CHAPTER 5

PISTON ENGINE LUBRICATION SYSTEM

Objectives

1. This Chapter has been written with the aim of helping you to satisfy objectives in the relevant Skills and Knowledge Specifications (SAKS) for the trade in this subject area. When you have studied this Chapter, together with the information contained in AP3279A, Chapter 4, Section 8, you will be able to:

a. Explain the purpose of a lubricant and the properties that it must contain.

b. State the types of oil system, *ie* wet and dry sump systems; recognize the components in the oil system and their purpose, and the servicing and safety precautions involved.

c. Explain the effects and possible cause of:

1. High or low oil pressure.
2. Excessive oil consumption.
3. High oil temperature.

LUBRICANTS AND THEIR PROPERTIES

Introduction

2. Before discussing an engine lubrication system, it is essential to understand the purpose of a lubricant and the properties it must contain to fulfil that purpose.

3. Lubrication is a procedure for reducing friction and wear. Friction is the resistance to motion encountered when one surface slides on another surface. Wear is any loss or destruction resulting from such sliding. Solid surfaces are never perfectly smooth, actual contact being limited to a number of high spots. These high spots are crushed by the load between the two surfaces until the area of contact is sufficiently large to support the load without further deformation. When high spots on rubbing surfaces are separated, fragments may be torn away. If these fragments are very small then the surfaces become smoother, but sometimes quite large fragments are torn away and the surfaces become rougher.

Purpose of a Lubricant

4. The purpose of a lubricant is to prevent the surfaces from touching each other and so eliminate friction and wear. This may be brought about under actual working conditions in two ways:

a. By 'fluid lubrication'.

b. By 'boundary lubrication'.

5. **Fluid lubrication.** This means that there is a thin but measurable and continuous film of oil separating the moving surfaces and preventing metal-to-metal contact. This film may be imagined as a cushion which takes the load, and although very thin (measurable in ten-thousandths of an inch), it comprises three distinct layers. The two outer layers cling to their

respective surfaces—for instance, the piston and cylinder bore, or a bearing and shaft. The central layer consists of particles of oil which are continually being torn apart from each other or 'sheared' and continually being reunited as the piston slides or the shaft revolves.

6. The thinner the oil, the more easily can this shearing (and therefore movement) take place. Apart from factors of load and speed, the thickness or *viscosity* of the oil affects operating efficiency. In other words, an oil which at a certain temperature is thick, will restrict free movement between surfaces to a greater extent than an oil which at the same temperature is thin. This is an important factor concerning the starting of a cold engine.

7. The ideal lubricating oil is one which is as fluid as possible at low temperatures, but which resists to the greatest extent the tendency found in all oils to thin out at high temperatures. When an oil thins out excessively, the 'cushion' of oil loses the capacity or strength that enables it to resist pressure. It is squeezed out from between the bearing surfaces and 'fluid lubrication' ceases. However, before the oil disappears entirely there is an intermediate state which is known as 'boundary lubrication'.

8. **Boundary lubrication.** This can be regarded as the condition bordering on breakdown, the oil film between the surfaces under load being reduced to almost nothing. The surfaces are not actually in contact and will continue to slide until the very thin smear of oil disappears completely. When conditions of boundary lubrication exist, the thickness or viscosity of the oil no longer matters, because there is no appreciable film to be sheared by the movement of the bearing surfaces. The important factor now is the 'oiliness' of the oil, which means its resistance to breakage or vaporization of the boundary film.

Desirable Properties of a Lubricant

9. The properties required in a lubricant are decided by the particular purposes for which it is to be used. Every lubricant must:

a. Wet the surfaces needing lubrication.

b. Possess suitable viscosity.

c. Not evaporate excessively in service.

d. Not injure any material with which it comes into contact.

e. Have no tendency to deposit gum, varnish, sludge or other materials which may interfere with its correct performance.

f. Be chemically stable under service conditions so that it will not become deficient in any of the above respects.

10. In addition, the lubricating oil is often required to carry away heat from engine parts, to protect surfaces against corrosive influences, and to perform many other special duties. To ensure that lubricating oils possess the desired properties, specifications are issued to which they must conform.

Viscosity

11. The viscosity of a liquid is a measure of its internal friction or its resistance to flow. A liquid which flows freely is said to have a low viscosity and one which is sluggish, a high viscosity. Viscosity is defined as 'the force required to move a plane surface of one square centimetre area, over another plane surface at the rate of one centimetre per second, when the two surfaces are separated by a layer of liquid one centimetre thick'. This force is known as the *poise* and is the unit of *absolute viscosity*.

12. *Kinematic viscosity* is the ratio of the absolute viscosity of a fluid to its specific gravity at the temperature at which its viscosity is measured. The unit of kinematic viscosity is the '*stoke*'.

13. Viscosity is one of the most important properties of a lubricating oil. In selecting oils it is important that the viscosity at the operating temperatures should be known, since this property varies immensely with temperature. The viscosity at the operating temperature should be such that a fluid film is continuously maintained. It should not, however, be so high that fluid friction becomes excessive, as this raises the temperature of the oil and consequently of the bearing.

14. There are various methods for measuring the viscosity of oil, but the principle of them all is the time taken for a certain amount of oil to flow past a constriction, or through a jet of given size, at a given temperature.

Additives

15. When the term *additives* is used in relation to lubricating oils, it may be defined as substances added in small quantities to an oil to give the oil some desirable property or properties which it would not otherwise possess. When fatty oils are added to mineral lubricants to improve oiliness, they are not called additives; the resulting oil is known as a *compounded oil*.

16. Additives may be divided into three classes as follows:

a. Extreme pressure additives.

b. Anti-corrosion additives.

c. Detergent additives.

A substance added primarily for its detergent effect, may at the same time possess anti-corrosion and/or extreme pressure properties.

Extreme Pressure Additives

17. An oil with good extreme pressure performance became a necessity with the introduction of the hypoid gear. The toothed motions of both the spur gear and the worm gear are combined in the hypoid, with the result that a scraping action is developed which quickly wipes away conventional lubricants. Consequently, lubricants for hypoid gears must possess, in addition to high oiliness, the ability to coat the gear surface with chemical films which act as an anti-weld coating, and so prevent scoring and scuffing, even when the oil is momentarily scraped away. These additives contain sulphur, phosphorus, chlorine and other chemicals. No indication of the composition of an extreme pressure oil is given by the manufacturers, and there is always a possibility that harmful chemical action between additives may result if two different types of extreme pressure oil are mixed. *Therefore, do not mix.*

Anti-corrosion Additives

18. The purpose of anti-corrosion additives is to protect some particular part of an engine from corrosion, such as bearing metals. These should not be confused with inhibitors which slow down the formation of oxidation products.

Detergent Additives

19. Detergency in an oil can be considered as the property of reducing the formation of

lacquer and other deposits on oil-wetted surfaces, such as pistons and rings, and of retaining insoluble impurities in suspension. The oils are usually known as HD oils.

Lubricants for use in the Air and on the Ground

20. There is no real difference between the basic requirements for an engine oil for aircraft or land transport. However, due to special requirements, the lubricating oils in general use on the ground differ from present aircraft lubricating oils, particularly in respect of additives.

21. Plain mineral oil is an adequate lubricant for most ground spark ignition engines. The viscosity of the oil used is mainly dependent on climatic conditions. Air-cooled engines usually require an oil of higher viscosity than liquid-cooled engines operating under the same conditions. High speed diesel engines generally need an oil containing a detergent to prevent piston ring sticking and excessive carbon deposit.

Piston Engines

22. For reciprocating aircraft engines in service with the RAF, extreme pressure additives in the lubricant are seldom used. Other additives, such as anti-corrosion and detergent, may however be included. Viscosity, pour point, carbon residue, flash point, total acidity, the ash content, and saponification requirements are specified, as necessary, to suit the engine design and the conditions under which it will be operating.

23. An important requirement is that the viscosity of the lubricating oil shall be as low as other factors permit in order to facilitate cold-starting. The engine crankshaft must be turned at a certain minimum speed and, for a given starter motor, the speed of turning will depend largely upon the viscosity of the engine lubricating oil.

24. Sometimes it is necessary to reduce this viscosity temporarily by diluting the lubricating oil with engine fuel. Oil dilution ensures an adequate flow of lubricant from the tank when the engine is running in a cold state; it also assists the cold starting of the engine in low temperatures by reducing the effort needed to motor it. As the engine warms up and the temperature of the oil rises, the gasoline evaporates, and so the viscosity of the lubricating oil is not permanently reduced. Only a volatile fuel, which does not leave 'heavy ends', can be used to dilute the oil in this way.

Aero-engine Oil Designation

25. As for fuels, lubricating oils have been allocated joint-services nomenclature and standard abbreviations. These comprise three parts as follows:

a. General nomenclature, oil.

b. A group of two or three letters indicating the nature of the oil.

c. A number representing approximately the viscosity in centi-stokes at 100°F.

26. **Significance of letter groups:**

a. **OM—Oil Mineral.** These are plain mineral oils and include others containing additives which do not alter the behaviour of the oil as a plain mineral oil; for instance, a plain mineral oil which includes a pour point depressant.

b. **OMD—Oil Mineral Detergent.** This is a reciprocating engine oil having an additive which alters its behaviour sufficiently to require distinction from a plain mineral oil.

c. **OEP—Oil Extreme Pressure.** This covers oils having additives which enable them to withstand extreme gear tooth pressures.

d. **OF—Oil Fatty.** This is the designation of the plain fatty oils containing no mineral oils, but in some cases containing solvents. Lockheed type brake fluid is an example.

e. **OC—Oil Compounded.** These are blends of mineral and fatty oils only.

f. **OX—Oil Miscellaneous.** This covers the synthetic oils and oils containing widely modifying additives which do not fall into any of the other classes.

27. Each aero-engine lubricating oil has a stores section and reference number, a joint service nomenclature, a NATO code number and a specification number, all of which should be quoted if there is any doubt that the designation will be understood.

Deterioration

28. Lubricating oils do not as a general rule deteriorate during storage, but contamination may arise from the same source as for gasoline and can have very serious effects. The following points are relevant:

29. **Water.** Water can cause any or all of the following:

a. Breakdown of lubrication at some heavily loaded bearing surface.

b. Excessive 'frothing' with subsequent loss of oil through the vents in the system.

c. Removal of additives from the oil, thus increasing the tendency to sludge formation.

d. Failure of lubrication as a result of water and oil forming an emulsion when the oil contains additives.

30. **Solids.** Rust and dust in suspension in the oil leads to the blocking of oil passages, or damage to component parts.

31. **Other lubricants.** The mixing of one grade of lubricating oil with another is, with very few exceptions, undesirable and dangerous. It may affect viscosity, increase or decrease an additive content and possibly increase sludge or varnish deposition with consequent bad effects.

32. **Gasoline and kerosine.** These will increase the fire risk and decrease the viscosity of the oil, the latter effect possibly resulting in brief seizure.

Detection of Impurities

33. **Water.** Water in lubricating oil may reveal itself in the form of 'pearly' globules or as a separate layer at the bottom of the vessel or container. If it is very finely divided, it may be held in suspension, thus causing the oil to look 'misty' instead of clear and bright. A quick method of testing for finely divided water can be carried out by heating a small quantity of the oil (about a tablespoonful) in a thoroughly dried container, to a temperature of 200°C. If the oil crackles while it is being heated, water is present.

34. **Solids.** Visual examination of a thin layer of oil, the oil being placed between the eye and the source of light, will reveal the presence of particles of solid matter in the oil. If the dark colour of the oil makes inspection difficult, the sample may be diluted with at least an equal quantity of gasoline, and then examined. Another method is to rub a small quantity of the oil between the fingers and the palm of the hand. It is possible with this method to feel very small particles of solid matter.

35. **Other grades of fuel and oil.** Contamination of oil by other grades of fuel or oil is very difficult to detect and *the importance of preventing it cannot be over-emphasized.* Rough tests for viscosity can be carried out in the field, but they are only comparative in nature. It is stressed that they must not be used to test the visocosity of an unknown lubricating oil.

36. One test is to note the time taken by a measured quantity of the oil under test to flow through an orifice in a container, and to compare this with the time taken for an equal quantity of oil of a known viscosity to complete the test. Another test can be made as follows: two similar glass vessels are filled with oils that are to be compared, until there is only a small space for air left at the top. After being sealed, the vessels are inverted and a note is taken of the time taken by the air bubbles in each vessel to rise to the top. The vessel in which the bubbles take *the least time* contains the oil of the *lower* viscosity.

Note: In each of these tests is is essential that the temperature of the oils should be the same.

LUBRICATION SYSTEMS

37. We shall now discuss lubrication systems, the components within the systems, and the precautions to be taken during servicing of the systems. We shall start by discussing pressure lubrication.

Pressure Lubrication

38. **General.** High speeds and high bearing loads have made 'force feed' of lubricant essential —firstly, to get the oil between the heavily loaded bearings, and secondly, to cause a high rate of flow to remove the heat generated. Where the heat generated is comparatively low and can be dissipated by suitable finning on the outside of the sump, the system is said to be 'wet sump'. This method cannot be used with high speed multi-cylinder engines where the heat generated is such that the oil must be passed through a heat exchanger or oil cooler. The system is then said to be a 'dry sump', the majority of the oil circulating from, and back to, a *separate* oil tank. In addition to the normal engine lubrication system, pressure oil can be directed to components such as the change speed mechanism of a two-speed supercharger or a constant speed propeller through a Constant Speed Unit (CSU) or a Manifold Air Pressure Control Unit (MAPCU).

39. **Wet sump system.** This system is used in the majority of light aircraft engines. A specified level of oil is maintained in the sump to supply the oil pump which is usually submerged in the oil and driven from the camshaft (Fig 1.5.1). Oil is supplied to the main journal bearings via a gallery pipe mounted in the crankcase. It reaches the crankpins via drillings down the crank webs, then out to lubricate the connecting rod big-end bearings, and then splashes onto the underside of the piston and the cylinder walls. Camshaft and rocker assemblies are often pressure and splash lubricated, usually at a reduced pressure. Finally, all the oil gravitates to the sump where it is filtered before going into the pump to repeat the process. A maximum possible pressure is controlled by a straightforward 'blow-off' type relief valve. This pressure is indicated either on a pressure gauge or by means of a tell-tale spring-loaded button or a lamp (which remains OFF when the pressure is satisfactory).

40. **Dry sump system.** The actual lubrication of the components in this system is the same as for the wet sump. The main difference between the two systems is that drainage oil going into the sump is scavenged by a separate pump called the scavenge pump and delivered to a separate oil tank and the oil cooler. To avoid any accumulation of oil in the sump, the scavenge pump has a greater capacity than the pressure pump. A dry sump lubrication system is illusstrated at Fig 1.5.2. In some instances, the hot scavenge oil is used to heat the carburettor intakes or throttle housings before it passes to the oil cooler.

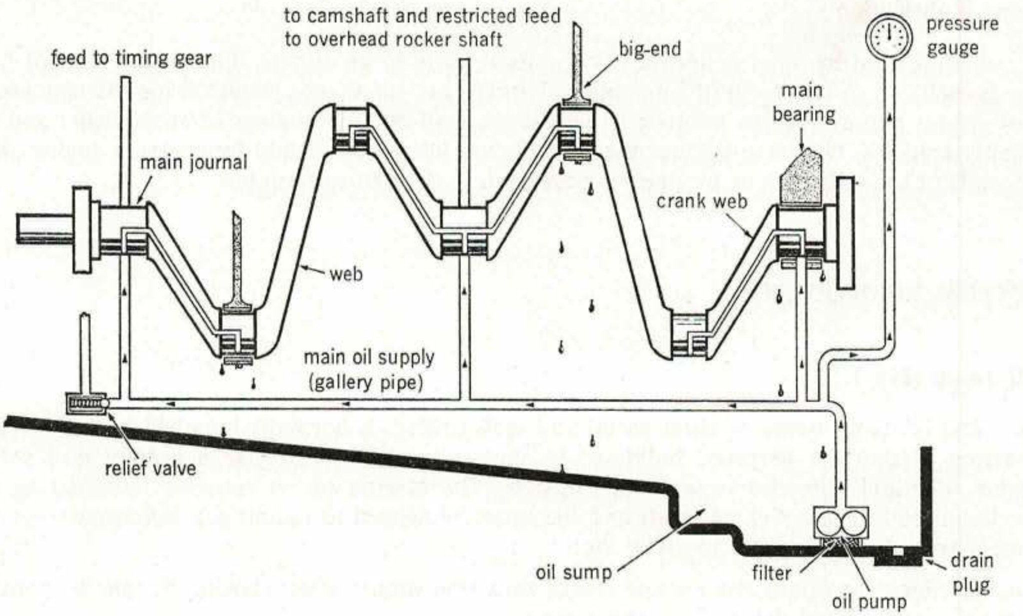

Fig 1.5.1 A wet sump lubrication system

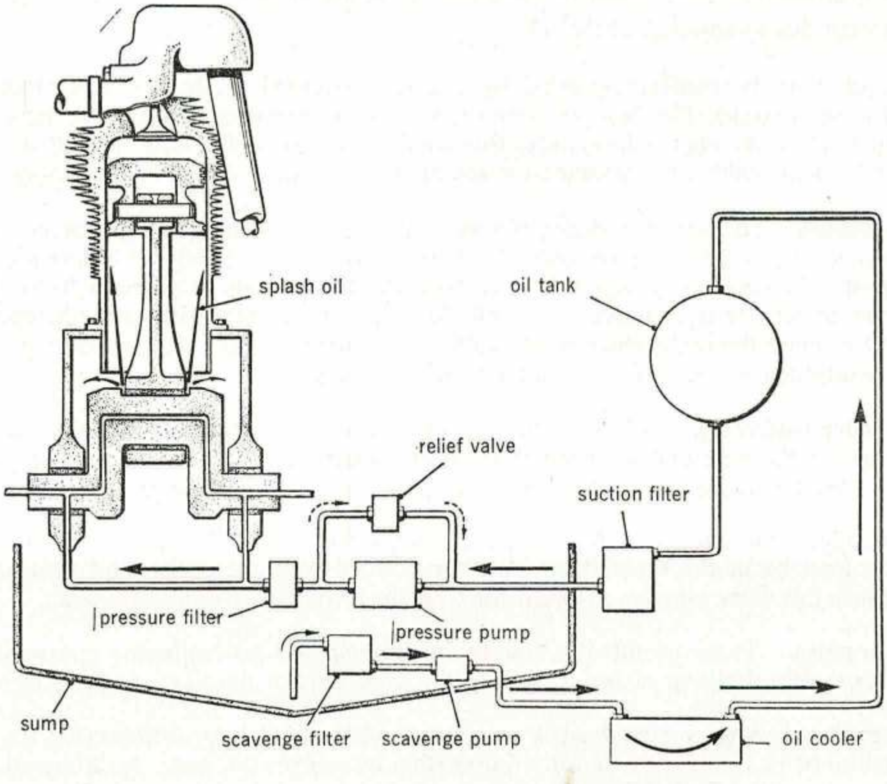

Fig 1.5.2 A dry sump lubrication system

Hand Lubrication

41. Lubrication by hand is necessary on certain parts of an engine. The engine control linkage is included in this form of lubrication. Nipples are sometimes provided for the attachment of a grease gun at various points on the linkage, and on the bearings of cross-shafts and the throttle spindles. On some engines the controls are lubricated simply by applying engine oil to the ends of the link rods or by smearing grease into the ball end joints.

SYSTEM COMPONENTS

Oil Tanks (Fig 1.5.3)

42. The oil tank, made of sheet metal and well baffled, is normally attached to the airframe structure behind the fireproof bulkhead in such a position as to give a gravity feed to the engine. The tank must be large enough to carry the reserve of oil required, considering the maximum endurance of the aircraft and the quantity needed to maintain a full circulation, yet must leave a large air space to allow for:

a. The increase above the normal return flow that occurs when starting the engine because of the accumulated drain oil in the sump.

b. The expansion of the oil due to increased temperature.

c. The displacement of oil from the propeller (variable pitch).

d. Frothing due to aeration of the oil.

43. The oil tank is usually supported by a cradle mounted in the airframe structure and secured by metal straps. The 'hot-pot' forms a separate compartment inside the tank (*see* Fig 1.5.3). On starting the engine from cold, this smaller section of the tank is used until heated return oil from the engine has warmed the remaining oil. This reduces the 'warm-up' time.

44. **De-aerator.** The scavenge return pumps of an engine with a dry sump system are always larger, and have greater pumping capacity, than the circulating pumps to ensure a dry sump. Consequently, the scavenge pumps return air with the oil and this produces a froth. The purpose of the de-aerator is to reduce the froth to a liquid, so increasing the efficiency of the cooler and keeping the tanks clear of oil froth. Oil spillage from the tank during excessive frothing is returned to the engine via the oil tank vent pipe.

45. **Propeller feathering.** When feathering propellers are fitted, the feed holes between the main section of the tank and the hot-pot are placed above the base of the tank to give a reserve of oil for feathering, even when the main tank has emptied through the normal outlet.

46. **Stack pipe.** A stack pipe in the sump reduces the tendency to circulate any sludge or water that may be in the tank. A gauze filter is fitted over the outlet, and it is usually so arranged that this filter may be removed for cleaning without removing the tank.

47. **Drain plugs.** These are fitted to both the tank sump and the feathering reserve section to allow for complete draining of the oil should the tank require flushing out for any reason.

48. **Oil content.** A graduated dipstick or a visual oil level indicator is fitted, and the oil filler cap is positioned in such a way that it is impossible to overfill the tank. An illustration of an oil tank is indicated at Fig 1.5.3.

49. **Servicing of oil tanks.** Oil systems and oil tanks get dirty with partly burnt, sticky oil sludge, and sometimes get contaminated with metal particles. The oil in the tank is heated and then drained through the drain plugs in the tank sump and the feathering reserve section. A flushing trolley, which is designed to flush and to scavenge the whole system at the same time, is used. This is a self-contained power driven unit on its own wheeled chassis; it has its own four stroke gasoline engine coupled to a reduction gear through a centrifugal clutch. The trolley supports a 100 gallon tank containing flushing oil together with flexible hoses and a pressure and scavenge pump.

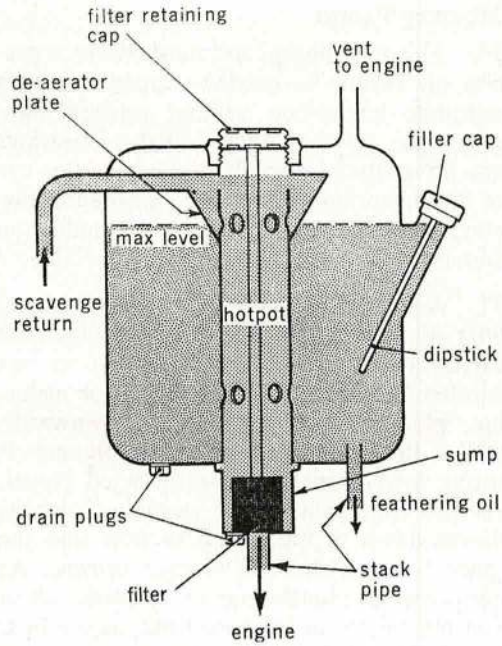

Fig 1.5.3 A typical oil tank

50. Replacement tanks are treated with inhibiting oil and must be thoroughly cleaned with gasoline before installation. The following precautions should be taken when replacing or fitting tanks:

a. Carefully examine the tanks for damage or cracks, especially at the seams.

b. Make sure that the packing under the straps is fitted correctly and that the tank is not rubbing against other components.

c. Do not overtighten the straps.

d. Tighten the pipe couplings carefully, using two spanners to avoid damage to the tank.

e. Check all sealing washers for serviceability.

f. Check all drain plugs, cocks, vents and unions for correct locking.

Engine Driven Pumps

51. **Spur gear type.** Both the pressure and the scavenge pumps are spur gear type pumps. A relief valve is fitted in the pressure pump to limit the maximum oil pressure in the system under varying conditions (*see* Fig 1.5.4). Sometimes a compound relief valve is fitted in the system to give different limiting pressures to separate engine components. The gears of the pumps are housed in close fitting chambers which allow the oil to be carried round by the gears when they rotate. The tips of the teeth are usually chamfered to relieve the pressure of the oil which is trapped between the gears where they mesh. As stated previously, the scavenge pump, having the greater capacity, is larger than the pressure pump.

52. **Servicing.** Spur gear pumps need little servicing. Loss of efficiency is shown by a decrease in oil pressure for a given engine speed and an increase in oil temperature. When this occurs, the pump should be removed for overhaul and a replacement should be fitted.

53. A replacement pump must be checked for freedom of rotation before fitment. Reference should always be made to the appropriate engine Air Publication prior to fitment. All pumps should be oil primed after fitting, and the pump which is removed should be inhibited and blanked off before being returned to the stores. An illustration of a spur gear type pump with a relief valve fitted is shown at Fig 1.5.4.

Metering Pumps

54. Metering pumps are used where a precise oil supply is needed—enough to give adequate lubrication without wasteful consumption. Supercharger impeller bearings are an example, the depression at the eye of the supercharger impeller tending to draw oil from the bearings into the induction system.

55. A light alloy casing is fitted with a steel liner to form a cylinder bore. The cylinder carries two plungers in opposition to one another (*see* Fig 1.5.5). The upper, or metering, plunger is spring loaded downwards, whilst the lower, or pumping plunger is spring loaded on to a cam operated tappet. As the cam rotates, the pumping plunger moves down to induce oil to flow into the space between the two plunger crowns. As the pumping plunger moves upwards, oil at first returns to the inlet feed but, as the inlet port is shut off, the remaining trapped oil moves upwards with the pumping plunger and the spring loaded metering plunger until the delivery port opens. The trapped oil is then discharged as the two plungers come together. The quantity of oil metered is altered by positioning the metering plunger in the cylinder to vary the amount of trapped oil. An example of a metering pump is illustrated at Fig 1.5.5.

56. **Servicing of metering pump.** If faulty operation is suspected, the pump delivery may be tested by disconnecting the delivery pipe and, with the engine running, checking the flow into a graduated measure. This test should be limited to the time specified in the engine Air Publication. The bearing fed with oil must be primed using a syringe after the test. When the pump output falls below the expected figures, the pump must be replaced. The pump should be examined for oil leaks at pipe unions and adjusting cap and also for insecurity of attachment. Make sure that the cap nut is locked.

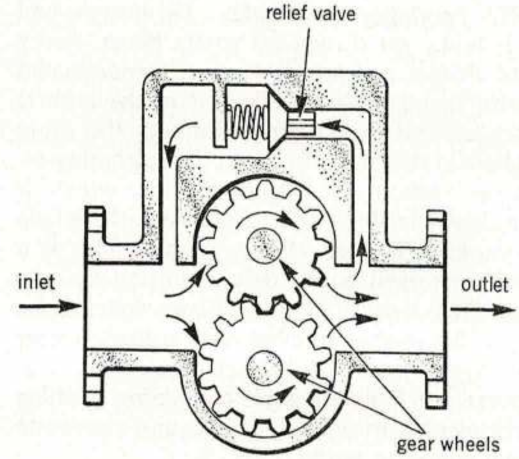

Fig 1.5.4 An oil pump with relief valve

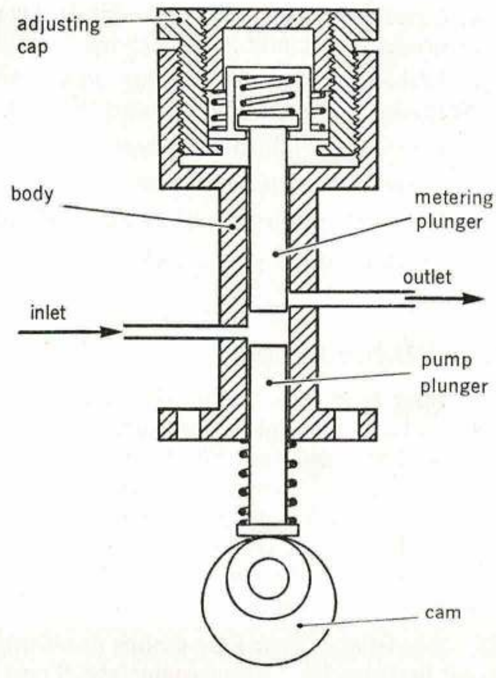

Fig 1.5.5 A metering pump

Relief Valves

57. Relief valves are included in oil systems to prevent the build-up of excessive pressures and to compensate for variations in oil flow caused by changes in engine speed or in the viscosity of the oil. Additional relief valves are sometimes fitted:

a. When an oil pressure, different from that of the main supply, is required to lubricate certain components of the engine.

b. Where the oil is led through the carburettor throttles, when too high an oil pressure, such as would occur when the oil is cold, may cause a leak at the oil seals on the butterfly spindles.

c. When an oil cooler is fitted in the system, to allow the oil, when above a certain pressure, to by-pass the oil cooler and flow direct to the tank. An example of a relief valve is illustrated at Fig 1.5.6.

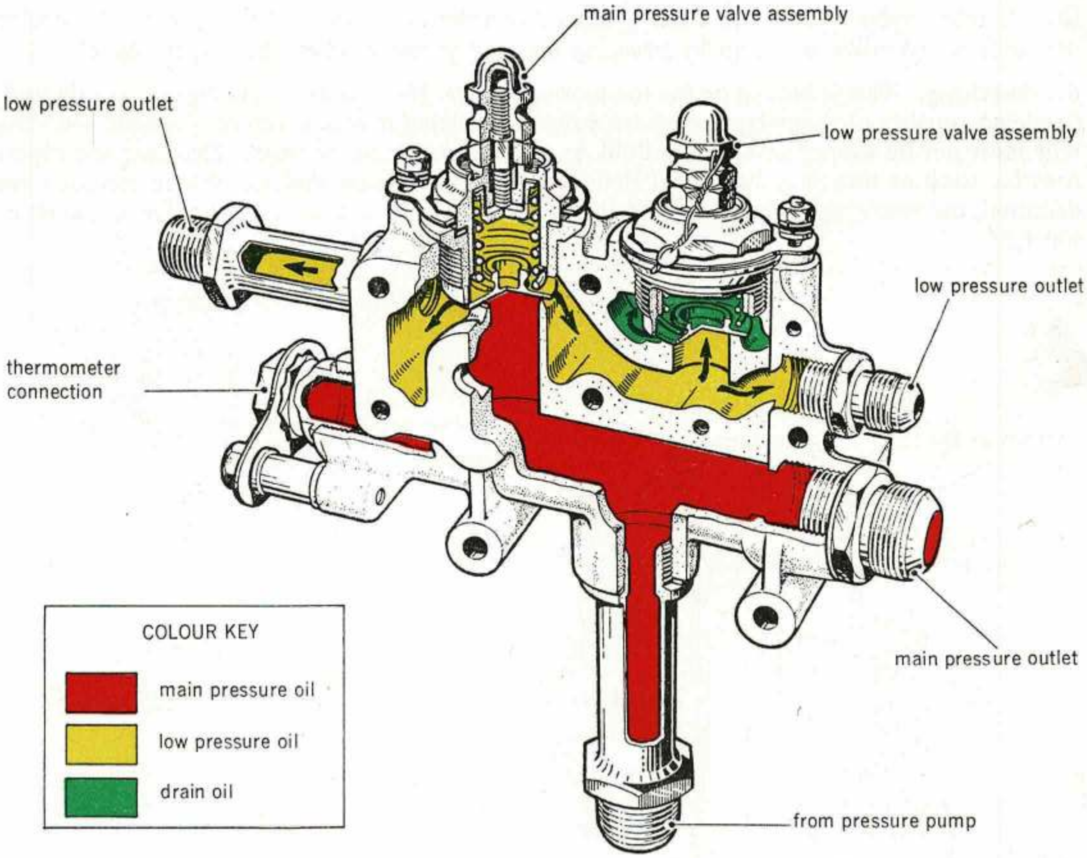

Fig 1.5.6 A relief valve

Thermostatic Valves

58. This valve is positioned in the oil system in the vicinity of the oil cooler, and its operation depends upon the temperature of the oil which is being expelled from the engine by the scavenge pump. At low temperatures, the valve allows this oil to continue in circulation without its passing through the matrix of the oil cooler. As the temperature of the oil rises, the thermostatic valve directs some of the oil through the cooler and continues to increase or decrease this flow according to variations in oil temperature.

59. The valve assembly consists of a spring-loaded sleeve valve, set in a casing with three ports: oil inlet, cooler outlet and a by-pass outlet (*see* Fig 1.5.7). The sleeve valve is actuated

by a thermal element. This is a cylinder carrying a piston with an extended rod. The cylinder is filled with wax. As the temperature of the oil rises, the wax melts and expands, forcing the piston and rod out of the cylinder (working thermostat). As the rod butts against the casing, the sleeve valve moves to open the port to the cooler.

60. A second thermal unit is fitted besides the normal unit (safety thermostat). Should wax leak past the seal of the normal unit, the tendency would be for the valve to open late or not at all, giving rise to abnormally high oil temperatures. The safety thermal unit operates at a higher temperature than the normal unit; thus, a higher minimum oil temperature indicates a fault in the normal thermal unit.

61. A relief valve is fitted to some types of thermostatic valves. This protects the cooler matrix from excessive pressures by releasing the high pressure oil to the by-pass outlet.

62. **Servicing.** This is limited on the thermostatic valve. No adjustments to the unit are allowed. Servicing consists of removing the sleeve valve and wiping it with a kerosene soaked rag. The unit must not be dipped in cleaning fluid, as the seals may be damaged. Examine the piston rods for truth as they may be bent if the sleeve valve has been sticking. Where the rods are distorted, the whole unit must be changed. An illustration of a thermostatic valve is shown at Fig 1.5.7.

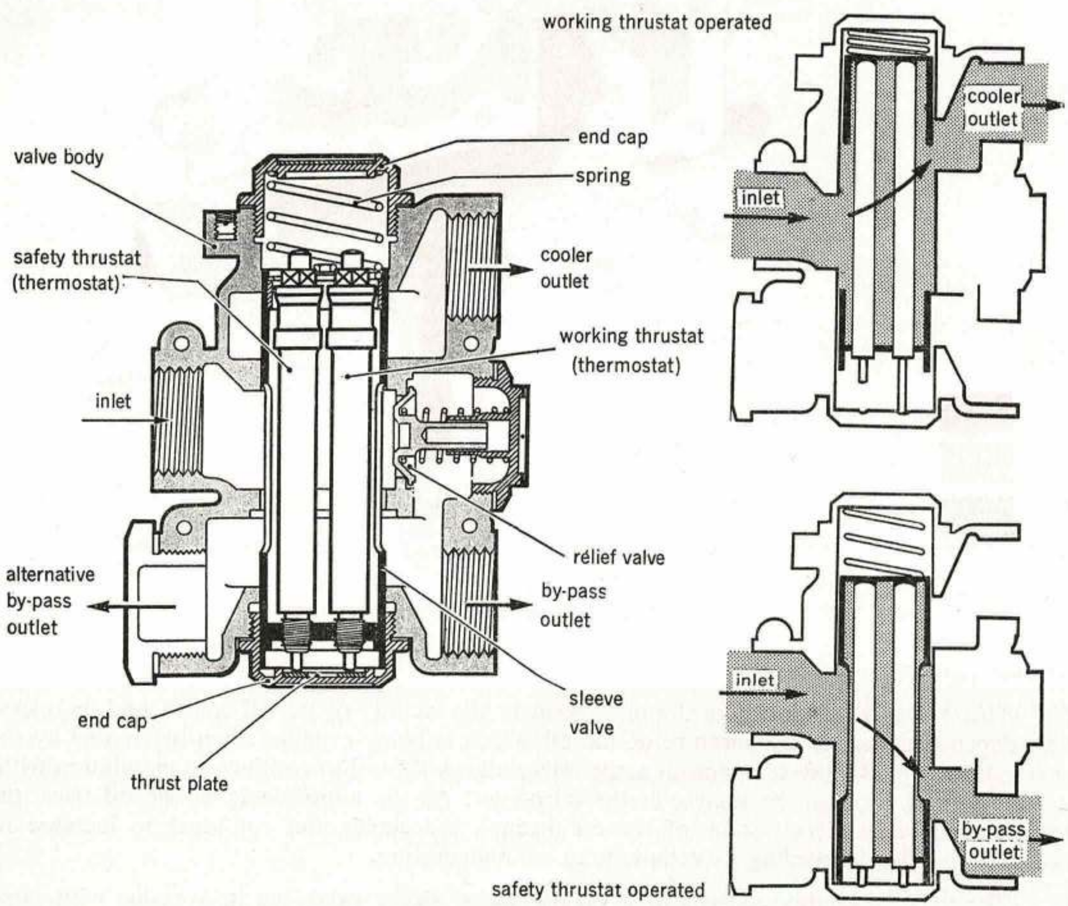

Fig 1.5.7 A thermostatic valve

Anti-surge Valve

63. The anti-surge valve is designed to protect the cooler matrix from high pressures when starting the engine under cold conditions. It performs three functions:

a. It limits the maximum pressure by by-passing excess oil flow directly to the tank.

b. Where the initial pressure is very high, it isolates the cooler and directs the full oil flow to the tank.

c. After the initial surge has dispersed, it acts as a relief valve until normal running conditions are attained, when the full flow of oil passes through the cooler.

64. The anti-surge valve consists of a casing with one inlet port and two outlet ports—one outlet port connecting to the oil cooler and other to the tank (*see* Fig 1.5.8). Enclosed in the casing is a double-headed valve; one head controls the flow to the cooler and the other controls flow to the tank. This valve is connected to a spring-loaded piston which is actuated by the pressure in the pipeline to the oil tank.

65. On starting the engine from cold, the initial oil pressure surge will overcome the spring loading on the by-pass valve, causing some of the oil to be directed to the tank. The resistance to the flow of the cold oil will then give a pressure rise to affect the underside of the anti-surge piston. As the effective area of the anti-surge piston is greater than that of the by-pass valve, the by-pass valve will open fully to close the cooler valve. The valve assembly will remain in this position until, as the oil warms, the resistance to flow falls, and the spring can overcome the pressure under the surge piston and the cooler valve. This will let the by-pass valve close and the cooler valve open, until a full flow is passing to the cooler. When this has occurred, the valve will act as a spring-loaded relief valve. An anti-surge valve is illustrated at Fig 1.5.8.

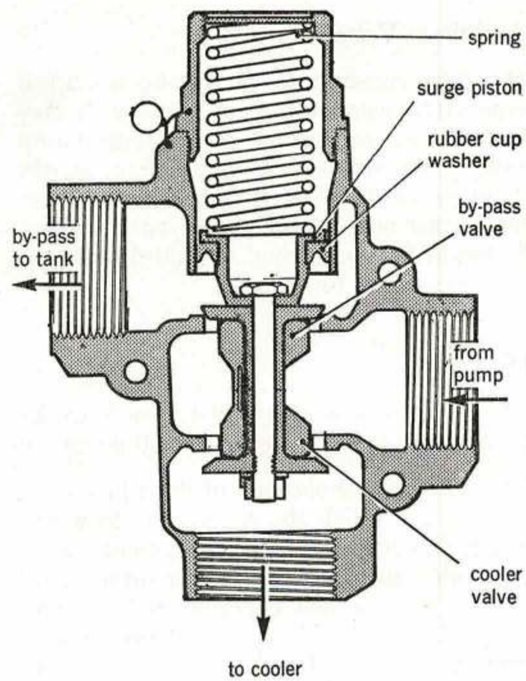

Fig 1.5.8 An anti-surge valve

66. **Servicing.** A faulty anti-surge valve may be serviced when a replacement is not available by stripping and cleaning as follows:

a. Remove the spring-loaded end cap (check on the number of shims under the cap).

b. Remove the central bolt of the valve assembly and withdraw the valves and piston.

c. Examine the valve faces, the valve seatings and the skirts of the piston for scoring and damage (no re-conditioning is permissible).

d. On assembly, fit the rubber seal to the piston with the cupped portion towards the tapered end.

e. Position the by-pass valve, assemble the valve, locate the cooler valve and secure the whole assembly into the valve casing with the central bolt.

f. Fit the correct number of shims into the cap nut and assemble with the spring to the valve housing. Lock the cap nut.

Non-return Valve

67. A non-return valve, illustrated at Fig 1.5.9, is normally fitted in the scavenge oil outlet union which is screwed into the main scavenge pump casing. The valve is operated by a calibrated coil spring which closes a conical valve when the engine stops. The valve is introduced to prevent surplus oil in the scavenge system from draining back into the engine when it is shut down.

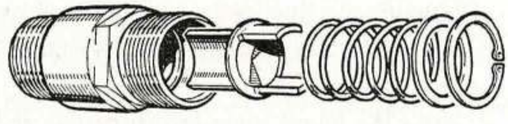

Fig 1.5.9 A non-return valve

Anti-drain Valve

68. The anti-drain valve is also a conical type valve operated by a coil spring. It may be fitted in the base of the pressure pump casing and serves to reduce the overnight drainage of oil from the aircraft tank into the engine and minimizes the possibility of hydraulic lock occurring. An anti-drain valve is illustrated at Fig 1.5.10.

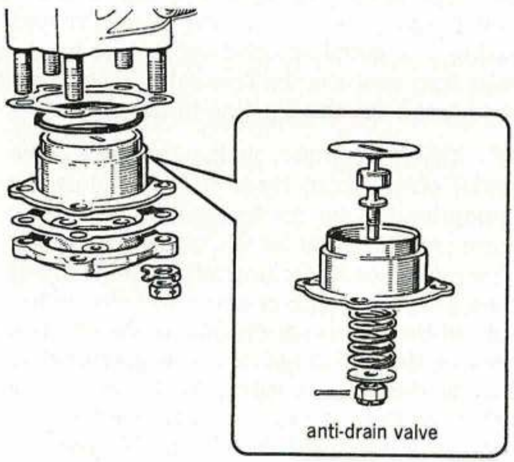

Fig 1.5.10 An anti-drain valve

Oil Cooler

69. The purpose of an oil cooler is to dissipate the excess heat absorbed by the oil in its passage through the engine and to control the maximum oil temperature.

70. The cooling capacity of the oil cooler must be sufficient to cater for many varying conditions under which the engine has to work. Under take-off and climb conditions, when the engine power is high and the forward speed of the aircraft is relatively low, there is the maximum amount of heat to extract from the oil with the minimum amount of air flow. When the aircraft has finished climbing and is operating under cruising conditions, the engine power output is less; less heat is produced and, therefore, less heat is absorbed by the oil. If the full cooling capacity of the cooler was still utilized, the oil would then be overcooled. Means must, therefore, be provided to maintain, as far as is possible, a steady temperature at the delivery side of the cooler no matter what the aircraft operating conditions may be. This is achieved by fitting the cooler in an air-duct facing the direction of flight, and controlling the amount of cooling air which is allowed to pass through the duct by a shutter. The control of the shutter is accomplished by means of the thermostatic valve operated by the oil temperature. Similarly, means must also be provided for the oil to by-pass the cooling elements when the oil is very cold (as for example, when starting the engine on a cold day), otherwise the cooler may burst due to excessive pressure. Damage can also be caused to an engine if it is opened up to high power whilst the oil is cold hence the reason for a relief valve already mentioned. As the initially cold oil heats up, it becomes more fluid, the pressure in the cooler drops, the relief valve progressively closes and circulation then continues through the main body of the cooler. An example of an oil cooler is illustrated in Fig 1.5.11.

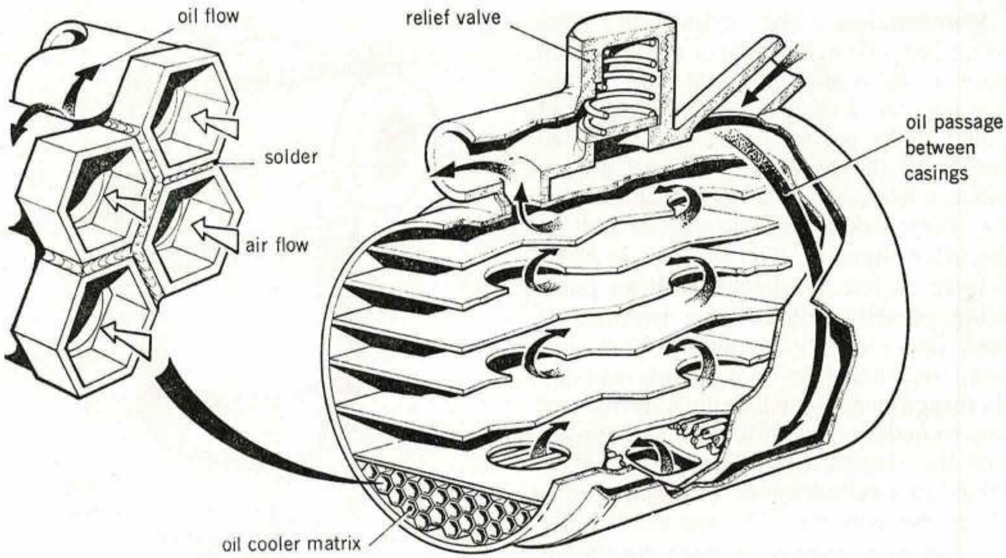

Fig 1.5.11 A sectioned oil cooler

71. **Servicing.** Apart from an examination of the cooler for leaks, insecurity of attachment, and making sure that the matrix is free from obstruction, the servicing of an oil cooler is limited. The cooler is returned to the manufacturers for repair or reconditioning normally at life expiry of the engine or when it is suspected that there are metal particles in the oil system.

Oil Filters

72. Although oil is filtered when it is poured into the aircraft oil tank, additional filters are always provided in the engine system. There are at least two of these, one of which filters the oil from the tank to the pressure pump, and the other the scavenge oil prior to its entry into the scavenge pump. The filters ensure that no foreign matter enters the gears of the pumps. In this respect, the filter in the oil return to the scavenge pump is of great importance. Any small particles from the interior of the engine will be trapped by this scavenge filter and, if an internal fault is suspected, valuable information is often gained by noting the condition of this filter; furthermore, any metal particles found in the filter, give an indication of the development of a serious internal fault. The identification of such metal particles is described in a later paragraph.

73. The majority of filters consist of a cylindrical chamber containing an element that can be readily withdrawn for cleaning purposes. The most common type of filter is made of wire gauze in the form of a cylinder which is attached to a metal frame or perforated tube to stiffen it and prevent collapse under pressure. The oil enters the filter chamber, passes through the gauze to the interior of the element, and any solid foreign matter is retained on the outside of the gauze. The oil is then led through the outlet duct or pipe connection of the filter.

74. As an example, the Vokes type filter illustrated at Fig 1.5.12 is representative of the standard type for use on aero-engine lubrication systems operating at normal pressures of up to 125 psi (8·6 bars). It is fitted with alternative connections for port or starboard mounting, with all components interchangeable, *ie* parts from the left-hand filter can be used in a right-hand filter, and *vice versa.*

75. **Construction.** The cylindrical filter chamber has a detachable head which is held in position by a sliding clamp ring. In the domed portion of the head is found the inlet and the outlet ports of the filter. On the underside of the head, a machined groove provides a seating for a large rubber ring which effects a joint with the lower portion of the filter chamber. The element is made of a layer of felt, reinforced with an outer covering of wire gauze. This material is crimped into a deeply corrugated form with the ends held together by a spring clip; the felt is turned over the wire gauze at top and bottom to make a seal with a felt pad at each end of the element. The fabric element is contained in a cylindrical brass cage which is closed by two end caps. The top cap is fitted with a tube which forms the entry for the oil into the element, and a bridge piece at the lower end anchors a bolt for the attachment of the bottom cap.

76. The whole element assembly is located in the outer casing by a large coil spring which holds the upper end of the inlet tube in position inside a central tubular spigot in the head, an inner oil tight joint being made with the head by a small rubber ring.

77. **Operation.** The filter is fitted in a pipeline with the inlet port facing the oil flow. The oil enters the inlet port in the head and is led through the tube attached to the top cover of the filter element into the interior of the filters. It then passes through the walls of the element to the outer casing and any impurities are retained on the inside of the element. The cleaned oil is returned from the outer casing through the outlet port in the head of the filter.

78. When the filter is clean, it offers only slight functional resistance to the flow of oil and the coil spring in the bottom of the outer casing maintains an oil-tight seal between the inlet tube on the top cap and the tubular spigot in the head. If the filter becomes choked, pressure builds up inside the element which overcomes the pressure of the spring and uncovers the slots in the inlet tube. A direct path is then established

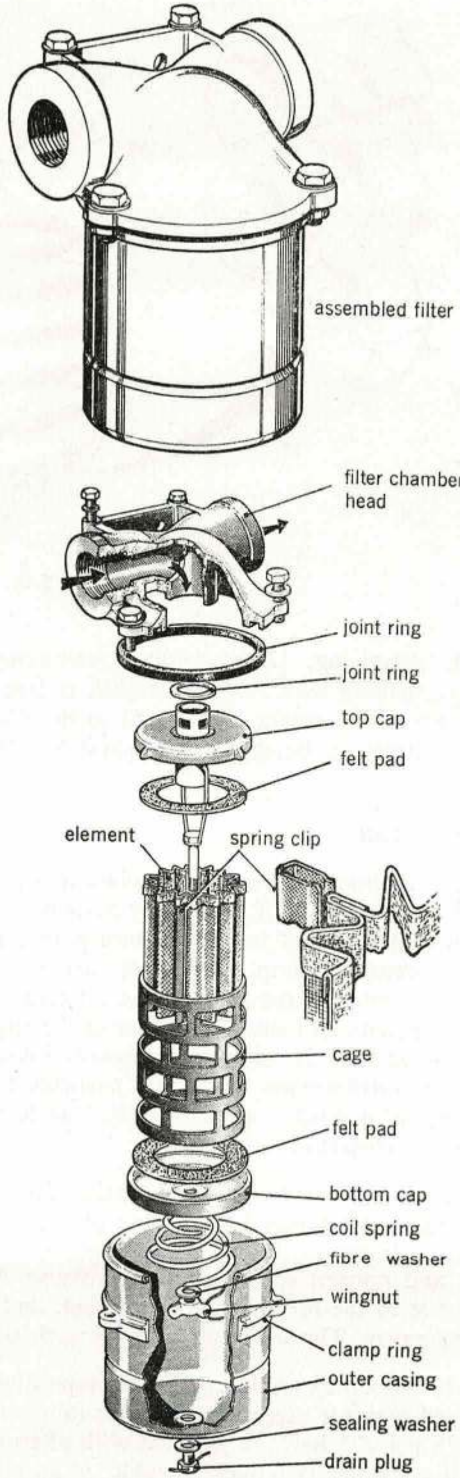

Fig 1.5.12 A Vokes oil filter

between the inlet and outlet ports, thus allowing the oil to by-pass the filter element and continue in circulation.

79. **Servicing.** When the element has been removed, it *must* be examined for metal particles *before* it is cleaned in gasoline. If damaged, or in any way faulty, it must be removed. The interior of the filter housing and the cap, together with any other parts must be thoroughly cleaned and examined after drying with compressed air. A stiff brush should be used for cleaning purposes. *Do not use cloth.* Sealing washers should be renewed. Make sure you tighten and lock the drain plug and that the clamp ring bolts are evenly tightened.

80. **Identification of metal particles.** Generally, if metal particles are found in a filter, this will mean an engine change, but the *identification* of the metal particles will assist those responsible for carrying out an investigation as to where the internal failure has occurred. *Do not destroy the evidence.* Advanced technology by means of spectro-analysis can now anticipate a failure *before* it occurs by subjecting the oil to special tests. After washing the particles, and by using a magnet to withdraw the ferrous metal, light alloy parts (magnesium alloy) can be identified by pouring a copper sulphate solution over the particles when effervescence will indicate their presence. Dural and aluminium may be identified by pouring a 10% solution of caustic soda over the particles—the duralumin will turn black and the aluminium will turn white. White metal can be identified by its flaky nature and bronze can be recognized by its distinctive colour.

Centrifugers

81. To prevent the formation of sludge deposits in the oilways and operating mechanisms of two-speed superchargers, centrifugers are sometimes employed in an oil circulation system. These are cylindrical casings, each made in two parts that are assembled either side of a gear which receives the drive. Each centrifuger is borne on a hollow spindle which passes through the axis of the unit and is supported at either end by a bracket. When in operation, one of the gears which drives the supercharger impeller, also meshes with the gear on the centrifuger, thus rotating it on its spindle at high speed. The oil from the pressure pump is led to the centrifuger through a duct in one end of the supporting bracket and into the hollow spindle from where it escapes into the interior of the centrifuger. The centrifuger action of the rotating unit causes the sludge to be separated from the oil and flung outwards and deposited on the outer walls of the centrifuger. The oil then leaves the centrifuger by a duct in the other end of the supporting bracket and passes to the control valve of the supercharger gear change.

Oil Dilution

82. Although oil dilution is not operative in piston engines in the Royal Air Force today, the facilities are built into the oil system to provide the need if required again. It will not be amiss to explain the system so that you are aware of its potential.

83. The primary purpose of diluting oil is to facilitate starting in cold weather. Other advantages are:

a. It allows the oil to flow more freely to the engine and lessens the risk of damage to pipelines and components by excessive high oil pressure during the warm-up period.

b. It has a cleansing effect and helps to keep the engine free from sludge.

84. The oil is diluted with fuel but there should be very little loss in lubrication efficiency as the fuel in the system will be vaporized within fifteen to thirty minutes of the engine starting. The oil dilution system consists of a fuel pipe connecting the outlet side of the fuel pump to the inlet side of the oil pressure pump. In this line there is a solenoid-operated valve. With the engine running, when the solenoid is energized, fuel may flow through a restrictor into the oil system. To limit dilution to the oil actually in circulation, a 'hot-pot' is fitted in the oil tank.

85. **Operation.** Before diluting the system, reference should always be made to the Engineering Orders and the relevant AP Volume 1, to find the dilution period. This will vary from one to four minutes according to expected atmospheric temperatures. The shortest period to give easy starting should always be used.

86. The oil tanks should be filled before dilution commences, otherwise the diluted oil in the hot-pot will be displaced. The oil temperature should also be allowed to drop sufficiently to prevent the added fuel evaporating. After the engine has cooled and the tank has been topped up, the engine should be run at approximately 1000 rev/min with an oil temperature of 10°C to 45°C. The dilution switch should be pressed for the dilution period, the engine being stopped in the normal manner before the switch is released.

87. After dilution the engine may be left for 2 or 3 days, even in cold weather, without the need for starting and warming up. An illustration of the oil dilution system is shown at Fig 1.5.13.

88. **Servicing.** Examine all pipelines for leaks and examine electrical connections for insecurity. To check the operation of the solenoid, operate the switch with the engine dead; the click of the valve should be heard.

89. As oil dilution has an internal cleansing effect on the engine, the scavenge filters should be examined at more frequent intervals when oil dilution is restarted.

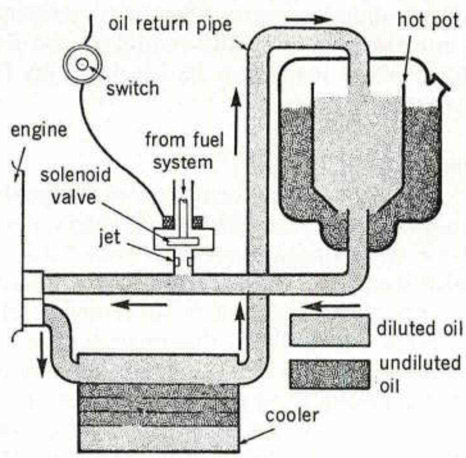

Fig 1.5.13 An oil dilution system

Summary

90. We have now discussed the purpose of a lubricant, its viscosity, its properties and why certain selected oils are used. We have also discussed the various components in typical systems, we have seen what they look like and why they are needed. We shall now consider the best way of applying this theoretical knowledge in order to maintain the engine in a serviceable condition.

91. The malfunction of oil system components are especially indicated through two visual aids in the cockpit: one is the oil pressure gauge and the other the oil temperature gauge. Serious damage may occur quickly through an oil pressure failure or through overheating of the system. The limitations for ground testing of engines laid down in the appropriate Air Publication, Volume 1 must be strictly adhered to. Normally with a rise in temperature, the oil pressure will decrease.

92. We shall now discuss some possible causes of oil system malfunction and indicate the remedy.

a. **Low Oil Pressure**

Possible Cause	Remedy
Insufficient oil in tank, or oil of unsuitable grade.	Check level of oil in tank, or refill with correct grade of oil.

Obstruction in oil pipeline, cracked or broken pipe or choked filters. Air leak on suction side of pressure filter.	Examine pipelines; carry out flow check. (A choked filter is the most common cause of low pressure.)
Relief valve dirty, sticking or not adjusted correctly.	The relief valve should not be adjusted until all other causes of low oil pressure have been investigated. Adjustment is usually effected by increasing the pressure on the spring, either by a screwed plug or by shims under the spring.
Faulty oil pump.	May be due to excessive diametric clearance between gears and pump body. This is a very remote possibility. The oil pump should be replaced.
Oil-pressure gauge defective.	Gauge may be under-reading or pipeline may be defective. Examine the pipeline, or check gauge with another gauge of known accuracy.
Excessive bearing clearances.	Increase in clearances may be due to wear or failure of the main or big-end bearings. The engine should be removed.
High oil temperature.	The oil is too thin, allowing excessive leakage from bearings.

b. **High Oil Pressure**

Possible Cause	Remedy
Incorrect setting of oil relief valve (oil cooler).	Adjust.
Incorrect grade of oil.	Refill with correct grade.
Faulty thermostatic valve (over-cooling).	Replace.
Insufficient bearing clearances.	Extended test bed running.

c. **Excessive Oil Consumption**

Possible Cause	Remedy
Wear on cylinder barrels or oil control rings. Wear on valve guides.	Recondition the engine.

d. **High Oil Temperature**

Possible Cause	Remedy
Insufficient oil in circulation, or incorrect grade.	Check oil contents, or fill with correct grade of oil.
Thermostatic valve faulty (under-cooling)	Replace.
Oil cooler shutters not opening sufficiently.	Check and reset where necessary.
Oil cooler matrix obstructed.	Clean matrix.
Oil temperature gauge defective.	Gauge may be over-reading. Check the gauge with another gauge of known accuracy.

Conclusion

93. Replenishment of the oil system and the precautions to be taken are contained in STTN AP3279A, Chapter 4, Section 8, and engine oil priming is explained in Chapter 7, Section 5 of the above Publication. Information on inhibiting and storage of aero-engines is contained in AP4471A, Volume 1, Part 2 and also in the AP100 series.

94. Once again:

- The importance of cleanliness is stressed, particularly in the use of equipment.
- It is vital to use the correct grade of oil.
- Before making any adjustments, refer to the appropriate Engine Air Publication, Volume 1.