DIESEL ELECTRIC SECTION

"Engine" and "Locomotive":

Remember: "Engine" always refers to the diesel engine itself, while "locomotive" means the complete vehicle - the locomotive as a whole. Locomotives have each end numbered : No. 1 end is the driving end (the end where the cab is) while the other end is No. 2 end. It is usual (on other than Dg class, or on shunting locomotives) to call these ends "short hood end" or "long hood end", which is self-explanatory as the driving cab is nearer one end than the other.

Internal-Combustion (I.C.) Engine:

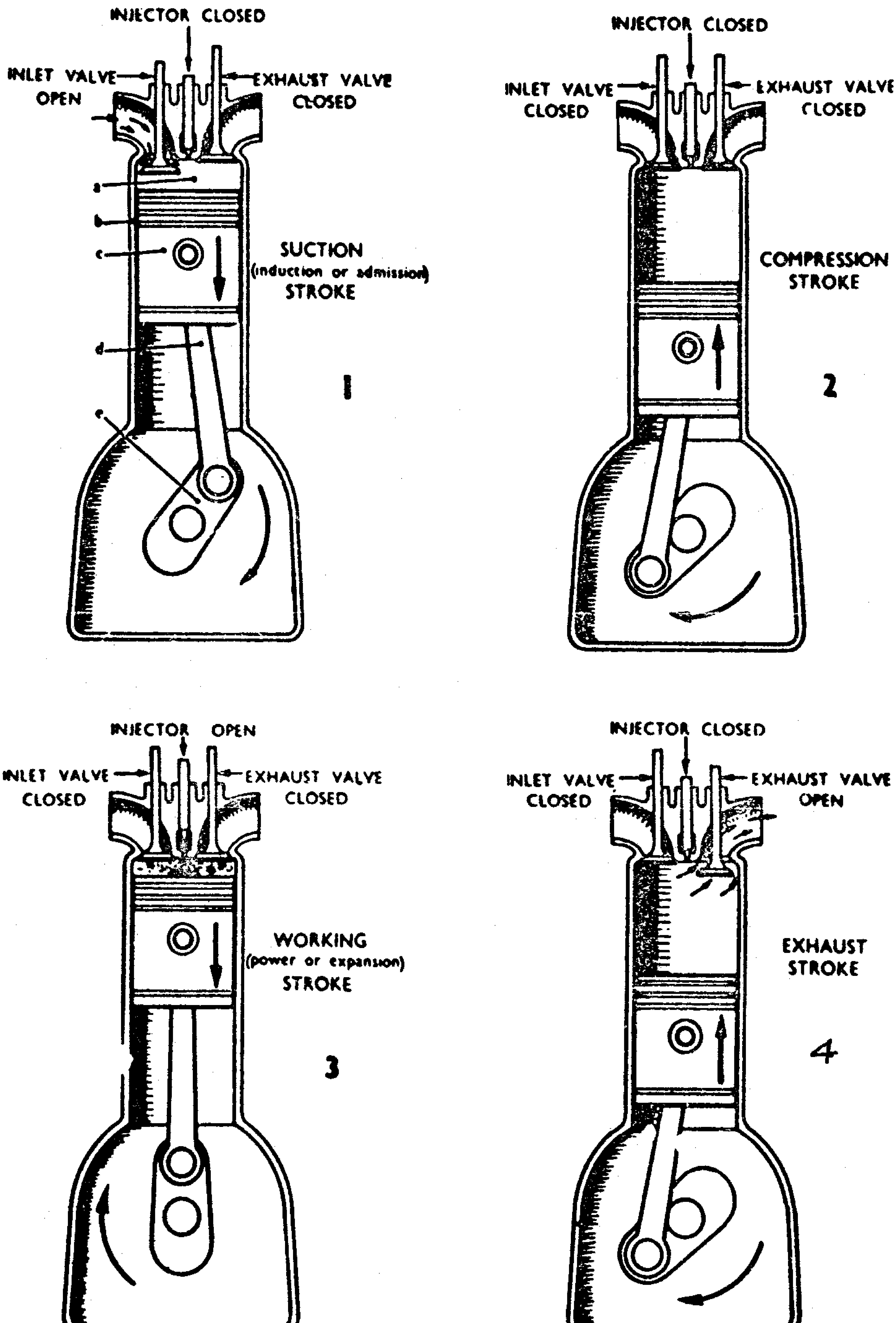
An internal-combustion engine is an engine where the combustion of the fuel takes place inside its cylinders.

Petrol, diesel and gas engines are referred to as I.C. engines as distinct from the steam engine which is an external-combustion engine (the fuel being burnt away from the engine).

Compression-Ignition (C.I.) Engine:

The diesel engine is termed a compression-ignition engine as the heat required to ignite the fuel oil (hereafter called fuel) is provided by the compression of air in the engine cylinders. The petrol engine is termed a spark-ignition engine as it depends upon a spark for the ignition of its fuel-air mixture. The diesel engine received its name from Dr Diesel, a German who was a pioneer in the C.I. engine field and the name is in universal use today.

The reciprocating I.C. engine may be classified into two types, those working on the four-stroke cycle and those on the two stroke cycle.



THE FOUR-STROKE CYCLE

a = *Combustion chamber*
b = *Cylinder*
c = *Piston*
d = *Connecting-rod*
e = *Crankshaft*

FIG. 1

THE FOUR-STROKE DIESEL CYCLE (See Fig. 1):

1. Induction stroke: As the piston moves down the cylinder air only is drawn in through the open inlet valve or valves (in a normally aspirated engine) or, in a pressure charged system, the air is blown in. As the piston nears B.D.C. (Bottom Dead Centre) the inlet valve(s) closes. The exhaust valve remains closed during induction.

2. Compression stroke: The piston moves up the cylinder compressing the air into a space say 1/16 its original volume (16:1 compression ratio) which will produce a pressure approximately 3450 kPa and an air temperature of between 500° and 800°C. Fuel is injected just before T.D.C. (Top Dead Centre) in the form of a very fine spray which ignites by the heat of compression.

3. Power stroke: Expansion of the burning gases forces the piston downwards. During the initial stages of combustion pressures may reach 6900 kPa with temperatures of 1650°C. As the piston nears B.D.C. the exhaust valve(s) opens.

4. Exhaust stroke: The piston moves up the cylinder forcing the burnt gases out past the exhaust valve. Near T.D.C. the exhaust valve closes, the inlet valve opens and the cycle is repeated.

The four strokes of the cycle are completed in two revolutions of the crankshaft.

Two Stroke

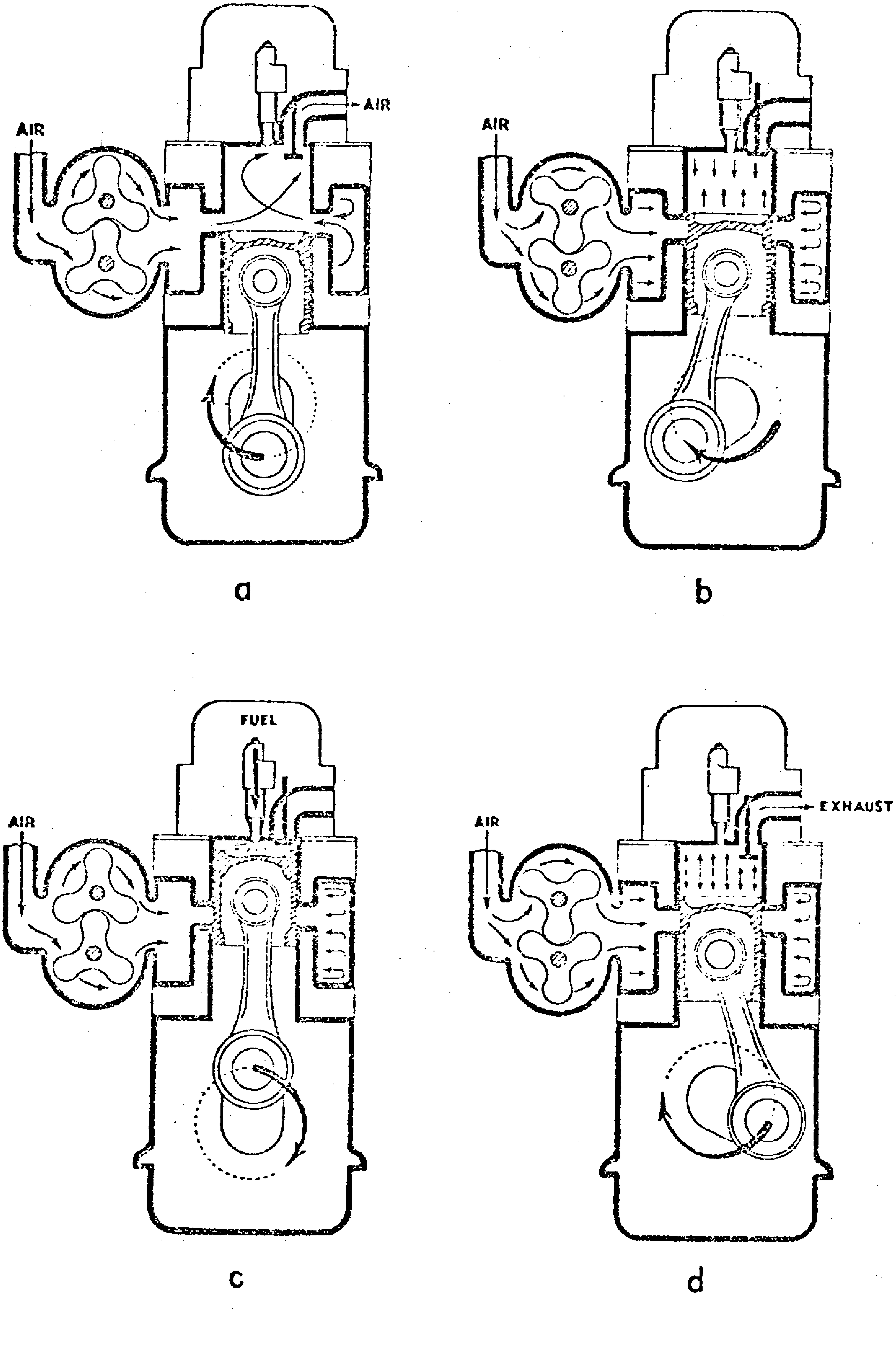


FIG 2

THE TWO-STROKE DIESEL CYCLE

The two-stroke engine sometimes dispenses with valves in favour of inlet and outlet ports in the cylinder walls. The downward movement of the piston on its working stroke uncovers the ports, allowing scavenging air to enter the inlet ports and blow the burnt gases out the outlet port. As the piston rises, both ports are covered and compression takes place, fuel is injected and the power stroke again takes place.

Many two-stroke engines use one or more poppet-type exhaust valves in the cylinder head dispensing with outlet ports in the cylinder wall. These engines are often referred to as the uniflow type.

The Uniflow Two-Stroke Diesel - e.g. G.M. Diesel Engines used by New Zealand Railways.

As the piston in this engine cannot be utilised as an air pump, an external means of supplying air must be provided. A specially designed blower (usually of the Roots type) which delivers a large volume of air at comparatively low pressure is used for this purpose. This blower is called a scavenging blower or pump and it supplies scavenging air. Scavenging means removing of refuse.

Intake

Figure 2 (a). The piston is at B.D.C. and scavenging air flows through ports in cylinder liner and expels any exhaust gases in cylinder via the open exhaust valve(s). As the piston starts its upward stroke the exhaust valve closes before the inlet ports are covered by the piston; this provides a degree of pressure charging or supercharging (increase in weight of air in cylinder).

Compression

Figure 2 (b). Air is compressed as the piston continues on the upward stroke.

Power

Figure 2 (c)/ Shortly before T.D.C. fuel injection commences with the resultant burning and expansion of gases as in the four-stroke; this forces the piston down on its power stroke.

Exhaust

Figure 2 (d). Just before the piston reaches the end of the power stroke, the exhaust valve opens releasing exhaust gases to atmosphere. The pressure in the cylinder has reduced sufficiently to be overcome by the scavenging air pressure by the time the inlet ports are uncovered by the piston.

Scavenging takes place and the cycle is repeated.

The cycle is completed in one revolution of the crankshaft.

We now understand how the two types of diesel engines operate, but to operate correctly the engine must have several systems incorporated, the three main ones being -

1. Fuel System: To ensure that the cylinders are supplied with clean fuel in sufficient amounts to be able to operate the engine through all speeds up to its correct rating.

2. Cooling System: To ensure that the engine is kept at its correct working temperature.

3. Lubricating Oil System: To ensure that the necessary moving parts are adequately lubricated to ensure that they do not overheat or seize up.

1. FUEL SYSTEM:

The fuel system consists of the following components -

(a) A vented fuel tank which contains diesel fuel.

(b) A fuel transfer pump which supplies fuel from the fuel tank to the fuel injection pumps.

(c) Filters to keep the fuel clean before it reaches the injection pump.

(d) An injection pump which measures and supplies the correct amount of fuel at high pressures. This may be driven by the camshaft or by a special flexible drive taken from the engine.

(e) Injection nozzles which supply the fuel in a very fine or atomised spray to the combustion chambers at the top of the pistons.

(f) Suction and pressure pipes which allow the fuel oil to be taken from the tank by suction and then passed by pressure from the injection pump to the cylinders.

(g) Return pipes which carry any excess fuel back to the fuel tank.

(h) Relief valves which allow any excess pressure to be reduced.

A simple fuel system would be as follows -

Fuel oil is drawn from the fuel tank by the fuel transfer pump via a suction filter and then forced on via a pressure filter to the fuel injection pump which then forces a carefully calibrated amount of fuel oil at the correct time, via high pressure pipes, to the nozzles where it is sprayed into the combustion chambers.

A relief valve is provided in the system at the filter which lifts and allows excess fuel to return to the fuel tank.

2. <u>COOLING SYSTEM</u>:

It stands to reason that an engine that relies on heat to operate it, could, if allowed, exceed the safe working temperature and thus cause certain parts of the engine to heat up to such a degree that they would melt. Also certain moving parts of the engine will heat up through friction and cause the lubrication of the engine to be affected. It should be also understood that uneven heating and cooling of metals can cause them to distort, buckle and often crack. It is therefore not only important that a diesel engine be adequately cooled but that the cooling be evenly spread over and through the hot surfaces to limit any heat stresses. and to ensure that the pistons, valves and other moving parts are able to get rid of excessive heat.

A simple cooling system would consist of the following -

(a) <u>A Water Pump</u> mechanically driven by the engine which will take the cooled water from the radiators and circulate it through the engine and return it to the radiators for cooling.

(b) <u>Radiators</u>:

These are made so that the hot water from the engine can pass into the top portion then through tubes which are cooled by air being forced around their cooling fins and the cooled water is then drawn by suction from the lower portion of the radiator.

(c) <u>Fans</u>:

These can be operated by belts, geared shafting or electric motors and when working draw or force the air around the radiator tubes for cooling the water.

(d) <u>Header Tanks</u>:

These are provided to give a reservoir of water in the cooling system and to allow for a certain amount of loss of water without the cooling system becoming dangerously low in water.

(e) Filler Pipes or Caps:

These are provided to allow the system to be topped up when necessary.

(f) Low water or high water temperature alarms:

These are fitted to give the operator a visual or audible warning that the water in the system has dropped to an unsafe level or that the water temperature has risen to a dangerous degree.

(g) Temperature Gauge:

This is fitted to allow the temperature of the engine cooling water to be seen by the operator.

(h) Diverter Valve:

This is fitted to allow the water to take a short circuit and bypass the radiators when the engine is cold and allow the engine to heat up quickly. When the engine reaches its normal working temperature this valve opens and the water will then pass through the radiators to be cooled.

Not all locomotives are fitted with a diverter valve but they all have a system to allow the engine to heat up quickly when it is cold.

A simple water system is as follows -

Water is drawn from the radiator by the water pump and forced through passages in the engine around the cylinders and other parts to be cooled and out through the cylinder head to a return pipe to the radiator where it is cooled and drawn back to the water pump by suction.

When sliding contact occurs between two dry metal surfaces under pressure, excessive friction causes heat and wear. If a fluid film can be maintained between the two sliding surfaces so that metal to metal contact is avoided, these effects can be considerably reduced. A lubricant such as oil or grease is used for this purpose. Under ordinary conditions in which a shaft rotating in a bearing is supplied with oil either under pressure or by other means, a continuous oil film exists between the surfaces, which keeps the metals apart thus preventing wear and reducing the heat to a safe level.

A simple lubricating system would consist of:

(a) Sump:

This is a reservoir fitted to the engine bed plate and contains sufficient oil to lubricate the engine.

(b) Oil pump:

This pump draws the oil from the sump and circulates it through the engine to the moving parts.

(c) Oil filter:

This is required to clean the oil which has been circulating through the engine so that it can be re-used.

(d) Oil cooler:

This is used to cool the oil after it has been circulated through the hot engine and keep it within a safe working temperature. The oil can be cooled by water from the cooling system or by an air draught forced through a radiator.

(e) Relief valves:

These are fitted to relieve excessive oil pressures.

(f) Filler pipe:

This is fitted in an accessible position so that the oil in the sump can be replenished or topped up.

(g) Pressure gauge:

This is fitted in the cab or in the engineroom to enable the operator to check the oil pressure in the system.

(h) Reducing valve:

This is fitted to reduce the pressure of the oil being supplied to the valve mechanism.

(i) Warning alarm:

This is fitted to give the operator a visual or audible warning that oil pressure has dropped to a dangerous level.

A simple oil system would be as follows -

Oil is drawn through a strainer in the sump by an oil pump, mechanically driven from the engine, and then forced past a relief valve which will open if pressure is too great and allow some of the oil to pass back to the sump and thus reduce the pressure. The oil then passes through a filter and cooler and is supplied to the big ends, main bearings, little ends, cylinder walls, timing and camshaft gears and bearings and thence back to the sump. A feed is taken from the main feed pipe via a reducing valve to the rocker gear and valve mechanism on top of the engine and then drain pipes return it to the sump.

In addition the following items of equipment are found on diesel-engined locomotives -

Manifolds:

These are placed on different places on the engine to collect from branch pipes or to supply braneh pipes with the different fluids or gases used in the engine. They are named as follows -

(a) Inlet Manifold: This supplies all the clean fresh air to be used in the engine. The air first passes through a filter before entering the inlet manifold.

(b) Exhaust Manifold: This carries all exhaust gases from the engine to the atmosphere.

(c) Inlet Water Manifold: This supplies all the cooling water for the engine from the water pump.

(d) Exhaust Water Manifold: This carries the hot water back from the engine to the radiators.

Bus Rail

On most large diesel engines an independent fuel pump is placed adjacent to each cylinder, and the term Bus Rail applies to the fuel supply pipe which runs the full length of the engine to supply the fuel injection pumps with fuel oil.

Governor

The function of the governor is to maintain the engine speed selected by the operator and automatically proportion the fuel to the load.

Overspeed Device

This device is provided to ensure the engine will shut down if it overspeeds through any fault or malfunction.

Supercharger

Two types are in general use:

(1) Roots Blower mechanically driven.

(2) Turbo-Blower, one that is driven from the exhaust gases.

Decompression or Relief Valves

These valves pass through the cylinder head to provide a vent from the combustion chamber to the atmosphere.

When open they prevent compression and allow an engine to be manually barred over to check for any excessive fluid in the cylinder. This must be done after an engine has been stopped for twelve hours or more unless instructions are issued to the contrary.

Although a Locomotive Trainee or Assistant does not have to know the full working details of a locomotive he is expected to learn what a locomotive consists of and how the power of the engine is transmitted to the road wheels.

He should remember the more interest he takes while he is working around the depot and on the locomotives, the more he will learn, which will be a big help to him later on in the service.

There are several types of locomotives in service and the Trainee will learn the different types by noting the letters and numbers on their number plates on the cab sides, such as Ds 205.

Types of Engines

There are different makes and sizes of diesel engines fitted to our locomotives which are as follows -

DA	General Motors 12 cyl. two stroke V type	1070 kW
DB	General Motors 8 cyl. two stroke V type	713 kW
DE	English Electric 6 cyl. 4 stroke in line	495 kW
DG	English Electric 6 cyl. 4 stroke in line	562 kW
DI	English Electric 6 cyl. 4 stroke in line	787 kW
DJ	Caterpillar 12 cyl. 4 stroke V type	787 kW
DSB	Caterpillar 6 cyl. 4 stroke in line	265 kW
DS	Gardner 8 cyl. 4 stroke in line	153 kW
DSC	Rolls Royce 6 cyl. 4 stroke in line	157 kW
DSC	Leyland 6 cyl. 4 stroke in line	157 kW
DSC	Cummins 6 cyl. 4 stroke in line	164 kW
DX	General Electric 12 cyl. 4 stroke V type	2062 kW

DIESEL MECHANICAL LOCOMOTIVES

The "Ds" class is a small diesel mechanical shunting locomotive of 153 kW. It is called "mechanical" because the transmission from the engine is through a fluid coupling to a change speed gearbox. The layout of the frame and transmission for this locomotive is shown in Fig. 1.

The following parts are used in the construction of this shunting locomotive:

1. FRAMES

The frame consists of thick metal side plates which, when riveted or welded to other portions form a strong rigid structure capable of withstanding all the shocks and loads met with when pulling or pushing trains.

On each side of the frame are openings into which are fitted the axleboxes.

2. HEADSTOCKS

These are attached to each end of the frame and carry the drawgear and necessary hoses to enable the locomotive to be coupled to the train. The cowcatcher or shunter's footstep is also attached to the headstock.

3. WHEELS AND AXLES

Inside the axleboxes are bearings which allow the axles to rotate freely. Firmly attached to the axles are the wheels.

The power from the diesel engine is taken through a suitable transmission to the driving wheels and rotates them.

4. SPRINGS

These are placed on top of the axleboxes and take the weight of all the equipment on the frame and transfer it on to the axleboxes.

They give the locomotive better riding qualities and reduce the shocks and jars which could damage the instruments, electrical gear and other equipment.

5. ENGINE

An 8-cylinder vertical-in-line Gardner diesel engine is fitted and is shown in Fig. 2.

6. HYDRAULIC COUPLING

This is also known as a "fluid coupling" and is fitted between the engine and gearbox to gradually take up the drive from the engine. The fluid in the coupling allows considerable "slip" at low engine speed and when the engine is accelerated the drive is taken up gradually until at working speed the drive is almost a solid connection with very little slip. This coupling provides a solid drive both when it is being driven by the engine and when the road wheels are turning the engine over. (See Fig. 3).

7. DRIVE SHAFTS

These carry the drive from the fluid coupling to the change speed gearbox and from the gearbox to the final drive gearbox.

8. CHANGE SPEED GEARBOX (Epicyclic): (See Fig. 4)

The drive from the hydraulic coupling is taken to the gearbox in which various gears are engaged by applying air-operated brake bands to the different clusters or trains of gears.

9. FINAL DRIVE GEARBOX (See Fig. 4)

From the change speed gearbox the drive is taken to the final drive gearbox which incorporates a reversing mechanism so that the locomotive can move in either direction.

A sliding dog clutch is operated by air from the cab to give the required direction of travel.

Inside this gearbox there are bevel wheels and pinions which take the drive to the jackshaft.

10. JACKSHAFT: (See Fig. 4)

This shaft extends from both sides of the final drive gearbox and is carried in large bearing brackets bolted to the side frames of the locomotive. The ends of the jackshaft carry cranks from which the drive is taken by coupling rods to the wheels; all driving wheels are coupled together by coupling rods.

11. BODY:

This is also called the superstructure and provides a covering for all the equipment necessary to drive the locomotive. Attached to the body is a cab which provides a place for the enginedriver and his assistant to carry out their duties and house all the necessary control equipment to operate the locomotive.

12. CAB EQUIPMENT: (See Fig. 5)

Although most of the equipment in the cab is provided for the enginedriver it is important for the Locomotive Assistant to know the function of each part and how to operate it correctly as he may be called upon at some time or another to act in an emergency and stop the engine or the train.

The diesel mechanical locomotives have dual controls and can be driven from either side.

The controls consist of the following:

(a) Throttle lever

This operates the fuel pump and allows the enginedriver to increase or decrease the amount of fuel supplied to the engine so he can control the speed of the engine and the train.

(b) Forward and Reverse Lever

This lever operates an air valve which allows air to flow to the pistons of the reversing mechanism on the final drive gearbox. This lever must not be moved to select forward or reverse direction unless the locomotive is stationary.

(c) Gear Control Lever

This lever operates air valves which enable the gears to be engaged one at a time.

It has six positions, namely neutral, 1-2-3-4-5-. When the lever is placed in neutral all gears are released. The gear lever must not be left in a position where a gear is engaged but must be placed in neutral whenever the locomotive is stationary with the brakes applied.

It must also be placed in neutral when the direction of the locomotive is reversed.

(d) Engine Stop Control

This is provided so that the engine may be stopped from the cab. It must be pulled out from the cab wall and held until the engine stops.

(e) Gauges

(1) Fuel tank gauge.
(2) Air gauges for air brake equipment.
(3) Ammeter to indicate the rate of charge or discharge to or from the battery.
(4) Oil pressure gauge.

(f) Warning Lights

These are provided to warn the driver that the oil pressure is low and also to indicate that the reverser has thrown or moved to its correct position on the final drive gearbox.

(g) Sanding Valves

Sand is carried in sandboxes on the frame and when the valves are opened sand is applied to the rails in front of the wheels. This helps to reduce slipping.

(h) Automatic Air Brake Valve and Handle

This is the larger of the two brake valves and when moved from the "release" position to the "application" position applies the brakes on the locomotive and the train.

(i) Straight Air Brake Valve and Handle

This is the smaller of the two brake valves and, when moved to the "Application" position, applies the locomotive brakes only.

(j) Handbrakes

Handbrakes are fitted to all locomotives and, when applied, force brake blocks on to certain wheels. Their purpose is to ensure that when a locomotive is left unattended the locomotive will remain stationary and not move off.

The Locomotive Assistant must ensure that when a locomotive is put away or is left unattended the hand-brake is screwed "fully on".

He must also ensure that when any locomotive is to be moved under its own power or towed by another locomotive, the handbrake is "fully released".

13. BRAKES:

The Automatic brake and the Straight Air brake are operated by air pressure while the handbrake is manually operated. All three systems use a rigging of rods and levers to force the brake blocks against the wheel tyres to slow or stop the locomotive or train. Brakes will be covered in a later lesson.

To supply the compressed air, there are -

(a) Compressors:

Which are belt driven from the engine and compress air into suitable reservoirs. This air under pressure is used to operate the brakes, horn, sand, change speed gearbox and the reversing section in the final drive gearbox.

(b) Reservoirs:

These are used to store compressed air at various pressures so that there is always sufficient air to operate all equipment.

(c) Compressor Governor

This equipment controls the pressure in the main reservoir, and only allows the compressors to pump in sufficient air to maintain a safe working pressure.

14. ELECTRICAL EQUIPMENT:

(a) Batteries

These are carried to supply electrical current to rotate the engine when starting and also to supply current to operate the lights.

(b) Generator

The generator is fitted to re-charge the batteries when the engine is running. It is usually belt-driven from a pulley on the engine.

(c) Starter Motors

These are fitted so that electrical energy from the battery can be used to rotate the starter ring gear on the engine flywheel and thus start the engine.

15. MISCELLANEOUS ITEMS:

There are other types of shunting locomotives built on the same lines but which have a diesel hydraulic transmission. These are powered by a 6-cylinder vertical in line 270 kW 4-cycle Caterpillar supercharged diesel engine.

The difference in the transmission is that the fluid coupling and the change speed gearbox are replaced by a torque converter.

The clutch lever should be in the disengaged position whenever the engine is stopped.

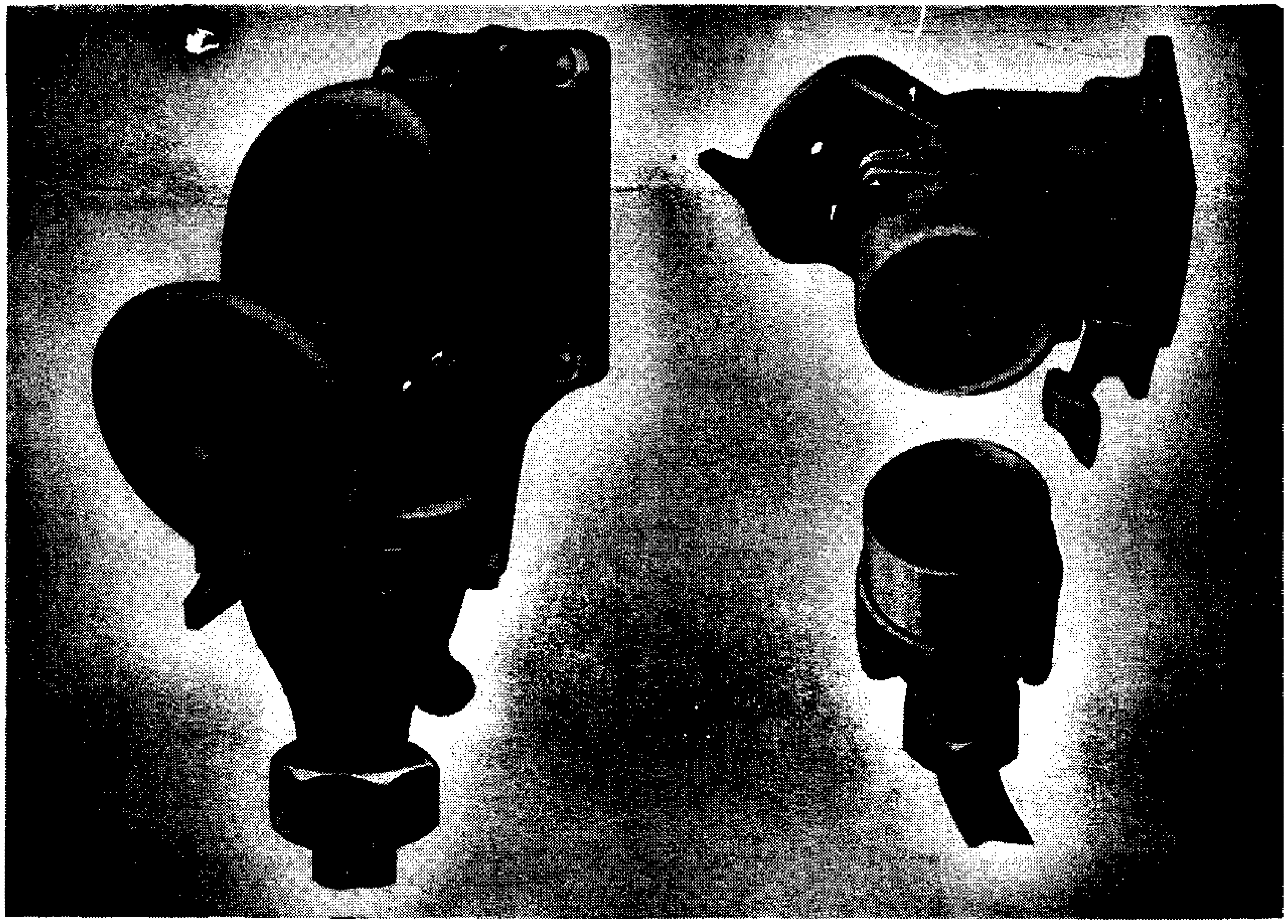
Other types of locomotives that a Locomotive Assistant or Trainee will be required to work on are known as Diesel Electric which have an electrical drive, and although some are used for shunting purposes, most are used for main line duties. These are -

Da, Db, De, Dg, Di, Dj, Dx and Dsc classes.

Here is a list of the pictures and diagrams enclosed with this lesson:

Other illustrations included are:

A 6-cylinder "in line" diesel engine.
A 12-cylinder "V form" diesel engine.
Bedplate, crankcase, cylinder head, valve mechanism, camshaft, crankshaft, piston and connecting rod.
Camshaft gear train and timing chain.
Fuel injection pump, lubricating oil pumps and water pump.
Mechanical drive for compressor and radiator fan, fuel supply unit and schematic external lubricating oil system.
Schematic diagrams of the external cooling and fuel systems.
Two-stroke 567 series diesel engine.



Control plug and socket, coupled and uncoupled

Fig. 1—Mechanical analogy of a diesel-electric locomotive drive. Here, the engine drives a pump (the generator) which forces water through pipes (the cables) to water wheels (the motors) which drive the axles

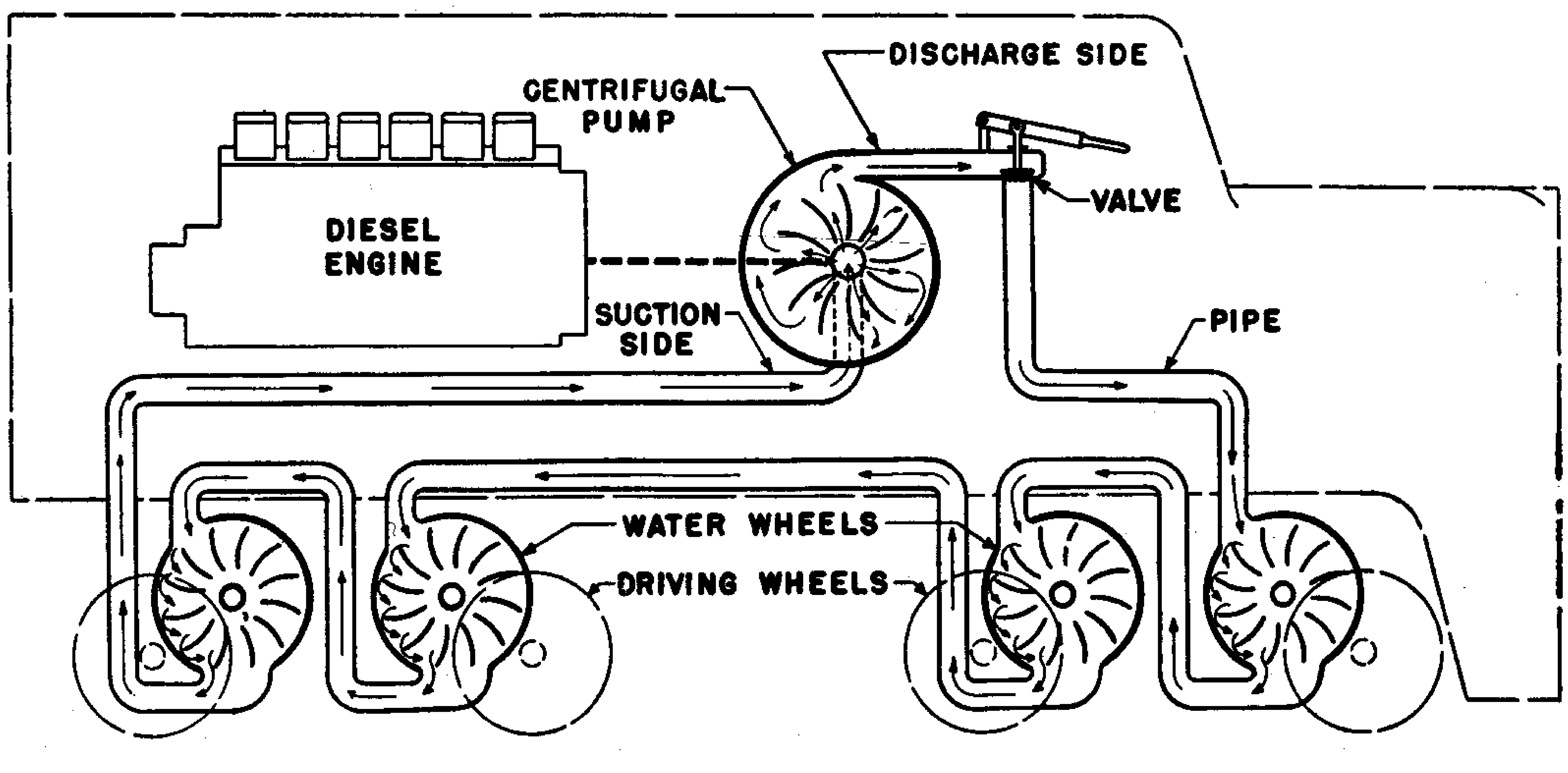
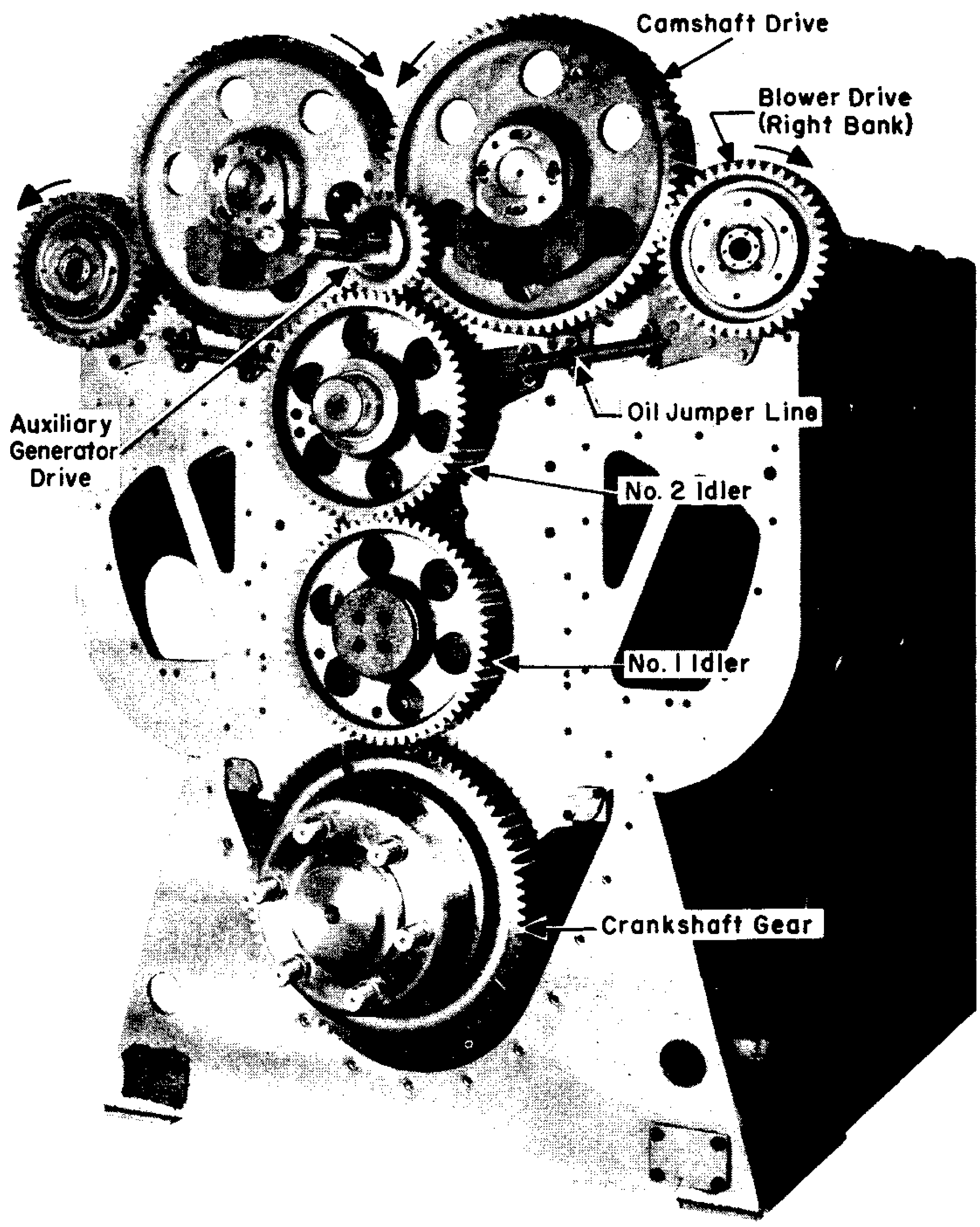
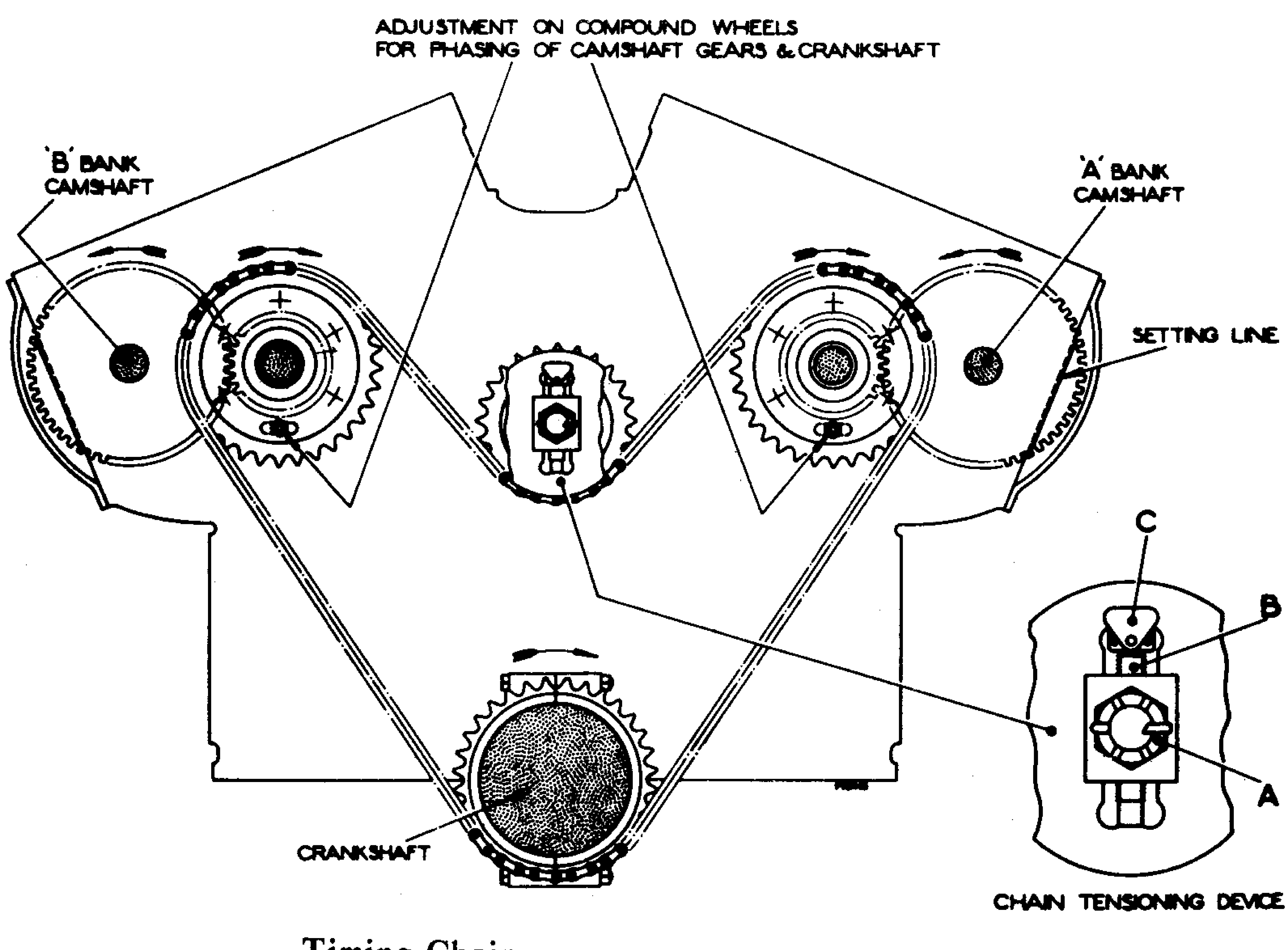


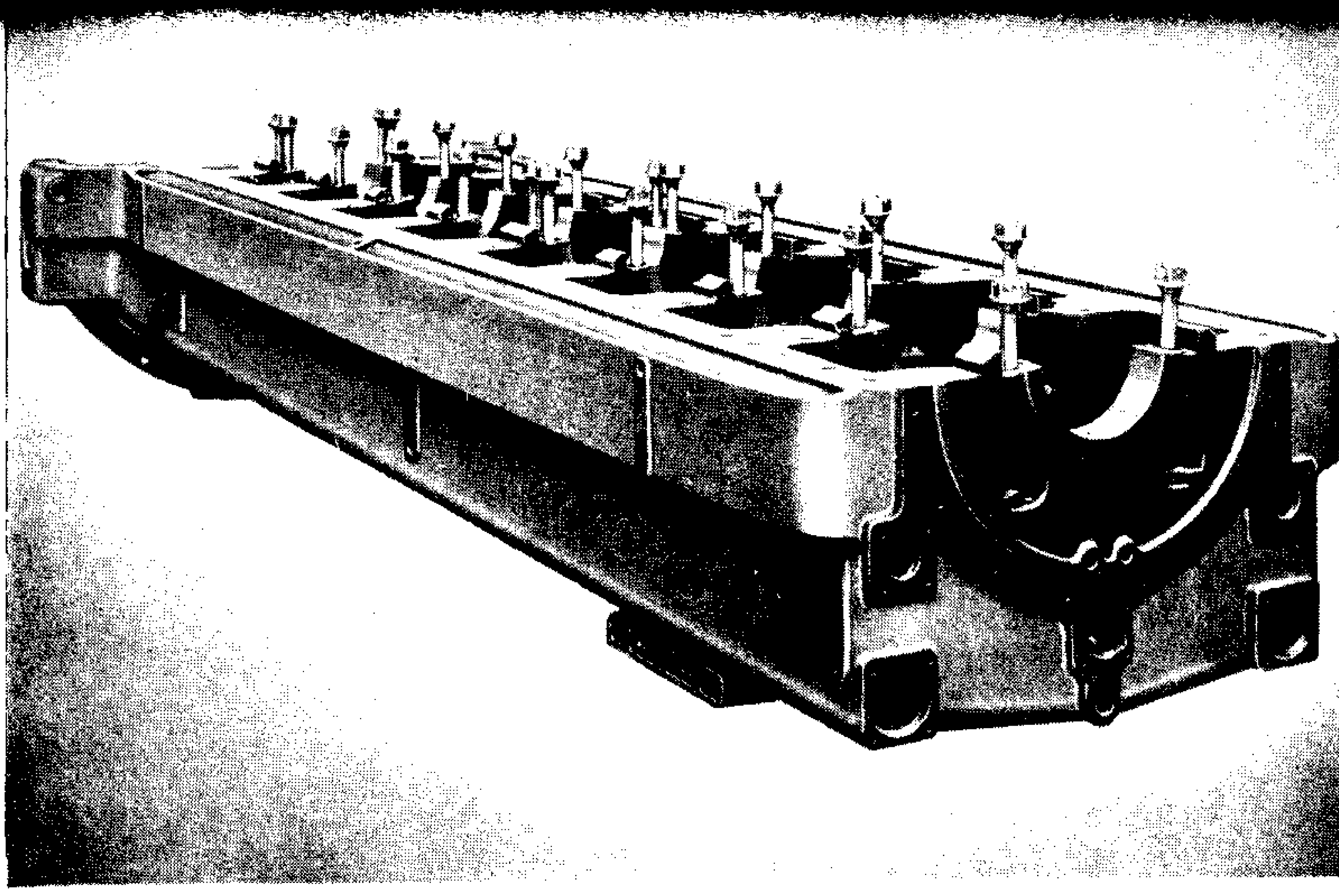
Fig 5
INTERIOR OF DRIVER'S CAB



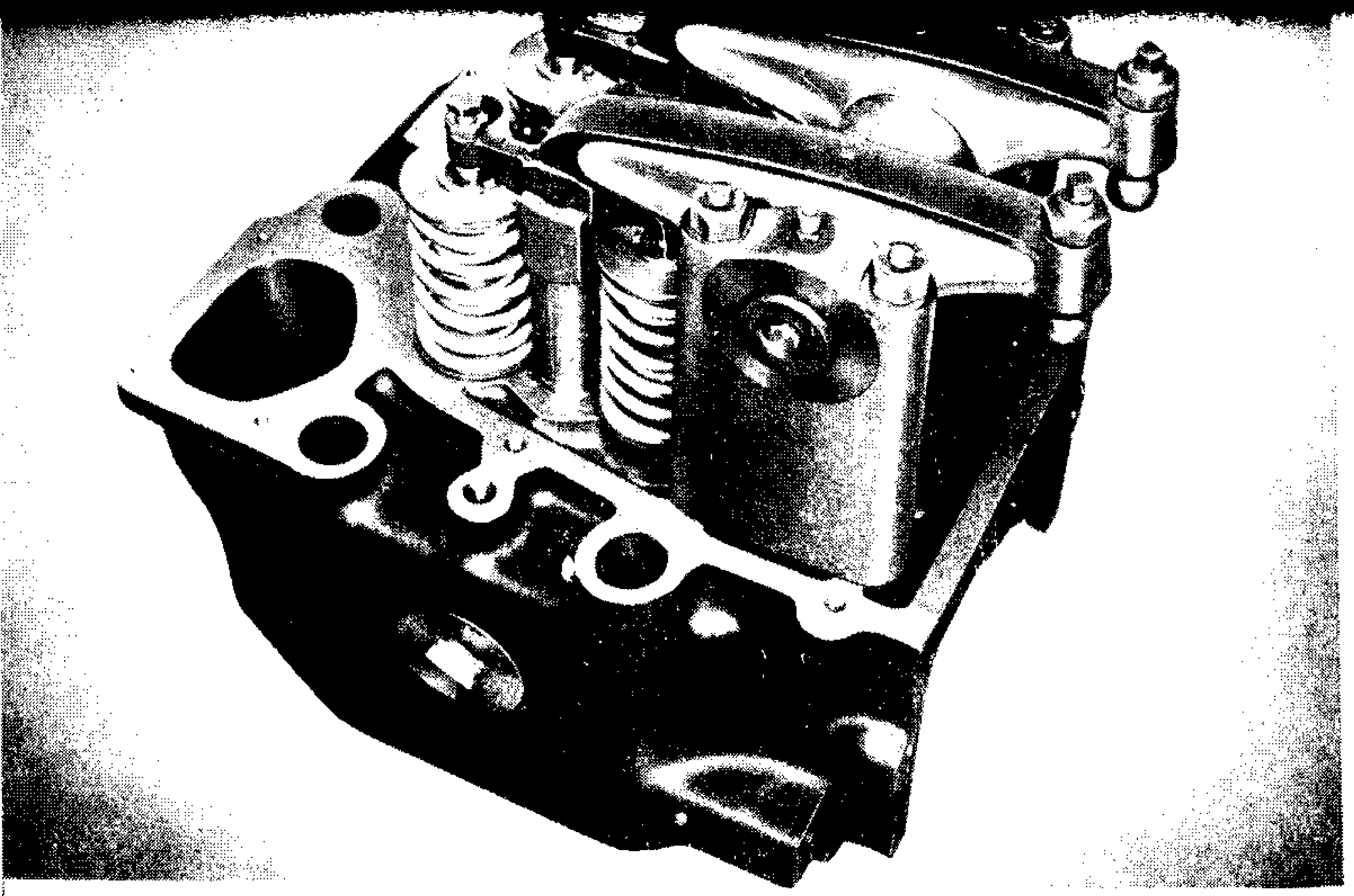
Camshaft Gear Train



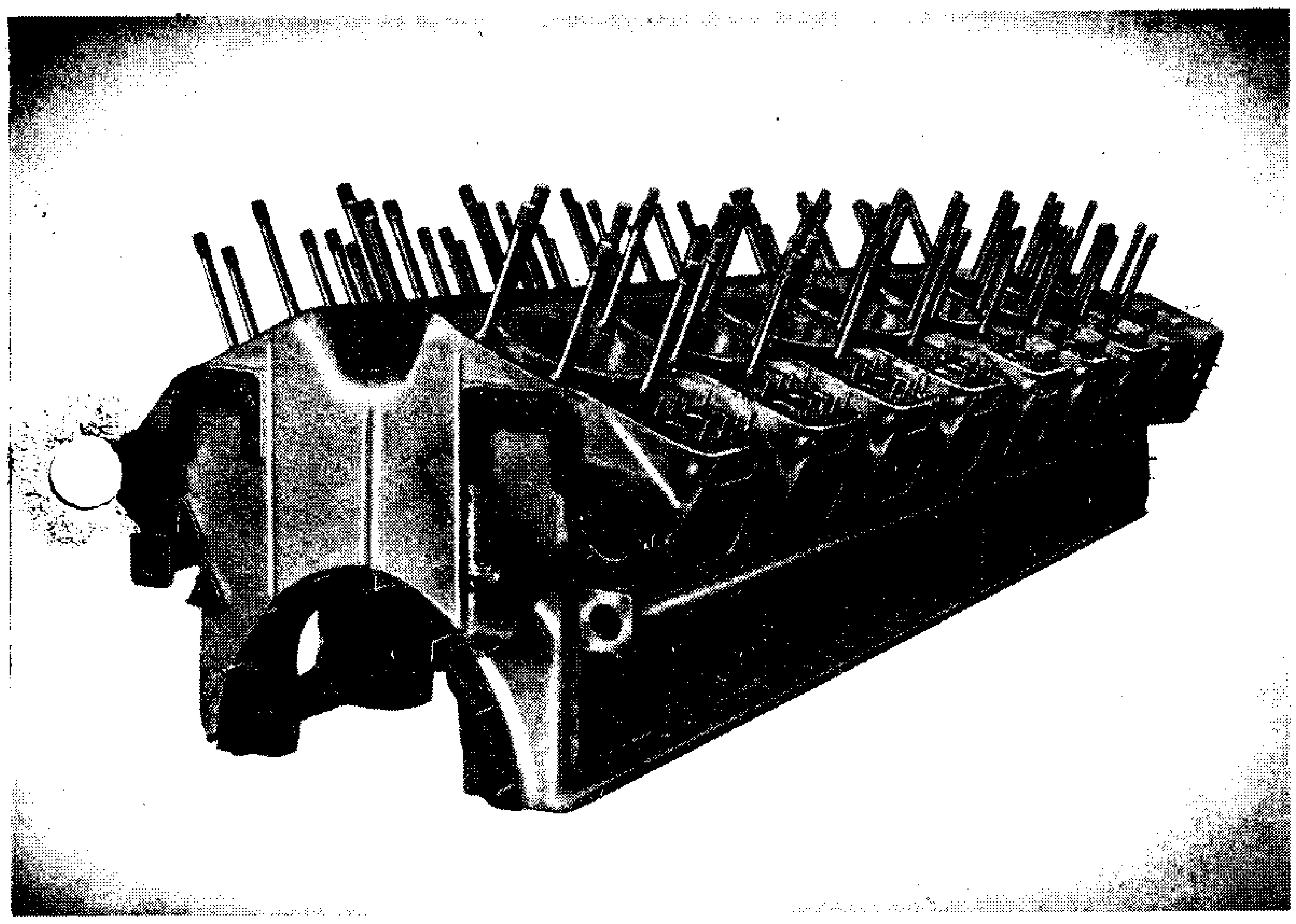
Timing Chain



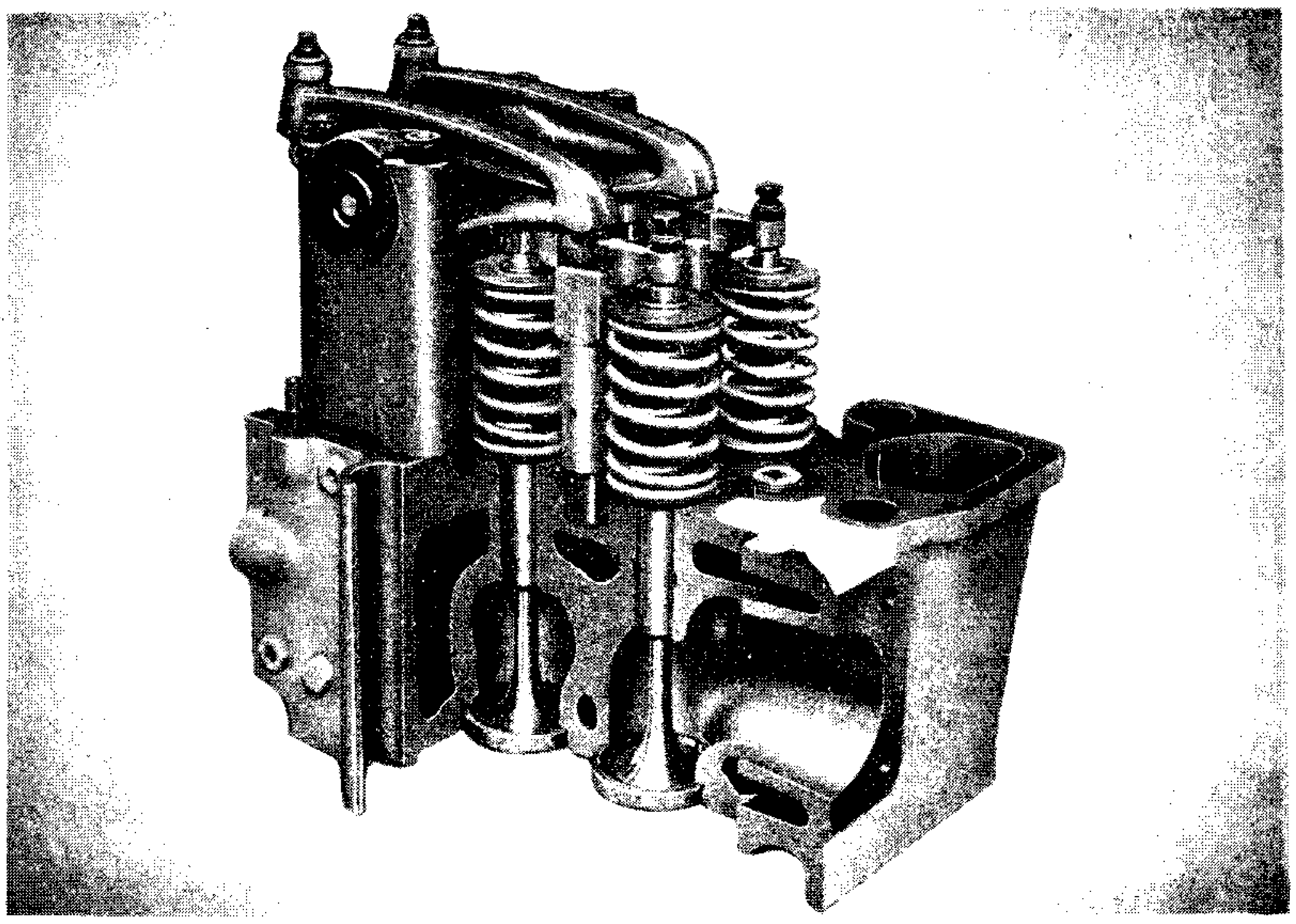
Bedplate



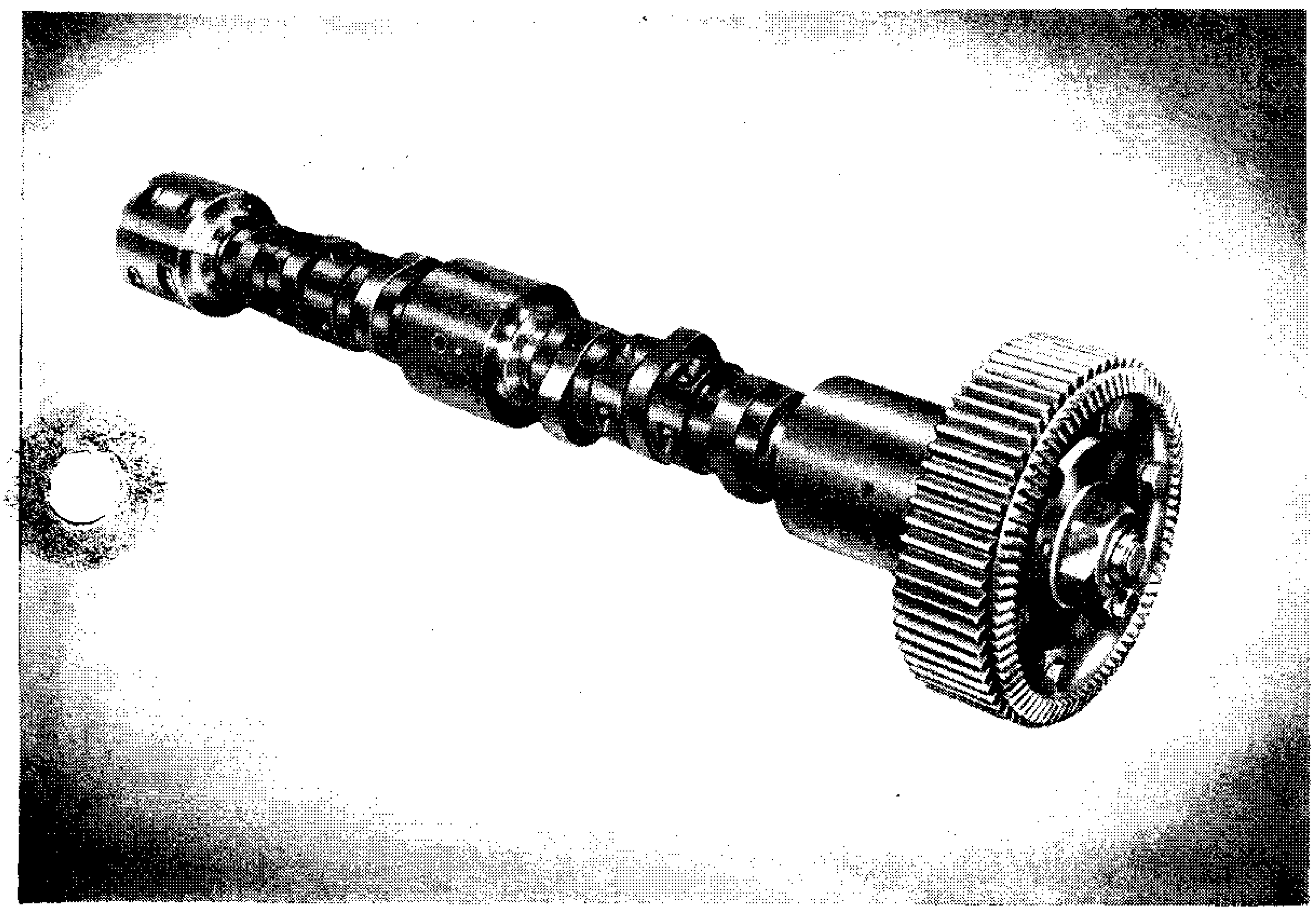
Valve mechanism



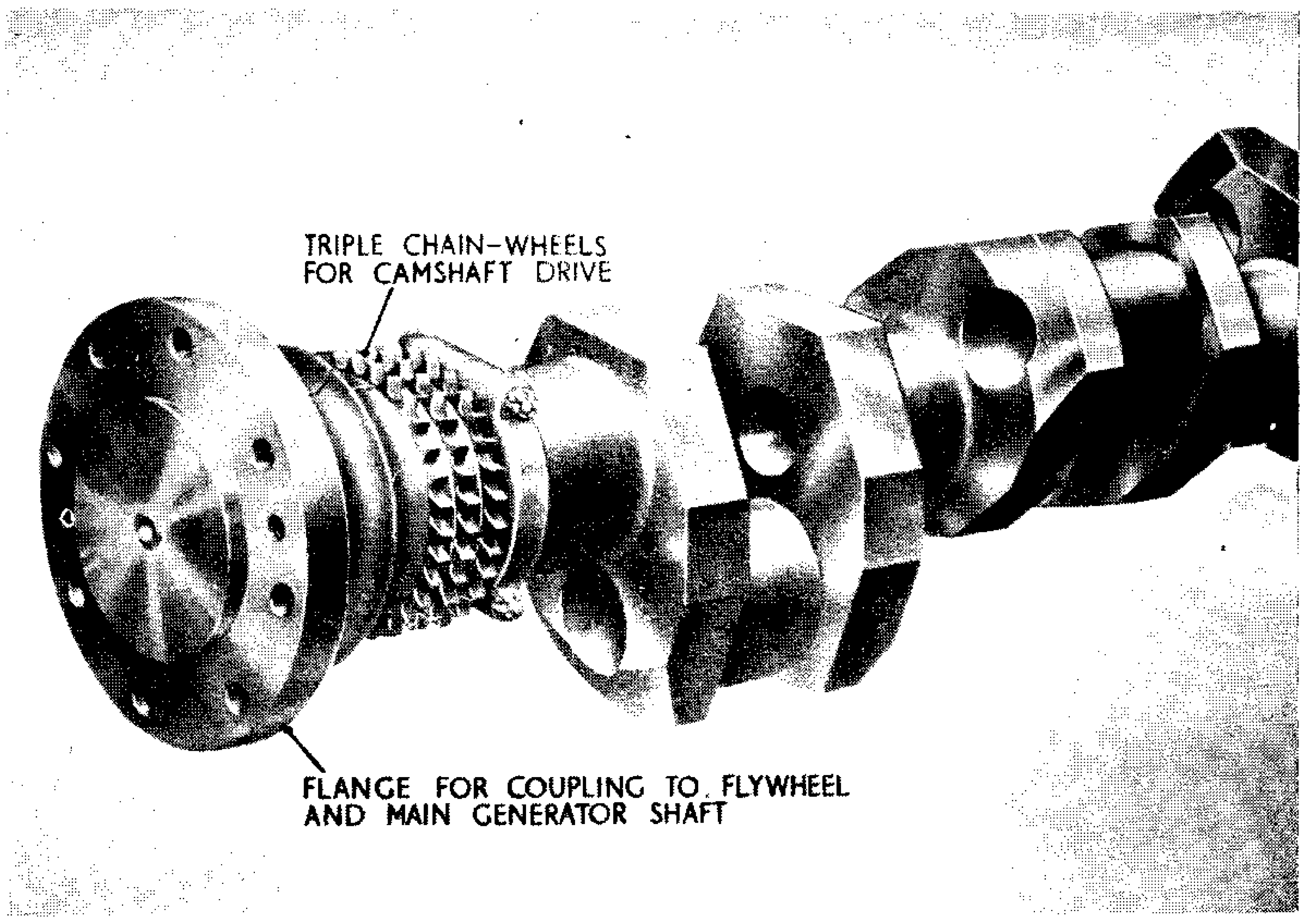
Crankcase



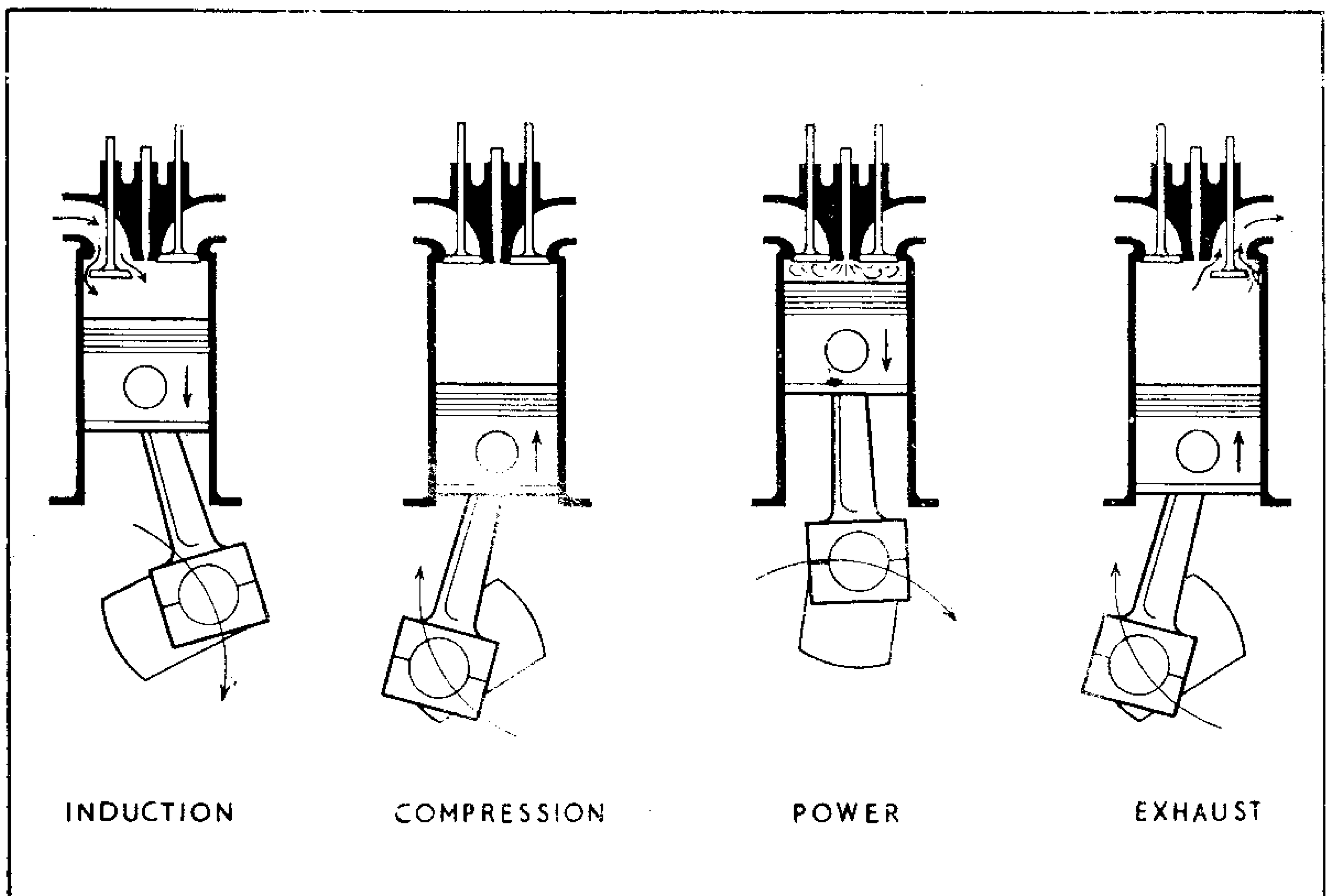
Cylinder head

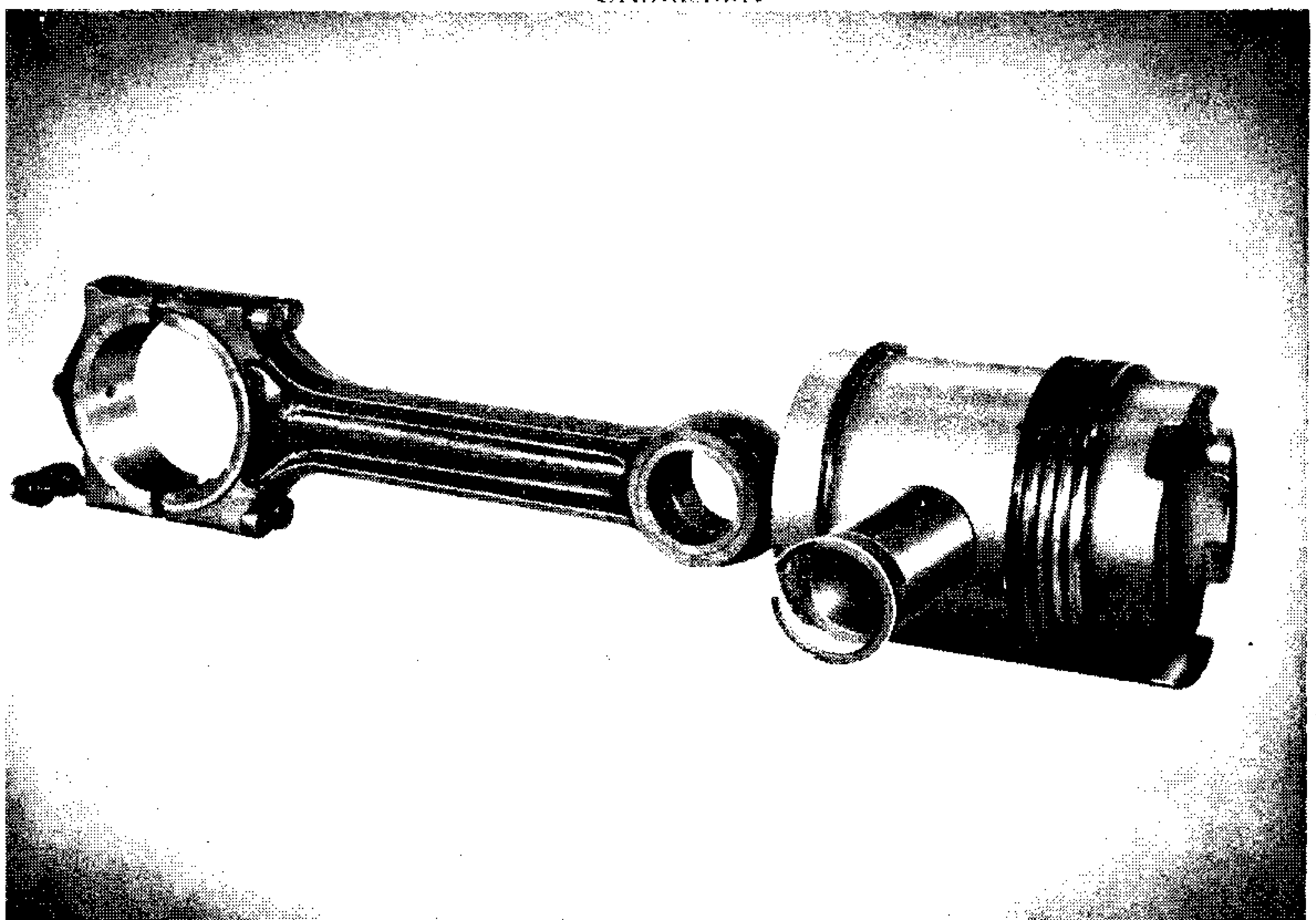


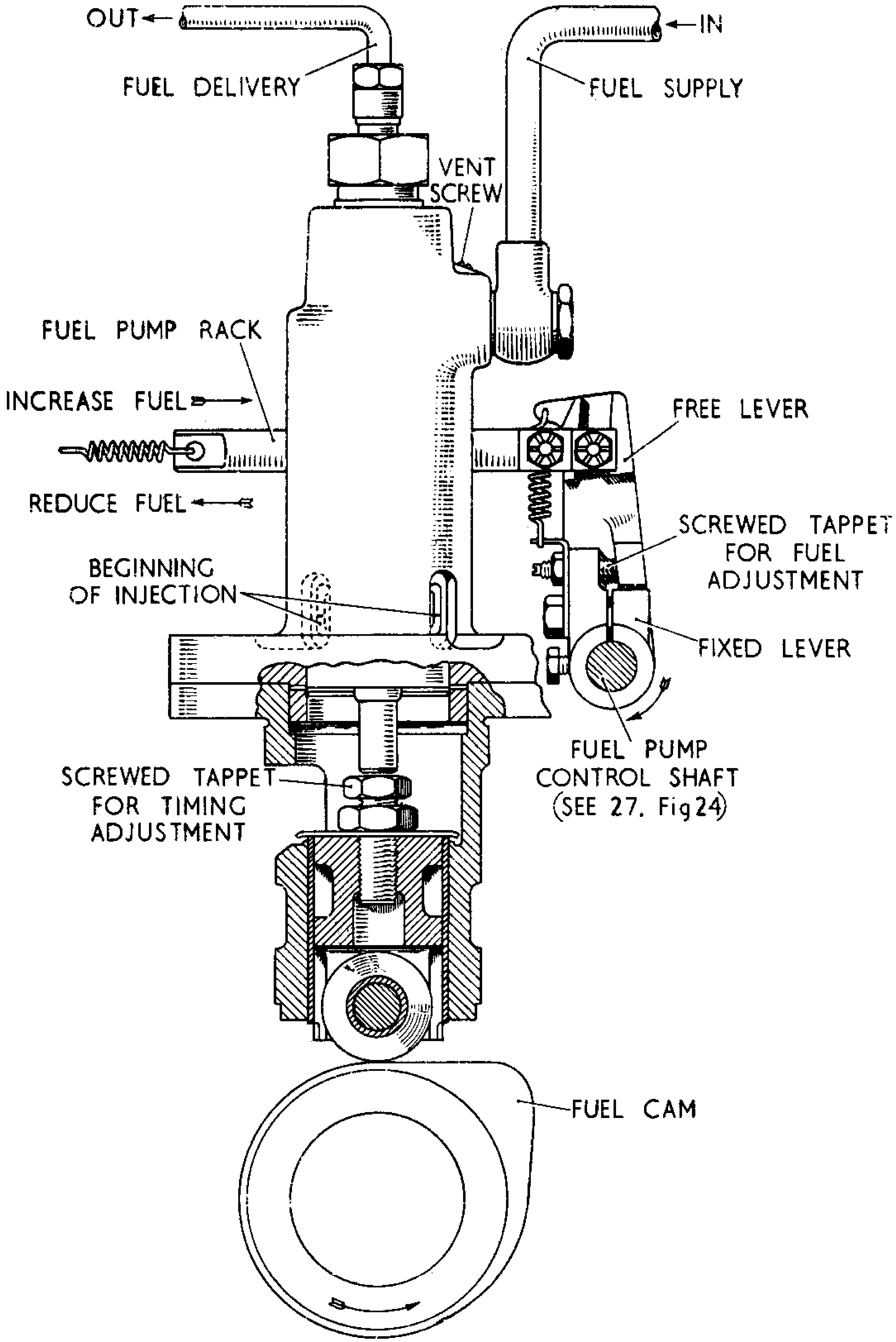
Camshaft



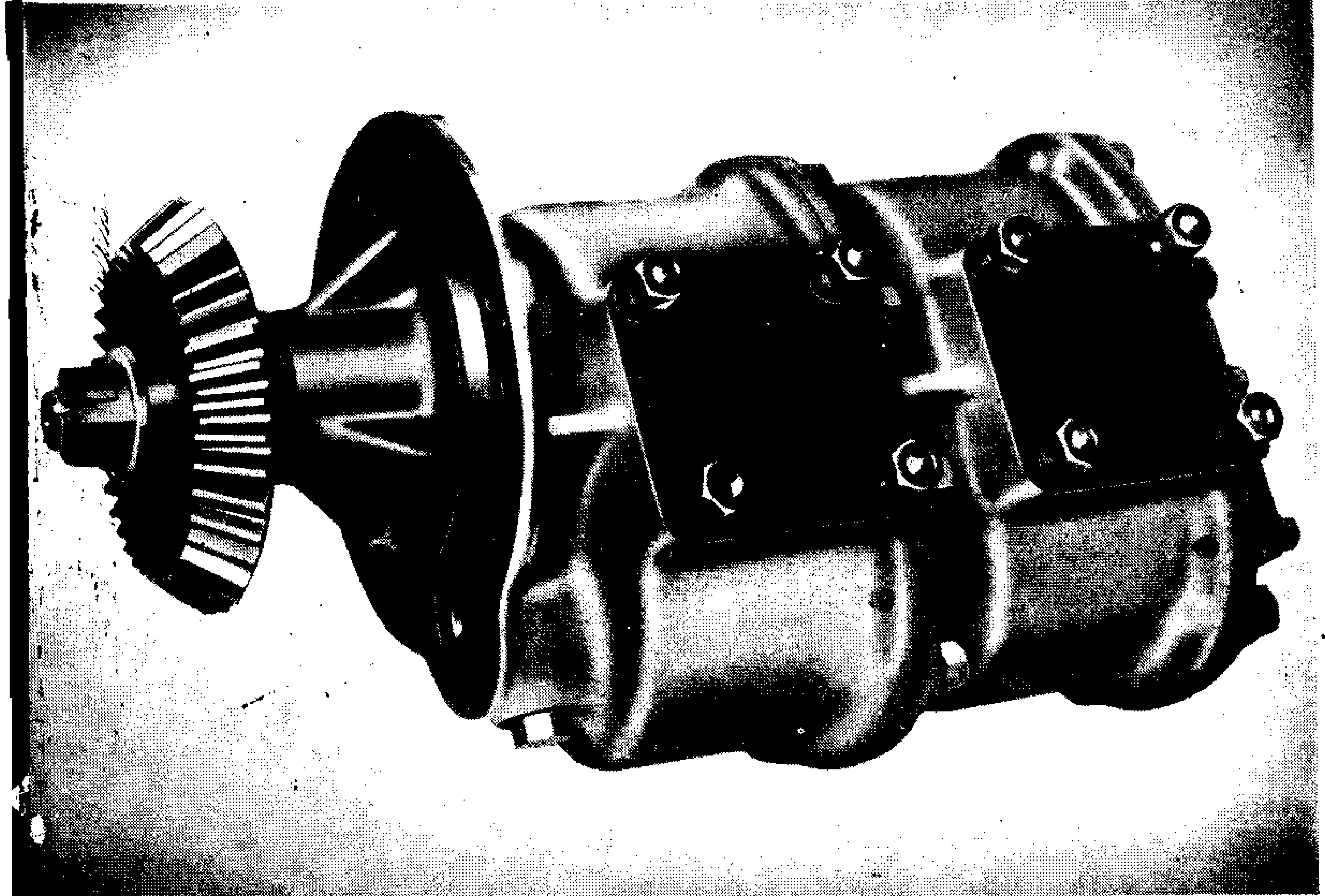
Crankshaft



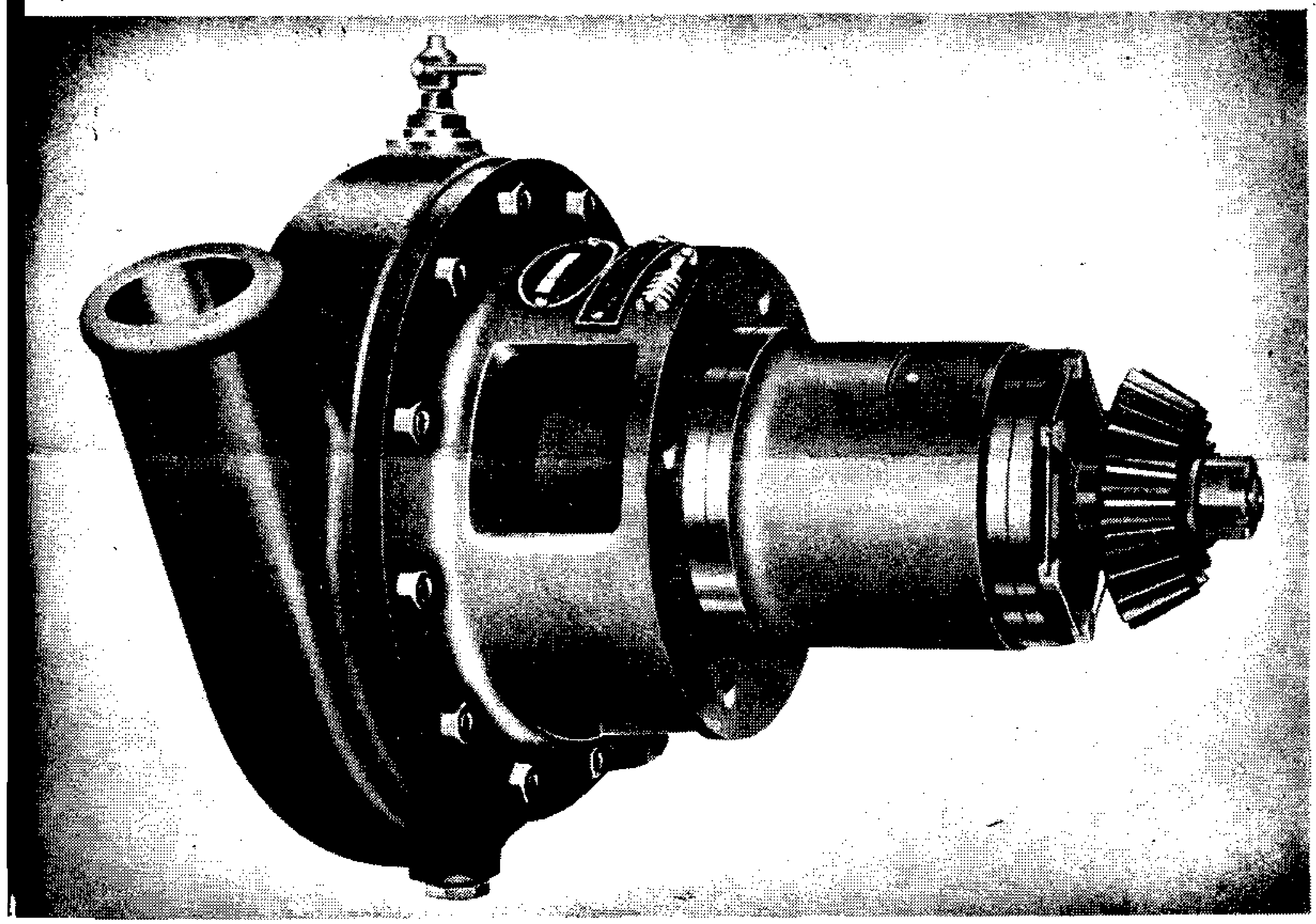




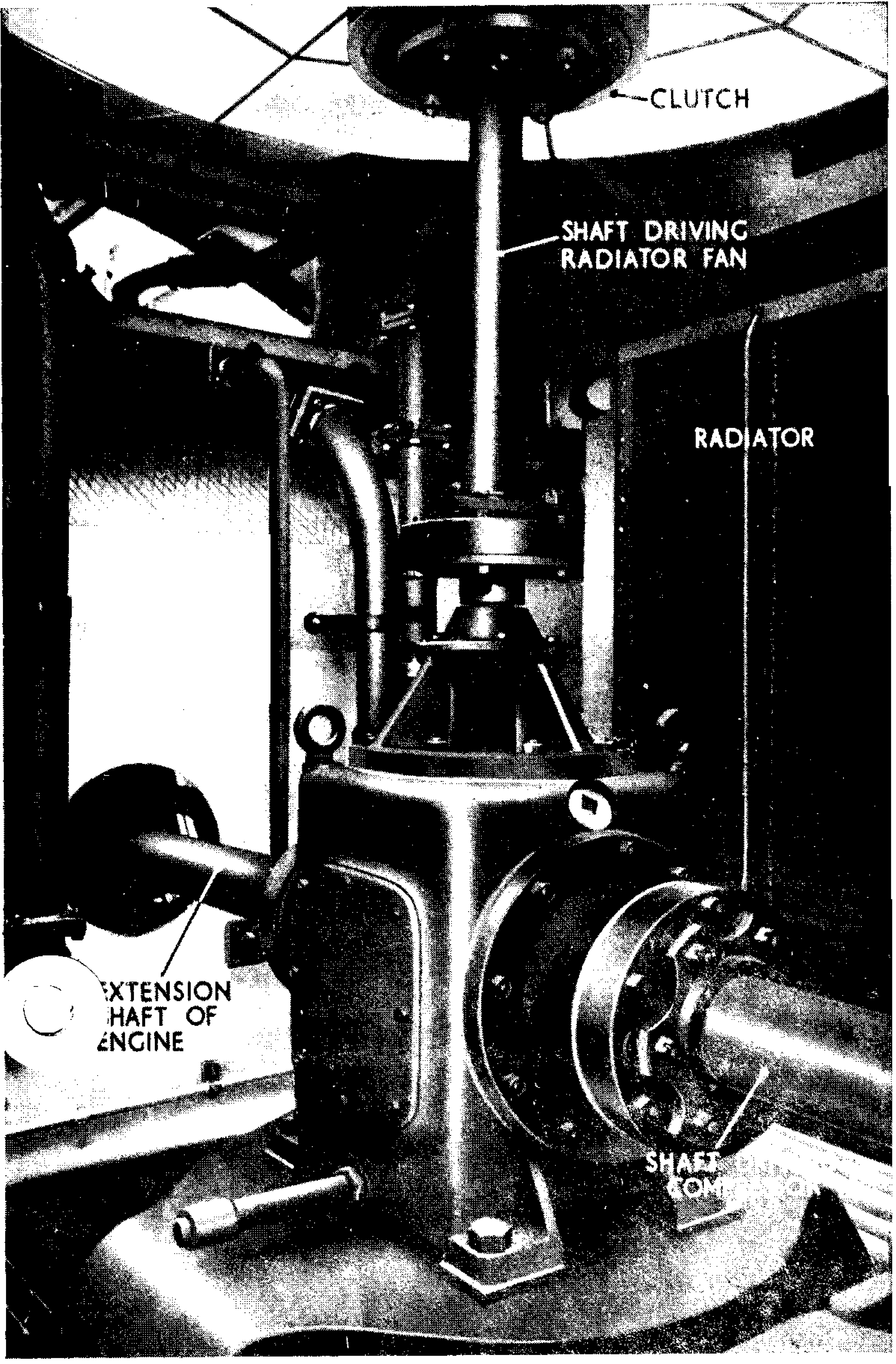
Fuel Injection Pump



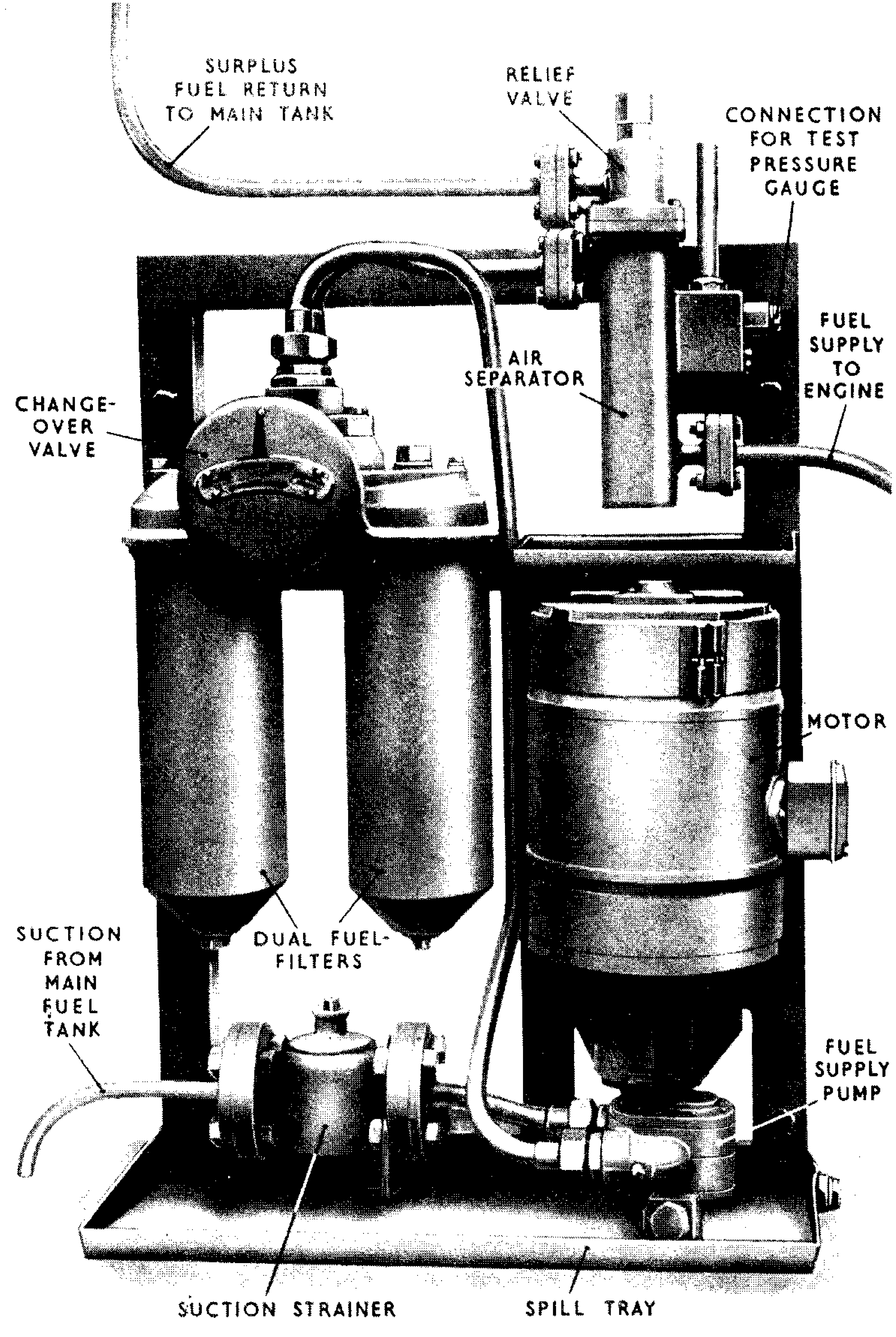
Lubricating oil pumps



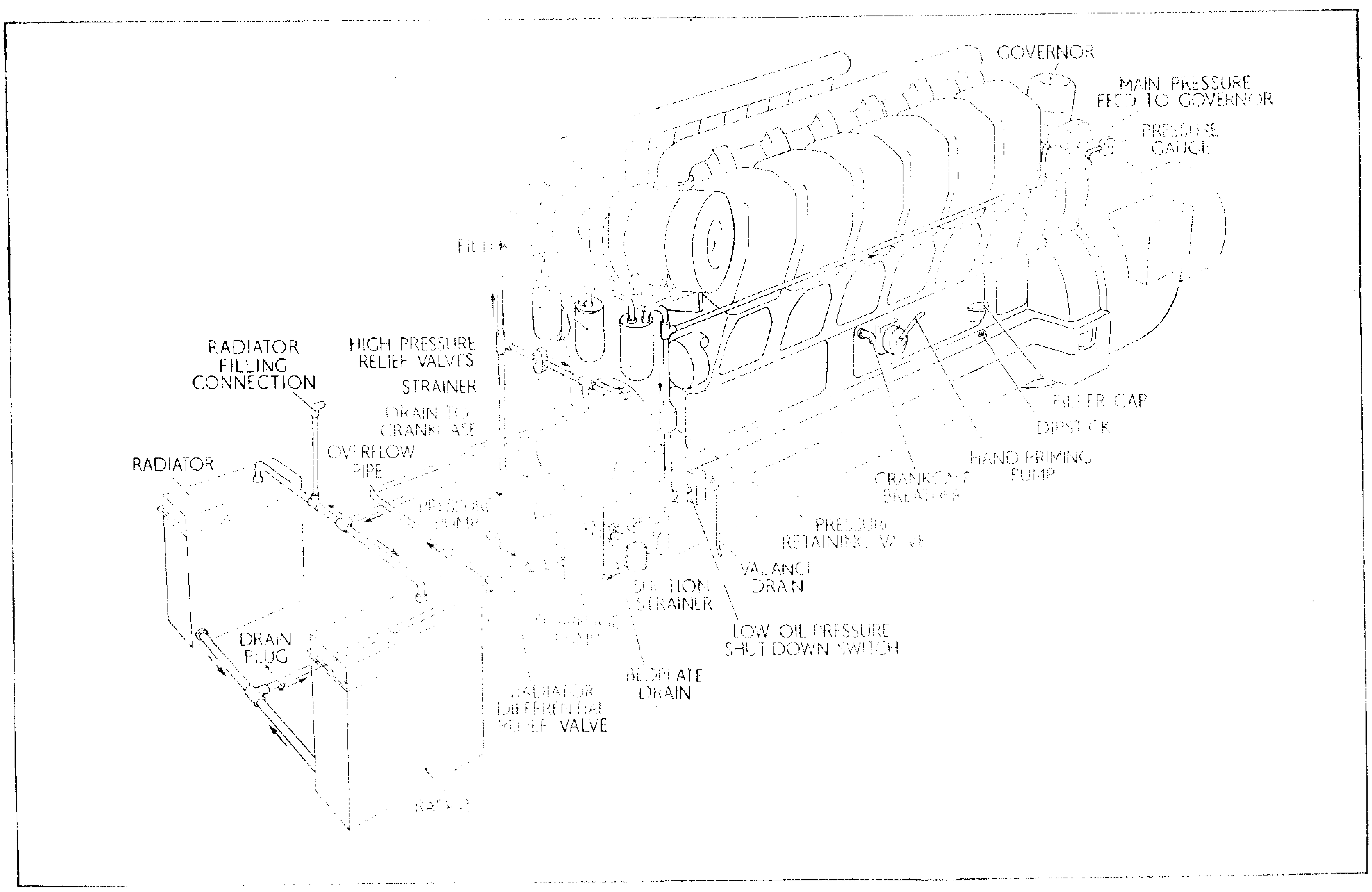
Water circulating pump



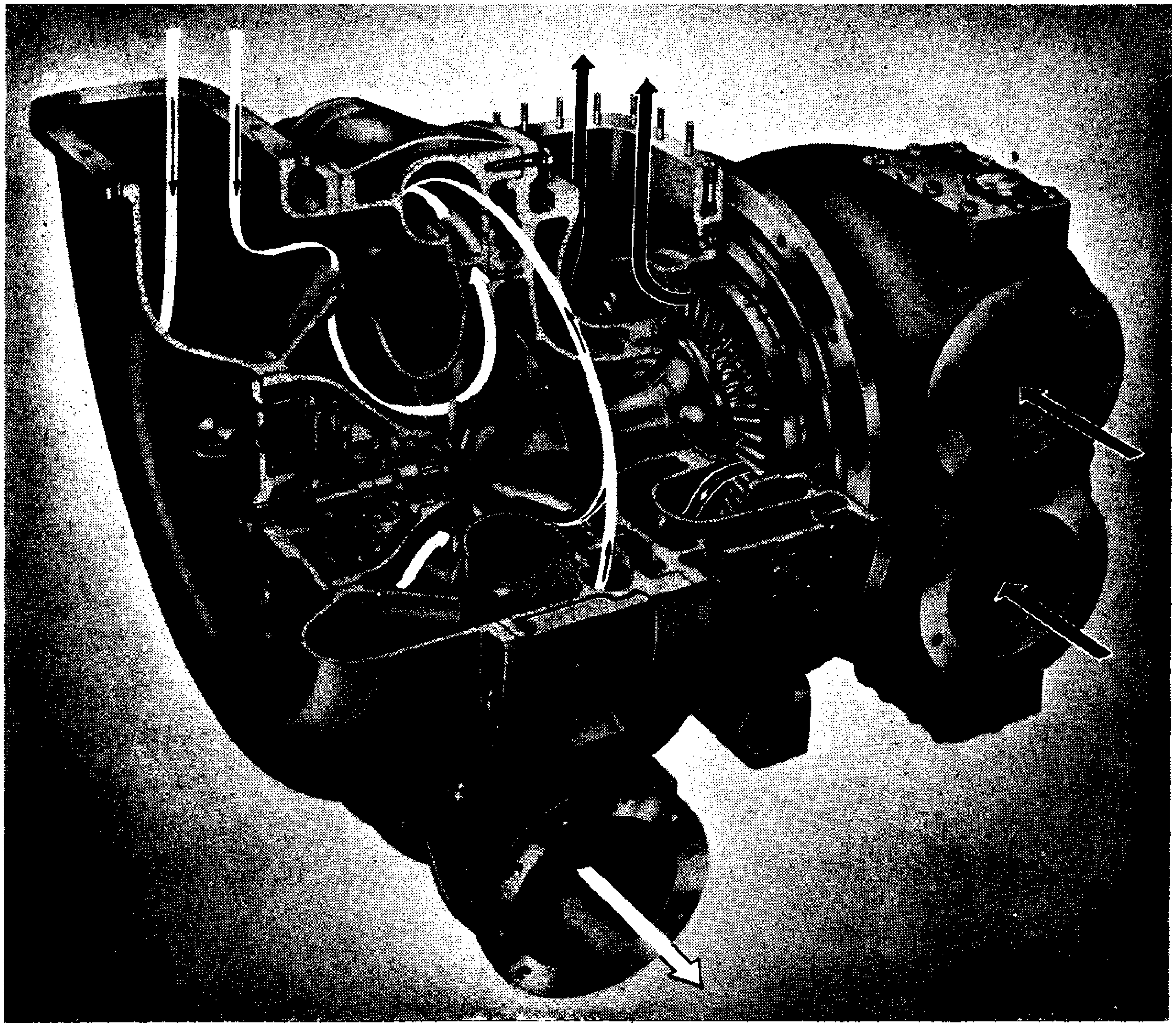
Mechanical drive for compressor and radiator fan

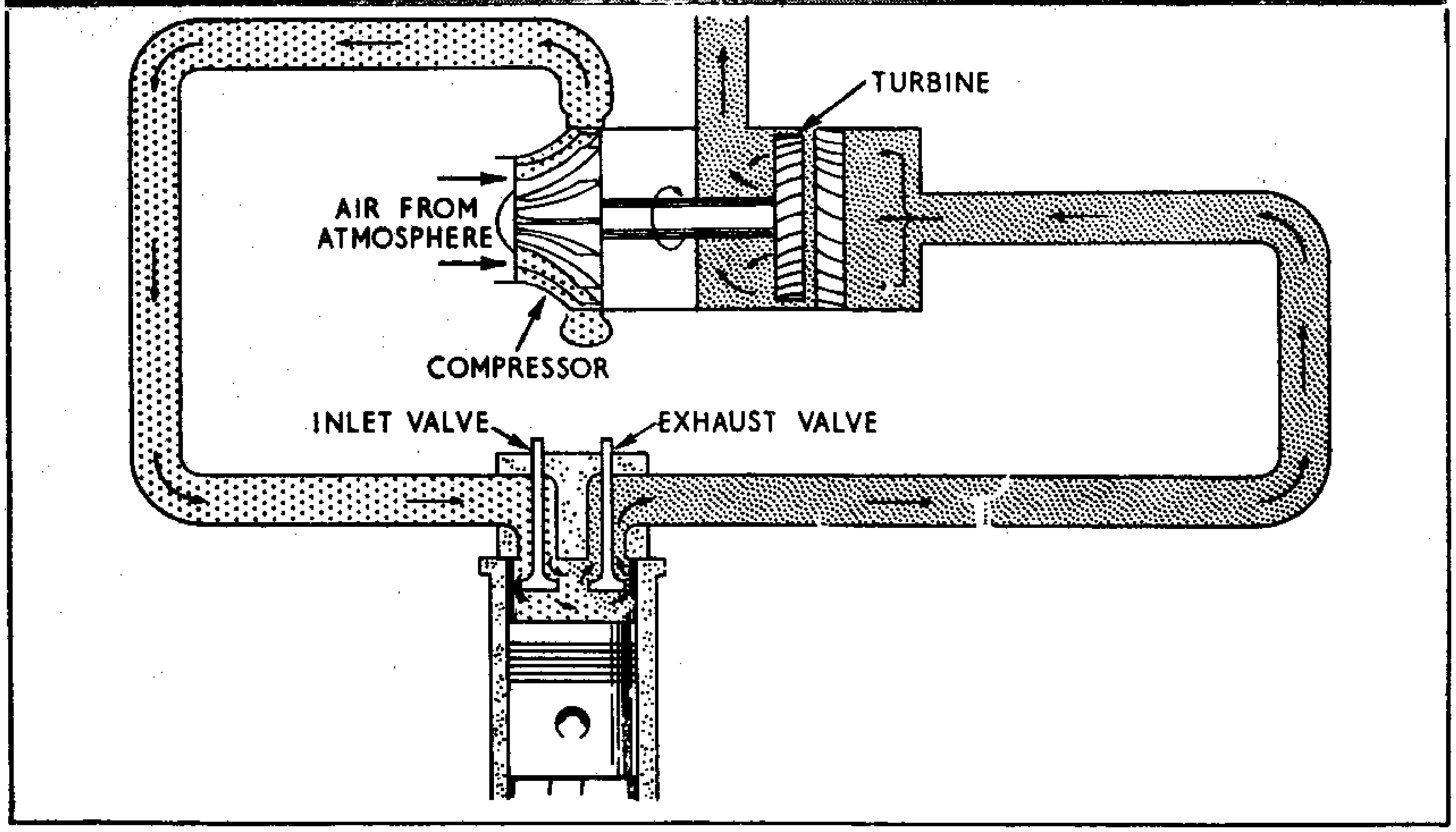


Fuel supply unit



hematic external lubricating oil system





Arrangement of pressure-charger and exhaust/induction circuits
Above: Dark arrows=exhaust gases, light arrows=air flows