CHAPTER 4

PETROLEUM DERIVATIVES

List of Contents

Introduction

1. The previous chapters have dealt with the most commonly known petroleum products. The list of products to date is too large to produce in this publication and this chapter will only deal with those fluids and compounds encountered in service aircraft or used in aircraft servicing.

WATER INJECTION MIXTURES

Requirements

2. The purpose of "water injection" mixtures is purely one of cooling. They gain their effect both by cooling the fuel/air charge, usually before it enters the combustion chambers, and by the direct cooling of the combustion chambers.

3. A mixture for injection must:

a. Evaporate at about the temperature of the incoming charge.

b. Not freeze at any temperature to which the aircraft might be subjected.

c. Have as high a latent heat of evaporation and specific heat as possible.

d. Be non-corrosive to the engine parts both before and after combustion of the charge.

e. Be inexpensive and readily available in quantity.

4. Pure water readily meets most of these requirements but owing to its high freezing temperature it is not suitable for general use. Methyl alcohol has a very high latent heat of evaporation and a low freezing point, and a blending of the two liquids is most commonly used.

COOLANT LIQUIDS

Introduction

5. The liquid that is required for the cooling system of an aero-engine must have many properties, the most important being:

a. Low freezing point.

b. High boiling point.

c. High specific heat.

d. Non-corrosive properties.

e. Non-dangerous and non-toxic properties.

f. Low inflammability.

6. **Low freezing point.** This is essential in order that the aircraft can be maintained and operated under very cold weather conditions. The fluid viscosity should remain fairly uniform at low temperatures.

7. **High Boiling Point.** A high boiling point enables the fluid to absorb a large amount of heat. The higher the coolant temperature at the entrance to the radiator, the higher the temperature difference between the coolant and the surrounding atmosphere, therefore there will be a higher rate of heat transfer. Therefore the higher the coolant temperature, the smaller the radiating area required for the same amount of heat transfer. It follows that with a smaller radiator surface area there will be a decrease in weight and drag.

8. **High Specific Heat.** The maximum amount of heat is required to be transferred from the cylinders to the radiator, by the minimum weight of coolant. Hence a liquid of high specific gravity is desirable in order that the total volume of coolant be kept down. A small quantity of coolant will lead to an all-round decrease of engine size and weight, hence a decrease in aircraft weight and drag.

9. **Non-Corrosive, Non-Toxic and Non-Dangerous.** These three properties eliminate many otherwise suitable liquids. The coolant must be non-corrosive to the various materials likely to be used in the aircraft and engine coolant system. The coolant, when it is in either a liquid or vapour state, must be safe to handle by personnel.

10. **Inflammability.** The fire danger from the coolant must be kept as low as possible.

Ethylene Glycol

11. This liquid satisfactorily complies with the first three requirements and can be made non-corrosive by the addition of inhibitors. Its fumes, when hot, should not be breathed even though they are not really dangerous. It has also the advantage of being relatively cheap. It is the liquid that is used in aero-engine cooling systems. It is normally diluted with water in the proportions 30 per cent ethylene glycol and 70 per cent water. This lowers the boiling point of the ethylene glycol and also lowers its freezing point. Both temperatures being still within the desired range, the dilution becomes an advantage. The water also increases the specific heat and decreases the fire risk.

12. Inhibited ethylene glycol A.L.3 (that is to say, that containing oxidation inhibitors such as triethanolamine phosphate) must always be used for aero-engine and M.T. coolant systems.

DE-ICING AND ANTI-FREEZING COMPOUNDS

Introduction

13. De-icing and anti-freeze compounds may be classified under the following headings:

a. De-frosting fluids—to remove hoar frost and light snow from aircraft surfaces whilst the aircraft is on the ground.

b. De-icing fluids—to remove, and to a certain extent to prevent the formation of ice on aircraft surfaces during flight.

c. Anti-freeze compounds—to prevent the freezing of liquids such as engine coolants and water-injection materials both in flight and on the ground.

d. De-icing pastes—to assist the dispersal of ice from aero-foil leading edges during flight.

14. The function of the types described in paragraph 13 *a*, *b* and *c*, is to form with water, a mixture with a low-freezing point. They must therefore:

a. Be soluble in water in all proportions.

b. Dissolve ice.

c. Depress the freezing point of water.

d. Be non-corrosive.

e. Be non-toxic.

f. When used in engine induction systems, not affect the combustion or other properties of the fuel.

15. The following alcohols have been selected for the purposes indicated:

a. Methyl alcohol—as a de-icing fluid.

b. Ethyl alcohol—as a de-frosting fluid.

c. Ethyl glycol—as an anti-freezing fluid.

Methyl Alcohol

16. Methyl alcohol is used with water as an anti-freeze for water injection purposes. As a 60/40 mixture of methyl alcohol and inhibited distilled water, it is called "Methanol water", methanol being the industrial name for methyl alcohol. The inhibitor used is an anti-corrosion oil ZX-15 used mainly to prevent corrosion of the containers. Methanol is particularly suitable as an anti-freeze agent for water injection systems because of its high heat of evaporation; it is on the cooling effect that water injection systems rely for their efficiency. For turbine-engined aircraft systems, the methanol water has different proportions and the inhibiting oil is omitted. Methanol is very poisonous if taken internally. It is not a drinkable alcohol and when used in the R.A.F., contains a nauseous additive to discourage any attempt at drinking.

Ethyl Alcohol

17. Ethyl alcohol is used as a de-icing fluid, for the removal of ice formed in flight, from windscreens and bomb-aimer's panels, also to remove ice that has formed in the air intakes and engine induction systems.

Ethylene Glycol

18. Ethylene glycol is used:

a. As an anti-freezing compound for most aero-engine and mechanical transport coolant systems.

b. As the basis of a de-icing fluid for propellers.

c. As the basis of a de-icing fluid for use in some distributors of the T.K.S. de-icing systems.

19. As a de-icing fluid it is known as Fluid Miscellaneous AL-5 and consists of 85 per cent. ethylene glycol, 5 per cent. ethyl alcohol and 10 per cent. distilled water. As a de-icing fluid for propellers it is not necessary for the ethylene glycol to dissolve the ice so long as it penetrates between the ice and the propeller surface when the ice is flung off by centrifugal force.

De-Frosting Fluids

20. The following de-frosting fluids are approved proprietary products, and they are accepted by the R.A.F. as fulfilling their designed purpose, without the composition of the products being generally disclosed. Their function is the same as the normal de-icing fluids. There are three main types, D.C.2*a*, which is used for the removal of hoar frost from aircraft surfaces; A.L.15, used for removing hoar frost from transparent panels of aircraft; A.L.7, used for propeller de-icing systems, and systems wholly equipped with Dunlop overshoes, or partly with T.K.S. porous metal distributors and partly with Dunlop overshoes.

De-Icing Pastes

21. The function of the plastic de-icing paste is to provide a slippery surface, so that accretions of ice on propeller leading edges slide off, or are blown off during flight. This is a proprietary product.

ANTI-CORROSION COMPOUNDS

Introduction

22. Corrosion and its prevention is still a problem of great importance. Extensive research into its causes has resulted in a general acceptance that the two types of surface corrosion are (1) direct

chemical attack of corrosive gases on metals and (2) electro-chemical action, in which the materials being corroded become part of an electrolytic cell in the presence of moisture.

23. The atmosphere consists broadly of 75 per cent. nitrogen and 24 per cent. oxygen, the balance of one per cent. consisting of neon, helium and other gases. In addition, air generally contains water vapour, sulphur compounds and dust particles. These constituents can form corrosive products which can attack the materials, the rate of attack being dependent on their hygroscopic properties. The moisture and oxygen play an important part in the reaction process, but both corrosive reactions can be effectively retarded if precautions are taken to exclude moisture.

24. Of the other corrosion products in the atmosphere, chlorine compounds near the coast, and sulphur compounds in industrial areas are the destructive agents. Aerated salt solutions attack metal surfaces at their weakest point in the oxide film, such as at scratches, cut edges and points of high strain. Once attack has commenced, undermining of the primary oxide and consequent flaking causes the attack to spread.

25. From the foregoing, it will be appreciated that the basic principle of corrosion prevention is to place a barrier between any moisture and the material to be protected. This section will discuss those substances which are applied as covering films and do not come under the category of dopes or paints. They are used to protect materials from corrosion during storage and not during use. The great majority of the components of these anti-corrosion compounds are grades or derivatives of petroleum. Most of the components which do not have their origin in petroleum are, animal fats, waxes or coal-tar products.

Objects and Requirements

26. The object of an anti-corrosion compound is to prevent corrosion of material by means of a covering film in immediate contact with the surface to be protected. This protection can be achieved by two entirely separate effects:

a. Physical protection.

b. Chemical protection.

The physical effect is that possessed by such materials as mineral jelly which protects the surface physically from direct access by corrosive compounds. Chemical protection is provided by chemicals which neutralize potentially corrosive compounds. A good anti-corrosive compound should possess both characteristics.

27. It is of fundamental importance that the surfaces of the object to be protected are perfectly clean and dry, and free from corrosion before the anti-corrosion compound is applied. If this is not so, the object is defeated right at the start. Although the anti-corrosion compound may prevent it partially, corrosion may well continue beneath the covering film.

28. The desirable properties of an anti-corrosion compound, are dependent on the following:

a. The composition of the objects to be protected.

b. The nature and function of the surfaces of the object.

c. The complexity of construction of the object.

d. The storage conditions to which the object is to be subjected.

e. The degree of protection involved.

f. The ease of, or necessity for, its removal before the object is put into use.

g. The nature of any protection for the film of anti-corrosion compounds.

h. Other functions required of the anti-corrosion compound.

j. Availability.

k. Difficulty of application.

Many of these requirements are inter-dependent. Generally speaking the last, *k*, is the least important. If a substance is the only one fulfilling most of the remaining requirements, there is usually some method of applying it.

29. Ordinary lubricating oils and greases are not in themselves good anti-corrosion compounds. They may be used as temporary expedients when nothing else is available. Every effort must be made to obtain the approved anti-corrosion compound as specified.

Types of Anti-Corrosion Compounds

30. There are four main types of anti-corrosion compounds. The first three are classified by the type of protective film they make. The fourth is dual purpose oils. The types are:

a. Hard, tough-film type.

b. Soft, solid-film type.

c. Oil-film type.

d. Dual purpose oils.

Hard, Tough-Film Type

31. Generally, these are mixtures of resin and lanolin, diluted with a solvent (usually special boiling-point petroleum spirit or coal-tar naphthas) and often containing other agents for toughening the film and improving its anti-corrosion properties. The solvent usually forms about 50 per cent of the mixture and on application it evaporates, leaving the tough lanolin-resin film.

32. There are three main anti-corrosion compounds of this type in use. They are:

a. Pigmented Lanolin Resin Solution PX-3, a zinc-chrome anti-corrosion compound.

b. Lanolin Resin Protective, PX-9, a red lanolin anti-corrosion compound.

c. Composition, Rust Preventative, PX-2.

33. If these three compounds are likely to affect the working of a part, or be dissolved by lubricating oil, they must be removed before use. For instance, spare valve springs are often coated with PX-9; this must be removed before the spring is fitted, as it would be dissolved into the engine lubricating oil and cause a gum-like substance in the oil. This would increase the possibility of piston-ring sticking and similar effects. All of these anti-corrosion compounds have the same effect on aero-engine lubricating oils. Care must be taken to remove these compounds from small holes, oil-ways and screw threads. All can be removed by kerosine or gasoline, wash or spray.

Soft, Solid-Film Types

34. Three types fall under this heading, they are:

a. Basically mineral jelly—these may be either pure mineral jelly, for instance, PX-7 or mineral jelly with a percentage of lanolin to increase protective power, or beeswax to give a harder film, for example, PX-11.

b. Greases—usually LG-280, which is a lime soap with mineral oil.

c. Lanolin with solvents (either coal-tar naphtha or white spirit) this gives a thin film, as opposed to the two above which give thick films. Temporary protective PX-1 is of this type.

35. These three types of anti-corrosion compounds give a range which can be used for almost any purpose. When used on the exterior of objects, it is usual to use an outer wrapping, as the films they produce may be broken by handling. They should be removed, as far as possible, before the object is put into use, in order to remove any grit and dirt which they may have collected. They have a sticky finish, but otherwise do no harm and can be dissolved away into the engine lubricating oil without danger. They are easily removed by kerosine or gasoline.

Oil-Film Types

36. These consist basically of a mineral lubricating oil and a diluent. Sometimes lanolin is added to increase the protective power, or wax to produce a harder, higher melting-point film or a corrosion inhibitor. Three types fall under this heading:

a. Engine Corrosion Preventative PX-13. This consists of aircraft-engine lubricating oil OM-270, petroleum wax, an approved corrosion inhibitor and petroleum spirit.

b. Corrosion Inhibiting Oil OX-12. This consists of a low viscosity mineral oil with an approved inhibitor; no diluent is included. It is intended for application to steel parts of aircraft instruments.

c. Composition Preservative, Spraying, PX-4. This consists of a light mineral oil blended with a corrosion inhibitor, and up to 5 per cent kerosine may be permitted as a diluent. It is suitable for unexposed internal surfaces only, such as engine cylinders, gear boxes, etc.

37. These types need not be removed before the units are used, they have no harmful effect on the running of an engine or other mechanism.

Dual Purpose, Lubricating/Anti-Corrosion Oil

38. This oil is known as storage oil OX-275. It consists of a normal aircraft-engine lubricating oil OM-270, to which has been added an approved corrosion inhibitor concentrate. This oil can only be used as a lubricating oil for an engine in storage, and must not be used in flight. The purpose of the oil is to neutralize the corrosive effects of combustion of leaded gasoline on internal aero-engine parts, other than the cylinders. Aircraft-engine lubricating oil is not in itself a good corrosion preventative, hence the use of an oil to which a corrosion inhibitor has been specially added.

Lanolin

39. Lanolin occurs in many corrosion preventatives and is prepared from wool-fat. Wool-fat is extracted from sheep's wool and after purification becomes an almost colourless, neutral fat (that is to say, non-acid, non-alkali) known as lanolin. As a preservative, lanolin is superior to petroleum products or other animal fats for the following reasons:

a. It is highly adhesive to surfaces.

b. It is insoluble in water, although it absorbs water.

c. It is neutral and hence non-corrosive.

d. It is stable.

e. It is very resistant to acids and alkalis.

f. When diluted with a solvent it is easily applied, and leaves a very good "coat" when the solvent evaporates.

APPROVED CORROSION INHIBITORS AND OTHER ADDITIVES

General

40. It will be noted that reference is made on numerous occasions in the preceding paragraphs to approved corrosion inhibitors and other additives, which may be added to various petroleum products. The reason for the inclusion of these additives is always made clear; the composition of the additive is seldom disclosed.

41. These corrosion inhibitors and other additives vary considerably according to the manufacturer and the purpose for which they are required; most of them are trade secrets. Their identity and composition will be known to the Ministry of Technology, but being trade secrets they are treated as confidential and not published for general information. As these compositions are continually being changed by improvements, no useful purpose can be served by attempting to describe them in detail.

42. This information on corrosion inhibitors and additives applies equally to those used in gasolines, kerosines, lubricating oils and greases, as well as the products mentioned in this chapter.

FLUSHING OIL (OM-21)

General

43. Oil, flushing OM-21, is used in the R.A.F. for cleaning and flushing out piston type aero-engines, M.T. engines, gear boxes. It is a light mineral oil with slight lubricating properties, but light enough to carry away sludge and carbonaceous products. It is in what is known as the spindle-oil range.

HYDRAULIC FLUIDS

General

44. The fluids required for ground equipment and aircraft hydraulic systems are much the same except for one factor, that is low temperature characteristics for the aircraft. Early ground equipment systems used water, or soap and water, but this fluid, having such a high freezing point and poor lubricating quality, falls short of the requirements for aircraft systems.

Requirements of a Hydraulic Fluid

45. A hydraulic fluid is required to have the following properties:

a. It must lubricate efficiently all moving parts in the system in which it is to be used.

b. It must be non-corrosive to the materials in the hydraulic system.

c. It must not cause swelling or deterioration of rubber, or rubber-like parts in the hydraulic system.

d. It must not deteriorate in any way either in use or during storage.

e. It must have as low a viscosity as possible at all operating temperatures, in order to reduce the power required to pump it around the system.

f. It should have a flash point above ambient temperatures.

46. Hydraulic fluids fall into two categories.

a. Mineral base.

b. Vegetable base.

Other than the nature of the base oil the main difference between these fluids is their action upon rubber and rubber-like substances. With mineral base fluids, synthetic rubber components are used, and with vegetable base fluids natural rubber parts are used. Mineral base fluids cause rapid deterioration of natural or pure rubber, whilst vegetable base fluids cause deterioration of synthetic rubber. It is of utmost importance that the two fluids are never allowed to contaminate each other.

47. To assist identification of the two fluids it is usual to add distinctive dyes; these colours also assist the "detection of leaks in hydraulic systems". The vegetable base fluids are diluted with ether or alcohols to reduce viscosity and power required for pumping.

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