery and alternator must be disconnected before commencing any electric welding when a pole strap is directly or indirectly connected to the engine.
- It is essential to ensure that nuts and bolts are tightened to the torques specified in this Workshop Manual.
- When re-assembling an engine lubricate all moving parts with engine oil.
- Renew nuts and bolts that have been taken from high stress locations. In particular nuts and/or bolts from the connecting rods should be renewed.
- The fuel injector can only be checked and set off the engine using suitable specialist test equipment.

The Use of Genuine Parts

Parts that have not been approved by the Lister Petter Power Systems organisation cannot be relied upon for correct material, dimensions or finish.

This Company cannot therefore, be responsible for any damage arising from the use of such parts and the guarantee may be invalidated.

When purchasing parts or giving instructions for repairs users should, in their own interests, always specify Genuine Lister Petter Power Systems Parts.

5.2 ROUTINE MAINTENANCE - SCHEDULE HOURS

DAILY
Check the fuel and lubricating oil levels.
Check for fuel and oil leaks.
Clean or replace the air cleaner element under very dusty conditions.
EVERY 125 HOURS
The above and the following items.
Check the condition of the battery, if fitted.
Clean or replace the air cleaner element under moderately dusty conditions.
On TX engines operating above 35°C (95°F) drain the sump, refill with new oil and renew the oil filter element.
EVERY 250 HOURS
The above and the following items.
Drain the sump and refill with new oil.
Renew the oil filter element.
Clean or replace the injectors if the exhaust is dirty.
Renew the fuel filter element if the fuel being used is not perfectly clean.
Check the TX axial fan drive belt tension.
EVERY 500 HOURS
The above and the following items.
Replace the air cleaner element.
Examine the exhaust and induction systems for leaks, damage or restrictions.
Renew the fuel filter element.
Check the battery charge winding system.

EVERY 1000 HOURS
The above and the following items.
Check the valve clearances.
Decarbonise if the engine performance has deteriorated.
Clean the cylinder and cylinder head cooling fins under dusty conditions.
Check the TX axial fan drive belt condition; replace if necessary.
EVERY 2000 HOURS
The above and the following items.
Check the injector nozzles and decarbonise, if necessary.
Replace the TX axial fan drive belt irrespective of its condition.
Check the fuel pump timing.
Check the governor and controls for free movement.
Examine the charge winding stator and rotor for damage.
Clean and check the TX axial fan for damage.
EVERY 6000 HOURS
The above and carry out a major overhaul.
EVERY YEAR - MARINE
Change the lubricating oil, oil filter and air cleaner elements if these were not changed at the prescribed intervals.

Notes:

1. It is recommended that the fuel lift pump diaphragm is inspected at frequent intervals if it is known the fuel is contaminated. It should also be inspected at regular intervals on engines in low duty cycle applications; for example, stand-by generating sets.

2. On engines in dumper truck applications the lubricating oil and filter change periods may be extended to every 300 hours.

5.3 SPANNER TORQUE SETTINGS

The tolerance for all spanner torque settings is +5%-0 and for practical purposes the figures have been rounded.

Location	Nm	lbf ft
Governor link adjusting screw	3.0	2.0
Polypropylene flywheel fan - TS1	4.0	3.0
Injector stud nut - TX Injector leak-off banjo screw Nylon side shield retainer - TS/TR1	6.0	4.5
Cold start oil cup (taper thread)	8.0 - 14.5	6.0 - 10.5
Polypropylene flywheel fan - TS2, 3	8.0	6.0
Decompressor screw nut Fuel filter to tank cap screw Manifold nuts (bottom row) - TS/TR Fuel pump retaining bolts	9.0	6.5
Inlet manifold nuts - TX	13.5	10.0
Camshaft catchpin retaining screw	16.0	12.0
Fuel filter adaptor (steel into aluminium)	19.0	14.0
Main bearing dowel locating plug	20.0	15.0
Injector clamp screw Valve rocker adjusting screw nuts Manifold nuts (top row) - TS/TR Exhaust manifold nuts - TX	21.0	15.5
Injector pipe nuts	22.0	16.0
Main bearing housing screws Sump retaining bolts Injector top plug	27.0	20.0
Connecting rod nuts Fanshroud securing bolts (only if fitted with tabwashers)	43.0	32.0
Fuel pump delivery valve holder	35.0 - 45.0	26.0 - 33.0
Alternator pulley nut - TX	40.0 - 55.0	35.0 - 40.0
Balance weight retaining bolt	57.0	42.0
Cylinder head nuts - TX	61.0	45.0
Cylinder head nuts - TS/TR	68.0	50.0
Fanshroud securing bolts (only if self-locking)	88.0	65.0
Crankshaft extension and pulley - TX	197.0	145.0
Gear end shaft extension nut (marine builds only)	230.0	170.0
Gear end crankshaft drives	362.0	267.0
Flywheel retaining screw/nut	475.0	350.0

5.4 JOINTING COMPOUNDS

Some engines will have been assembled with jointing compounds that have been superseded. Providing all traces of the old compound and joint are removed the later specified compounds can be used.

<u>Valve Gear Cover</u> Assemble the joint dry and with all surfaces clean and dry.
<u>Bottom of cylinders - TS/TR</u> Coat the cylinder on the jointing face with Hylomar PL32/M, stick the joint to it and coat the joint.
<u>Valve Guides - TS/TR</u> Coat the outside diameters of the guides with Wellseal before driving in the plug.
<u>Camshaft Expansion Plug</u> Coat the outside diameter of the plug with Wellseal before driving in the plug.
<u>Flanged Oil Sump Drain Plug</u> Coat the threads with Wellseal.
<u>Taper Plugs</u> Bind the threads with PTFE tape or coat the threads with Three Bond 1110B before screwing in the plug.
<u>Oil Seals (not lip type) - TS/TR</u> Apply a little Hylomar PL32/M to the outside diameter of the seal.
<u>Cylinder Head Gasket and Shims - TS/TR</u> Smear a small amount of High Melting Point Grease where the shims seat, the side of the recess, both sides of each shim and the gasket.
<u>Cylinder Barrel Shims - TX</u> Assemble the shims dry with surfaces clean and dry.
<u>Valve Rocker Stub Shafts - TS/TR</u> Coat the sealing groove nearest to the bolt hole with Wellseal or Hylomar PL32/M.
<u>Oil Pump Feed Plug</u> Coat the outside diameter of the plug with Wellseal.
<u>Decompressor Bore</u> Apply Wellseal to the outside diameter of the TS/TR plug before fitting. Apply Wellseal or Hylomar PL32/M to the outside diameter of the TX plug before fitting.

<u>Flywheel End Bearing Housing Shims</u> Coat the bearing housing face with Loctite 221, place a shim in place and coat the shim. Coat both sides of any subsequent shims.
<u>Cylinder Head Nuts and the Top Threads of the Cylinder Head Studs - TS/TR</u> Coat the threads at the top of the stud, the nut threads and the area of the top plate in contact with the nut with Wellseal.
<u>Fuel Lift Pump</u> Assemble the joint between the pump and crankcase with all surfaces clean and dry.
<u>Crankcase Breather Pipe - TS/TR</u> Coat the knurls of the pipe with Loctite 601 and push it into the top plate. Before the pipe reaches the hole in the cylinder head coat the lower end of it. Take care not to block the bore of the pipe.
<u>Crankshaft Bucket Plug</u> Coat the plug periphery with Loctite 572 or Three Bond 1110B.
<u>End Cover Bush - TS/TR</u> Coat the outside diameter of the bush before assembly with Loctite 601 or Three Bond 1303.
<u>Speeder Spring Anchor Pin</u> Coat the threads with Loctite 222 or Three Bond 1344 before assembling the anchor pin to the speed control spindle.
<u>End Cover</u> Assemble the joint between the cover and crankcase with all surfaces clean and dry.
<u>Push Rod Tube Seals</u> Lightly coat the bore of the seal with Hellenine rubber lubricant to aid assembly.
<u>Oil Sump</u> Assemble the joint between the sump and crankcase with all surfaces clean and dry.
<u>Dipstick - TX</u> Lightly coat the 'O' ring to aid fitting into the crankcase.

5.5 DIMENSIONS OF WEARING PARTS

The following information is given as a guide to the extent by which components may reasonably be expected to wear, without appreciable loss of performance. To maintain the engine in good running order it is therefore recommended that when the "Maximum Clearance" figure is reached, one or more components affecting the clearance be replaced.

The wear to be allowed in parts refitted to an engine depends on the life required to the next overhaul and the relative cost of labour and materials. If labour costs are high it may pay to replace parts before the maximum wear condition is reached to avoid further work before the next scheduled overhaul.

Cylinder Bore Wear

The maximum advisable piston to cylinder clearance given is the clearance between the bottom of the piston skirt, across the faces, and the cylinder bore measured in the region of travel of the piston skirt. The clearance is not to be measured at the top of the bore.

When cylinders are rebored the lower skirt should be etched or painted with the amount of the over-size.

Piston Ring Wear

The ring gaps given in the table are those to be anticipated when checking rings in an unworn part of the bore. For every 0.01mm (0.0004in) by which the actual bore size exceeds the initial dimension, the ring gap will increase by approximately 0.03mm (0.0012in).

The firing ring side clearance is measured with a new ring flush with the top piston land.

Oversize and Undersize Items

Oversize pistons and piston rings, and undersize big end and main bearing shells are available.

Reference should be made to the relevant Master Parts Manual for the relevant part numbers.

The variations from the standard dimensions are:

0.010in (0.254mm)

0.020in (0.508mm)

0.030in (0.762mm)

0.040in (1.016mm)

Non-standard sizes are marked, by the amount they are under or oversize, as a suffix to the part numbers which can be found in the following locations:

- a. Piston Rings - stamped on the face of the ring.
- b. Pistons - stamped on the top surface.
- c. Bearings - stamped on the steel outside surface of the bearing.

TS, TR Wearing Parts

Component TS/TR	Initial Dimension (mm)	Initial Clearance (mm)	Max. Clearance (mm)
TS - Builds 01 - 43			
Cylinder Bore	95.275	0.261	0.35
	95.300		
Piston Diameter - bottom of skirt across thrust face	95.065	0.210	
	95.039		
Firing Ring Gap	0.30	0.38	0.98
	0.50	0.66	
Compression Ring Gap	0.20	0.28	0.90
	0.40	0.56	
Conformable Oil Ring Gap	0.25	0.33	0.90
	0.45	0.61	
Slotted Oil Ring Gap	0.30	0.38	0.85
	0.50	0.66	0.86
Firing Ring Side Clearance		0.00	0.10
		0.06	
Compression Ring Width	2.380	0.122	0.23
	2.355		
Compression Ring Groove Width	2.502	0.172	
	2.527		
2nd Compression Ring Groove Width	2.456	0.076	0.23
	2.482	0.127	
Oil Ring Width	4.763	0.050	0.15
	4.737		
Oil Ring Groove Width	4.813	0.102	
	4.839		
TS - Builds 60-65			
Cylinder Bore	95.275	0.128	0.22
	95.300		
Piston Diameter - bottom of skirt across thrust face	95.212	0.063	
	95.172		
Firing Ring Gap	0.30	0.36	0.85
	0.50	0.66	
Compression Ring Gap	0.20	0.28	0.90
	0.45	0.61	
Conformable Oil Ring Gap	0.25	0.33	0.90
	0.45	0.61	
Firing Ring Side Clearance		0.00	0.10
		0.06	
Compression Ring Width	2.380	0.122	0.23
	2.355		
Compression Ring Groove Width	2.502	0.172	
	2.527		
Oil Ring Width	4.763	0.050	0.15
	4.737		
Oil Ring Groove Width	4.813	0.102	
	4.839		
TS - All Builds			
Cylinder Bore	98.450	0.192	0.28
	98.475		
Piston Diameter - bottom of skirt across thrust face	98.323	0.127	
	98.283		
Firing Ring Gap	0.30	0.38	0.85
	0.50	0.66	
Compression Ring Gap	0.20	0.28	0.90
	0.40	0.56	
Conformable Oil Ring Gap	0.25	0.33	0.90
	0.45	0.61	
Firing Ring Side Clearance		0.00	0.10
		0.06	
Compression Ring Width	2.380	0.076	0.23
	2.355		
Compression Ring Groove Width	2.456	0.127	
	2.482		
Oil Ring Width	4.763	0.050	0.15
	4.737		
Oil Ring Groove Width	4.813	0.102	
	4.839		

TS, TR Wearing Parts

Component TS/TR	Initial Dimension (mm)	Initial Clearance (mm)	Max. Clearance (mm)
TS and TR - All Builds			
Small End Bearing Diameter	33.3807	0.0432	0.09
	33.3934		
Gudgeon Pin Diameter	33.3375	0.0610	
	33.3324		
Big End Bore - in rod	67.2080	0.0376	0.14
	67.2210		
Bearing Shell Thickness	1.8352	0.0814	
	1.8263		
Crankpin Diameter	63.5000		
	63.4870		
Main Bearing Housing Bore	67.196	0.0386	0.16
	67.221		
Bearing Shell Thickness	1.8352	0.0934	
	1.8263		
Crankshaft Journal Diameter	63.4870		
	63.4750		
Thrust Bearing Thickness - TS/TR1	2.360	0.178	0.37
	2.310	0.254	
Thrust Bearing Thickness - TS/TR2, 3	2.360	0.229	0.43
	2.310	0.305	
Camshaft Bush Bore - centre	44.407	0.0586	0.22
	44.506		
Camshaft Journal Diameter - centre	44.3484	0.1703	
	44.3357		
Camshaft Bush Bore - flywheel end	39.975	0.023	0.20
	40.060		
Camshaft Journal Diameter - flywheel end	39.952	0.121	
	39.939		
Fuel Pump Tappet Diameter	24.987	0.013	0.10
	24.962		
Fuel Pump Tappet Guide Bore	25.000	0.068	
	25.030		
Oil Pump Tappet Diameter	15.850	0.025	0.12
	15.830		
Oil Pump Tappet Crankcase Bore	15.875	0.070	
	15.900		
Oil Pump Plunger Diameter	29.960	0.040	0.13
	29.935		
Oil Pump Cylinder Diameter	30.000	0.098	
	30.033		
Valve Spring - approximate free length	52.00		50.40
Valve Guide Bore	8.731	0.0683	0.13
	8.752		
Valve Stem Diameter	8.6627	0.1020	
	8.6500		
Valve Rocker Bush Bore	25.4620	0.018	0.07
	25.4750		
Valve Rocker Shaft Diameter	25.4440	0.0395	
	25.4360		
Backlash Between Gears		0.13 max	0.20

1mm = 0.03937 in

TX Wearing Parts

Component TS/TR	Initial Dimension (mm)	Initial Clearance (mm)	Max. Clearance (mm)
TX - All Builds			
Cylinder Bore	100.000	0.164	0.25
	100.025		
Piston Diameter - bottom of skirt across thrust face	99.879	0.121	
	99.861		
Firing Ring Gap	0.40	0.40	1.05
	0.65		
Compression Ring Gap	0.40	0.40	1.02
	0.65		
Conformable Oil Ring Gap	0.25	0.25	0.90
	0.55		
Firing Ring Side Clearance		0.00	0.10
Compression Ring Width	2.490	0.070	0.18
	2.478		
Compression Ring Groove Width	2.560	0.102	
	2.580		
Oil Ring Width	3.990	0.030	0.11
	3.978		
Oil Ring Groove Width	4.020	0.062	
	4.040		
Small End Bearing Diameter	33.3807	0.0437	0.09
	33.3934		
Gudgeon Pin Diameter	33.3370	0.0624	
	33.3310		
Big End Bore - in rod	67.2080	0.0376	0.14
	67.2210		
Bearing Shell Thickness	1.8352	0.0814	
	1.8263		
Crankpin Diameter	63.5000		
	63.4870		
Main Bearing Housing Bore	67.196	0.0386	0.16
	67.221		
Bearing Shell Thickness	1.8352	0.0934	
	1.8263		
Crankshaft Journal Diameter	63.4870		
	63.4750		
Thrust Bearing Thickness	2.360	0.229	0.43
	2.310		
Camshaft Bush Bore - centre	46.772	0.017	0.22
	46.878		
Camshaft Journal Diameter - centre	46.755	0.138	
	46.740		
Camshaft Bush Bore - flywheel end	39.975	0.023	0.20
	40.060		
Camshaft Journal Diameter - flywheel end	39.952	0.121	
	39.9390		

1mm = 0.03937 in

TX Wearing Parts

Component TS/TR	Initial Dimension (mm)	Initial Clearance (mm)	Max. Clearance (mm)
Fuel Pump Tappet Diameter	24.987	0.013	0.10
	24.962		
Fuel Pump Tappet Guide Bore	25.000	0.068	
	25.030		
Oil Pump Tappet Diameter	15.850	0.025	0.12
	15.830		
Oil Pump Tappet Crankcase Bore	15.875	0.070	
	15.900		
Oil Pump Plunger Diameter - Tx2	29.960	0.040	0.13
	29.935		
Oil Pump Cylinder Diameter - Tx2	30.000	0.098	
	30.033		
Oil Pump Plunger Diameter - Tx3	32.960	0.040	0.13
	32.935		
Oil Pump Cylinder Diameter - Tx3	33.000	0.098	
	33.033		
Valve Spring - approximate free length	48.00		46.60
Valve Guide Bore	7.957	0.073	0.15
	7.980		
Valve Stem Diameter	7.884	0.119	
	7.861		
Valve Rocker Bush Bore	16.000	0.020	0.10
	16.0270		
Valve Rocker Shaft Diameter	15.980	0.067	
	15.960		
Backlash Between Gears		0.13 ^a	0.20

Notes

^a Maximum Initial Clearance

1mm = 0.03937 in

5.5 LONG TERM STORAGE

Preparing the Engine for Storage

The following routine should be carried out when it is known that the engine will not be required for some months.

If the following procedure is not carried out the engine should be run on full load for approximately 45 minutes once a month.

⚠ CAUTION

As a direct result of combustion the lubricating oil may contain harmful acids and therefore it should not be left in the sump if it is known engine will not be used for extended periods.

- a. Replace the fuel in the tank with a small supply of suitable inhibition fluid.
- b. Drain the lubricating oil from the sump and refill with new oil.
- c. Run the engine for a period to circulate the oil through the system and to ensure the inhibition fluid is passed through the fuel pumps and injectors.
- d. Stop the engine and drain the lubricating oil from the sump.
The crankshaft should NOT be turned until the engine is again required for service.
The inhibition fluid should be left in the fuel system.
- e. Seal all openings on the engine with tape.
- f. Remove the batteries and store them fully charged after coating the terminals with petroleum jelly.
- g. Grease all external bright metal parts and the speed control linkage.
- h. Tie labels on the engine clearly stating what steps have been taken to inhibit the engine during storage.

Returning the Engine to Service

Refer to the appropriate sections for the relevant detailed instructions as necessary to complete this work.

- a. Remove the tie-on labels and all the protective coverings from openings and apertures.
- b. Check the drive belt for deterioration and correct tension.
- c. Fill the fuel tank.
- d. Refill the lubricating oil sump with new oil of the correct specification and viscosity.
- e. Remove the batteries from store. If they are still fully charged reconnect them to the engine.
Coat the terminals with petroleum jelly.
- f. Start the engine and check for fuel and oil leaks before applying load.

6. TROUBLESHOOTING

6.1 PRELIMINARY INFORMATION

Troubleshooting mechanical engine problems can be difficult. This section lists possible engine problems that could be encountered with possible causes and corrections. The information given is of a general nature as it covers the basic engine and your particular application may be different.

Electrical wiring diagrams can be found in section 9. If you are in any doubt, contact your local Lister Petter Power Systems distributor.

Before starting any dismantling procedure the following should be considered:

- a. Do you know and understand the engine and all the related systems?
- b. Do you have sufficient electrical and mechanical knowledge and skills to understand the symptoms?
- c. Do you have suitable electrical diagnostic equipment available?
- d. Do you have, or access to, the necessary Lister Petter Power Systems spare parts before you commence dismantling?

6.2 METHOD OF TROUBLESHOOTING

1. Diagnose the problem by eliminating the easiest things first.
2. Before starting to remove or dismantle any components double check your observations.
3. During dismantling keep all cylinder related items together. This will ensure they are refitted in the original orientation.
4. When electrical troubleshooting always start at the battery first.

6.3 TROUBLESHOOTING TABLES

<i>Problem</i>	<i>Method of Correction</i>
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Difficult Starting or Failure to Start

Incorrect starting procedure.	Refer to the correct procedure.
Unsuitable lubricating oil (too heavy).	Use oil of the correct viscosity and specification.
Incorrect fuel.	Use fuel of the correct specification.
No fuel in the tank.	Refill the tank.
Choked fuel filter.	Replace the filter.
Air lock in the fuel system.	Check the fuel level. Prime the fuel filter.
Water or dirt in the fuel system.	Drain, flush, refill and prime the filter.
Dirty or faulty injector.	Replace the injector or have it serviced.
Discharged battery.	Recharge or replace the battery.
Fuel pump solenoid not energised.	Check the electrical supply.
Poor battery connections.	Clean, replace and coat with petroleum jelly.
Faulty fuel pump.	Contact a Lister Petter Power Systems distributor.

Excessive Carbon Deposits

Choked air filter.	Dismantle and clean the cap and element.
Choked exhaust system.	Dismantle and clean.
Unsuitable fuel.	Use fuel of the correct specification.
Unsuitable lubricating oil.	Use oil of the correct viscosity and specification.
Continuous low, or no load running.	Investigate your load management programme.

White Exhaust Smoke

Water in the fuel system.	Drain, flush, refill and prime the filter.
Faulty fuel pump.	Contact a Lister Petter Power Systems distributor.

Light Blue Exhaust Smoke

Generally as a result of light load.	Investigate the load management programme.
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Heavy Blue Exhaust Smoke

Lubricating oil passing the piston rings.	Check the crankcase vacuum. Check for wear.
Stuck, worn or broken piston rings.	Check for damage, decarbonise, replace the rings.
Worn cylinder bore.	Replace the piston and piston rings.
Overfull oil sump.	Correct the level.

Black Exhaust Smoke

Overload.	Reduce the load.
Choked air filter.	Dismantle and clean the cap and element.
Inlet air temperature too high.	Investigate the reason.
Water in the fuel system.	Drain, flush, refill and prime the filter.
Unsuitable fuel.	Use fuel of the correct specification.

Continued on the next page

<i>Problem</i>	<i>Method of Correction</i>
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Engine Stops

Lack of fuel.	Check the system. Refill the tank.
Air in the fuel system.	Prime the fuel filter.
Water in the fuel system.	Drain, flush, refill and prime the fuel filter.
Choked fuel filter.	Replace the filter.
Choked air filter.	Dismantle and clean the cap and element.
Overload.	Reduce the load.
Overheating.	See the 'Overheating' section.
Loss of compression.	Check the piston rings and the valves.
Loss of electrical supply to the fuel solenoid.	Check the electrical feed.
Automatic shutdown, if protective devices are fitted.	Investigate the cause and rectify.

Lack or Loss of Power

Loss of compression.	Check the piston rings and the valves.
Choked air filter.	Dismantle and clean the cap and element.
Choked exhaust system.	Dismantle and clean.
Overload.	Reduce the load.
Choked fuel filter.	Replace the filter.
Worn engine.	Give the engine a major overhaul.

Overheating

Overload.	Reduce the load.
Lubricating oil level too low.	Add oil of the correct specification and viscosity.
Incorrect fuel.	Drain the system, add fuel of the correct specification.
Recirculation of exhaust gasses or cooling air.	Investigate and eliminate the cause.
Air cooling system obstructed.	Check for restrictions and clean the cylinder head and cylinder barrel cooling fins

High Fuel Consumption

Incorrect type of fuel.	Drain the system, add fuel of the correct specification.
Overload.	Reduce the load.
Dirty or faulty injector.	Clean or replace.
Choked air filter.	Dismantle and clean the cap and element.

Continued on the next page

<i>Problem</i>	<i>Method of Correction</i>
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Undercharging

Excessive electrical load from added accessories.	Remove accessories.
Poor electrical connections to alternator or battery.	Inspect, clean and rectify the cause.
Faulty battery.	Test, recharge or replace.
Faulty alternator or charge windings.	Test or replace.

Overcharging

Faulty alternator or charge windings.	Test or replace.
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Battery Requires Excessive Amounts of Water

Battery case leaking.	Clean surrounding area and replace the battery.
Defective battery.	Test or replace the battery.
Battery charging rate is too high.	Check the alternator output or battery charging system.

Battery will not Charge

Loose or corroded connections	Clean and tighten the connections.
Worn out battery.	Replace the battery.
Loose alternator drive belt.	Replace or re-tension the drive belt.

Starter Motor does not Operate

Loose or corroded connections.	Clean and tighten the connections.
Worn out battery.	Replace the battery.
Faulty starter panel or connections.	Check the connections or replace the panel.

7. DISMANTLE & REBUILD

TS/TR DISMANTLE AND REBUILD

These notes are of a general nature and are included as an aide memoir and in no way are they intended as instructions.

Dismantling

Before beginning any work on the engine drain all of the fuel and oil from the engine and disconnect all services, including the battery. Remove the air filter, silencer and fuel tank (if fitted).

1. Remove the bolts from the lifting eye and lift it off.
2. Remove the cylinder head covers.
3. Slacken both ends of the fuel pipes from the pumps to the injectors and remove the pipes.
4. Remove the injector clamp.
5. Remove the injector and leak off pipe.
Note that a washer is fitted over the nozzle of each injector.
6. Remove the inlet and exhaust manifolds and the two gaskets.
7. Unscrew and remove the cold start pots, if these are fitted.
8. Ensure the fuel pipe from the filter to the pumps is removed.
9. Remove the fuel lift pump, if fitted.
10. Remove the fuel filter, if engine mounted.
11. Remove the gear end side shield, the air cowling and the flywheel end side shield.
12. Remove the valve rocker oil feed pipe and unions from the crankcase and cylinder heads.
13. Remove the four cylinder head nuts from No.1 cylinder.
14. Lift off the cylinder head and place it on its side on a bench.
15. Remove the gasket and shims if these have remained on the top of the cylinder barrel.
16. Remove the push rods and tubes.
17. Fit a retaining tube over one cylinder head stud and secure it with a hand tight nut.
This will prevent the cylinder from rising if the crankshaft is turned.
18. Repeat items 13 to 17 for the remaining cylinders.
19. Remove the air baffles.
20. Remove the plastic dustcap in the end cover boss.

On early engines:

- a. Turn the crankshaft until the spring pin of the starting handle catch pin in the camshaft is visible through the hole in the cover boss.
- b. Tap out the pin with a suitable punch.

c. Turn the engine through 90° and drift out the starting handle catch pin.

On later engines:

- d. Remove the grub screw from the end of the camshaft.
- e. Drift out the pin.

21. Fit the service tool (317-50063) and remove the end cover.
22. Remove the thrust washer and shim from the camshaft.
23. Remove all fuel pump inspection doors.
24. Disconnect the governor link from all fuel pump racks.
25. Remove the two fulcrum pins from the governor lever assembly pivot supports taking care to retain the spring and shims.
26. Using long nosed pliers, remove the speeder spring from its control.
27. Remove the governor lever assembly complete.
28. Remove the governor sleeve assembly from the camshaft.
29. Remove the fuel pump taking care to retain the timing shims with the correct pump.
30. Remove the fuel pump tappet and cap using long nosed pliers.
31. Remove the fuel pump tappet guide locating bolts from the side of the crankcase.
32. Remove the fuel pump tappet guides noting which way they are fitted.
33. Remove the oil dipstick.
34. Stand the engine on its flywheel using a suitable piece of timber between the recessed flywheel and the plinth.
35. Remove the sump.
36. Remove the oil pump and oil pump push rod.
37. If necessary dismantle the oil pump.
38. Ensure the push rod cam followers are at their highest positions to clear the camshaft.
39. Keeping the camshaft square' gently ease it out of the crankcase.
40. Rotate the crankcase until No. 1 piston is at BDC.
41. Remove NO.1 connecting rod cap.
42. Rotate the crankcase until No.1 piston is at TDC.
43. Remove the retaining tube and gently lift off the cylinder barrel piston and connecting rod as one unit.
44. Replace the bearing cap on to the connecting rod.

- 45.Repeat items 40 to 44 for the remaining cylinders.
- 46.Remove the Allen screws and crankshaft balance weights.
- 47.Remove the cam followers.
- 48.Replace the sump holding it with four bolts (one each side).
- 49.Turn the engine to its normal position.
- 50.Unscrew the flywheel retaining bolt two turns using a 65mm socket.
- 51.Use the service tool and break the tapered seal between the flywheel and the crankshaft, in an emergency tap the flywheel retaining bolt with a copper hammer.
- 52.Using a crane if available and with the hook in one of the flywheel fins just take the strain.
- 53.Remove the flywheel retaining bolt and fit the mandrel, 317-50046, in its place.
- 54.Keeping the flywheel square ease the flywheel out from the housing and place it in a safe position.
- 55.Remove the rectifier cover.
- 56.Mark the four rectifier cables for identification and remove them from their respective positions.
- 57.Remove the rectifier from the flywheel housing.
- 58.Remove the cable retaining clip from inside the housing.
- 59.Remove the stator gently easing the cable through the housing as this is being done.
- 60.Remove the fanshroud.
- 61.Use a brass drift to remove the flywheel key.
- 62.Remove the intermediate bearing retaining bolts from the side of the crankcase.
- 63.Remove the intermediate bearing dowels by screwing a suitable bolt into the dowel and withdrawing it.
The bolt should be left in the dowel to identify the correct assembly procedure as the dowel is threaded at one end only.
- 64.Remove the alternator adaptor plate.
- 65.Remove the flywheel end main bearing housing.
- 66.Use the Service Tool. 317-50058 or 39317 to remove the crankshaft gear.
- 67.Gently remove the crankshaft from the crankcase.
- 68.Remove the split thrust washers from inside the crankcase at the gear end and from the main bearing housing.

Rebuild

When assembling the engine use normal engine lubricating oil to spray all moving parts during assembly. All bearing surfaces must be well

lubricated including the valve stems and the cups of the push rods.

New camshaft bushes should be immersed in clean engine oil for four hours before fitting.

The pistons with rings and connecting rods assembled, must be submerged in oil just before fitting into the cylinder. After submersion drain both ways so that no oil is left in the combustion chamber or inside the piston.

Replace all joints and gaskets.

- 1.Turn the crankcase on to its manifold side using a suitable piece of wood to support it.

- 2.Remove the sump.

- 3.Grease the steel backs of the split thrust washers and refit them into the gear end of the crankcase and the main bearing housing.

- 4.Replace the crankshaft taking care to ensure the bearing locating dowel is in line with the hole in the crankcase before the dowel enters the housing.

If, on the final assembly, the holes are not in line use a brass drift to rotate the bearing housing.

Check exact alignment by using a tapered rod.

- 5.Replace the Intermediate bearing dowel with a bolt fitted to ensure the threaded section is facing outwards.

- 6.Refit the crankshaft balance weights in their correct order with the larger flanges (and part numbers) facing each other.

- 7.Replace the crankshaft end float shims on to the main bearing housing and refit the housing and all bolts.

- 8.Check and adjust if necessary the crankshaft end float.

- 9.Remove the bearing housing bolts.

- 10.Replace the alternator adaptor making sure the slot on the face is towards the top of the crankcase.

- 11.Remove the centre bearing dowel.

- 12.Replace the oil seal to the bearing housing.

- 13.Replace the centre bearing dowel and the dowel retaining bolt.

- 14.Replace the flywheel key.

- 15.Heat the crankshaft pinion gear and ensure the "0" timing mark will be facing outwards when the gear is refitted to the crankshaft.

- 16.Replace the sump with four bolts (one each side).

- 17.Turn the crankcase the correct way up.

- 18.Replace the fanshroud.

- 19.Replace the stator.

- 20.Replace the cable clip.

- 21.Turn the crankshaft until the flywheel key is at TDC and fit the mandrel, Service Tool 317-50045.

22. Rub chalk over the flywheel timing marks to aid identification during later procedures.
 23. Use a crane (if available) to replace the flywheel ensuring that it is offered up dead square.
 24. Remove the mandrel and replace the flywheel retainer.
 25. Check that the 'key is still in position and turn the flywheel to check for free movement.
 26. Replace the rectifier, cables and cover.
The two large cutouts in the cover are towards the bottom of the rectifier.
 27. Stand the engine on its flywheel using a suitable piece of timber between the recessed flywheel and the plinth.
 28. Remove the sump.
 29. Replace the push rod cam followers. a tool with a rubber suction pad (as used to grind in valves) can be used to advantage.
 30. Gently replace the camshaft keeping it square at all times, and ensure that the "0" timing marks on the camshaft and crankshaft gears coincide exactly with each other on final assembly.
 31. Replace the fuel pump tappet guides, the end with the two flats enters the crankcase first.
Take extreme care to ensure the bolt holes are correctly aligned.
 32. Replace the fuel pump tappet guide bolt making sure a copper washer is fitted under the bolt head.
 33. Using the flywheel as a pivot rotate the crankcase until No.1 cylinder crankshaft throw is at TOC
 34. Replace No.1 cylinder, connecting rod and piston.
 35. Fit a retaining rube on to one end of the cylinder studs and secure it with a hand tightened nut.
 36. Push down on the top of the piston as the crankcase is turned' until the piston is at BDC.
 37. Fit the connecting rod bearing cap.
 38. Rotate the crankcase to check for free movement.
 39. Repeat items 33 to 38 for the remaining cylinders.
 40. Replace the oil pump push rod and then the pump.
 41. Replace the sump ensuring the oil strainer is fitted correctly.
 42. Turn the engine the normal way up and replace the oil dipstick.
 43. Replace the fuel pump tappets and tappet caps.
 44. Refit the air baffles with the spring clips facing the manifold side.
 45. Replace the fuel pumps and shims.
 46. Replace the governor sleeve assembly with the spring ring facing outwards.
- It will be necessary to open the governor weights to ensure the assembly is pushed fully on to the shaft.
47. Replace the governor lever assembly and both fulcrum pins taking care to ensure the holes are facing outwards.
 48. Measure and adjust as necessary, the end play between pivot and lever assembly.
 49. Connect the governor interconnecting lever to the fuel pump racks.
 50. Adjust the fuel pump racks.
 51. Reconnect the speeder spring to its control.
 52. Check the governor lever and rack for correct operation.
 53. Set the governor.
 54. Replace the camshaft end float shims and then the camshaft thrust washer.
 55. Replace the end cover using the service tool, 317-50063, to protect the oil seal.
 56. Check the camshaft end float.
 57. Refit the starting dowel and pin.
 58. Remove the retaining tube from No.1 cylinder.
 59. Replace the cylinder head and diagonally torque the nuts.
 60. Check the cylinder head clearance.
 61. With the cylinder head removed, replace the push rods and tubes.
A very small mount of grease added to the tube sealing rubbers will ease the fitting of the heads.
 62. Replace the cylinder head complete with gasket and shims making sure it is fully seated and then replace the nuts hand tight.
 63. Repeat items 58 on page 111 to 62 for the remaining cylinders.
 64. Replace a manifold with one nut on each cylinder head to ensure the heads are correctly aligned.
 65. Torque the cylinder head nuts.
 66. Remove the manifold.
 67. Spill time the fuel pumps.
 68. Replace the side shields at the gear and flywheel ends.
 69. Replace the air cowling with the gasket on the outside of the cowling.
 70. Replace both manifolds using the thick spacer on the top studs between both manifolds.
 71. Replace the valve rocker oil feed pipe to the heads and crankcase.
 72. Turn the engine to TDC No. 1 cylinder firing stroke and set the inlet and exhaust valve clearances.
 73. With the engine still at TDC No.1 firing stroke set the decompressors.
 74. Repeat items 72 to 73 for the remaining cylinders.

75. Check and reset, if necessary, the fuel injector setting.
 76. Replace the injectors and leak off pipes complete.
- Ensure a new washer is fitted at the nozzle end.
77. Replace the fuel pump to injector pipes leaving the nuts finger tight.
 78. Replace the injector clamp.
 79. Tighten all of the fuel pipes.
 80. Replace the fuel pump inspection doors.
 81. Replace the cylinder head covers.
 82. Replace the lifting eye.
 83. Refit air filter, silencer and fuel tank, reconnect all services and replenish the fuel and oil supplies.

TX DISMANTLE AND REBUILD

These notes are of a general nature and are included as an aide memoir and in no way are they intended as instructions.

Dismantling

Before beginning any work on the engine drain all of the fuel and oil from the engine and disconnect all services, including the battery. Remove the air filter, alternator, starter and fuel tank.

1. Remove the lifting eye bracket.
2. Remove the exhaust manifold.
3. Remove the axial fan cowling.
4. Remove the inlet manifold.
5. Slacken the alternator and remove the drive belt.
6. Remove the alternator.
7. Remove the axial fan and bracket.
8. Pull off the injector leak-off pipes.
9. Remove all of the fuel pipes.
10. Remove the fuel lift pump, if fitted.
11. Remove the fuel filter.
12. Remove the gear and flywheel end air shields.
13. Remove the injector clamp.
14. Lift out the injector; note that a washer is fitted over the nozzle of each injector.
15. Remove the valve rocker cover (6mm Allen key).
16. Remove the valve rocker assembly and oil restrictor plate.
17. Remove the inlet and exhaust valve stem caps.
18. Lift out the push rods.
19. Remove the valve rocker oil feed pipe and unions from the crankcase and cylinder heads.
20. Remove the four cylinder head bolts from each cylinder.
21. Lift off the cylinder heads and place them on a bench.
22. Remove the push rod tubes.
23. Fit a suitable retaining tube over one cylinder head bolt for each cylinder and replace the bolt hand tight this will prevent the cylinders from rising if the crankshaft is turned.
24. Remove the air baffles between the cylinders.
25. Remove the end cover.
26. Remove the thrust washer and shim from the camshaft.
27. Remove all the fuel pump inspection doors.
28. Disconnect the governor link from all the fuel pump racks.
29. Remove the two fulcrum pins from the governor lever assembly pivot supports taking care to retain the spring and shims.
30. Using long nosed pliers, remove the speeder spring from its control.
31. Remove the governor lever assembly complete.
32. Remove the governor sleeve assembly from the camshaft.
33. Remove the fuel pump taking care to retain the timing shims with the correct pump.
34. Remove the fuel pump tappet and cap using long nosed pliers.
35. Remove the fuel pump tappet guide locating bolts from the side of the crankcase.
36. Remove the fuel pump tappet guides noting which way they are fitted.
37. Remove the oil dipstick.
38. Stand the engine on its flywheel using a suitable piece of timber between the recessed flywheel and the plinth.
39. Remove the sump.
40. Remove the oil pump and oil pump push rod.
41. If necessary dismantle the oil pump.
42. Ensure the push rod cam followers are at their highest positions to clear the camshaft.
43. Keeping the camshaft square gently ease it out of the crankcase.
44. Rotate the crankcase until No. 1 piston is at BDC.
45. Remove No.1 connecting rod cap.
46. Rotate the crankcase until No.1 piston is at TDC.
47. Remove the retaining tube and gently lift off the cylinder barrel, piston and connecting rod as one unit.
48. Replace the bearing cap on to the connecting rod.
49. Repeat the procedure for the remaining cylinders.
50. Remove the Allen screws and crankshaft balance weights.

51. Remove the cam followers.
52. Replace the sump holding it with four bolts (one each side).
53. Remove the crankshaft gear.
54. Turn the engine to its normal position.
55. Unscrew the flywheel retaining nut two turns using a 65mm socket.
56. Use the service tool and break the tapered seal between the flywheel and the crankshaft.
57. Remove the flywheel nut and fit the mandrel 317-50046, in its place.
58. Keeping the flywheel square ease the flywheel from the crankshaft and place it in a safe position.
59. Remove the flywheel housing.
60. Use a brass drift to remove the flywheel key.
61. Remove the intermediate bearing retaining bolts from the side of the crankcase.
62. Remove the intermediate bearing dowels by screwing a suitable bolt into the dowel and withdrawing it.
The bolt should be left in the dowel to identify the correct assembly procedure as the dowel is threaded at one end only.
63. Remove the flywheel end main bearing housing.
64. Gently remove the crankshaft from the crankcase.
65. Remove the split thrust washers from inside the crankcase at the gear end and from the main bearing housing.

Rebuild

When assembling the engine, use normal engine lubricating oil to spray all moving parts during assembly. All bearing surfaces must be well lubricated including the valve stems and the cups of the push rods.

New camshaft bushes should be immersed in clean engine oil for four hours before fitting.

The pistons with rings and connecting rods assembled, must be submerged in oil just before fitting into the cylinder. After submersion drain both ways so that no oil is left in the combustion chamber or inside the piston.

Replace all joints and gaskets.

1. Turn the crankcase onto its side using a suitable piece of wood to support it.
2. With the sump removed grease the steel backs of the split thrust washers and refit them into the gear end of the crankcase and the main bearing housing.
3. Replace the crankshaft taking care to ensure the bearing locating dowel is in line with the hole in the

crankcase before the dowel enters the housing. If, on the final assembly, the holes are not in line use a brass drift to rotate the bearing housing.

Check exact alignment by using a tapered rod.

4. Replace the Intermediate bearing dowel with a bolt fitted to ensure the threaded section is facing outwards.
5. Refit the crankshaft balance weights in their correct order with the larger flanges facing each other.
6. Replace the crankshaft end float shims on to the main bearing housing and refit the housing and all bolts.
7. Check and adjust the crankshaft end float.
8. Replace the oil seal to the bearing housing.
9. Replace the centre bearing dowel and the dowel retaining bolt.
10. Replace the flywheel key.
11. Heat the crankshaft pinion gear and ensure the "0" timing mark will be facing outwards when the gear is refitted to the crankshaft.
12. Replace the sump with four bolts; one on each side.
13. Turn the crankcase the correct way up.
14. Replace the flywheel housing.
15. Turn the crankshaft until the flywheel key is at TDC and fit the mandrel. Service Tool 317-50045.
16. Rub chalk over the flywheel timing marks to aid identification during later procedures.
17. Replace the flywheel ensuring that it is offered up dead square.
18. Remove the mandrel and replace the flywheel nut.
19. Check that the key is still in position and turn the flywheel to check for free movement.
20. Stand the engine on its flywheel using a suitable piece of timber between the recessed flywheel and the plinth.
21. Remove the sump.
22. Replace the push rod cam followers; a tool with a rubber suction pad, as used to grind in valves, can be used to advantage.
23. Gently replace the camshaft keeping it square at all times, and ensure that the "0" timing marks on the camshaft and crankshaft gears coincide exactly with each other on final assembly.
24. Replace the fuel pump tappet guides, the end with the two flats enters the crankcase first. Take extreme care to ensure the bolt holes are correctly aligned.
25. Replace the fuel pump tappet guide bolt making sure a copper washer is fitted under the bolt head.

26. Using the flywheel as a pivot rotate the crankcase until No.1 cylinder crankshaft throw is at TDC.
27. Replace No.1 cylinder, connecting rod and piston.
28. Fit a retaining tube on to one cylinder head bolt and secure it hand tightened.
29. Push down on the top of the piston as the crankcase is turned until the piston is at BDC.
30. Fit the connecting rod bearing cap.
31. Rotate the crankcase to check for free movement.
32. Repeat the procedure for the remaining cylinders.
33. Replace the oil pump push rod and then the pump.
34. Replace the sump ensuring the oil strainer is fitted correctly.
35. Turn the engine the normal way up and replace the oil dipstick.
36. Replace the fuel pump tappets and tappet caps.
37. Refit the air baffles with the spring clips facing the manifold side.
38. Replace the fuel pumps and shims.
39. Replace the governor sleeve assembly with the spring ring facing outwards.
40. Replace the governor lever assembly and both fulcrum pins taking care to ensure the holes are facing outwards.
41. Check the end play between pivot and lever assembly is correct.
42. Connect the governor interconnecting lever to the fuel pump racks.
43. Adjust the fuel pump racks.
44. Reconnect the speeder spring to its control.
45. Check the governor lever and rack for correct operation.
46. Set the governor.
47. Replace the camshaft end float shims and then the camshaft thrust washer.
48. Replace the end cover using the service tool to protect the oil seal.
49. Check the camshaft end float.
50. Remove the retaining tube from No.1 cylinder.
51. Replace the cylinder head and diagonally torque the bolts.
52. Check the cylinder head clearance.
53. With the cylinder head removed, replace the push rods and tubes: a very small amount of grease added to the tube sealing rubbers will ease the fitting of the heads.
54. Replace the cylinder head making sure it is fully seated and then replace the bolts hand tight.
55. Repeat the procedure for the remaining cylinders.
56. Replace a manifold with one nut on each cylinder head to ensure the heads are correctly aligned.
57. Torque the cylinder head nuts.
58. Remove the manifold.
59. Spill time the fuel pumps.
60. Replace the side shields at the gear and flywheel ends.
61. Replace the air cowling.
62. Replace both manifolds.
63. Replace the valve rocker oil feed pipe to the heads and crankcase.
64. Turn the engine to TDC No. 1 cylinder firing stroke and set the inlet and exhaust valve clearances: repeat for the remaining cylinders.
65. Check the fuel injector setting.
66. Replace the injectors with a new washer and leak off pipes.
67. Replace the injector clamp.
68. Replace the fuel pipes.
69. Tighten all of the fuel pipes.
70. Replace the fuel pump inspection doors.
71. Replace the valve rocker covers.
72. Replace the lifting eye.
73. Refit the air filter, alternator, starter and fuel tank, reconnect all services and replenish the fuel and oil supplies.

8. FLYWHEEL CHARGE WINDINGS

8.1 CHARGE WINDINGS

One of two types of charge windings may be fitted to TS and TR engines.

1. Syncro - TS and TR up to, but not on, the engine numbers shown.
2. Nicsa - TS and TR first fitted on the following engines:

41 00433 TS1	41 00240 TR1
41 01651 TS2	41 00281 TR2
41 01568 TS3	41 00301 TR3

The Syncro and Nicsa charge winding components are not interchangeable.

The flywheel charge winding system comprises of three components: a stator, rotor and regulator.

The rotor, in the form of permanent magnets, is attached to the back of the flywheel.

The stator consists of coils of copper wire wound onto a laminated iron core which is attached to the main bearing housing.

The stator output leads pass through the flywheel housing to the regulator unit which is attached to the outside of the housing. Should any of the output cables be attached to the wrong terminal the regulator unit will be permanently damaged when the battery is connected into the circuit.

Battery Charge Indicator Light

Some engines may be fitted with an impulse transmitter and warning light to provide an indication of when the system is faulty. The transmitter is fitted between the rectifier/regulator and the battery, during periods of running the indicator light will remain unlit unless there is a fault in the charging system.

The battery charge indicator light will always be lit to indicate a charging fault. The light will also be switched on with a fully serviceable system under the following circumstances:

- a. If the charge rate drops below 2 Amps at normal engine speed and the battery is fully charged.
- b. The charge rate drops below 4 Amps at idling speed.

8.2 SYNCRO CHARGE WINDINGS

Maximum Output - voltage held at 13 Volts

r/min	Amps
1000	8.0
1500	12.5
2000	15.0
3000	17.0

Fault Finding

The most common faults associated with this system are dealt with in the flow charts.

In cases where no electric start is possible reference should firstly be made to 'Starter Motor, Battery and Charge System Fault Diagnosis Flow Chart', proceeding through to other charts if a charge system fault becomes evident.

In cases where a specific charging fault is known to exist refer directly to the relevant flow chart.

The necessary instruments and connection diagram to carry out the tests are given in "Nicsa Charge Windings".

Stator Winding Resistance at 20°C (68°F)

	Resistance
Black to Black	0.22 - 0.33
Red to Red	2.00 - 3.00

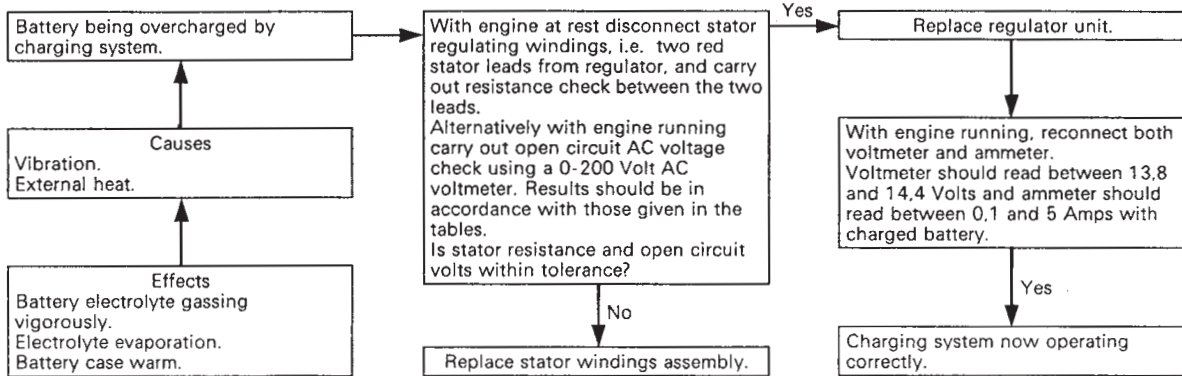
Stator Winding AC Open Circuit Voltages at 20°C (68°F)

The values given are True rms AC Volts.

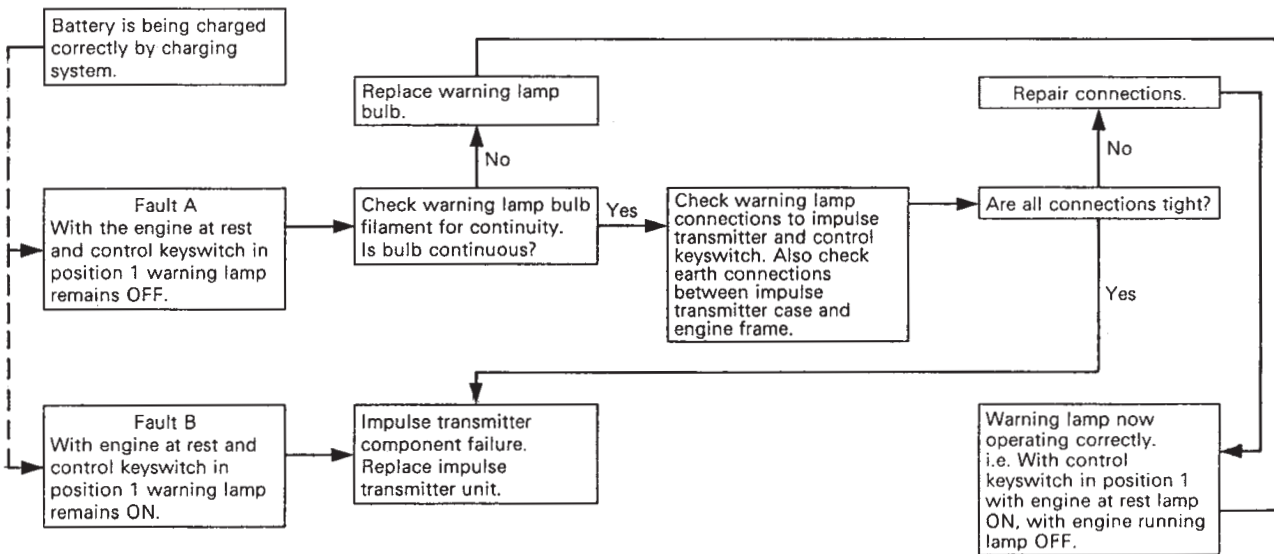
r/min	Black to Black	Red to Red
1000	16 - 24	42 - 63
1500	23 - 35	62 - 93
2000	31 - 46	81 - 121
2500	37 - 56	99 - 149
3000	45 - 68	121 - 181

Syncro Fault Finding Flow Charts

Charge System Overcharging

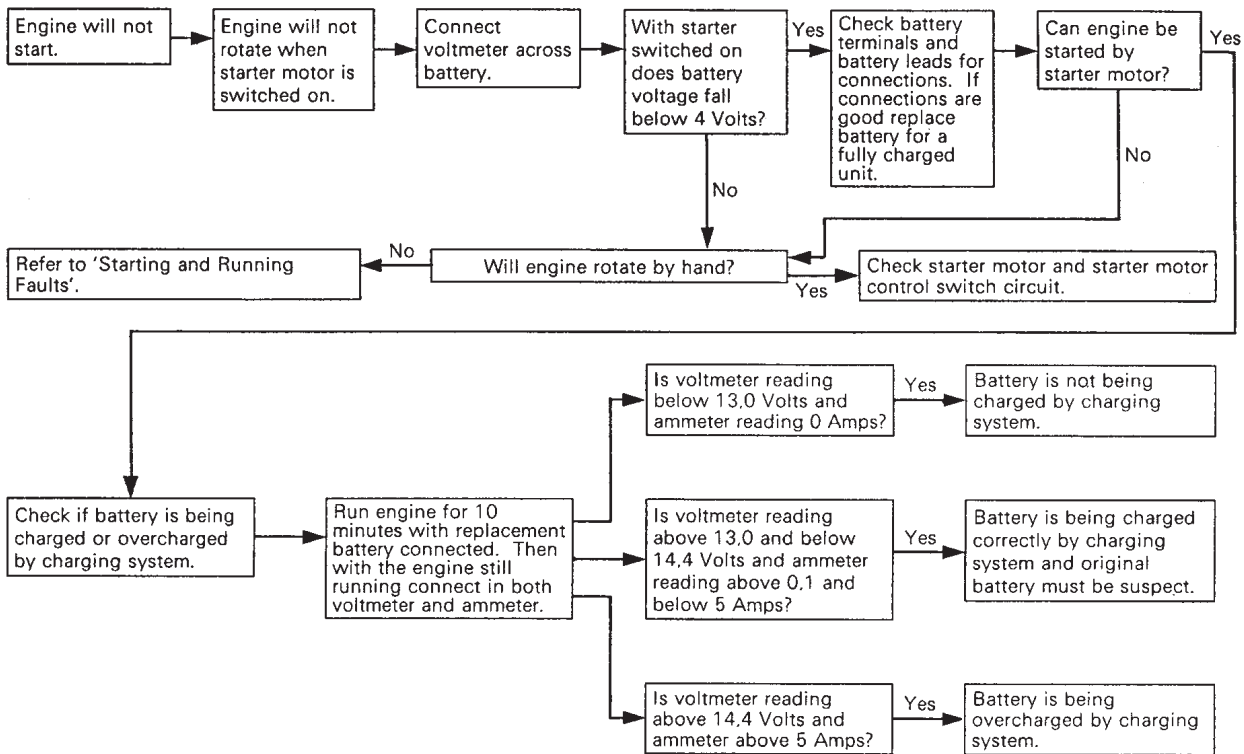


Charge System Warning Lamp Malfunction

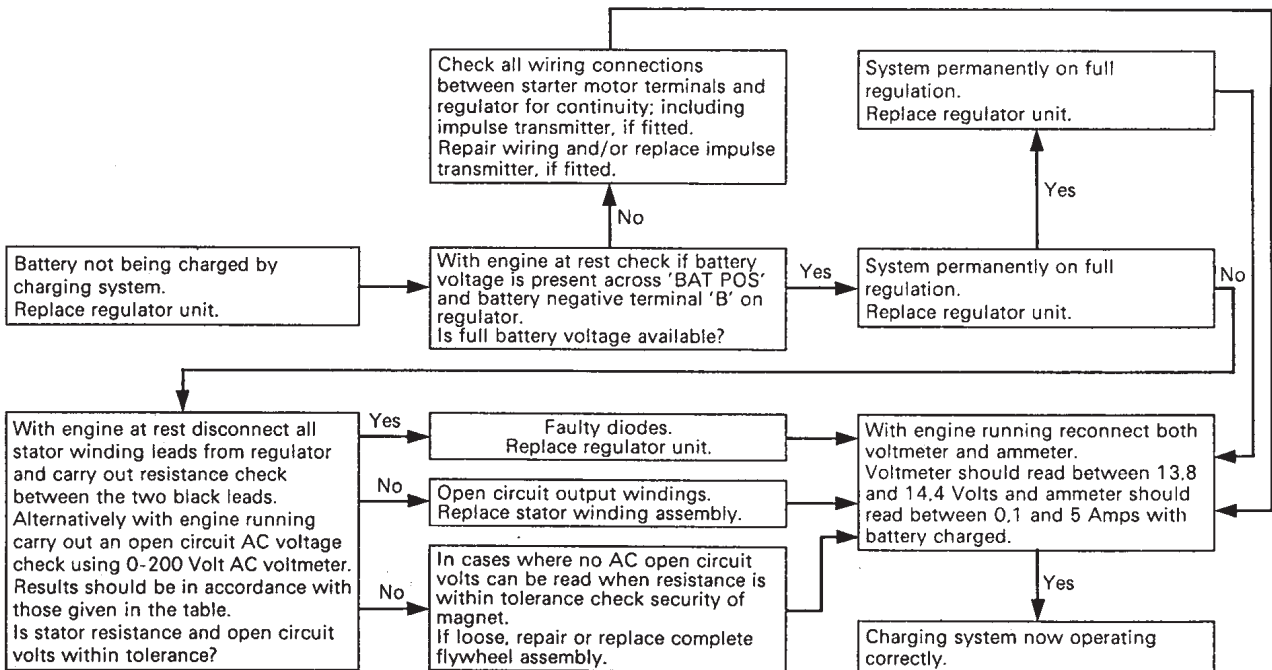


Syncro Fault Finding Flow Charts

Starter Motor, Battery and Charge System



Charge System - no charge



8.3 NICSA CHARGE WINDINGS

Fault Finding

The most common faults associated with this system are dealt with in the flow charts on the following pages.

In cases where no electric start is possible reference should firstly be made to "Starter Motor, Battery and Charge System Diagnostic Flow Chart", proceeding through to other charts if a charge system fault becomes evident.

In cases where a specific charging fault is known to exist refer directly to the relevant flow chart.

The following instruments are necessary to carry out the tests.

- 1.0-20A moving coil ammeter.
- 2.0-20V moving coil voltmeter or a DC multimeter.
- 3.0-200V moving iron voltmeter or an AC multimeter.
- 4.0-5 Ohm meter or multimeter.

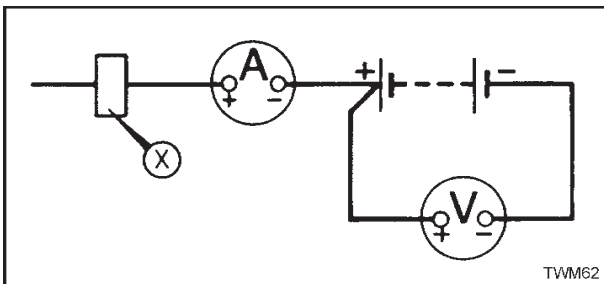


Figure 7.3.1 Test Instrument Connection Diagram X - Removed B+ Battery Terminal

Stator Winding Resistance at 20°C (68°F)

Leads	Resistance
Yellow to Yellow	0.45 - 0.55
Red to one Yellow	0.225 - 0.275
Red to the other Yellow	0.225 - 0.275

Stator Winding AC Open Circuit Voltages at 20°C (68°F)

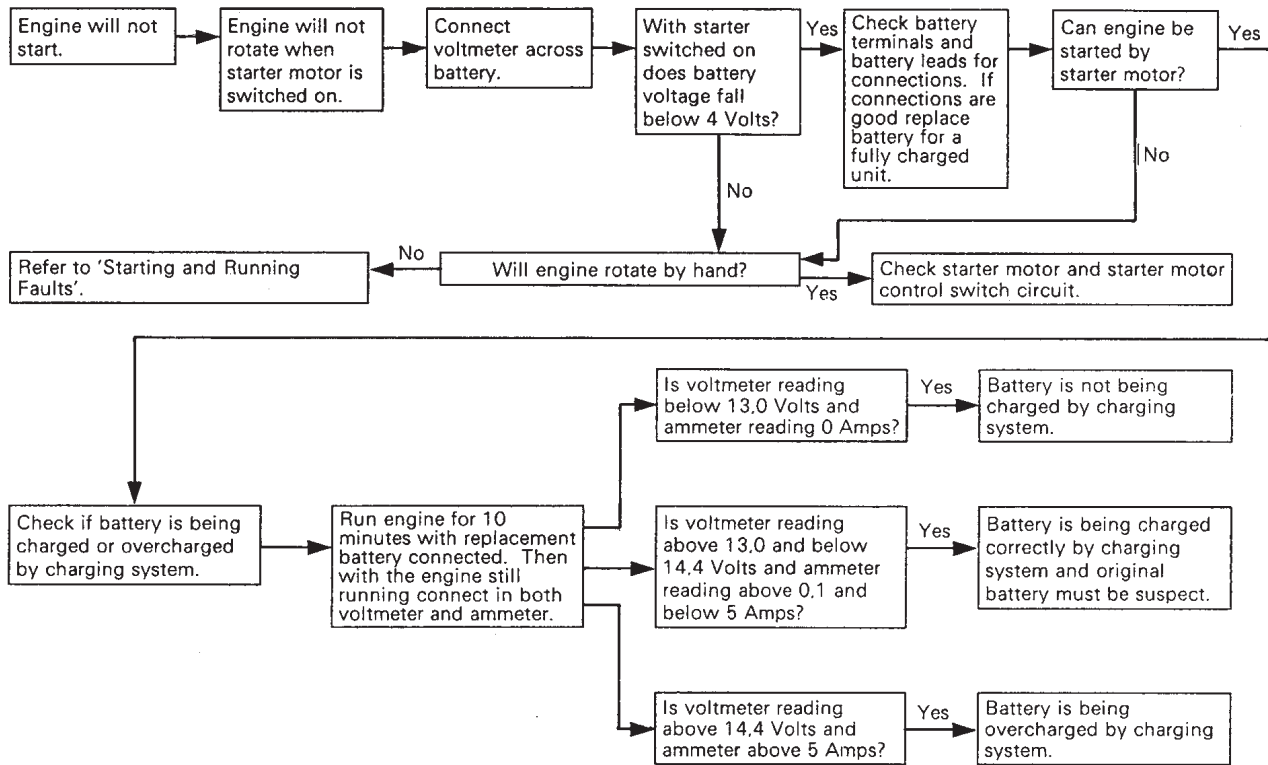
r/min	Yellow to Yellow	Red to Yellow
1000	30 - 34	13 - 17
1500	43 - 49	21 - 24
2000	53 - 62	26 - 32
2500	69 - 77	33 - 39
3000	82 - 92	30 - 46

Output Charge Rate - voltage held at 12.5 Volts

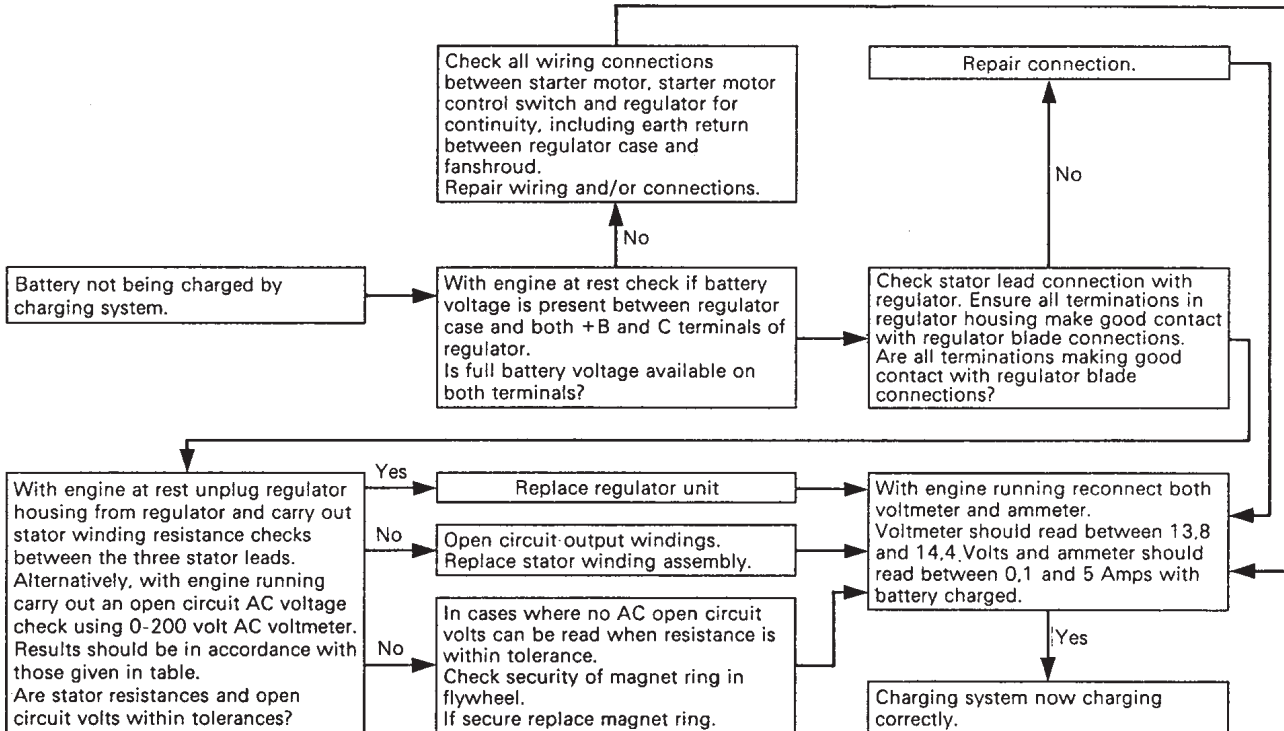
r/min	Amps
1000	5.5 - 7.0
1500	10.0 - 11.5
2000	13.0 - 14.5
2500	15.0 - 16.5
3000	16.0 - 17.5

Nisca Fault Finding Flow Charts

Starter Motor, Battery and Charge System

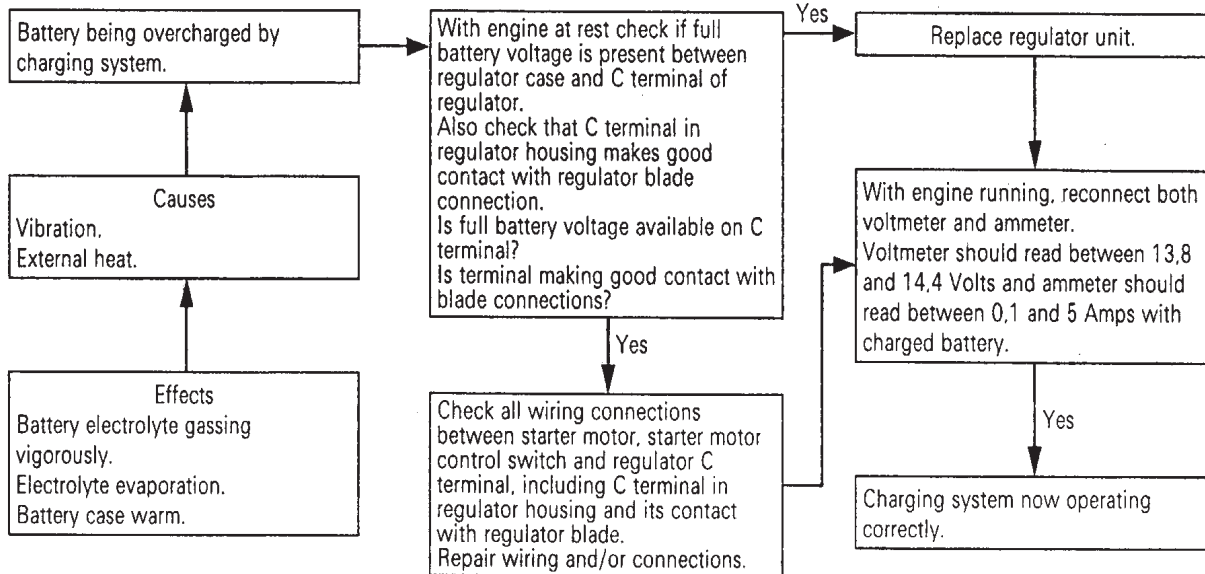


Charge System - no charge

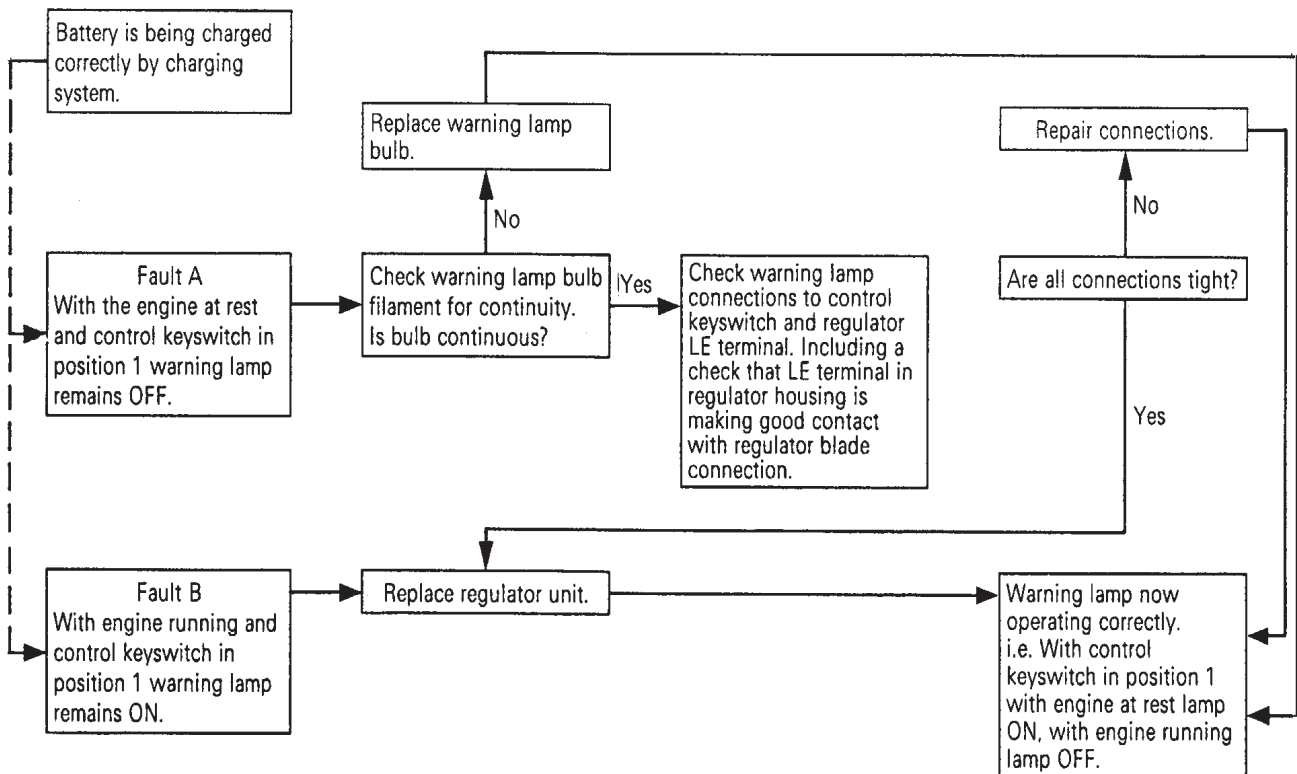


Nisca Fault Finding Flow Charts

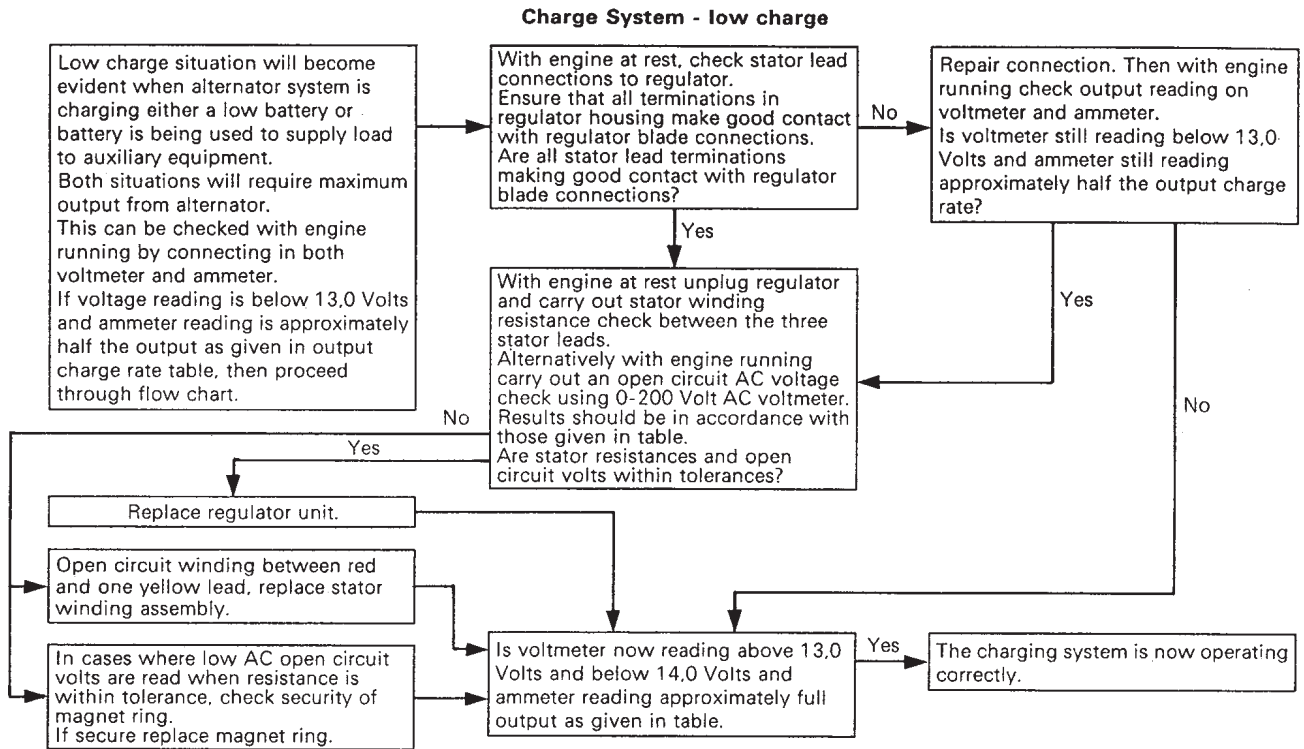
Charge System Overcharging



Charge System Warning Lamp Malfunction



Nicsa Fault Finding Flow Chart



9. ELECTRICAL WIRING DIAGRAMS

9.1 WIRING DIAGRAMS

All cables must be PVC insulated automobile cable to BS6862.

The cable sizes given relate to the cables between the control panel, or loose components, and the engine being a maximum length of 1.5m (4.9ft) with 'Syncro' charge windings and 2.0m (6.6ft) with 'Nicsa' charge windings, and the cables between the battery and engine being a maximum length of 0.94m (3.1ft).

In cases where 'Nicsa' charge windings are used without a starter motor the cable size given relates to the cable between the regulator and battery being a minimum length of 0.5m (1.6ft).

The small numbered boxes shown attached to some cables are cable identification numbers.

The heater plug (17) is an optional accessory.

Key to all Diagrams

1. Flywheel alternator stator.

2. Control keyswitch.

3. Engine temperature switch.

The air temperature switch must be wired in irradiated PVC cable suitable for temperatures up to 120°C (248°F).

4. Fuel control solenoid circuit breaker.

5. Fuel control solenoid.

6. Impulse transmitter.

7. Oil pressure override push-button.

8. Oil pressure switch.

9. Regulator.

10. Starter battery.

11. Starter motor.

12. Control switch (5A rating) - not supplied.

13. Warning lamp.

14. Protective switch relay.

15. Starter solenoid.

16. Socket (16a) and Plug (16b).

All terminal arrangements are shown as viewed from the rear.

17. Heater plug.

18. Resistance.

Cable Colour Code for all Diagrams

Red = Red.

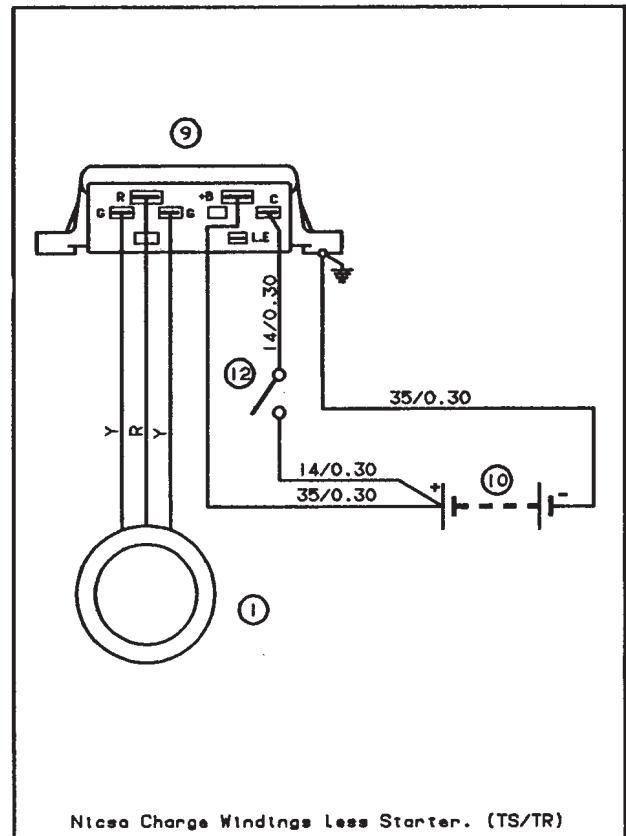
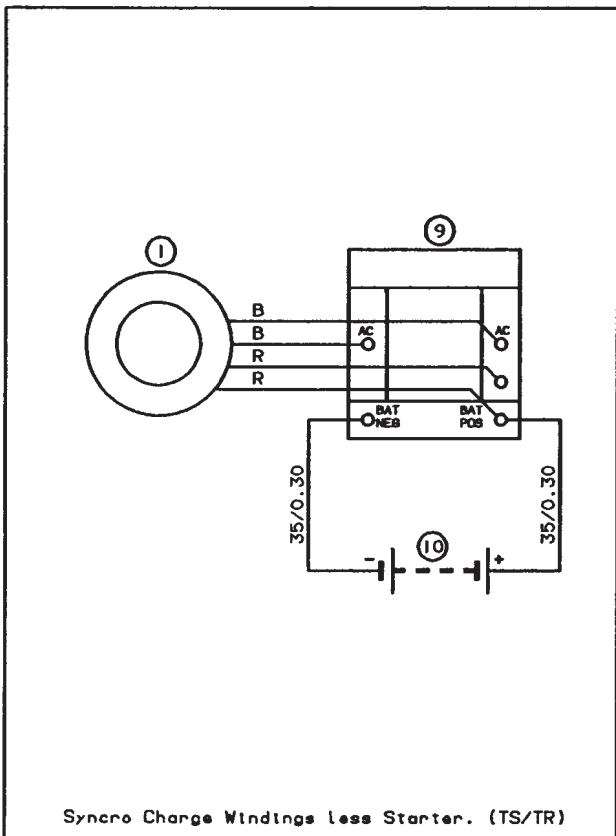
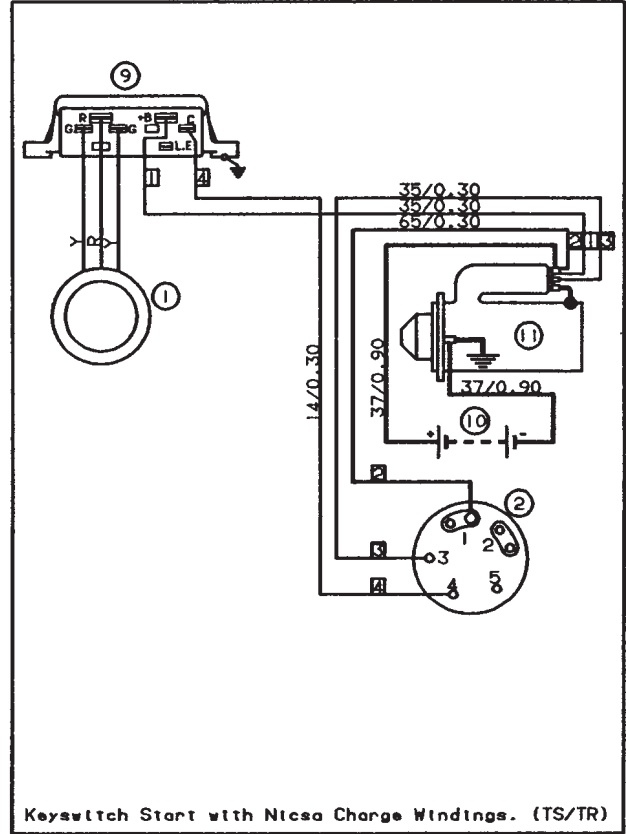
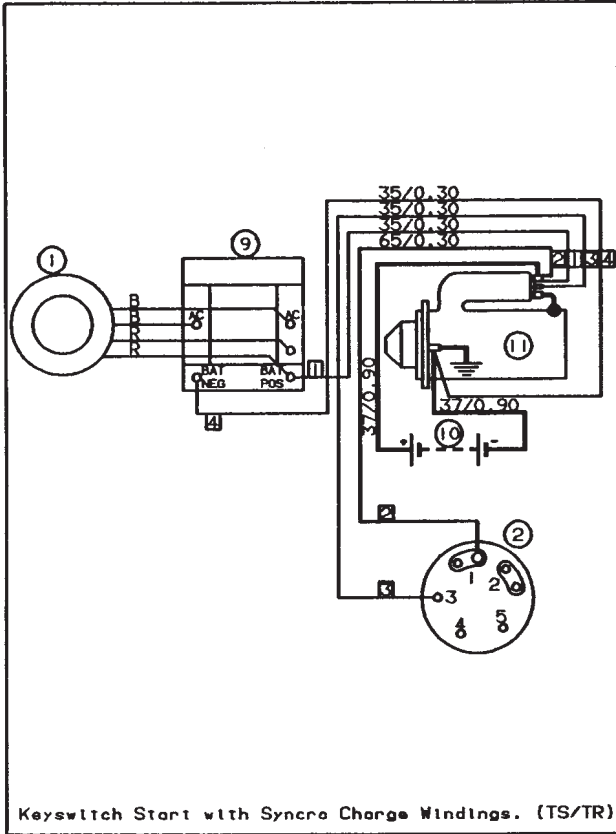
Y = Yellow.

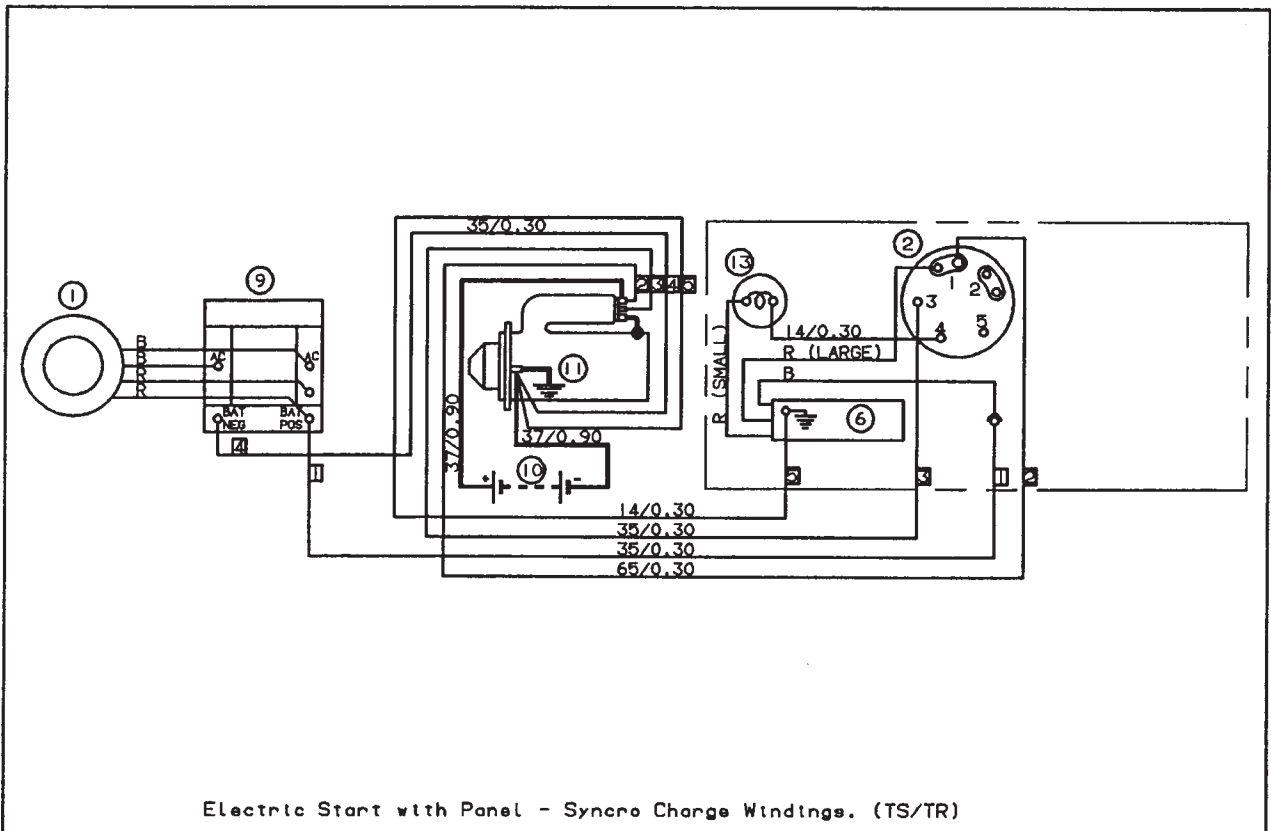
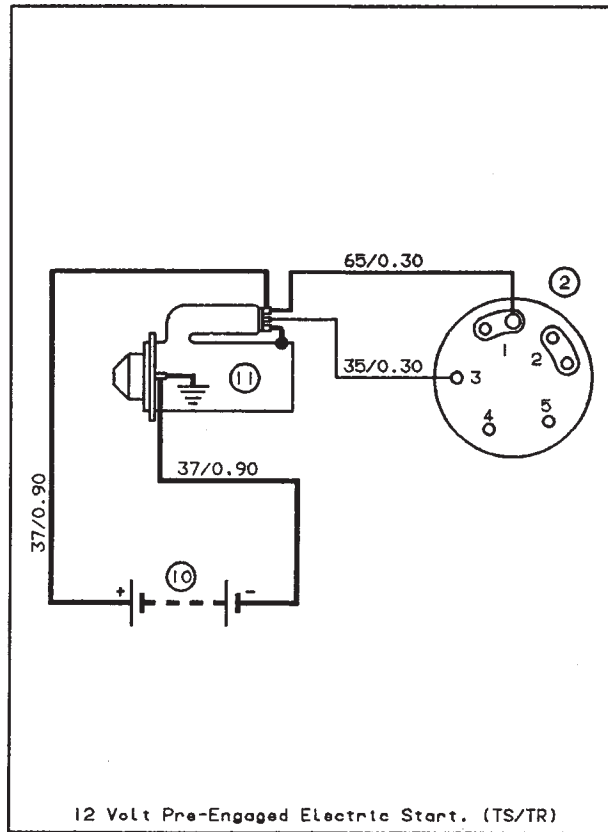
B = Black.

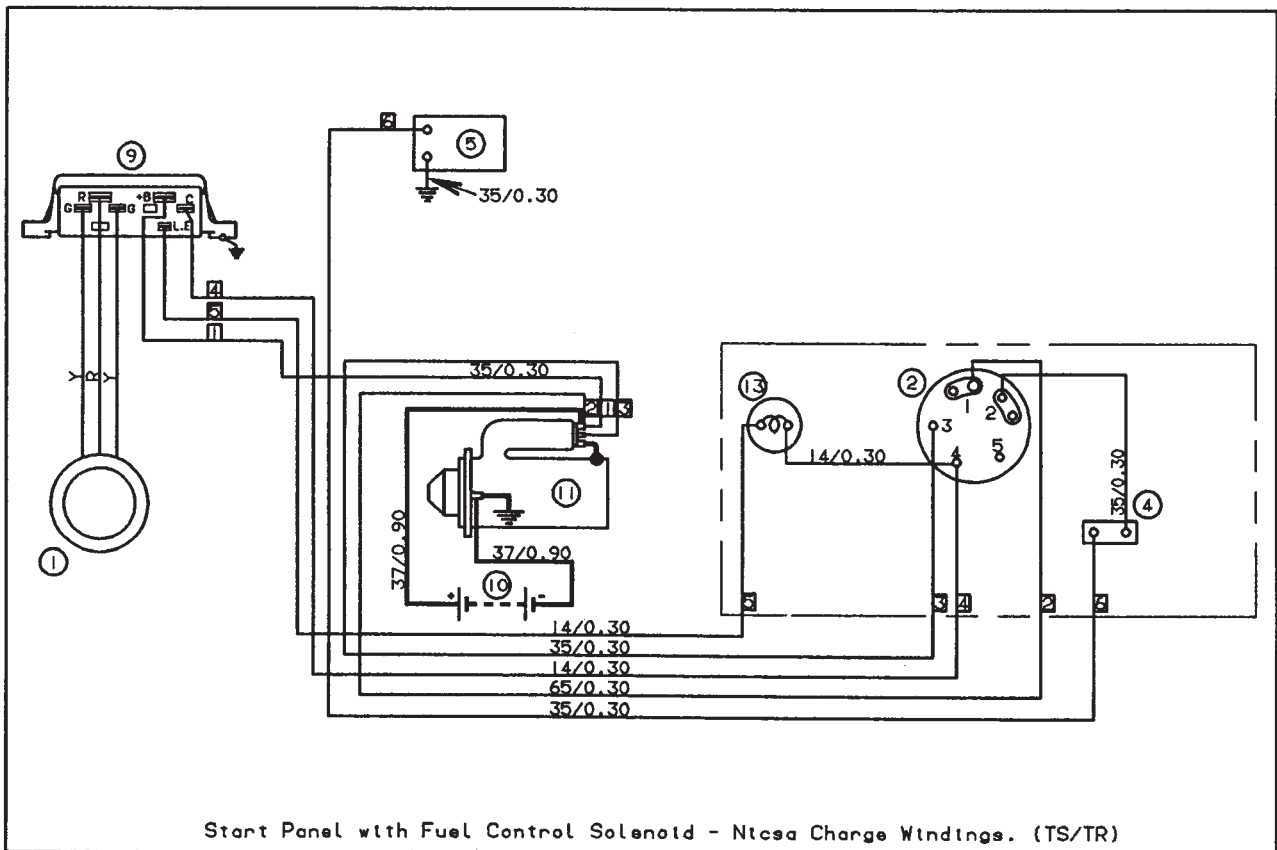
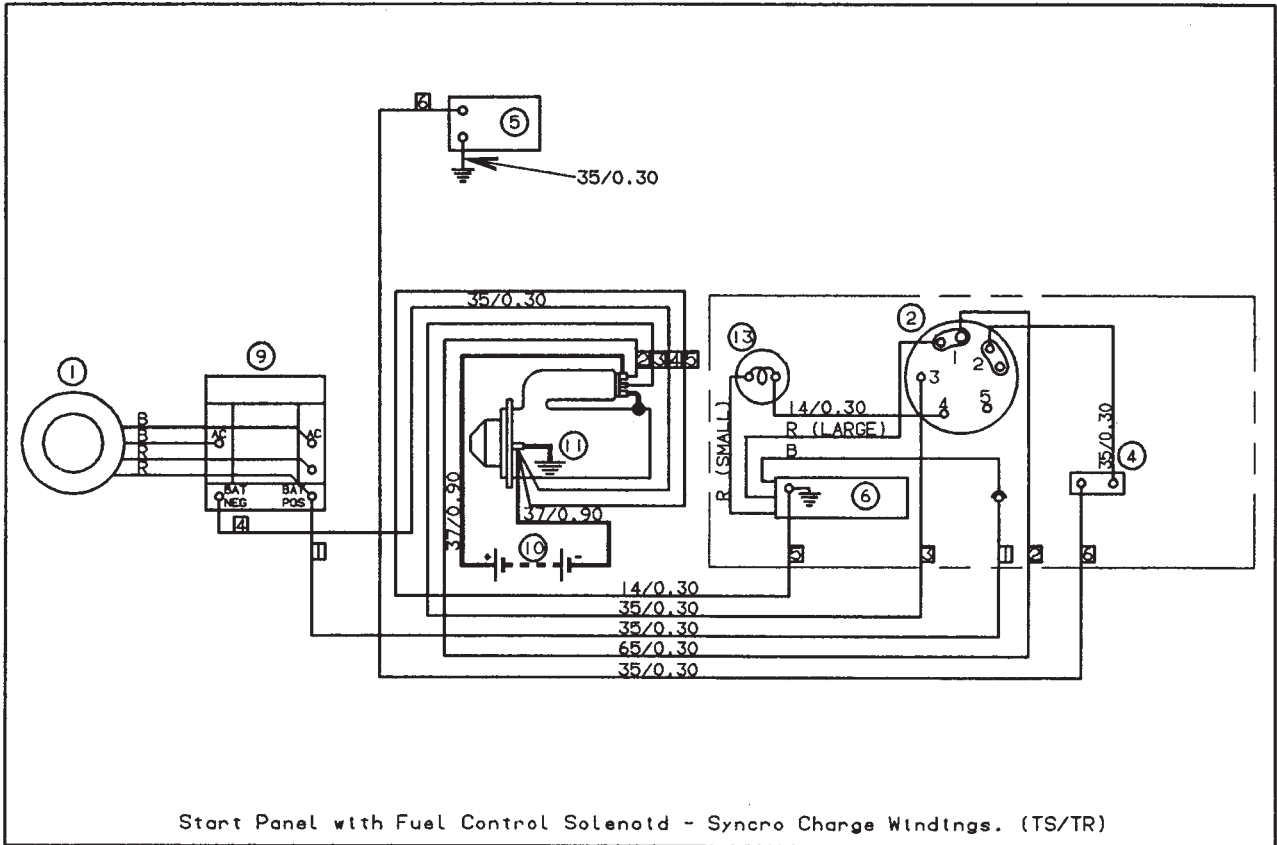
Rectifier/regulator Terminals

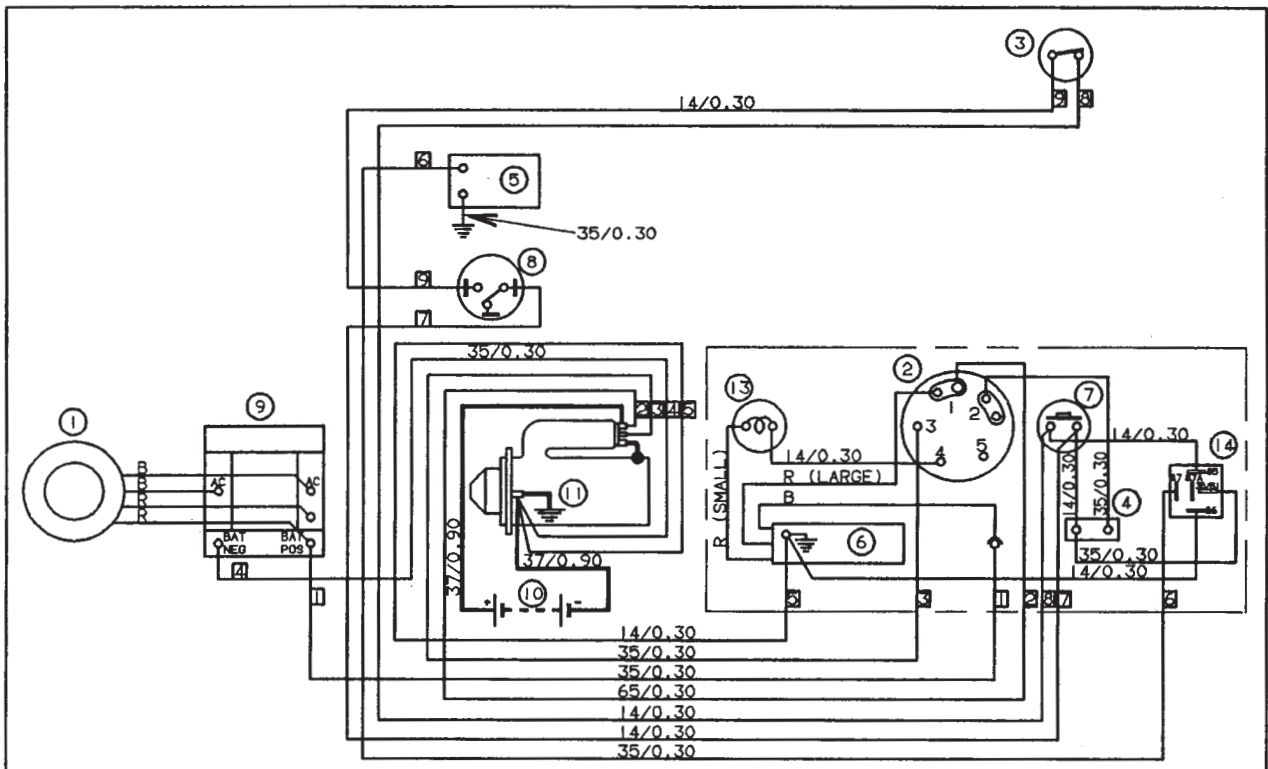
BAT POS = Battery +

BAT NEG = Battery -

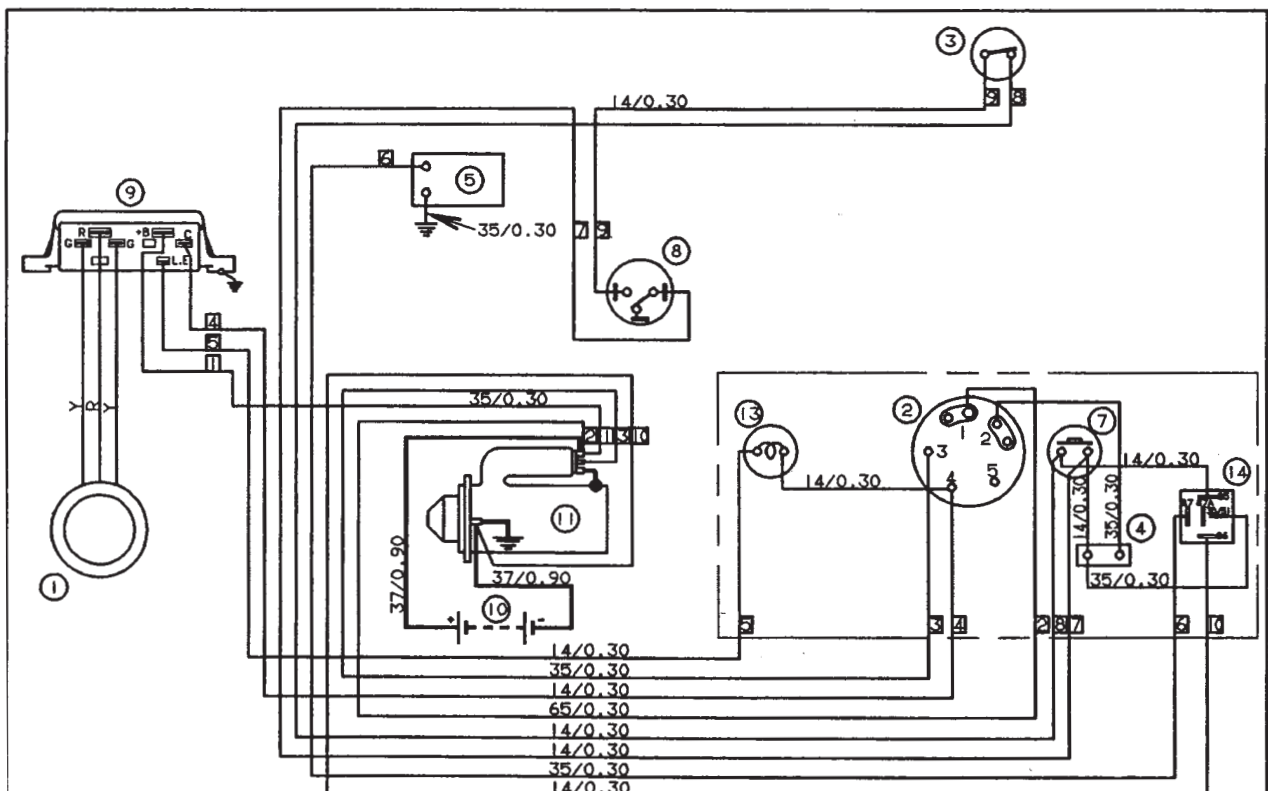




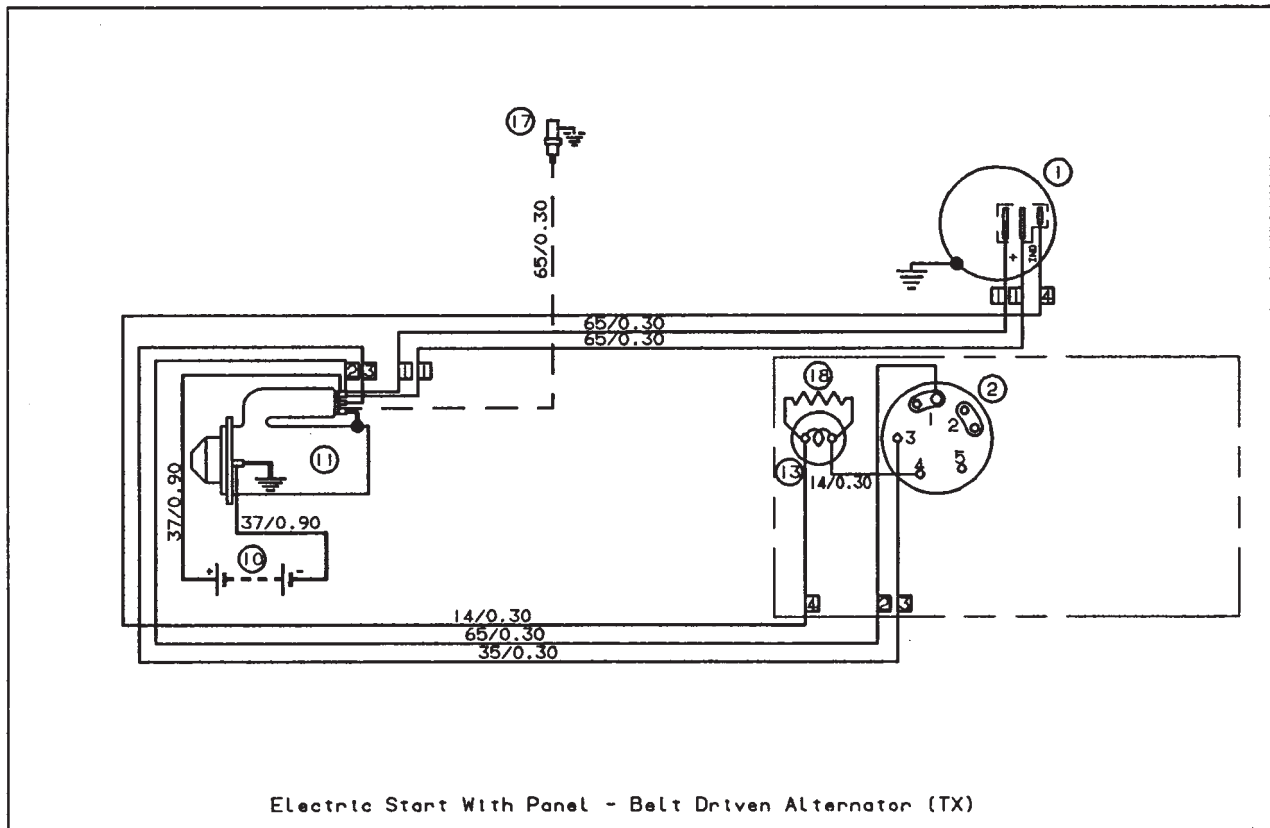
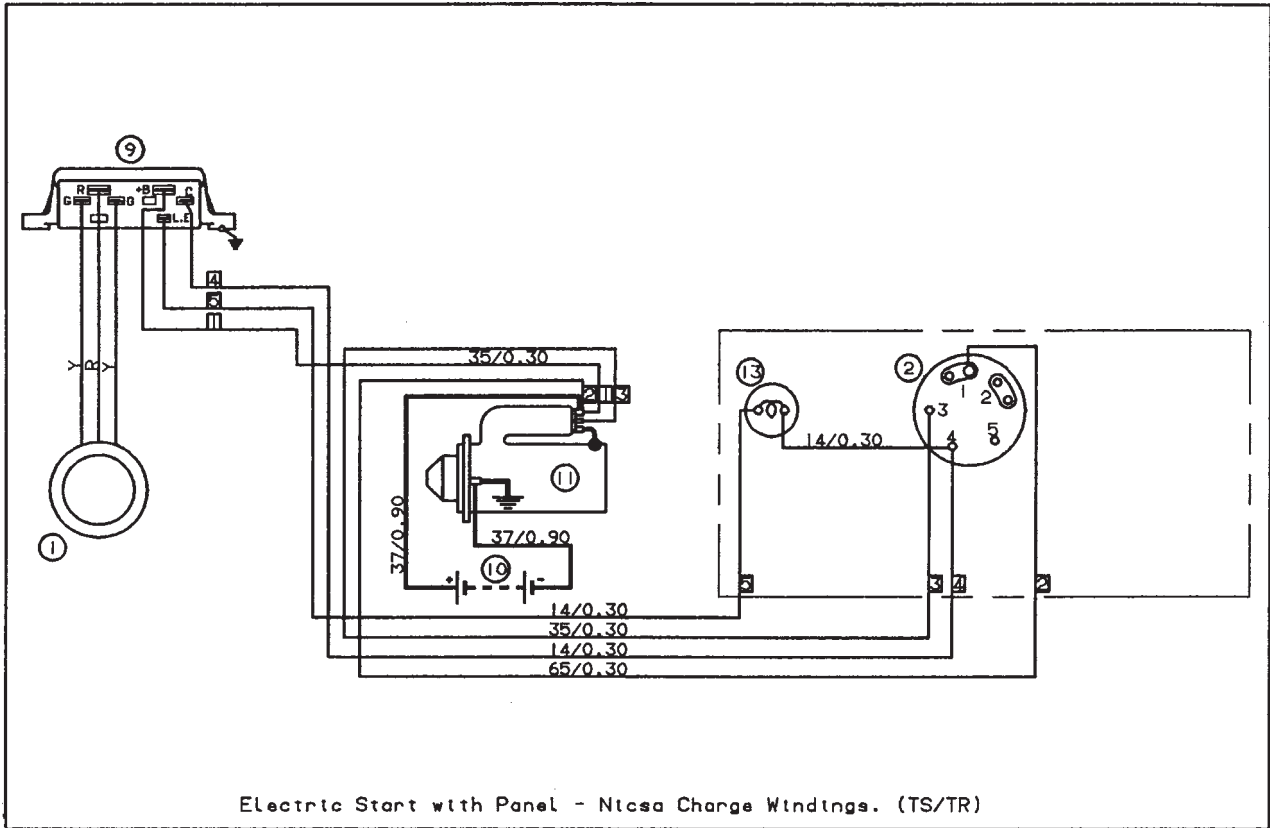


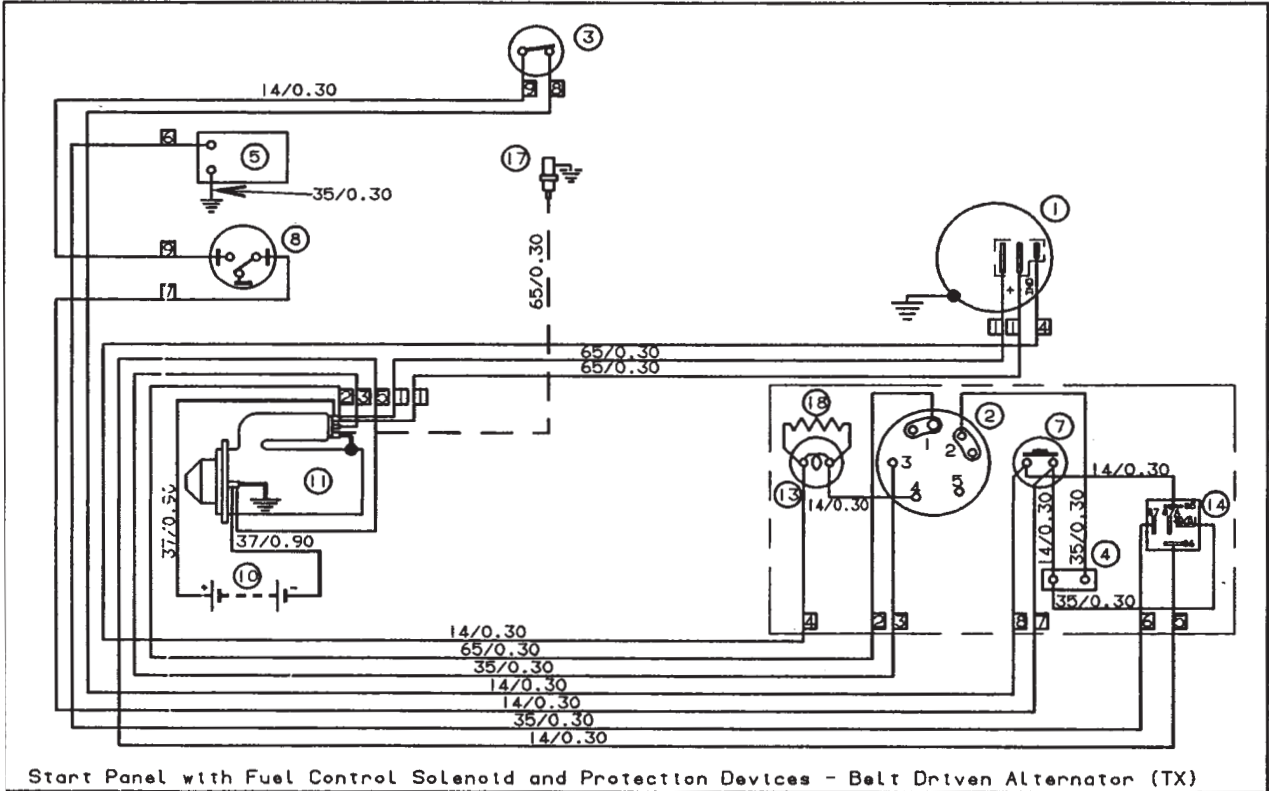
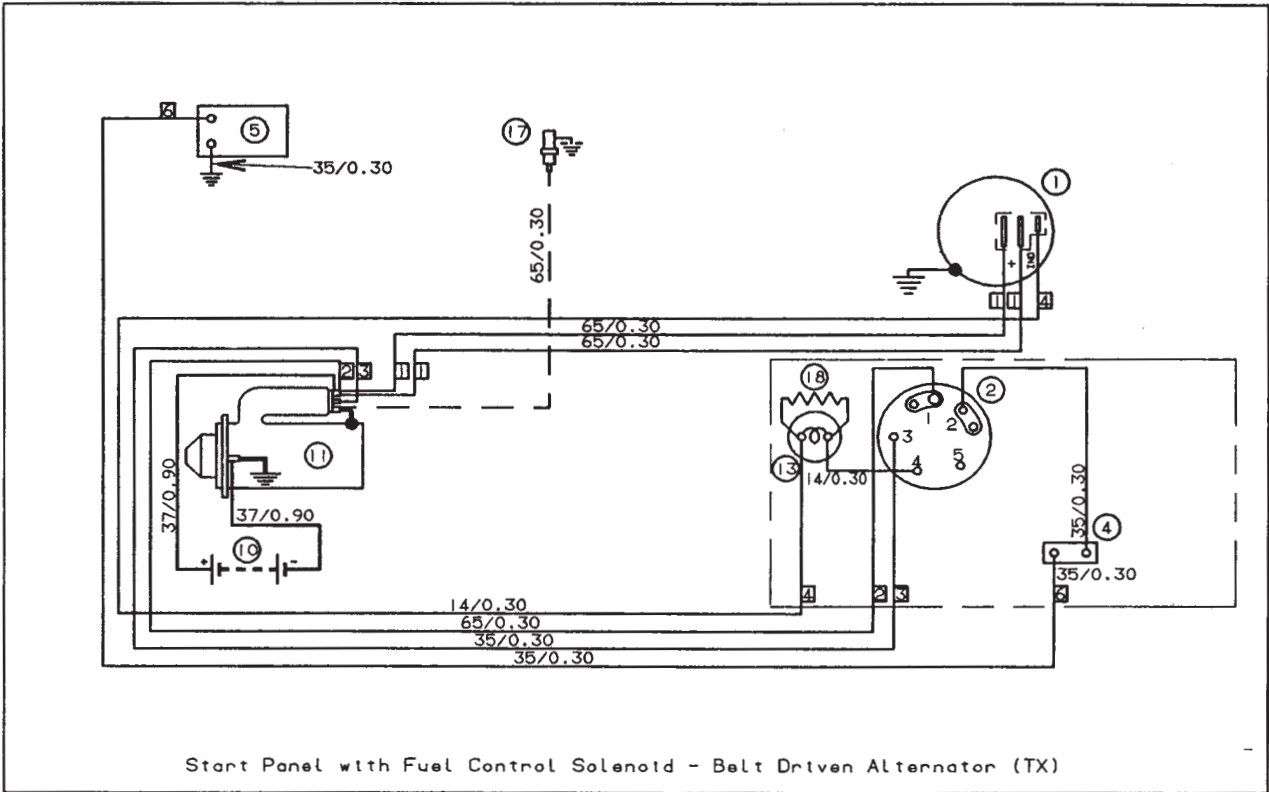


Start Panel with Fuel Control Solenoid and Protection Devices - Syncro Charge Windings. (TS/TR)



Start Panel with Fuel Control Solenoid and Protection Devices - Nicso Charge Windings. (TS/TR)





10. TECHNICAL DATA

10.1 ENGINE MECHANICAL DATA - TS

		TS1	TS2	TS3
Injection		Direct	Direct	Direct
Cooling		Air	Air	Air
Cooling fan		Flywheel	Flywheel	Flywheel
Direction of rotation - looking on flywheel end		Anti-clock	Anti-clock	Anti-clock
Nominal bore - not to be used for machining purposes	mm	95.25	95.25	95.25
	in	3.75	3.75	3.75
Stroke	mm	88.9	88.9	88.9
	in	3.50	3.50	3.50
Number of cylinders		1	2	3
Cylinder capacity - total	litre	0.63	1.27	1.89
	in ³	38.66	77.31	115.95
Compression ratio		15.5:1	15.5:1	15.5:1
Mean piston speed at 3000r/min	m/sec	7.41	7.41	7.41
	ft/min	1458	1458	1458
Lubricating oil pressure - mean	bar	2.0	2.0	2.0
	lbf/in ²	29.0	29.0	29.0
Lubricating oil sump capacity	litre	2.7	4.0	5.5
	pt	4.7	7.0	5.8
	US qt	2.8	4.2	5.8
Engine mounted fuel tank capacity	litre	8.25 / 13.5	13.5	13.5
	pt	14.5 / 23.7	23.7	23.7
	US qt	8.7 / 14.2	14.2	14.2
Maximum crankshaft end thrust	kg	132	132	132
	lb	290	290	290
Number of flywheel gear ring teeth		110	110	110
Minimum idling speed	r/min	850	850	85

Injector Setting

Injector Type		bar	atmos
Bryce		195-210	192-207
OMAP	New	220-230	217-227
	Used	200-210	197-207
Delphi	New	195-210	192-207
	Used	200-210	197-207

Crankcase Vacuum

		Minimum	Average
TS1	mm WG	20.0	35.0
	in WG	0.8	1.4
TS2	mm WG	25.0	45.0
	in WG	1.0	1.8
TS3	mm WG	30.0	75.0
	in WG	1.2	2.9

10.2 ENGINE MECHANICAL DATA - TR

		TS1	TS2	TS3
Injection		Direct	Direct	Direct
Cooling		Air	Air	Air
Cooling fan		Flywheel	Flywheel	Flywheel
Direction of rotation - looking on flywheel end		Anti-clock	Anti-clock	Anti-clock
Nominal bore - not to be used for machining purposes	mm	98.42	98.42	98.42
	in	3.875	3.875	3.875
Stroke	mm	101.6	101.6	101.6
	in	4.00	4.00	4.00
Number of cylinders		1	2	3
Cylinder capacity - total	litre	0.773	1.55	2.32
	in ³	47.17	94.35	141.52
Compression ratio		15.5:1	15.5:1	15.5:1
Mean piston speed at 3000r/min	m/sec	8.47	8.47	8.47
	ft/min	1667	1667	1667
Lubricating oil pressure - mean	bar	2.0	2.0	2.0
	lbf/in ²	29.0	29.0	29.0
Lubricating oil sump capacity	litre	2.7	4.0	5.5
	pt	4.7	7.0	5.8
	US qt	2.8	4.2	5.8
Engine mounted fuel tank capacity	litre	8.25 / 13.5	13.5	13.5
	pt	14.5 / 23.7	23.7	23.7
	US qt	8.7 / 14.2	14.2	14.2
Maximum crankshaft end thrust	kg	132	132	132
	lb	290	290	290
Number of flywheel gear ring teeth		110	110	110
Minimum idling speed	r/min	850	850	850

Injector Setting

Injector Type		bar	atmos
Bryce		195-210	192-207
OMAP	New	220-230	217-227
	Used	200-210	197-207
Delphi	New	195-210	192-207
	Used	200-210	197-207

Crankcase Vacuum

		Minimum	Average
TR1	mm WG	20.0	35.0
	in WG	0.8	1.4
TR2	mm WG	25.0	45.0
	in WG	1.0	1.8
TR3	mm WG	30.0	75.0
	in WG	1.2	2.9

10.3 ENGINE MECHANICAL DATA - TX

		TS1	TS3
Injection		Direct	Direct
Cooling		Air	Air
Cooling fan		Axial	Axial
Direction of rotation - looking on flywheel end		Anti-clock	Anti-clock
Nominal bore - not to be used for machining purposes	mm	100.00	100.00
	in	3.937	3.937
Stroke	mm	101.6	101.6
	in	4.00	4.00
Number of cylinders		2	3
Cylinder capacity - total	litre	1.59	2.39
	in ³	97.77	146.65
Compression ratio		15.5:1	15.5:1
Mean piston speed at 3000r/min	m/sec	10.16	10.16
	ft/min	2000	2000
Lubricating oil pressure - minimum at 1000r/min	bar	0.7	0.7
	lbf/in ²	10.0	10.0
Lubricating oil pressure - minimum at 1500r/min	bar	1.25	1.25
	lbf/in ²	18.0	18.0
Lubricating oil sump capacity	litre	4.0	6.0
	pt	7.0	10.6
	US qt	4.2	6.3
Engine mounted fuel tank capacity	litre	25.0	25.0
	pt	43.9	43.9
	US qt	26.3	26.3
Maximum crankshaft end thrust	kg	132	132
	lb	290	290
Number of flywheel gear ring teeth		110	110
Minimum idling speed	r/min	850	85

Injector Setting

Injector Type		bar	atmos
Bryce	New	210-215	207-212
	Used	200	197
OMAP	New	210-220	207-217
	Used	200	197
Delphi	New	210-215	207-212
	Used	200	197

Crankcase Vacuum

		Minimum	Average
TX2	mm WG	25.0	45.0
	in WG	1.0	1.8
TX3	mm WG	30.0	75.0
	in WG	1.2	2.9

10.4 BUILDS - TS

Where the build number is preceded by a 9 this indicates that the engine is either of a non-standard configuration, or contains non-standard parts or accessories.

When new parts are required for such a build it is suggested that reference be made to Lister Petter Power Systems to determine the exact engine specification and which parts are non-standard.

Where an engine number appears with GTS this indicates that it was built into a generating set by Lister Petter Power Systems.

Some builds may not be available in all cylinder configurations.

Build Detail

- 01 Variable speed up to 2500 r/min (2000 r/min on TS1) with no overload.
- 02 Variable speed up to 2500 r/min (2000 r/min on TS1) with no overload.
- 03 Variable speed up to 3000 r/min with no overload, high speed flywheel.
- 04 Variable speed up to 3000 r/min with no overload.
- 05 Variable speed up to 2500 r/min with overload, provision for hydraulic pump.
- 06 Variable speed up to 2500 r/min (2000 r/min on TS1) with overload, provision for hydraulic pump.
- 07 Variable speed up to 2500 r/min (2000 r/min on TS1) with overload, provision for hydraulic pump.
- 08 Genset Build, 1500 r/min with overload.
- 09 Fixed speed 1500 r/min with overload, high speed flywheel.
- 10 Genset Build, 1500 r/min with overload.
- 11 Genset Build, 1800 r/min with overload.
- 12 Genset Build, 3000 r/min with overload.
- 13 Genset Build, 3000 r/min with overload.
- 14 Dumper Build, variable speed up to 2500 r/min with overload.
- 15 Dumper Build, variable speed up to 2500 r/min with overload.
- 16 Variable speed up to 2000 r/min with overload, sheet metal fanshroud.
- 18 Genset Build, up to 2200 r/min with no overload.
- 40 Marine Build, variable speed - up to 2600 r/min with no overload.
- 41 Marine Build, variable speed- up to 2000 r/min with no overload.
- 42 Marine Build, variable speed - up to 2600 r/min with no overload.
- 43 Marine Genset Build, fixed speed 1500/1800r/min with overload.
- 60 Variable speed - up to 2500 r/min with no overload, low noise Q Build.
- 61 Variable speed - up to 2500 r/min* with no overload, low noise Q Build.
- 62 Fixed speed - 1500 r/min with overload, low noise Q Build.
- 63 Fixed speed - 1500 r/min with overload, low noise Q Build.
- 64 Fixed speed - 1800 r/min with overload, low noise Q Build.
- 65 Fixed speed - 1800 r/min with overload, low noise Q Build.
- 66 Fixed speed - 1500 r/min with overload, low noise Q Build, provision for hydraulic pump.
- 78 Fixed speed - 1500 r/min with overload.
- 101 Fixed speed - 1500 r/min with overload.
- 102 Variable speed - 2500 r/min with no overload.
- 103 Variable speed - 2500 r/min with no overload.
- 104 Variable speed - 2500 r/min with overload.

10.5 BUILDS - TR

Where the build number is preceded by a 9 this indicates that the engine is either of a non-standard configuration, or contains non-standard parts or accessories.

When new parts are required for such a build it is suggested that reference be made to Lister Petter Power Systems to determine the exact engine specification and which parts are non-standard.

Where an engine number appears with GTS this indicates that it was built into a generating set by Lister Petter Power Systems.

Some builds may not be available in all cylinder configurations.

Build Detail

- 01 Variable speed up to 2500 r/min (2000 r/min on TR1) with no overload.
- 02 Variable speed up to 2500 r/min (2000 r/min on TR1) with no overload.
- 03 Variable speed up to 3000 r/min with no overload, high speed flywheel.
- 04 Variable speed up to 3000 r/min with no overload.
- 05 Variable speed up to 2500 r/min with overload, provision for hydraulic pump.
- 06 Variable speed up to 2500 r/min (2000 r/min on TR1) with overload, provision for hydraulic pump.
- 07 Variable speed up to 2500 r/min (2000 r/min on TR1) with overload, provision for hydraulic pump.
- 08 TR1 - Genset Build - 1500 r/min with overload, heavy flywheel.
TR2, 3 - Genset Build - up to 1800 r/min with overload, heavy flywheel.
- 09 Fixed speed up to 1500 r/min with overload.
- 10 Genset Build - 1800 r/min with overload.
- 11 Genset Build - 1800 r/min with overload.
- 12 Fixed speed - 3000 r/min with overload, high speed flywheel.
- 13 Fixed speed - 3000 r/min with overload, high speed flywheel.
- 14 TR1 - Variable speed - up to 2500 r/min with overload.
TR2 - Variable speed - up to 2000 r/min with no overload.
- 15 TR1 - Variable speed - up to 2500 r/min with overload.
TR2 - Variable speed - up to 2000 r/min with no overload.
- 16 Variable speed - up to 2500 r/min with overload, sheet metal fanshroud.
- 18 Genset Build - up to 2200 r/min with no overload.
- 50 Fixed Speed - up to 2500 r/min with no overload.
- 78 Fixed speed - 1500 r/min with overload.
- 101 Fixed speed - 1500 or 1800 r/min with overload.

10.6 BUILDS - TX

Where the build number is preceded by a 9 this indicates that the engine is either of a non-standard configuration, or contains non-standard parts or accessories.

When new parts are required for such a build it is suggested that reference be made to Lister Petter Power Systems to determine the exact engine specification and which parts are non-standard.

Where an engine number appears with GTS this indicates that it was built into a generating set by Lister Petter Power Systems.

Some builds may not be available in all cylinder configurations.

Build Detail

- 01 Variable speed up to 2500 r/min with no overload.
- 02 Variable speed up to 2500 r/min with overload.
- 03 Variable speed up to 3000 r/min with no overload.
- 04 Variable speed up to 2800 r/min with overload.
- 05 Variable speed up to 2500 r/min with no overload.
- 06 Variable speed up to 2500 r/min with no overload.
- 07 Variable speed up to 3000 r/min with no overload.
- 08 Variable speed up to 2800 r/min with no overload.
- 09 Fixed speed 1500 r/min with no overload.
- 10 Fixed speed up to 1800 r/min with overload.
- 11 Fixed speed up to 1800 r/min with overload.
- 12 Fixed speed - 3000 r/min with no overload.
- 13 Variable speed up to 2900 r/min with no overload.
- 14 Variable speed up to 2500 r/min with no overload.
- 15 Variable speed up to 2500 r/min with no overload.
- 16 Variable speed up to 2500 r/min with no overload.
- 17 Variable speed up to 2500 r/min with no overload.
- 20 Variable Speed - 2800 r/min with no overload, compressor build.
- 21 Variable Speed - 2500 r/min with no overload, compressor build.
- 51 Fixed speed - 1800 r/min with overload.
- 52 Variable speed - 2000 r/min with no overload.
- 78 Variable speed - 1500 r/min with no overload.

11. CONVERSION FACTORS

11.1 FORMULAE

BMEP

$$\text{Bar} = \frac{\text{kW} \times 60000 \times 20000}{\text{Cylinders} \times \text{r/min} \times \text{bore area (mm}^2\text{)} \times \text{stroke (mm)}}$$

$$\text{lbf/in}^2 = \frac{\text{bhp} \times 792000}{\text{Cylinders} \times \text{r/min} \times \text{bore area (in}^2\text{)} \times \text{stroke (in)}}$$

Torque

$$\text{Nm} = \frac{\text{kW} \times 9549}{\text{r/min}} \times \text{load factor}$$

$$\text{lbf ft} = \frac{\text{bhp} \times 5252}{\text{r/min}} \times \text{load factor}$$

Load factor:

No overload = 1,0

10% overload = 1,1

Fuel Consumption

A Specific Gravity of 0.84 is assumed

$$\text{l/h} = \frac{\text{g/kWh} \times \text{kW} \times \text{load factor}}{840}$$

$$\text{pt/h} = \frac{\text{lb/bhp h} \times \text{bhp} \times \text{load factor}}{1.05}$$

Load Factor - Naturally aspirated engines

100% = 1.0 50% = 0.58

75% = 0.78 25% = 0.40

Load Factor - Turbocharged engines

100% = 1.0 50% = 0.55

75% = 0.76 5% = 0.38

Oil Consumption

A Specific Gravity of 0.886 is assumed

$$\text{litres/24hours} = \frac{\text{g/kWh} \times \text{kW}}{4922}$$

$$\text{pints/24hours} = \frac{\text{lb/bhp h} \times \text{bhp}}{0.15}$$

Piston Speed

$$\text{metres/second} = \frac{\text{stroke (mm)} \times \text{r/min}}{30000}$$

$$\text{feet/minute} = \frac{\text{stroke (in)} \times \text{r/min}}{6}$$

Mechanical Efficiency

$$\% = \frac{\text{bhp} \times 100}{\text{ihp}}$$

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Cyclic Irregularity

$$\frac{\text{max flywheel speed} - \text{min flywheel speed}}{\text{mean flywheel speed}}$$

Power

$$\text{kW} = \frac{\text{r/min} \times \text{torque(Nm)}}{9549}$$

$$\text{bhp} = \frac{\text{r/min} \times \text{torque (lb ft)}}{5252}$$

Temperature

The temperature unit in most practical use in any countries is the degree Celsius (°C), however the terms Centigrade (°C) and Fahrenheit (°F) are still in use. The Fahrenheit scale is not formally defined but it is generally recognized that the temperature difference of 1°F is equal to five ninths of the temperature difference of one degree °C.

$$1^\circ\text{F} = 9/5^\circ\text{C} + 32$$

$$1^\circ\text{C} = 5/9(^\circ\text{F} - 32)$$

The refinements of temperature scales are abstruse, but for most practical purposes the following relationships apply. For the same temperature, if t and Ø represent the temperature on the Fahrenheit or Celsius scales, similarly rand T the Rankine (absolute Fahrenheit °R) and Kelyin (absolute Celsius K) temperatures, respectively, then

$$\text{Ø} = 5/9 - (t - 32)$$

$$T = 5/9(t + 459.67)$$

$$r = t + 459.67$$

The temperature at the triple point of water, (where water, ice and water vapour are in equilibrium) is very slightly removed from the temperature of the melting point of ice at atmospheric pressure (the ice point).

Calorific Value Of Fuel

kJ/kg - 42800

Btu/lb - 18400

Air Density

$$= 1.205\text{kg/m}^3 = 0.0752\text{lb/ft}^3$$

Continuous Power

1bhp = 1.014CV = 0.746kW

1kW = 1.340bhp = 1.359CV

1CV = 0.986bhp = 0.736kW

1CV = 1Ch = 1PS

Intermittent Power

1.1bhp = 1.115CV = 0.821kW

1.1kW = 1.474bhp = 1.495CV

1.1CV = 1.085bhp = 0.810kW

1CV = 1CH = 1PS

11.2 CONVERSION FACTORS

The conversion tables in this section have been derived from BS350.

To use the tables the left hand base unit is multiplied by the relevant conversion factor given in one of the right hand columns.

For example:

To convert 6.28 metres to inches using the 'Length' Table

6.28 x 39.3701 (factor from third column) = 247.244 in

It is not good practice to round-up the conversion factors given.

Length

	metre m	inch in	foot ft	yard yd
1 metre	=	39.3701	3.2808	1.0936
1 inch	=	0.0254	0.0833	0.0278
1 foot	=	0.3048	12.0000	0.3333
1 yard	=	0.9144	36.0000	3.0000

1 in = 25.4mm

1mm = 0.03937in

Liquid Capacity

	litre l	UK pint ¹ pt	UK gallon ² gal	US pint pt
1 litre	=	1.7598	0.2199	2.1134
1 UK pint	=	0.5683	0.1250	1.2009
1 UK gallon	=	4.5464	8.0000	9.6076
1 US pint	=	0.4732	0.8327	0.1041

¹ Also known as the Imperial pint

² Also known as the Imperial gallon

1 UK gallon = 1.2009 US gallon

1 US gallon = 0.8326 UK gallon

Volume

	cubic metre m ³	litre l	cubic inch in ³	cubic foot ft ³
1 cubic metre	=	1000.0	61023.8	35.3147
1 litre	=	0.0010	61.0238	0.0353
1 cubic inch	=	1.6387 x 10 ⁻⁵	0.0164	5.7870 x 10 ⁻⁴
1 cubic foot	=	0.0283	28.3168	1728.0

1dm³ = 1litre

1in³ = 16.3871 cm³

Linear Velocity

	metre per second m/s	foot per second ft/s	foot per minute ft/m	inch per second in/s
1 metre/second	=	3.2808	196.850	39.3701
1 foot/second	=	0.3048	60.0000	12.0000
1 foot/minute	=	0.0051	0.0167	0.2000
1 inch/second	=	0.0254	0.0833	5.0000

Rate of Flow - Mass

	kilogram per second kg/sec	kilogram per hour kg/hr	pound per second lb/sec	pound per hour lb/hr
1 kilogram/second		3600.0	2.2046	7936.6
1 kilogram/hour	2.7777×10^{-4}		6.1239×10^{-4}	2.2046
1 pound/second	0.4535	1632.9		3600.0
1 pound/hour	1.2599×10^{-4}	0.4535	2.7777×10^{-4}	

Rate of Flow - Volume

	cubic metre per second - m ³ /sec	litre per second l/sec	cubic foot per second - ft ³ /sec	UK gallon per second - gal/sec
1 m ³ /sec		1000.0	35.3147	219.969
1 l/sec	0.0010		0.0353	0.2200
1 ft ³ /sec	0.0263	28.3168		6.2288
1 UK gal/sec	4.5460×10^{-3}	4.5461	0.1605	

1 UK gallon = 1.2009 US gallon

Pressure - Table 1

	newton per square millimetre N/mm ²	kilogram-force per square centimetre kgf/cm ²	pound-force per square inch lbf/in ²	pound-force per square foot lbf/ft ²
1 N/mm ²		10.1972	145.038	20885.4
1 kgf/cm ²	9.8066×10^{-2}		14.2233	2048.16
1 lbf/in ²	6.8947×10^{-3}	0.703		144.000
1 lbf/ft ²	4.7880×10^{-5}	4.8824×10^{-4}	6.9444×10^{-3}	

Pressure - Table 2

	bar bar	atmosphere atm	kilogram-force per square centimetre kgf/cm ²	pound-force per square in lbf/in ²
1 bar		0.9869	1.0197	14.5038
1 atm	1.0132		1.0332	14.6959
1 kgf/cm ²	0.9807	0.9678		14.2233
1 lbf/in ²	0.0689	0.0680	0.073	

Pressure - Table 3

	inch of water in H ₂ O	foot of water ft H ₂ O	millimetre of mercury mm Hg	inch of mercury in Hg
1 in H ₂ O		0.0833	1.8683	0.0735
1 ft H ₂ O	12.000		22.4198	0.8827
1 mm H ₂ O	0.5352	0.0446		0.0394
1 in Hg	13.5951	1.1329	25.400	

1 in H₂O = 0.00248 bar

Torque (Moment of Force)

	newton metre Nm	kilogram-force metre kgf m	pound-force foot lbf ft	pound-force inch lbf in
1 Nm		0.1020	0.7376	8.8507
1 kgf m	9.8066		7.230	86.8507
1 lbf ft	1.3558	0.1382		12.000
1 lbf in	0.1130	0.0115	0.0833	

The kilogram is known as the kilopond (kp) in Germany. 1 kgf m = 1 kp m

Force (Mass x Acceleration)

	newton N	kilogram-force kgf	pound-force lbf	poundal pdl
1 newton		0.1019	0.2248	7.2230
1 kilogram-force	9.8066		2.2046	70.9316
1 pound-force	4.4482	0.4536		32.1740
1 poundal	0.1382	0.0141	0.0311	

The kilogram is known as the kilopond (kp) in Germany. 1 kgf m = 1 kp m
 1 pdl = 1 lb ft/s² 1 N = 1 kg m/s²

Energy - Table 1

	kilowatt hour kWh	kilogram-force metre - kgf m	foot-pound force ft lbf	horsepower hour hp h
1 kWh		3.6709 x 10 ⁵	2.6552 x 10 ⁶	1.3410
1 kgf m	2.7240 x 10 ⁻⁶		7.2330	3.6530 x 10 ⁻⁶
1 ft lbf	3.7661 x 10 ⁻⁷	0.1382		5.0505
1 hp h	0.7457	2.7373 x 10 ⁶	1.98 x 10 ⁶	

Energy - Table 2

	joule J	horsepower hour hp h	calorie cal	British thermal unit Btu
1 joule		3.7250 x 10 ⁻⁷	0.2388	9.4781 x 10 ⁻⁴
1 hp h	2.6846 x 10 ⁶		641186	2544.43
1 cal	4.1868	1.5596 x 10 ⁻⁶		3.9683 x 10 ⁻³
1 Btu	1055.06	3.9301 x 10 ⁻⁴	251.996	

Power - Table 1

	kilowatt kW	metric horsepower CV	brake horsepower bhp	British thermal unit per hour - Btu h
1 kW		1.3596	1.3410	3412.14
1 CV	0.7355		0.9863	2509.63
1 bhp	0.7457	1.0139		2544.43
1 Btu h	0.00029	3.9846 x 10 ⁻⁴	3.9301 x 10 ⁻⁴	

Power - Table 2

	watt W	kilo calorie per hour k cal/h	British thermal unit Btu
1 watt		0.08598	3.4121
1 k cal/h	1.1630		3.9683
1 Btu	0.2930	0.2519	

Specific Fuel Consumption

	pounds per horsepower hour lb/hp h	pounds per Cheval Vapeur hour lb/CV h	grams per kilowatt hour g/kW h	grams per Cheval Vapeur hour g/CV h
1 lb/hp h		0.9862	608.27	447.33
1 lb/CV h	1.0140		616.80	453.59
1 g/kW h	1.6440 x 10 ⁻³	1.621 x 10 ⁻³		0.7354
1 g/CV h	2.235 x 10 ⁻³	2.205 x 10 ⁻³	1.3600	

The Cheval Vapeur (CV) is also known as the metric horsepower (1CV = 1CH = 1PS)

1 lb = 453.592 grams

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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.

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