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INSTRUCTION MANUAL

RUSTON DIESEL LOCOMOTIVES

LBT • LBU

PRICE 15/=

RUSTON & HORNSBY LTD • LINCOLN • ENGLAND
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FOREWORD

This Instruction Manual has been compiled to assist the personnel responsible for the operation and maintenance of the Ruston LB locomotive. It is issued for the purpose of information and instruction and should not be taken to constitute a specification of the locomotive. The fact that reference is made to a particular item of equipment does not infer that such equipment is incorporated in any particular machine although we have endeavoured to include as much information as possible within the limits imposed by customers special requirements and changes due to progress in design.

It is recommended that the manual be studied before the locomotive is used for the first time and thereafter be readily available to all personnel engaged in the operation and servicing of the machine. Additional copies may be obtained from Head Office on application, the publication number should be quoted when ordering.

In addition to the information contained in this manual, practical assistance and advice are always available from the Ruston Service Department. In all correspondence dealing with the machine it is recommended that the serial number be quoted. This is to be found on the plate in the cab and on the right hand side of the frame top plate.

INDEX TO SECTIONS

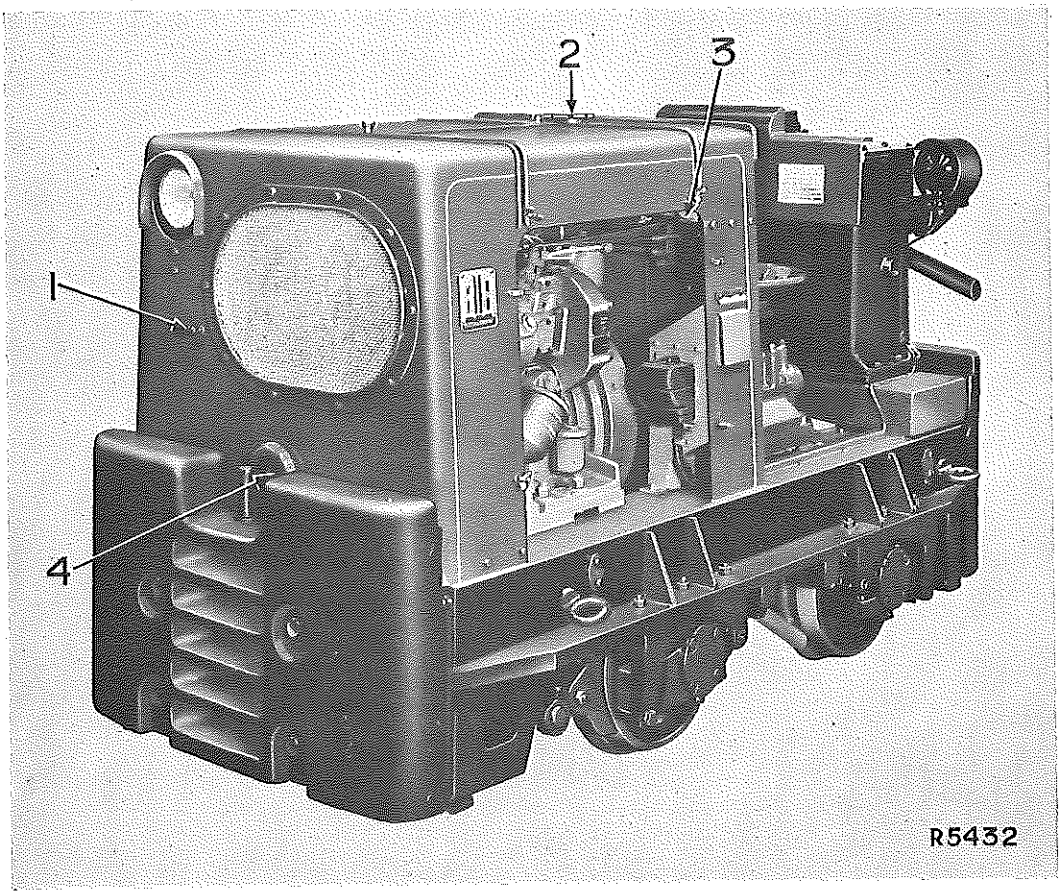


Fig. 1. RUSTON LBU LOCOMOTIVE

1. Decompressor control
2. Fuel tank filler
3. Fuel cock
4. Hand starting dog

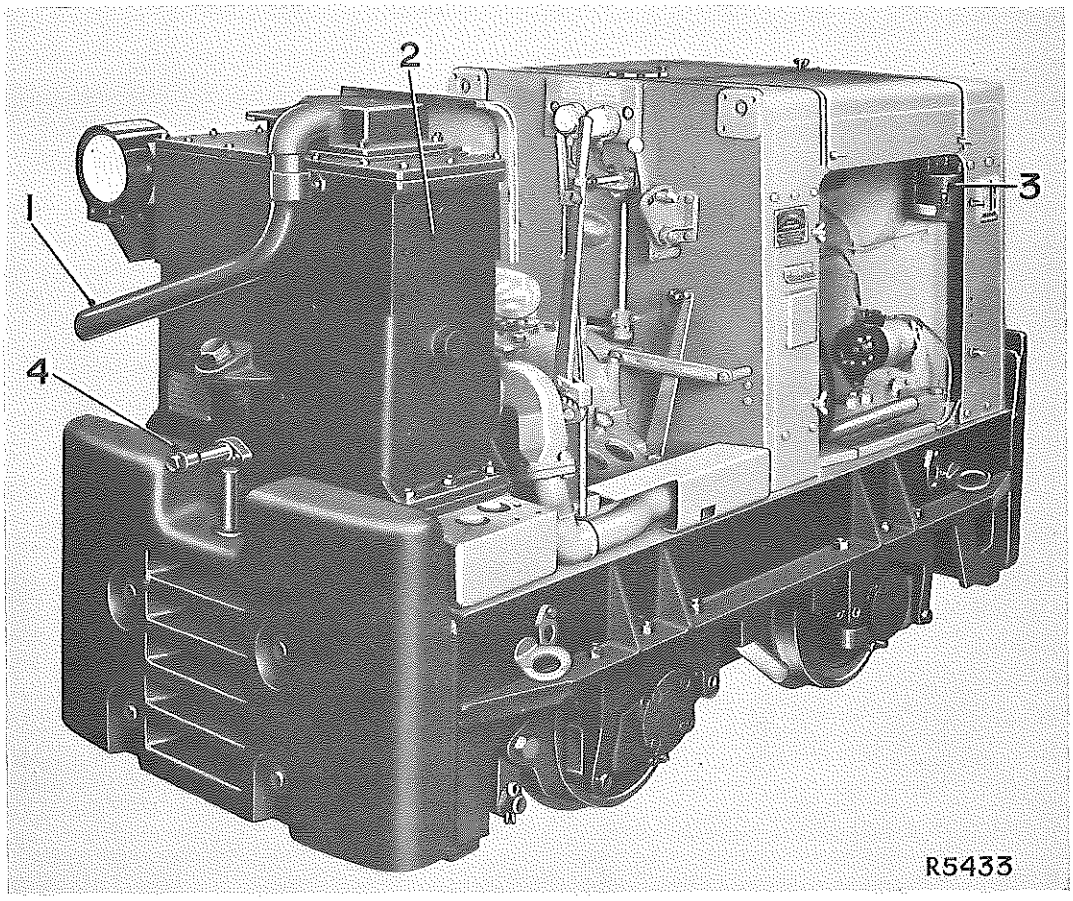


Fig. 2. RUSTON LBU LOCOMOTIVE

1. Exhaust outlet
2. Exhaust conditioner
3. Air cleaner
4. Conditioner drain

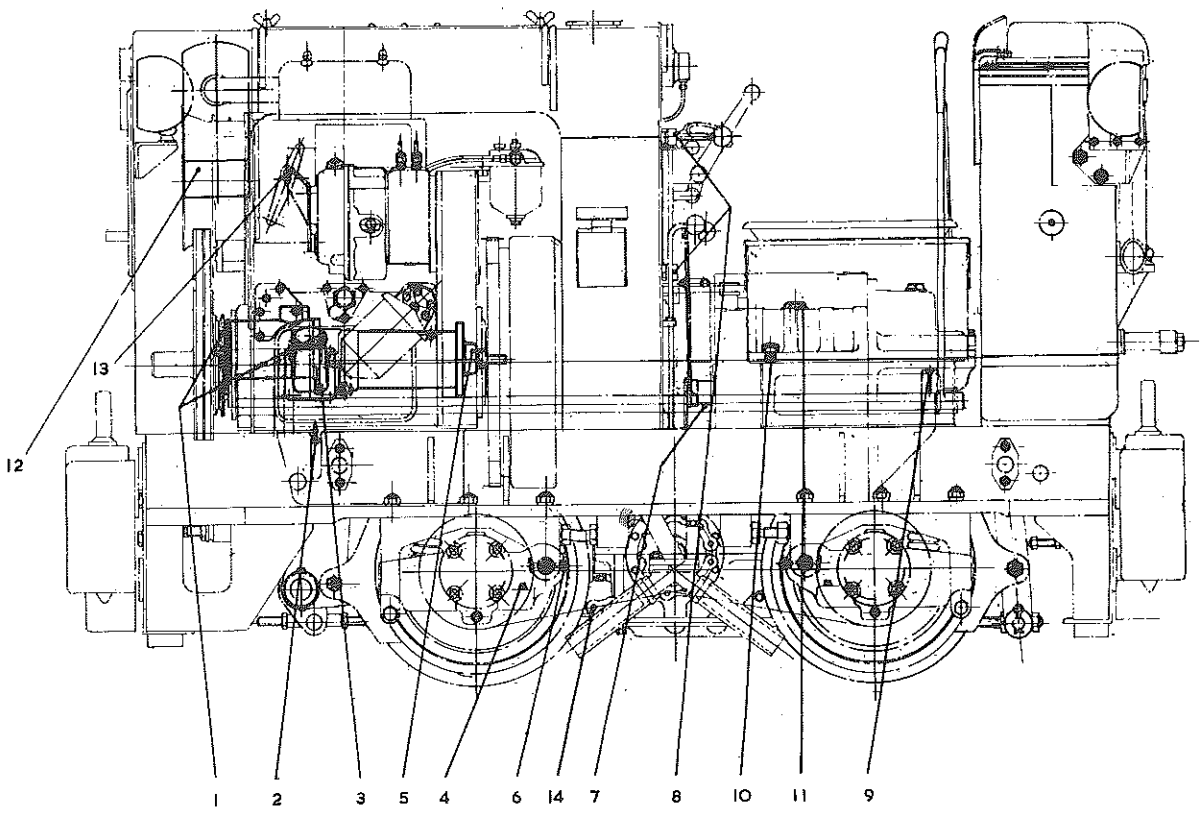


Fig. 3 LUBRICATION DIAGRAM

Ref. No.	Location	Lubricant	No. of Points
1	Dynamo (where applicable, see instruction manual)	Oil or Grease	2
2	Engine Oil Dipstick	—	—
3	Engine Oil Filter	Oil	1
4	Axlebox	Oil	4
5	Starter Motor (where applicable, see instruction manual)	Oil or Grease	1
6	Axlebox Bracket Pin	Grease	4
7	Gearbox Reverse Lever	Grease	
8	Gearbox Change Speed Lever	Grease	2
9	Brake Shaft Bearing	Oil	2
10	Gearbox Oil Dipstick	—	—
11	Gearbox Oil Filler Plug	Oil	1
12	Burgess Oil Bath Air Filter	Oil	1
13	Engine Control (Fuel pump)	Oil	1
14	Chain Lubrication (*a*) with chain guards (*b*) without chain guards	Oil Grease see pages 5, 3 and 6, 49.	2

GENERAL DESCRIPTION

The Ruston LB series of locomotives are units of the comprehensive range of diesel machines which we manufacture for both surface and underground haulage duties. The LBT locomotive is designed for surface duties and the LBU for underground operation.

ENGINE

The machine is fitted with a Ruston 2YDAL air cooled, compression ignition engine which develops 31.5 b.h.p. at 1800 r.p.m. The power unit is a two cylinder, normally aspirated, direct injection type operating on the four stroke cycle.

LUBRICATION

A self priming gear type pump, which is gear-driven from the crankshaft, supplies oil under pressure to the main and large end bearings, camshaft, valve rocker gear and timing gears. Lubrication of the pistons and small end bearings is by splash. A suction strainer is fitted in the sump and a full flow lubricating oil filter is incorporated in the system.

FUEL SYSTEM

Fuel passes from the service tank, through a paper element type filter to the fuel injection pump which accurately meters and delivers it to the injectors in the correct firing order. The speed of the engine is controlled by varying the amount of fuel injected, the fuel pump control rod being connected to the drivers' throttle lever in the cab. A mechanical governor maintains any speed predetermined by the setting of the throttle lever.

COOLING SYSTEM

The engine is cooled by a high performance, axial flow fan which is driven by vee belts from the end of the crankshaft. Air is delivered through detachable ducting to the cylinder heads and barrels which are finned to ensure effective heat dissipation.

TRANSMISSION

The drive is transmitted from the engine to the gearbox through a flexible coupling. The gearbox is a constant mesh, oil operated type of Ruston design and manufacture and can be arranged for 2 or 3 speeds

in both directions of travel. A low pressure hydraulic system is utilized and a seperate cone clutch provided for each speed. The final drive is by roller chain to each axle.

UNDERCARRIAGE

The axles are suspended by coil springs. Hand operated brakes provided on all wheels, the system being compensated to ensure even wear.

SANDING GEAR

Sanding is controlled by a lever on the dashplate, sand being delivered in front of the wheels for both directions of travel.

ELECTRICAL SYSTEM

The 12 volt Exide lead acid battery of 67 amp. hour capacity supplies current for lighting, horn operation and engine starting, when a starter motor is fitted. A C.A.V. compensated voltage control dynamo is fitted and a control board, which comprises a regulator and cut out, maintains control over charging.

CONTROLS & INSTRUMENTS

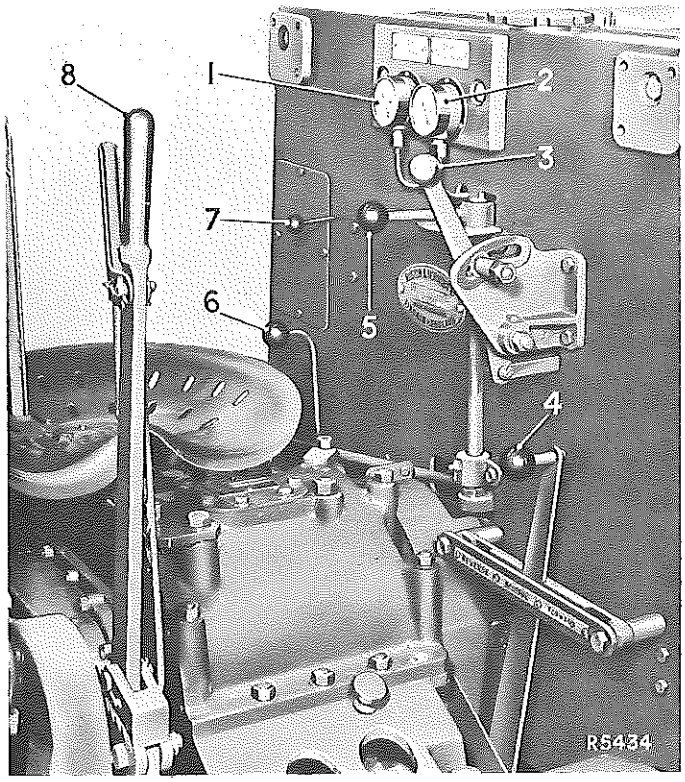


Fig. 4. CONTROLS AND INSTRUMENTS

1. GEARBOX OIL PRESSURE GAUGE

   Indicates the pressure supplied by the gearbox oil pump for clutch operation and lubrication purposes.

2. ENGINE OIL PRESSURE GAUGE

   Indicates the pressure supplied by the engine lubricating oil pump.

3. ENGINE SPEED CONTROL LEVER

   This control should be moved forward to increase, and back to decrease, engine speed. The engine will not stop if the lever is moved back against its stop as the engine is set to 'idle' at this position.

4. DIRECTION CONTROL LEVER

Controls the direction of travel of the locomotive.

NOTE:- Running with the engine ahead is 'FORWARD' movement and with the cab ahead 'REVERSE'.

5. GEAR CHANGE LEVER

6. SANDING CONTROL

7. ENGINE CUTOUT CONTROL

Provides a means of stopping the engine by shutting off the supply of fuel to the injectors, when the control is pulled out and the engine speed control lever set in the 'idling' position.

8. HANDBRAKE

In addition both the excess fuel device, which forms an integral part of the cutout lever on the engine, and the decompressor control are used during engine starting. These items are illustrated in Figs. 22 and 1 respectively.

OPERATING INSTRUCTIONS

PREPARING TO START

The following instructions should be carried out before the locomotive is started for the first time i.e., on receipt, after overhaul or after a period of prolonged standing. Certain of these operations need not be carried out prior to normal routine starting, this does not however infer that they should not be checked.

1. Ensure that the handbrake is fully 'ON', the gearlever and direction control lever in the 'NEUTRAL' positions.

2. Fill the fuel tank with clean fuel oil of the correct grade (see Section 8). Scrupulous cleanliness must be observed during this operation and the strainer provided should be used. It is recommended that the fuel tank be kept full when the locomotive is not in use to minimise condensation with the possible ingress of water into the fuel injection system. Prime the fuel system, (see Note B).

3. Check the level of oil in the engine crankcase and, if necessary fill to the high level mark on the dipstick. The correct grade of oil is specified in Section 8.

4. Fill the cup of the engine air cleaner with fresh engine oil to the level mark on the casing.

5. Fill the gearbox, with oil of the grade specified in Section 8, to the level mark on the dipstick. The oil must be admitted through the filler hole provided and not through the top inspection aperture.

6. Ensure that the axleboxes and chain case lubricators (when fitted) are filled with fresh engine oil.

7. Lubricate all points in accordance with the lubrication diagram (see Fig. 3).

8. Fill the sandboxes with clean, dry sand.

9. Check the level of the electrolyte in the battery and restore as necessary using DISTILLED WATER ONLY. The level is correct when it reaches the underside of the plate group bars.

10. Ensure that the cooling fan belts are in correct tension and all cooling air ducts are correctly positioned.

11. On machines fitted with hand starting check the starting handle for cleanliness, and ensure that it disengages freely.

12. Check all nuts and bolts for security.

13. Prime the lubrication system (Note A).

NOTE A - PRIMING THE LUBRICATION SYSTEM

i. Set the decompressor lever to the "START" position.

ii. Turn the crankshaft until pressure is registered on the oil pressure gauge.

NOTE B- PRIMING THE FUEL SYSTEM

i. Set the engine speed control lever to the maximum speed position i.e., fully forward.

ii. Unscrew the air release plug on the fuel filter and the vent plug on the fuel pump (Fig.21).

iii. Open the fuel tank cock and operate the priming lever on the fuel lift pump (if fitted) until a bubble free flow of fuel emerges from each vent point. Retighten the plugs, commencing at the filter.

iv. Slacken the delivery pipe union at each injector.

v. Turn the crankshaft until fuel leaks from the unions. Retighten the unions.

vi. Continue to rotate the engine until a "creak" at each injector indicates that the system is fully primed.

STARTING

Before starting the engine ensure that all tools and other items of equipment, including cotton waste, rags or wipers, have been removed from the near vicinity of the engine. Check that all ducting, covers and panels are secure.

HAND STARTING

1. Ensure that the relevant items detailed under 'Preparing to Start' have been carried out.

2. Check that the handbrake is 'ON' and the gear and direction control levers in 'NEUTRAL'.

3. Ensure that the engine stop control is pushed fully forward.

4. Set the engine speed control lever in the maximum speed position i.e., fully forward.

5. Press the engine stop control, on the governor casing (2 Fig. 21). inwards i.e., towards the governor. This will provide an extra supply of oil for cold starting and it will automatically disengage when the engine starts.

6. Engage the starting handle and pull the decompressor lever forward.

7. Rotate the crankshaft briskly by turning the starting handle in a clockwise direction. When it is revolving freely at sufficient speed push the decompressor back. The engine should then start.

8. Remove the starting handle.

9. Ensure that pressure is registered on the oil pressure gauges immediately after starting. If pressure is not indicated stop the engine IMMEDIATELY and investigate the cause. Pressures will be high during the warming up period but this is a normal condition due to the cold oil having a high viscosity. The pressures will gradually drop to the normal 35-45 lb/sq.in. in the case of the engine, and 40 lb/sq.in. in the gearbox, as the machine warms up.

10. Set the engine speed control lever to obtain idling speed.

ELECTRIC STARTING

1. Carry out items 1 to 5 detailed under 'HAND STARTING'.

2. Press the starter button and the engine will start.

3. Do not operate the starter for more than a few seconds at a time. Prolonged use will overheat the battery and if the engine does not fire within a few seconds allow the battery to recuperate for a short period before operating the starter again. Should starting difficulty be encountered consult Section 7.

4. Check all pressures as previously detailed.

5. Reduce the engine speed to idling.

DRIVING

1. Ensure that the engine speed control lever is fully back in the idling position.

2. Set the direction control lever in the required direction of travel.

3. With the engine speed at idling, engage first gear.

4. Release the handbrake and increase the engine speed gradually.

5. As the locomotive starts to move increase the engine speed.

6. When the locomotive has attained the maximum speed in first gear, change into second gear. To do this move the gearlever to the next gear position and at the same time reduce the engine speed to idling.

7. Change into third gear (if fitted) in the above manner ensuring that the maximum speed is attained in the existing gear before attempting a change. Do not attempt to 'miss' a gear i.e., by changing directly from first to third.

NOTE:- To change direction of travel, bring the locomotive to rest and move the lever smartly from one position to the other.

8. Change down to a lower gear must not be attempted before the locomotive speed is reduced to correspond with the maximum speed in the next lower gear. To ensure this reduce the locomotive speed by moving the engine speed control back to idling. Then, as the gear lever is moved to the next lower gear position, increase the engine speed to maximum.

Should the engine revolutions tend to 'fall-off', change down to a lower gear. On entering a gradient change down in good time to prevent overloading of the engine which might otherwise result in stalling.

9. To stop the locomotive, move the gear lever to 'NEUTRAL' and apply the brake.

10. The engine should be stopped, the handbrake applied, and the gear and direction control levers set in 'NEUTRAL' before the locomotive is left unattended.

MINOR FAULTS

Minor faults should receive immediate attention and not be allowed to develop. Neglect may lead to the necessity for more costly repairs.

Careful observation should be maintained over the locomotive for fuel and lubricating oil leaks which should be rectified immediately.

ENGINE 'KNOCKING'

At idling speed or when the engine is cold, a characteristic knock may be heard. Provided that this does not become excessive, or occur when the engine is running at normal speed, investigation will not be necessary. Any knock occuring whilst the engine is running at normal speed must be investigated immediately. Serious damage may arise through failure to ascertain the cause and take appropriate action. The knock may be due to poor combustion or a mechanical defect and can usually be diagnosed by an engineer with experience of diesel engines.

MAINTENANCE SCHEDULE

The maintenance schedule has been prepared as a guide for the Engineer in Charge of the locomotive. It is based on experience gained under normal operating conditions and may be varied to suit the conditions of service and facilities available.

Any unusual sound, a rise in temperature, a loss of pressure or any other indication of trouble should be investigated without delay. For details of recommended lubricants, see Section 8.

LOCOMOTIVE LOG

It is desirable that the operator should maintain a daily log so that reference can be made to the total hours run and particulars of performance. Periodical inspections, adjustments and replacement of parts should be recorded.

NEW ENGINES

When a new engine is fitted, we recommend that, in the interest of ensuring long component life the following points should receive attention.

1. Check the security of all nuts, bolts and covers.

2. Remove the lubricating oil filter element and replace with a new element after 100-150 hours running.

3. Remove the cylinder heads and grind in the valves after 500-1000 hours running.

ROUTINE ATTENTION

One Hourly (LBU Locomotives only)

Check the level of water in the exhaust conditioner and top up as required. (See page 66).

DAILY (Before Starting)

1. Check level of fuel in service tank and 'top up' with fuel of the correct grade as required. It is recommended that the fuel tank be kept as full as possible at all times to minimise condensation with the attendant risk of water entering the fuel system. ALWAYS USE THE STRAINER PROVIDED WHEN REFUELLING.

2. Check the level of oil in the engine sump using the dipstick provided (Fig. 19). Restore the level as necessary using only the correct grade of oil.

3. Check the gearbox oil level using the dipstick and restore as necessary. It is important that the oil is admitted through the filler and not the inspection aperture.

4. Lubricate all points specified on the lubrication diagram. (Fig.3).

5. Fill the sandbox with clean, dry sand.

6. LBU locomotives only:-

   Fill the exhaust conditioner with fresh water, if possible adding about a handful of common soda to each gallon of water (see page 66).

DAILY (After Starting)

1. Check the locomotive for fuel and lubricating oil leaks.

2. Check the operation of the brakes before moving off.

OCCASIONALLY

1. Check the tension of the fan driving belts and the dynamo belt.

2. Lubricate the links and connections of all controls.

50 HOURS

1. Clean the air cleaner and top up with fresh engine oil to level mark on the casing. In dusty conditions this should be carried out daily. DO NOT OVERFILL THE CLEANER.

2. Lubricate the handbrake rachet.

3. Check all nuts and bolts on the running gear for security.

4. Check the oil level in the axleboxes and top up as necessary.

5. Examine the driving chains and sprockets, adjusting as required.

6. Check the level of electrolyte in the battery cells and top up with distilled water as required.

100 HOURS

Check the level of oil in the governor housing and top up as required with fresh engine oil (See Page 6.3 3).

AFTER 150 HOURS RUNNING

Drain and flush the axleboxes, afterwards filling with fresh oil of the grade specified in Section 8.

250 HOURS

1. Check the tension of all belt drives.

2. Inspect and clean the exhaust conditioner in accordance with the instructions detailed on (Page 6.4 1). (LBU locomotive only).

500 HOURS

1. Inspect the fuel filter element. Renew if necessary.

2. Renew the lubricating oil filter element.

3. Drain the engine lubricating oil sump and refill with new oil.

4. Clean the engine lubricating oil filler gauze and crankcase breather.

5. Clean the exhaust system between the engine and exhaust conditioner. (LBU locomotives only).

6. Drain, flush and replenish the gearbox oil after the first 500 hours running. The second oil change should be carried out after a total of 1000 hours, and all subsequent changes every 1000 hours.

7. Remove and clean the gearbox oil strainer.

8. Drain the axleboxes, flush and refill with fresh oil.

9. Remove driving chains and grease lubricate as detailed under 'RUNNING GEAR' (Page 6.49) if chain guards are not fitted.

1000 HOURS

1. Remove injectors and test the spray. If satisfactory, replace without interference.

1500 HOURS

1. Renew fuel filter elements.

2. Inspect cooling system for obstruction to air flow particularly in the area adjacent to the fan and between the fins of the cylinder head and barrel.

3. If the engine shows signs of a loss in power, remove cylinder heads, decarbonise, and service the valves.

4. Examine and service the dynamo commutator and brush gear.

5. Check all electrical connections for cleanliness and security.

6. Examine the flexible coupling between the engine and the gearbox. Check the nuts and bolts for security.

3000 HOURS

1. Remove cylinder heads examine inlet and exhaust valves, decarbonise and 'grind in' the valves.

2. Withdraw and clean the pistons, check that the rings are free and that wear is within the recommended tolerances (Section 8).

3. Check the valve tappet clearances.

4. Clean the exhaust ports, pipes and silencer.

6000 HOURS

1. Examine the main bearings and check the crankshaft for ovality and scoring.

2. Examine the large end bearings and check the crankpins for ovality and scoring.

3. Remove and examine the lubricating oil pump and clean suction strainer.

4. Flush through all fuel and lubricating oil pipes.

5. Drain and clean the interior of the fuel tank.

6. Check the condition of the fan drive and tensioning gear.

7. Renew the connecting rod bolts.

COMPLETE OVERHAUL

It is not possible to give a definite indication of the period before a complete major overhaul becomes necessary as this will depend on site

and operating conditions, the standard of maintenance, etc.

The need can only be decided after an assessment of the machine's condition at the first 3000 and 6000 hours inspection periods on the basis of the recommended figures for the maximum wear on the various components before replacement becomes necessary.

NOTE:-

1. In estimating the life of worn components the condition of bearing surfaces in addition to dimensional wear must influence the decision to renew the components.

2. The maintenance required at any particular inspection period should include the items detailed in the previous inspections.

3. Certain operating conditions may result in the accumulation of dust between the fins of the cylinder barrels and heads. Such deposits should be removed as determined to be necessary.

OVERHAULED LOCOMOTIVES

When a locomotive is placed in service following overhaul, the following attention is necessary.

During First Run:-

1. Check the engine and gearbox oil pressures.

2. Remove valve rocker cover and ensure that an adequate quantity of oil is reaching the valve gear.

3. With the engine idling, and the gearbox in neutral, carefully remove the top inspection cover on the gearbox and ensure that oil is being sprayed into the gears.

4. Check for fuel and oil leaks.

After First 2 or 3 Hours Run on Load:-

1. Remove the crankcase cover and check that the engine bearing temperatures are not excessive.

2. Ensure that all bearing nuts are tight and locking devices secure.

3. Replace inspection doors.

4. Ensure that all nuts, bolts, screws, guards and unions are secure.

After 100-150 Hours:-

Renew the lubricating oil filter elements.

After 1000 HOURS:-

Remove the cylinder head and 'grind in' the valves.

THEREAFTER the recommendations in the maintenance schedule should be followed.

EXPENDABLE STORES

Engine users are recommended to always carry a stock of expendable stores such as split pins, tab washers, oil seals etc. i.e. items which when removed should NOT be used again.

MAINTENANCE & OVERHAUL

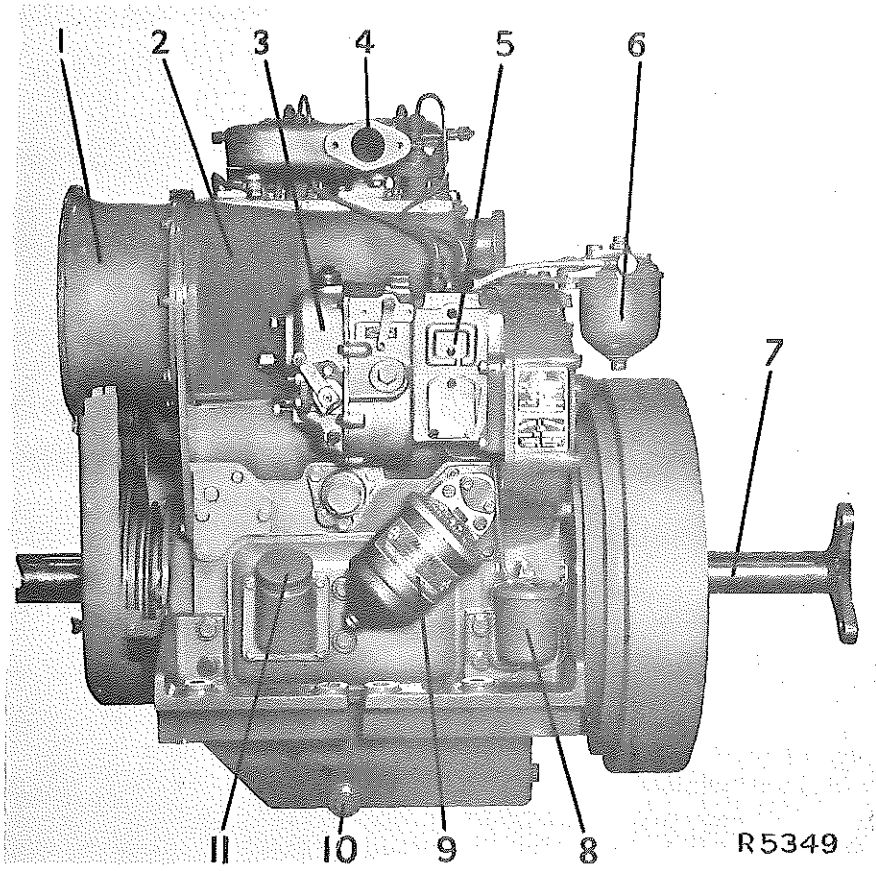
The purpose of this section is to enable the operator to maintain the locomotive in such a condition that maximum utilisation will be obtained and at the same time to obtain the greatest possible efficiency combined with economy of running. The points covered are within the limits of periodical inspections and except where mentioned can be carried out on site. A brief description of each component is included where this is considered necessary.

Unnecessary dismantling should be avoided. If there is no evidence of unsatisfactory running, normal maintenance should keep the machine in sound mechanical condition. The tendency to dismantle components, particularly those in the fuel system, should be resisted without positive evidence that the details are at fault.

Supplied with the locomotive are certain tools and gauges to facilitate dismantling and adjusting various components. These tools should be used when carrying out an operation which calls for their use. Damage can easily be caused by the use of unsuitable tools.

When dismantling is proceeding, all small components should be placed in trays or on greaseproof paper. The larger components being arranged in an orderly manner to prevent incorrect re-assembly. For the same reason all assembly marks should be noted on dismantling.

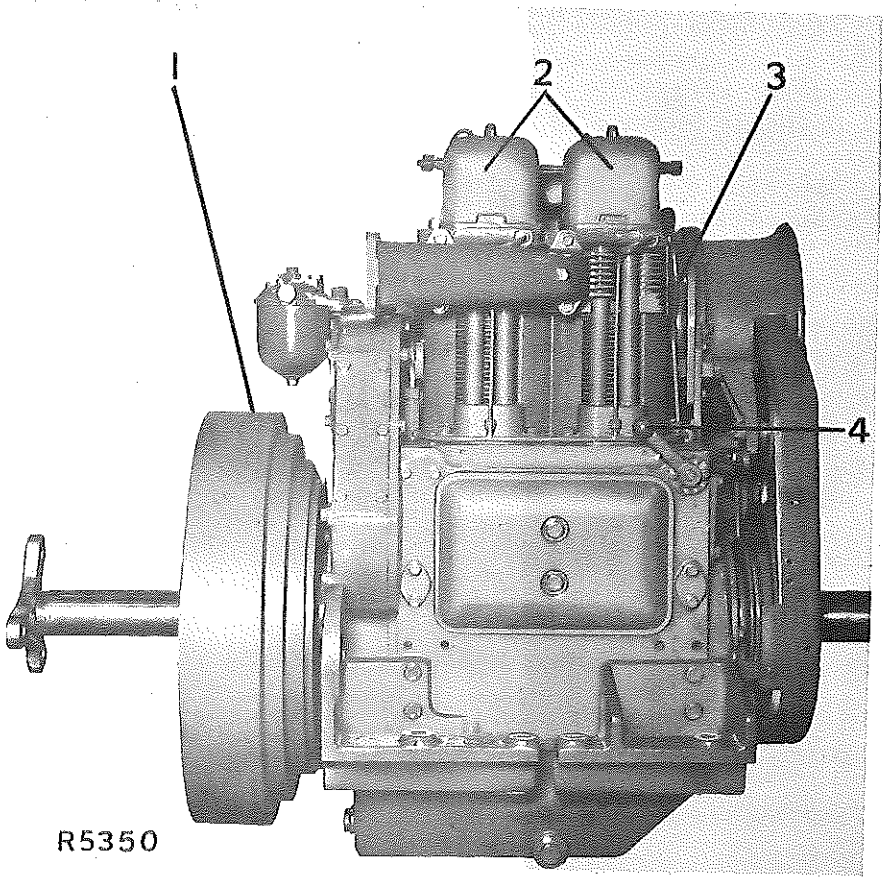
Locking devices i.e., split pins, tab washers etc., must be discarded on dismantling except where stated.



1. Fan Cowl
2. Air ducting
3. Governor
4. Induction manifold
5. Fuel pump.
6. Fuel filter.
7. Extension shaft
8. Leak off can
9. Lub. oil filter
10. Sump drain
11. Oil filler

Fig. 5. RUSTON 2YDAL ENGINE

1. Rear slinging point
2. Valve rocker covers
3. Front slinging eye
4. Decompressor lever



ENGINE

CYLINDER HEAD

The cylinder head, which is spigot mounted on the cylinder barrel, carries the inlet and exhaust valves, the valve operating gear and the injectors. A gasket is NOT fitted between the cylinder head and barrel, the piston top or bumping clearance being controlled by the thickness of shims interposed between the barrel and crankcase.

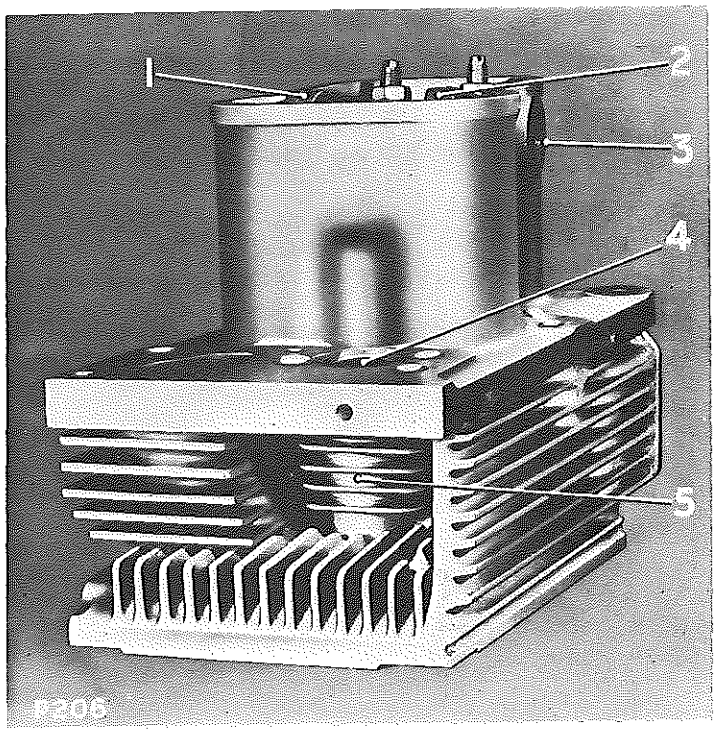


Fig. 6 CYLINDER HEAD

1. Inlet valve rocker
2. Exhaust valve rocker
3. Rocker fulcrum pin
4. Injector orifice
5. Injector shroud

REMOVEL

Certain operations such as decarbonising, removing or replacing valves and pistons etc., require the removal of the cylinder head.

The procedure is as follows:-

1. Turn off the fuel at the service tank.

2. Remove the air cleaner.

3. Remove the cylinder head covers.

4. Disconnect and remove the fuel delivery pipes and spill rails.

5. Remove the injectors.

6. Disconnect and remove the valve gear oil pipes to the cylinder head and the pipe to the pressure gauge.

7. Remove the air ducting and baffles.

8. Remove the induction manifold.

9. Remove the exhaust silencer and manifold.

10. Remove the valve rocker pedestals complete with rockers. It is advisable to remove each pedestal with the relevent piston on t.d.c. compression stroke, thereby relieving the valve spring pressure on the rocker levers.

11. Withdraw the push rods.

12. Remove the cylinder head nuts.

13. The cylinder head can now be removed.

NOTE:-

The cylinder head is of aluminium alloy and care should be taken to avoid damage, particularly to the fins, during removal.

CLEANING AND DECARBONISING

On removing the cylinder head for any maintenance or overhaul it is advisable to decarbonise the head and piston. This should be carried out as follows:-

1. Using a soft scraper, carefully remove all deposits from the inside of the head. Care must be taken not to damage the outer face of the recess which forms the gas tight seal between the head and barrel.

2. Thoroughly clean the fins on the cylinder head and on the cylinder barrel.

3. Inspect and clean all ports and the injector cooling shroud, taking care not to damage the machined faces.

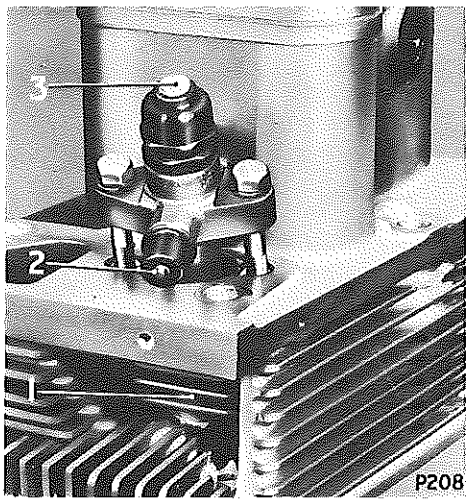


Fig. 7 INJECTOR ASSEMBLY

1. Injector shroud 2. Fuel inlet
3. Fuel leak off

4. Turn the engine until the respective piston is on t.d.c.

5. Scrape the carbon from the piston top and remove all particles.

6. Smear the cylinder bore with lubricating oil and rotate the crankshaft through three or four revolutions.

7. With the piston at bottom dead centre wipe the oil and carbon from the inside of the liner.

PISTON TOP CLEARANCE

Before replacing the cylinder head after fitting new details i.e. pistons, connecting rods etc., the piston top clearance should be checked.

Proceed as follows:-

1. Place the piston at t.d.c.

2. Place a short piece of soft lead wire approximately 1/16in. (1.59 mm) dia. on top of the piston above each gudgeon pin boss.

3. Replace the cylinder head and tighten the nuts down as detailed under 'Tightening Sequence' below.

4. Turn the flywheel a short distance either side of t.d.c.

5. Remove the cylinder head.

6. Check the thickness of each piece of flattened lead wire with a micrometer and take the average of the two dimensions. The resultant figure is the top or 'bumping clearance' which should fall within the limits laid down in Section 9. Adjustment may be made by varying the number and thickness of the shims between the cylinder barrel and crankcase. These are supplied in three thicknesses as follows:-

Ref.	Thickness
1	28 S.W.G. (1.0148 in.)
2	25 S.W.G. (.020 in.)
3	23 S.W.G. (.024 in.)

These should be used as follows to maintain the bumping clearance within the prescribed limits:-

1 off Ref. 1 or 1 off Ref. 2 or 1 off Ref. 3

2 off Ref. 1 or 1 off Ref. 1 and 1 off Ref. 2

1 off Ref. 1 and 1 off Ref. 3

REPLACING CYLINDER HEAD

The procedure for replacing is as follows:-

1. Ensure that the joint faces are scrupulously clean.

2. Run the nuts down the studs by hand (Any that are too tight to enable this to be done should be loosened before proceeding further).

3. Replace the injector shrouds (Fig. 7) ensuring that they are centrally disposed in their recesses, i.e. not contacting the outer walls of the head.

4. Replace the cylinder head and fit the stud nuts. Before tightening down, align the heads by placing a straight edge along the machined faces of the exhaust manifold. It is possible to align the heads by fitting the exhaust manifold and carefully tightening the nuts evenly and progressively. This will pull the heads into alignment.

5. Tighten down the cylinder head stud nuts in the sequence laid down (see below).

6. Reassemble using the reverse of the sequence outlined in 'Removal'.

7. After final tightening, check the valve tappet clearances (see Page 6.11)

TIGHTENING SEQUENCE

The head must be pulled down evenly to avoid distortion. For this reason tighten each pair of nuts diagonally opposite, half a turn at a time until all are exerting equal pressure.

TIGHTENING TORQUE

It is recommended that a torque spanner be used to tighten the cylinder head nuts. These spanners are not supplied with the engine tool kit, but may be purchased from Head Office. When a torque spanner is available proceed as follows:-

1. Run the nuts down by hand, or using a box spanner without the tommy bar. Any that are too tight to enable this to be done should be loosened before proceeding further.

2. Nuts should be tightened in the sequence laid down to 50-60 lb.ft. DO NOT OVERTIGHTEN.

3. Check twice in the correct sequence to ensure that during tightening none of the nuts have deviated from the correct setting.

THE ENGINES MUST BE COLD WHEN TIGHTENING THE CYLINDER HEAD NUTS.

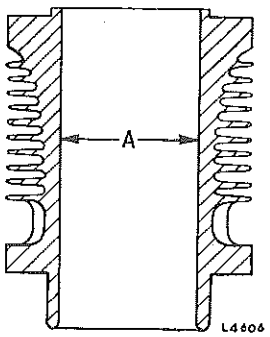
CYLINDER BARREL

The cast iron cylinder barrel is located by a spigot in the crankcase and retained by the cylinder head nuts. The barrel is not fitted with a liner

REBORES

The cylinder barrel may be rebored up to .060 in. oversize in three stages as follows:-

Ref.	Rebore	Oversize	'A' Cyl. Barrel Bore
1	1st	.020 in.	4.3985 4.3990
2	2nd	.040 in.	4.4185 4.4190
3	3rd	.060 in.	4.4385 4.4390



When a rebore is carried out oversize pistons will be required. A table in Section 9 gives details of the oversize components available.

VALVE GEAR

Two valve springs are fitted to each valve assembly and before dismantling it should be observed that these are assembled with the coils running in opposite directions. It is possible to remove the valve springs without disturbing the cylinder head if the following procedure is observed:-

1. Place the crank for the cylinder receiving attention on top dead centre, compression stroke i.e., with the respective inlet and exhaust valve closed.

2. Remove the cylinder head cover.

3. Remove the valve rocker pedestal.

4. Decompress each valve spring sufficiently to remove the split collets. Fig. 8 shows a type of tool whoch can be used for this operation, but any suitable decompressing tool may be used.

Fig. 8 REMOVING VALVE SPRINGS

To replace the springs, reverse the procedure detailed above.

NOTE:-

The crankshaft must not be turned during this operation otherwise the valve will drop into the cylinder.

VALVES

The valves cannot be removed without first removing the cylinder head. The head should be lifted and after removing the valve springs, the valves withdrawn from the underside of the head.

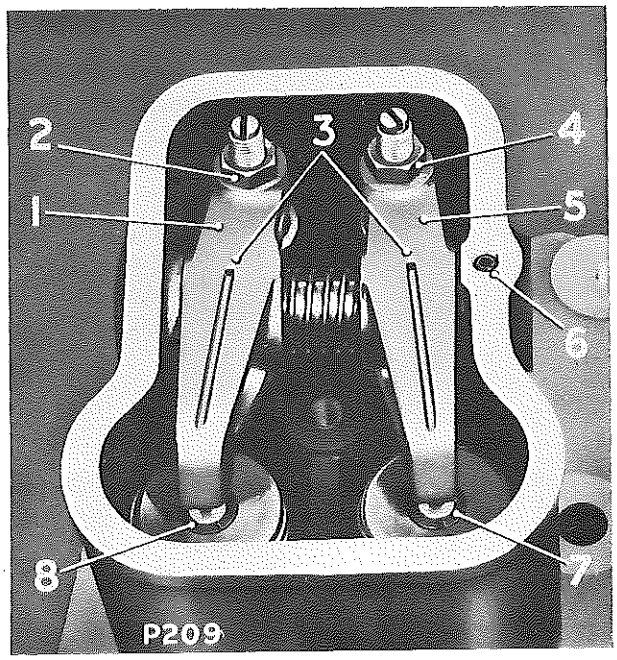


Fig. 9 VALVE ROCKER GEAR

1. Inlet valve rocker
2. Inlet tappet adjustment
3. Lub. oil holes
4. Exhaust tappet adjustment
5. Exhuast valve rocker
6. Rocker fulcrum grub screw
7. Exhaust valve
8. Inlet valve

INSPECTION AND CLEANING

The valves are in good condition if the line of contact with the seating shows bright all round. If the line of contact is discoloured or pitted regrinding will be necessary (see below). Clean the valves with paraffin or other approved cleansing agent, remove all carbon deposits from the head and stem.

Examine valve springs and compare spring tensions, replace with new any found defective.

REGRINDING VALVES

The condition of the valves may be such that regrinding of the valve contact face, and the seat, is necessary if the engine is to maintain its maximum efficiency.

Assume for this operation that the valve has been dismantled.

1. Smear valve grinding compound on the valve face and rotate the valve on its seating with an oscilating motion, exerting slight pressure. Lift the valve occasionally and turn to a different position.

2. Continue grinding until an unbroken contact mark is made around the valve, it is not essential for all the pits to be removed from the valve and seat provided the line of contact is not broken by pits or imperfections.

3. Wipe clean, dry the valve seating; replace the valve and again rotate it on the seat.

4. A bright uninterrupted line of contact should be obtained, if there are still imperfections or interruptions in this line, continue the grinding process.

5. Ensure that all traces of grinding compound are removed from the valve and seat before reassembling.

RE-ASSEMBLING

1. Smear lubricating oil on the valve stemsand guides.

2. Replace the valves in the guides.

3. Complete the operation by reversing the removal sequence.

VALVE SEAT INSERTS

The cylinder head is fitted with austenetic iron valve seat inserts which are "chilled" in position.

VALVE GUIDES

If clearance between the valve stems and the guides becomes excessive, the valve guides may require renewing. To do so, the head and valve should be removed and the guides knocked out from the underside of the head. The new guides should be driven in with a suitable drift, care being taken not to use excessive force and to ensure that the guide does not enter the hole at an angle.

VALVE TAPPET CLEARANCES

The valve tappet clearances (i.e., the clearances between the valve stem top and the rocker lever contact pad) should be checked periodically and always after disturbing the cylinder head.

1. Turn the flywheel until the tappet rests on the dwell of the cam (see Fig. 10).

2. Apply slight pressure on top of the adjusting screw and check the clearance with feeler gauges.

3. If the clearance is incorrect, adjust by means of the slotted screw and locknut. The correct clearances are shown in Section 8.

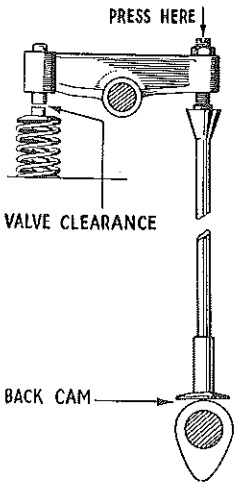


Fig. 10. CHECKING TAPPET CLEARANCES

VALVE TIMING

The inlet and exhaust cams are integral with the camshaft and cannot be moved relative to each other. Therefore if the valve tappet clearances are correct and the timing of one of the valves is correct, the remainder will also be in order. The method of valve timing is shown under 'Camshaft Gearwheel', page 6. 20 .

PISTON

The pistons are of low expansion, silicon aluminium alloy and each is anodised on the crown, in the combustion bowl and in the piston ring grooves.

REMOVAL

1. Remove the cylinder heads and crankcase doors.

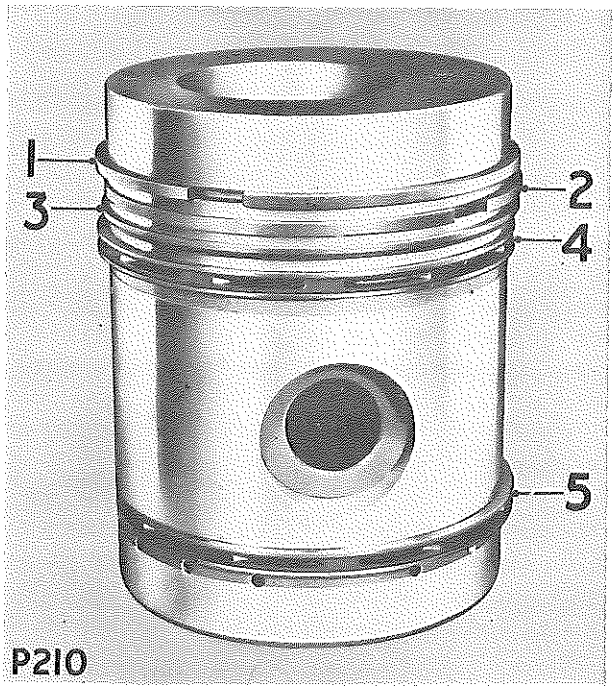


Fig. 11 PISTON AND RINGS

1. Pressure ring
2. Taper periphery pressure ring
3. Stepped scraper ring
4. Slotted scraper ring
5. Slotted scraper ring

2. Straighten the tab washers on the connecting rod and remove the set bolts and washers.

3. Remove the lower half of the large end bearing.

4. Push the rod and piston upward through the liner until the gudgeon pin holes are clear.

REPLACING

1. Smear clean lubricating oil on the piston and liner.

2. Place the piston rings so that gaps are positioned around the circumference of the piston as follows:-

   Set numbers 1 and 2 ring gaps 180^{o} apart. Number 3 and 4 ring gaps 180^{o} apart but at 90^{o} to Numbers 1 and 2 ring gaps. Set number 5 ring gap in line with No.1 ring gap.

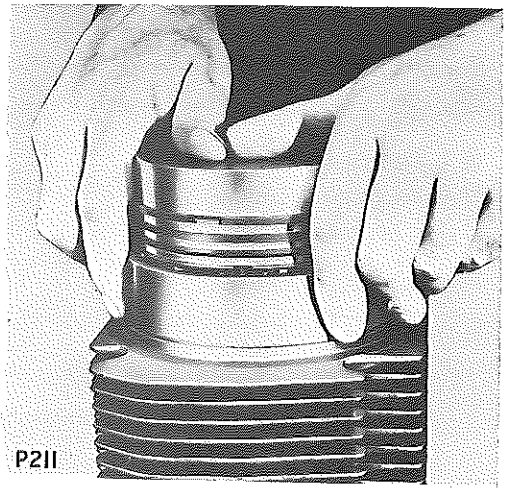


Fig. 12 REPLACING PISTON

3. Place a piston ring taper sleeve or clamp as shown in Fig. 12 around the rings, so tightened that it will allow the piston to be pushed through when it butts against the top of the barrel. The operation should be done with care, otherwise the rings may be broken.

4. Refit connecting rod large end bearing, using new tab locking washers.

GUDGEON PIN

The gudgeon pin can be removed or replaced by immersing the piston in boiling water, hot oil or by standing it on a hot plate. This will expand the piston and allow the pin to be pushed in or out freely.

PISTON RINGS

To remove the piston rings, first soak the piston in paraffin (kerosene) then spring the rings open and insert thin metal strips between the rings and the piston at four different points (Fig. 14). Remove the rings by sliding them over the metal strips.

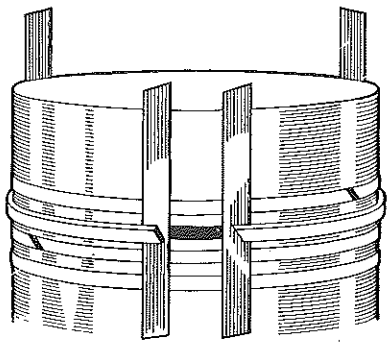

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Fig. 13. Method of removing piston rings.

When replacing the rings always fit them in their original grooves, as shown in Fig. 11 . The rings should be renewed when the ring gap and clearance in the groove exceeds the maximum clearance given in Section 8. The ring gap can be measured by inserting the ring into the unworn portion at the lower end of the barrel. The ring must be inserted squarely and must be parallel with the top face of the barrel. The gap can be measured by the use of feelers.

CONNECTING ROD

The connecting rod, of 'H' section steel, has the large end bearing split at an angle; this enables the rod to pass upwards through the bore of the barrel after the large end caps have been removed.

The joint faces between the rod and the end cap have serrations which fit into each other. It is essential that the serrations are scrupulously clean on assembly.

The large end bearings consist of split steel shells lined with copper lead alloy. Each small end bearing is a copper lead-lined steel bush. The shells are held in position by tags formed on the periphery of each half at the parting line which locate in recesses in the connecting rod large end.

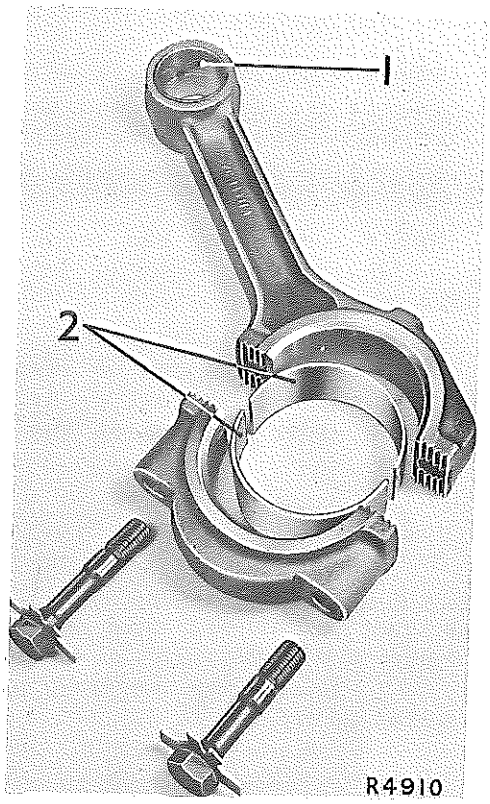


Fig. 14. CONNECTING ROD ASSEMBLY

1. Small end bush
2. Large end bearings

BEARING CLEARANCE

It is important to maintain the correct clearance. Clearances are listed in Section 8.

Insufficient clearance causes excessive friction, and therefore overheating, wear and danger of damage to the bearing. Excessive clearance causes reduced lubricating oil pressure, 'hammer' and consequent excessive wear.

ADJUSTMENT OF LARGE END BEARINGS

When the large end bearing clearance becomes excessive (see Section 8), adjust as follows:-

1. If crankpin wear is less than .003 in. (.076 mm) fit new bearing shells.

2. If crankpin wear is more than .003 in. (.076 mm) regrind the crankpin and fit a suitable undersize bearing shell. (See Section 8 for details).

NOTE:- The bearing must under no circumstances be scraped before fitting.

ASSEMBLING LARGE END BEARINGS

Before bearings are fitted, they are not exactly circular but slightly wider across the 'horns' to ensure correct bedding when assembled. To fit bearings:-

1. Assemble the bearings in the bore of the connecting rod (do not file the outside or scrape the bore).

2. Tighten the set bolts lightly and check that there is a gap between the faces of the cap and the connecting rod; this gap is essential to ensure that a definite 'NIP' is obtained when the setscrews are fully tightened.

3. Insert setscrews and ensure they are free enough to be turned by hand, or box spanner without a tommy bar, to the final tightening position.

4. Tighten the setscrews with an open-ended or torque spanner, in the usual manner. (Do not use a spanner longer than 10 in.).

5. Knock the tabs of the locking washers to the flat of the hexagon head of screw and to the face of the bearing cap to lock the setscrew in position.

TIGHTENING WHEN USING TORQUE SPANNER

When a torque spanner is available it is advisable to use it for tightening the connecting rod setscrews, as follows:-

1. Insert the setscrews and screw in by hand or using a box spanner without the use of a tommy bar, to the final tightening position.

2. Tighten up in gradual and equal stages until the final permissible torque is obtained, i.e., 90/100 lb.ft. Torque spanners are not included in the standard set of tools, but may be purchased from Head Office if required.

Connecting Rod Bolts

Connecting rod bolts must be renewed after the engine has run 6000 hours or earlier if required, i.e., should the engine have been shock loaded by serious piston seizure. Bolts must not be annealed and used again.

TAB LOCKING WASHERS SHOULD NEVER BE USED TWICE. NEW ONES MUST BE FITTED EACH TIME THE CONNECTING ROD IS RE-ASSEMBLED.

CRANKCASE BREATHER

The engine is supplied with a crankcase breather and to ensure efficient breathing the gauze element should be kept clean and free from obstruction. The appearance of the gauze is no guide to its cleanliness as wax-like deposits may build up between the mesh which can restrict the release of pressure from the crankcase. This pressure if allowed to build may eventually lead to oil leaks from the joints.

CRANKSHAFT AND MAIN BEARINGS

Should main bearing or connecting rod large end bearing trouble be suspected, it will be necessary to remove the main bearing caps and connecting rod large end bearing caps one at a time, and carry out an inspection on the lower half of each main bearing shell, and the rod half of each large end bearing shell, for signs of scoring, overheating etc.

If the respective journals do not show signs of abnormal wear, it will not be necessary to remove the crankshaft as the faulty bearings can be renewed quite readily. Indication of worn bearings are low lubricating oil pressure at starting and insufficient pressure at running speed.

UNDERSIZE BEARINGS

When, as a result of crankshaft inspection, it is decided to regrind the main bearing journals to remove any ovality that may be present, it will be necessary to fit undersize bearings.

The table in Section 8 gives details of standard and undersize bearings, that should be fitted after the various regrinds.

The bearings are of the copper lead type and under no circumstances must they be scraped on fitting.

REMOVAL OF CRANKSHAFT

1. Drain the lubricating oil sump, preferably whilst the engine is still warm.

2. Remove the engine from the locomotive (see page 6.40)

3. Remove the flywheel and extension shaft.

4. Remove the cylinder heads, piston, connecting rods, and cylinder barrels observing the procedure previously detailed.

5. Remove the shims from between the cylinder barrels and crankcase. The shims must be retained in sets to ensure correct replacement under their respective barrels. For this reason it is recommended that the sets be lightly wired together on removal.

6. Drain and remove the fuel filter and fuel injection pump. Blank off all orifices on these components to prevent the ingress of dust.

7. Remove the fan belt guard, slacken the belt tension and remove the belts.

8. Remove the nuts which retain the fan cowl to the crankcase and withdraw the fan assembly complete.

9. Invert the engine, placing it firmly on wooden blocks. Care must be taken to ensure that the supports are in every way adequate to prevent the possibility of the engine falling over whilst the crankshaft is being removed. A stand can be supplied if ordered.

10. Remove the lubricating oil sump.

11. Remove the lubricating oil pump, drive and brackets.

12. Withdraw the stub shaft, vee belt pulley and oil seal housing from the free end.

13. Withdraw the oil seal from the drive end.

14. Turn back the tab washers, remove the stud nuts and main bearing caps.

INSPECTION OF CRANKSHAFT

When the crankshaft has been removed, a thorough inspection should be made before re-fitting into the engine.

In particular, the inspection should include the following:-

1. That all oil passages are clear of obstruction.

2. Measure main bearing and crankpin journals in several places around the diameter in order to show the smallest diameter and to ascertain whether or not the journals have worn oval.

3. If the shaft has been damaged, i.e. scored, burred, etc. it may be honed with a smooth oil stone and polished afterwards.

REPLACING THE CRANKSHAFT

To replace the crankshaft, the sequence of operations stated under 'REMOVAL' should be reversed, and the bearings and the shaft liberally smeared with clean lubricating oil.

IMPORTANT:-

When replacing the crankshaft with the camshaft still in position, ensure that the teeth are meshed correctly with those of the camshaft gearwheel. For correct positioning, see description under 'CAMSHAFT'.

MAIN BEARINGS

All the main bearings are of the steel backed, copper-lead lined type and are prefitted, thus ensuring easy replacement or renewal without machining.

Thrust faces are fitted on each side of the flywheel end bearing. When re-assembling bearings, the figures stamped on the bearing and housing should always coincide.

FITTING NEW BEARINGS

When fitting new bearings, scraping and bedding will not be necessary, and must NOT be done, as they are pre-finished to fine limits. A bearing should always be renewed if it has been over-heated, or is badly scored. Knocking and lack of oil pressure is usually an indication of worn bearings.

MAIN BEARING "NIP"

1. Fit the bearings in the bedplate, with the bearing cap in position.

2. Tighten the stud nuts finger tight (spanner held close to jaws) then check the gap between bedplate and main bearing cap. When the two halves of the bearing are in close metal-to-metal contact, there should be a gap of .0015 in. (.038 mm.) between bedplate and cap, so that when fully tightened down the bearings are effectively 'NIPPED' in position.

3. When tightening the stud nuts do not use a spanner more than 10 in. long.

NOTE:- NEW TAB WASHERS MUST BE FITTED AND THE NUTS LOCKED BY THEM BEFORE THE ENGINE IS STARTED.

TIGHTENING USING A TORQUE SPANNER

It is recommended that main bearing nuts be tightened down with a torque spanner to ensure correct loading. When a torque spanner is used, the sequence of operation should be as follows:-

1. Run the nuts down the studs by hand or using a box spanner with-out the use of a tommy bar. Any that are too tight to enable this to be done should be loosened before proceeding.

2. Each pair of nuts should be tightened in equal stages until the final torque figure is obtained, i.e., 100/120 lb.ft.

CAMSHAFT

To withdraw the camshaft the flywheel must be removed, after which proceed as follows:-

1. Drain, disconnect and remove the fuel filter.

2. Remove the drive end cover.

3. Remove the valve rocker gear and pushrods as previously detailed.

4. Remove the three setscrews and spring washers which retain the camshaft locating piece. Access to each of the screws can be gained by bringing the holes in the camshaft gearwheel into line with the screws.

5. Carefully withdraw the camshaft so as to catch each tappet as it comes clear of the camshaft. Tappets must be kept clean and replaced in their respective bores.

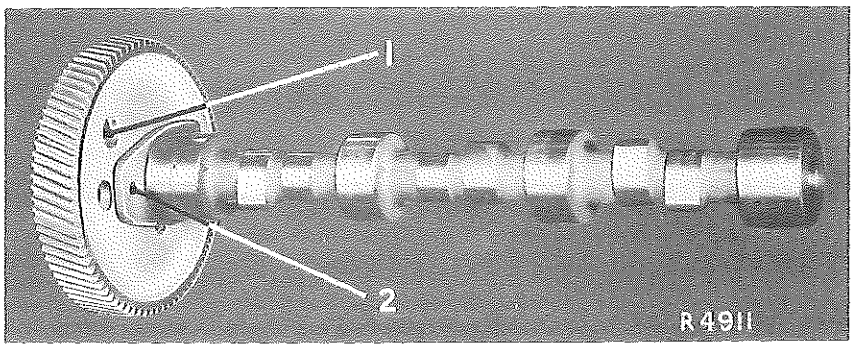


Fig. 15. CAMSHAFT

1. Access holes 2. Locating piece

REPLACEMENT

1. Wipe the tappets clean and smear liberally with clean grease. Replace in their respective bores where they should be retained, by the grease, clear of the cams.

2. Replace the camshaft together with the locating piece so that the gearwheel is correctly positioned in relation to the crankshaft see 'CAMSHAFT GEARWHEEL' below.

3. Align the locating piece and refit the three setscrews and spring washers. Tighten each setscrew securely.

4. Complete the assembly using the reverse of the procedure used for dismantling.

CAMSHAFT GEARWHEEL

The correct position of this gearwheel in relation to the crankshaft gearwheel is vitally important as the setting of the valve is governed by the positioning of these wheels.

The camshaft gearwheel is marked with a drill-point on one tooth and this mark must be aligned, using a straight edge, with a similar mark on the plate as shown in Fig. 16. This illustration shows the correct settings for both the camshaft gearwheel and the fuel pump drive with the piston of the cylinder adjacent to the gears i.e., No. 2 cylinder, on T.D.C.

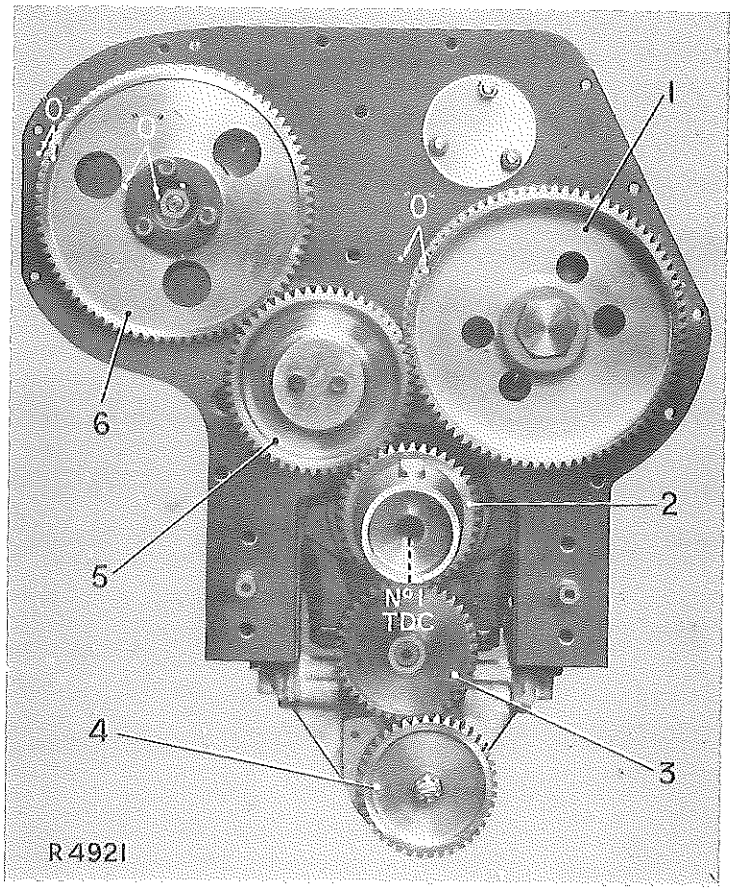


Fig. 16. TIMING GEARS

1. Camshaft gear
2. Crankshaft gear
3. Idler gear
4. Oil pump gear
5. Intermediate gear
6. Fuel pump gear

There are two drill-point marks on the fuel pump gearwheel. One, marked "2,3", is the timing mark for 2 and 3 cylinder engines. The second point which is diametrically opposite, is marked "4,6" and is only used on 4 and 6 cylinder engines. The illustration (Fig. 16) shows the gears aligned for the 2 cylinder engine fitted to the LB machine).

The gears are correctly set before the engine leaves our Works and will not require adjustment unless they are removed for any reason.

LUBRICATING OIL FILTER

The filter is a full flow type and so arranged that when the pressure drop across the element becomes excessive, the pressure inside the element overcomes the pressure of the spring (5) and so allows a full flow of oil from the filter even though cleaning is overdue.

SERVICING

1. Remove the drain plug (7) and drain the oil from the case (6), unscrew nut (1) and withdraw the case.

NOTE:- If the filter has been in use for some time difficulty may be experienced in removing the case due to the joint ring (2) sticking.

2. Remove the element assembly (3) and discard. (Do not attempt to clean the element).

3. Clean the filter case using clean petrol, or other approved cleansing agent and allow to dry by evaporation.

4. Drop the spring into the case and fit a new element assembly over the centre bolt. Ensure that the joint ring (2) is correctly seated in the head groove. (A smear of mineral jelly, or equal on the face of the joint ring will ensure ease of breaking at the next servicing operation)

5. Offer the case to the head, replace the washers and sleeve nut and tighten firmly into position.

6. Replace the drain plug and washer.
The filter is now ready for service.

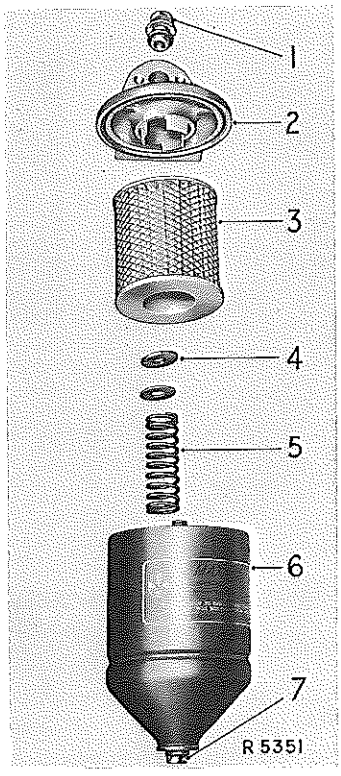


Fig. 17. LUBRICATING OIL FILTER

LUBRICATING OIL STRAINER

Two lubricating oil strainers are fitted, one in the oil filler and the other in the oil sump on the suction side of the lubricating oil pump. To clean the strainers, they should be removed and washed in clean petrol or paraffin and allowed to dry before replacing.

NOTE:-

The sump must be drained before the crankcase strainer can be removed.

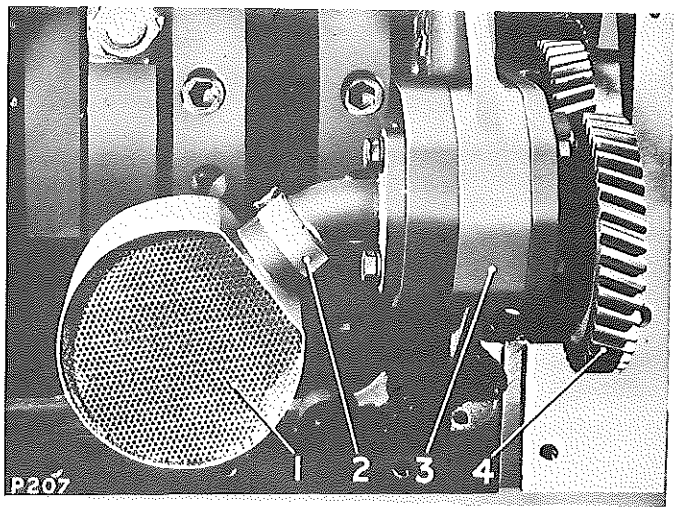


Fig. 18 LUBRICATING OIL PUMP

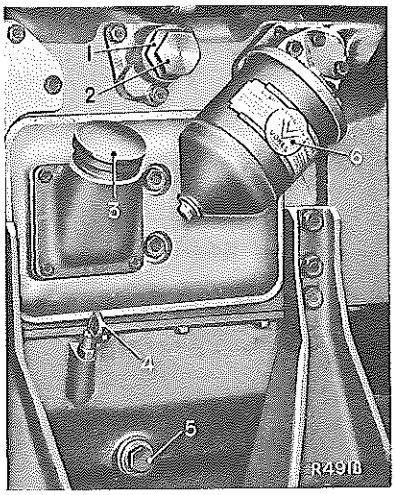
1. Suction strainer
2. Jubilee clip
3. Pump body
4. Driving gear

LUBRICATING OIL RELIEF VALVE

A relief valve is provided for the adjustment of the lubricating oil pressure. To regulate the pressure, the locknut (1 Fig.19) should be released and the adjusting screw (2) turned until the desired pressure is obtained. Remember to retighten the locknut after making the adjustment.

Fig. 19. LUBRICATING OIL SECTION

1. Relief valve locknut
2. Adjusting screw
3. Oil filler
4. Dipstick
5. Drain plug
6. Lub. oil filter



FUEL SYSTEM

The fuel system comprises the following components:-

1. Service tank.

2. Fuel filter on the suction side of the fuel pump.

3. Monobloc type fuel injection pump with integral governor.

4. Fuel injectors, one per cylinder.

In addition, a fuel lift pump may be fitted if specially ordered.

C.A.V. TWIN BOWL-LESS FUEL FILTER

This filter has twin paper elements which cannot be cleaned and must be discarded when choked.

The elements become discoloured in service and it is not possible to tell by external examination when renewal is necessary.

Fig. 20 illustrates a single element and for convenience the following instructions also apply to a single element only, both elements being identical.

DISMANTLING

1. Turn off fuel supply at tap.

2. Unscrew retaining bolt (11) and release base (9).

3. Withdraw base, remove element and discard.

RE-ASSEMBLY

1. Fit new paper element (6) complete with sealing rings. The element must be fitted with the strengthened rim uppermost.

2. Engage retaining bolt (11) with the centre stud and screw up tightly.

3. Prime the fuel system.

The filter elements should be renewed every 1500 hours.

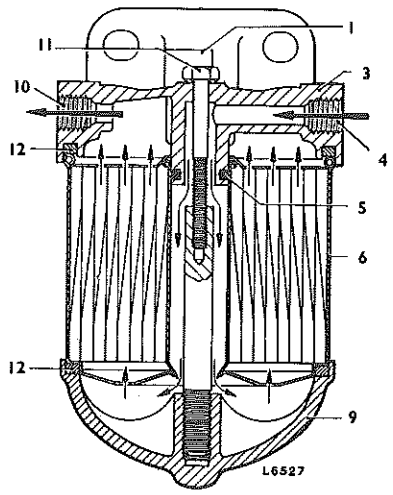


Fig. 20. Fuel Filter (Bowl-less Type)

1. Vent Connection
3. Filter Head
4. Inlet
5. Sealing Ring
6. Element
9. Filter Base
10. Outlet
11. Retaining Bolt
12. Sealing Ring

FUEL PUMP

The fuel injection pump (Fig.21) embodies a seperate pumping element for each cylinder. These element assemblies are arranged within an aluminium housing and operated by an enclosed camshaft which is driven at half engine speed.

A typical element assembly is shown in Fig. 23 and consists essentially of a spring loaded delivery valve (D) and seating (E) situated above the plunger (G) and barrel (F). The delivery valve seating is retained by the holder (A).

Fuel is supplied to a gallery in the pump housing, either by gravity feed from the tank which is positioned at a suitable height above the pump, or by force feed from a fuel lift pump. Each element is supplied with fuel through ports in the barrel (F) and to enable the quantity of fuel to be varied, the effective pumping part of the plunger stroke is made variable by means of a control helix machined around the plunger.

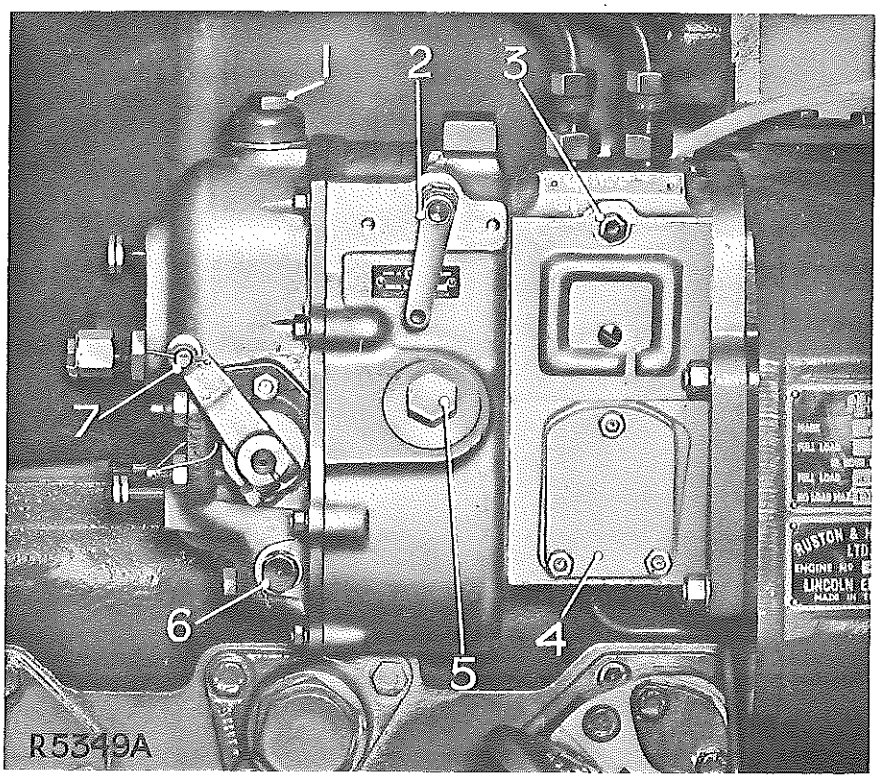


Fig. 21. FUEL INJECTION PUMP

1. Governor breather
2. Cutout lever
3. Vent plug
4. Lift pump flange
5. Governor access plug
6. Governor level plug
7. Engine speed control

OPERATION

Fuel can enter the element barrel through the ports provided when the plunger is at its B.D.C. position (a), Fig. 22. The plunger rises under the influence of its cam until position (b) is reached when the top edge of the plunger has closed both ports and the fuel charge is trapped in the space between the plunger and spring-loaded delivery valve.

The increasing pressure now exerted upon the charge by the upward movement of the plunger, lifts the delivery valve from its seat and fuel is forced in the delivery pipe to the injector on the engine. Further movement of the plunger increases the pressure of the fuel in the delivery pipe until the inertia of the nozzle valve spring is overcome and fuel is sprayed into the engine cylinder.

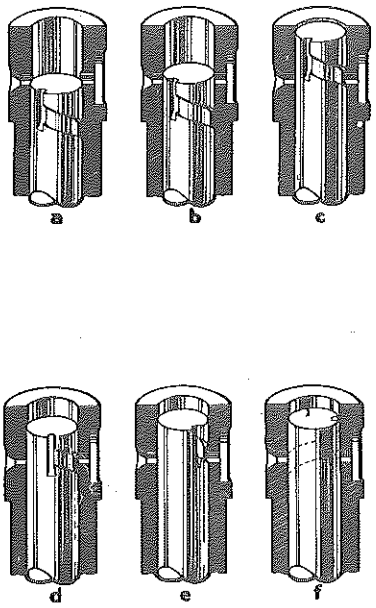


Fig. 22

PRINCIPLE OF FUEL METERING

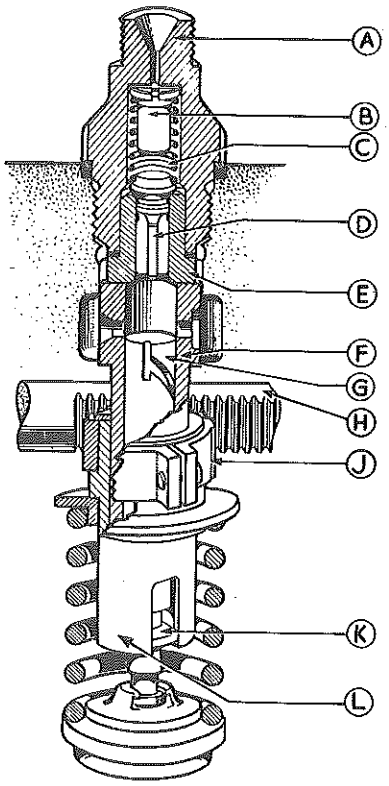


Fig 23. SECTION THROUGH FUEL PUMP ELEMENT

The pumping stroke of the plunger continues until position (c) is reached, when the edge of the control helix uncovers the spill port in the barrel and fuel above the plunger is by-passed to the fuel gallery. The consequent reduction in pressure above the plunger allows the delivery valve and nozzle valve to close under the action of their springs and thus terminate injection. On completion of its stroke, the plunger is returned to the B.D.C. position by its spring.

The distance travelled between positions (b) and (c) is the effective pumping part of the plunger stroke. To decrease, or increase, the quantity of fuel delivered per stroke, the distance between (b) and (c) can be altered by rotating the plunger in its barrel to align a higher or lower portion of the control helix to the spillport. Diagrams (c) (d) and (e) show approximate positions of the helix for full load, half load and idling, respectively. In the engine stopped position (f) Fig. 22 the vertical channel of the plunger is opposite the right-hand port of the barrel and no fuel is delivered if the engine is turned.

Control of Output

The plunger is rotated by means of a toothed quadrant, (J) Fig. 23 clamped to a sleeve (L), which engages the dog (K) of the plunger. The quadrant meshes with a rack on the control rod, (H), which similarly engages the quadrant of the other pumping element contained in the unit. Thus, movement of the control rod causes both the plungers to rotate in unison. The rack is in turn, connected to the governor and the engine speed control.

DELIVERY VALVE

The injection pump is fitted with simple mitred-face delivery valves of fluted construction. These have flutes machined in their stems to provide a flow path for the fuel to the injectors.

Each valve is provided with an unloading collar to enable rapid cessation of the fuel spray from the injector nozzle on completion of the pump plunger delivery stroke. When the valve returns to its seat, the collar acts as a piston and displaces a volume of oil from the delivery pipe equal to its own volume. This effects a proportional decrease in pressure in the pipe which enables the nozzle valve to snap on to its seat and ensure a clean termination to injection.

LUBRICATION

After initially filling the camshaft chamber with engine oil, subsequent replenishing is unnecessary as additional lubrication is supplied by back leakage of fuel oil past the shanks of the pump plungers.

The pump is fully dustproofed and for this reason a dipstick is not fitted, a drain being provided to ensure that the oil in the camshaft chamber is maintained at the correct level.

PUMP FAULTS AND SERVICING

Although the fuel injection pump is of simple and robust construction, its adjustment and assembly requires the greatest care and attention together with the use of appropriate tools and equipment, as the slightest inaccuracy may seriously affect the running of the engine.

The pump is assembled and adjusted by highly skilled specialists using special apparatus for calibrating, phasing and checking. For this reason we recommend that, whenever possible, all overhauls should be carried out by our agent or nearest C.A.V. Servicing Department.

It is recommended therefore, that servicing in the field be confined to the replacement of delivery valves or of the complete pump. Any dismantling affecting the relative position of the pump element barrel and its control quadrant involves problems of readjustment for which special equipment is required.

In the event of failure or unsatisfactory operation of the fuel system, the following tests should be made before assuming that the pump is faulty:-

1. Check the flow of oil to fuel feed pump.

2. Test fuel feed pump.

The above checks only apply when a fuel feed pump is fitted, otherwise check that there is an ample supply of fuel oil by gravity feed to the main pump.

3. Inspect all fuel pipes and connections for cracks, etc.

4. Inspect and test the filter element.

5. Test both injectors or that on the faulty cylinder.

CHECKING PUMP ON ENGINE

Check the discharge from each pump element by disconnecting each of the injection pipe unions in turn at the pump end while the engine is running (or being turned by the starter motor).

With the fuel control bar in the idling position the fuel should be delivered in well defined spurts regularly and in uniform quantity.

SERVICING DELIVERY VALVES

In the event of the above test revealing that one or more elements are either failing to deliver fuel or doing so irregularly, the delivery valves should be removed, cleaned and tested, or replaced

1. Unscrew the injector pipe union nut and disconnect pipe.

2. Unscrew delivery valve holder and lift out the valve and spring.

3. Wash the valve in paraffin or fuel oil.

4. Ensure it is free in its guide and replace with a new joint washer.

If the valve is still allowing a dribble to occur at the injector at the end of the injection stroke, or is operating unsatisfactorily in any way, the complete valve and seating should be replaced.

To remove the valve seat, lift out the valve and spring using the extractor supplied, the valve seat may then be removed.

IMPORTANT:-

If any fault other than delivery trouble is diagnosed, it is almost certain that the pump will have to be removed from the engine and serviced by our agent or C.A.V. Servicing Dept.

FUEL INJECTION TIMING

On a new or replacement pump, the elements will be correctly 'phased' at equi-angular intervals corresponding to the firing order of the engine cylinders. It is only necessary, therefore, to check the timing on one element only. To check the timing, proceed as follows:-

1. Remove the fuel supply pipe serving the cylinder adjacent to gears from the injection pump.

2. Remove the inspection cover plate.

3. Remove the delivery valve holder, delivery valve and spring. Replace the valve holder to retain the barrel in position.

4. Set the control rod in the running position.

5. Turn the fuel cock 'ON'.

NOTE:-

Where a fuel lift pump is fitted it will be necessary to operate the priming device slowly whilst checking the timing.

6. Turn the flywheel until the injection mark for the cylinder adjacent to gears, i.e., No. 2 cylinder, is opposite the pointer on the crankcase.

7. Turn the engine backwards until fuel commences to flow, then turn slowly forwards (i.e., normal direction of rotation) until flow just ceases.

8. Verify the cessation of flow by wiping the finger across the top of the valve holders.

If it is found that injection is not occuring at the exact point on the flywheel it will be necessary to adjust the timing. Proceed as follows:-

1. Remove the cover plate situated immediately behind the fuel pump, on the rear cover.

2. Loosen the three setscrews which retain the fuel pump gear to coupling shaft (6 Fig. 16).

3. Carefully turn the coupling to advance or retard the point at which fuel ceases to flow.

4. Tighten the setscrews and recheck the timing.

5. Replace the cover plate.

NOTE:-

The pump is timed to the engine at the Works and correctly set with the mark 'O' on the gear hub adjacent to mark on the locking ring. A second mark 'O' near the periphery of the gear indicates the correct meshing of the gear for assembly purposes. The correct alignment of these marks in relation to the crankshaft gearwheel is shown in Fig.16.

FUEL FEED PUMP

The lift pump, shown sectioned in Fig. 25, is driven by the pump camshaft. Inlet connections (4) and outlet (3) are located side by side at the top of the cover (14), above the opposed action spring-loaded valves (2) and (5)

During the suction stroke of the lift pump, the diaphragm (6) is displaced by the action of the eccentric (9) on the sintered lever (10). The reduction in pressure on the cover side of the diaphragm, due to this movement, opens inlet valve (5) against its spring and allows fuel to enter the cavity (11), through passage (15). As the valves (2) and (5) act in opposite directions, the outlet valve (2) is held firmly on its seat during the suction stroke.

Further movement of the camshaft (8) relieves the thrust on lever (10) and spring (7) returns the diaphragm to its former position. The spring pressure thus transmitted to the fuel in cavity (11), closes the valve (5) and forces valve (2) off its seat. Fuel is then pumped to the filter in the supply piping and to the injection pump gallery.

The output is limited progressively as the pressure in the injection pump fuel gallery increases. Conversely, the output of the lift pump is increased when the pressure in the fuel gallery decreases.

A leak-off connection is provided on the engine side of the fuel injection pump body to maintain the correct level of oil in the camshaft chamber. A drip can is provided.

The fuel injection system can be primed by a simple pressing action on the lever (13), Fig. 25, which displaces the diaphragm (6). When not in use, the lever (13) is held out of engagement by the spring (12).

The arrangement of the priming device is such that it will operate irrespective of the position of the eccentric.

GOVERNOR

The C.A.V. variable speed type mechanical governor is designed to maintain, within close limits any engine speed within its range to which the control lever is set. The movement of the spring loaded flyweights is transmitted through bell crank levers and a cross-head assembly to the injection pump control rod by suitable linkage. Movement of the control rod is however, also affected by the control lever.

The control lever (3 Fig. 24) and the weight mechanism are linked in such a manner that the position of the control lever may be altered at any engine speed irrespective of the position or action of the flyweights. This is achieved by enabling the pivot (5), on which the lever (7) floats, to be displaced by movement of the control lever (3). At any set position of the control lever, the fly-weights (14) will move the lever (7) above the pivot (5) to compensate for changing load conditions. The pivot (5) is held in form (4) which can be moved about the fixed fulcrum pin (17) by the control lever through the medium of the crank (1).

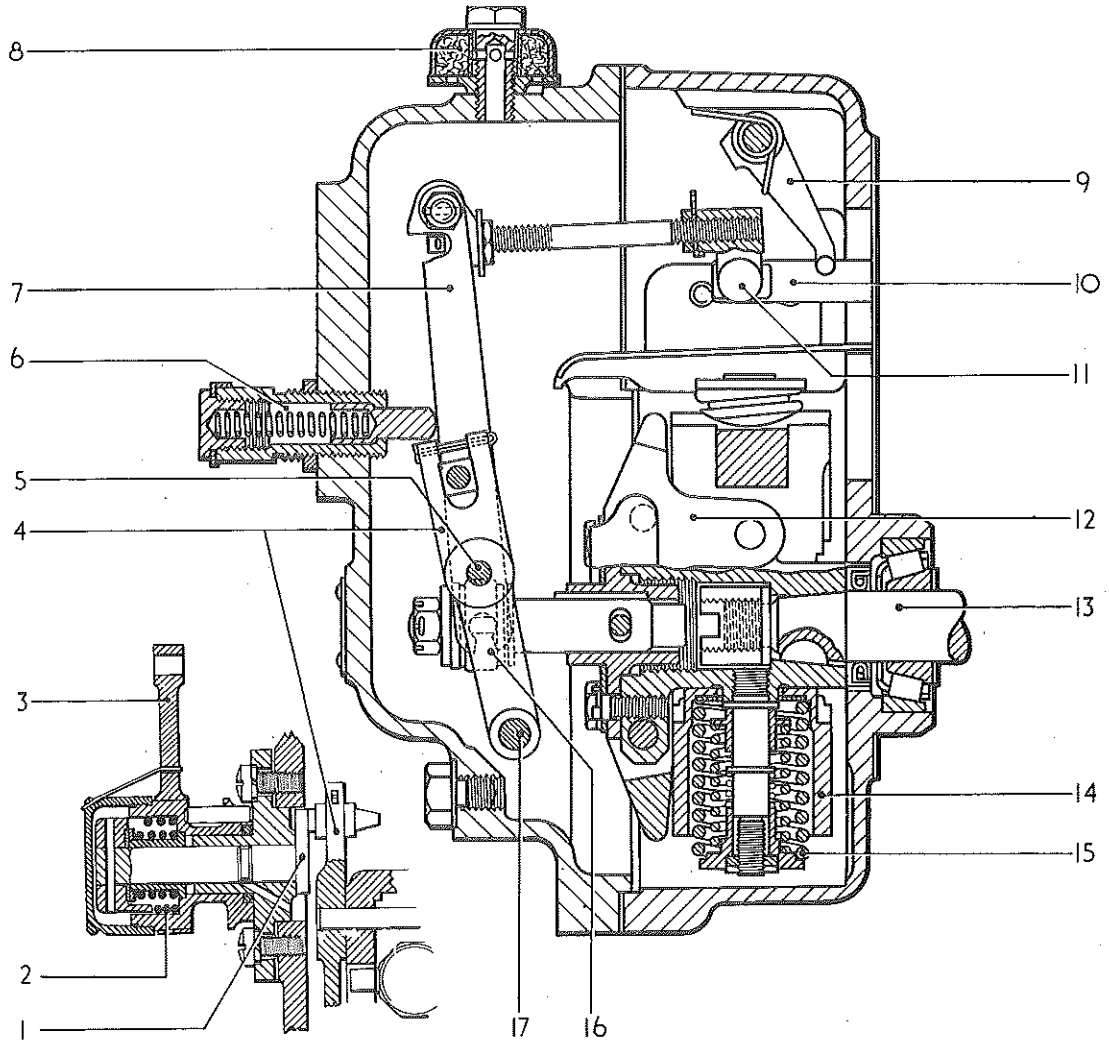


Fig. 24. SECTION THROUGH GOVERNOR

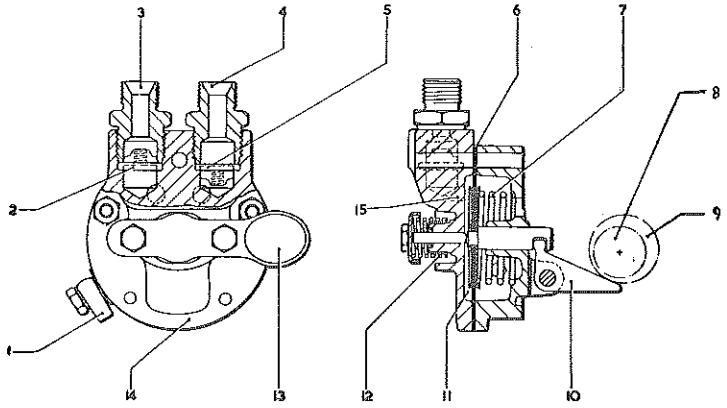


Fig. 25. FUEL FEED PUMP

If the position of the control lever is altered to increase or decrease the engine speed, the fork (4) will be moved about the pin (17) and displace the pivot (5) and lever (7) accordingly. Thus the control rod (10) will be moved to increase or decrease the amount of fuel delivered to the engine, and the fly-weights will then maintain the engine speed at this new setting of the control lever.

LUBRICATION

The governor mechanism is lubricated from a small quantity of oil in the housing. The correct level, up to the drain plug at the rear of the housing, should be checked every 100 hours. Restore the level with engine oil through the access plug.

ADJUSTMENTS

The governor is correctly set and sealed before the engine leaves the Works. Do not attempt to alter any of the settings without first consulting our agent or C.A.V. Servicing Dept.

INJECTOR

The C.A.V. injector assembly (Fig. 26) consists of two main components:-

1. The nozzle valve.

2. The nozzle holder.

The nozzle valve takes the form of a plunger lapped into the nozzle body within which it will work freely.

The inner end of the nozzle valve is reduced in diameter to provide a stem upon which a valve is formed, whilst the outer end is provided with a stalk. Fuel is fed to the mouth of the nozzle body, which terminates in an annular gallery just above the valve seating. The nozzle valve is raised from its seating in the nozzle by the pressure of oil fed from the pump. Thus the fuel in the gallery is forced, by the upward movement of the plunger in the pump, through the holes in the nozzle to form a spray in the engine combustion chamber.

WARNING

The dismantling, cleaning and testing of C.A.V. injector assemblies calls for the use of special tools. Unless the operator is in possession of this equipment, the complete injector assembly should be sent to the nearest C.A.V. agent when investigation proves that the injector requires servicing.

CARE OF NOZZLES

Injectors should be taken out for examination at regular intervals. It is not easy to state just how long the intervals should be owing to the widely different conditions under which engines operate, but under normal conditions an inspection every 1000 hours should suffice.

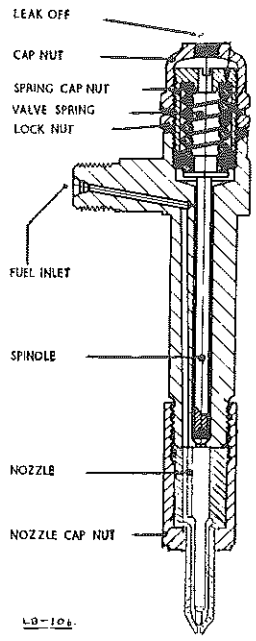


Fig. 26. FUEL INJECTOR

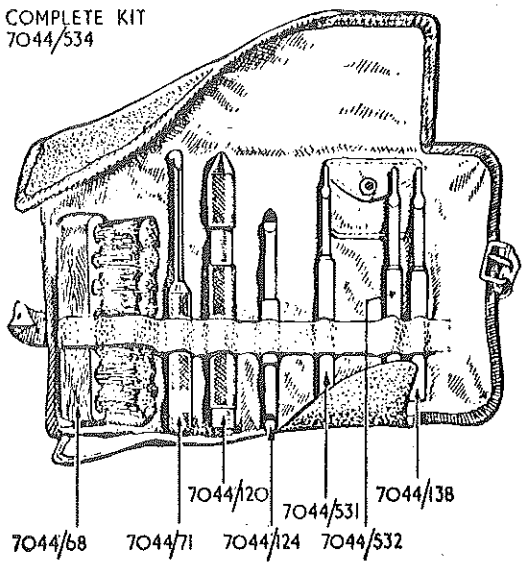
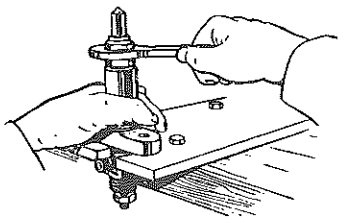


Fig. 27. NOZZLE CLEANING KIT

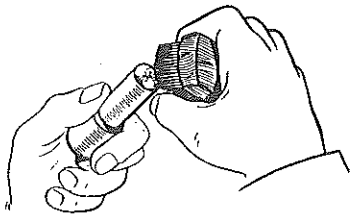
After the engine has been in service for a considerable period, it may be found that starting has become difficult owing to a fall in the injection pressure. This can be corrected by an adjustment to the injector spring compression, but such adjustment should only be carried out with the injector removed from the engine and coupled to a testing outfit capable of indicating release pressures.

Cleaning the Nozzles

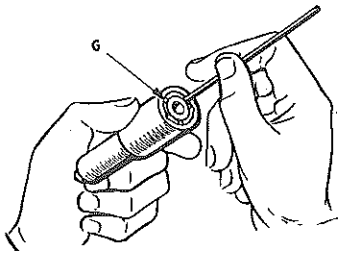
For the purpose of carrying out the following cleaning operations to the fuel injectors, a special set of tools is available and illustrated in Fig. 27 .



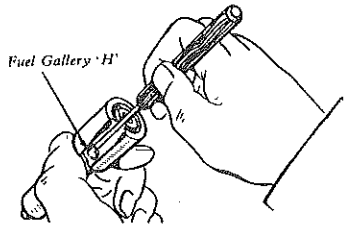
1. Release pressure on nozzle holder spring by undoing adjusting screw, then remove nozzle cap nut and nozzle.



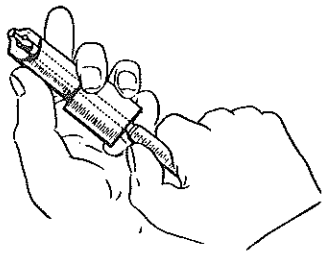
2. Brush all carbon from outside with brass wire brush.



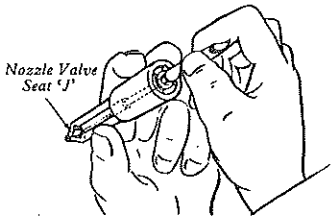
3. Clean out small feed channel bores " G " with drill or wire.



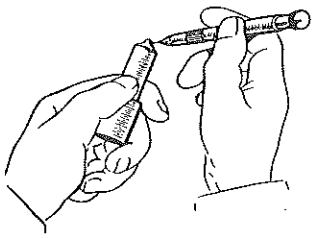
4. Insert groove scraper until nose locates in fuel gallery " H ". Press hard against side of cavity and rotate to clear all carbon deposits from this area.



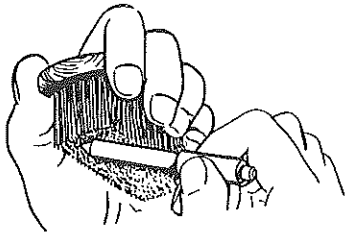
5. Insert dome cavity scraper, and in the same manner as operation 4, remove any carbon deposit adhering to inside of dome.



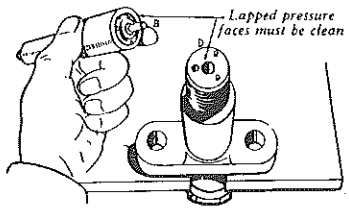
6. With seat scraper clean all carbon from valve seating " J " by rotating and pressing tool on to the seating.



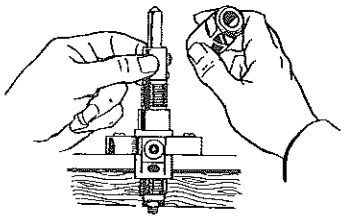
7. Clear spray holes by use of probing tool.



8. Clean needle valve tip carefully by brushing away carbon with brass wire brush.



9. Ensure that the lapped pressure faces " B " on the nozzle and " D " on the holder are clean and free from dirt or metallic particles.



10. Tighten cap nut with spanner taking care not to over-tighten, as this may cause distortion and lead to seizure of the nozzle valve.

Fig. 28, CLEANING INJECTOR

The canvas hold-all 7044/534 contains the following main items: (from left to right) brass wire brush, nozzle body groove scraper, probing tool, nozzle body seat cleaner, nozzle body, dome cavity cleaner.

Hold injector in vice with nozzle pointing upwards.

Remove nozzle cap with spanner 7044/841. Examine nozzle for carbon and note if the valve lifts out freely. Immerse in paraffin or other approved cleansing agent.

The nozzle should be free from damage and it is important that it is not 'blued' due to over-heating.

All polished surfaces should be relatively bright without scratches or dull patches. It is essential that the surfaces 'B' and 'D' (Fig. 28) are absolutely clean, as these must register together to form a high pressure joint between nozzle holder and nozzle.

Clean residue from oil channel and borings 'G'. Scrape all carbon from valve seating with soft brass scraper 7044/124 and, using body groove scraper 7044/71, clear the gallery 'H' of carbon.

Spray holes should next be examined and if choked, use probing tool 7044/120 in conjunction with the appropriate size of wire (.015 in.). Brush nozzle valve gently with wire brush 7044/68 paying particular attention to valve seat. Finally, using 7044/137, thoroughly flush the nozzle through to ensure that all carbon particles and foreign matter are removed from the inside. If the nozzle is not required for use, smear with vaseline and store.

IMPORTANT

If the nozzle is 'Blued, or the seating has a dull circumferential ring indicating wear or pitting, the complete nozzle assembly should be replaced.

In no circumstances must an attempt be made to lap the nozzle valve and body as this is a specialised process and any attempt to perform this may render any subsequent effort useless. Unless, therefore, the Ruston agent is also an agent for C.A.V. it is recommended that nozzle assemblies which will not respond to the treatment detailed herein, be sent to the nearest CA.V. agent for specialised treatment.

REPLACING NOZZLES

Absolute cleanliness must be observed, the holder and nozzle being re-assembled direct from the cleaning bath.

Hold injector in vice, nozzle face upwards. Replace nozzle assembly, and tighten cap nut with 7044/841.

NOZZLE HOLDER MAINTENANCE

The nozzle holder should be washed in clean paraffin, care being taken to protect the pressure face 'D' (Fig. 28). This face must register with the nozzle pressure surface cleanly and squarely to form a high pressure joint, and should be handled in such a way as to avoid damage.

Warning

The injector spring is set to release the pressure at 2,500 lb/sq.in. No attempt should be made to alter the release pressure by the adjusting screw unless an injector pressure test pump is available.

DISMANTLING

Remove the nozzle cap nut and nozzle assembly.

Remove cap nut and release lock nut at spring end with spanner 7044/870.

Unscrew spring cap nut with screwdriver, take out spring and spindle.

Thoroughly clean all parts in paraffin.

RE-ASSEMBLING

Re-insert spindle and spring, screw on spring cap and lock nut, and tighten to take up initial spring tension.

Mount nozzle on nozzle holder pressure face, making sure that both surfaces are absolutely clean and undamaged, and screw on the nozzle cap nut. Tighten well but not excessively with spanner 7044/841; too great a leverage may result in distortion of the nozzle.

Re-set injection pressure by means of the adjusting screw and locknut, and test on the injector test pump.

Replace cap nut.

COOLING

To ensure the efficient operation of the air cooling system it is essential that the following points be noted and acted upon at the periods specified.

FAN ASSEMBLY

Both the fan and jockey pulley are supported by ball bearings which are sealed at one side to prevent the ingress of dirt. Grease nipples are not provided as the bearings are packed on assembly and no further attention is required for up to 5000 hours when the bearings should be dismantled.

BELT DRIVE

The belts are supplied in matched sets and should not be renewed individually. Care must be taken to ensure that the correct tension is maintained. Adjustment is effected by moving the jockey pulley.

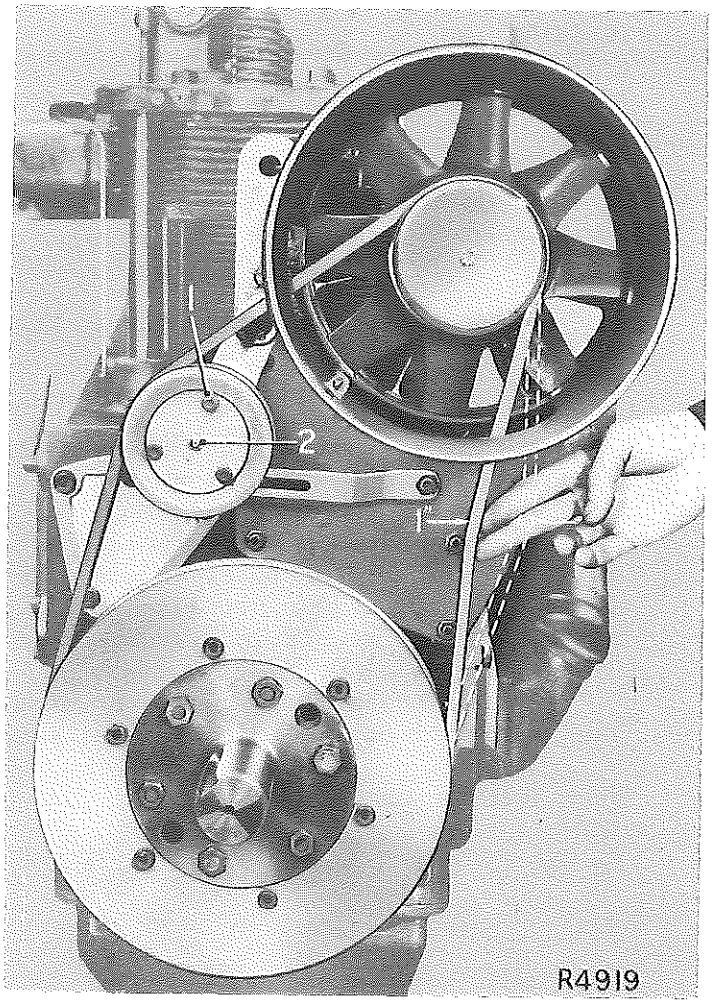


Fig. 29. FAN DRIVE

1. Jockey pulley
2. Grease nipple

The measure of correct tension should be a deflection of $\frac{3}{4}$ in. to 1 in. out of line of the true path of the belt when pressed by hand with moderate force. The tension should be checked after the first 8/10 hours running in service and thereafter periodically. The belts are assembled dry and no belt dressing should be used. Care must be taken to ensure that grease and oil are not deposited on the belts.

COWLING AND BAFFLES

The cowling and baffles are arranged to ensure uniform cooling of the cylinder barrels and heads. No attempt must be made to alter the cooling characteristics of the engine by distorting or repositioning these components. The engine must not, on any account be started unless the cowling and baffles are CORRECTLY positioned.

Absolute cleanliness, particularly on the internal walls, is of vital importance and the cowlings and baffles, together with the cylinder barrel and head fins should be cleaned periodically. The period at which this will become necessary will, of course, depend upon operating conditions.

AIR FILTER

SERVICING

1. Remove the oil cup at the base of the filter, empty it of oil and scrape out the sludge.

Provided the correct level of oil has been maintained the wire screen filtering element will, due to the washing action of the filter, require very little attention, but it should be inspected and foreign matter removed.

2. Refill the inner and outer compartments of the cup to the level bead with fresh engine oil and refit to the filter.

DO NOT:-

Remove oil cup whilst engine is running.

Use heavier oil than in the engine crankcase.

Allow sludge to exceed $\frac{1}{2}$ in.

Under or over fill.

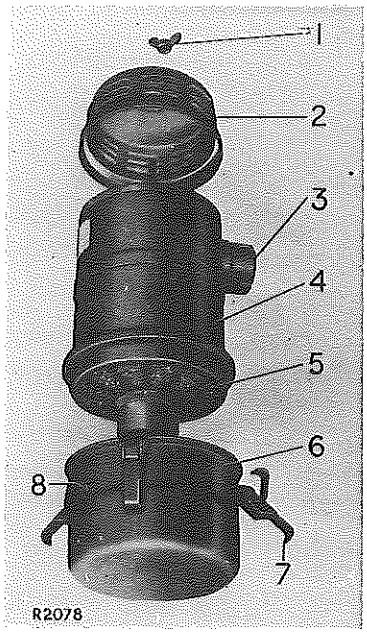


Fig. 30. AIR CLEANER

1. Wing nut
2. Cover
3. Inlet to engine
4. Filter body
5. Filter element
6. Oil container
7. Spring clips
8. Oil level bead

REMOVING THE ENGINE

Before attempting to remove the engine from the machine the following should be considered:-

1. The engine should preferably be warm when the lubricating oil sump is drained.

2. The fuel cock must be turned OFF and the pipe union at the filter disconnected.

3. The air filter should be removed carefully as this is filled with oil.

4. It will be necessary to remove the front superstructure to draw the engine forward during removal. This is retained to the frame by setscrews and care must be taken to ensure that the electrical connections to the front light etc., and the decompressor control, are disconnected.

5. Ensure that all electrical connections to the dynamo, starter etc., and all engine controls, are disconnected.

6. Sling the engine at the two points shown in Fig. 5.

7. Uncouple the extension shaft at the flexible coupling by removing the three nuts.

8. The engine is retained by eight holding down bolts, the bearer feet being shimmed from the frame to ensure correct alignment. On re-assembl these shims must be replaced in the positions occupied before dismantling.

EXHAUST CONDITIONER (LBU)

The exhaust conditioner is fitted to machines for underground duties to enable the exhaust gases from the engine to be thoroughly washed and obnoxious odour removed before passing to atmosphere.

This is done by first directing the exhaust gas under the water surface and then thoroughly separating it from the entrained water by passing through perforated baffles A and B (Fig. 31). This system of baffles prevents the passage of water through to the conditioner outlet G.

The gas enters a chamber in the side of the conditioner, then passes through a hole in the top into chamber C which is partially filled with water. From this chamber the gas is directed under the water into the

main chamber D. For filling and emptying the system, two plugs E and F are provided.

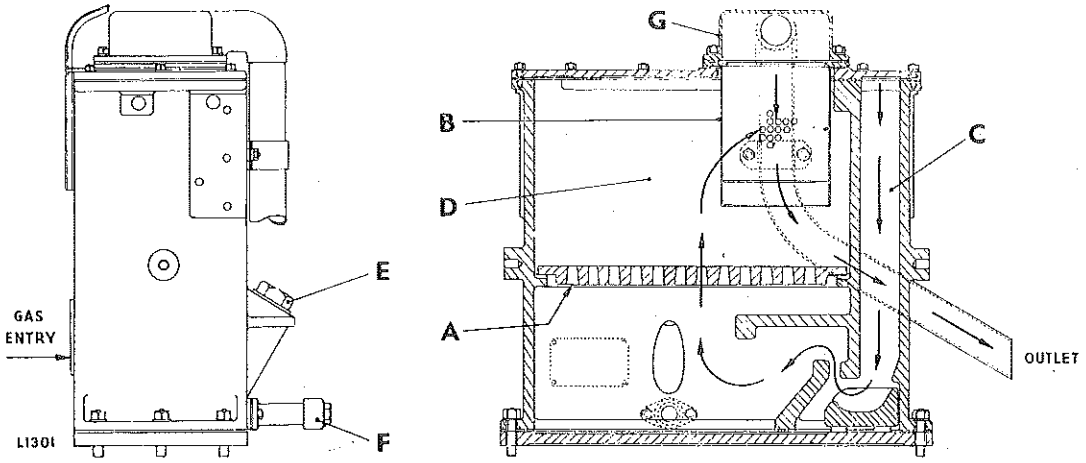


Fig. 31. EXHAUST CONDITIONER

MAINTENANCE

The amount of make up water required will vary according to the duty being worked and the level should be kept to within 2 or 3 inches of the top level. It is recommended that the level be examined at 2 hourly intervals and topped up as necessary.

To prevent the bottom of the box becoming badly fouled with carbon the water should be drained off at the end of the day's working. To counter acidity it will be found advisable to add about a handful of common soda to each gallon of water when filling each morning. To fill the box, remove plug E and pour in water using a can. DO NOT USE A HOSE PIPE as uncontrolled filling may result in the ingress of water into the engine.

The amount of carbon deposit will depend upon the condition of the engine, in particular the fuel injectors. Periodically flush out the box after removing the vertical baffles B and plugs E and F. Horizontal baffle A can be lifted and an inspection made of the bottom. If badly fouled the deposits should be scraped out and the box flushed with water. This should not be necessary more often than after 250 hours running.

It is recommended that the exhaust system between the engine and conditioner be cleaned out every 500 hours.

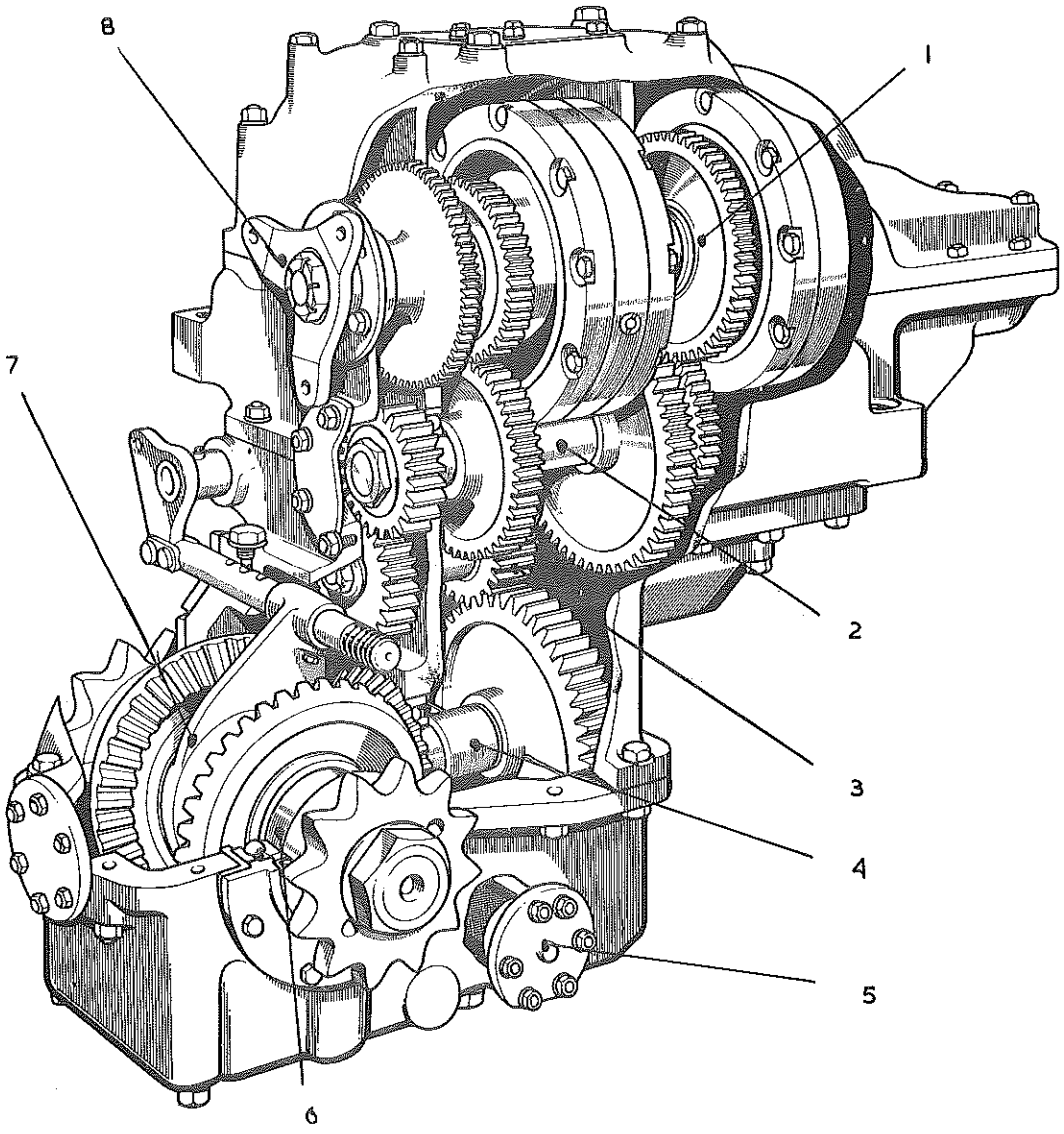


Fig. 32. GEARBOX

1. Clutchshaft
2. Layshaft
3. Intermediate shaft
4. Bevel pinion shaft
5. Oil strainer
6. Final drive shaft
7. Direction control dog
8. Input coupling.

TRANSMISSION

GEARBOX

The gearbox (Fig. 32) is a constant mesh type in which the gears are brought into operation by oil operated cone clutches. All speeds are available for forward and reverse operation in both the two and three speed versions.

The speed gears on the clutch shaft are free to rotate on roller bearings, and each is provided with a steel, conical clutch spinner (C Fig. 33) which is carried on splines and free to move axially. Bronze female cones (B) are carried on clutch housing (D) which is keyed to the shaft. The cones are normally held out of engagement by the axial springs (A).

A gear type oil pump, which is driven by gear (J) from the clutch shaft, provides oil for both lubrication and clutch operation. The pressure is controlled at 40 lb/sq.in. by a relief valve and lubrication is provided immediately the engine is started.

OPERATING SEQUENCE

Oil from the control valve is fed through a muff on the clutch shaft (H) and, by way of axial drillings through the shaft to the clutch. The oil pressurises the back of the pilot ring (F) in the clutch, bringing the male and female cones (C) and (B) into contact, giving partial engagement (See Fig. 34). This initial pressure seals the cavity between the spinner and the housing of the clutch, thereby allowing pressure to build up and overcome the spring loaded valve (E) and apply full pressure behind the clutch spinner (See B Fig. 34). This permits full transmission of torque through the gears and provides a smooth take up of load on starting or with change of speed.

Movement of the control lever to neutral or other gear position cuts off the supply of oil to the clutch assembly and permits oil to escape along a slot in the selector valve. The resultant pressure drop allows the spring loaded valve (E) to expose the exhaust port permitting oil to flow radially outwards from the back of the spinner. The spinner is then moved out of engagement by the springs (See C Fig. 34).

An additional clutch assembly (G Fig. 33) is fitted on three speed boxes, its construction and operation being similar to that described above.

The forward and reverse bevels K and M (Fig. 35), are free to idle on roller bearings on the final drive shaft. Direction is selected by manual operation of a sliding dog (L), between the bevel gears which brings the selected bevel into drive with the shaft. An interlock, operated by oil pressure to the clutch assemblies, prevents movement of the sliding dog when a clutch is engaged.

MAINTENANCE

The correct operating oil pressure for the clutches is 40 lb/sq.in. This pressure may drop slightly when idling, but if it drops below 35 lb/sq. in. during normal running an inspection should be made and the cause found and remedied.

Reduction in the oil pressure may be due to any of the following faults:—

1. Insufficient oil in gearbox.

   The level should be checked at the dipstick.

2. Relief Valve Spring requires adjustment.

   The relief valve is located on the nearside of the centre casing. To adjust the valve, the hexagonal blanking plug and washer should first be removed. The screwed plug now exposed should be rotated by means of the screwdriver slot provided. By screwing this plug in or out, the oil pressure may be returned to 40 lb/sq.in. Remember to replace the blanking plug after adjusting.

3. Leaking Oil Pump Joint

4. Choked Oil Filter.

Daily

1. Check oil level on dipstick. If necessary, top up with clean oil of the appropriate grade.

Every 2000 Hours

1. With the engine idling and the gearbox in "NEUTRAL", carefully remove the top inspection cover and check that oil is being sprayed on to the gears. If the spray is not evident, or it appears unsatisfactory, after stopping the engine, the top casing must be removed and the spray passages in this casing cleared of all foreign matter.

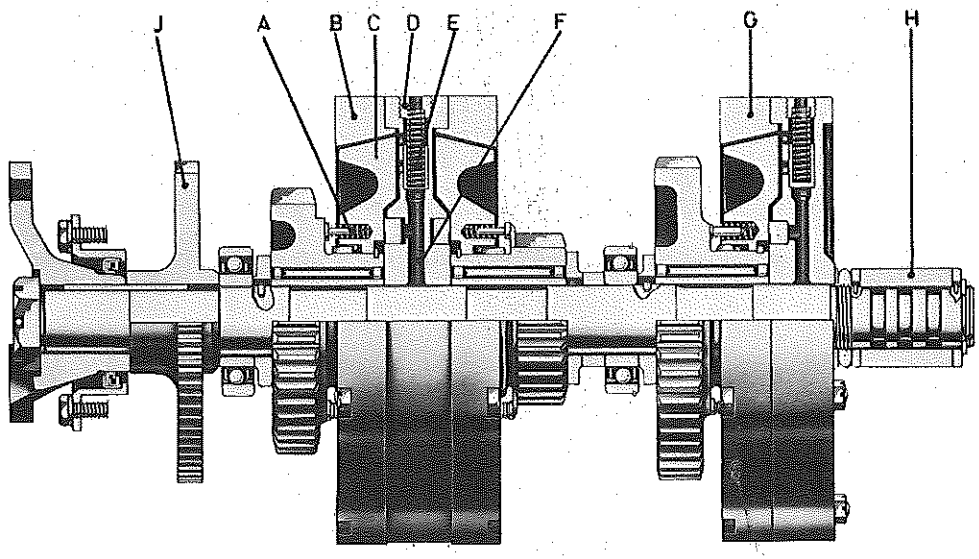


Fig. 33– CLUTCHSHAFT ASSEMBLY

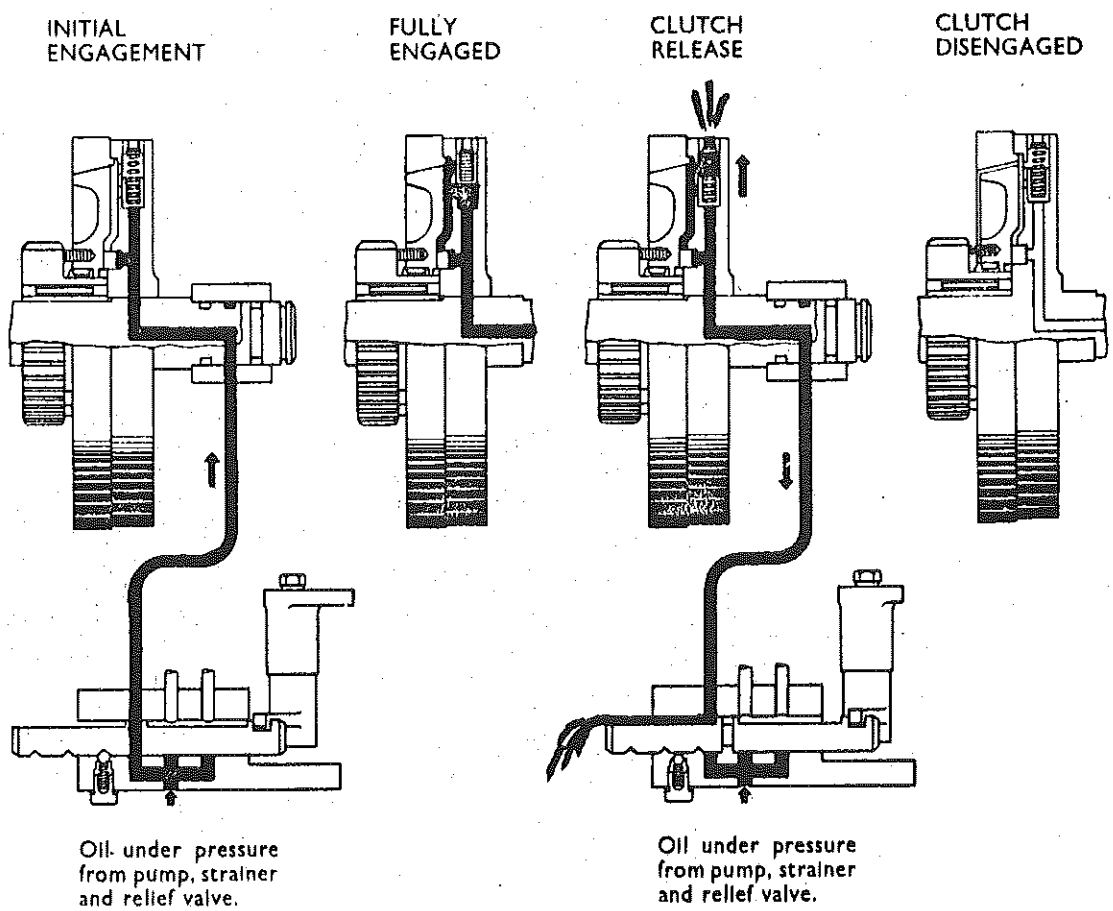


Fig. 34, SEQUENCE OF CLUTCH OPERATION

2. Drain all the oil from the gearbox by means of the drain located on the nearside of the sump, immediately below the gearbox chain sprocket. There is also an oil reservoir in the gearbox casing which has to be drained and the plug for this is also on the nearside under the centre case joint flange. Replace the plugs.

3. Remove the oil filter (also on the nearside of the sump) by unscrewing the six flange nuts.

   Unscrew the central plug and clean the magnetic filters.

   Clean the perforated shell of the filter.

   Re-assemble, fit the joint and replace in the gearbox.

4. Clean oil of the correct grade should now be poured into the gearbox and it is important that the oil is admitted through the filler plug and NOT THE TOP INSPECTION HOLE. This is to ensure that the internal reservoir (holding one gallon) is filled first, otherwise, when the engine is started, oil will be drawn from the sump and pumped into the reservoir and so reduce the quantity of oil in circulation.

   FOR THE CORRECT GRADE OF OIL, SEE SECTION 8.

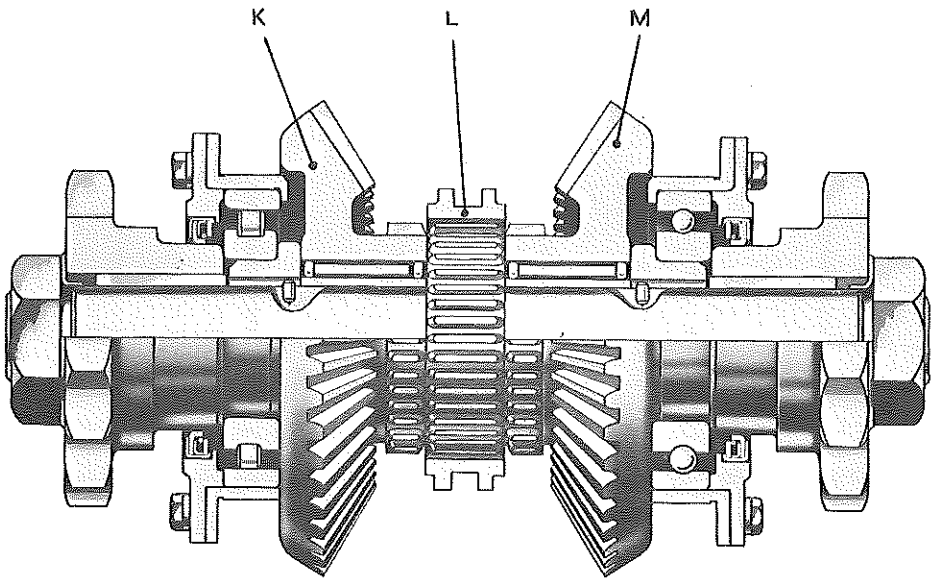


Fig. 35. FINAL DRIVE ASSEMBLY

CHAIN DRIVE

The drive is transmitted to the wheels through two roller chains. It is important to ensure that chains are lubricated periodically and maintained at the correct tension. In order to lubricate the chains remove them every 500 hours (3 months), wash in paraffin and dry thoroughly, then immerse in hot grease and allow to soak. Remove and allow to cool, in this way the grease will penetrate all the chain links and help to prevent dust and grit gaining access.

To adjust the chain tension proceed as follows:-

(a) Loosen the nuts A (Fig. 36) securing the axle-boxes to the frame.

(b) Loosen the locknuts B.

(c) By turning the adjusting bolts C, move the axle-boxes in the required direction to effect adjustment.

(d) Tighten locknuts B and the nuts A on the frame.

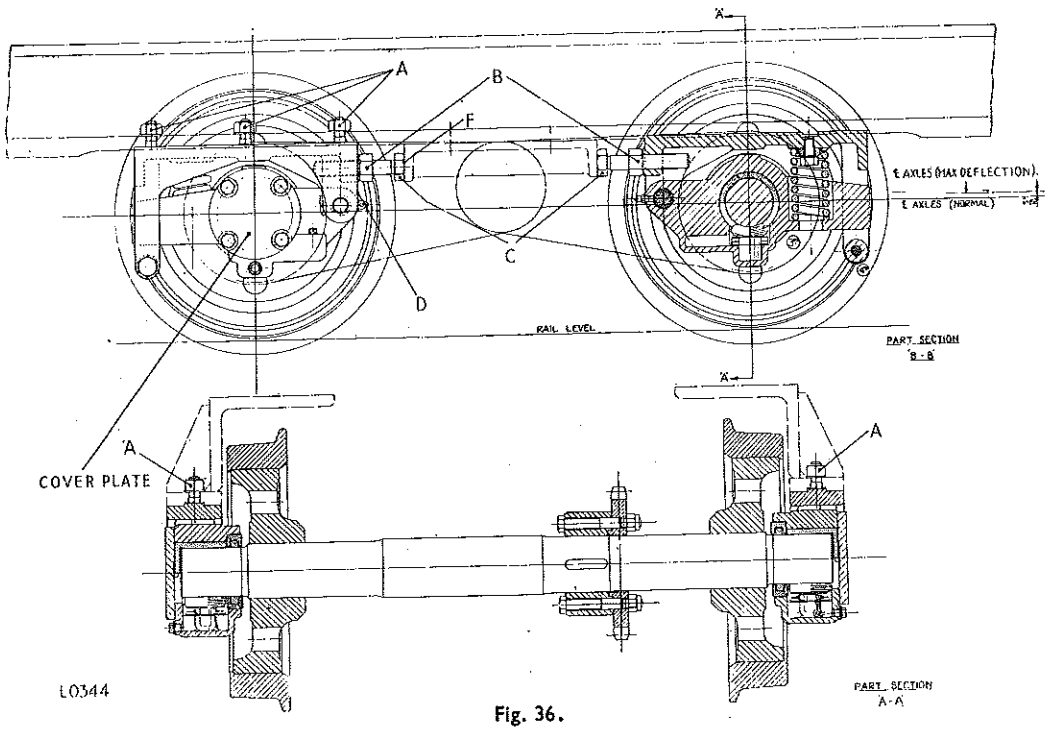


Fig. 36.

IMPORTANT

When adjusting the position of the axleboxes ensure that the axles are kept parallel and are at right angles to the axis of the gearbox and engine. To ensure this check the distance between D and F, on both sides of the frame, before and after adjustment. When no further adjustment can be obtained by moving the axleboxes, a link may be removed from the chain and the tension reset.

AXLES BOXES

Each axlebox is fitted with a bronze bearing which is lubricated by an oil pad from the reservoir in the base of the axle box. The level should be checked at weekly intervals, topping up with the correct grade of oil (Section 8) as required. The boxes should be drained, flushed and refilled with fresh oil at three monthly intervals.

The axle bearings should be withdrawn and inspected for wear periodically by removing the cover plate. It will however, be necessary to lift the locomotive to carry out this operation.

WHEELS

Solid type wheels (type 2) are normally supplied on standard locomotives but tyred wheels (type 3) may be fitted to suit customer's requirements. The solid wheels can, when worn, be machined to accomodate tyres and when the tread diameter is reduced to the limit of wear groove, which is machined around the wheel, adopt the following procedure:-

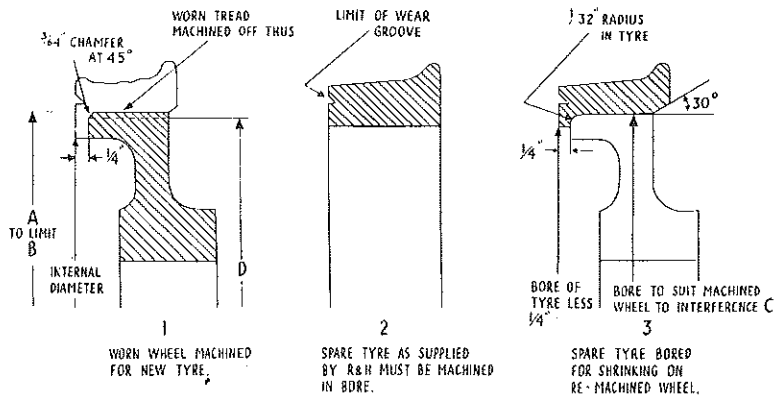
(a) Remove the wheels and axles from the machine and turn the outer periphery of the wheel down to the dimensions indicated in columns A and B (Fig. 38). To allow for the correct location of the tyre the rim must be reduced by $\frac{1}{4}$ in. on the outer face of the wheel centre.

(b) For subsequent retyring operations, care must be taken to ensure that the wheel is not reduced below the dimension shown in column D.

(c) Replacement tyres are supplied in a fully machined condition with the exception of the bore which is left unfinished. This should be bored to suit the wheel with an interference fit as indicated in column C. This operation should not be taken across the full width of the tyre, a shoulder $\frac{1}{4}$ in. deep being left on the outer face of the rim.

NOTE:-

Care must be taken to ensure that the chamfer on the centre and the radius on the tyre are machined to the dimensions shown on the drawing.



	A	B (Limits for A)	C (Shrinkage Limits)	D (Minimum Dia.)	E
Type 2 wheels	$13\frac{7}{8}$" 352 mm.	+.000/—.002" +0/—.05 mm.	—.018/.020" —.45/.5 mm.	$13\frac{1}{2}$" 343 mm.	+.020" +.5 mm.
Type 3 wheels	—	—	—.018/.020" —.45/.5 mm.	$12\frac{1}{4}$" 311 mm.	+.020" +.5 mm.

Fig. 37. RETYRING THE WHEELS

HEATING THE TYRE

The tyre should be heated gradually and evenly all round so that it expands a sufficient amount to allow it to be slipped over the wheel centre. The amount will vary with the wheel size and our practice is to allow .0015 in. per inch of centre diameter. This expansion, which should be measured with a stick gauge, is shown in column E.

Where available heating arrangements preclude the use of a stick gauge, heat the tyre until it is just changing from black, giving the following temperatures:-

In daylight 500°C to 530°C

In sunlight 550°C to 580°C

The temperature must not exceed 600 C and care must be taken to ensure that the shoulder in the bore is up to the face of the wheel centre. The wheel should be allowed to cool in this position.

NOTE:-

Wear must not be allowed to develop beyond the 'limit of wear' groove to ensure the minimum ground clearance and to maintain sufficient metal on the wheel centre for retyring.

RETYRING TYRED WHEELS

The procedure is substantially the same as that detailed above, but care must be taken not to damage the wheel centre when cutting off the old tyre. If however, the centre is found to be damaged, it may be cleaned up but not reduced below the dimension shown in column C.

NOTE:-

It is not necessary to machine the outside face of the wheel centre as it is already suitable for tyres. If the centre has been cleaned up, the chamfer must be remachined as shown in Fig. 37 .

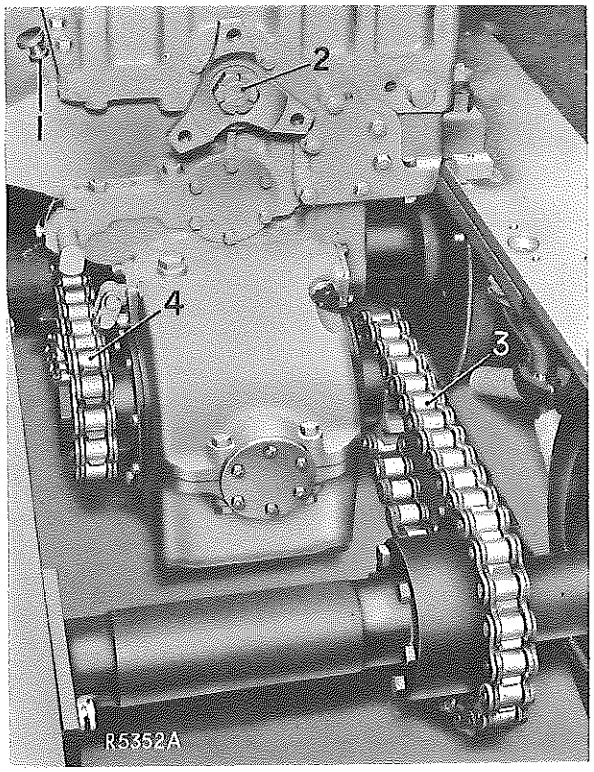


Fig. 38. TRANSMISSION

1. Dipstick
2. Input coupling
3. Front chain
4. Rear chain

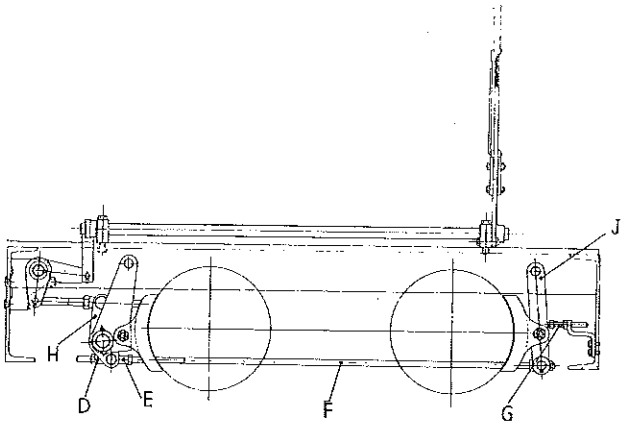
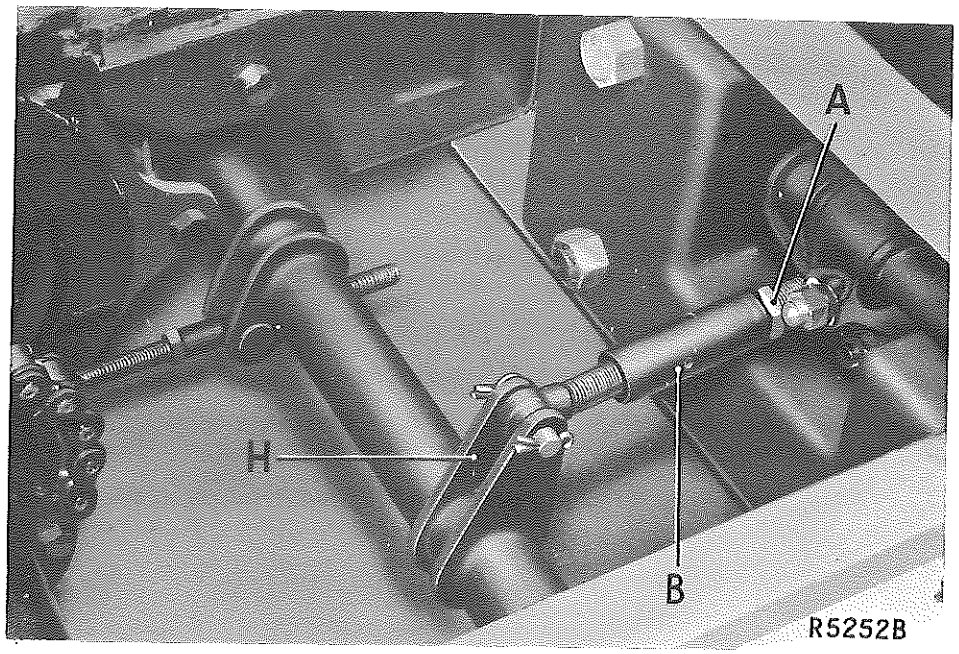


Fig. 39 ARRANGEMENT OF BRAKE GEAR



BRAKES

The locomotive is fitted with a hand brake 8 (Fig. 4) which is situated at the rear of the cab and operated on a ratchet.

1. The linkage and ratchet should be lubricated frequently.

2. Periodically examine the condition of the pins and forks in the linkage.

3. As wear takes place in the brake shoes, adjustment should be made in the following manner:-

   (a) Set the hand brake lever so that the ratchet is approximately half-way across the quadrant.

   (b) Slacken nuts A,B,D and E (Fig 39).

   (c) Adjust the nuts to keep lever H vertical while bringing the shoes in contact with both wheels.

   (d) When this has been done, tighten all locknuts.

   (e) Adjust stop screw G (on each side of the locomotive) to be just clear of lever J.

   The release of the handbrake will then allow sufficient working clearance between the brake and the railwheels.

SANDING GEAR

The sanding gear is operated mechanically by a lever on the dashplate and sand boxes are provided at each side of the machine. The gear requires little attention apart from ensuring that the sandboxes are kept full. Clean fine dry sand should only be used.

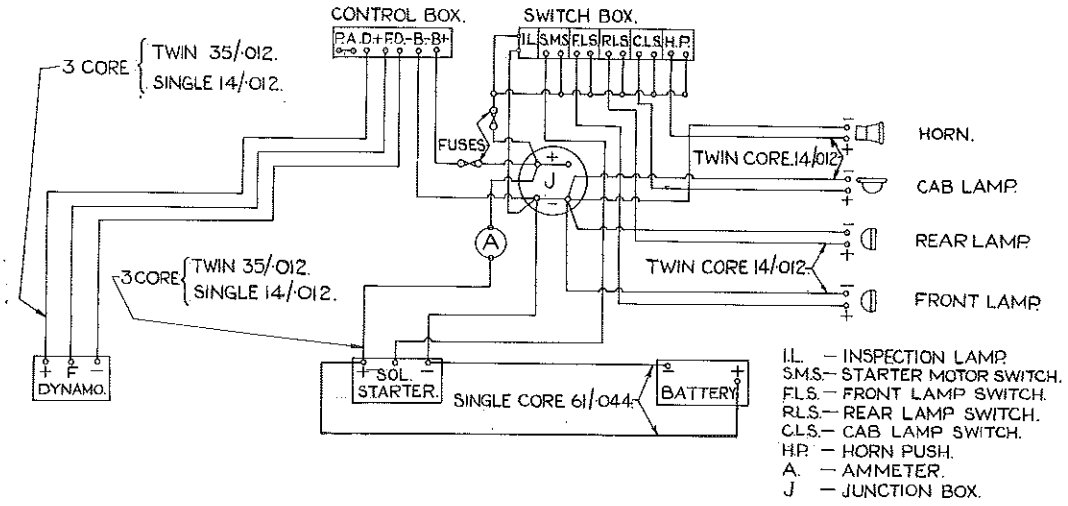


Fig. 40. WIRING DIAGRAM

ELECTRICAL EQUIPMENT

The 12 volt compensated voltage control system provides for the automatic adjustment of the charging rate in relation to the condition of the battery. When the dynamo exceeds the cutting-in speed its output voltage is kept slightly in excess of the back pressure of the battery irrespective of any variation in speed. In addition, the excess voltage of the dynamo is made greater as the battery becomes discharged and less as the battery becomes more fully charged.

DYNAMO

When the machine is received in a new condition, it can be safely assumed that all necessary adjustments and tests have been carried out. The dynamo requires little maintenance and the following are the only points which should need attention during service, at the periods specified in Section 5.

COMMUTATOR AND DRIVE END BEARINGS

A high melting point grease is recommended for both ball and roller bearings. The bearing, which is not fitted with a greaser, will only require packing with grease at the overhaul period.

BRUSHES

These should be inspected and if damaged or excessively worn, replaced by a brush of the correct grade. It is not practical to supply new brushes in a 'bedded' condition, as the periphery of a particular commutator may vary from standard equipment dependent upon the number of 'skimming' operations, carried out.

The 'bedding' operation is carried out by wrapping a piece of fine glass or carborundum paper around the commutator with the abrasive surface upwards. The brushes should now be fitted to their respective holders, and the armature rotated in the normal direction of rotation until the correct brush shape is achieved. (Fig. 41).

The brushes should be free to move vertically in the holders, and may be freed by lightly polishing the sides of the brush with a smooth file.

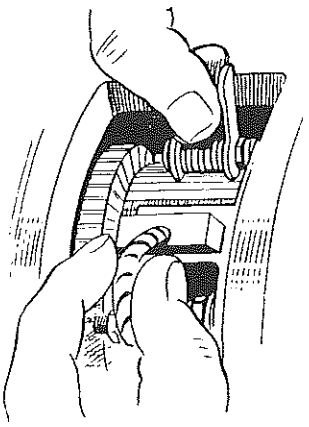
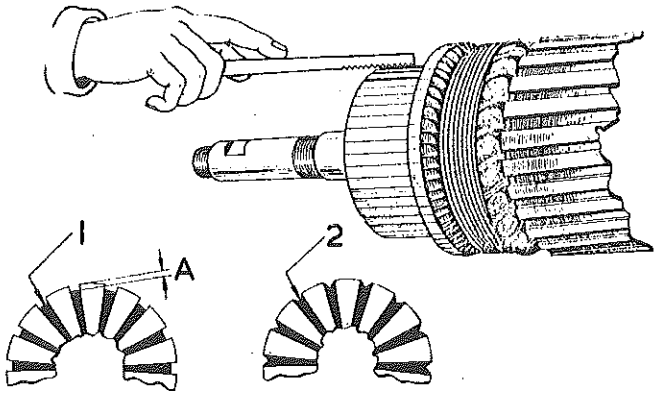


Fig. 41. Dynamo brushes.

COMMUTATOR

The commutator should be clean, of uniform colour, and there should be no bridging of the inter-segment insulation.

The surface should normally be cleaned with a petrol soaked cloth, but if excessive pitting has developed it must be treated as described under 'OVERHAUL'.



KEY TO NUMBERS:
1. CORRECT WAY OF UNDER-CUTTING COMMUTATOR
2. INCORRECT WAY OF UNDER-CUTTING COMMUTATOR

Fig. 42.

OVERHAUL

Removing the Armature

To remove the armature, proceed as follows:-

i. Lift the brushes clear of the commutator surface. (It is not necessary to remove them from their holders as the spring trigger can be wedged in position).

ii. Extract the driving end shield bolts and remove end shield.

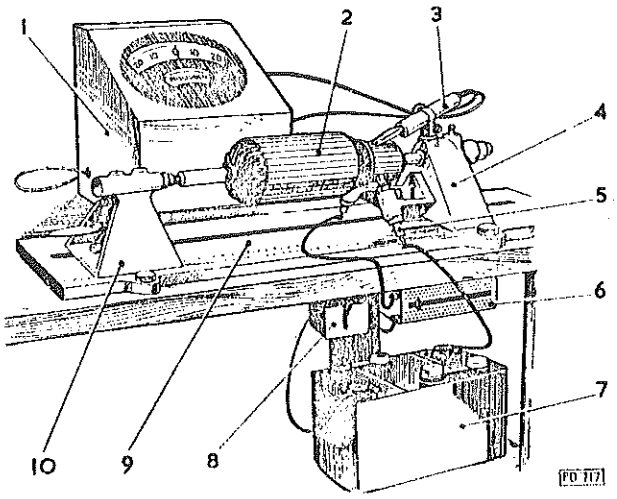
iii. Carefully withdraw the armature.

The commutator surface should be cleaned and examined for discolouration and excessive pitting. The surface can be restored by applying a very fine grade of glass or carborundum paper (emery cloth must not be used). If the pitting is excessive, it may not respond to the above treatment in which case the armature should be mounted on a lathe and 'skimmed'. A very light cut should be made and where possible a diamond pointed tool should be used. After turning, the commutator should be 'undercut', i.e., the mica insulation between the commutator bars should be removed to a depth of 1/32 in. (.8 mm.) below the surface of the copper. Care should be taken to ensure that the full width of the mica is removed. A hacksaw blade, suitably reduced in thickness makes a serviceable tool for this purpose (Fig. 42). It is advisable to fit new brushes at the overhaul period and these should be 'bedded' as detailed under (b) above.

Armature Test

The armature windings can be tested for continuity as follows:-

i. Mount the armature on a block (Fig. 43).



KEY TO NUMBERS:—

1. MILLIVOLT METER
2. ARMATURE UNDER TEST
3. HAND SPIKE
4. HEADSTOCK
5. BRASS OR COPPER BRUSHES
6. VARIABLE RESISTANCE
7. BATTERY
8. SWITCH
9. BASE FOR HEADSTOCK
10. TAILSTOCK

Fig. 43.

ii. Connect the armature to a battery having a variable resistance (set to provide 2 volts) in circuit with it. Contact should be made through the medium of two copper brushes mounted on the commutator segments at an angle of 90° to each other.

iii. Contact any two adjacent commutator bars by means of handspikes connected through a milli-volt meter.

iv. Rotate the armature applying the handspikes to each adjacent pair of commutator bars until all the bars have been tested. The reading on the milli-volt meter should be approximately the same in each case. A wide variation indicates a fault in the winding connected to one of the commutator bars under test. A reduced reading will generally be due to a short circuit, and an increased reading will indicate an open circuit or faulty connection.

A faulty armature should be returned to the manufacturers or their agents for re-winding.

Field Coil Test

The field windings can be tested for continuity without removing them from the yoke by connecting them in series with a 12 volt battery and a 12 volt, 36 watt bulb (Fig. 44). If the coils are servicable, the bulb will light up, but its brilliance will be somewhat less then when it is connected directly to the battery.

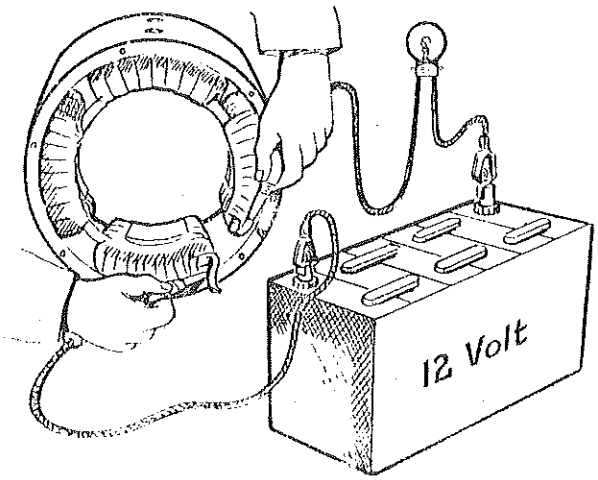


Fig. 44.

Failure of the bulb to light indicates an open circuit in the winding. If the bulb lights with full brilliance the field coils are earthed to the pole shoes or dynamo yoke. In both cases the field coils should be renewed.

Brush Spring Test

The brush spring pressure can be tested by fitting a spring balance to the brush trigger (Fig. 45). The pressure should be between 10 and 16 ounces, adjustment being effected by twisting the spring into different slot locations on the trigger.

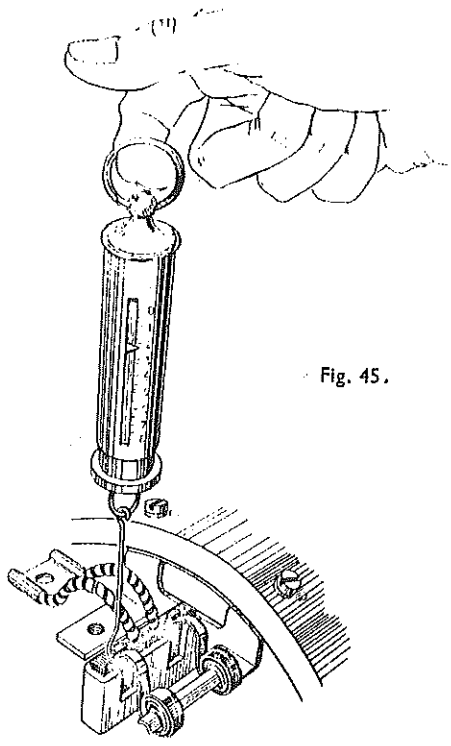


Fig. 45.

DYNAMO OUTPUT TEST

i. Disconnect all cables from their respective terminals.

ii. Bridge the two main terminals.

iii. Clip the leads of a moving coil voltmeter, having a suitable range, to the two large main terminals.

iv. Run the dynamo and gradually increase its speed until a reading of 13 volts is obtained. Do not, however exceed a dynamo speed of 1300 r.p.m.

If the voltmeter reading remains at zero, check the dynamo brush gear and internal connections for a break in the circuit.

A very low reading throughout the speed range indicates a possible fault in the field coils, and a low maximum voltage, a fault in the armature windings.

CONTROL BOARD

Serious damage may be caused by unskilled interference with the regulator or cutout and it is recommended that, when possible, a unit requiring attention should be returned to a service depot for adjustment or exchange for a replacement unit.

REGULATOR

The totally enclosed barrel type regulator is shown in Fig. 46. The main body A and two end caps (B) are permanently fixed in position by spinning over the ends of the body. In the centre is the armature C into which is screwed a brass distance piece D. These two pieces are held in a floating position by attachment to the spring F by means of contact screws G and H. Screwed into the caps at each end are the adjustable contacts J and S which, after setting, are locked in position by means of the locknuts X and R.

One pair of contacts inserts a resistance in the field circuit of the dynamo and the second cuts out the field completely when the dynamo is running at high speeds. The output of the dynamo is thereby controlled over a wide range of speed.

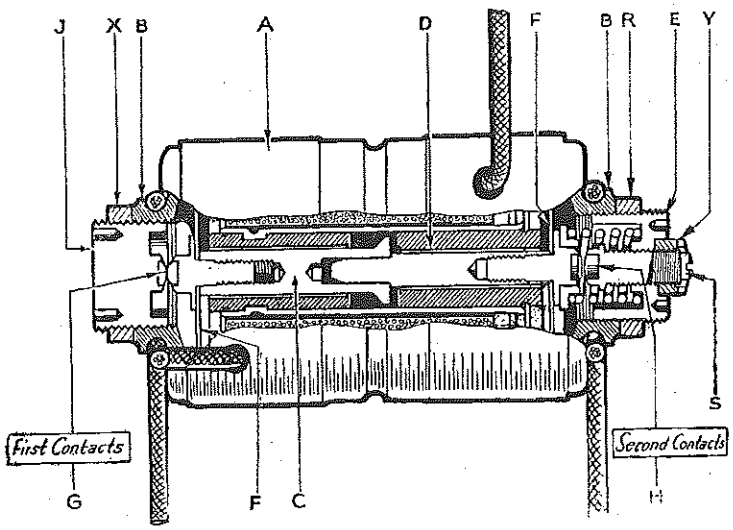


Fig. 46. REGULATOR

ADJUSTMENT

The need for attention to the regulator is usually indicated by an excessive charging rate with a well charged battery, or a low charging rate with a battery in a low state of charge. If no charge is shown on the ammeter, the trouble is not likely to be in the regulator.

The following instructions for testing and adjusting regulators should only be carried out by suitably qualified personnel using the correct tools (Fig. 47).

ANY ATTEMPT TO ADJUST THE REGULATOR WHEN THE ENGINE IS RUNNING MAY RESULT IN THE CONTACTS BEING WELDED TOGETHER. RENDERING THE REGULATOR TOTALLY UNSERVICEABLE.

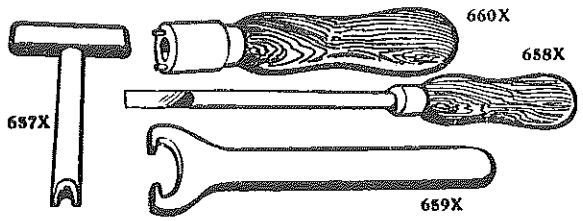


Fig. 47.

Adjustment is carried out as follows:-

i. Slacken locknuts X, R and Y, - tools 659x and 657x.

ii. Screw back contact J, - tool 660x.

iii. Screw back contact S as far as possible, - tool 658x.

iv. Screw back sleeve E, - tool 669x.

v. Screw in first contact J as far as it will go, i.e., until the armature C makes contact with sleeve D.

vi. Screw back first contact approximately one and a half complete turns.

vii. Lock first contact screw J in this position by means of locking nut X.

viii. Run the dynamo at approximately 1000 r.p.m.

ix. Screw in sleeve E until first contact setting is not more than 15.3 volts.

x. Lock sleeve E in position by means of locknut R.

xi. Stop dynamo. Screw in contact S as far as it will go. Turn contacts back one complete turn and lock in position by locknut Y.

xii. Run dynamo up to 2000 r.p.m. Voltage setting on second contacts should be at least 15.2 volts but within the limits of 15 to 15.5 volts.

xiii. If second contact voltage is above limit, stop dynamo and screw J in slightly. Recheck first contact setting and then proceed as in (xi).

xiv. If second contact voltage is below first contact, stop the dynamo and screw J out slightly. Recheck first contact setting and then proceed as in (xi).

NOTE:-

The adjustment of contact S is only possible when the dynamo is stationary. If the contact is screwed up when the dynamo is running a short circuit is set up in the dynamo resulting in fusing or welding of the regulator contacts.

CUTOUT

The cut-out ensures that the battery is disconnected from the dynamo at low dynamo revolutions and when the engine is stationary. The 'U' shaped magnetic frame (a Fig. 48) supports the centre cone B and bobbin C. A moving arm and contact E is hinged to one arm of the main frame and kept apart from the fixed contact M by means of spring G. The spring tension can be varied by turning nut J and a terminal plate K is provided for the external cable connections.

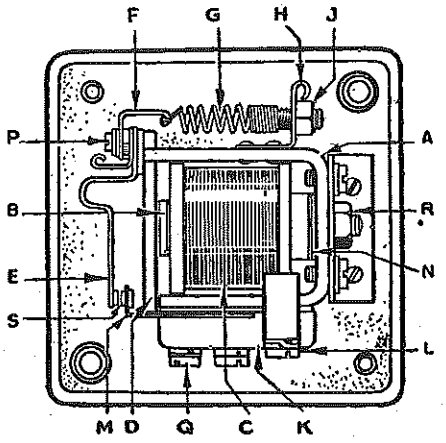


Fig. 48. CUTOUT

MECHANICAL SETTING

i. Set the contact air gap S to .002 in. - .025 in. by carefully bending the moving contact strip arms E.

ii. Ensure that the air gap S between the cone and armature lies between 0.010 in. and 0.015 in. Adjustment can be made by varying the number of shims at N.

ELECTRICAL SETTING

i. Run the dynamo and adjust the cutting in voltage to 12.25 - 12.75 volts by turning nut J.

ii. Following adjustment, ensure that the nut J is located firmly in position against the curl of the soldering tag H to prevent it turning.

BATTERY

The battery fitted to standard locomotives is a lead acid type with a capacity of 67 ampere hours at the 10 hr. rate. In locomotives delivered to the home market, the battery is delivered in a fully charged condition and ready for immediate use. The battery is dry charged in locomotives delivered overseas and electrolyte consisting of sulphuric acid and distilled water must be added before placing into service.

The following operations will ensure that the battery is maintained in a fully serviceable condition:-

i. The electrolyte level should be checked periodically and restored as necessary, by adding, DISTILLED WATER only. The level is correct when it reaches the under side of the plate group bars.

ii. The state of charge can be determined by the specific gravity of the electrolyte which should be checked with a hydrometer. The specific gravity of the battery, with the electrolyte at the correct level, in various states of charge can be seen in the following table:-

Fully Charged	-	1.275	to	1.285
Half Discharged	-	1.200	to	1.215
Fully Discharged	-	1.140		

iii. Do not allow naked flame in the vicinity of the cells as the gases given off are explosive.

iv. Care must be taken to exclude all dirt and foreign matter from the cells. All exposed metal work should be coated with petroleum jelly to prevent corrosion.

v. The battery tops must be kept clean and dry and any spilt acid removed immediately. The connections should be kept tight and smeared with petroleum jelly or protective grease.

STARTER MOTOR

The starter motor is a C.A.V. 'co-axial' type, in which the pinion moves axially along the armature to engage the flywheel. As will be seen from Fig. 49 the pinion is carried by a long sleeve on the armature shaft, pinion and shaft being provided with a helical thread; a light return spring is fitted.

Fitted on the sleeve, and provided with a thrust shoulder, is a second sleeve or cylindrical plunger which slides inside the solenoid. A trip collar is carried on the pinion sleeve, for tripping the trigger which closes the second stage contacts on the solenoid plunger.

A special locking device is provided to prevent the premature ejection of the pinion. This consists of a set of four steel balls which are located in holes in the pinion sleeve, and which may be held in the 'locked' position by a spring-loaded, ball lock collar with a steep chamfer on its inner edge. When the starter is at rest, the balls rest on the surface of the shaft and hold back the lock collar. When the pinion sleeve moves forward to the fully engaged position, the balls drop into dimpled recesses in the armature shaft, the lock collar travels over the top of the balls under pressure of its spring and locks them in position. The pinion sleeve is thus held endwise on the shaft until the starter switch is released, the solenoid is de-energised, and the plunger returns to its normal position; in doing so, it pushes back the lock collar, releases the balls and allows the pinion sleeve to slide and the pinion to disengage.

OPERATION

When the starter switch is pressed, the solenoid is energised and the solenoid plunger moves axially forward 5/16 in. (7.9 mm.), bringing the pinion nose into mesh with the engine flywheel teeth. At the same time a first set of contacts mounted on the plunger closes, and current limited by a resistance incorporated in the starter, passes through the windings, causing the armature shaft to rotate slowly.

The pinion is then drawn into full engagement by the action of the helix and the slowly rotating armature. Just before the fully engaged position is reached, the collar carried on the pinion sleeve trips the trigger operating the second contacts. When the contacts are made the resistance is short circuited, and full current passes through the field and armature windings. Full starting torque is exerted only when the pinion is in proper engagement and the risk of damage to pinion and flywheel teeth is minimised.

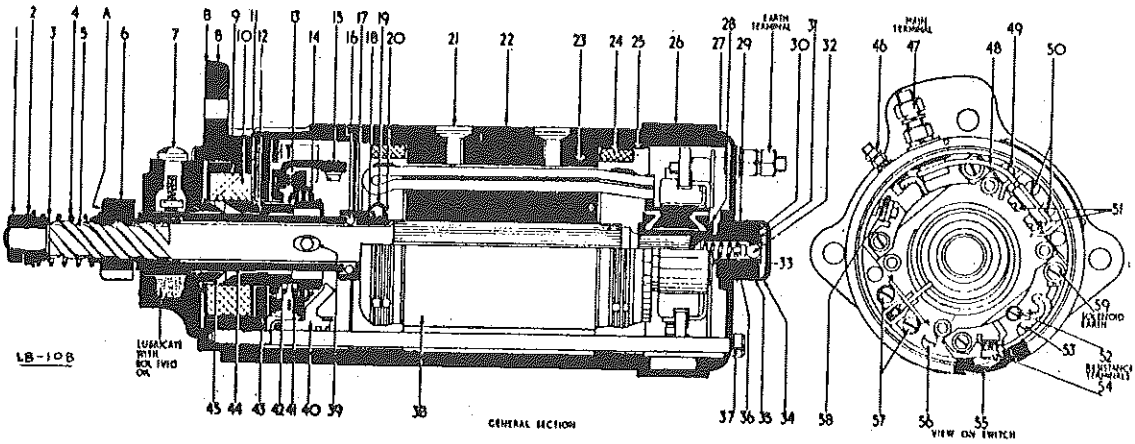


Fig. 49. SECTION THROUGH STARTER

As the pinion sleeve moves forward, the locking balls in the sleeve drop into the shaft dimples, and lock collar travels over them as already described. The pinion cannot be ejected prematurely, but will remain in mesh so long as the starter switch is depressed.

The return spring fitted on the forward end of the pinion helps disengagement, and prevents the pinion wandering towards the flywheel while the engine is running.

On rare occassions, badly worn pinion and flywheel teeth may meet face to face, preventing engagement, and causing the pinion to remain stationary against the flywheel when the starter button is pressed. Special provision is made for overcoming this difficulty. At the commutator end of the armature, a steel ball thrust device is fitted, the shaft being held in its endwise position by a coil spring. The armature, under the influence of the helix, will be turned slightly and at the same time forced back against the spring; end movement of approximately $\frac{1}{8}$ in. (1.6 mm.) is permitted. When the starter button is released the armature and pinion will come back to the normal disengaged position, but the radial position of the pinion will be slightly in advance of the previous position, so that the next engagement will be made quite smoothly.

MAINTENANCE

The large oil reservoir in the drive end shield need only be replenished during overhaul periods when a supply of 'Bolivio' oil should be added through the oil plug. An oil impregnated bronze bush is fitted at the commutator end and needs no further attention.

The pressure of the brush springs should be checked with a spring balance and these should be 30-40 ounces taken at the point of contact with the brush. If spring pressures are not within the specified limits the spring should be replaced. The commutator should be clean and free from uneven discolouration. Cleaning should be carried out with a non-fluffy rag moistened in carbon tetrachloride or, if necessary, fine glass or carborundum paper (do not use emery cloth). If the surface is badly scored or pitted it may be lightly skimmed, if possible, a diamond tool being used. DO NOT UNDER-CUT THE MICAS.

DISMANTLING THE STARTER

1. Unscrew the shaft lock-nut (1) (L.H. thread), pinion stop (2), shim washers (3) and return spring (4).

2. Remove the two cover screws (55) from the drive end-shield and unscrew the exposed field coil terminal screws (54) and (58).

3. Remove the commutator end cover-band (26).

4. Unscrew the brush-lead screws, ease off brush springs and lift brushes from the holders. Note that removing the brush screws also frees the field coil and interconnector leads.

5. Remove the spring-clip (29) and take off the end cap (34).

6. Remove the circlip (31), thrust washer (30), shim-washers (35), steel ball (32) and spring (36).

7. Unscrew and withdraw the two through-bolts (37) from the commutator end-shield (27).

8. Remove the commutator end-shield, and take off the shaft-shims (28).

9. The yoke (22), pole-pieces (23) and field coils (24) can now be removed as one assembly, leaving the armature completely exposed.

10. Unscrew the eight pole-shoe fixing screws (21) and take out the pole-pieces and field-coils, taking care not to damage the leatheroid (25), inserted between the coils and yoke.

DISMANTLING THE OPERATING MECHANISM

1. Holding the pinion (6) and drive-end shield (8) rigid, release the ball lock and withdraw the shaft from the pinion sleeve (44), by rotating the armature in an anti-clockwise direction.

NOTE:-

This may require a little more than normal force, because of probable burring resulting from the action of the ball lock.

Withdrawal of the shaft causes the four steel balls (16) to fall through to the inside of the pinion sleeve, and these should now be recovered.

2. Using circlip pliers, remove the circlip (20) from the pinion sleeve-end.

3. Remove the trip-collar (19) and ball locking-collar spring (18). Slide off the locking collar (17).

4. Withdraw the pinion (6).

5. Remove the two screws (51) from the main terminal connecting link (48). Loosen the main terminal (47) and remove the link.

6. Remove the resistance lead (52) from the moving contact plate.

7. Remove the two screws (57) holding the trip-gear and remove by threading the trigger (40) through the slot in the moving contact plate.

8. Remove the two screws (50) holding the stop plate and remove the plunger assembly (11).

9. Unhook the plunger spring (14) from the sliding plunger (11).

10. Take off the moving contact plate, remove the contact spring (42).

11. Remove both solenoid and main terminals (46) and (47) from the end-shield.

12. Unscrew the three solenoid end-plate fixing screws (49), (53) and (56). Take out the end-plate (43) complete with the solenoid housing. If the plate offers resistance, screw in two 2BA screws, (approx. 2 in. long), one into the trip gear fixing hole, the other into the stop-plate fixing hole. The end plate may then be easily extracted.

Under no circumstances should the solenoid windings and resistor assembly be disturbed or any damage done to the mica housing.

ASSEMBLING THE STARTER

1. Assemble the pole-shoes and field-coils and fix into yoke with the aid of a pole-shoe expander and a wheel operated screw-driver. Care should be taken not to trap the leatheroid (25) beneath the pole-pieces.

   See that the screw holes in the field coils are in the correct position for connecting to the brush boxes and solenoid switch.

ASSEMBLING SWITCH

1. Screw the solenoid into the drive end-shield. Check that the solenoid end-plate is flush against the drive end-shield shoulder, and paint insulating varnish at live points near to earth to prevent tracking.

2. See that the solenoid earth lead is attached to the "fixed" contact screw (59). (Note that in "insulated return" machines, this lead is taken to a different point, viz, one side of connecting link bracket).

3. Assemble solenoid terminal (46) in drive end-shield and connect the solenoid lead to it.

   Assemble the positive main terminal (47) in position, but do not tighten.

4. Assemble the moving contact onto the plunger and see that the contact spring is correctly and firmly located. Ensure that the second turn of the spring cannot jump over the first coil, by pushing the plunger through the moving contact assembly, until it is fully compressed.

5. Place the plunger return spring (14) in position. Oil the plunger by lightly smearing with Caltex Thuben 90 oil. Insert the assembled contact and plunger into the solenoid. As the plunger is inserted, its locating shoulders must pick up with the return spring.

6. Thread the trigger (40) of the trip assembly, through the moving contact slot. Place the two fixing screws (57) into the trip support, press the plunger assembly downwards maintaining the pressure, whilst tightening the fixing screws.

7. Fix the contact stop-plate into position by means of the two screws (50). Secure the flexible resistance lead to the moving contact (52). Ensure that the square-ended tag does NOT touch the backplate, and that the solenoid leads are outside this lead to prevent chafing.

8. Check that the plunger can be compressed at least .3125 in. without the trip being released, and that the first contact makes between .057 in. - .081 in. movement.

9. Insert the connecting link (48) between the positive terminal (47) and the fixed contact. Screw in the two screws (51) before tightening the positive terminal post (47).

ASSEMBLING PINION

1. Unscrew and remove the oil-plug (7) and wick-spring. Push the wick temporarily out of the way to ensure free entry of the pinion sleeve.

2. Insert the pinion into the drive end-shield.

3. Fit the ball-lock collar (17) in place, with its spring, trip collar (19) and circlip. Ensure that the lock collar slides freely.

4. Using a medium grade grease, assemble the four steel balls (16) into the pinion-sleeve holes by inserting them through the sleeve bore. Press the balls firmly into the holes to allow free entry of the armature shaft.

ASSEMBLING ARMATURE

1. When assembling the armature to the pinion, it should be noted that the helices are formed by a three start thread, and the correct thread must be selected so that the steel balls forming the lock will locate in the shaft recesses (39). To assist correct selection, both pinion and shaft ends have corresponding "pop" marks.

   Release the ball-lock by pulling the lock collar towards the commutator end and holding in this position push the pinion up to the shaft shoulder.

2. Assemble armature and drive end shield to yoke assembly, ensuring that dowel is correctly located.

3. Stand the above assembly vertical, with the flange resting on a support and the pinion face resting on another support $1\frac{7}{8}$ in. $\pm$ .002 in. lower.

   Place a straight-edge across the yoke face and build up with shims on shaft until a dimension of .285 in. + .020 in. between the commutator sleeve and the yoke face is obtained.

   This will give 1/16 in. end movement of the shaft, when the commutator end-shield is assembled.

4. Check that the commutator end-shield turns freely on the shaft and screw up the two through bolts (37).

5. If necessary, add shims between the commutator end-sheild and the

shaft circlip (31), to maintain a dimension of 1.875 in. + .002 in. - .003 in., between the pinion nose (6A) and flange face (8B).

6. Place the shaft spring (36) in position, and insert the pad and ball. Replace the cover and clip into position. The end-shield should be stoned to remove any scoring etc., sustained in dismantling the end cover clip. Failure to do so, may result in damage to the sintered bronze bearing.

7. Complete the assembly by fitting brushes, field screws, pinion return-spring, stop, and shaft lock-nut.

   Screw the two cover-screws (55) into position, in the drive end-shield, and replace the commutator end cover-band accurately to exclude all dirt.

TEST PROCEDURE

Tests on complete starter

1. Ensure that there is NO connection to the main terminal.

2. Pull the pinion forward by hand, approximately 1/16 in., and release. The pinion should return to its original position.

3. Energise the solenoid, by means of a battery connected between the solenoid terminal (46) Fig. 49 and the earth terminal on the commutator end-shield. The pinion must move forward $\frac{1}{4}$ in. minimum.

4. With the solenoid still energised, pull the pinion slowly forward by hand. The trip collar must act upon the trigger at least $\frac{1}{8}$ in. before the pinion reaches its stop. It is possible to feel this action taking place.

5. With the pinion at the end of its outward travel, the ball-lock device should now have come into operation, locking the pinion. There must be approximately .005 in. - .010 in. play between the pinion and shaft stop.

6. Apply a spring load pressure of 30 lb., to the pinion face, by means of a compression spring balance. The pinion must remain in the forward position.

7. Remove the solenoid connection. The pinion must now return to its normal position in one sharp movement.

8. Remove the shaft lock-nut, pinion stop, shim and spring. Pull the pinion forward about $\frac{1}{4}$ in.

9. Apply a spring load to the drive end of the shaft. The spring at the commutator end must start to compress between 13-19 lb. reading, 19-25 lb. after 1/16 in. movement.

10. Replace shaft nuts, shim and spring.

Performance Tests

1. Brushes to be bedded over at least 75% of their area.

2. Fit the starter to a special flywheel rig and connect the power supply.

3. With a supply of 10 volts only, check that the starter fully engages with the flywheel.

4. With a 12 volts supply in circuit, complete 5 operations under each of the following conditions, on a locked flywheel.

   (a) Distance between flywheel and pinion set at .068 in.

   (b) Distance between flywheel and pinion set at .196 in.

Performance Figures

The figures obtained must be within the following limits.

	AMPS	VOLTS	R.P.M.	TORQUE LB/FT
Lock Torque	950-1050	6.0	0	36.5
Running Torque	420-480	9.5	1250 - 1300	12
Light Running	100-120	12.0	7000	0

Insulation Test

1. Using a 500 v megger, the following tests should show an insulation resistance of not less than 1 megohm.

2. Lift earth brushes and check the main terminal to earth.

3. With earth brushes still raised, check the positive brush to earth.

FAULT DIAGNOSIS

ENGINE

Fault	Remedy
DIFFICULT STARTING	
1. Fuel shortage	Check level in tank and fill up as necessary.
2. Water in fuel	Drain tank and system. Refill with clean fuel and prime system.
3. Unsuitable fuel	Change to correct grade.
4. Air in fuel system	Check suction joints and prime the system.
5. Fuel leakage.	Check pipe connections (especially between pump and injector).
6. Obstruction in fuel system.	Inspect filter and clean if necessary. Flush all pipes.
7. Faulty fuel pump controls.	Check pins and linkage for excessive wear, incorrect settings etc.
8. Faulty injector.	Test spray, clean or recondition injector if necessary.
9. Incorrect fuel pump timing.	Check and reset.
10. Worn fuel pump.	Replace pump or return to Works or our Agents.
11. Lack of compression due to:-	
a) Leakage at cylinder head joint.	Check tightness of cylinder head nuts.
b) Weak or broken valve springs.	Renew springs.

Fault	Remedy
c) Incorrect valve tappet clearances	Adjust to correct clearances.
d) Valves sticking or leaking.	Clean and grind valves. Ensure that the valves move freely in their guides. Reset tappet clearances.
e) Sticking piston rings.	Remove piston, clean and free rings.
f) Piston rings worn or broken.	Fit new rings. Examine bore to ascertain if scored by broken rings.
g) Worn or scored cylinder bore.	Rebore and fit oversize piston and rings.
INSUFFICIENT POWER	
12. Can result from any of the above faults.	Apply appropriate remedy.
LOW LUBRICATING OIL PRESSURE	
13. Incorrect grade of oil.	Change to correct grade.
14. Obstructed circulation.	Remove obstruction, clean pipes and sump filter.
15. Excessive main and large end bearing clearances.	Fit new bearings. Regrind journals as necessary.
16. Faulty pressure relief valve caused by:-	
a) Stuck or badly seating valve.	Dismantle, clean and reassemble
b) Weakened spring.	Fit new spring.
c) Incorrect adjustment.	Adjust in prescribed manner.
KNOCKING	
17. Can be results of troubles given under 3,8,9,11(f), 11(g).	

	Fault	Remedy
18.	Excessive carbon deposit on piston and head.	Decarbonise.
19.	Slack bearings.	Fit new bearings and if necessary regrind crankshaft.
20.	Bearings badly worn or damaged.	Fit new bearings. Ensure that the oil ways are not obstructed. Remove burrs on pins and journals with smooth carborundum stone.
21.	Piston slap.	Rebore barrels and fit oversize pistons.
22.	Choked exhaust system.	Clean exhaust pipes and silencer.

OVER HEATING

23.	Can be result of troubles given under 3,7,8,9,10,11(c).	Use appropriate remedy.
24.	Unsuitable lubricant.	Change to correct grade.
25.	Defective cooling system.	Examine cooling fan and drive. Ensure that cylinder head and barrel fins are not choked and that there is a free passage for the air. Check and if necessary adjust tension of driving belts.

ELECTRICAL SYSTEM

DYNAMO

NOT CHARGING

1.	Fuses blown.	Ascertain reason for blowing and fit new fuse.
2.	Belt drive slipping, greasy or worn.	Retension, clean or renew.

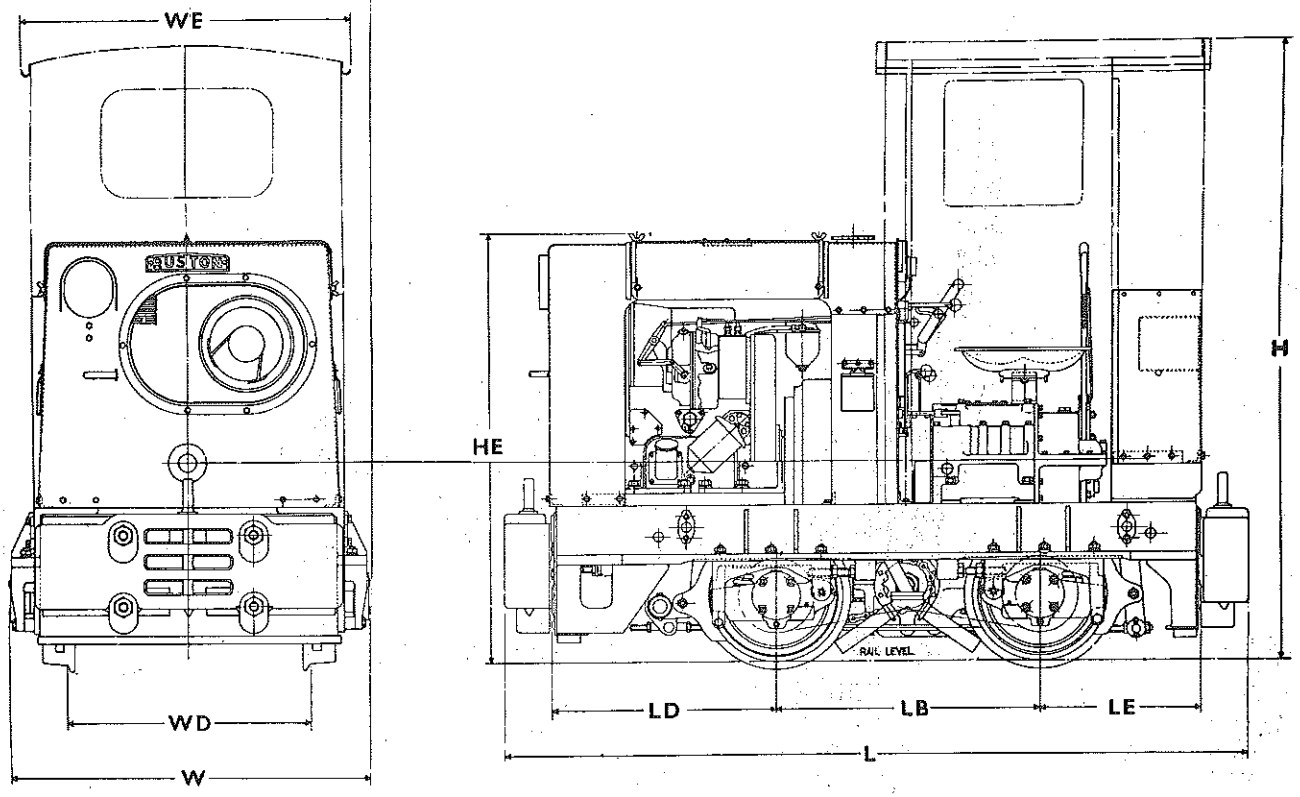
	Fault	Remedy
3.	Belt bottoming in groove.	Renew belt.
4.	Pulleys worn or loose on shafts.	Remove pulley and check for wear.
5.	Key sheared.	Fit new key.
6.	Dirty or oily commutator.	Clean and ascertain course of oil leakage.
7.	Commutator bars short circuited due to carbon dust or dirt.	Blow out dirt and dust, check commutator for roughness and high mica. Dismantle generator and undercut commutator.
8.	Sticking brushes.	Ease brushes and clean holders.
9.	Brushes excessively worn.	Renew brushes and bed.
10.	Broken or fatigued springs, possibly caused by overheating.	Renew springs and ascertain the cause of overheating.
11.	Brushes not correctly bedded.	Clean commutator and rebed brushes.
12.	Flex leads or soldered connections broken.	Clean connections and resolder. Check security of all connections.
13.	Faulty or dirty terminal connections.	Remove cable sockets, clean terminals and connections.
14.	Loose terminal screws or nuts.	Clean and tighten connections.
15.	Cable insulation pierced chafed or fractured.	Renew cables.
	LOW CHARGE RATE	
16.	Belt drive slipping.	See above.
17.	Dirty commutator.	See above.
18.	Faulty cables or connections.	See above.

Fault	Remedy
19. Regulator setting disturbed.	Reset.
HIGH CHARGE RATE	
21. Ammeter reading incorrect.	Check against new ammeter.
22. Regulator setting disturbed.	Reset.
OVERHEATING	
23. Dirty commutator.	See above.
24. Insufficient brush spring pressure causing sparking.	Renew springs or replace worn brushes.
25. Regulator setting disturbed.	Reset.
26. Defective bearing.	Remove generator from engine, release brushes and check machine for free running.
27. Inadequate Ventilation.	Ensure that pipes carrying hot gases and liquids do not contact the machine.
NOISY	
28. Belt Bottoming in Pulley.	Renew belt and tension correctly.
29. Loose Mounting.	Tighten.
30. Worn or defective Bearings.	Check machine for smooth running. Renew bearings as necessary.
MAIN FUSE	
BLOWING	
31. Fuse connections loose.	Tighten.
32. Sticking brushes, faulty insulation of brush flexes.	See above.
33. Broken brush springs.	See above.

Fault	Remedy
34. Generator dirty internally.	Dismantle and clean.
35. Generator damp.	Dry out in oven at temperature not exceeding 212°F (100°C).
36. Internal shorts in battery	Test battery.
37. Battery discharged.	Check specific gravity. If low, charge from an external source.
BATTERY DISCHARGED	
38. Generator charge rate low.	Reset regulator.
39. Cutout points not opening.	Examine cut-out and adjust setting.
40. Leakage of current from battery due to moisture corrosion or loose electrolyte on the top of the battery.	Clean the top of the battery with a clean cloth to remove moisture and dirt. Remove any corrosion and coat terminals with petroleum jelly.
41. Faulty insulation of cables and loose connections.	Renew cables and tighten loose connections.

DATA

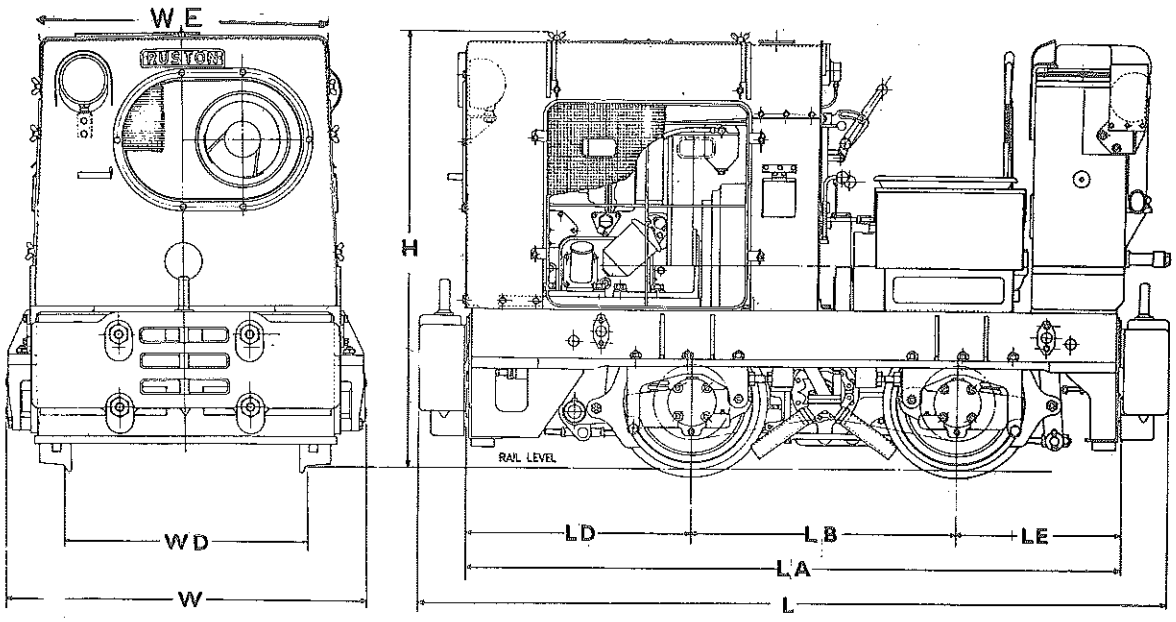
LBT LOCOMOTIVE - DIMENSIONS



WD GAUGE	W	WE	L	LB	LD	LE	H	HE
1′ 6″—1′ 8¼″ 457mm—514mm	3′ 8″ 1120mm	3′ 4″ 1015 mm	7′ 6″ 2285mm	2 7¾″ 810mm	2′ 3″ 685mm	1′ 7½″ 495mm	6′ 3″ 1905mm	4′ 4½″ 1335mm
1′ 8¼″—2′ 0″ 514mm—610mm	3′ 2¼″ 970mm	3′ 4″ 1015mm	7′ 6″ 2285mm	2′ 7¾ 810mm	2′ 3″ 685mm	1′ 7½″ 495mm	6′ 3″ 1905mm	4′ 4½″ 1335mm
2′ 0¼″—2′ 6″ 616mm—762mm	3′ 8″ 1120mm	3′ 4″ 1015mm	7′ 6″ 2285mm	2′ 7¾″ 810mm	2′ 3″ 685mm	1′ 7½″ 495mm	6′ 3″ 1905mm	4′ 4½″ 1335mm
2′ 6¼″—3′ 0″ 768mm—914mm	4′ 1¾″ 1265mm	3′ 4″ 1015mm	7′ 6″ 2285mm	2′ 7¾″ 810mm	2′ 3″ 685mm	1′ 7½″ 495mm	6′ 3″ 1905mm	4′ 4½″ 1335mm
3′ 0¼″—3′ 6″ 920mm—1067mm	4′ 7¾″ 1415mm	3′ 4″ 1015mm	7′ 6″ 2285mm	2′ 7¾″ 810mm	2′ 3″ 685mm	1′ 7½″ 495mm	6′ 3″ 1905mm	4′ 4½″ 1335mm

The following drawbar heights are available :—
3½ ton model 7″ — 13¼″ (178mm — 336mm)
4½ ton model 6⅜″ — 18⅞″ (162mm — 480mm)
For hauling, the minimum curve recommended is 30 ft. (9.15m).
When running light, the locomotive can negotiate a minimum curve of 15 ft. (4.55 m).

LBT LOCOMOTIVE - DIMENSIONS



WD Gauge	W	L	LA	LB	LD	LE	H
1′ 6″—1′ 8¼″ 457mm—514mm	3′ 8″ 1120mm	7′ 6″ 2285mm	6′ 6½″ 1995mm	2′ 7¾″ 810mm	2′ 3″ 685mm	1′ 7½″ 495mm	4′ 4½″ 1335mm
1′ 8¼″—2′ 0″ 514mm—610mm	3′ 2¼″ 970mm	7′ 6″ 2285mm	6′ 6½″ 1995mm	2′ 7¾″ 810mm	2′ 3″ 685mm	1′ 7½″ 495mm	4′ 4½″ 1335mm
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3′ 0¼″—3′ 6″ 920mm—1067mm	4′ 7¾″ 1415mm	7′ 6″ 2285mm	6′ 6½″ 1995mm	2′ 7¾″ 810mm	2′ 3″ 685mm	1′ 7½″ 495mm	4′ 4½″ 1335mm

HAULAGE CAPACITY

Gross weight behind Locomotive based on adhesion of 560 lb. (254 kg.) per ton (1016 kg.) and rolling resistance of 22 lb. (10 kg.) per ton (1016 kg.).

	Gear	Speed Range m.p.h. km.p.h.	T.E. lb. kg.	Maximum Drawbar pull lb./kg.	Loads hauled on straight track — Tons (Kg.)							
					Level 0.0%	1/200 0.5%	1/100 1%	1/80 1.25%	1/50 2%	1/30 3.33%	1/25 4%	1/20 5%
3½ ton 3 speed model	1	1.07—3.22 1.72—5.18	1960 887	1883 854	86 87300	55 55800	41 41700	36 36600	26 26400	16½ 16800	14 14400	11 11200
	2	1.94—5.85 3.13—9.42	1720 778	1643 745	75 76200	48 48800	35 35500	31 31500	22 22400	14 14400	12 12200	9 9150
	3	3.31—9.96 5.34—16	1010 457	933 423	42 42700	27 27400	19 19300	17 17300	11½ 11700	7 7100	5½ 5600	4 4060
3½ ton 2 speed model	1	1.18—3.56 1.9—5.74	1960 887	1883 854	86 87300	55 55800	41 41700	36 36600	26 26400	16½ 16800	14 14400	11 11200
	2	2.5—7.52 4.03—12.1	1350 612	1273 577	58 58900	37 37600	27 27400	24 24400	16½ 16800	10½ 10700	8½ 8600	6½ 6600
4½ ton 3 speed model	1	1.07—3.22 1.72—5.18	2520 1142	2421 1100	111 112800	71 72100	52 52800	46 46700	33 33500	21 21400	18 18300	14 14400
	2	1.94—5.85 3.13—9.42	1720 778	1621 735	74 75100	47 47700	34 34500	30 30500	21 21400	13 13200	11 11200	8 8100
	3	3.31—9.96 5.34—16	1010 457	911 413	41 41700	26 26400	18 18300	16 16300	10½ 10700	6 6100	4½ 4570	3 3050
4½ ton 2 speed model	1	1.18—3.56 1.9—5.74	2520 1142	2421 1100	111 112800	71 72100	52 52800	46 46700	33 33500	21 21400	18 18300	14 14400
	2	2.5—7.52 4.03—12.1	1350 612	1251 567	57 57800	36 36600	26 26400	23 23400	15½ 15700	9½ 9650	7½ 7600	5½ 5600

OPERATING DATA

CAPACITIES

	Fuel Tank	Engine Sump	Gearbox
Gallons	6.5	1.43 (11½ pints)	2.25
Litres	29.64	6.5	10.23

PRESSURES

Engine Oil

Normal	35-45 lb/sq.in.	(2.5 - 3.2 kg/cm^2)
Idling	15 lb/sq.in.	(1.1 kg/cm^2)
Gearbox Oil	40 lb/sq.in.	(2.85 kg/cm^2)

ENGINE DATA

Type	Ruston 2 YDAL
B.H.P.	31.5 at 1800 r.p.m.
Bore	4.375 in. (111mm).
Stroke	5 in. (127 mm.)
Piston Displacement	150.4 cu.in. (2464 cu.cm.)
B.M.E.P. (1800 r.p.m.)	85 lb/sq.in. (5.97 kg/cm^2)
Compression Pressure	500 lb/sq.in. (35.2 kg/cm^2)
Firing Pressure	950 lb/sq.in. (66.8 kg/cm^2)
Fuel Injection Pressure	2500 lb/sq.in. (175.8 kg/cm^2)

SERVICING DATA

	Limits when New		Service Limit
Inlet and Exhaust Valve Tappet Clearance (cold)	in.	.003	
	mm.	.076	
Piston/Cylinder Head Bumping Clearance	in.	.040/.045	
	mm.	1.01/1.14	
Main Bearing Clearance	in.	.0025/.0045	.006/.007
	mm.	.064/.114	.152/.178
Connecting Rod Large End Bearing Clearance	in.	.0025/.004	.006/.007
	mm.	.064/.102	.152/.178
Connecting Rod Small End Bearing Clearance	in.	.001/.002	.004
	mm.	.025/.051	.100
Piston Ring Gap (in position)	in.	.0225/.029	.040
	mm.	.571/.736	.100
Piston Ring Groove (Side clearance)	in.	.0025/.0045	.009
	mm.	.064/.114	.228

UNDERSIZE BEARINGS

The table below gives details of undersize bearings that should be fitted after the various shaft regrinds:-

		Use with Bearing No.		
Description	Nominal Undersize	Main (wide)	Main (narrow)	Large End
Standard	-	YC.17814A	YC.17815A	YC.14114B
1st. Regrind or lap	.005 in.	YC.17831	YC.17851	YC.14141
2nd Regrind	.010 in.	YC.17832	YC.17852	YC.14142
3rd Regrind	.020 in.	YC.17833	YC.17853	YC.14143

4th Regrind	.030 in.	YC.17834	YC.17854	YC.14144
5th Regrind	.040 in.	YC.17835	YC.17855	YC.14145

The bearings should under no circumstances be scraped before fitting.

OVERSIZE PISTONS	.020 in.	.040 in.	.060 in.
Piston complete comprising	Y2DA-14310	Y2DA-14330	Y2DA-14090
Piston	Y2DA-14311	Y2DA-14331	Y2DA-14054
Crome Pressure Ring (top)	Y2DA-14312	Y2DA-14332	Y2DA-14095
Taper Periphery compression ring	Y2DA-14314	Y2DA-14334	Y2DA 14091
Pressure Ring (stepped)	Y2DA-14315	Y2DA-14335	Y2DA-14094
Scraper Ring	Y2DA-14316	Y2DA-14336	Y2DA-14093
Gudgeon Pin	YC-14012	YC-14012	YC-14012
Circlips	YC-14019	YC-14019	YC-14019
Chrome Pressure Ring (top) Oversize Width			
.010 in	Y2DA-14317	Y2DA-14337	Y2DA-14096
.020 in.	Y2DA-14318	Y2DA-14338	Y2DA-14097
.010 in.	(Standard diameter Y2DA-14044)		
.020 in.	(Standard diameter Y2DA-14045)		

Machining of top piston ring groove

	Oversize Width	Groove Size
1st Machining	.010 in.	.1375 - .1385 in.
2nd Machining	.020 in.	.1475 - .1485 in.

NOTE:

The additional width of .010 in. or .020 in. must be machined equally from both sides of the groove. On no account must the 2nd (final) .010 in. be exceeded on the bottom face of the piston ring groove.

TORQUE - TIGHTENING DATA

Cylinder Head Studs	50-60 lb. ft. (cold)
Main Bearing Studs	110-120 lb.ft.
Large End Bearing Bolts	90-100 lb.ft.

ELECTRICAL DATA

DYNAMO

Type	C.A.V.	D54DN
Voltage	12	
Amps	10 at 1020 r.p.m.	
Fuse	22 amps (30 S.W.G. tinned copper).	

CONTROL BOARD

Type	C.A.V.	75 B 19 T (Tropicalised)
Regulator	B 2 type	
Cutout	DR type	

BATTERY

Type	Exide	6-KHV11R
Capacity	67 a.h. at 10 hr. rata.	

STARTER MOTOR (IF FITTED)

Type	CA 45C12 - 11
Voltage	12
D.O.R.	Clockwise.
Brush Spring Pressure	30-40 ounces

WIRING

P.V.C. Insulated and Sheathed.

Twin	35/.012	9 feet
Twin	14/.012	24 feet
3 core	2-35/.021	9 feet
	1-14/.021	

Additional for Electrical Starting

Twin	14/.012	14 feet
Single	61/.044	18 feet

FUEL AND LUBRICATING OIL

FUEL

The fuel specification should comply with -

B.S.S. 2869 (1957) Class A.

ENGINE LUBRICATING OIL

A good quality heavy duty type conforming to specification MIL-L-2104A, DEF-2101B, Supplement 1, or B.S.S. 1905 (1952). The following viscosities should be used to suit the minimum ambient temperature at which the engine is required to start.

Ambient starting temperature	Grade of Oil.
Below 40°F (4.4°C).	SAE-10W
Above 40°F (4.4°C) Up to 85°F (29.4°C).	SAE-20
Above 85°F (29.4°C).	SAE-30

GEARBOX OIL

As for engine.

RUNNING GEAR

As for engine.

GREASES

For grease points throughout the locomotive a good quality grease is advised. Our Services, together with those of our Agents are at the disposal of customers for dealing with any problem relating to the suitability of fuels and lubricating oils.