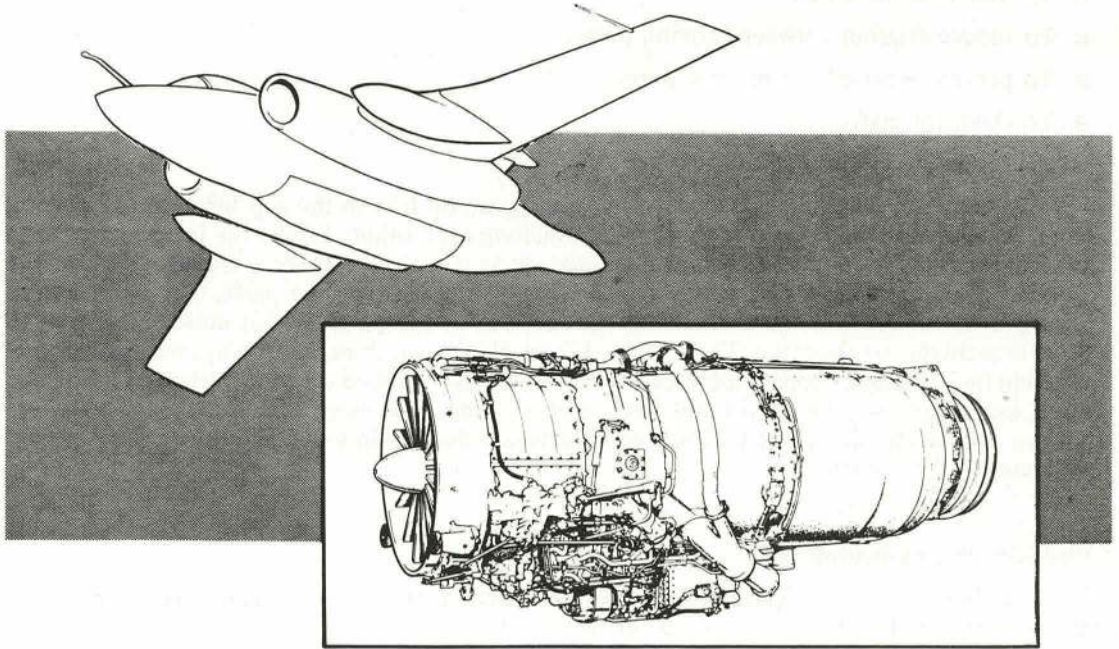


## CHAPTER 2

# LUBRICATING OILS



### Introduction

1. When two parts are rubbed together, there is a resistance to their relative movement by a force called friction. The frictional force may be defined as the resistance to movement that is felt when one surface is moved across another surface. Resistance to movement, or friction, can generate heat and cause a considerable amount of wear to occur between the parts. The amount of friction generated depends upon the standard of the surface finish, the material from which the parts are manufactured, their relative operating speed, and the surface loading. Some materials, when rubbed together, produce more friction than others; and all materials produce less friction when a wetting agent (lubricant) is introduced between the moving surfaces.

2. Friction is always generated when two surfaces are rubbed together. Even smooth surfaces exhibit minute cavities depressions and projections, when viewed under a microscope. The relative motion causes the projections and cavities to catch on each other, and even at low speeds the movement can generate intense local heating, leading to local welding and damage to the surfaces. At higher surface speeds, and over longer periods, intense heating of the entire surface may develop, and cause expansion and subsequent deformation of the surface to occur. In extreme cases, large surface areas may be melted by the heat, causing them to weld together and seize. The introduction of a lubricant will maintain slippery surfaces between the moving parts, and allow them to slide easily over each other.

## LUBRICATION THEORY

### The Function of a Lubricant

3. A lubricant is essential for the efficient operation of an aero-engine, and its associated components. The main functions of a lubricant are:

- To lubricate the parts.
- To reduce friction between moving parts.
- To prevent wear of the moving parts.
- To clean the parts.
- To act as a cooling medium.

4. A lubricating oil fulfils its function by forming an oil film in the gap between the moving parts, which effectively prevents them from touching each other. Whilst the introduction of a lubricant reduces the frictional forces generated, there will always be some friction, because the lubricating oil introduces what is known as viscous drag between the parts. The viscous drag is created by an oil film that adheres to the surfaces of the parts, which must be sheared to allow movement to take place. The frictional force, or viscous drag, will always be considerably less than the frictional forces generated when two parts are rubbed together without a lubricant. Thus, movement may be continuous when a lubricating oil is used, and because the parts are not touching each other there will be a considerable reduction in wear, and the amount of heat generated will be small.

### Viscosity of Lubricating Oils

5. The viscosity of a lubricating oil is its most important characteristic. There are two methods used to determine the viscosity of an oil, which are:

- Dynamic viscosity.
- Kinematic viscosity.

6. **Dynamic viscosity.** The dynamic viscosity, or coefficient of viscosity of an oil may be defined in general terms as the force required to overcome the resistance of the oil to deformation or shear. It is commonly known as the 'thickness' or the 'body' of an oil. Normally, a thin oil which runs freely has a low viscosity, and a thick oil that is difficult to pour from an oil container has a high viscosity. The inclusion of additives in some oils has given them 'easy flow' characteristics, whilst film strengths have been increased.

7. **Kinematic viscosity.** The viscosity of a lubricating oil used in the RAF is usually specified in terms of its kinematic viscosity. It is derived by dividing the dynamic viscosity of an oil by its density, both of which must be at the same temperature.

8. The effect that the viscosity of a lubricating oil has on the frictional forces generated by the oil is illustrated by Fig 4.2.1. In this illustration, two plates are placed in close proximity to each other, and the gap between the plates filled with an oil. Imagine plate A to be moving, whilst plate B is stationary. The oil in immediate contact with the plates does not move in relation to them, but slipping does occur in the main body of the oil. Now imagine that the oil is made up of a very large number of very thin layers of oil; the oil which is attached to plate B will be stationary, whilst the oil attached to plate A will be moving at the same velocity as the plate. The intermediate layers of oil will move at velocities which are proportional to the amount of slip that has taken place between each layer. The work done in moving plate A in relation to plate B is expended in overcoming the viscous drag (frictional forces) between the thin layers of oil within the body of the oil.

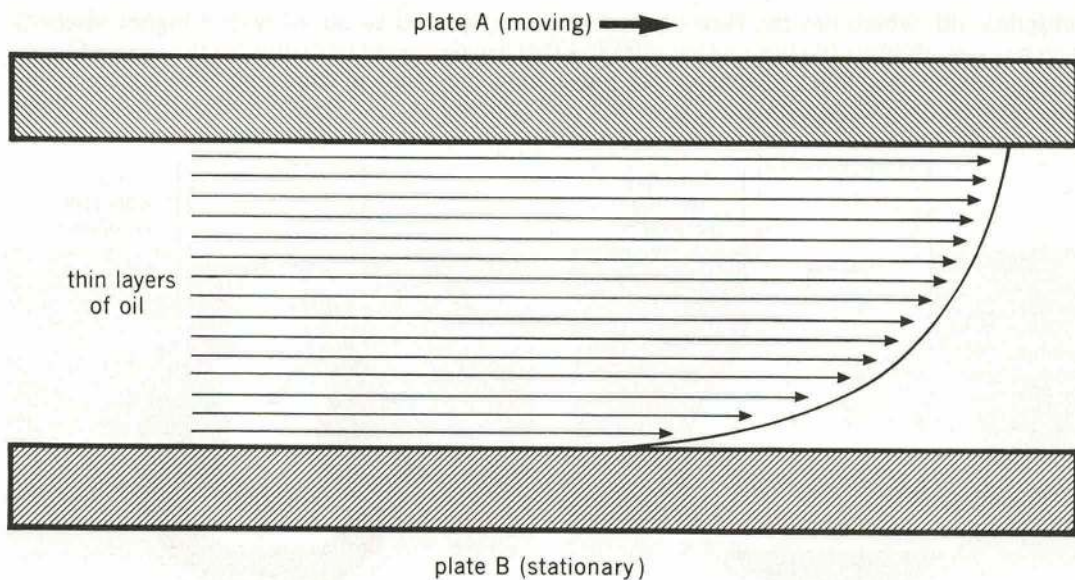


Fig 4.2.1 Lubricating oil friction

9. **Determination of viscosity.** The viscosity of an oil is determined by passing oil that has been heated to a specified temperature, through an orifice of a given size, for a given time. The quantity of oil that has passed through the orifice is measured, and the kinematic viscosity calculated in  $\text{mm}^2/\text{s}$  (centistokes). The viscosity of an aero engine lubricating oil is usually stated at specific temperatures, depending upon the specification requirement. For some oils, the viscosity may be stated at more than one temperature. An example of the viscosity characteristics of OIL OX-26 are as follows:

Viscosity at  $204.4^\circ\text{C}$  min  $1.3 \text{ mm}^2/\text{s}$

Viscosity at  $99^\circ\text{C}$  max  $5.5 \text{ mm}^2/\text{s}$

Viscosity at  $38^\circ\text{C}$  min  $25.00 \text{ mm}^2/\text{s}$

Viscosity at  $-40^\circ\text{C}$  max  $13,000 \text{ mm}^2/\text{s}$ .

10. **Oiliness.** When a lubricating oil reduces the friction produced in a bearing to a lower value than that produced by another oil of similar viscosity, the oil is said to have a greater 'oiliness' than the original oil.

### The Effect of Temperature

11. Lubricating oils react in different ways when heated; some oils exhibit little change in viscosity, whereas others show a considerable change. Good quality oils tend to exhibit a smaller change in viscosity than others when heated. It is particularly important to select the correct grade of oil for use in a lubrication system if a change in temperature is likely to occur, because of the resulting change in viscosity that can take place. For this reason, the operating temperature of the system must be known before the selection can be made. A thick oil, with a high viscosity, will protect heavily loaded parts once it is circulating around the system, but when it is cold such an oil will not flow quickly, causing wear to take place due to oil starvation. On the other hand, a thin oil with a low viscosity, will flow quickly to all parts of the system, and give good initial lubrication to the parts when the oil is cold. Such an oil, however, does not have the film strength that is necessary to protect heavily loaded surfaces or bearings when the oil is hot, because the oil film is not strong enough to keep the bearing surfaces apart. A

multigrade oil, which has the flow characteristics equivalent to an oil with a higher viscosity when it is hot, exhibits the lubrication qualities that are necessary to overcome this type of lubrication problem. Fig 4.2.2 illustrates the lubrication qualities of thick and thin grades of oil when used in cold conditions.

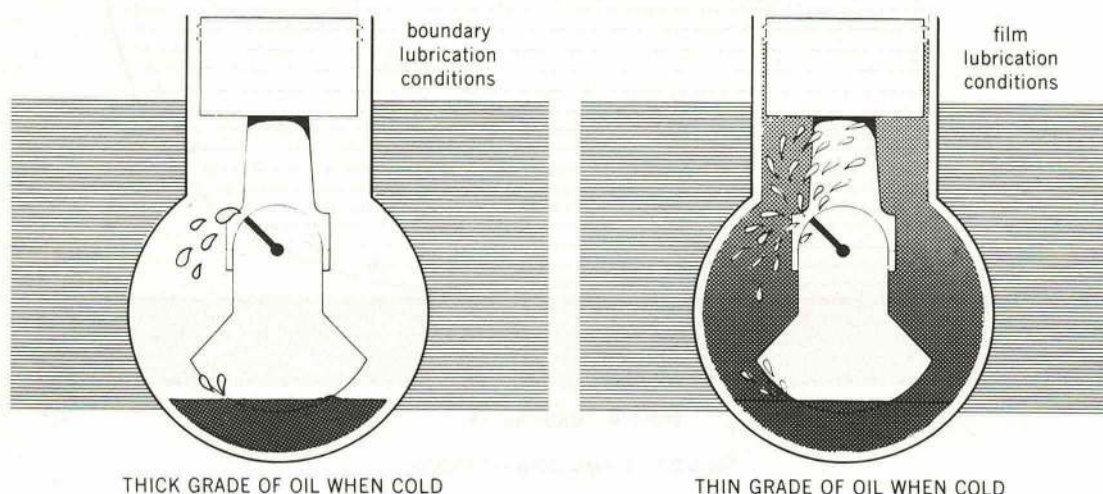


Fig 4.2.2 The effect of temperature upon lubricating oil

12. **Viscosity index.** The viscosity index (VI) is an empirical number which has been devised to assess the change in the viscosity of an oil with changes in temperature. High index numbers represent small changes in the viscosity with temperature, whilst low numbers represent a large change in the viscosity.

13. The VI of a lubricating oil is determined by comparing its viscosity with the viscosity of a 'bad' oil having a VI of 100; both of which have the same viscosity as the sample at 100°C.

14. **Pour point.** It has been stated earlier in the Chapter that the viscosity of an oil decreases as its temperature increases. The 'pour point' of an oil identifies the temperature at which free oil flow commences, and may be defined as the temperature that an oil moves visibly in a 30 mm diameter test tube, held horizontally for a period of five seconds.

### Phases of Lubrication

15. There are two distinct phases in the lubrication process, which are:

- Film lubrication.
- Boundary lubrication.

16. **Film lubrication.** Film lubrication is the most common phase of lubrication. It occurs when rubbing surfaces are supplied with a large quantity of oil, which creates a relatively thick layer of oil (up to 100,000 oil molecules in thickness) between the surfaces to be lubricated, and has the effect of keeping the surfaces apart. Under film lubrication conditions, the coefficient of friction is very small, and could be as low as 0.001.

17. The lubrication of a simple bearing, such as one that supports a rotating shaft, is a good example of the application of film lubrication. (Fig 4.2.3). The rotating shaft carries oil around with it by adhesion, and successive layers of oil are carried along by fluid friction. As the shaft rotates, it moves off-centre, resulting in a narrow wedge of oil within which the pressure increases as the wedge narrows. For efficient lubrication, this wedge, and the resulting increase

of pressure, is essential to keep the surfaces apart. If the steady increase of pressure in the bearing breaks down, efficient film lubrication ceases, and boundary lubrication conditions commence.

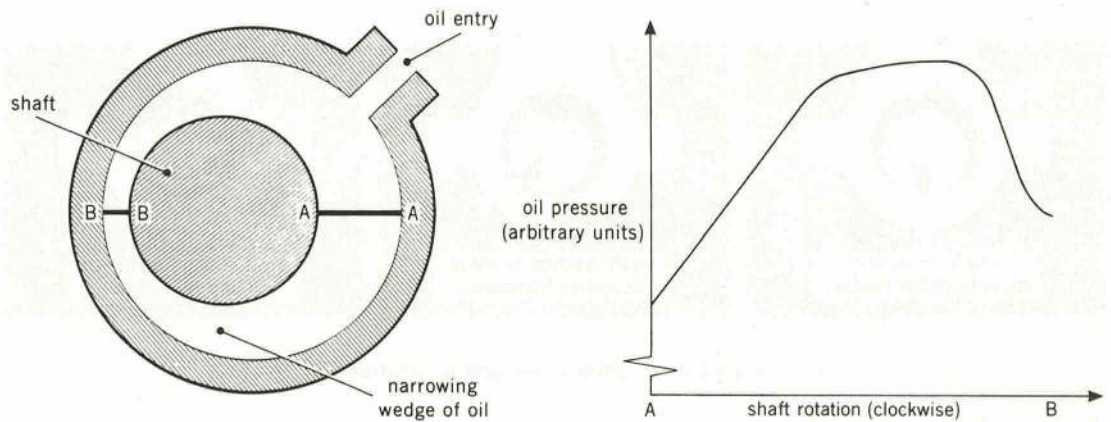


Fig 4.2.3 Shaft lubrication

18. In film lubrication, viscosity is a very important factor in the lubrication process, because it is the viscosity that controls the ability of the oil to keep the surfaces apart. A shaft revolving at high speed in a bearing must be free to carry oil around with it, with as little drag as possible. The rapid movement of one layer of oil slipping over another, with a minimum amount of drag, can only be achieved with a low viscosity oil. As the rotational speed of the shaft decreases, the rate of deformation of the oil and its associated drag will decrease. Consequently, an oil with a higher viscosity may be needed if it is to be carried around the bearing surfaces successfully.

19. The running temperature of a bearing is equally as important as its speed of rotation, because it is its temperature that determines the viscosity of the oil that must be used. Bearing temperatures can vary over a wide operating range, hence the need for lubricating oils to have a high viscosity index.

20. **Boundary lubrication.** If a shaft carries an appreciable load, and rotates very slowly in a bearing, it will not carry sufficient oil around the bearing to form a continuous film of oil. Under such conditions, boundary lubrication will occur, in which the bearing friction is many times greater than with film lubrication.

21. Boundary lubrication is said to exist when the oil film is exceedingly thin (perhaps less than  $10^{-6}$ mm), and may only consist of a very few layers of oil molecules. It occurs due to high bearing loads, inadequate viscosity (possibly due to excessive bearing temperatures) oil starvation or loss of oil pressure. The friction is independent of the viscosity of the oil, but depends upon the bearing load and the oiliness of the lubricant. It is thought that the reduction in friction is achieved by the fatty acids in the oil combining chemically with the bearing metal to form a 'soap', which creates a boundary layer between the thin oil film and the bearing material to protect the metals from welding together.

22. Boundary lubrication is not a desirable phase of lubrication, as rupture of the thin film allows wear to occur, a very high surface temperature, and possible seizure of the lubricated part. Therefore, lubrication is usually designed to be hydro-dynamic (film), if at all possible. However, boundary lubrication often occurs during engine starting, and may occur in piston engines at the end of the reciprocating strokes. There is no precise division between boundary

and film lubrication, although each is quite distinct in the way that the lubrication process is achieved. In practice, both phases of lubrication occur during the lubrication cycle giving a mixture of film and boundary lubrication conditions. Fig 4.2.4 gives an example of the application of boundary and film lubrication conditions.

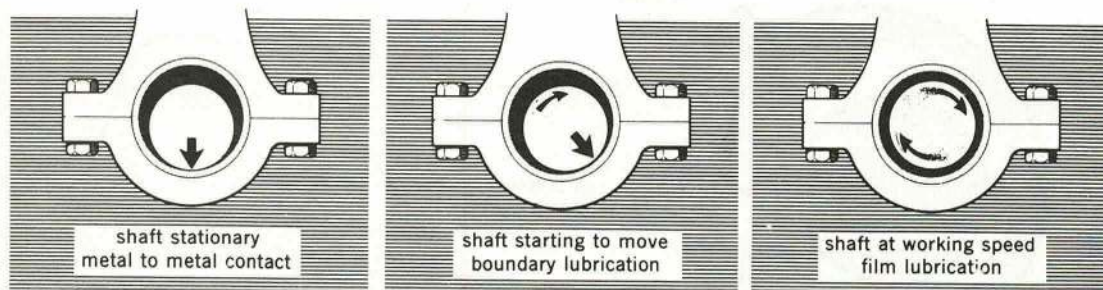


Fig 4.2.4 Boundary and film lubrication

### Types of Lubricating Oil

23. Lubricating oils are manufactured from various base materials, which fall into three distinct groups. These are:

- Mineral oils.
- Vegetable oils.
- Synthetic oils.

24. **Mineral oils.** These oils are produced from various types of crude oil extracted from beneath the surface of the earth. The oil is usually separated from the crude oil by a vacuum distillation process, or alternatively, a low temperature filtration process may be used. Mineral oils have many different uses on modern aircraft and engines, some examples of which are listed below:

- Turbine engine lubricating oil.
- Piston engine lubricating oil.
- Hydraulic fluid.
- Electrical insulating oil.

25. **Vegetable oils.** These oils, such as cotton oil and castor oil, are not used in their basic form on military aircraft for lubrication purposes.

26. **Synthetic oils.** Synthetic oils are obtained from various sources of fatty acids having a mineral or vegetable base. Due to the distillation process, or modifying additives used during the manufacture of synthetic oils, they do not fit into the specifications for either of the other basic groups of oils. There are many applications for synthetic oils, some of which are as follows:

- Turbine engine lubricating oil.
- Hydraulic fluid.
- Undercarriage shock-absorbing fluid.
- Aircraft instrument and electronic equipment cleaning and lubricating oil.

### Colour of Oils

27. The colour of an oil is not in itself a positive means of identifying it. Oils which have

identical properties, may be entirely different in their colour due to the origin of the materials from which they were manufactured. The origin, the methods, and the extent of refining a crude oil can have a bearing on the colour, hence its colour should not be used as a means of identification. However, all oils should appear to be clear and bright when they are in good condition.

### **The Properties and Selection of an Oil**

28. **Properties of an oil.** The properties that a lubricant must possess are decided upon for each lubrication task. The properties include:

- It must wet the surfaces to be lubricated.
- Not evaporate excessively in service.
- Not cause damage to any material that it must come in contact with during the lubrication process.
- Does not have a tendency to deposit gum, varnish, sludge, or any other material which may interfere with the lubrication process.
- Good pumpability.
- Be chemically stable under all service conditions.
- High viscosity index.
- Conform to all specification requirements.

29. In addition to the properties specified in the previous paragraph, a lubricating oil is often required to carry heat away from engine parts, to protect the internal surfaces of an engine against corrosive substances, and to perform many other special duties. To ensure that lubricating oils possess the required properties, specifications are issued, to which the oils must conform.

30. **Selection of an oil.** Before a lubricating oil can be selected for a given task, the lubrication requirement must be identified, which may include the following factors:

- Bearing load.
- Bearing clearances.
- Sliding speeds.
- Oil pump capacity.
- Operating temperature range.
- Rotational speed.

### **Lubricating Oil Additives**

31. A lubricating oil additive can be defined as a substance that is added to a lubricating oil in small quantities, to give the oil some desirable property, or properties, which it would not otherwise possess. There are various types of additive used in modern lubricating oils, which include the following:

- Detergent additives.
- Anti-corrosive additives.
- Extreme pressure additives.

32. **Detergent additives.** Detergent additives are added to a lubricating oil to keep the internal parts of components and lubrication systems clean. The additives do not prevent the formation of sludge and other contaminants in the oil, but they do keep the sludge in suspension, and reduce the tendency for it to accumulate in piston ring grooves, oil pipes, and other small oilways. The additives help to prevent such problems as piston rings sticking in their grooves, and oil starvation due to blocked oilways.

33. **Anti-corrosive additives.** Anti-corrosive additives are generally added to a lubricating oil to protect some particular part of a component from corrosion, such as piston engine bearings.

An anti-corrosive additive should not be confused with inhibitors, which are sometimes added to lubricating oils to slow down the formation of oxidation products in the oil.

34. **Extreme pressure additives.** Lubricants containing an extreme pressure additive may be described as those which are designed to operate under extreme pressure conditions. They appear to work in the same way as a fatty acid, in that they combine chemically with the surface of the bearing metal to be lubricated. Extreme pressure additives are used to lubricate heavily loaded gear trains, such as those fitted to helicopter gearboxes, and many hypoid gears fitted to motor vehicle transmissions.

### Contamination of Lubricating Oils

35. Lubricating oils are susceptible to contamination by various contaminants, which may include the following:

- Water.
- Solids, such as rust and dust particles.
- Other lubricating oils.
- Lighter petroleum fractions, such as gasoline and kerosene.
- Heavier petroleum fractions, such as heavy fuel oils and asphalts.
- Dirty oil dispensing equipment.

36. **Contamination with water.** Contamination of a lubricating oil with water can occur at any stage during handling or storage. When an oil has become contaminated with water, the water may separate out from the oil and settle to the bottom of the oil container, or it may remain in suspension in the oil. If the water does remain in suspension, the oil will have a misty appearance, rather than a clear bright appearance that a good clean oil exhibits. Contaminated oil must not be used, and clean oil should not be stored with oil known to contain water.

37. The presence of water in a lubricating oil may have the following effects on the lubricated parts:

- Lead to total breakdown of an engine lubrication system.
- Cause additives to separate out from the oil.
- Cause frothing of an engine lubricating oil with consequent losses of oil through the engine breathing system.
- Lead to an emulsion of oil and water, when the oil contains certain additives.

38. **Contamination with solids.** The usual solid oil contaminants to be found in a lubricating oil are rust and dust particles, which frequently remain in suspension in the oil. Solids can be removed from lubricating oils by careful filtration, but it is a very slow process because of the viscous nature of the oil, and should only be carried out by specialists in this field. Contamination of oil by solids can lead to a failure of lubrication due to blocked oilways, particularly when close tolerance components such as ball and roller bearings are used. A clean supply of oil is therefore essential, if damage to precision ground surfaces is to be prevented.

39. **Contamination by other lubricating oils.** The contamination of a lubricating oil by another oil may be very difficult to detect, because the viscosity of the oil may be similar to the viscosity of the contaminant. In cases where it is suspected that an oil has been contaminated by another oil, it must not be used until its viscosity, viscosity index, pour point, and inclusion of additives has been checked, and proved to be within the specification. The con-

tamination of a lubricating oil by another oil can have a detrimental effect on the lubrication qualities of the oil, depending upon the type of contaminant, and the degree of contamination. For example, an oil may not have additives included in its composition, whereas a contaminating oil may include additives, which could cause damage to the lubricated parts.

40. **Contamination by lighter petroleum fractions.** Contamination of a lubricating oil by lighter petroleum fractions, such as kerosene and gasoline, can cause a decrease in the viscosity of the oil. If the contamination is of sufficient strength to cause a permanent reduction in viscosity, it will lead to a fall in the lubrication qualities of the oil, which could result in seizure of the lubricated parts. Gasoline, being a more volatile fuel, is a less serious engine oil contaminant in this respect than kerosene, because it evaporates completely when the engine oil is warmed up. Contamination by lighter petroleum fractions may be detected by checking the flash point of the oil, or by verifying its viscosity.

41. **Contamination by higher petroleum fractions.** Lubricating oil is unlikely to be contaminated by heavy fuel oils, soft asphalts etc, but if it were to occur it would be highly undesirable and dangerous.

42. **Contamination by dispensing and storage equipment.** Contamination of a lubricating oil can easily occur when it is transferred from a storage container or receptacle, to another store, or for use in an engine or component. Cleanliness is of the utmost importance when handling lubricating oils, and hence the following points should always be remembered:

- Always check to see that the seal is intact on new containers, before they are opened for use.
- All oil containers, storage installations and dispensers, must be clearly marked with their contents.
- All containers, receptacles, and dispensers must be kept scrupulously clean, and examined for cleanliness before use.
- All pipes and orifices must be fitted with approved blanks when not in use.

#### **Identification of Lubricating Oils**

43. Lubricating oils are identified for service use by the Joint Service Designation allocated to the oil. The designation consists of either two or three letters, followed by a number having one, two or three digits. The letters denote the type of oil to which they refer, and the number to the approximate viscosity in mm<sup>2</sup>/s (centistokes) at a prescribed temperature (usually 40°C). For example, oil OM-33 identifies a mineral oil with an approximate viscosity of 33 mm<sup>2</sup>/s at 40°C.

44. The Joint Service Designation letters allocated to the various types of lubricating oil used on military aircraft are:

- **OEP—Oil Extreme Pressure**—An oil containing additives which enables it to withstand extreme gear tooth pressures.
- **OF—Oil Fatty**—A plain fatty oil or a fatty oil plus solvent.
- **OM—Oil Mineral**—A plain mineral oil, or one containing additives which are intended to improve its behaviour without conferring radically different properties to the oil (eg by lowering the pour point of the oil).
- **OMD—Oil Mineral Detergent**—A heavy duty internal combustion engine oil containing detergent (or dispersant) additives.
- **OX—Oil Miscellaneous**—A synthetic or mineral oil containing modifying additives not covered by the designations OEP and OMD.

Joint Service Designation markings are to be found on all lubricating oil containers. Some examples of which are shown in Table 4.2.1.

### NATO Code Numbers

45. Some lubricating oils are identified by a NATO Code Number issued by the Military Agency for Standardization. These oils are standardized products which may be used within NATO for similar approved aircraft applications. The code number consists of an index letter, followed by a number having one, two or three digits. Table 4.2.1 gives some examples of lubricating oils for which a NATO code number has been issued.

TABLE 4.2.1 Examples of lubricating oils

NATO CODE NO	JOINT SERVICES DESIGNATION	SERVICE USE	REMARKS
0-136	OEP-71	Aircraft turbine engines and gearboxes.	Contains an extreme pressure additive.
—	OEP-215	Helicopter gearboxes.	Contains an extreme pressure additive, and pour point depressant.
0-128	OMD-370	Aircraft piston engines.	Mineral oil containing pour point depressant, anti-oxidants and ashless additives.
—	OX-7	Aircraft turbine engines and auxiliary equipment.	Synthetic oil with additives. Unsuitable for use with natural and polychloroprene (neoprene) rubbers.
0-160	OX-26	Aircraft turbine engines and auxiliary equipment.	Synthetic oil with additives. Unsuitable for use with natural and polychloroprene rubbers.
0-156	OX-27	Aircraft turbine engines, auxiliary equipment and helicopter transmissions over the temperature range -40°C to +200°C.	Synthetic oil with additives. Unsuitable for use with natural and polychloroprene rubbers.

### Supply Identification System

46. All lubricating oils and associated products must be positively identified for supply purposes. Lubricating oil containers are identified in the RAF by the following markings:

- RAF Management Code and Stock Number.
- Joint Services Code (para 43).
- NATO Code (para 45).
- NATO Stock Number.
- Batch Number.

47. **RAF management code and stock number.** The management code and stock numbers used in the RAF are issued by MOD (Air), Director General of Supply (RAF), and are comprised of a two figure digit followed by an index letter.

The codes used for lubricating oils are 34B and 34D. Each code is followed by seven digits, which is known as the stock number, and identifies a particular store within the RAF Supply system.

48. Lubricating oils are usually packaged in various sizes of container. Each size of container is issued with a different stock number, to ensure that a positive method of identifying each store is maintained. An example of the identification system for various sizes of container is as follows:

- 34B/2251747 Oil OX-27 in 1 litre containers.
- 34B/2201940 Oil OX-27 in 5 litre containers.
- 34B/2201939 Oil OX-27 in 200 litre containers.

49. **NATO stock number.** The NATO stock numbers for lubricating oils are issued by the Army Cataloguing Agency, and consist of a 13 digit number. For example, the NATO stock number for Oil OX-26, supplied in 5 litre containers, is 9150-99-2250985. Each NATO stock number is in three groups of digits, hyphenated between each group; which in this format provides significant supply information (Fig 4.2.5). The first group of four digits represent the class and the second group of two digits the national code; both groups of digits replace the RAF Management Code. The NATO Stock Number is marked on all RAF documentation and oil containers. An example of the difference between the NATO stock numbering system and the RAF system is shown thus: 9150-99-2250985 becomes 34B/2250985.

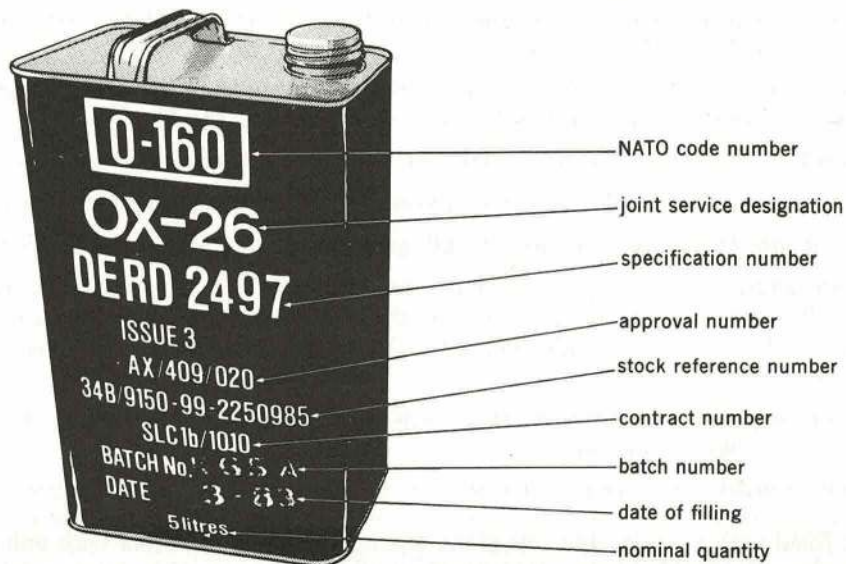


Fig 4.2.5 Oil container identification markings

50. **Batch number.** Each consignment of lubricating oil is allocated a batch number by the oil manufacturer. The batch number is used to maintain the identity of an oil whilst it is held in stock in the Equipment Depot, Supply Squadron or user Squadron stores. The Supply Squadron maintains a record of all batches of oil held in the store, and of consignments issued to user squadrons.

## Lifing of Lubricating Oils

51. Lubricating oils may deteriorate whilst they are held in storage. Hence, all aircraft and engine oils are allocated a storage life, and are subjected to routine periodic testing. The object of the testing is to identify any deterioration in the quality of an oil whilst it has been held in storage. The frequency between each test is specified in AP3160 Vol 2, and may vary from 12 months for a visual test, to 60 months for a full test, depending upon the specification and test requirements of the oil being tested. The implementation of the test procedure is the responsibility of the supply squadron, who will arrange for samples of all batches of oil held in stock to be submitted for test as required by the testing authority. Whilst it is the responsibility of the supply squadron to arrange for the routine testing of lubricating oils, it is equally the responsibility of the aircraft technician to ensure that life expired oils are not used to lubricate aircraft engines and their associated parts. To assist in identifying the life of an oil, containers are usually marked with the date of manufacture (eg 4/83) of the contents. Lubricating oil that has been subjected to a periodic re-test, is usually identified by a 'stick-on' label affixed to the oil container, to indicate when the next test is due.

## Glossary of Lubrication Terms

52. A glossary of commonly used lubrication and associated terms is given below; this is designed to assist the student in his understanding of the lubrication subject.

- **Anti-wear additive.** A substance which by surface activity increases the disruption resistance of lubrication films.
- **Cloud point.** The temperature at which a cloud or haze begins to appear when an oil, which has been previously dried, is cooled under prescribed conditions. Such cloud is usually due to the separation of paraffin wax.
- **Cold test.** The lowest temperature at which the substance will flow when observed under specified conditions not identical with those of the pour point test.
- **Compounded oil.** A blend of oil, usually of fatty oil with mineral lubricating oils.
- **Corrosion inhibitor.** An additive which reduces the corrosive properties of a product.
- **Density of lubricating oil.** The mass in kilogrammes of one litre of oil at 15°C.
- **Detergent additive.** A substance which when dissolved in lubricating oil reduces the adhesion between solid particules (eg of gummy or carbonaceous matter) and metals. Most detergent additives confer a light increase in load-carrying capacity, but tend to promote oxidation.
- **Dispersant additive.** A substance which when dissolved in a lubricating oil, keeps low temperature sludges dispersed.
- **Dynamic viscosity.** The dynamic viscosity of a fluid is defined as the tangential force on a unit area of either of two parallel planes at unit distance apart, when the space between them is filled with a liquid, and one plane moves relative to the other with unit velocity in its own plane. In simple terms, viscosity of an oil is a measure of its internal friction or its resistance to flow. The SI unit of dynamic viscosity is equal to one kilogram per metre per second. The common laboratory units are the poise (P) and the centipoise (cP).
- **Extreme pressure additive.** An oil soluble compound of sulphur, chlorine or other active element which releases that element at the very high temperature reached at the early stages of scuffing between hardened steel surfaces. The active element combines with iron, and prevents the welding of rubbing parts which otherwise would lead to tearing of the surfaces. Oils containing these additives may only be used for prescribed lubrication tasks.

- **Fatty oil.** Ester (a compound) of animal, fish or vegetable origin, as distinct from mineral or synthetic oil.
- **Hard asphalt.** Asphaltic matter distinguished by insolubility in petroleum spirit. It is formed, with other substances, by oxidation of mineral oil.
- **Kinematic viscosity.** The result of the dynamic viscosity divided by the density, both at the same temperature. Kinematic viscosities of oils are usually determined by taking readings from gravity flow viscometers at standard temperatures. The SI unit of kinematic viscosity is  $10^4$  Stokes (St) with centistokes (cSt) as a more convenient laboratory unit.
- **Load-carrying additive.** An anti-wear or extreme pressure additive.
- **Oxidation inhibitor.** An additive which reduces the rate of oxidation and subsequent deterioration of oils.
- **Pour point depressant.** An additive which lowers the pour point generally by modifying crystallization traces of dissolved wax.
- **Synthetic lubricants.** Lubricants prepared by chemical processes.

### Conclusion

53. In the foregoing Chapter, the basic principles of lubrication, and some of the properties and uses of a lubricating oil have been explained. Lubricating oils have been developed to perform a wide range of lubrication tasks, without which many modern aircraft and engines would not be able to function. It must always be remembered, however, that the performance of a lubricating oil depends largely upon the technicians who use it. The correct grade of oil must always be used, it must always be within its authorized life, and it must be kept clean and free from every type of contamination.

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