R.A.N.

AP·1464 C

VOL·I·

AERO-ENGINES & POWER PLANTS

AMENDMENT RECORD SHEET

Incorporation of an Amendment List in this publication is to be recorded by inserting the Amendment List number, signing in the appropriate column, and inserting the date of making the amendment.

● SEE A.P.2462A PAGE 12 — "AMENDMENT LISTS AND HOW TO AMEND PUBLICATIONS".

A.L. No.	AMENDED BY	DATE	A.L. No.	AMENDED BY	DATE
1 to 24	Incorporated	May, 1944			

Continued overleaf

AMENDMENT RECORD SHEET
—CONTINUED

A.L. No.	AMENDED BY	DATE

A.L. No.	AMENDED BY	DATE

* *An Amendment Record Continuation Sheet (R.A.F. Form 2094A) obtainable from APFS Kensington, will be required when this page is full. Order it now.*

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS
This is A.L. No. 1 to A.P.1464C, Vol. I
Insert these leaves.

RESTRICTED
(For official use only)

THE "1464" SERIES

1. The Engineering Manual of the Royal Air Force, A.P.1464A and 1464B, has been divided into seven Air Publications, as follows:—

1464A—R.A.F. Engineering—organisation and administration—principles and regulations

1464B—R.A.F. Engineering—general engineering

1464C—R.A.F. Engineering—aero-engines and power plants

1464D—R.A.F. Engineering—aircraft

1464E—R.A.F. Engineering—mechanical transport

1464F—R.A.F. Engineering—marine craft and marine engines

1464G—R.A.F. Engineering—ground equipment

2. The layout of the seven publications has been standardised and each Vol. I is divided into three parts, as follows:—

(i) Part 1 gives broad principles which govern the subject, and will be useful to the trainee and the experienced engineer as a reference book.

(ii) Part 2 houses information on a miscellany of stores which are within the scope of the title but which do not yet justify the existence of an independent publication. Part 2 will contain the description, instructions for use, and servicing information on these stores and will be divided into convenient sections which may, when considerations of bulk and distribution make it desirable, be extracted to form the basis of an independent specialist publication. When this is done, a reference is inserted in Part 3.

(iii) Part 3 is a list of specialist and associated publications.

3. Each Vol. I of the new series has a corresponding Vol. II, consisting of Part 1 (Leaflets) only.

4. A complete list of the original references and the new location of the information is given at the beginning of each Vol. I in the "1464" series.

5. Chapters which have not been revised are printed in the old style in which the descriptive matter is set the full width of the page.

6. New chapters and chapters which have been revised are printed in a new style in which the descriptive matter is usually set in two columns to a page.

7. The above plan is shown pictorially in A.D.4162, "Engineer Publications and their Relation to the New 1464 Series".

LAYOUT TREE

A.P.1464C—R.A.F. ENGINEERING
AERO-ENGINES AND POWER PLANTS

- **VOL. I**
  - **PART 1** — Principles of aero engines, propellers, etc.
    - Sect. 1—Physics of gases
    - Sect. 2—Elementary Chemistry of fuels
    - Sect. 3—Heat engines—I.C. engines
    - *(continued)
  - **PART 2** — Miscellaneous aero-engine and power plant subjects
    - **SECT. 1** General
    - **SECT. 2** General practice
      - Chap. 1—Aero-engines—General
      - Chap. 2—Aero-engines—Dismantling
      - Chap. 3—Aero-engines—Cleaning
      - *(continued)
    - **SECT. 3** Lubricating systems
      - Chap. 1—General
      - Chap. 2—Viscosity valves
      - Chap. 3—Oil cleaners—Vokes
      - *(continued)
    - **SECT. 4** De-icing equipment
      - Chap. 1—De-icing equipment for propellers
      - Chap. 2—De-icing equipment for aero-engine induction systems
    - **SECT. 5** Cooling Systems
      - Chap. 1—General
      - Chap. 2—Aero-engine cooling systems—servicing
      - Chap. 3—Thermostatic header tank relief valve, type DS
      - *(continued)
    - **SECT 6** Fuel systems
      - Chap. 1—General
      - Chap. 2—Fuel pressure reducing valve—Amal.
    - **SECT. 7** Air filters and Superchargers
      - Chap. 1—General
      - Chap. 2—Vokes air filter
      - Chap. 3—Vokes dry element air filters
      - *(continued)
  - **PART 3** — List of aero-engine and power plant publications
- **VOL. II**
  - **PART 1** — General orders and modifications referring to the equipment in Vol. I, Part 2
  - **PART 2** (None)
  - **PART 3** (None)

**This Layout Tree shows the basic arrangement of the Volumes, Parts, Sections, and Chapters of this publication. See the Lists of Sections and Lists of Chapters for the complete contents.*

FOR OFFICIAL USE ONLY

September, 1944
AIR MINISTRY

Amendment List No. 25
to
AIR PUBLICATION 1464C
Volume I

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

PART 2
SECTION 2

(1) List of Chapters. *Cut out* the following and affix it over the reference to "Chapter 8":—

(2) *Insert* the attached Chapter 8 to follow Chapter 6.

When you have done this make an entry in the Amendment Record Sheet.

ENGINEER

Chapter 8 . . . AERO-ENGINE CORROSION INHIBITING EQUIPMENT

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. Specially designed compressed air operated spray guns are provided in the Service to afford an efficient means of depositing an even film of corrosion inhibitor fluid on aero-engine cylinder walls without removing the cylinder heads. The effectiveness of the inhibition is dependent upon the working efficiency of the spraying equipment used, and this chapter details the correct methods of using and servicing the equipment provided.

2. There are three main types of inhibitor spray guns at present in use: the A.I.D. Type T.F.3–C.1, the Miller Type C.S.101, and the Miller Type C.S.C.103. Any of these guns is available under Stores Ref. 3A/1034. The principle of liquid atomization is similar in each of these guns, but the differences in construction and operation require separate operating and servicing instructions.

A.I.D. SPRAY GUNS

A.I.D. Type T.F.3-C.1 spray gun

Description

3. The A.I.D. Type T.F.3–C.1 spray gun is illustrated in fig. 1 and 2. The gun is self-contained and may be operated from any compressed air supply which will provide a pressure of between 100 and 150 lb. per sq. in. A pressure cup, holding one half-pint of the inhibitor fluid, is mounted on the gun forward and to the left of the butt. The fluid in the cup is under pressure from the air which is by-passed to the cup through the pressure cup air connection. When the inlet valve control screw is opened, the fluid passes through the syphon pipe and along the feed channels to the measuring cylinder, where it forces the measuring plunger outwards. The measuring plunger continues to be forced outwards until it either reaches the limit of its travel, or is stopped by the locating pin. When the gun trigger is pressed the air and material valves are opened simultaneously. Air passes from the air valve both to the gun material nozzle and through the air feed pipe to the rear side of the measuring plunger. The air at the rear side of the measuring plunger forces the fluid out of the measuring cylinder to meet with the air at the

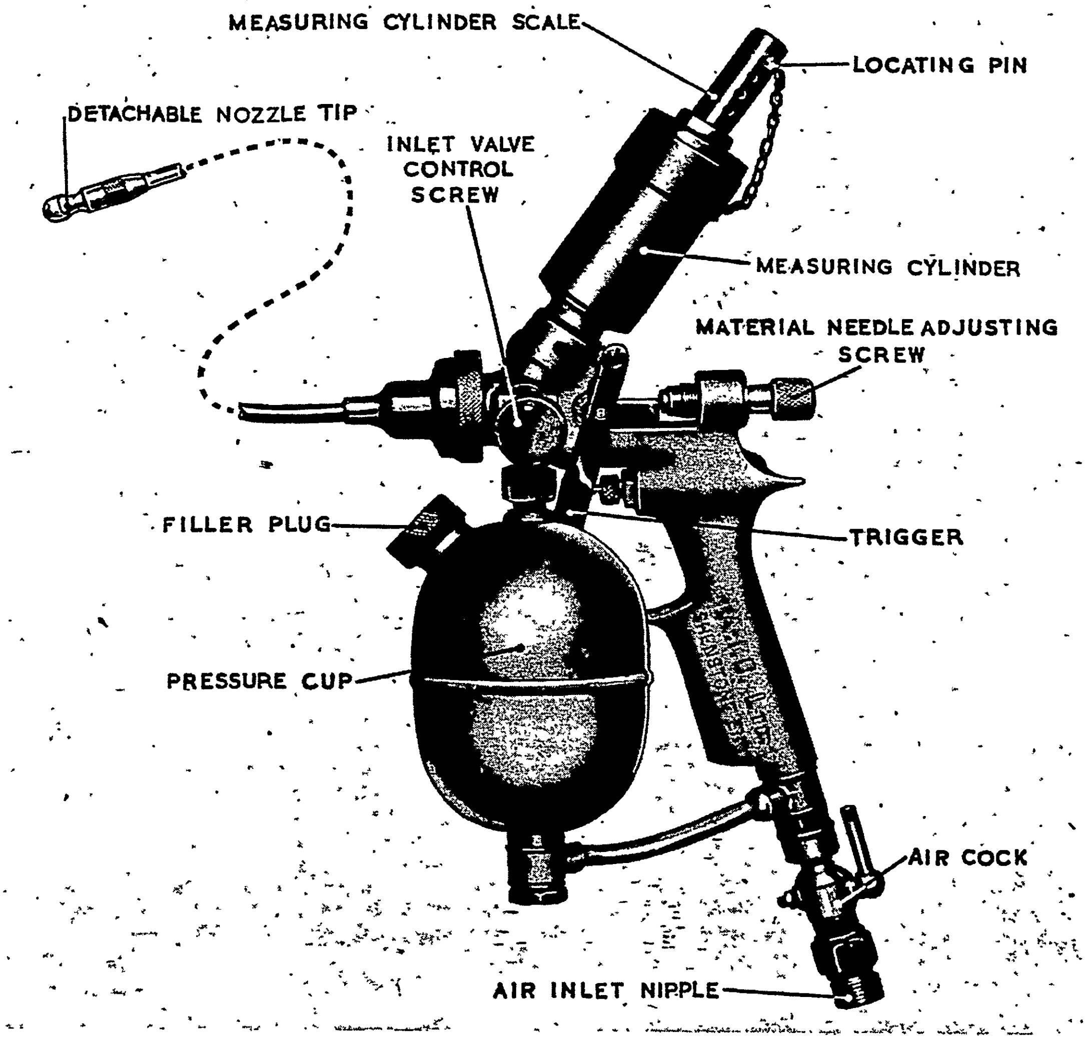


Fig. 1.—A.I.D. Type T.F.3-C.1 corrosion inhibitor spray gun

material nozzle. Atomization of the fluid takes place at this point. The atomized fluid passes along the nozzle tube and is sprayed out through the fine holes in the nozzle tip in a spherical pattern.

4. The material needle can be adjusted to limit its travel, so regulating the rate of flow of the fluid relative to the flow of the air at the material nozzle. The amount of fluid to be sprayed into the aero-engine cylinder is pre-set by placing the locating pin in one or other of the holes in the measuring cylinder scale. There are four holes in the scale, marked 5, 10, 15, and 20 respectively. These figures denote the quantity of the fluid in cubic centimetres. The quantity sprayed with the locating pin removed from the scale is 25 c.c.

Preparing the spray gun for use

5. To ensure that all air is expelled from the fluid passages of the gun before it is used for inhibiting an aero-engine, the gun should be operated once as follows:—

(i) Ascertain that the air line which it is proposed to use supplies a pressure of from 100 to 150 lb. per sq. in.

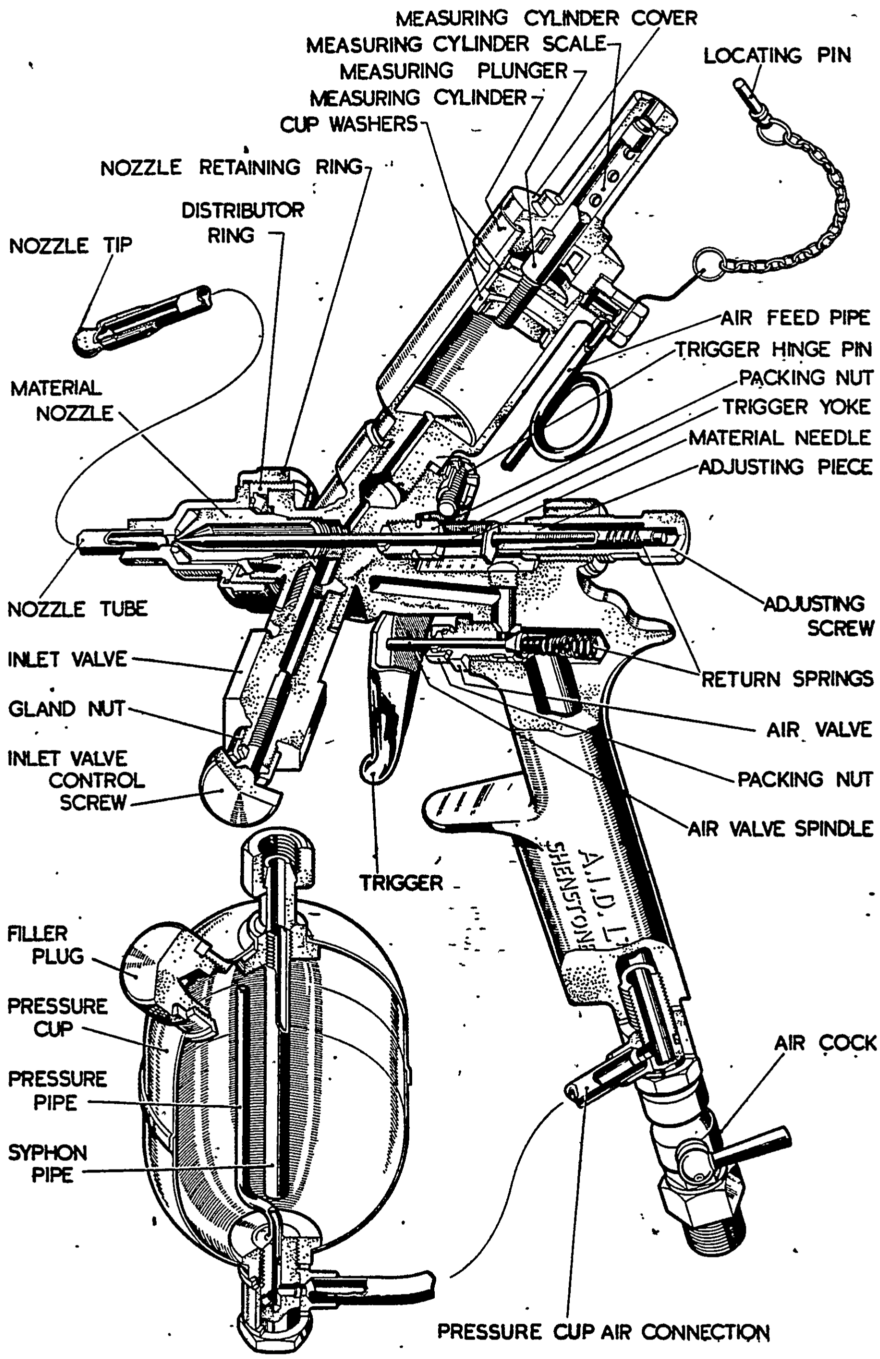


Fig. 2.—Cutaway view of A.I.D. gun

(ii) Connect the air line to the union on the gun handle. *Do not turn on the air supply.*

(iii) Fill the pressure cup with anti-corrosion inhibitor fluid (Stores Ref. 33C/777), and replace the filler plug tightly.

(iv) Remove the locating pin from the scale on the measuring cylinder.

(v) Turn on the air supply.

(vi) Unscrew the material needle adjusting screw almost fully, so as to allow the material needle its maximum travel.

(vii) Unscrew the inlet valve control screw two turns. The measuring plunger should then rise slowly.

(viii) When the measuring plunger has reached the limit of its travel, close the inlet valve control screw and press the gun trigger. The contents of the measuring cylinder will then be atomized at the material nozzle, and sprayed from the nozzle tip into the air. Keep the trigger back until the measuring plunger has reached the bottom of its travel. Whilst the fluid is being sprayed into the air, observe the shape of the spray pattern. It should be even, and almost spherical.

Operation

6. The gun is now ready for use, and the inhibition of the aero-engine should be proceeded with in the following manner. (These instructions should be read in conjunction with those contained in Leaflet No. C.32—W, "Storage of Aero-engines", A.P.1464, Vol. II.)

(i) Set the material needle adjusting screw so as to allow the material needle a travel of between $\frac{1}{32}$ and $\frac{1}{16}$ in. To do this, screw in the adjusting screw until it comes to a stop, then unscrew it from one to two turns. The travel of the needle can be checked visually when the gun trigger is pulled.

(ii) Ascertain the appropriate quantity of inhibitor fluid for each cylinder of the particular engine which is to be treated, and place the locating pin in the hole in the measuring cylinder scale which is marked with the corresponding number of cubic centimetres. Where the quantity required falls between the figures on the scale, that which is the nearest in excess should be sprayed.

(iii) Open the inlet valve control screw two turns and wait until the measuring plunger is hard against the locating pin.

(iv) Close the inlet valve control screw.

(v) Insert the gun nozzle in the engine cylinder plug hole.

(vi) Press the gun trigger and wait until the measuring plunger reaches the bottom of its travel. The nozzle should be moved up and down in the engine cylinder so that the fluid is evenly distributed over the cylinder walls.

(vii) Repeat the operations described in sub-para. (iii) to (vi) inclusive for each of the remaining engine cylinders.

7. *CAUTION—Never remove the pressure cup filler plug without first turning off the air supply. If it is required to refill the pressure cup whilst the gun is in use, the air supply must be turned off either at the source, at the air cock on the bottom of the gun butt, or at the pressure cup air connection, where, on later models of the gun, a small stop-cock is fitted.*

8. When the gun is in use it is important that the nozzle retaining ring be kept screwed up tightly. The material needle packing nut, the air valve body, and the inlet valve body must also be kept tight and free from leakage. A key is provided with the gun for tightening the material needle packing nut; the air valve packing nut and the inlet valve gland nut should be tightened by hand.

9. It is advisable to clear the nozzle of the gun when the inhibition of the aero-engine has been completed in order to prevent any fluid from congealing in the small spraying nozzle holes whilst the gun is not in use. This is best done by closing the inlet valve control screw tightly, unscrewing the material needle adjusting screw almost fully, and pressing the gun trigger so as to eject several intermittent blasts of air.

Servicing

Cleaning

10. The importance of keeping the gun scrupulously clean cannot be over-emphasized. No foreign matter should be allowed to enter the pressure cup; the holes in the nozzle tip are of very small diameter, and may be clogged by even the smallest particle of grit. Should the nozzle tip become choked, however, the fact will be indicated by an irregularity of the spray pattern and a tendency for the measuring plunger to remain in the upper position when the gun trigger is pressed. Immediately these symptoms are observed the nozzle should be cleaned as follows:—

(i) Unscrew the nozzle retaining ring and remove the nozzle tube from the gun.

(ii) Soak the whole nozzle tube in paraffin for at least fifteen minutes, or alternatively, immerse it in boiling water for between five and ten minutes.

(iii) Gently probe each of the holes in the nozzle tip with a piece of 24 to 28 S.W.G. *copper* wire. Care must be exercised to avoid damaging the holes, as any enlarging of them will cause unevenness in the spray pattern.

(iv) Insert the nozzle tip into the open end of a compressed air supply line and turn on the air for a few seconds. This will cause the obstructive matter to be blown out at the reverse end of the nozzle tube. This cannot be done by blowing air through the tube in the normal direction of flow.

Note . . . Before using the gun again, make sure that no paraffin or water remains in the nozzle tube.

Lubricating

11. The following parts of the gun should occasionally be lightly oiled:—

(i) The material needle, where it enters the material needle packing nut.
(ii) The material needle adjusting piece, where it enters the material needle adjusting screw.
(iii) The air valve spindle, where it enters the air valve packing nut.
(iv) The measuring plunger. This is best done when the plunger is at the top of its travel.
(v) The four points of the trigger assembly: two at the hinge pin, and two at the pins of the trigger yoke.

Periodical inspection

12. The measuring cylinder cover should periodically be removed and the cup washers examined. If these are hard or worn they should be renewed. All other joints should similarly be kept air-tight, new washers being fitted when necessary.

Repair

13. Any gun which requires repairs other than those involving only the renewal of worn or damaged parts should be labelled UNSERVICEABLE and returned to Stores.

Other models of A.I.D. gun

14. The foregoing instructions apply also to other models of the A.I.D. type gun to which the inhibitor fluid is supplied from a separate container. A fluid pipe from the container is fitted directly to the inlet valve in place of the half-pint pressure cup. The operational and servicing procedure is identical.

MILLER TYPE SPRAY GUNS

Miller Type C.S.101 spray gun

Description

15. The Miller Type C.S.101 spray gun is illustrated in fig. 4. This gun operates from a specially designed air compressor unit which is illustrated in fig. 3.

Compressor

16. The compressor is an electrically driven, single-stage machine which is mounted on two wheels. The electric motor is of a voltage to suit the supply at the Service station on which the equipment is to be used. The inhibitor fluid is fed to the spray gun under pressure from a four-pint fluid container which is mounted on the trolley alongside the compressor pump. The fluid in the container can be agitated from time to time during inhibiting operations, by means of the mixing handle. An automatic cut-out switch is fitted to the motor which allows it to run until a pressure of 150 lb. per sq. in. has been reached in the receiver. The motor will restart when the pressure has dropped to 120 lb. per sq. in. A gauge indicates the pressure at which the air is stored in the receiver, and an air cock is fitted to enable the fluid container and the spray gun to be isolated from the air supply. When the equipment is not in use, the flexible hoses are stowed on hose stowage brackets which are fitted on the right-hand side of the compressor trolley, and the gun is stowed in spring clips between the hand-shafts.

Spray gun

17. The unions for the air and fluid hoses are fitted at the bottom of the gun butt. The amount of fluid to be sprayed into the aero-engine cylinder is pre-set in a similar manner to that afforded in the A.I.D. gun, except that a thumb lever takes the place of the A.I.D. control valve screw. It will be seen from fig. 4 that the measuring cylinder lies horizontally along the top of the gun, with the thumb lever fitted at its rear end.

18. The fluid is carried from the measuring cylinder to the nozzle tip through an annealed copper tube which is fitted inside the outer swan-neck air tube. Atomization of the fluid takes place at the nozzle tip.

Preparing the equipment for use

19. When preparing the equipment for use the following operations should be effected:—

Compressor trolley

(i) Fill the container with anti-corrosion inhibitor fluid (Stores Ref. 33C/777) and replace the filler plug tightly.

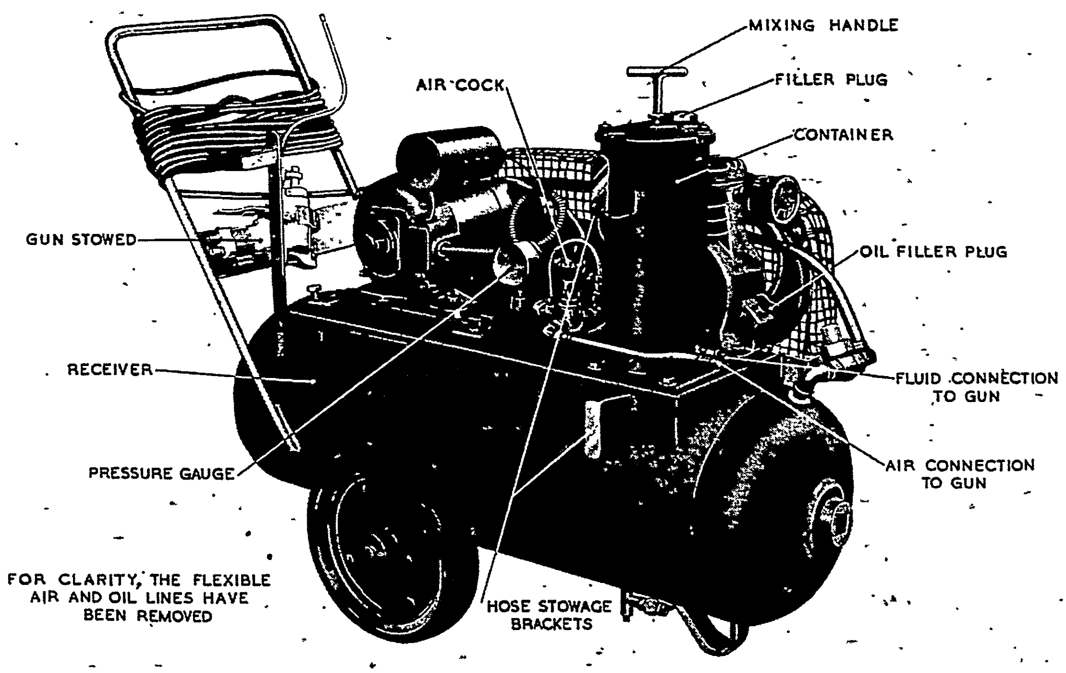


Fig. 3.—Compressor for Miller Type C.S.101 gun

(ii) Connect the compressor motor with the electricity supply and switch on the current.

(iii) Wait until the receiver is charged to a pressure of 150 lb. per sq. in., when the motor will cut out.

Spray gun

(iv) Set the plunger stop bracket in the outermost of the four slots in the plunger stop channel.

(v) Press the thumb lever and wait until the end of the plunger meets the stop bracket.

(vi) Open the air screw two or three turns and press the gun trigger. If there is air in the measuring cylinder it will escape around the thread of the air screw. Keep the trigger pressed until all the air is excluded, and when inhibitor fluid begins to escape around the screw thread, release the trigger and close the air screw tightly.

(vii) Press the thumb lever again, and wait until the end of the plunger meets the stop bracket.

(viii) Press the gun trigger and wait until the plunger reaches the limit of its inward travel, spraying 20 c.c. of fluid into the air. Observe the shape of the spray pattern. It should be even, and almost spherical. The plunger should recede into the measuring cylinder at a steady rate.

Operation

20. There are four slots in the plunger stop bracket marked 5, 10, 15, and 20 c.c. respectively. The stop bracket cannot be removed from the stop channel, and the maximum quantity which can be sprayed at one setting is 20 c.c.

21. When the gun has been prepared for use as described in para. 19, the inhibition of the aero-engine may be proceeded with as follows. (These instructions should be read in conjunction with those contained in Leaflet No. C.32—W, "Storage of Aero-engines", A.P.1464, Vol. II).

(i) Ascertain the appropriate quantity of inhibitor fluid for each engine cylinder.

(ii) Set the plunger stop bracket in the slot which corresponds with the quantity required, or which is the nearest in excess.

(iii) Press the thumb lever and wait until the plunger spindle meets the stop bracket.

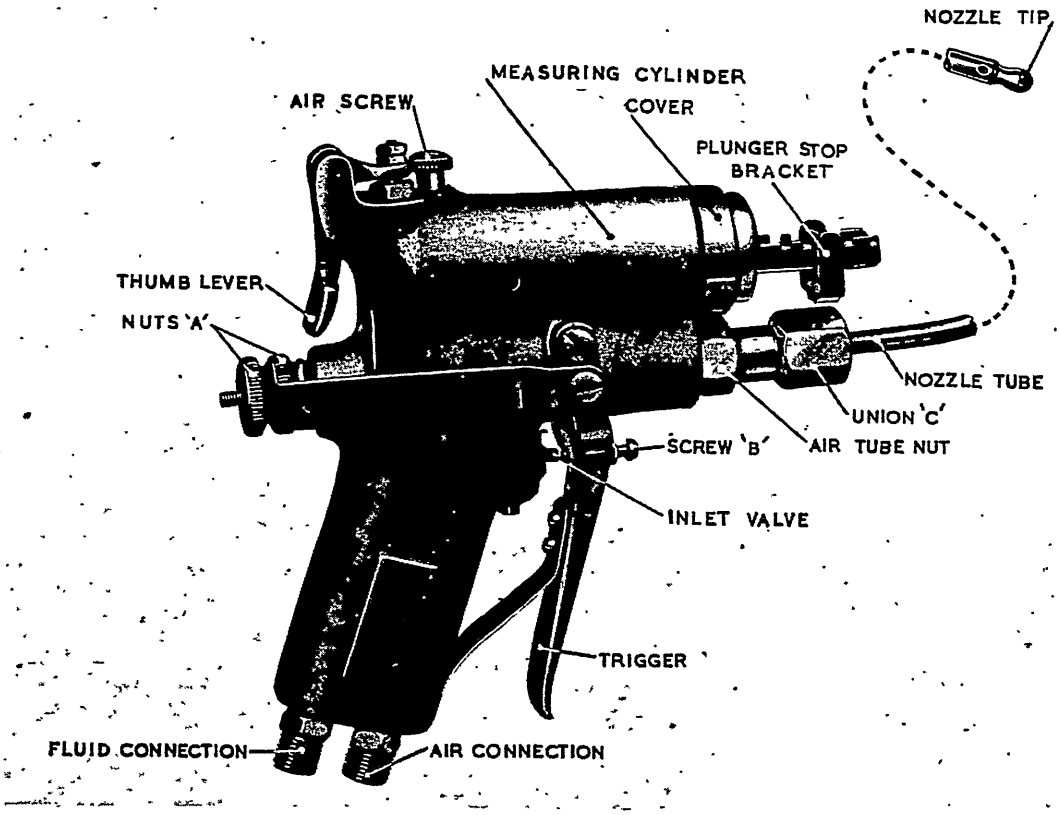


Fig. 4.—Miller Type C.S.101 corrosion inhibitor spray gun

(iv) Insert the nozzle tip in the engine cylinder plug hole and press the gun trigger. Move the nozzle slowly up and down in the cylinder whilst the fluid is being sprayed, and keep the trigger pressed until the plunger reaches the limit of its inward travel.

(v) Repeat the operations (iii) and (iv) for each subsequent engine cylinder.

22. *CAUTION—Never remove the filler plug from the fluid container on the compressor trolley without first turning off the air supply. If it becomes necessary to refill the container during the process of inhibition, isolate the container from the air supply in the receiver by closing the air cock on the compressor firmly.*

23. When the inhibition of the aero-engine has been completed it is advisable to clear the nozzle tip and tube of the spray gun before it is stored. This will prevent any fluid residue from coagulating in the holes of the nozzle tip. Clearance of the nozzle tube can be effected by pressing the gun trigger so as to emit several short blasts of air with the measuring cylinder empty.

Diagnosis of faults

24. If, when the gun trigger is pressed, the measuring plunger spindle remains stationary and fluid is continually sprayed through the nozzle, the measure valve (*see fig. 5*) is not seating properly. To rectify this, first see that the thumb lever is free and not sticking in any way, then tap the top of the spring plunger lightly with a piece of wood or soft metal. If the fault is not cured by this means the valve must be removed and cleaned, and the valve seating examined for the presence of grit.

25 Should fluid not be sprayed through the nozzle when the gun trigger is pressed, the nuts 'A' (*see fig. 4*) at the rear of the gun should be adjusted slightly forward. Care must be exercised in doing this as an over-adjustment may leave the valve constantly open, allowing

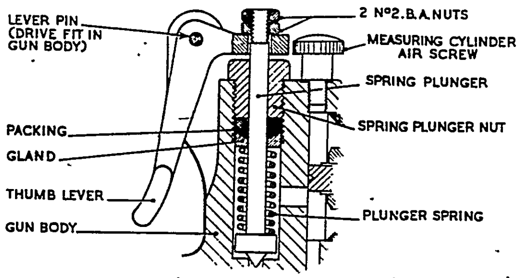


Fig. 5.—Section through measure valve (Miller type guns)

fluid to escape without the gun trigger being pressed.

26. If, when the gun trigger is pressed, no air passes to the nozzle, the screw 'B' (*see fig. 4*) in the trigger should be adjusted so as to make earlier contact with the inlet valve.

27. If air leaks continually at the nozzle without the gun trigger being pressed, the screw 'B' in the trigger should be adjusted so as to allow the inlet valve to seat properly.

28. If no fluid is delivered to the nozzle when the gun trigger is pressed, close the air cock on the compressor unit and examine the container to see if there is an adequate supply of the fluid. If fluid is present, disconnect the fluid pipe union from the gun butt (*see fig. 4*), open the compressor air cock and ascertain whether fluid flows freely to the end of the fluid hose. If the stoppage is not in the fluid hose, close the compressor air cock and reconnect the hose to the gun. Next, disconnect the nozzle tube at the union 'C' (*see fig. 4*, and the note in para. 30 (i) below), open the compressor air cock and press the gun trigger. If fluid flows to this point the obstruction will be found in the nozzle tip or in the nozzle tube. These must be cleaned as described in para. 30 below. If no fluid reaches the nozzle tube union, the stoppage will be found in the passage leading to the measure valve. The measure valve, in this event, must be removed and the passage cleared.

29. If air escapes past the measuring plunger, the bucket leathers fitted to the plunger are at fault. The measuring cylinder cover (*see fig. 4*) should be removed, the plunger drawn out of the cylinder, and the bucket leathers renewed.

Servicing

Cleaning

30. It is important that the gun be kept scrupulously clean. No foreign matter must be allowed to enter the fluid container; the holes in the nozzle tip are of very small diameter, and may be clogged by even the smallest particles of grit. Should the nozzle become choked, however, the fact will be indicated by an irregularity of the spray pattern and a tendency for the measuring plunger to remain in the outer position. When these symptoms are observed the nozzle should be removed and cleaned as follows:—

(i) Unscrew the union nut 'C' (*see fig. 4*). **Note . . .** When unscrewing the union 'C' it is imperative that the air tube nut be held securely against any tendency to turn with the union. If the air tube nut is allowed to turn, the inner fluid tube may be twisted and rendered unserviceable.

(ii) Gently pull the outer tube off the inner tube. The inner tube will straighten and come out without trouble if this is done slowly and firmly.

(iii) Unscrew the air tube nut and withdraw the inner nozzle tube from the gun.

(iv) Soak both tubes in paraffin for at least fifteen minutes.

(v) Gently probe the spraying holes in the end of each tube with a piece of 26 or 28 S.W.G. *copper* wire. Care must be exercised not to enlarge the holes, as this will prevent efficient atomization of the fluid and cause irregularity in the spray pattern.

(vi) Insert the end of each tube in the open end of a compressed air hose and turn on the air for a few seconds.

(vii) Make sure that no paraffin remains in the tubes before reassembling them to the gun.

Lubricating

31. All external moving parts of the gun should be lightly oiled when they are seen to be dry of lubricant. The measuring plunger is best oiled when it is at the full extent of its outward travel.

32. The compressor should be lubricated by occasionally topping up the level of the oil at the filler plug which is to be found at the forward side of the base casting of the pump housing. The level of the oil should be approximately ½ in. below the top of the filling hole. Light grade mechanical transport lubricating oil, Stores Ref. 34A/161, should be used.

Repair

33. Any gun which requires repairs other than those involving only the renewal of worn or damaged parts should be labelled UNSERVICEABLE and returned to Stores.

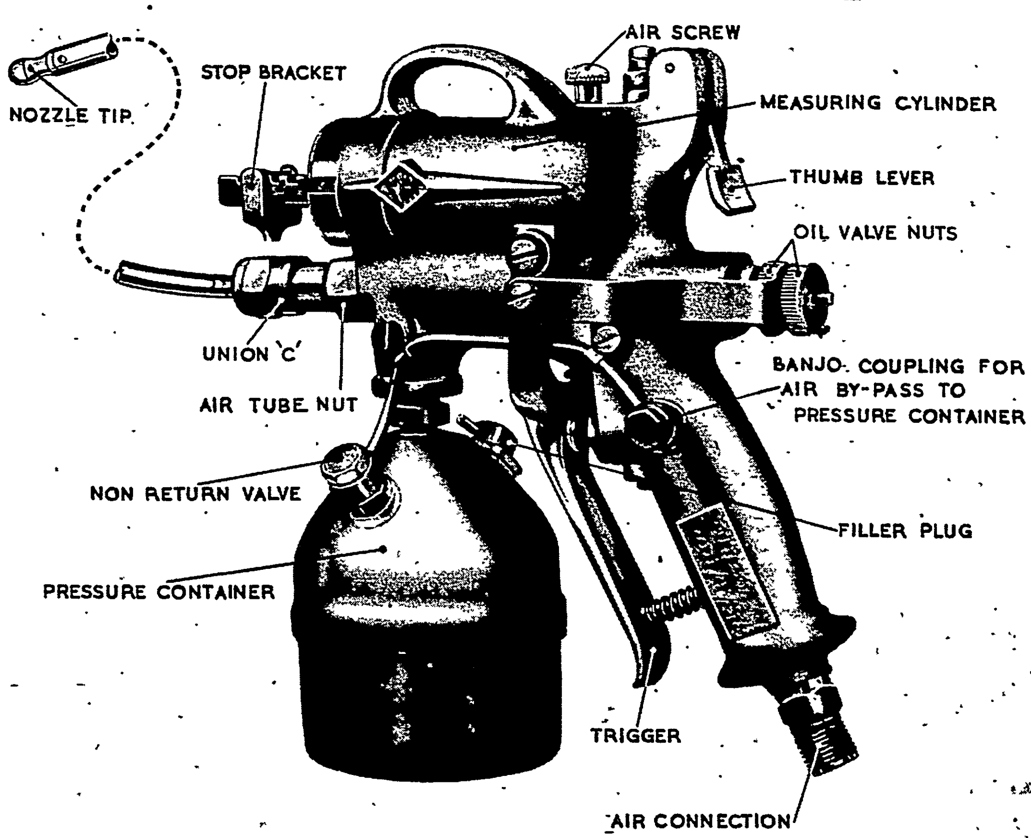


Fig. 6.—Miller Type C.S.C.103 corrosion inhibitor spray gun

Miller Type C.S.C.103 spray gun

Description

34. The Miller Type C.S.C.103 spray gun is illustrated in fig. 6. The gun is self-contained, and operates from any source of compressed air supply which will provide a pressure of between 120 and 150 lb. per sq. in. The supply of one half-pint of the inhibitor fluid is held in a pressure container which is fitted on the underside of the gun forward of the trigger. Air is passed to the container through a small tube which taps the air supply from the air passage which passes through the butt of the gun. When the measure valve is opened, by pressing the thumb lever, the air pressure in the container forces the fluid up through a central tube into the measuring cylinder. In all other respects the gun is the same as the Miller Type C.S.101, except that there is no inlet valve actuating screw in the trigger.

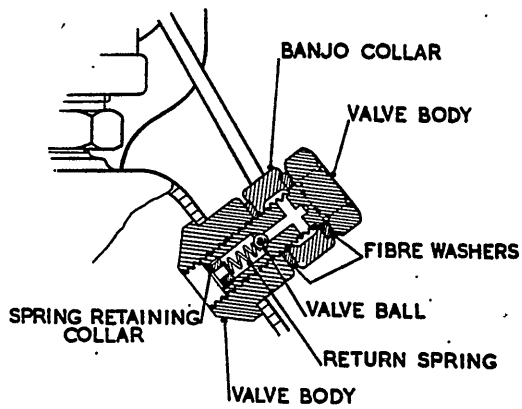


Fig. 7.—Section through non-return valve (Miller Type C.S.C.103 gun)

Operation and servicing

35. Operating and servicing instructions are the same as for the Miller Type C.S.101 spray gun except for the following:—

36. Para. 26 and 27 are inapplicable, there being no adjustment screw in the trigger for the inlet valve.

37. *CAUTION—The air supply must be turned off at the source before the filler plug, situated on the right-hand side of the pressure container, is removed for any purpose.*

38. If no fluid is delivered to the nozzle when the trigger is pressed, first turn off the air supply at the source and examine the pressure container to see if there is sufficient fluid present. When removing the filler plug it is advisable to notice whether a small escape of air occurs. This is a useful indication of the presence of air pressure in the pressure container. If there is fluid in the container, but no air pressure, the non-return valve, fig. 7, is either sticking or obstructed, and should be removed and cleaned. If both fluid and air pressure are present in the container, disconnect the nozzle tube at the union 'C' (*see fig. 6*, and the note in para. 30 (i), above) and press the gun trigger. If no fluid flows to the nozzle tube union, the obstruction will be found in the passage leading to the measure valve (*see fig. 6*). The valve should be removed, and the passage cleared. If fluid flows to the nozzle tube union, the obstruction is in the nozzle tube. This should be cleaned as detailed in para. 30.

39. Para. 32 is inapplicable, as there is no specially designed compressor for use with this gun.

P6171 M. /G3155 1/45 5250 C & P **Gp. 1**

AIR MINISTRY
January, 1945

A.L. No. 26 to A.P.1464C
Volume I

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

Part 2
Section 4

(1) Chapter 2, para. 13 (iii). *Amend* "Stores Ref. 34A/104 (D.T.D. Spec. 386)" to read "Stores Ref. 33C/720". Write "A.L.26" in the outer margin against the amendment.

Section 5

(2) Chapter 2, para. 39. *Cut out* the following and *affix* to cover the first eight lines of the paragraph:—

Linolite C.C. hose clips

39. The Linolite C.C. and the A.G.S.605 are the two types of hose clip most widely used in the Service. The latter type is of a well-known, simple design, and need not be described here.

(A.L.26)

The Linolite C.C.

When you have done this, make an entry in the Amendment Record Sheet at the beginning of the book.

ENGINEER

P6820 M /G4188 3/45 5250 C & P Gp. 1

RESTRICTED
(For official use only)

AIR MINISTRY | **A.L. No. 27 to A.P.1464C**
October, 1945 | **Volume I**

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

Part 2
Section 5

1. Chapter 2. *Remove* and *dispose of* the existing leaves bearing para. 1–6 and 7–18 and *insert* the attached leaves.
2. *Delete* para. 29–32 and *write* "A.L.27" in the outer margin.
3. *Remove* and *dispose of* the leaves bearing para. 33–40 and 41–42.

When you have done this, make an entry in the Amendment Record Sheet at the beginning of the book.

ENGINEER

CHAPTER 2

AERO-ENGINE COOLING SYSTEMS—SERVICING

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The efficiency of a properly designed aero-engine cooling system depends mainly on the thoroughness of the servicing. The information given in this chapter is of a general nature because each type of cooling system has its own peculiarities, and local conditions must also be taken into consideration. This chapter, should therefore, be read in conjunction with information contained in the relevant aircraft handbook and further augmented by reference to Vol. II leaflets and personal experience. The routine servicing instructions for cooling systems are laid down in the relevant aircraft handbook; Vol. II, Part 2.

2. In the cooling systems of all types of liquid-cooled aero-engines, ethylene glycol is used either in an approved form alone, or mixed to a specific percentage with water; the resulting liquids are termed "Coolants". The use of ethylene glycol is essential to prevent the cooling system from freezing up during service in cold climates and also during long glides at great altitudes. In order to avoid any risk of confusion a liquid-cooled aero-engine must not be referred to as "water cooled", whatever coolant is used. The cooling systems of Service aircraft may be broadly classified in two main categories, namely:—

(i) Those using coolant consisting of 30 per cent ethylene glycol (D.T.D.344, or D.T.D.344A) mixed with 70 per cent water. In this category are included the earlier types of liquid-cooled aero-engines in which the coolant circulates at atmospheric pressure, and the latest types where the whole cooling system is under a controlled internal pressure.

(ii) Those using coolant consisting of ethylene glycol without water. (D.T.D.344, or D.T.D. 344A.)

CORROSION

General

3. One of the principal defects experienced in cooling systems is the corrosive action of the coolant on the various metals used in the system. This corrosion continues all the time the coolant

is in the system, whether the engine is standing idle or is in constant use. Since leaking radiators or coolant pipes, resulting from such corrosion action, may well cause the loss of an aircraft, it is of primary importance that corrosion be reduced to a minimum.

Corrosion inhibitor

4. Ethylene glycol in its pure form (D.T.D.116A) does not contain a corrosion inhibitor and when used as a coolant, alone or mixed with water, will itself attack the solders in the radiators. If used for any length of time ethylene glycol becomes acidic; its corrosive effect is thereby increased and the various metals in the cooling system, especially mild steel, are also affected. It is therefore necessary to protect the cooling system components subject to attack by adding an inhibitor (Triethanalomine Phosphate). Ethylene glycol containing this substance is now the standard used in the Service for all liquid-cooled aero-engines, either neat or as a 30/70 per cent coolant, according to the requirements of the particular cooling system. Ethylene glycol containing corrosion inhibitor is available to the Service to specifications D.T.D.344 and D.T.D.344A. Both specifications include the addition of the inhibitor, but D.T.D.344A, which is a more recent specification, contains 0·2 per cent more of the inhibitor than D.T.D.344. Ethylene glycol to either specification may be used, but it is preferable that D.T.D.344A is used in the preparation of the 30/70 per cent coolant.

COOLING SYSTEMS USING 30/70 PER CENT. COOLANT

5. Where coolant having an admixture of water is used in liquid-cooled aero-engines, it should be prepared as follows, subject to the precautions detailed:—

(i) *Local mains water.*—Local mains water may be used in the preparation of 30/70 per cent. coolant. The use of distilled water has been discontinued owing to the danger of the glass carboy containers being contaminated by sulphuric acid. The inhibitor included in the standard glycol (D.T.D.344A) is triethanolamine phosphate, which acts as an efficient water softener. It is therefore unnecessary to resort to any further softening process.

(ii) *Chlorinated water.*—The quantity of chlorine present in chlorinated water is so small that it is unlikely to have any significant effect on coolant corrosion. Action to de-chlorinate water supplies is therefore unnecessary.

Mixing 30/70 per cent. coolant

6. Provided that all the apparatus used in mixing the 30/70 per cent. coolant is clean, the coolant may be transferred to the aero-engine cooling system after being thoroughly stirred and tested for suitability (see para. 6B) and for specific gravity (see para. 7). Purely as a precautionary measure, however, it is advisable to pour the coolant into a settling tank, where it should be allowed to stand for as long as possible before being used. For aircraft with secondary surface radiators it is recommended that the coolant should be allowed to settle in the tank for a minimum period of 4 hours.

6A. The settling tank should be supported above ground level and should be fitted with a large-bore drain cock in the base so that sediment and sludge may be removed easily. For drawing off the pure coolant, a second drain cock should be fitted in the side of the tank at a height from the bottom sufficient to prevent sediment from passing out with the coolant. Alternatively, clean coolant may be syphoned out of the tank by the use of a pipe, the submerged end of which is supported 8 in. above the bottom of the tank. The settling tank should be thoroughly cleaned and flushed with clean water before it is used for a new quantity of coolant.

E.C.64 test papers

6B. E.C.64 test papers enable the serviceability or otherwise of the coolant mixture to be checked. The test paper must be immersed in the coolant for 10 seconds. The coolant reaction is complete after 30 seconds. If the paper turns green, it indicates that the coolant is satisfactory, but if it turns purple or red the coolant must be rejected. In the latter instance, the system must be drained, flushed, and re-filled.

6C. The test papers may also be used for checking the presence or absence of the triethanolamine phosphate inhibitor in unused 100 per cent. glycol. In this instance, a green colour indicates that the glycol is inhibited and a purple or red colour that no inhibitor is present. Uninhibited glycol must not be used for the mixing of 30/70 per cent. coolant.

Testing specific gravity of 30/70 per cent coolant

7. The strength of the solution is tested by taking its specific gravity by means of a suitable hydrometer (see A.P.1086), but special precautions must be taken to ensure that each hydrometer reading taken is representative of the whole bulk of the solution. Because of the possible variation of the purity of ethylene glycol (D.T.D.344 or D.T.D.344A), it may be found that the specific gravity of the coolant when made up in the proportions of 30 per cent glycol to 70 per cent water may not conform to that indicated in fig. 1. After making up the coolant it should be well stirred and a sample taken without delay in a clean glass or other suitable vessel, and the specific gravity measured. The hydrometer reading must be taken at the meniscus or the base of the curve formed by the liquid on the stem of the instrument and, at the same time, the temperature of the sample should be taken in degrees Centigrade by means of a reliable thermometer. Reference to the graph (fig. 1) will show whether the hydrometer reading is the correct one relative to the temperature of the mixture. The curve in the graph is intended to indicate the particular hydrometer reading that must be obtained at any given temperature. If the hydrometer reading obtained is too low, more ethylene glycol is required to be added to the mixture in the container; if the reading is too high the addition of more distilled water is necessary. The hydrometer and thermometer test should be repeated on samples until the concentration is correct, special care being taken to stir the liquid each time water or ethylene glycol is added and to wash the testing vessel before each test, thus avoiding errors in obtaining readings.

30/70 per cent coolant in use

8. It is essential that the correct specific gravity of the coolant in use should be maintained and, as evaporation resulting from high engine temperatures or prolonged use will affect the strength of the coolant, samples must be drawn from the cooling system periodically and tested. Any evaporation that takes place is almost entirely that of the water, and consequently the specific gravity of the mixture will tend to increase. If, as the result of a test on a sample drawn from the cooling system, it is found that the specific gravity of the coolant is incorrect, the whole of the coolant must be drawn from the system and the specific gravity adjusted by the method described in para. 7. If samples of coolant are found to be so discoloured as to indicate the presence of an excessive amount of rust, the aero-engine should be run up and opened out to full ground level power for 30 seconds, in order to circulate the coolant thoroughly, after which the cooling system should be drained immediately. The liquid should be allowed to stand in the settling tank until the impurities have subsided, after which the coolant should be adjusted to the correct strength and returned to the cooling system after this has been flushed through with clean soft water.

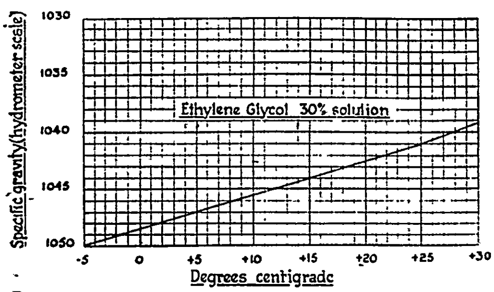


Fig. 1.—Graph, indicating specific gravity of 30/70 per cent coolant at various temperatures

Aircraft delivered from contractors

9. The cooling systems of aircraft which are delivered by air to Units direct from contractors may not contain coolant to Service standards. The cooling systems of all such aircraft should be drained, the coolant examined and treated in accordance with the directions given in the preceding paragraphs.

Foaming of coolant in engines

10. Foaming of the coolant in aero-engines gives rise to very serious consequences. The trouble usually occurs when the coolant temperature has risen to 80° C. under running conditions, large quantities of foam being formed and then lost via the header tank relief valve. It will readily be appreciated that, in conjunction with the consequent reduction in the quantity of coolant available, the fact that foam rather than liquid is being circulated through the system seriously reduces the cooling efficiency of the coolant, resulting in overheating and consequent damage to the engine. Foaming of the coolant may result in the loss of as much as 4 to 6 gallons from the cooling system of a typical single engine on an operational flight of 6 hours' duration.

11. It has been proved by experiments that, where coolant is kept scrupulously clean, foaming cannot take place. Foaming appears to be the result of a very fine dispersion or colloidal suspension of impurities in the coolant. Such fine impurities may have been introduced during mixing in the

tanks, or may be a result of corrosion within the cooling system itself. Coolant which becomes discoloured during use should be treated with suspicion and if very obviously dirty should be discarded. *Suspected coolant should not be rejected lightly.* Whilst some trouble caused by foaming has been experienced in the Service, this cannot be said to have reached any serious proportions, and only where strong evidence as to the foaming propensities of the coolant has been definitely established under running conditions, should it be discarded.

12. Evaporation of water from 30/70 per cent coolant causes an increase in the concentration of impurities present in the system. When draining the cooling system for correction of the specific gravity of the coolant by the addition of water (see para. 8) the opportunity should be taken to examine the coolant for signs of foaming. When foaming in a coolant system has been definitely established, there is only one sure method of dealing with the trouble, namely, the cooling system must be drained, washed out with water, and refilled with new coolant.

13. Where evaporation of the water content of the coolant has occurred, on no account must the cooling system be topped up with water alone. If this is done, any impurities in the water, such as those which give rise to permanent or temporary hardness, will be precipitated, causing sludging, and also greatly increasing the possibility of foaming. In an emergency when there is no time to drain the cooling system and to refill with the correct coolant, the system should be topped up with clean coolant or, if this is not available, with neat ethylene glycol (D.T.D.344, or D.T.D.344A).

Draining the engine coolant system

14. When it is necessary to drain the coolant from the cooling system, the following is the procedure to be adopted. The engine should be run up until the coolant has reached a temperature of 85° C. The engine should then be switched off and the hot coolant immediately removed. This ensures that any sludge or sediment in the coolant is first thoroughly agitated and then cleared from the cooling system. When it is seen that the coolant is dirty, and it is considered advisable to flush the system for this reason, it should be refilled with distilled water, or the softest water obtainable, and the engine run up again until the temperature of this water reaches 85° C., upon which it should be drained off at once. If the water drained from the system is very dirty, the process should be repeated until clear, and the cooling system filled finally with clean coolant. In all such operations the apparatus used must be kept clean.

Safety precautions

15. Personnel should exercise great care when draining an engine cooling system to avoid getting splashed with hot coolant, as the resulting burns are both painful and serious. The fumes given off by the hot coolant should not be inhaled where this can possibly be avoided. The 30/70 per cent coolant and neat ethylene glycol coolant, whether hot or cold, have a deleterious effect on rubber and similar materials. This is an additional reason for avoiding splashing and awkward handling of the fluid. Any rubber components, such as tyres, electrical cables, etc., which have unavoidably come into contact with coolant should be wiped dry at once.

Salvage of coolant

16. All coolant removed from a cooling system and which is considered to be unfit for further use, or is known to be contaminated, should be returned to Stores in salvage drums for despatch to the manufacturers who can reclaim such coolant no matter in what condition it has come from the engine.

COOLING SYSTEMS USING ETHYLENE GLYCOL WITHOUT WATER

17. Those aero-engine cooling systems using neat ethylene glycol must always use inhibited ethylene glycol to Specification D.T.D.344 or 344A.

18. Ethylene glycol tends to decompose in use, due to the repeated heating to normal engine temperatures, and evidence of this will be shown by foaming; foaming may also be caused by dilution with water or by contamination with oil, or by the presence of dirt. Because of the higher operating temperatures of ethylene glycol, care should be taken to ensure that water is not inadvertently introduced either directly or indirectly into the system, as, for example, when cleaning and flushing

P9165 M /G2997 1/46 5250 C & P Gp. 1

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS
This is A.L. No. 28 to A.P.1464C, Vol. I, and concerns Part 2, Sect. 2
Remove and dispose of the existing Chap. 3, insert this new Chap. 3, and make an entry in the Amendment Record Sheet at the beginning of the book.

ENGINEER

Chapter 3 . . . AERO-ENGINES—CLEANING

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The method of cleaning aero-engines as described in this chapter is common to most types of aero-engine. For detailed information regarding particular aero-engines, reference should be made to the relevant aero-engine Air Publication.

2. Standard types of baths are available for the cleaning of aero-engine parts; these include:—

(i) Paraffin baths for both the preliminary and final washing of all aero-engine parts and for the cleaning of those parts which must not be placed in the hot solutions.

(ii) Trichlorethylene de-greasers for the removal of the more persistent grease and dirt.

(iii) Cresylic acid baths for loosening the hard carbon deposits from those parts which are subjected to intense heat during the running of the aero-engine.

(iv) Nitric acid baths for the cleaning of aero-engine valves.

3. Before the aero-engine is dismantled, the exterior should be washed with paraffin. This removes the excessive oil and dirt and simplifies the dismantling operations.

4. When the components have been dismantled, each part must be identified. One method of effecting this identification is to allot a letter of the alphabet to each aero-engine number by book record. As the aero-engine is dismantled through the cleaning shop, a metal tally bearing this letter should be attached to each part or set of parts. When the cleaning processes have been completed, the full set of tallies should be returned for use on another aero-engine. This not only ensures complete identification but affords, through the book record, accurate progressing of the aero-engines through the shop.

5. After dismantling, the parts are given a further de-greasing with either paraffin or trichlorethylene. Those parts which need it are then placed in the carbon-removing solution, after which any remaining deposit is removed by mechanical means. A typical cleaning shop lay-out for an in-line aero-engine is shown in fig. 1.

6. Ensure that fire-fighting equipment is available and that inflammable solvents are stored in accordance with the Fire Regulations as laid down in Air Publication 957. The shop should be adequately ventilated and gloves, aprons, etc., should be provided for the protection of operating personnel.

Cleaning equipment

7. Lightly-constructed stands should be made up locally, on which aero-engine parts can be rested within the tanks during cleaning operations, in order to leave a sludge space at the bottom of the tanks. The tanks should be cleaned out at frequent intervals and replenished with fresh cleaning fluid. The paraffin tank should be drained after the sludge has been allowed to settle for several hours, the paraffin being strained and used again. Racks for the reception of components should be used during the draining and drying operations and for the holding of parts which have had their final cleaning.

8. To assist in the removal of dirt and carbon deposits, suitable wire brushes of the hand or power-driven rotary type may be used on most of the components. A.P.1464B, Vol. I, Part 2, Sect. 3, Chap. 6 gives further information on electric brushing machines. Parts which have been subjected to mechanical cleaning operations should be washed with paraffin or blown out with a compressed air jet to remove swarf and dirt which may have collected on them during the process. Coarse grades of emery cloth should not be used for cleaning aero-engine components, although the finer grades, dipped in paraffin, may be used with discretion for cleaning valve stems, pump spindles, cams, etc. Emery cloth must not be used for the cleaning of any non-ferrous metals, and extreme care must be taken, at all times, to avoid scratching any aero-engine components.

DE-GREASING

General

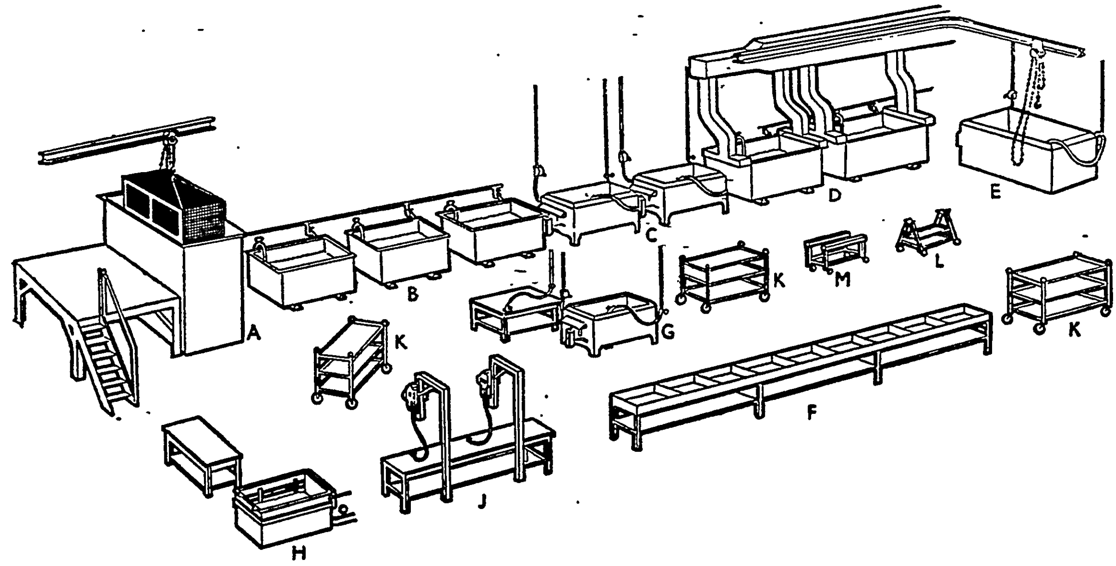
9. When the engine has been dismantled, all parts which have an appreciable coating of oil, grease or sludge should be de-greased. If paraffin is used as a de-greasing agent, surplus paraffin must be removed from the parts before they are immersed in the carbon-removing solution.

Trichlorethylene de-greasing

10. The usual method of de-greasing aero-engine parts is by trichlorethylene vapour condensation. During this process the vapours rise and condense on the cold parts which are suspended above the liquid, and so dissolve and remove the grease. When the articles reach vapour temperature the cleaning action ceases, so that if further de-greasing is necessary the parts should be removed, cooled, and put back into the de-greaser. As an anti-corrosion precaution the parts should be raised to the temperature of the vapour before they are removed from the de-greaser. They should then be coated with thin, clear oil as a rust-preventative as soon as possible.

11. Trichlorethylene (Stores Ref. 33C/547/836) is authorised for use in approved de-greasers only. The equipment should be operated to enable the vapour to condense completely as close to the top of the condensing unit as possible and safely below the top of the tank. The exit water should be as warm as possible. 38° C. (100° F.) is a good operating temperature, while retaining the vapours at a safe operating level.

12. Adequate shop ventilation should be provided in order to prevent the fumes or liquid coming into contact with the operating personnel and the parts should be fully drained before being removed from the de-greaser. A.P.1464B, Vol. I, Part 2, Sect. 3, Chap. 12



A — LARGE DE-GREASING PLANT
B — GENERAL CRESOL SOAP TANKS
C — GENERAL PARAFFIN WASH
D — CRESOL SOAP TANKS FOR CRANKSHAFTS & CRANKCASES
E — PARAFFIN WASH FOR CRANKSHAFTS & CRANKCASES
F — PARAFFIN TRAYS (CLEANING SMALL PARTS)
G — PARAFFIN WASH (SMALL PARTS)
H — PISTON DE-GREASER
J — PISTON DE-CARBONIZERS
K — TRANSPORT TROLLEYS
L — CRANKSHAFT WASHING STAND
M — CRANKCASE WASHING STAND

Fig. 1.—A typical cleaning shop lay-out for an in-line aero-engine

gives information on the precautions to be taken whilst trichlorethylene de-greasing is in progress.

Solution control

13. Trichlorethylene de-greasers must be operated so that the trichlorethylene is alkaline at all times. Triethylamine is used as an inhibiting agent for this purpose. To ensure that trichlorethylene will not be corrosive, either to the parts to be cleaned or to the equipment, it must be inhibited initially and periodically thereafter.

14. The most satisfactory method to determine whether the solution is of acid or alkaline content is by titration with an acid. The following test is recommended:—

(i) Take 100 millilitres of the used trichlorethylene, add it to 100 millilitres of distilled water, and then stir in a few drops of methyl orange indicator. Should the water layer turn red, the inhibitor is absent and the solution is acid. If the water layer is yellow the inhibitor is present and the solution is alkaline.

(ii) To determine the alkaline content of the trichlorethylene, fill a burette with 1/10th normal hydrochloric acid solution and read off the level.

(iii) Next, allow the hydrochloric acid to run into the yellow trichlorethylene solution drop by drop, stirring continuously, and watch for a change of colour. Continue the process, adding a drop at a time until the solution takes on a definite orange tinge.

(iv) Now read from the burette the amount of acid used. This will indicate the proportion of inhibitor present. From this reading and by comparison with the quantities quoted in the next paragraphs, the amount of triethylamine to be added to the solution, to make it sufficiently alkaline for the metal to be cleaned, may be determined.

Steel and brass

15. For de-greasing steel and brass, trichlorethylene in use usually requires not less than one millilitre of 1/10th normal hydrochloric acid to turn the water layer orange. Unused trichlorethylene usually requires not more than three millilitres of 1/10th normal hydrochloric acid to turn the water layer orange.

Aluminium-alloys

16. For de-greasing aluminium alloys, trichlorethylene in use requires not less than 10 millilitres of 1/10th normal hydrochloric acid to turn the water layer orange, particularly if the solution is contaminated with aluminium particles. Unused trichlorethylene requires not less than 23 millilitres of 1/10th normal hydrochloric acid to turn the water layer orange.

Uninhibited trichlorethylene

17. New uninhibited trichlorethylene can be inhibited for steel by the addition of 75·8 millilitres or 2·9 fluid ounces of technical grade triethylamine per 55 gallon drum of trichlorethylene, and for aluminium alloys by the addition of 656·6 millilitres or 22·2 fluid ounces of technical grade triethylamine per 55 gallon drum of trichlorethylene.

CARBON REMOVAL

General

18. The high temperature generated inside the aero-engine breaks down the oil and causes carbon to be formed as a lacquer-like coating closely bonded to the metal parts. Over a period of time, this coating breaks down and forms a carbon deposit on its outer surface. The carbon removers attack or dissolve the lacquer-like coating but not the carbon. The carbon dust then peels off and drops to the bottom of the solution.

19. Parts, such as pistons, are subjected to intense heat and there is little, if any, lacquer for the carbon-remover to dissolve. Lead from the petrol is deposited with the carbon and combines to form so hard a deposit that after immersion in the carbon-removing solution it has to be removed by mechanical means.

Carbon-remover solutions

20. Carbon-removers containing cresylic acid or phenol are far superior to any other solvents. Cresylic acid of high ortho-cresol content to Specification BSS.517 (Stores Ref. 33C/596) has been found satisfactory and is approved for use in service repair depots. Various other solvents, soaps, wetting agents, inhibitor or corrosion-preventive agents, are added to make the solution more effective. The soaps and wetting agents produce a cleaning action, while the other solvents are attacking the carbon and lacquer coating. The inhibiting agent prevents the carbon-removers from attacking the metals themselves. Care should be taken to avoid splashing during the cresylic or nitric acid bath treatment, otherwise severe burns may result.

21. The carbon-remover solutions mentioned in para. 20 may be used hot. The base solution of this type should be diluted and used as instructed in para. 22–28. It is preferable to have a series of carbon-removing baths, each calculated to clean a certain group of aero-engine parts. Details of the carbon-remover solution content and the operating conditions for these groups are given below. They may be used hot and are typical of present-day practice.

Grouping of engine parts

Tank 1. Pistons

22. Owing to the excessive quantity of carbon collected on the pistons it is usually necessary to soak them in the cresylic acid bath for a much longer period than for any other engine parts. The extent of carbon deposit varies according to the number of hours the engine has run. Discretion is therefore needed when the soaking time is being determined. The piston bath should contain as much cresol solution as can be physically tolerated by the operators. A typical bath composition is as follows:—

200 gallons water.

2 gallons cresol, liquid, ortho (Stores Ref. 33C/596).

2 lb. bar white windsor soap, shredded (Stores Ref. 33D/178).

23. The water must first be heated to the operating temperature (between 60° C. and 75° C.) after which the shredded soap can be dissolved. To maintain a constant strength, a further 2 lb. of shredded soap should be added every 10 hours. The whole bath need only be changed when the solution is so polluted as to merit complete replenishment.

Tank 2. Aluminium casings, auxiliary drive casings, sumps, supercharger casings, reduction gear cases, etc.

24. The above parts do not contain hard carbon deposits and a soaking period of 1½ hours has been found to be adequate. The bath should be operated at a temperature of 60° C.–75° C. A suitable composition for this bath is as follows:—

200 gallons water.

½-gallon cresol, liquid, ortho (Stores Ref. 33C/596).

2 lb. bar white windsor soap, shredded (Stores Ref. 33D/178).

25. The bath should be prepared as for Tank 1, and 2 lb. of shredded soap must be added every 10 hours.

Tank 3. Steel parts

26. The composition should be the same as for Tank 2, with similar 10-hourly soap additions.

Note . . . The bath should be made up beforehand. Cresylic acid must not be added during the immersion of steel parts.

Tank 4. Crankcases

27. The tank solution for crankcases should be the same as for pistons. These bear cellulose paint marks which must be removed before the test for crack detection can be carried out. It is only necessary to soak crankcases for 1½ hours in this solution. They are then ready for withdrawal at the same time as the steel and aluminium parts. The carbon remover solution does not altogether remove the markings, and the parts must be washed in paraffin. The markings may then easily be removed by the use of compressed air jets or wire brushes.

Tank 5. Highly-polished steel parts

28. The soaking time for highly-polished steel parts is the same as for aluminium casings, steel parts and crankcases, but the solution differs. Cresol carbon-removing solution has a tendency to discolour the highly-polished journals, so that they have to be lapped after removal from the tank, even when inspection shows it to be dimensionally unnecessary. The cresol carbon-remover must therefore not be used in the highly-polished steel part washing tank. The following composition is satisfactory with a soaking time of 1½ hours:—

200 gallons water.

4 lb. bar white windsor soap, shredded (Stores Ref. 33D/178).

29. The shredded soap must be thoroughly absorbed before the highly-polished parts are immersed. A further 4 lb. of soap must be added every 10 hours to enable the soaking time to be kept standard.

30. With the exception of Tank 1 (Pistons) the soaking times, as stated, should be accepted as the maximum and are intended only as a guide for aero-engines in their dirtiest possible condition. Discretion and experience will help those in charge of operations to determine accurate times according to the condition of the parts. In many instances it will be found that the cleaning time for some batches of parts may be as short as 30 to 60 minutes.

31. Small parts, especially those made of brass, need not be soaked in the carbon-removing solution if they can be satisfactorily cleaned in the paraffin bath. Clutch linings, clutch plates, oil seals, magnesium and rubber parts must never be placed in the hot solutions, but should be cleaned with paraffin.

Treatment after the removal of carbon

32. All parts that have been washed in the carbon-removing solutions should be transferred to the paraffin baths immediately after their withdrawal. Discoloration and corrosion are likely to occur if parts are exposed to the atmosphere for any length of time. If it is impracticable to effect an immediate transfer, the trays or basket of parts should be treated with a suitable anti-corrosion agent. The carbon deposit on pistons, although considerably loosened by the carbon-removing solution, can only be removed completely by mechanical methods. After this process they should be finally washed in the paraffin bath, de-greased and thoroughly dried. Gudgeon pins and connecting rods which have been soaked in the carbon-removing solution should be given a paraffin wash and then buffed to obtain a production finish and to facilitate crack detection. These parts should be de-greased and protected against corrosion before being passed to clean trays in their complete and fully-identified sets.

Cleaning of aero-engine valves, etc.

33. To avoid the necessity for polishing the large radiused portion on the underside of the inlet and exhaust valves, chemical cleaning in a nitric acid bath has been introduced. Valves cleaned by this process are acceptable without additional polishing. A coating of oxide is left on the surface of the material after the carbon has been chemically removed, but this is not detrimental. Separate treatments are necessary for the inlet and exhaust valves because the deposits are widely different in composition. The inlet valve is chiefly coated with carbon, particularly under the head. No acid treatment is effective until this has been removed. The deposits on the exhaust valve are usually lead compounds, apart from a small amount of carbon on the stem. Little advantage is therefore gained by oven treatment prior to the nitric acid immersion. During the nitric acid process, very little lead goes into solution, and most of the deposit will be found as sludge at the bottom of the tank.

Inlet valves

34. Inlet valves should be de-greased in trichlorethylene and placed in an oven at a temperature of 550/575° C. for approximately 30 minutes. Adequate ventilation of the oven is necessary to give the air supply needed to burn off the carbon. The operation is completed when the carbon ceases to glow. The valves should then be allowed to cool. The small, loose deposit of lead oxide which may be observed after this treatment, can be readily removed with a stiff bristle brush of the hand or rotary type. If the valves bear a fairly heavy adherent lead deposit, nitric acid treatment may be necessary. This is carried out by immersing the valves for a few seconds in a strong nitric acid solution and then in a solution containing 25 per cent. commercial nitric acid, by volume in water, for 5 to 15 minutes, although a longer period of immersion will not harm the valves. A stainless steel tank, externally heated, must be employed and fume extraction will be necessary. The solution should preferably be at a temperature of between 80°–90° C., as this will speed up the operation. If means of heating are not available the solution may be used effectively at atmospheric temperature, when a stoneware or other suitable vessel may be employed. After the nitric acid treatment the valves should be washed well in water, then immersed in boiling water, dried, and the carbon deposit removed from the stem and the valve tip by means of a rotary soft steel or hard brass wire brush. The valve head will be covered with a black or brownish-black oxide coating which is hard and chemically resistant. No attempt need be made to remove it. Apart from re-grinding the face, the valve is now ready for inspection.

Exhaust valves

35. The treatment for exhaust valves is the same as for inlet valves with the omission of the oven treatment. Exhaust valves with pressed-on, case-hardened stellite tips must have the latter protected during the nitric acid treatment; a suggested method is to slip a rubber cap over the tip and to stand the valve in such a position that the tip-end of the stem is not immersed in the solution. The rubber caps should be removed before the washing process is carried out.

Valve springs

36. Valve springs may be cleaned by means of a rotary wire brush followed by a paraffin wash.

Ball bearings

37. During the cleaning of ball bearings, the races should not be allowed to spin when a paraffin spray or brush is used, but should be slowly rotated to enable the balls or rollers to be cleaned. Surplus paraffin should be removed by means of compressed air jets and the bearings should then be dipped in thin clear oil to prevent corrosion pending viewing operations.

P10412 M13093/G703 7/46 5250 C & P Gp. 1

AIR MINISTRY
November, 1946

A.L. No. 29 to A.P.1464C, Vol. I

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

Part 2
Section 5
Chapter 2

1. *Remove* and *dispose of* the existing leaf bearing para. 1 to 6C, and *substitute* the attached new leaf bearing para. 1 to 6E.
2. Para. 7, line 15. *Delete* "distilled" and *write* "A.L.29" in the outer margin of the page.
3. Para. 27. *Amend* this paragraph to read "For information on permanent repairs to aircraft radiators, reference should be made to A.P.2850A, Vol. II, Part 3", and *write* "A.L.29" in the outer margin.

When you have done this, *make an entry* in the Amendment Record Sheet at the beginning of the book.

ENGINEER

CHAPTER 2

AERO-ENGINE COOLING SYSTEMS—SERVICING

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The efficiency of a properly designed aero-engine cooling system depends mainly on the thoroughness of the servicing. The information given in this chapter is of a general nature because each type of cooling system has its own peculiarities, and local conditions must also be taken into consideration. This chapter, should therefore, be read in conjunction with information contained in the relevant aircraft handbook and further augmented by reference to Vol. II, Part 1 leaflets and personal experience. The routine servicing instructions for cooling systems are laid down in the relevant aircraft handbook, Vol. II, Part. 2.

2. In the cooling systems of all types of liquid-cooled aero-engines, ethylene glycol is used either in an approved form alone, or mixed to a specific percentage with water; the resulting liquids are termed "coolants". The use of ethylene glycol is essential to prevent the cooling system from freezing up during service in cold climates and also during long glides at great altitudes. In order to avoid any risk of confusion a liquid-cooled aero-engine must not be referred to as "water-cooled", whatever coolant is used. The cooling systems of Service aircraft may be broadly classified in two main categories, namely:—

- (i) Those using coolant consisting of 30 per cent ethylene glycol (D.T.D.344, or D.T.D.344A) mixed with 70 per cent water. In this category are included the earlier types of liquid-cooled aero-engines in which the coolant circulates at atmospheric pressure, and the latest types where the whole cooling system is under a controlled internal pressure.
- (ii) Those using coolant consisting of ethylene glycol (D.T.D.344, or D.T.D. 344A) without water.

CORROSION

General

3. One of the principal defects experienced in cooling systems is the corrosive action of the coolant on the various metals used in the system. This corrosion continues all the time the coolant is in the system, whether the engine is standing idle or is in constant use. Since leaking radiators or coolant pipes, resulting from such corrosive action, may well cause the loss of an aircraft, it is of primary importance that corrosion be reduced to a minimum.

Corrosion inhibitor

4. Ethylene glycol in its pure form (D.T.D.116A) does not contain a corrosion inhibitor and when used as a coolant, alone or mixed with water, will itself attack the solders in the radiators. If used for any length of time ethylene glycol becomes acidic; its corrosive effect is thereby increased and the various metals in the cooling system, especially mild steel, are also affected. It is therefore necessary to protect the cooling system components subject to attack by adding an inhibitor

(triethanolomine phosphate). Ethylene glycol containing this substance is now the standard used in the Service for all liquid-cooled aero-engines, either neat or as a 30/70 per cent coolant, according to the requirements of the particular cooling system. Ethylene glycol containing corrosion inhibitor is available to the Service to Specifications D.T.D.344 and D.T.D.344A. Both specifications include the addition of the inhibitor, but D.T.D.344A, which is a more recent specification, contains 0·2 per cent more of the inhibitor than D.T.D.344. Ethylene glycol to either specification may be used, but it is preferable that D.T.D.344A is used in the preparation of the 30/70 per cent coolant.

COOLING SYSTEMS USING 30/70 PER CENT COOLANT

5. Where coolant having an admixture of water is used in liquid-cooled aero-engines, it should be prepared as follows, subject to the precautions detailed:—

(i) *Local mains water.*—Local mains water may be used in the preparation of 30/70 per cent. coolant. The use of distilled water has been discontinued owing to the danger of the glass carboy containers being contaminated by sulphuric acid. The inhibitor included in the standard glycol (D.T.D.344A) is triethanolamine phosphate, which acts as an efficient water softener. It is therefore unnecessary to resort to any further softening process.

(ii) *Chlorinated water.*—The quantity of chlorine present in chlorinated water is so small that it is unlikely to have any significant effect on coolant corrosion. Action to de-chlorinate water supplies is therefore unnecessary.

Mixing 30/70 per cent. coolant

6. Provided that all the apparatus used in mixing the 30/70 per cent. coolant is clean, the coolant may be transferred to the aero-engine cooling system after being thoroughly stirred and tested for suitability (see para. 6B) and for specific gravity (see para. 7). Purely as a precautionary measure, however, it is advisable to pour the coolant into a settling tank, where it should be allowed to stand for as long as possible before being used. For aircraft with secondary-surface radiators it is recommended that the coolant should be allowed to settle in the tank for a minimum period of 4 hours.

6A. The settling tank should be supported above ground level and should be fitted with a large-bore drain cock in the base so that sediment and sludge may be removed easily. For drawing off the pure coolant, a second drain cock should be fitted in the side of the tank at a height from the bottom sufficient to prevent sediment from passing out with the coolant. Alternatively, clean coolant may be syphoned out of the tank by the use of a pipe, the submerged end of which is supported 8 in. above the bottom of the tank. The settling tank should be thoroughly cleaned and flushed with clean water before it is used for a new quantity of coolant.

E.C.64 test papers

6B. E.C.64 test papers enable the serviceability or otherwise of the coolant mixture to be checked. The test paper must be immersed in the coolant for 10 seconds. The coolant reaction is complete after 30 seconds. If the paper turns green, it indicates that the coolant is satisfactory, but if it turns purple or red the coolant must be rejected. In the latter instance, the system must be drained, flushed, and re-filled.

6C. The test papers may also be used for checking the presence or absence of the triethanolamine phosphate inhibitor in unused 100 per cent glycol. In this instance, a green colour indicates that the glycol is inhibited and a purple or red colour that no inhibitor is present. Uninhibited glycol must not be used for the mixing of 30/70 per cent coolant.

Test reagent

6D. A more positive means of verifying the presence or otherwise of the triethanolamine phosphate inhibitor in unused 100 per cent ethylene glycol is by the use of ethylene glycol, reagent, test (Stores Ref. 33C/1106). This test is applicable to glycol drawn directly from bulk stocks and should not be used for testing 30/70 per cent coolant mixtures.

6E. To test for the presence of the inhibitor, 5 c.c. of the reagent must be thoroughly mixed in a clean test tube or other suitable vessel with about the same volume of ethylene glycol. The formation of a white precipitate or cloudiness indicates that the glycol is inhibited, while if the liquid remains clear, the glycol is uninhibited.

P11040 M22878/G1891 12/46 5250 C & P Gp. 1

LIST OF CHAPTER REFERENCES

This is a complete list of chapters contained in the 1464 Old Series. The left-hand reference gives the position of the chapter in the Old Series (1464A and B). The right-hand reference gives the position of the chapter in the New Series (1464A to G)

Old ref.				Chapter Titles	New ref.			
Vol. I	Part	Sect.	Chap.		Vol. I	Part	Sect.	Chap.
1464A	2	1	14	Parachute and dinghy maintenance organisation	1464A	1		12
1464A	3	1	2	Station workshops	1464B	2	3	2
1464A	3	3	1	Aircraft radiators	1464C	2	5	5
1464A	3	3	2	Tank repairs	1464D	2	5	2
1464A	3	7	1	Sparking plugs—Routine maintenance and re-conditioning	Transferred to A.P. 1374, Vol. I			
1464A	3	8	1	Timber	1464B	2	4	2
1464A	3	13	1	Metals and alloys	1464B	2	4	3
1464A	3	13	2	Crack detection—Metals and alloys	1464B	2	3	3
1464A	3	13	3	Marking of metals and alloys	1464B	2	4	4
1464A	3	14	1	Self-sealing protective covering (D.T.D.1074) for rigid fuel tanks	1464D	2	5	8
1464A	3	14	2	Self-sealing protective covering (D.T.D.1057) for rigid fuel tanks	1464D	2	5	9
1464A	3	14	3	Self-sealing protective covering (D.T.D.1047) for rigid fuel tanks	1464D	2	5	10
1464A	3	14	4	C.I.M.A. protection for aircraft fuel tanks	1464D	2	5	3
1464A	3	14	5	Linatex protection for aircraft fuel tanks	1464D	2	5	4
1464A	3	14	6	Semape protection for aircraft fuel tanks	1464D	2	5	5
1464A	3	14	7	Henderson protected fuel tanks for aircraft	1464D	2	5	7
1464A	3	14	8	Sorbo protection for aircraft fuel tanks	1464D	2	5	6
1464A	3	14	9	Self-sealing protective covering (D.T.D.1066) for rigid fuel tanks	1464D	2	5	11
1464A	3	14	10	Self-sealing protective covering (D.T.D.1070) for rigid fuel tanks	1464D	2	5	12
1464A	3	14	11	Protective covering for fuel pipes	1464D	2	3	7
1464A	3	14	12	Self-sealing protective covering (D.T.D.1048) for flexible fuel tanks	1464D	2	5	16
1464A	3	14	13	Self-sealing protective covering (D.T.D.1046) for rigid fuel tanks	1464D	2	5	13
1464A	3	14	14	Self-sealing protective covering (D.T.D.1049) for flexible fuel tanks	1464D	2	5	17
1464A	3	14	15	Crash-proof protective covering (D.T.D.1064) for rigid fuel tanks	1464D	2	5	14
1464A	3	14	16	Crash-proof protective covering (D.T.D.1072) for rigid fuel tanks	1464D	2	5	15
1464A	3	15	2	Working and repair of transparent plastics	1464B	2	4	5
1464A	3	16	1	Painting and doping of aircraft	1464D	2	1	1
1464A	3	16	2	Spraying equipment	1464B	2	3	4
1464A	3	16	3	Spraying technique	1464B	2	3	5
1464A	3	17	1	Glazing and sealing aircraft components	1464B	2	4	6
1464A	3	17	2	General adhesives and glazing and sealing compounds	1464B	2	4	7
1464A	4	1	1	Aero-engines—General	1464C	2	2	1
1464A	4	2	1	Aero-engines—Dismantling	1464C	2	2	2
1464A	4	2	1	Aero-engines—Cleaning	1464C	2	2	3
1464A	4	4	1	Aero-engines—Viewing } (New title:—Aero-engines—Viewing and viewing procedure)				
1464A	4	4	2	Aero-engines—Viewing procedure	1464C	2	2	4
1464A	4	4	3	Aero-engines—Alignment tests	1464C	2	2	5

LIST OF CHAPTER REFERENCES—CONTD.

Old ref.				Chapter Titles	New ref.			
Vol. I	Part	Sect.	Chap.		Vol. I	Part	Sect.	Chap.
1464A	4	5	6	Carburettor maintenance (New title:—Aero-engines—Carburettor servicing)	1464C	2	2	6
1464A	5	1	2	Aircraft salvage	1464D	2	1	2
1464A	5	8	1	Aero-engine oil systems (New title:—General)	1464C	2	3	1
1464A	5	8	2	Aero-engine cooling systems—Maintenance (New title:—Aero-engine cooling systems—Servicing)	1464C	2	5	2
1464A	5	8	5	Marking of piping on aircraft	1464D	2	3	2
1464A	5	8	6	Metal tubing for aircraft pipelines	1464D	2	3	3
1464A	5	8	7	Flexible tubing for aircraft pipelines	1464D	2	3	4
1464A	5	8	8	Metal couplings for aircraft pipelines	1464D	2	3	5
1464A	5	8	9	"Avimo" high pressure pipe couplings	1464D	2	3	6
1464A	5	10	2	Bonding and screening	1464D	2	1	5
1464A	5	12	1	Determination of the centre of gravity and the loading of aircraft	1464D	2	1	3
1464A	8	1	2	Picketing of aircraft	1464G	2	5	2
1464A	8	8	4	Installation of electrical power and lighting equipment for R.A.F. units in the field	Transferred to A.P. 1095G, Vol. I			
1464A	Appendix A, Issue No. 1			Standard colour scheme — New titles:— Standard colour scheme and index	1464B	2	5	2
				B.S. specifications	1464B	2	5	3
				D.T.D. specifications	1464B	2	5	4
1464A	Appendix A, Issue No. 2			Newal standard system of fits and tolerances	1464B	2	5	5
1464B	3	1	6	Electric brushing machine type AI/MY	1464B	2	3	6
1464B	3	1	7	Tru-loc cable end-fitting swaging machine	1464B	2	3	7
1464B	3	3	4	Tube bending machine	1464B	2	3	8
1464B	3	3	5	Chobert riveting rool	1464B	2	3	9
1464B	3	3	6	Dzus fasteners	1464B	2	6	3
1464B	3	3	7	Rivnuts and tools	1464B	2	6	2
1464B	3	3	8	Oddie fasteners	1464B	2	6	4
1464B	3	12	1	Measuring instruments and appliances	1464B	2	3	10
1464B	3	12	4	Jet calibrating machines	1464B	2	3	11
1464B	5	1	1	Aeroplanes—Furniture and equipment for servicing	1464G	2	5	9
1464B	5	5	14	Graviner automatic fire extinguisher equipment	1464D	2	1	4
1464B	5	6	2	Exactor controls—Hydraulic and mechanical	1464D	2	2	4
1464B	5	6	3	Bloctube control system	1464D	2	2	5
1464B	5	6	5	Simmonds Corsey control	1464D	2	2	2
1464B	5	6	6	Teleflex controls	1464D	2	2	3
1464B	5	7	3	Fuel pressure reducing valve, Amal.	1464C	2	6	2
1464B	5	7	4	Automatic pressure control valve for aircraft fuel tanks	1464D	2	6	2
1464B	5	7	5	Automatic altitude control for aero-engine supercharger	1464C	2	7	5
1464B	5	7	6	Vokes air filter	1464C	2	7	2
1464B	5	7	7	Vokes dry-element air filters	1464C	2	7	3
1464B	5	8	1	Oil coolers	1464C	2	3	6
1464B	5	8	2	Oil cooler—Robertson	1464C	2	3	7
1464B	5	8	2	Relief valves—Robertson	1464C	2	3	9
1464B	5	8	3	Oil coolers—Serck types	1464C	2	3	8
1464B	5	8	5	Viscosity valves	1464C	2	3	2
1464B	5	8	6	Oil dilution system	1464C	2	3	5
1464B	5	8	7	Oil cleaners—Vokes	1464C	2	3	3
1464B	5	8	8	Oil cleaners—Tecalemit	1464C	2	3	4
1464B	5	9	3	Hydraulic windscreen wiper	1464D	2	4	5
1464B	5	10	1	Thermostatic header tank relief valve type D.S.	1464C	2	5	3
1464B	5	10	2	Aero-engine liquid cooling system thermostat (New title:—Thermostat for liquid-cooled aero-engines)	1464C	2	5	4
1464B	5	2	1	De-icing equipment and materials for aircraft	1464D	2	4	2
1464B	5	2	2	Aerofoil de-icing equipment—Goodrich system	1464D	2	4	3
1464B	5	2	3	De-icing equipment for airscrews (New title:—De-icing equipment for propellers)	1464C	2	4	1
1464B	5	2	4	De-icing equipment for aero-engine induction systems (New title:—De-icing equipment for induction systems)	1464C	2	4	2

LIST OF CHAPTER REFERENCES—CONTD.

Old ref.				Chapter Titles	New ref.			
Vol. 1	Part	Sect.	Chap.		Vol. 1	Part	Sect.	Chap.
1464B	5	2	5	Windscreen wipers and de-icing equipment for pilot's windscreen and bomb-aimer's window	1464D	2	4	5
1464B	5	2	7	De-icing materials	1464D	2	4	4
1464B	5	12	1	Flotation gear	Cancelled			
1464B	5	12	2	Carbon dioxide cylinders	1464G	2	3	12
1464B	5	12	2	Operating heads	See A.P. 1182, Vol. 1			
1464B	5	12	4	Youngman dinghy	Cancelled			
1464B	5	12	5	Inflatable wing bags	Cancelled			
1464B	5	12	6	Inflatable fuselage bags	Cancelled			
1464B	5	12	7	Non-inflatable flotation systems	Cancelled			
1464B	6	4	2	Auto-klean lubricating oil strainer	1464E & F	2	2	2
1464B	6	5	1	Tecalemit type D fuel pump	1464E & F	2	3	3
1464B	6	5	2	A.C. fuel pumps	1464E & F	2	3	2
1464B	6	5	3	Zenith carburettors	1464E & F	2	3	4
1464B	6	5	4	Zenith carburettors, types 24-U and 24-U.H.	1464E & F	2	3	5
1464B	6	5	5	Solex carburettors, types F.V. and F.H.	1464E & F	2	3	7
1464B	6	5	6	Solex carburettors, types B.F.V. and B.F.H.	1464E & F	2	3	6
1464B	6	8	2	Borg and Beck clutch	1464E	2	4	2
1464B	6	12	1	Repairs to M.T. tyres (outer covers only) at units	1464E	2	4	3
1464B	8	1	1	Ground equipment	Cancelled			
1464B	8	2	2	Aircraft concealment nets	1464G	2	5	3
1464B	8	7	1	Fuel oil and water pumping equipment (Old title) (New title) Replenishment equipment on airfields—General	1464G	2	3	1
1464B	8	7	2	Delivery nozzles	1464G	2	3	6
1464B	8	7	3	Flexible hoses	1464G	2	3	7
1464B	8	7	4	Pumps for replenishing operations	1464G	2	3	8
1464B	8	7	5	Filters and strainers	1464G	2	3	9
1464B	8	7	7	Internal preservation of fuel storage tanks	1464G	2	3	10
1464B	8	7	8	Liquid measuring and recording meters	1464G	2	3	11
1464B	8	7	9	Portable fuel tanks	1464G	2	3	2
1464B	8	7	10	Portable oil tanks	1464G	2	3	3
1464B	8	7	12	Bulk installations on aerodromes	1464G	2	3	4
1464B	8	7	15	Oil cleaning plant	1464G	2	3	5
1464B	8	9	1	Flameless heater	1464G	2	5	4
1464B	8	9	2	Paraffin heaters	1464G	2	5	5
1464B	8	9	3	Portable floodlight	Transferred to A.P. 1095G, Vol. 1			
1464B	8	9	5	Compressed air operated oil primer	1464G	2	5	7
1464B	8	9	6	Flameless heaters, types B and C	1464G	2	5	6
1464B	8	9	7	Inflation adaptors for oleo-leg servicing equipment	1464G	2	5	10
1464B	8	10	2	Bristol compressor trolley unit	1464G	2	5	8
1464B	8	10	3	Instrument-testing trolley	1464G	2	5	11
1464B	8	10	4	Pneumatic servicing trolley—Low pressure	1464G	2	5	12
1464B	8	10	5	Pneumatic servicing trolley—High pressure	1464G	2	5	13
1464B	8	10	13	Accumulator trolley—Aero-engine electric starting	1464G	2	5	14
1464B	8	10	14	Aero-engine starting accumulator charging sets	1464G	2	5	15
1464B	8	10	15	Aero-engine starting accumulator charging set	1464G	2	5	16

NOTE TO READERS

Air Ministry Orders and Vol. II, Part I leaflets either in this A.P., or in the A.P.'s listed below, or even in some others, may affect the subject matter of this publication. Where possible, Amendment Lists are issued to bring this volume into line, but it is not always practicable to do so, for example when a modification has not been embodied in all the stores in service.

When an Order or leaflet is found to contradict any portion of this publication, the Order or leaflet is to be taken as the overriding authority.

When this volume is amended by the insertion of new leaves in an existing section or chapter, the new or amended technical information is indicated by a vertical line in the outer margin. This line is merely to denote a change and is not to be taken as a mark of emphasis. When a section or chapter is re-issued in completely revised form, the vertical line is not used.

Each leaf is marked in the top left-hand corner with the number of the A.L. with which it was issued.

★ ★ ★

FOR LIST OF ASSOCIATED PUBLICATIONS SEE PART THREE OF THIS VOLUME

LIST OF PARTS

Note.—*A list of sections appears at the beginning of each part*

R. A. F. ENGINEERING

AERO-ENGINES AND POWER PLANTS

PART 2

MISCELLANEOUS AERO-ENGINE AND POWER PLANT SUBJECTS

LIST OF SECTIONS

Note.—*A list of chapters appears at the beginning of each section*

SECTION 2

GENERAL PRACTICE

LIST OF CHAPTERS

***Note.**—A list of contents appears at the beginning of each chapter*

CHAPTER 1

AERO-ENGINES—GENERAL

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. Reference to the respective aero-engine handbooks will show that the methods of dismantling, overhauling and erecting are detailed to suit individual engines. These methods are based upon experience gained at the makers' works and should be used as a guide by service personnel. When this procedure is followed, a change of personnel during the work will not prevent its continuation, although such change should be avoided if possible.

2. There are certain mechanical processes that are alike in the main essentials and these, together with the precautions to be taken, apply equally well to all types of aero-engine, i.e., radial and in-line (including Vee and arrow). The following chapters, which deal with such general operations, should therefore be read in conjunction with the handbook of the engine, and although there may be some unavoidable overlapping, the repetition is made so that the particular operation might be adapted for other engines. Nothing in these chapters is intended to overrule official instructions issued to cover any specific point, nor is it to be understood that there are no alternative methods to those given.

3. It is of primary importance that personnel employed in the engine repair shops are informed that absolute cleanliness, the highest degree of accuracy and the very best workmanship are essential. The fits, clearances and repair tolerances as detailed in the Volume II, Part 2, of the engine handbooks are of the utmost importance and should be rigidly adhered to in all instances.

Tool kits

4. To assist in the overhaul and repair of engines there are two types of tool kits supplied, i.e., flight and workshop tool kits. In addition to these tool kits, special jigs and tools are available for use when carrying out a specific operation on a particular engine. All the tools and jigs, together with the correct method of their application, are dealt with in the engine handbook. The flight tool kit comprises those tools necessary to carry out the various operations in the daily maintenance routine, i.e., external adjustments. The workshop tool kit includes the flight tool kit and also those tools necessary in the dismantling and assembling operations. In addition to the workshop kit, locally made jigs, fixtures and tools, are sometimes required for a specific job; special jigs and tools may also be introduced to reduce the time required for a certain operation. The principle of these jigs, etc., can often be used in designing other special fitments. Personnel should be encouraged to submit their ideas and if these ideas are found to be satisfactory, the ultimate result will be to increase the efficiency and output of the shop. The extent to which it is economical to prepare special fixtures of a permanent nature will be decided by the amount of use to which the fixtures can be put in the

unit concerned. Thus, in a depot where the same operation has been carried out many times on the same type of engine, there is every reason to prepare any fixture or device which will facilitate the operation. In a smaller unit, however, where each one operation is only carried out occasionally, it will be better as a rule to improvise the necessary equipment by making a temporary assembly of standard material. In several chapters of this manual suggestions are given for employing both of these systems, the selection being made by the unit according to the principle stated above.

5. The maintenance and upkeep of the tool kit is often overlooked and it is very necessary that unserviceable tools should be immediately repaired or exchanged, thereby eliminating the chance of damage to a component, e.g., a spanner which does not fit properly may cause more damage to a component than the value of the tool—this obviously is false economy. This instruction not only applies to the tool kits specified above but to all tools. Tools should only be used for the purpose for which they are supplied. The boxes containing engine tool kits are furnished with recesses and spigots for the retention and protection of certain tools. It is very important that the tools be replaced in their proper positions after use and not allowed to lie haphazard in the bottom of the box. This method of storage has the additional advantages of permitting an easy check of the tool kit and quick access to any particular tool.

Benches

6. A type of workshop bench which gives efficient service in the engine repair shops is one having its top made from 9 in. × 2 in. deals bolted to cast-iron legs and reinforced with cross members to make the whole structure steady; the total height should not exceed 3 ft. Satisfactory results are not obtainable when benches are shaky, and therefore all securing nuts should be tightened as soon as this defect occurs. The bench top should be covered with soft metal, preferably zinc, countersunk screws being used for securing purposes. The benches should be kept as clean as possible by periodic washing with soapy water or paraffin. Wooden-topped benches, if uncovered, allow particles of metal to become enbedded therein which are liable to cause damage to engine components.

7. The benches may be divided into self-contained bays by the erection of low partitions wherein operations necessitating specialised treatment can be undertaken. These bays can be fitted up with special equipment, e.g., testing apparatus, jigs, etc., which will avoid the necessity of transporting assemblies from one part of the shop to another. The components will also be kept within bounds and thus the risk of them becoming mixed with those of other assemblies will be reduced.

Vices

8. Parallel vices of the quick-grip pattern are desirable and should be furnished with detachable aluminium or lead clams to act as protection when holding soft metal components or those having machined surfaces. The vices should be rigidly secured to the benches and at a convenient distance from one another to avoid overcrowding. The most convenient height for a vice is best gauged by the operator's elbow, which should just rest on the uppermost portion of the vice when his arm is hung at the side of the body and then bent upwards.

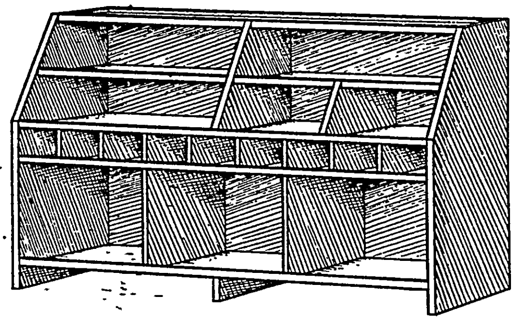


FIG. 1.

Component bins

9. As there are no standard bins issued for use in the engine repair shop to contain engine components, the introduction of locally made equipment is usual, this varying according to the type of engine that is being dealt with. The regulations governing the manufacture of items of equipment, e.g., component bins, are laid down in Air Publication 830. When for warding requisitions for such items of equipment as are not available in Air Publication 1086, a fully dimensioned drawing should always be attached thereto, together with any special information which will assist in the manufacture of the item.

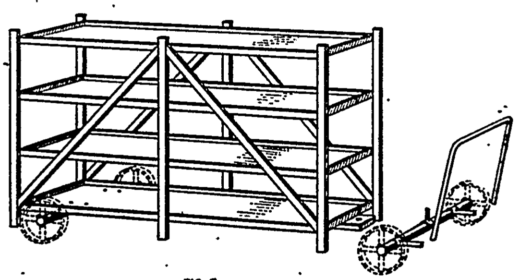


FIG. 2.

Fig. 1 and 2.—Storage racks for components

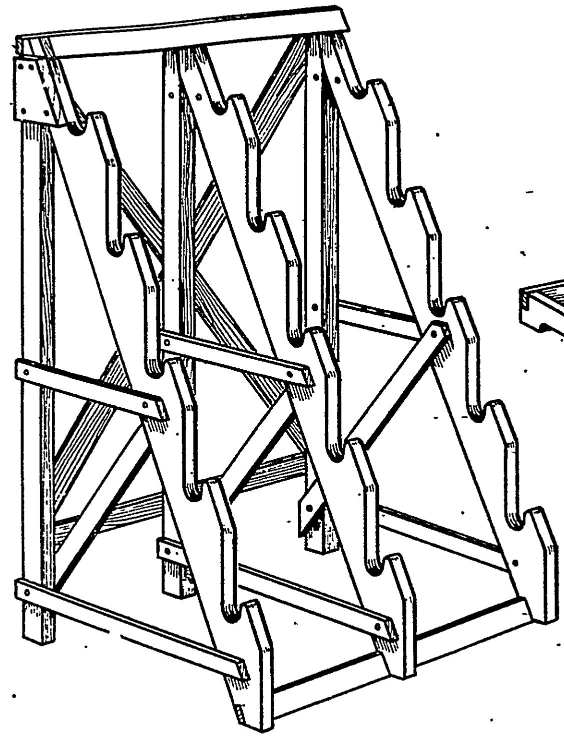


FIG. 3.
IN-LINE CRANKSHAFT RACK.

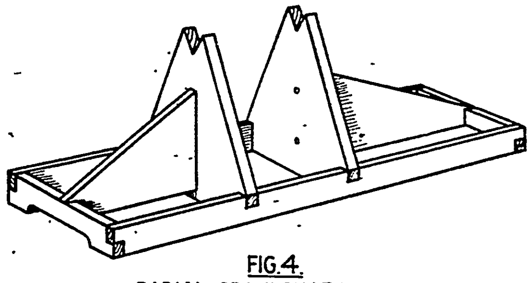
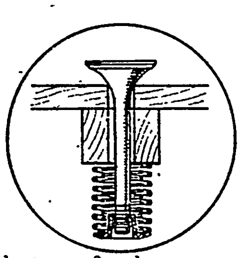


FIG.4.
RADIAL CRANKSHAFT RACK.



Enlarged view of valve assembly in rack.

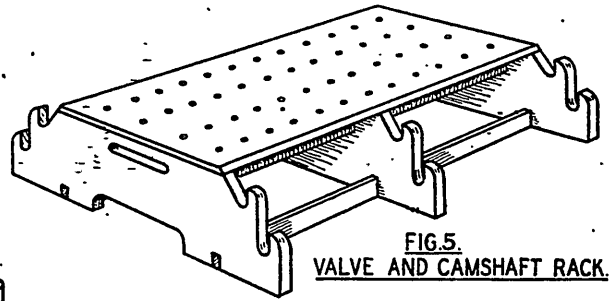


FIG.5.
VALVE AND CAMSHAFT RACK.

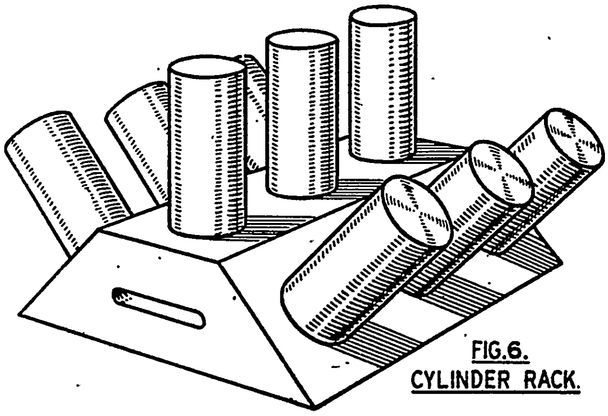


FIG.6.
CYLINDER RACK.

Fig. 3 to 6.—Storage racks

10. A component bin of wooden construction suitable for use with an engine having nine cylinders is shown in fig. 1, from which it will be observed that the whole structure is divided into a number of shelves having vertical members arranged to form compartments varying in size. The bottom shelf is divided into three compartments each large enough to take three cylinders. The next shelf is divided into a number of smaller compartments each capable of holding a piston, connecting rod and gudgeon pin. The next shelf can be used for crankcase, covers, induction pipes, exhaust manifolds, etc., and the upper shelf can accommodate the pumps, magnetos, reduction gear cover, ignition cables, carburettors, etc. This type of bin can also be used for an engine having three blocks of cylinders, one cylinder block occupying the space suggested for the three cylinders previously mentioned. In this instance, additional compartments would be necessitated owing to the increased number of pistons, etc. Each shelf has a 2 in. rail along the front.

11. Another component bin or rack is shown in fig. 2 and comprises a series of wooden shelves secured in position by uprights and cross members made of angle iron and strip mild steel. The bin should be made large enough to accommodate the components of one engine. Each shelf is surrounded by a 2 in. wooden rail. Normally, the complete assembly rests upon the ground on its six upright members. An axle is fixed at one end of the underside of the lowest shelf for the reception of wheels and the other end of the shelf is provided with a protruding board to which another pair of wheels can be attached. The latter pair of wheels is mounted on an axle attached to a wooden frame pivoted by a bolt to the protruding board. This permits the front pair of wheels to act on a swivel. A suitably bent handle is provided to assist manipulation of the rack when required for transporting purposes, e.g., from the dismantling shop to the cleaning shop, etc. The wheels should be removed when the stand is not being transported. Where bolts are employed in the construction of a bin of this description, they should be periodically examined and tightened up if necessary.

Method of supporting components

12. Components of the shaft type should be supported in a manner which will prevent sag. In this respect, care must be taken to ensure that the supports, on which the journals rest, are in alignment. It is desirable for the actual supports to be covered with sheet lead. The use of felt is not recommended as it will gradually become damp owing to the humidity of the atmosphere and corrosion is likely to occur on the journals.

13. Crankshafts should be supported horizontally on their journals in wooden racks adapted for each type of shaft, so that the shafts do not come in contact with one another. Long crankshafts as fitted to some water-cooled engines should be supported at their ends and centre journals as shown in fig. 3. Crankshafts of radial engines should be supported on wooden racks arranged so that the journals adjacent to the webs are resting on the supports, see fig. 4.

14. Camshafts should be supported horizontally on their journals in racks specially adapted for each type of camshaft so that they do not come in contact with one another. Valves should be kept as complete units, i.e., with their particular springs, washers, etc., in the manner shown in fig. 5, so that there is no possibility of their faces becoming damaged. It will be observed that the valve components are assembled in removable wooden bushes.

15. Cylinders and cylinder blocks should be stored in a vertical position wherever possible. Fig. 6 shows a method of supporting cylinders on dollies affixed to three boards mounted at an angle. The dollies should be somewhat smaller in diameter than the bores of the cylinders.

16. Pistons should stand independently on their crowns and should never be placed one on another. In no circumstances should pistons be placed on their sides. The gudgeon-pin should be placed with its respective piston. Piston rings, including replacement rings, should be hung on pegs numbered to correspond with the number of the piston to which they are to be fitted. Some arrangements should be made to keep each ring in a corresponding position to that which it normally occupies on the piston. In this respect, each ring may be placed in order on the numbered peg, say, with its upper face outwards. It may happen that a component, although not worn below its minimum permissible dimension, will give a clearance greater than the maximum permitted when in its place. In such cases the component will be serviceable for use on another engine and there will be no purpose in preserving its exact position on the original engine. It is therefore desirable to use such a system of temporary storage as will allow a component to be replaced exactly as it originally worked, but as soon as it has to be rejected for refitting on the same engine, it should be removed to the part-worn but serviceable section of the workshops. Stress is laid upon the need of replacing the rings in their particular grooves and also the right way up in the grooves, in order that the original "mating" surfaces of the ring and the sides of the groove may be in contact, thereby avoiding excessive oil consumption, loss of compression, etc., when the rings are finally assembled in the engine.

17. Pinions, gear wheels and similar parts should be placed in such a manner that the wearing surfaces cannot become damaged. It is essential that "mating" wheels should be tied together to prevent them from being mixed with similar components.

18. Connecting rods require careful handling and should be placed in a manner which will protect them from damage by other components. Suitably partitioned boxes will be found useful for this purpose. The wrist-pins, together with their bushes, should accompany their respective connecting rods. Floating bushes should be tied to the rods with string passed through their bores.

19. Crankcases and covers should always rest on their joint faces and never in an upright position. Large aluminium parts if inadequately supported, are liable to become distorted and it is therefore essential that adequate support be provided.

20. All racks, stands, etc., should be provided with a holder wherein a card, bearing the engine type and number, can be inserted.

21. To prevent the accumulation of oil, etc., on the floor of the shop, suitable drip trays should be placed under the engine whilst the latter is being dismantled or cleaned; the floors of the shops should be kept as clean as possible.

Overhauls

22. The various types of overhauls are detailed in K.R. & A.C.I. and relevant Leaflets in Volumes II to which reference should be made before commencing operations on an aero-engine.

23. Aero-engines can only be certified fit for service requirements when it has been ascertained that every operation which has been performed on them during the overhaul has been satisfactorily completed, whether it be the viewing of a component or the final examination of an assembly. It is therefore necessary to maintain the efficiency of every operation, not only by ensuring that the ability of the operator is adequate to carry out the job, but also by maintaining constant supervision and inspection at every major stage of assembling the engine.

24. The list overleaf gives the sequence of the various stages through which an aero-engine progresses through the shops. It is important that records should be kept in an approved manner regarding the viewing, incorporation of modifications and the repair processes. These records should either be passed from shop to shop with the component or assembly, or they should be kept in such a way as to be available for inspection at any time during the overhaul of the engine. The records should then be filed in such a manner as to be immediately accessible when required, as it is generally some time before the engine has completed its first test and is returned to the shops for further examination, etc. The record cards should state in detail what work has been carried out (including new parts fitted and the serial number of the component or other means of identification, as applicable), the name of the personnel employed on the various jobs and the name of the N.C.O. responsible for supervising the work. By the method outlined above, faulty workmanship will be kept in check to a great extent and the source traced. In addition to the repair cards, suitable test charts should be improvised so that after every stage of the testing, the charts can be scrutinised and any irregularities and adjustments effected as necessary.

(i) Receipt of engine.
(ii) External examination for completeness.
(iii) Dismantling.
(iv) Cleaning.
(v) Viewing.
(vi) Overhauls of components and assemblies.
(vii) Re-erection after overhaul.
(viii) Running-in and tuning engine.
(ix) Endurance test.
(x) Stripping after endurance test.
(xi) Second erection.
(xii) Running-in, tuning-up and adjustments before final test.
(xiii) Final test.
(xiv) Completion of engine and external final inspection.
(xv) Compilation of record of overhaul and the engine log book from record cards.
(xvi) Preparation—despatch and packing.

Slinging of engines

25. The slinging of engines is dealt with in Vol. II of this A.P.

26. Units may find it convenient to make some sort of adjustable cradle, supported from the ground, which will take the weight of heavy assemblies, e.g., reduction gear, during the dismantling and assembling operations. Slings are not altogether satisfactory when used for this purpose, as it is difficult to adjust with precision the correct position of the upper end of the sling.

Engine erecting stands

27. Standard types of aero-engine errecting stands are available, these being listed in A.P.1086, Section 4D:—

(i) The in-line aero-engine stand—Type A.
(ii). The in-line aero-engine stand—Type C.
(iii) The radial aero-engine stand.

28. The correct method of mounting an aero-engine on its stand will be described in the appropriate handbook.

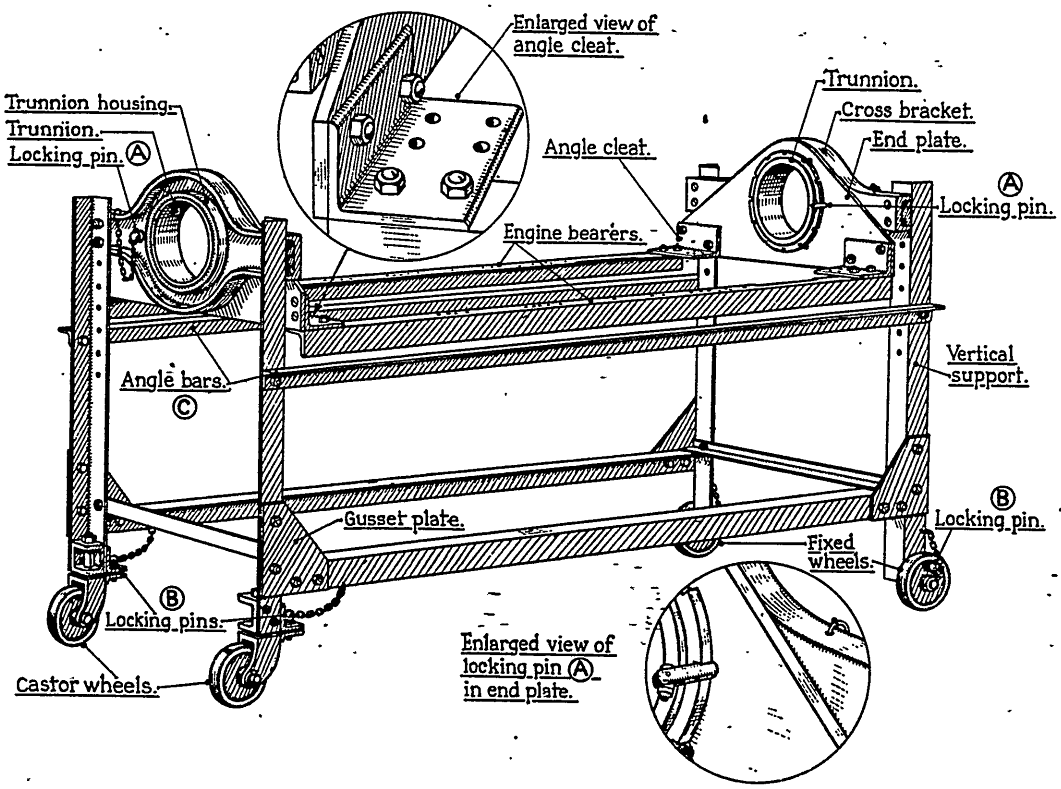


Fig. 7.—In-line aero-engine erecting stand, Type A

29. *In-line aero-engine stands.—Type A.*—The Type A erecting stand shown in fig. 7 is one which can be used for many types of in-line aero-engines and consists of longitudinal and cross bracing members (angle section and strip steel) arranged so as to form a framework upon which a rotating cradle is mounted. The framework carries at each end a cast cross member having a large hole bored to act as a bearing for the trunnion sleeve of the cradle. Two castor wheels at one end and two fixed wheels at the other end are provided to facilitate transportation of the stand. The cradle consists of two angle section longitudinal members which act as bearers for the engine and two end supports, the four components being bolted together. Each end support is provided with a large flanged trunnion, located by locking plates which fit into serrations in the flange. The trunnion sleeve fits into the bearing in the cross member of the frame. This arrangement permits the engine, when mounted on the bearers, to be rotated, in order that the engine may be worked upon in a tilted or inverted position.

Six evenly-spaced holes on the pitch circle of the trunnion and two holes 30 degrees apart in the cros s members are provided so that the cradle can be secured in twelve convenient positions, each position being fixed by a suitable locking pin (A) attached to the stand by a chain. The upper longitudinal bracings (C) of the framework can be removed to permit the engine to be rotated to certain positions. These bracings should always be replaced, as without them the stand is liable to become distorted or unstable, this being particularly important if the stand is to be removed with the engine in position.

30. To facilitate accessibility to an engine when erected on the stand, eight holes are provided in each vertical support so that the height of the cradle can be adjusted. Detachable side steps, locally made, may be found convenient: leaflet A.P.1464/G.11 details the construction of the steps and the method of attachment to the stand. The distance between the bearers of the cradle has to be adjusted to suit the various sizes of engine, facilities being provided for this in the position of the securing bolt holes in the angle cleats which are stamped for each type of aero-engine. In some instances the engine feet are bolted direct to the bearers, using standard or special bolts according to the engine concerned, whilst other engines require distance or packing pieces between the feet and the bearers to give the necessary clearance for a carburettor or other component—see para. 28.

31. To make the stand rigid when in use, both the castor and fixed travelling wheels can be secured by means of the locking pins (B) attached to the stand by chains.

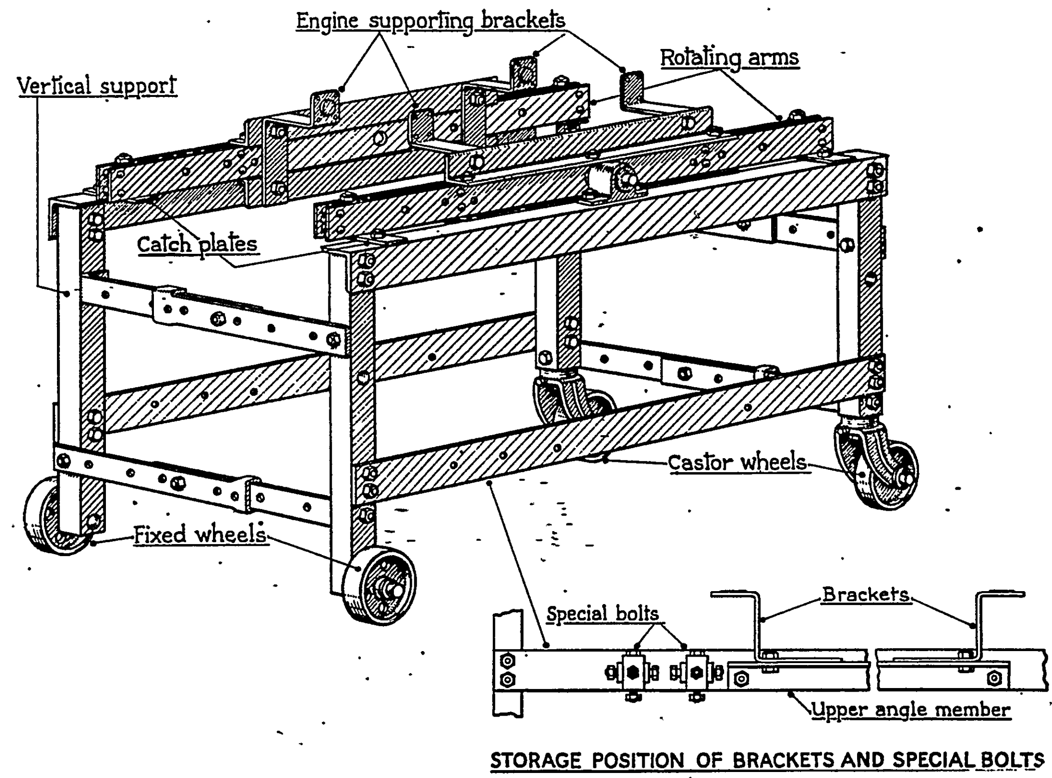


Fig. 8.—In-line aero-engine erecting stand, Type C

32. *In-line aero-engine stand—Type C.*—This stand, which is shown in fig. 8, is intended for the accommodation of Gipsy engines. The stand consists of two principal members, namely, the framework and a pair of rotating arms. The framework is built up from four solid steel legs mounted on two fixed and two castor type wheels to facilitate transportation. These legs are braced with steel strip, bolts being used at each point of attachment. The transverse bracings at each end of the stand are made in two parts and so arranged that they will slide in one another, thus permitting the stand to be extended or reduced in width. The maximum width, i.e., internal distance between the rotating arms, to which the stand can be extended with safety is approximately 2 feet. When the desired width

is obtained, the bracing members are bolted together, thereby making the framework rigid. Each rotating arm is constructed from two pieces of strip steel riveted together, tubular distance pieces being introduced so that a space is formed between the strips. A stub spindle, mounted at the centre of each rotating arm, works in a bearing or plummer block bolted to the face of the upper longitudinal member. The rotating arms are retained in a horizontal position by means of catch plates near each end of the upper longitudinal members. These plates can be swung clear of the arms when desired.

33. Some engines can be mounted on the rotating arms and secured thereto by means of bolts passed through the space in the arms and through the engine feet. To enable the stand to be used for certain engines, e.g., Gipsy I and III, a pair of brackets are mounted on the rotating arms—see para. 28.

34. It is essential that the engine be positioned on the rotating arms so that its centre of gravity is as near as possible to the arm bearings. The catch plates should always be bolted to the rotating arms when the engine is in an upright or inverted position. Special care must, of course, be taken when, during the rotation of the engine, the bearer arms approach the vertical, in order that the unbalanced weight of the engine may be kept under proper control.

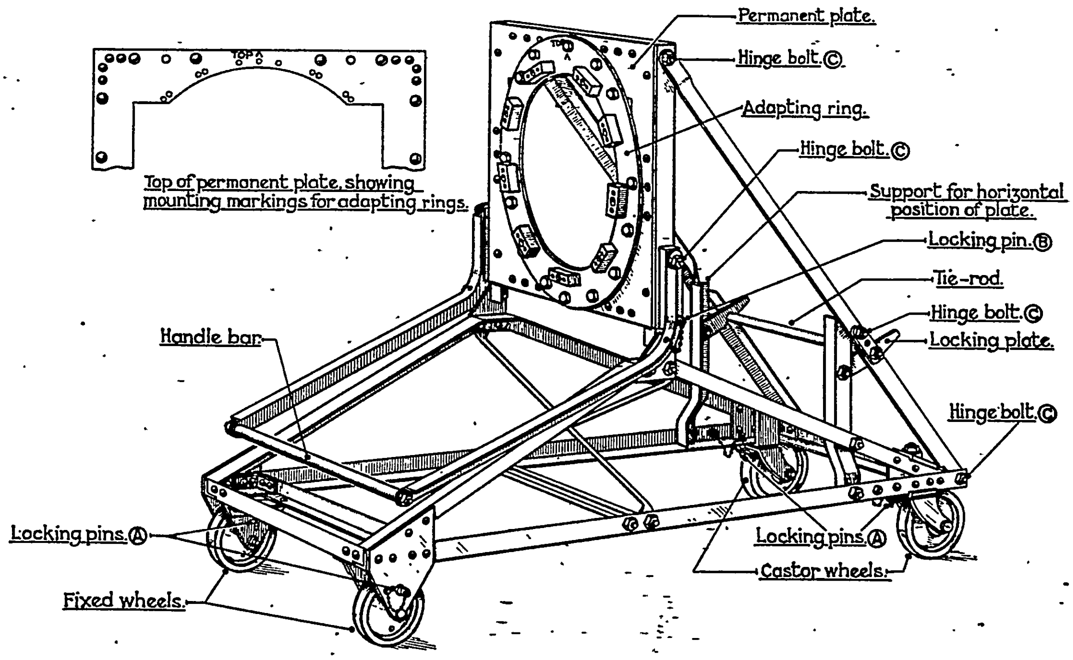


Fig. 9.—Radial aero-engine erecting stand

35. *Radial aero-engine stands.*—The engine stand shown in fig. 9 will accommodate all types of radial aero-engines and has the advantage that the engine can be worked upon either in a vertical or horizontal position. This stand is constructed principally from angle section and steel strip members bolted or riveted together; gusset plates are introduced as required for the attachment of certain members. The construction of the bogie framework is clearly shown in the illustration, the bogie having two fixed wheels and two castor wheels at the front and rear ends respectively to facilitate transportation. These wheels can be secured by means of locking pins (A) attached by chains to the stand when it is desired to make the bogie rigid. A cradle, hinged at eight points and mounted on the bogie, consists of a framework of angle section and strip steel members and incorporates a permanent plate.

36. An adapting ring or an adapting plate, for bolting to the permanent plate is provided for certain engines—see para. 28. The permanent plate is secured at one end by two hinge bolts (C), and when in its horizontal position, it rests upon two supports at the other end. To ensure accuracy of positioning, the bolt holes in both permanent plate and adapting ring have been drilled to jig. When mounting an adapting ring care should be taken that the arrow marked "TOP" on the ring coincides with a similar marking on the permanent plate.

37. When it is desired to move the permanent plate (and adapting ring) from one position to another with the engine in position, the handle bar must be secured by means of the locking pins (B), but before doing so all wheels must also be locked by their pins. It is important that the unbalanced weight of the engine is restrained when approaching either the horizontal or vertical position, especially those engines weighing approximately 700 lb. and over. In this direction, chain tackle may be employed with advantage. The removal of the locking pins (B) allows the handle bar to be swung clear when the permanent plate is horizontal.

Servicing of aero-engine erecting stands

38. Stands in use should be maintained completely assembled and all bolts, etc., are to be kept tightened.

39. The primary purpose of the wheels on an engine stand is to allow transportation of the engine without the necessity of lifting it from the stand, and, therefore, when the stands are used for this purpose special care should be employed in negotiating recesses and projections on the ground to avoid undue strain on the stands. The stands should not be used over very rough surfaces. On no account should the Type A stand be transported with the upper longitudinal bracings removed.

40. When it is desired to transport a stand by rail or otherwise, it should be dismantled to a convenient or necessary extent and all nuts and bolts replaced in their proper places. All brackets, etc., should be bolted to any convenient part to prevent loss during transit.

P5039 M /1315 9/44 5250 C & P Gp. 1

RESTRICTED
(For official use only)

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 3 to A.P.1464C, Vol. I and concerns Part 2, Sect. 2

Insert this chapter.

AIR MINISTRY
May, 1944

CHAPTER 2

AERO-ENGINES—DISMANTLING

General

1. The dismantling shop should contain the necessary equipment for stripping the engine. This equipment includes the benches, vices, storage racks, etc., and also complete kits of tools required for the various operations, see Chap. 1 to 5. Certain tools listed in the respective Air Publications, Volume III, are supplied for specific dismantling operations. The indiscriminate use of metal drifts on aero-engine work should not be permitted; these drifts are easily burred over, the burrs break off and the fragments are often difficult to find. Soft metal drifts may, however, properly be used where called for in engine handbooks.

2. Before any component is removed or dismantled, it is essential that reference should be made to the appropriate handbook wherein the respective operation is described in detail. This procedure is necessary owing to the variance in the design of aero-engines and will obviate irregular methods being adopted. Some assemblies in aero-engines have components which have been "selected" to mate together by the makers and it is essential that precautions should be observed during each overhaul operation to prevent mixing these parts with those of a similar nature.

3. During the process of stripping an engine, apart from the usual scrutiny of the components as they are removed, it should be definitely borne in mind that examination should be made of all the components at two stages of the operations. The first stage is during the actual removal of the components, when each should be closely examined for signs of burnt or discoloured oil or minute particles of detached metal. The former defect may be indicative of overheating or faulty operation of the particular components, whilst the latter defect may be caused by failure of that component or any other component in the vicinity; and the source of the particles should be located. For example, if when partially stripping an engine, particles of metal were found in the assembly which has been removed, it would be obvious that some component or components have broken down. Careful search should then be made throughout the surrounding assemblies until the damaged component is traced; this may involve the removal of other assemblies. Personnel should bring to the notice of the "E" officer or warrant officer (Engineer) any irregularity which may be discovered, before commencing further dismantling operations. The second stage of examination commences when the components have been cleaned and are laid out on the bench, this examination, named "viewing", being dealt with in Chap. 4.

4. It is very important to consider these two stages, for it sometimes happens that the bush of a component has been overheated or partially seized and if watch has been kept during the first stage of the dismantling, it will be realised that trouble is present and the parts can be examined before they are cleaned. On the other hand, if the first examination has been ignored, it is possible that the signs might be regarded as simply the result of prolonged wear and if the bush is within the permissible worn dimensions, it may be refitted without the trouble being rectified. Indications of the troubles referred to above may become obliterated, with the possible exception of discoloration of the material through heat.

5. During the dismantling operations it will be observed that certain components are discoloured, the colour ranging from brown to black. Generally speaking, the discoloration is due to burnt or carbonised oil on the surfaces, but this has no deleterious effect upon components. Discoloration can also be due to overheating. For example, if a gudgeon-pin bush has been under-lubricated, overheating will have taken place and according to the amount of frictional heat generated the discoloration will vary in colour from light straw to purple. If these temper colours are present they will be local, but if the discoloration has been caused through burnt or carbonised oil, the stains will be general. A weak mixture may also be the cause of discoloration and may be traced to signs of overheating of the cylinder head or to burnt valves. Crankpins and journals are often found discoloured, this being caused by inadequate clearance between the working surfaces. Insufficient lubrication which causes frictional heat can sometimes be attributed to a faulty pump.

6. Cylinder walls are sometimes found coated with a thin film of oil containing small particles of an aluminium alloy or the walls may have streaks of aluminium alloy embedded therein caused through the piston picking up on the walls, the streaks taking a line parallel with the side of the cylinder. The latter deposits are too fine to be felt with the fingers and are only discernible on very close examination with the aid of a highly polished mirror and a small electric lamp. Insufficient clearance between the piston and the cylinder, probably due to ovality or distortion of the piston, or to inadequate lubrication, are the principal causes of these defects.

7. The oil from the sump should be inspected for the presence of foreign matter and metallic sediment. Metal deposits will often be in the form of fine granules or flakes, and indicate the incipient failure or wear of components. For example, aluminium may indicate the spinning of ball or roller bearings in their housings, duralumin chippings may be from gears, bearing metal particles may be caused by the bedding of the side faces and radii of the bearings. The sediment should be tested as explained below, to ascertain whether it contains these metals:—

(i) Clean the particles of metal with petrol to remove any oil and allow them to dry off.

(ii) Place the suspected particles in a test tube and pour about 10 to 20 c.cs. of 10 per cent. caustic soda solution over the particles. If the particles are unattacked, they are most probably whitemetal, but if some dissolve they will be of aluminium or duralumin. If doubt exists as to the residue, it is necessary to throw away the liquid and repeat the test with fresh solution. The absence of gas evolution shows that the metal sediment is whitemetal.

(iii) As the liquid is very corrosive, care is to be exercised in making up the solution in the proportions of 10 per cent. caustic soda to 90 per cent. water—by weight.

8. If water is suspected to be present in the oil, a rough test can be made by half filling a tin container with a sample of the oil and heating the tin over a flame to a temperature slightly over 212° F. (100° C.). If water is present, a crackling noise will be heard.

9. In addition to the standard aero-engine tool kit, the following items will be found of considerable use for stripping and assembling the engine, and can easily be made up.

(i) In order to prevent the loose connecting rods damaging the cylinder apertures when the cylinders are removed, small aluminium plates, preferably covered with a thin sheet of rubber, should be made up and threaded over the studs on the crankcase so that the rubber-covered portions lie on either side of the cylinder aperture and act as protectors for the crankcase. The rubber may be secured in position by nipping it under the bent-over edge of the aluminium sheet at each end.

(ii) A number of small steel wedges may often be found useful when separating flanged joints, etc., but it is imperative that they are used only where specifically called for in the engine handbooks. These wedges should be made from silver or tool steel and then tempered; they should be about 2 in. long × 1 in. wide, and have an angle of not less than 10°. It will be seen by referring to these Air Publications that the wedges are only to be used to actually break the joint and this operation is difficult (in some designs) to do by other means owing to the setting of the jointing compound used. The utmost care is necessary in order to avoid distortion and defacement of the flanges. In some instances it may be found that two pairs of adjoining nut bosses, one pair being diametrically opposite to the other, have been left "bridged" and the flanges slightly chamfered at their outer edges to permit easy entry of the thin end of the wedge for the purpose of breaking the joint. An extractor should invariably be used to separate the parts in preference to the use of wedges, if a choice between the two methods is possible.

(iii) A soft-headed hammer, preferably of hide, should be provided.

(iv) Wooden spigots or dollies fixed to the bench or to the stand will be found useful to receive the cylinders as each is removed from the engine. The dollies will not only ensure that the cylinders are not knocked over accidentally, but they will prevent the valves dropping through when the split collars and springs are removed.

10. During stripping operations, not only should constant observation be made of all assembly markings, but as far as possible, written observations should be made of the position of each component, for while markings may be easily identified by mechanics accustomed to stripping that particular type of engine, those mechanics who are less familiar with the engine are liable to misinterpret the marks and the erection of the components may then be incorrect.

11. Difficulties are frequently experienced in unscrewing tightly fitting components. When metals are dissimilar, advantage may often be taken of their different rates of expansion by immersing them in hot oil. This will often cause sufficient movement to release the two components when a suitable tool is applied. The use of a blow lamp to provide local heating must not be permitted, as it is impossible to control the heat sufficiently, and distortion is likely to be caused by the operation.

12. To facilitate the withdrawal of such parts as ball bearings, roller races, eccentrics, etc., from shafts, it is advisable to smear the shaft with oil prior to commencing the operation.

13. When withdrawing shafts fitted with roller bearings, the rollers are often released. In these instances, the rollers should be caught by placing a tray or other receptacle under the shaft. The rollers should be counted to ensure none is lost; isolation from rollers of similar dimensions is recommended. The races of a roller bearing should not be disturbed except in special cases where

the operation is necessary to remove the deposit which has collected in the oilway formed around the radius at the back of the race, or for the renewal of the race. When removing a ball bearing or a roller bearing race it is essential that the race is kept square during the operation.

14. If it is necessary to secure a long shaft, e.g., a crankshaft, in a vice, lead clams should always be fitted to the vice jaws. As a precaution against bending, a wooden leg having a "Vee" end may be placed beneath the portion of the shaft that overhangs the vice.

15. Connecting rods may be held rigidly between vice jaws without damaging the components if suitably shaped wooden blocks are fitted in the channel sections on either side of the rod. Tubular rods may be held between wooden blocks having a "Vee" cut in their faces, similar to a V-block.

16. If during the stripping operations, any locking devices such as tabwashers, circlips, spring washers and split pins, are found to be fractured or, very exceptionally, missing, the fact should be investigated to find the cause. Any such written records should be passed to the cleaning shop when the dismantling operations have been completed. The locking devices mentioned above are not to be used more than once, except in extreme urgency. When locking devices are being removed, care should be exercised that no unnecessary damage is caused to other components. Any roughness on a gudgeon pin, for example, which is caused when removing a circlip, should be smoothed down with a slip-stone, as the burr might score the bores of the bosses when the pin is pushed out.

17. It is good practice to tie all bolts and nuts to their respective components and to replace all nuts and spring washers on their studs. This method of "placing" the components concerned provides an easy means of checking their quantities and ensures that the assembly or component is complete on being passed to other shops.

18. In some components, split pins are often very troublesome to remove and a chisel has to be used to cut off the heads of the pins. In this respect, care should be taken to ensure that the cutting edge of the chisel causes no damage to other components of the engine; the width of the chisel should be equal to the width of slot in the nut.

19. After each component has been removed from the engine it is desirable that it should be placed in a component bin or upon a suitable rack, see Chap. 1. Suitably stamped metal tabs, bearing the engine type and number, should be wired to the respective components. Metal tabs will be found more serviceable than those made from cardboard, as the latter are easily torn off and the metal tabs have the advantage that they can remain on the component should the latter be immersed in a cleaning bath. This precaution is necessary when more engines than one of a type are being dismantled simultaneously.

20. Parts which have failed or are obviously defective, e.g., fractured, should be rough-cleaned, care being taken to avoid further damage to the part and to ensure that no tool or cleaning agent is permitted in the vicinity of the defect. The parts should immediately be marked with red paint in such a way as to avoid obscuring the defect either by the paint itself or its subsequent removal. All defective parts should be labelled as follows:—

Section..	Part No............
Engine type...	No............
Nature of defect...	
....	
Date............................	....
	O. i/c Group.

21. In some units it is the custom to retain the magneto, carburettor, auxiliary drive casing, reduction gear, etc., as complete assemblies and not dismantle them during the general stripping operations. This has the advantage that the complete sequence of overhaul or repair operations for these components can be done in specially equipped bays by personnel selected for the duty, owing to certain operations demanding skill of a very high standard.

22. In some engines the cylinders and their respective heads are integral, whilst in others the heads are separate. With the former type the cylinders can be regarded as complete units but in some of the other types there are specific instructions as to the conditions under which these units may be dismantled. Again, in radial engines the crankshaft and therefore the connecting rod

assembly varies to a large extent according to the type. Some crankshafts have single throws, and where the big-end bearing of the master rod is in one piece, a built-up shaft is necessitated, whilst in others the big-end bearing of the master rod is in two halves, in which type the shaft is in one piece. Some radial engines have crankshafts with multiple throws; this again may involve many differences in details of the components.

23. From the foregoing it will be appreciated that no standard procedure can be laid down which will apply equally well to all types of aero-engines, and therefore in the following sections only the principal operations will be described.

24. The necessity for temporarily storing the various components in such a manner as will keep those of a particular engine together is emphasised, as much time is wasted and also components are lost through non-observance of this precaution.

P5041 M. /1317 9/44 5250 C & P Gp. 1

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO ENGINES AND POWER PLANTS

This is A.L. No. 4 to A.P.1464C, Vol. I and concerns Part 2, Sect. 2.
Insert this chapter.

RESTRICTED
(For official use only)

CHAPTER 3

AERO-ENGINES—CLEANING

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

General

1. The method of cleaning aero-engine components will vary according to circumstances and although local conditions may preclude the use of some of the equipment, in general, the methods detailed in this chapter should be adopted. The cleaning mediums described below should only be used as directed and their composition should not be altered. Where an I.C.I. degreasing plant is available the method described for cleaning by means of paraffin does not apply. It is essential after components have been washed in paraffin to take suitable precautions against corrosion because of the hygroscopic nature of paraffin. Engines that have been immersed in sea water require special treatment when cleaning, details of which are given in other Sections of this publication (see General Index).

Cleaning equipment

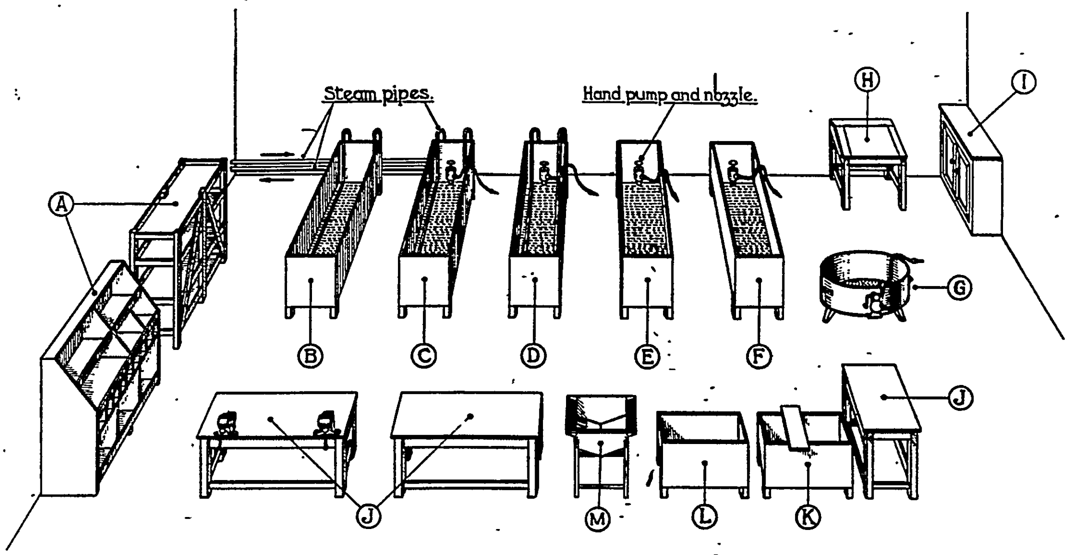
2. Standard types of cleaning tanks are available, three being the minimum number used, namely, hot water tank, hot soapy water tank and paraffin tank. Lightly constructed stands should be made up, on which engine parts can be rested within the tanks during cleaning in order to leave a sludge space at the bottom of the tanks; the tanks should be cleaned out at frequent intervals and replenished with fresh cleaning fluid. In the case of paraffin, the tank should be drained after the sludge has been allowed to settle for several hours, the paraffin being strained and used again. Where large numbers of engine components are to be cleaned, two paraffin tanks should be used, one being employed during the removal of heavy deposits of dirt, the other for rinsing; the relatively clean paraffin can then be transferred from the latter to the former after the sludge has been removed and thereby clean paraffin is always available for final rinsing operations. Racks for the reception of components should be used during draining and drying operations, for the purpose also of holding parts which have been finally cleaned.

3. A typical layout of the major items of the cleaning equipment for a station workshop is shown in A.P.1464B, Vol. I, Part 2, Sect. 3, Chap. 2, fig. 1, whilst another suggested layout is shown in fig. 1 of this chapter. Steam heating coils immersed in the hot water tanks may be used when such facilities are available, but when the hot water tanks are heated by means of blow lamps the greatest care should be taken to keep the paraffin cleaning equipment at a safe distance away from such heating appliances. The various tanks and cleaning solutions should be used as follows:—

(i) *I.C.I. degreasing plant.*—An I.C.I. degreasing plant should be used, when available, for the purpose of removing oil and grease from aero-engine components. Parts immersed in the fluid should not be wet with water because it is liable to form hydrochloric acid when in contact with trichlorethylene, resulting in corrosive attack on the metal parts. The plant should only be used by personnel who are fully conversant with the method of operation.

(ii) *Hot water tank.*—This tank should contain hot water maintained at a temperature of approximately 95° C. The hot water will soften most of the deposits on the components and thus assist in their removal. Certain components must be blanked off at the inlets and outlets before being immersed in this bath (see Volumes I and II of the relevant handbooks). The use of chlorinated water should be avoided wherever possible, but in circumstances where none other is available, it is essential that the chlorinated water be boiled vigorously for a period of at least five minutes before being used for cleaning aero-engine parts. It is of the utmost importance that parts are not allowed to remain in chlorinated water for long periods, particularly those made of aluminium or magnesium alloys.

(iii) *Hot soapy water tank.*—The soap and water solution in this tank should be maintained at a temperature of 60° C. This bath will be found useful for removing oily deposits and for softening paint, when the chemical degreasing plant is not available. The remarks in the preceding sub-paragraph on the use of chlorinated water apply here also. Soft soap or caustic soda solutions should not be used on any account. The solution should be made



A—Component storage racks.
B—Hot water tank.
C—Hot soapy water tank.
D—Paraffin tank (Ferrous parts)
E—Paraffin tank. (Ferrous parts.)
F—Finishing tank. (Paraffin & lubricating oil.)
G—Paraffin tank. (Non-ferrous parts.)
H—Workshop desk.
I—Lock-up for tools.
J—Cleaning benches.
K—Scouring tank.
L—Rinsing tank.
M—Paraffin tank (ball and roller bearings)

Fig. 1.—Typical cleaning shop equipment

up of yellow soap, one per cent. by weight of water in the tank, and cresol 0·25 per cent. by volume of water in the tank. The soap should be thoroughly dissolved in hot water and after it has been ensured that all the soap is dissolved, the cresol should be added and the mixture stirred well, after which it should be mixed with hot water in the cleaning tank. When the solution is at a temperature of about 60° C. the engine parts to be cleaned should be immersed and allowed to remain for a period of from 15 minutes to one hour or until the deposits are loosened. Immediately the parts are removed from this bath they should be rinsed in the hot water bath described in sub-para. (ii) in order to remove all traces of the soap solution from the pores of the metal. The increased temperature will also assist in the drying of the parts and in the subsequent cleaning in paraffin.

(iv) *Paraffin tank.*—The engine components to be cleaned in the paraffin tank should be as dry as possible and all parts should be cleaned by the aid of engine cleaning brushes, also, if available, an air and paraffin blast will be found useful. Screw holes and oil ducts should be examined methodically and thoroughly cleaned. After washing in paraffin, the parts should be left to drain on suitable racks and any surplus paraffin should be wiped off, using rag of a non-fluffy nature. Engine components that have been washed in paraffin should be passed on for viewing without delay. If it is not possible to proceed with subsequent operations the ferrous parts must be protected against corrosion by the application of clean oil or sozol.

Warning.—During the process of degreasing, cleaning, and the final assembly of aircraft component parts, it is extremely important that personnel should bear in mind that under no circumstances whatever should components manufactured of neoprene or synthetic rubber be contaminated by trichlorethylene as the complete solution of this material would result.

Stove-enamelled and cellulose-enamelled parts

4. The removal of stove enamelling from engine components is not permitted—see leaflets in engine handbooks (Vol. II). Components which have been coated with cellulose enamel should be cleaned by the aid of a brush and standard dope solvent, which will remove the whole coating, except possibly that in crevices which cannot be reached by the brush; such positions can be cleaned by the careful use of scrapers.

Cleaning agents

5. In order to assist in the removal of dirt and carbon deposits, suitable wire brushes of the hand or power-driven rotary type may be used on most of the ferrous components but non-ferrous parts should be cleaned by the aid of a soft bristle brush; the standard engine cleaning brush will be found satisfactory during the majority of cleaning operations. Coarse grades of emery cloth should not be used for cleaning engine components although the fine grades dipped in paraffin may be used with discretion for cleaning up valve stems, pump spindles, cams, etc. where slight picking up has occurred. Emery cloth must not be used for cleaning any non-ferrous metals because particles of emery become embedded in the soft metal resulting subsequently in serious abrasion and wear. Piston ring grooves can be cleaned free from carbon by means of a piece of broken piston ring of the same width as the groove filed at one end to an angle of approximately 70 degrees and used as a scraper. The greatest care should be used throughout cleaning operations to prevent damage being caused by contact of parts with one another or with hardened steel tools, etc. Scrapers will be necessary in some instances for the removal of hard carbon deposits and extreme care must be taken to avoid scratching any engine components. Decarbonising equipment incorporating rotating brushes electrically driven are available for the purpose of removing carbon deposits from valve ports, etc. The crowns only of pistons should be polished by means of buffing provided that care is exercised not to buff the outer edge.

Sequence of cleaning operations

6. All components may be degreased in an I.C.I. degreasing plant when such equipment is available. When chemical degreasing is not possible, parts should be cleaned in the cleaning tanks as described in para. 3. Ferrous metals and bronzes or other copper alloys may be cleaned first in the hot soapy water solution then rinsed in the hot water tank, followed by a paraffin bath. It is preferable that aluminium, magnesium or duralumin parts are washed only in paraffin because of the risk of corrosion and of soapy water remaining in the pores of the metal, which results in oil frothing when the engine is subsequently put into use. Anodised components, also magnesium parts which have been given a chromic coating as a protection against corrosion, should be washed carefully.

Cleaning ball and roller bearings

7. Ball and roller bearings should be cleaned in paraffin in a suitable receptacle and not mixed with other engine parts. During cleaning the races should not be allowed to spin when a paraffin spray or brush is used but should be rotated slowly to enable the balls or rollers to be cleaned. Surplus paraffin should be drained off or removed by means of compressed air, after which the bearings should be dipped in thin clean oil in order to prevent corrosion during viewing or other operations.

P5043 M /1318 5250 9/44 C & P Gp. 1

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 5 to A.P.1464C, Vol. I and concerns Part 2, Sect. 2
Insert this chapter.

RESTRICTED
(For official use only)

CHAPTER 4

AERO-ENGINES—VIEWING AND VIEWING PROCEDURE

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

General

1. When engine components have been dismantled and cleaned, before any further operation is put in hand it is necessary to subject them to a thorough inspection (called "viewing" in the Service). A set of view-sheets should be improvised so that a record may be made regarding the various defects, etc., which are observed during the viewing procedure; the lay-out of the sheets are left to the discretion of the Unit.

2. The necessity for systematic and accurate viewing of aero-engine components cannot be too greatly emphasised as from this inspection the degree of serviceability of the components can be determined and at the same time an estimate formed as to the requirements, e.g., repairs, modifications, etc., necessary to make them serviceable. All engine components should be within the limits laid down in Volume II, Part 2, of the appropriate Air Publication, which also gives notes on application of the schedule. It is usual for all replacements to be demanded in the viewing shop so that when the component is finally transferred to the particular repair bay it is complete in all details. As each item is received from the stores it should be appropriately labelled and placed with its assembly or component. By this means the latter is kept as complete as possible and misplacement is avoided. To reduce scrapping to a minimum it is advisable that the components which have been condemned by the viewer should be temporarily placed on one side. The viewer should not be empowered to consign apparently defective parts to the scrap-heap, but components so condemned should be further examined by the Officer i/c Group or his deputy, who should decide as to their ultimate repair or rejection, i.e., returned to stores as unserviceable. This plan also serves to bring defects to the notice of the Officer i/c Group, who should log them in a book kept for the purpose. A summary could then be compiled and comparisons made between the various types of engine which would be useful as a guide for viewing similar components. Further, this book will be found invaluable when filling up

the appropriate form for report of defects and failures, as it will contain a complete record of those troubles experienced in the unit. The action to take with regard to defects is laid down in K.R. and A.C.I. and relevant Leaflets in Volumes II.

3. Before viewing is commenced, the defects recorded in the dismantling and cleaning shops and also the engine log book should be carefully scrutinised for any information which may be of assistance in the viewing procedure. A component cannot be satisfactorily viewed unless the measuring instruments used are accurate, and therefore periodic checks are necessary to ensure that no inaccuracy has arisen. It is preferable for these checks to be carried out in the tool room of the general engineering section of a depôt where the specialist personnel and equipment are available.

Equipment and tools

4. To enable viewing to be carried out in a satisfactory manner, the shop should be equipped with a large marking-off table specially trued up for the purpose (preferably not smaller than 5 ft. × 3 ft.) and various measuring instruments; these are described in 1464B, Vol. I, Part 2, Sect. 3, Chap. 10. The following is a list of the principal instruments which should be available in the viewing shop:—

(i) Inside and outside micrometer calipers ranging from 0–1 in. to 5–6 in. sizes.
(ii) Set of micrometer three-point gauges.
(iii) Cylinder gauge fitted with a dial indicator.
(iv) Depth gauges.
(v) Vernier height gauge.
(vi) Vernier calipers, 4 in., 9 in., and 12 in.
(vii) Universal scribing blocks.
(viii) V-blocks in pairs.
(ix) Parallel strips in pairs.
(x) Surface plates.
(xi) A good collection of steel rules, squares and calipers.
(xii) Limit gauges.
(xiii) Dial test indicator gauge.
(xiv) Feeler, radius and screw pitch gauges.
(xv) 4 ft. steel straightedge.

5. In addition to manufactured instruments, certain improvised "rigs" consisting of clips, attachments, fittings, etc., will have to be made up for measuring clearances which are inaccessible to ordinary equipment. Engine handbooks contain information and suggestions on the method of measuring such clearances and on the design of the clips and fittings required for the particular engine. It should be clearly understood that the rigs described in the handbooks and in this manual are only intended to serve as suggestions and that as experience is gained the methods employed may be simplified or altered in any suitable way. The underlying principle should always be to design attachments and fittings capable of widespread use, so that the same fitting may be employed in as many measuring operations as possible, and may be suitable for use on more than one type of engine. It is particularly desired that personnel concerned should receive encouragement and freedom to apply ingenuity and resource to the problems presented by particular engines and components being dealt with, in order that the necessary work may be carried out in the most effective, economical and convenient manner.

Cylinders, general

6. Examine the cylinder walls for signs of scoring, rusting, pitting, corrugations, cracks and overheating. Mount the cylinder in some sort of fixture similar to that shown in fig. 1 so that it may be held in a rigid manner which will leave both hands free to manipulate the measuring instruments. The fixture may be made from $\frac{3}{16}$ in. or $\frac{1}{4}$ in. sheet mild steel or where convenient may be made in the form of a casting. To enable the fixture to be used for different types of engine the casting should be bored to take adaptor rings appropriate to the cylinder spigots. In the absence of such a fixture, the cylinders should be rested either on suitably shaped packing blocks or on a surface table with the mouth of the cylinder pointing upwards, according to the design of the cylinder. Proceed to check the bore of the cylinder for wear, i.e., parallelism and ovality, using an inside micrometer, a three-point micrometer or a cylinder gauge—see 1464B, Vol. I, Part 2, Sect. 3, Chap. 10. Except where otherwise stated in Volume II, Part 2, of the appropriate Air Publication, the readings in respect of wear must be taken at three positions on the working surface of the cylinder, i.e., approximately 2 in. from the mouth of the cylinder, centre of stroke and approximately 2 in. from the top of the stroke. Two measurements are necessary in each position, one parallel to the gudgeon-pin and the other at right-angles to it. These measurements should be noted on a label, the latter being tied to the cylinder.

7. The valve guides should be examined for wear and signs of scoring and cracks. The bores of the guides should be measured for size and ovality using limit gauges (see 1464B, Vol. I, Part 2, Sect. 3, Chap. 10. The gauge should be inserted in different positions around the circumference of the bore and should be passed through the bore. Valve guides should not be removed from their housings unless they are faulty, in which case a withdrawing tool or in certain instances a suitable drift should be used. Examine all valve seats for uneven wear, ridges, pitting, surface cracks and burning. Measure the width of the valve seat, this may be done by lightly marking the seat with prussian blue water colour paint and using a new valve or a gauge made to standard dimensions. Where applicable, subject the valve seats to a water pressure test—see relevant handbooks, Volumes I and II. The valve rocker gear should be examined for signs of wear, as detailed in the particular engine handbook. Where ball bearings are used in the valve rocker gear, they should be examined and tested as detailed in paras. 36 and 37 of this chapter.

8. Examine the threads in sparking plug orifices for wear and for stripping; a screwed plug gauge is supplied for this purpose—see Air Publication 1086. Examine plug adaptors for looseness. The gas starter non-return valve should be examined for wear. The unit should be completely stripped and if the valve has not been closing properly the spring should be rejected. Examine all studs, bolts and nuts for looseness and condition of visible threads. The studs and bolts should also be examined for mal-alignment and signs of rubbing.

Cylinders, air-cooled

9. In addition to making the measurements detailed above, the cylinders should be examined as follows:—

- (i) Fins for cracks and flaws. Test the contact faces of the cylinder barrel and the head (if normally separable) for truth on a surface plate.
- (ii) Flange for distortion. This may be done by using a surface plate having a hole slightly larger than the cylinder spigot.
- (iii) Cylinder barrel locking ring for cracking and the locking ring bolt for bending.

Cylinders, water-cooled

10. The examination of the water-cooled cylinders is given in paras. 6 to 8 of this Chapter. The jackets of the water-cooled cylinders should be subjected to a pressure test—see fig. 2, and it is very important that replacement cylinders drawn from stores are also subjected to these tests before passing the cylinders fit for service. The methods of sealing up the ports of the particular jackets is described in the engine handbooks. The procedure for carrying out the test is as follows:—

- (i) Dry out the interior of the cylinder water jacket by warming the cylinder or by air blast and examine for corrosion, if this is possible.
- (ii) Couple up an air pump to the main water inlet connection and seal all remaining orifices with clamps and rubber blanks.
- (iii) Submerge the cylinder or cylinder block in hot water at a temperature of 80° C. (176° F.) until the cylinder is at a uniform temperature.
- (iv) Apply air pressure internally for 5 minutes and make notes where leakage occurs; particulars of pressure are given in the engine handbook. Cylinders showing signs of leakage should be rejected.
- (v) Dismantle the testing rig and lightly spray the component internally and externally with thin lubricating oil to prevent rusting.

Cylinders, monobloc

11. Monobloc cylinders are generally fitted with liners which are sometimes withdrawn from the block during the complete overhaul of certain engines. It is important that the necessary operations should be in accordance with those stated in the particular handbook and the precautions laid down therein must be strictly observed during the operations. In regard to other types of overhauls the liners should not be disturbed unless otherwise ordered. Two types of cylinder block fixtures are shown in figs. 3 and 4.

- (i) Examine the base of the jacket for cracks, especially at the sockets for the end retaining studs.
- (ii) See that all the studs are firm and free from distortion and that no cracks exist in the block.
- (iii) Examine the liners for signs of pitting or corrosion.
- (iv) Test the whole cylinder block under pressure as detailed in the particular engine handbook—see para. 10 of this chapter.

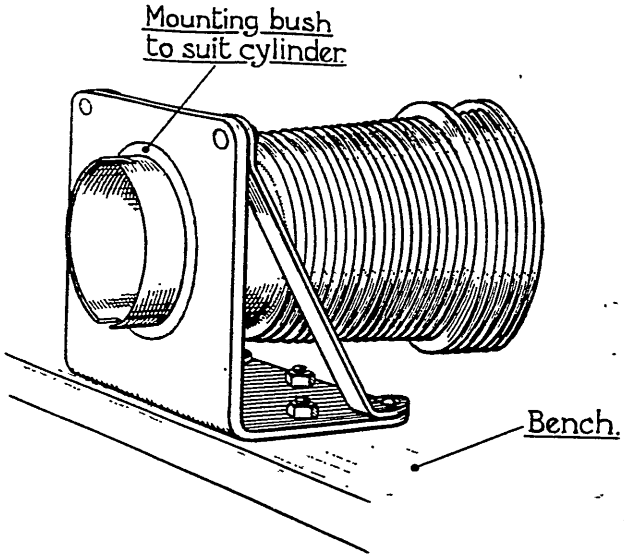


Fig. 1.—Cylinder mounting fixture

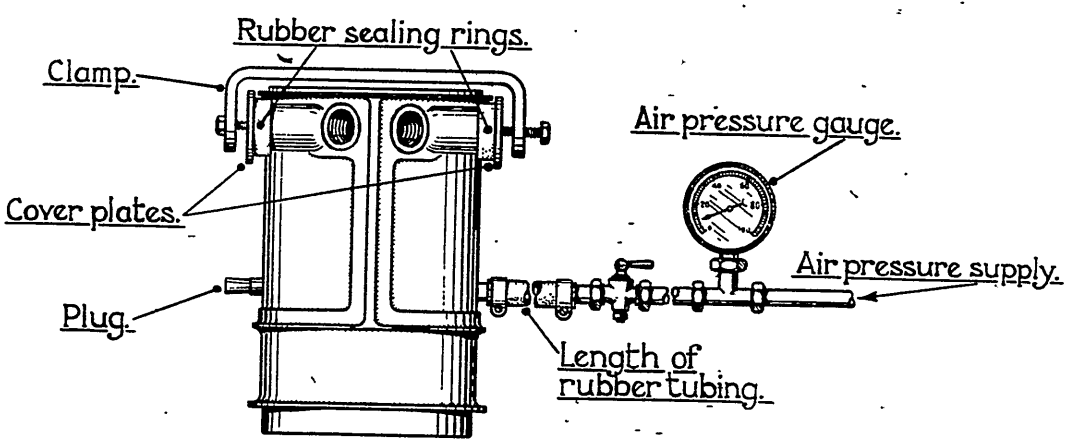


Fig. 2.—Rig for pressure test of water-jacket

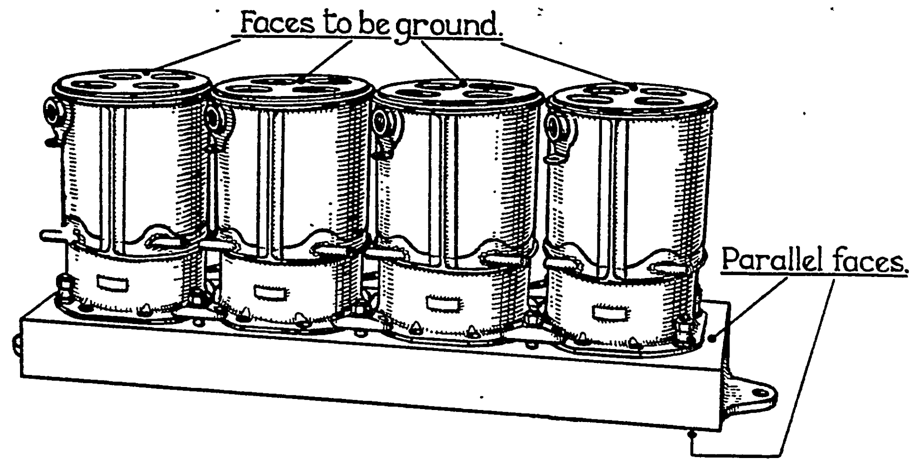


Fig. 3.—Cylinder block grinding fixture

Valves

12. Examine the valve faces for bright or discontinuous markings, indicating distortion, before cleaning off the scale and also for uneven wear, ridges, overheating, pitting and surface cracks.

(i) Test the valve face for distortion by securing the valve stem in a lathe chuck or a bench grinder chuck and using a dial indicator. It is essential that there should be no end play in the lathe or bench grinder spindles and also that the valve stem should be gripped in the chuck by that portion of the stem which is not normally in the valve guide. When using the bench valve grinding machine for this test it is necessary to mount the dial indicator, as shown in fig. 5. The dial indicator rig is of the usual type having a plate base for the location of the vertical spindle and also an arm attachment on the same principle as the scribing block. The first test is to take readings on the valve stem to ensure this is running true. The dial spindle should then be set so that when the contact point is touching the valve face and the latter is rotated, a plus and minus reading is recorded on the dial. The sum of the readings on either side of the zero mark will denote the amount of distortion of the valve face or eccentricity of head to stem. Sketches I and II (fig. 5) show forms of adaptor which can be used when testing the concentricity of small components.

13. An alternative method of checking the valve face for truth is by using the gauge shown in fig. 6. The gauge must be made to the dimensions given in the appropriate schedule of fits and clearances, i.e., the diameters A and B should agree with the larger and smaller dimensions of the valve face. A light marking should be applied to the seating in the gauge, and the valve inserted and rotated partially in both directions. When the valve is removed any discontinuous marking will denote that the head is distorted. The thickness of most valve heads can be ascertained by placing the valve in the gauge, as shown in sketches II and III; sketch II shows a valve which must be rejected.

14. Examine the valve stems for discoloration, corrosion and scores and the stem end for concavity due to wear. Some valve stem ends can be ground within certain limits, but it is first necessary to measure the distance between the end of the stem and the edge of the cotter groove. Check the diameter of the stem for wear and ovality and test for clearance in its guide.

(i) Measure the width of the end lands of the valve stem, where applicable, using a gauge similar to that shown in fig. 6. The amount protruding above the gauge will determine the maximum amount of metal which can be ground off.

Valve seats

15. Measure the width of the seat. This can be done by using a gauge similar to that shown in fig. 7. The angle of the tool should agree with a standard valve and the larger and smaller diameters (A and B) should conform to the dimensions laid down in the Volume II, Part 2, of the appropriate engine handbook. To use the gauge, lightly mark the angle face with prussian blue water colour paint and insert the gauge in position. Rotate the gauge a few turns and inspect the marking on the valve seat with the aid of an inspection lamp.

Valve springs

16. Examine the springs for "draw" marks, distortion, excessive or uneven butting between coils, broken ends, wear from contact with other parts and surface defects, e.g., corrosion. Any of these defects must involve rejection of the spring.

(i) Test the springs for strength using a rig working on the dead load principle similar to that shown in fig. 8. The test is described in detail in para. 17. If a spring is found to have taken a permanent set or bulges out on one side when under test, it should be rejected as it not only indicates that the spring itself is below the desired strength, but the effect of running the engine with such a spring will be to cause the valve to draw over to one side and wear will take place accordingly.

Spring testing

17. All valve and other springs may be tested with the rig shown in fig. 8. The test consists of applying some predetermined load (see Vol. II, Part 2, of the particular engine handbook) to the spring under test and gauging its length when so loaded. The loading of the springs is effected by resting the base of the spring under test on a centring bush fitted to the base and suspending the appropriate weight from its upper end through a centring washer, cotter and loading spindle. By this means, the spring is compressed and its length should be measured by inserting a plate gauge

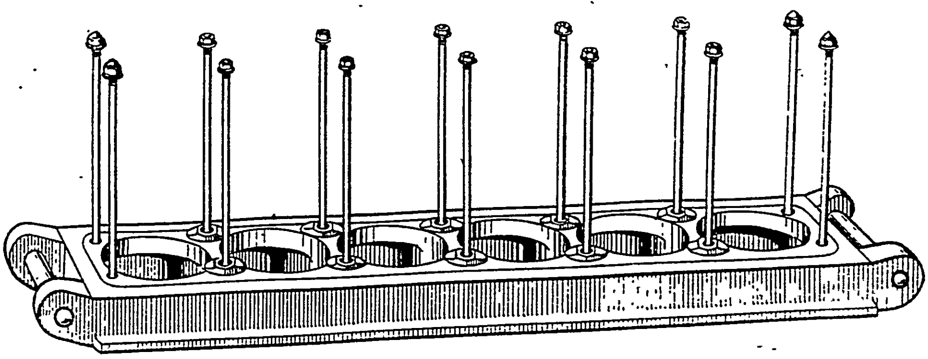


Fig. 4.—Cylinder block fixture

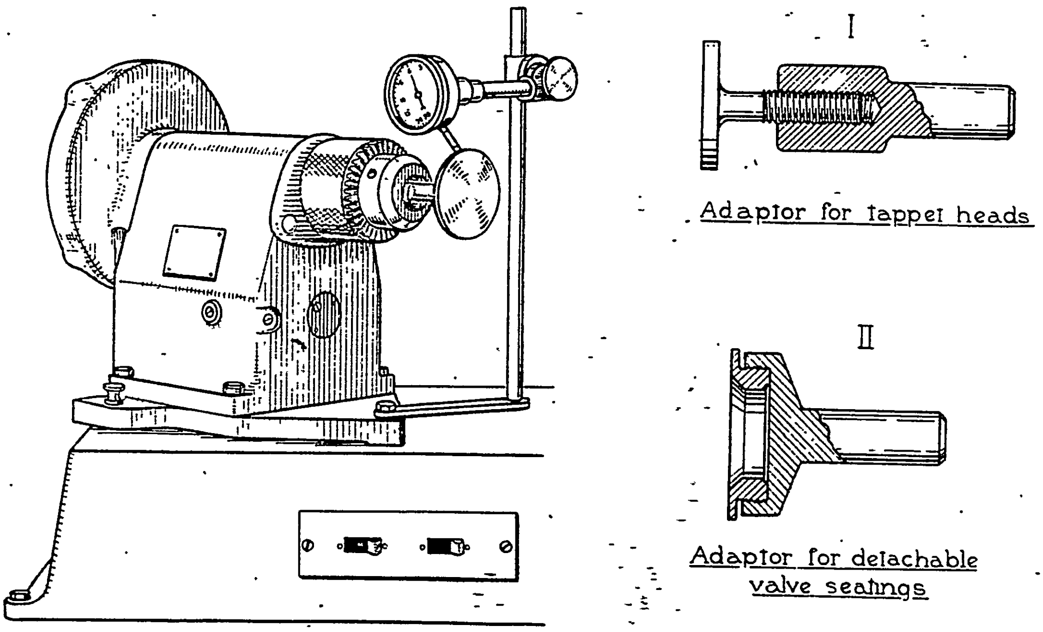


Fig. 5.—Testing valve faces for truth in bench grinder

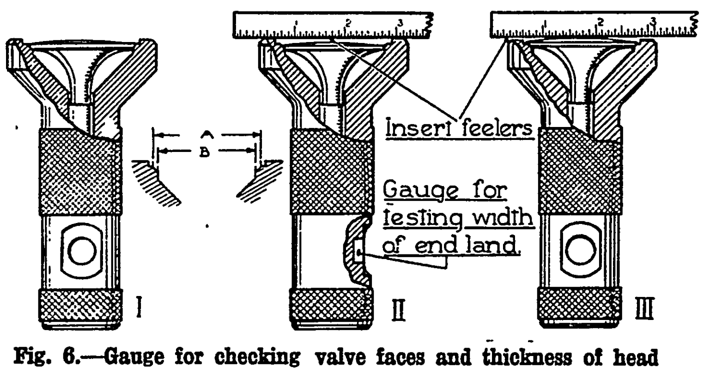


Fig. 6.—Gauge for checking valve faces and thickness of head

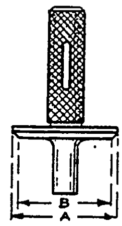


Fig. 7.—Gauge for checking width of valve seat

between the centring washer and base. The loading weight, dimensions of the gauge and the centring bush will differ for various springs. In the case of aero-engine valve springs, the necessary data will be found in Volume II, Part 2, of the appropriate handbook. A detachable hand lever is provided for lifting and locking the weight and loading spindle to the base at the conclusion of the test. When the rig is not in use, the handle and locating spindle are intended to be removed and secured with clips beneath the bench to which the base is attached.

18. Detailed instructions for using the rig are given below:—

(i) Pass the loading spindle fitted with spherical based nut and one of the lock-nuts through the side members of the hand lever. The spindle should be passed between the two spacers close to the catch in such a manner that its plain end lies on the same side of the lever as the catch. Having positioned the loading spindle, screw the hook to its lower end and lock it with the second nut.

(ii) Pass the end of the loading spindle through the hole in the base from the under side and then attach the end of the hand lever to the bracket with the pin.

(iii) Raise the hand lever and engage the catch with the hole in the end of the base.

(iv) Fit the appropriate centring bush to the base and then pass the spring to be tested over the loading spindle and allow the spring to rest on or around the bush as the case may be.

(v) Pass the centring washer over the end of the loading spindle so as to locate the upper end of the spring concentrically with the spindle and then engage the cotter with the end of the spindle.

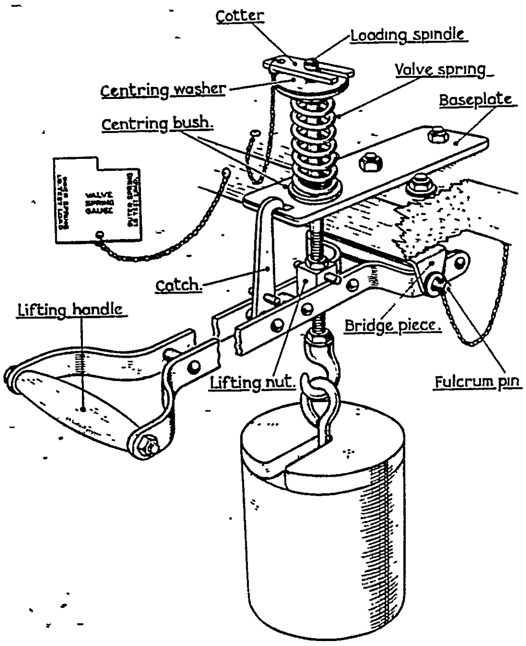


Fig. 8.—Spring testing rig

(vi) Adjust the nuts so that the cotter just clears the top of the centring washer and lock it in this position with the nut and then suspend the weight (appropriate for the spring under test) from the hook.

(vii) Raise the hand lever sufficiently to allow the catch to be disengaged from the base and then lower the lever to its full extent.

(viii) Attempt to enter the appropriate gauge between the base and the centring washer. If the gauge cannot be entered, the spring must be rejected.

(ix) Raise the hand lever until the catch can be engaged with the base. Disengage the cotter from the end of the loading spindle, remove the spring and centring washer, substitute a fresh spring for that tested and replace the centring washer and cotter. Repeat operations (vii) to (ix).

(x) After use, the hand lever and loading spindle should be dismantled and clipped beneath the bench top.

Note.—A gauge of the type illustrated will only be made up in cases where a number of similar springs have to be tested from time to time. The gauge should be made of steel to the dimensions given in Volumes II, Part 2, and stamped with the following information:—

(*a*) Engine type and series.
(*b*) Name of spring.
(*c*) Loading in pounds.
(*d*) Test length in inches.

To prevent loss, the gauge and any other loose parts may be secured to the rig by means of a chain as shown in the illustration.

Camshafts and bearings

19. Check the diameters of journals for ovality and size.

(i) Examine the journals for discoloration, wear, pitting and scoring.

(ii) Examine the cams for wear and pitting. If the cams are badly worn the shaft should be rejected. Ridges due to mal-alignment of the roller can be eliminated by careful stoning.

(iii) Examine the camshaft bearings for wear and their oilways for obstruction.

(iv) Test the camshaft for parallelism and twist—see Chapter 5.

(v) Examine the teeth of the driving wheel for wear, signs of pitting, blueing and cracks, the bores for picking up and wear of keyways caused by an incorrectly fitting key. If the teeth are badly worn the wheel should be rejected, in which case a new key will be required and must be fitted both to the wheel and to the shaft.

(vi) Examine the camshaft gears for backlash. The method for measuring the backlash is a specialised one and is described together with the necessary rig in the appropriate handbook.

Cam ring units

20. The cam ring and carrier is generally regarded as one unit and therefore must be rejected if one of the components is found to be defective:—

(i) Examine the cam track for scoring, wear, pitting, ridges and cracks.

(ii) Examine the teeth, where applicable, for wear and picking up.

(iii) Test the cam ring for truth as laid down in the particular handbook.

Tappets and push rods

21. The following should be read in conjunction with the particular handbooks:—

(i) Examine the tappets for discoloration and signs of seizure. Check for wear and ovality.

(ii) Check the roller pins for size and for end play in tappets and the end play of each tappet in its guide.

(iii) Examine the junction between the sockets of the push rods and the rods. In some engine the junctions are soldered.

(iv) Check the push rods for alignment by rolling them on a flat surface.

Tappet guides

22. Check the bores of the guides for size and ovality by using limit gauges, and for wear in the slots—see para. 7 of this chapter.

Pistons

23. Check the skirts for wear, ovality and examine for scoring.

(i) Examine the piston for cracks, especially in the vicinity of the gudgeon-pin bosses, the lugs in the crown and in the vicinity of any pronounced machining marks.

(ii) Check the width of the piston ring grooves. The width of the grooves can be measured by locally made thickness gauges, or by using a new ring and a feeler gauge.

(iii) Check the dimensions of the gudgeon-pin bush and examine for step at the end of the boss.

(iv) Examine the circlip grooves for burring.

(v) Examine the pegs for the gas rings (if fitted) for looseness. If these pegs are loose, new ones should be fitted as described in the particular handbook.

(vi) Clear all transfer holes and examine for flaws in the vicinity of the holes.

Piston rings—gas and scraper

24. Check the gaps between the butts of the rings by using feelers. It is essential for the rings to be placed independently in the cylinder and their edges to be parallel with the axes of the cylinder bore. To effect this condition, a piston may be employed to push the ring up the cylinder when the gap can be measured at any part of the stroke.

(i) Measure the width of the rings with a micrometer and the side clearance of each ring in its groove with feelers.

(ii) Clear all transfer holes of scraper rings an examine for flaws in the vicinity of these holes.

Gudgeon-pins and wrist-pins

25. Examine for wear, longitudinal fractures, scores and signs of overheating and seizure and check the pins for size and ovality.

Connecting rods

26. A number of types of connecting-rod assemblies will be found in present-day aero-engines, these being illustrated in figs. 1 to 6 in chapter 5 of this Section. The assemblies are here separated into two groups for convenience. The viewing is similar for all types.

Master and auxiliary rods

27. This type of assembly usually consists of a forked and a plain rod, the latter rod working within the recess of the former rod. The big-end bearing may be either a bearing block or in the form of a pair of bearing shells; the inside and outside of the big-end bearing in both types is remetalled.

(i) Examine the inner and outer bearing metal surfaces of the bearing block or shells and reject those components which show signs or cracks, pitting, scores or seizures and lack of adhesion of the bearing metal. If no defects appear on the surface of the bearing metal, an adhesion test in the case of whitemetal should be made. Normally, i.e., at complete overhauls, all bearing blocks and shells are renewed regardless of their condition.

(ii) Measure the internal and external diameters of the big-end bearing for size, ovality and taper, and test for end float.

(iii) Examine the joint faces between the rod and the cap for signs of fretting. Check the fit of the cap and the rod.

(iv) Examine the rod for cracks and signs of overheating. Check the rods for end clearance.

(v) Check the bores of the gudgeon-pin bearings for wear, using limit gauges—see A.P.1464B, Vol. I, Part 2, Sect. 3, Chap. 10, and examine for signs of overheating and seizure. If the bushes are of the floating type, examine them externally for wear and check for size, ovality and taper, and examine for signs of overheating and seizure.

(vi) Examine the retaining bolts or studs for "draw" marks and for stretching. Examine the condition of all visible threads and check the nuts for fit on their respective bolts or studs.

(vii) Test the rods for parallelism and twist—see Chapter 5.

Master and articulated rod

28. This type of assembly consists of a master rod upon which a number of articulated rods are hinged. The viewing is similar to that described in para. 27.

Adhesion test

29. All whitemetal-lined bearings must be subjected to the following adhesion test. Submerge the bearing shell or bearing block for 15 minutes in an oil bath which has been raised to a temperature of 105° C. (220° F.). Remove the bearing and thoroughly dry off. Apply a mixture of powdered french chalk and methylated spirit to all surfaces and allow the bearing to stand for 24 hours. Should the adhesion of the whitemetal be imperfect at the edges, the chalk will be stained in the vicinity of any porous area and also where the metal has separated from the shell or block. Special note must be made of any signs of porosity in the bearing surface itself. Should any discoloration of the chalk occur, the bearing must be rejected.

Crankshafts—journals and crankpins

30. Examine for signs of overheating. Slight "draw" marks may be found on the maneton and upon journals where ball and roller bearings have been removed. These "draw" marks and scores may often be removed by careful stoning. Examine the joints between built-up portions of the crankshaft for signs of fretting. Examine the transverse bolt in the maneton in the case of split-webbed crankshafts, and the nut for soundness of thread.

(i) Check the diameters of the journals and crankpins for size, ovality and taper.

(ii) Check the radii at the end of each journal and crankpin with a radius gauge and examine for scoring and flaws.

(iii) Check the length of the crankpin or where plain crankshaft journal bearings are used, check the length of the journal.

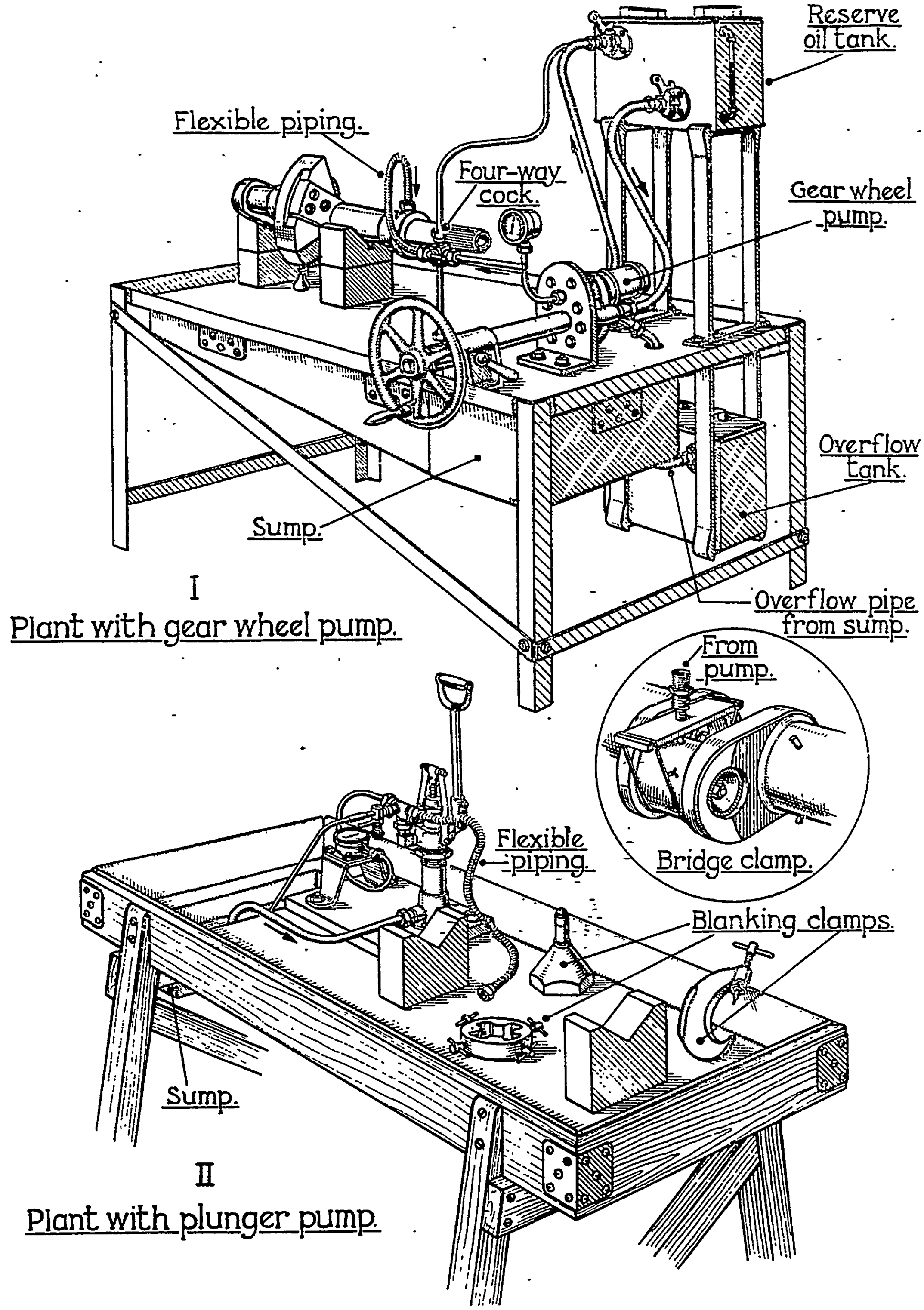


Fig. 9.—Oil pressure tests on crankshafts

(iv) Examine the splines for wear and cracks. Examine the sides of the splines for side bearing marks and the ends for stepping.

(v) Examine the keys for "draw" marks and check the fit of the keys in their keyways.

(vi) Examine the threaded portions of the shaft for wear.

(vii) Examine the spigot and dogs, where applicable, for wear (in conjunction with the auxiliary drive shaft). The method of measuring the backlash is given in the engine handbook.

(viii) Test the crankshaft for alignment—see Chapter 5 of this Section.

Oil pressure tests of crankshafts

31. Fig. 9 shows two forms of testing plant which can be used for testing radial and in-line engine crankshafts under oil pressure, the amount of pressure being stated in the respective engine handbooks. The test is to determine the soundness of the joints of the sealing caps and plugs in the crankwebs. The following test must be made on each circuit of the crankshaft:—

(i) Replace sealing caps and plugs (where fitted). Before inserting the plugs a thin coating of tallow should be applied to their shanks.

(ii) Seal all oil holes, except one, with tapered copper pins lightly tapped in position or by strips of rubber secured with hose clips. Several types of clamps are shown in the illustrations which may be used for blanking off the oil holes in the shafts; the bodies of the clamps are made of aluminium and the ends of the steel bolts are fitted with detachable copper pins. Other suitable types of clamps are described in the handbooks. A device, similar to that shown in the inset of fig. 9, can be sometimes used as a connection for the supply pipe from the pressure pump. This clamp consists of a bridge piece having a screwed union tapered at one end for inserting in the unblanked hole of the shaft. The bridge piece is strapped to the shaft by heavy gauge iron wire, which is tightened by screwing the union through the bridge piece. Should the sealing caps or plugs leak at the pressure laid down, these items must be reground or renewed as necessary. The shaft must then be retested for serviceability.

Crankcases

32. The examination for defects, etc., is practically identical for all types of crankcase. At each complete overhaul it is essential that the crankcase should be thoroughly examined for cracks. In certain circumstances the position of the crack necessitates the rejection of the crankcase, whilst in others the crack may be disregarded—see Leaflets in Volumes II. All parts in which cracks are suspected should be brushed with a thin mixture of methylated spirit and french chalk. This quickly dries and any crack will be easily discernible owing to the oil exuding and staining the white surface. A note should be made during the viewing operations regarding the positions of the cracks so that action can be taken during overhaul of the component. An entry should be made in the record of overhaul and the aero-engine log book in order that the rate of development of any accepted crack can be determined at subsequent examinations.

(i) Examine for cracks around the mounting feet, flanges or bosses, internal webs, stud and bolt holes, bearing housings, cylinder barrel recesses, the bosses of all cylinder holding-down studs and in the vicinity of all other studs. Test the mounting feet upon a pair of long parallel strips placed on a surface table. For depôt work a stand similar to that shown in fig. 10 may be usefully employed.

(ii) Examine all studs for looseness and the condition of visible threads. A crankcase should not normally be rejected for looseness of studs as it is possible to replace such studs by oversize studs where these are provided.

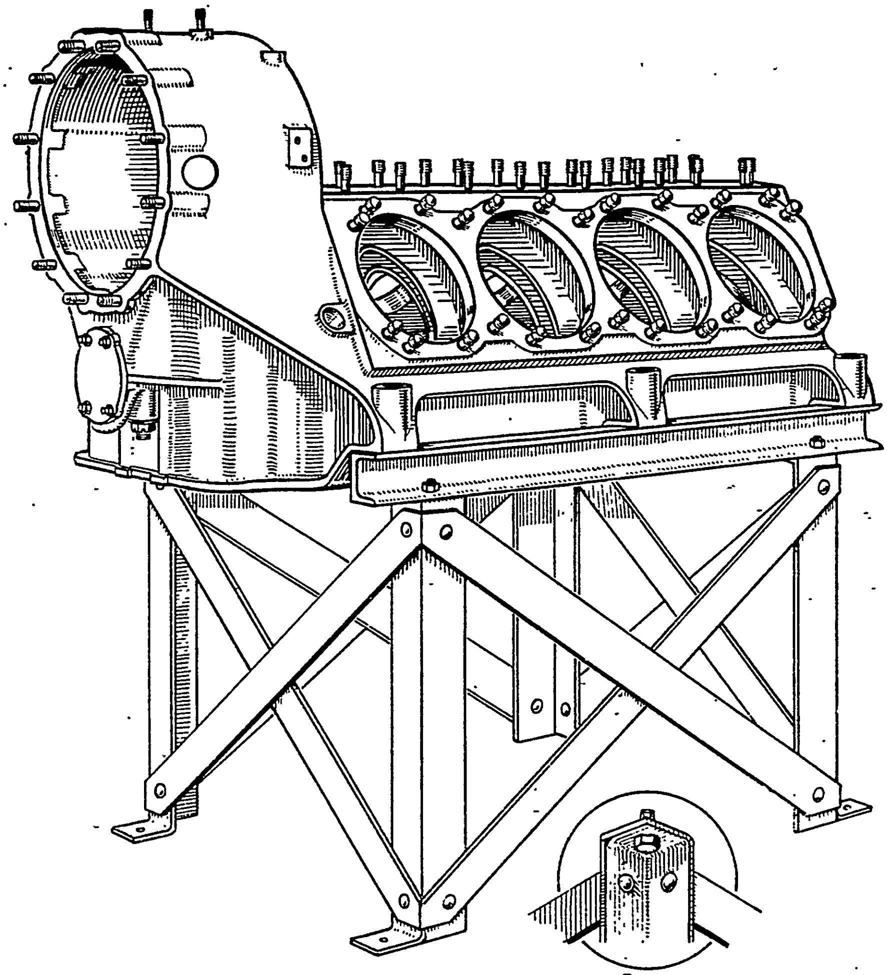
(iii) Examine all bearing housings for signs of scoring due to creeping or spinning of the bearing. If this has been excessive, oversize bearings will be required.

(iv) Check the cylinder facings on the crankcase for distortion by means of a surface plate. A rough estimate may be made with a straightedge. When testing the facings on an in-line engine, the plate or straightedge should be in contact with all facings for one bank of cylinders.

(v) Examine the joint faces for distortion and fretting.

Pumps—gear wheel type

33. The appropriate procedure for viewing these pumps is dealt with in the relevant handbooks, to which reference should be made owing to the variance in design of these components. The general viewing is given below:—



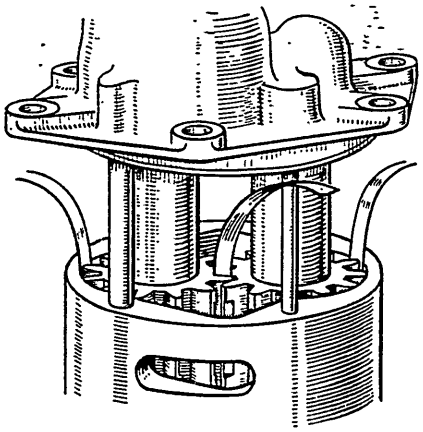


Fig. 10.—Crankcase mounting feet test stand
Fig. 11.—Radial clearance and backlash tests of gear wheel pump

(i) Examine the casings for cracks, especially in the vicinity of stud and bolt holes and test as indicated in para. 32.

(ii) Examine studs, bolts and nuts for looseness and condition of visible threads. Examine the studs and bolts for mal-alignment and signs of rubbing.

(iii) Examine the teeth of gear wheels—see para. 35.

(iv) Examine all bushes and journals for ovality and wear and for signs of scoring due to foreign matter in the oil.

(v) Examine keys for "draw" marks, and check the fit of the keys in their keyways.

(vi) Examine filters for soundness.

(vii) Check the gear wheels for end clearance in the casings. This measurement is important and may be ascertained by assembling the end plates, gears, etc., in their casings, placing a straightedge across the upper face of the casing and inserting the feelers between the straightedge and the gear wheels. It is, of course, necessary to verify the truth of the casing faces before these measurements are taken; this may be done by using a surface plate provided with holes to clear the studs.

(viii) Check the radial clearance between the gear wheels and the walls of the casings, using narrow feelers—see fig. 11.

(ix) Test each pair of gear wheels for backlash, using narrow feelers between the meshing teeth.

(x) Check the pump spindles and their housings for size and ovality and examine for wear.

(xi) Examine the threads of all adaptors and nuts for serviceability.

(xii) Examine relief valves for correct functioning.

Pumps—impellor or rotor type

34. Examine the casing for cracks (see para. 32), all studs for looseness and visible threads for wear. Examine the pump chamber for signs of corrosion.

(i) Check to ensure that the rotor has been assembled in the correct manner—see handbook.

(ii) Examine the rotor blades for corrosion and damage.

(iii) Examine the pump spindle and bushes for scores, corrosion and wear, and check for ovality. Check the clearance of the spindles in their bushes.

(iv) Check the clearance between the face of the rotor and the casing.

(v) Check the rotor for end float. In some pumps this can be ascertained by placing the rotor in the assembled casing and then inserting feelers between the pad which takes the end-loading of the rotor and the end of the rotor spindle. In other pumps it will be found necessary to assemble the pump without any packing in the gland and to move the spindle forward and backward, noting the amount of movement of the spindle.

(vi) Examine the drain cock, if fitted, for serviceability.

(vii) Examine the condition of the packing. Note that the packing conforms with the instructions given in the handbook of the engine.

Gear wheels

35. The general viewing of gear wheels is very similar for all types and involves examination for signs of wear at the contact faces, broken and fractured teeth and for cracks in the body and hub of the wheel. Wear will be shown by a hard bearing line on the pitch circle or a rough surface on the tooth. In certain instances the surface of the teeth may be touched up by careful stoning but before doing so it is essential that the teeth are measured. A comparative reading may be taken by mounting the wheel on suitable V-blocks and placing a ground roller of suitable diameter between two teeth and then measuring the height of the roller with a dial test indicator. Readings should be taken for all teeth to obtain the most satisfactory results. The wheels may be checked for distortion by placing them on a suitable mandrel, mounting the assembly on a pair of V-blocks and using a dial test indicator in contact with the side of the wheel.

Bearings—ball and roller

36. Before viewing can be satisfactorily undertaken on these components it is essential for them to be thoroughly cleansed with paraffin to remove all oil and dirt. It is not possible to view all types of these bearings owing to the fact that in some bearings the cages almost entirely conceal the tracks, balls or rollers. In view of this, bearings should be viewed on all visible surfaces and the balls or

rollers checked for corrosion as far as possible. If any doubt exists as to its serviceability, a bearing should be rejected. All ball bearings should be subjected to a suitable test for end float. Where possible, the following visual examination should be carried out:—

(i) Examine the races both internally and externally for wear, corrosion and picking up. Seriously pitted rings must on no account be passed for re-assembly in an engine.

(ii) Check the clearance between the rollers and their outer race.

(iii) Examine balls or rollers for cracks, scores and undue wear. A defective ball or roller sometimes necessitates rejection of the bearing. A roller bearing can seldom be dismantled, but where this is possible, the viewer can measure each roller with a micrometer. It is most important that the components of one bearing shall not be mixed with similar components of another bearing as parts of the same type are not always interchangeable.

(iv) Examine the cages and their rivets for soundness and distortion.

(v) Test rollers for end float. This can be done by inserting feelers between the rollers and the sides of the track. The operation should be repeated at various points around the track with different rollers.

(vi) Test ball bearings for end float as detailed in para. 37 of this chapter.

(vii) Test the fit of the inner race on the shaft. If slackness is present, check the diameter of the shaft and if found to be correct, the bearing should be rejected.

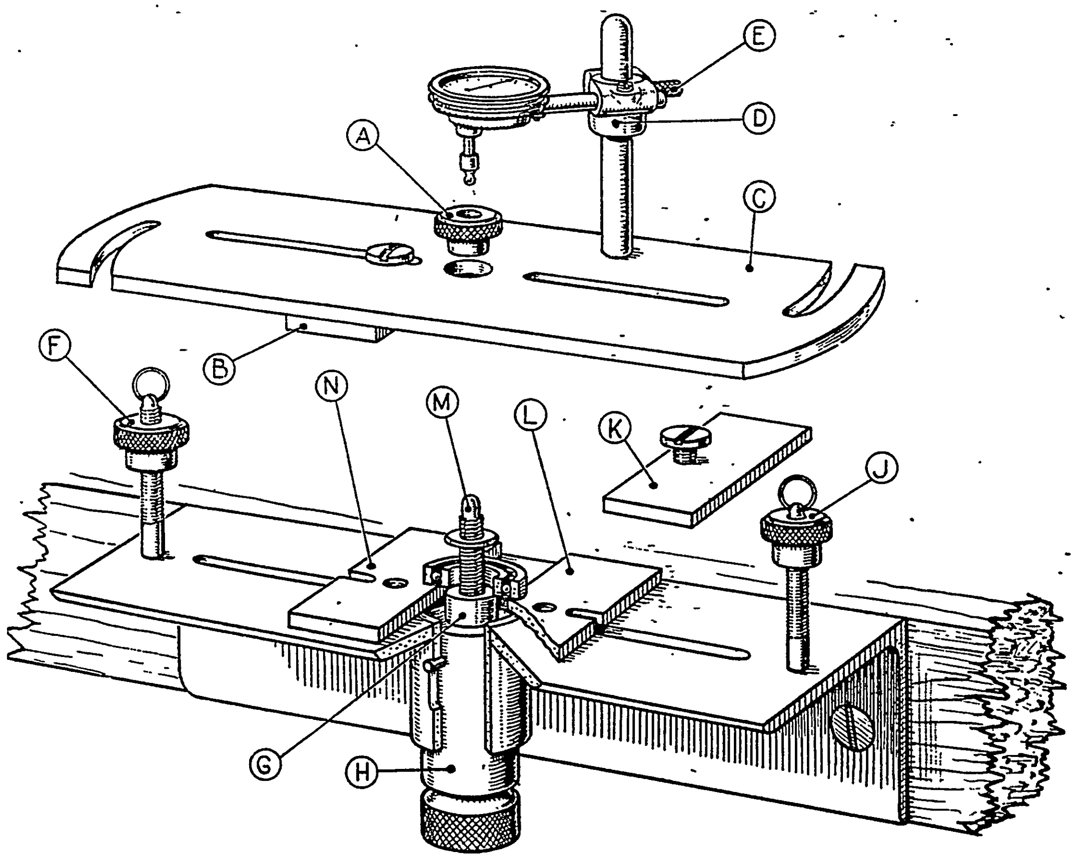


Fig. 12.—Ball bearing test rig

Measuring the end float of ball bearings

37. The end float of a large range of ball bearings can be measured with the rig shown in fig. 12. The rig, which is intended to be screwed to the side of a bench, operates as follows:—The outer race of the bearing to be tested is secured between the base and the top plate, being clamped between the adjustable slides. The inner race of the bearing is secured to the plunger by the thumb nut being clamped between a washer and a distance piece; a second washer is substituted for the distance piece if the inner race of the bearing is of greater diameter than the plunger. A dial indicator,

mounted on the top plate, as shown in the illustration, is then adjusted to bear on the end of the spindle and the plunger is moved to its full extent up and down the bore of the sleeve. The magnitude of the movement of the plunger and hence that of the end float of the ball bearing is registered by the dial indicator. Detailed instructions are given below for operating the rig:—

(i) Unscrew the thumb nut (A), slacken the thumb nuts (F and J), and lift off the top plate (C).

(ii) If the inner race of the ball bearing to be tested is of smaller diameter than the plunger (H), pass a tubular distance piece (G) of suitable depth and diameter to enable it to support the inner race of the bearing without fouling the outer race, over the spindle (M). If the inner race of the bearing is of larger diameter than the plunger (H), pass a 16 s.w.g. washer of a suitable diameter over the spindle (M), to enable it to support the inner race of the bearing without fouling the outer race.

(iii) Rest the outer race of the bearing to be tested upon the two adjustable slides (N and L) on the base. The slides should be positioned so that the bearing may be set approximately concentric with the spindle (M) and it should be observed that they do not come in contact with the inner race of the bearing.

(iv) Pass a 16 s.w.g. washer of suitable diameter to enable it to rest on the inner race of the bearing without fouling the outer race over the end of the spindle (M).

(v) Secure the top plate (C) to the base after first having set the adjustable slides (B and K) so that, when the plate is in position, they will rest on the outer race of the bearing without fouling the inner race. The plate is to be secured by screwing up the thumb nuts (F and J), finger-tight only.

(vi) Screw the thumb nut (A) over to the end of the spindle (M) until the inner race of the bearing is securely gripped on the plunger (H).

(vii) Slacken the thumb screw (E) and swing the dial indicator bracket (D) round on the standard until the ball end of the indicator bears upon the end of the spindle and a deflection is caused. Turn the knurled rim of the dial so that it is reading at zero.

(viii) Raise and lower the plunger (H) in the sleeve and thus force the inner race of the bearing through its range of end float. Note the amount of deflection on the dial; this deflection will be equal to the end float of the bearing.

(ix) Swing the indicator clear of the end of the spindle. Remove the thumb nut (A), slacken the thumb nuts (F and J), lift off the top plate (C) and remove the bearing.

(x) When the jig is not in use, the top plate (C) should be screwed to the base with the thumb nuts (F and J) and the thumb nut (A) screwed to the end of the spindle (M). The dial indicator should be removed from the clip and stored in its box and all washers used in connection with the rig should be collected and preserved for future use.

Propeller shaft and reduction gear

38. When the assembly has been completely dismantled, the following parts should be examined as under:—

(i) Cover for general soundness and for defects such as flaws, cracks, etc. Even a small crack necessitates rejection of the component. Minute cracks are very difficult to find and where they are suspected, the methylated spirit and french chalk test should be applied to the component—see para. 32 in this chapter.

(ii) Shaft for distortion. The shaft should be mounted upon suitable V-blocks and a dial test indicator used for taking readings of the intermediate journals, etc.

(iii) Splines for signs of fretting and for "picking up". If any slight irregularities are observed they may be removed by careful stoning.

(iv) Threaded portions of the shaft for wear.

(v) Teeth on the bevel wheels and spur wheels for wear. High spots are indicated by polished areas on the pitch circle and if these are not too pronounced, they should be stoned down; but if the wear appears excessive, the wheel must be rejected.

(vi) Spur wheel securing bolts for signs of wear and for stretching and their nuts for general soundness and fit. Bolt holes for distortion.

(vii) Bearings for defects. The procedure for viewing ball and roller bearings is given in para. 37 of this chapter. Bearings of the plain and phosphor bronze type should have their internal and external diameters measured and checked for size, ovality and wear. Although whitemetal-lined bearings are renewed at each complete overhaul, they should be viewed in a similar manner to the plain type and also examined for cracks, pitting, scores, signs of seizure and lack of adhesion of the lining. If no defects appear on the surface of the white-metal, the bearing should be subjected to an adhesion test as detailed in para. 29 of this chapter.

(viii) Thrust washers for wear in their tracks.

(ix) Locking devices. It is essential for these to be replaced by corresponding new parts.

(x) Keys and keyways for signs of wear, e.g., scores. A scored or badly fitting key should be replaced by a new one.

(xi) Bore of shaft for signs of rust. If this is present, the bore should be thoroughly cleaned with fine emery cloth and paraffin and then given a thin coating of rust preventive.

(xii) Oil channels and jets for obstruction. In some cases the sludge can be removed by syringing, but if this fails to have the desired effect, a steam or air pressure jet should be used. Oil channels and jets must be perfectly clear to ensure that the components will be adequately lubricated.

Locking devices

39. The locking devices removed from the engine should be checked as regards numbers, after which they should be made completely unserviceable, either by bending or breaking, as they are not to be used more than once, except in extreme urgency. Care must be taken to avoid old locking devices becoming mixed with fresh supplies. An entry must be made in the record of overhaul and also in the aero-engine log book giving particulars of the circumstances which prevented this procedure from being carried out.

P5045 M /1320 9/44 5250 C & P Gp. 1

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 6 to A.P.1464C, Vol. I and concerns Part 2, Sect. 2.
Insert this chapter.

CHAPTER 5

AERO-ENGINES—ALIGNMENT TESTS

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

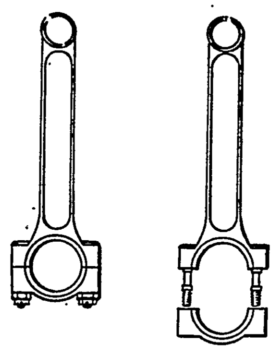


FIG. 1. IN-LINE.

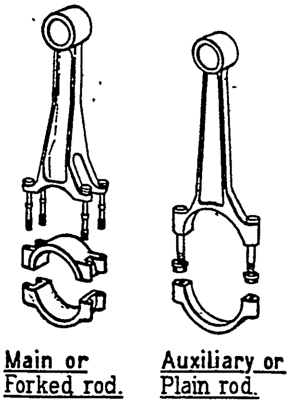


FIG. 2. VEE.

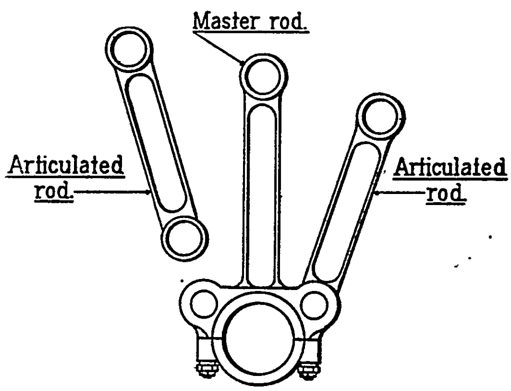


FIG. 3. ARROW.

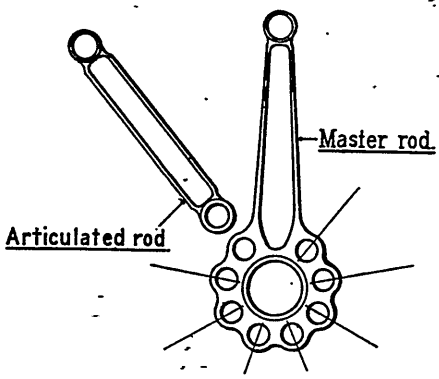


FIG. 4. RADIAL.

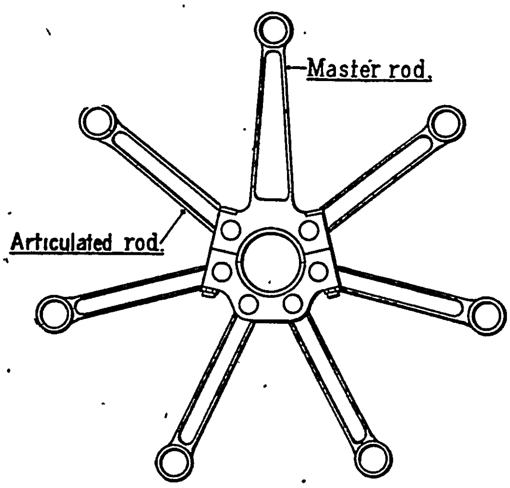


FIG. 5. RADIAL

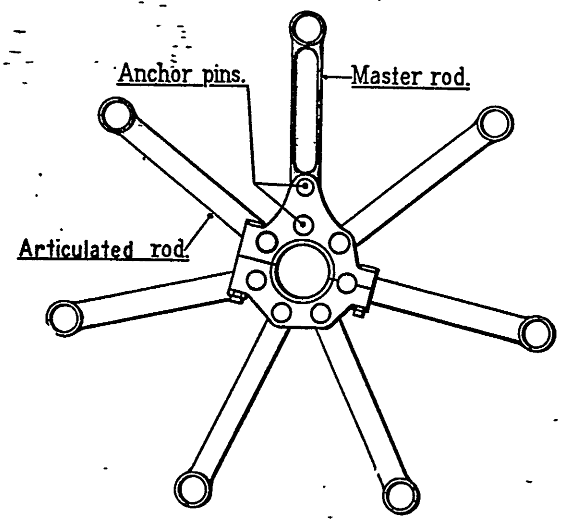


FIG. 6. RADIAL.

Fig. 1 to 6—Types of aero-engine connecting-rod assemblies

CHAPTER 5

AERO-ENGINES—ALIGNMENT TESTS

Introduction

1. In addition to the viewing procedure detailed in Chapter 4, all connecting rods, crankshafts and camshafts should be subjected to alignment tests at each complete overhaul of the engine.

2. Six types of connecting rod assemblies and four types of crankshaft assemblies are illustrated in figs. 1 to 6 and 12 to 15 respectively. Although the tests for the rods and those for the crankshafts are similar, they are separately described to facilitate reference.

Equipment and tools

3. The following equipment and tools will be required to carry out the alignment tests described in this chapter. It is most important that these items are accurate and free from burrs, etc., in order that satisfactory results are obtained.

(i) Surface plate or a surface or a marking-out table. These items should be of convenient size according to the dimensions of the engine components being tested. If a marking-out table is used, care must be taken to ensure its working surfaces are true.
(ii) V blocks (in pairs) of various sizes—see A.P.1464B, Vol. I, Part 2, Section 3, Chapter 10.
(iii) Square.
(iv) Universal scribing block.
(v) Dial test indicator.
(vi) Toolmaker's jack.
(vii) Parallel mandrels of various diameters accurately ground to be a slide fit in the respective bores of the big-end, gudgeon-pin and wrist-pin bearings or housings. The mandrels for the gudgeon and wrist-pin bearings should be lightly marked at each inch of their length to avoid having to take these measurements during the tests. Sets of these mandrels are supplied to Squadrons, Bases and other Units not having facilities for manufacture; Depots should make up their requisite sets of mandrels.

4. When taking dial indicator readings it should be remembered that the actual error will be half the difference of the maximum and minimum readings registered by the dial (this warning is not repeated in the descriptions of the tests). The viewers should prepare appropriate view-sheets on which the readings may be recorded, so that comparison may be made with the data given in the Volume II, Part 2, of the handbook for the engine. This information is most valuable in the event of the component requiring to be reconditioned, e.g., regrinding of crankshaft journals and pins.

Testing connecting rods

5. The errors which may be anticipated when testing connecting rods are lack of parallelism and twist, both defects being detrimental to the satisfactory running of the engine—see fig. 7. A connecting rod is true when the axes of the big-end bearing are parallel to the axes of gudgeon-pin bearing—see sketch I. This condition may be checked in two stages:—

(i) *Parallelism.*—A rod is considered to be parallel when the horizontal plane of the gudgeon-pin axis is in a plane parallel to the horizontal plane containing the big-end axis—see sketch I.
(ii) *Twist.*—A rod is considered to be free from twist when the vertical plane of the gudgeon-pin axis is in a plane parallel to the vertical plane containing the big-end axis—see sketch II.

Note.—It is possible for a rod to have combined lack of parallelism and twist—see sketch V

Parallelism

6. The condition (i) above can be checked by direct measurement between the two extremities of the big-end axis and a surface table (or plate) and also between the extremities of the gudgeon-pin axis and the surface table when mounted in a vertical position. For convenience in taking these measurements the big-end bearing can be mounted on a parallel mandrel and another mandrel inserted in the gudgeon-pin bearing, the mandrels being a slide fit in the bearings, and the assembly placed upon a pair of V-blocks. The first operation is to check the height of the mandrel to ensure it is parallel to the table, this being done by traversing a dial indicator across the upper surface of each end of the mandrel. Should a slight adjustment be necessary, pieces of steel foil can be placed under one of the V-blocks. Steel foil having thicknesses of ·00015, ·001, ·002, ·003 in. etc., are available and will provide a degree of accuracy within 0·0005 in. Several methods of adjusting the height of V-blocks are shown in fig. 12 of A.P.1464B, Vol. I, Part 2, Sect. 3, Chap. 10. In a similar manner

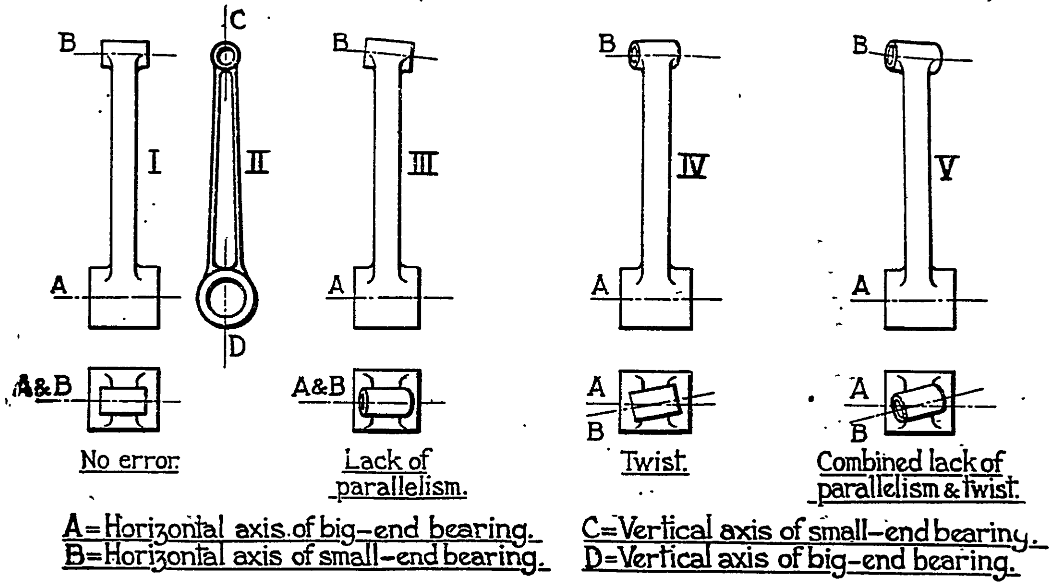


Fig. 7—Alignment errors of connecting-rods

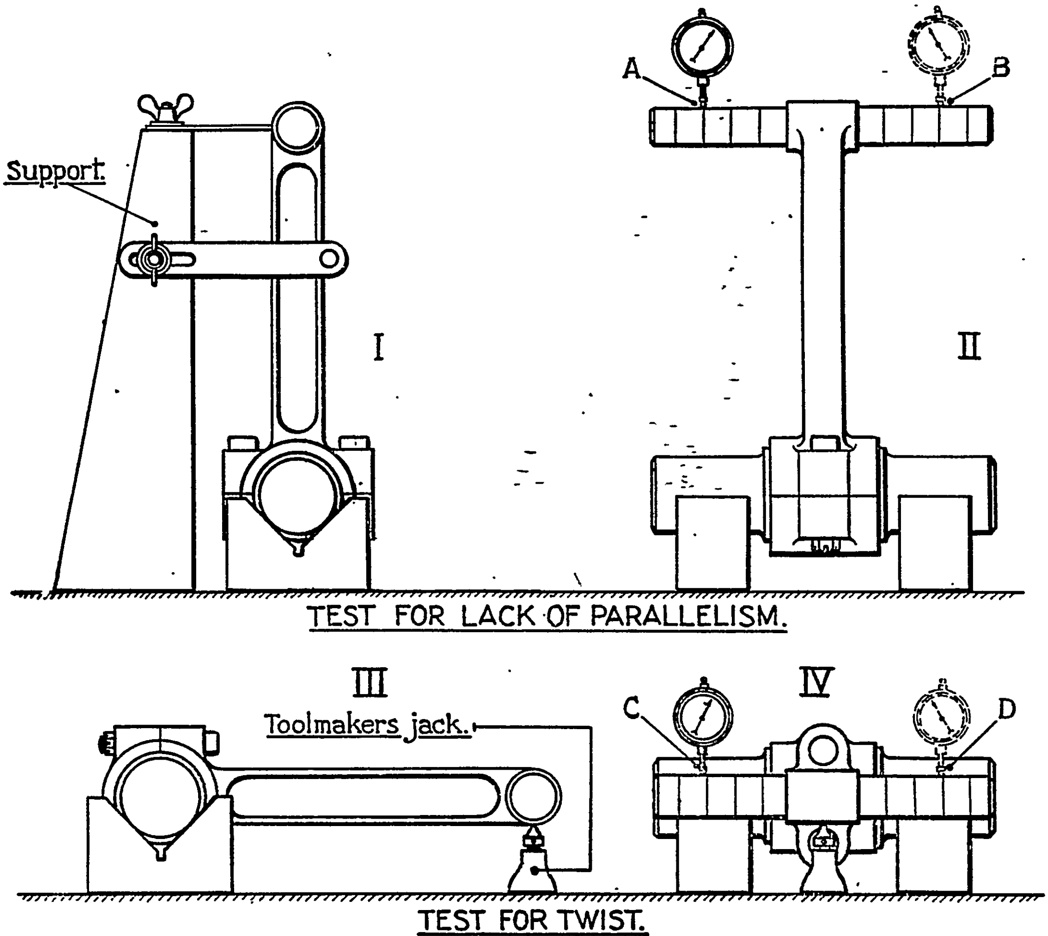


Fig. 8.—Plain connecting-rod alignment tests

the height of the small-end mandrel can be measured in relation to the table or the distance between the two mandrels can be ascertained by direct measurement with an inside micrometer. Assuming that the big-end mandrel is parallel to the table, any deviation at the small-end mandrel will denote the amount of error due to lack of parallelism. In aero-engine practice this amount is reckoned at so much per inch length of mandrel where the dial readings are taken. Supposing the readings were $\pm$ 0 at one end of the mandrel and 0·003 in. at the other end, and the readings were taken four inches apart, the error would amount to 0·00075 in. for each length of the mandrel. By referring to the appropriate schedule of fits and clearances, the viewer would be able to ascertain whether the rod is within the permissible tolerance.

Twist

7. The above test does not discover errors due to twist, where the horizontal axis of the gudgeon-pin bearing although in a plane parallel to the table, lies in a different vertical plane from that of the big-end bearing axis. Twist is revealed by dropping the rod to a horizontal position so that the two axes will no longer both be parallel to the table and therefore to each other when twist is present. The amount of twist is measured by mounting the rod upon a pair of V-blocks as before and supporting the small end of the rod by means of packing pieces or a toolmaker's jack, the rod being in a horizontal plane on the table. Dial readings should now be taken on the small-end mandrel as detailed above when the amount of twist can be calculated for each inch length of the mandrel. By referring to the Volume II, Part 2, of the appropriate engine handbook, the viewer can ascertain whether the rod is within the permissible tolerance.

8. Any connecting rod having errors which exceed the permissible tolerance should be rejected as unserviceable and labelled to this effect. In addition, the component should be marked with red paint.

Single type connecting rods

9. This is the usual type of connecting rod having big-end and gudgeon-pin bearings, as shown in fig. 1, or the rod may be of the auxiliary or articulated type. In either case the tests are similar except for the size of mandrels which will be required.

Test for parallelism

10. The rod is tested for parallelism, see fig. 8, as follows:—

(i) Fit the mandrel to the big-end bearing.

(ii) Mount the rod on V-blocks as shown in sketch I, tightening up the securing nuts to their normal tension.

(iii) Test the mandrel for parallelism to the surface table.

(iv) Insert a mandrel in the gudgeon-pin bearing and rotate the rod until it is pointing vertical and allow the small end of the rod to rest against a support as shown.

(v) Proceed to take dial readings at position A (see sketch II). Without disturbing the indicator setting, repeat the operations at position B and make a note of the two readings and also the exact position in which they were taken. If these readings agree, the rod is parallel, i.e., the distance between the extremities of the axes of the big-end and small-end are equal. If the readings do not agree, calculate the amount of difference per inch length of mandrel which is the error due to lack of parallelism and make a note to this effect.

Test for twist

11. The rod is tested for twist as follows:—

(i) Rotate the rod to the position shown in sketch III, i.e., the rod should be approximately parallel to the table; the overhung portion of the rod may be supported by a toolmaker's jack, as shown.

(ii) Proceed to take dial readings at each end of the mandrel at positions C and D in sketch IV, as detailed in the preceding paragraph and make a note of the readings obtained per inch length of mandrel; the difference in the readings denotes the amount of twist which is present in the rod.

12. Reference should now be made to the Volume II, Part 2, of the respective engine handbook to ascertain whether the rod is within the permissible tolerance.

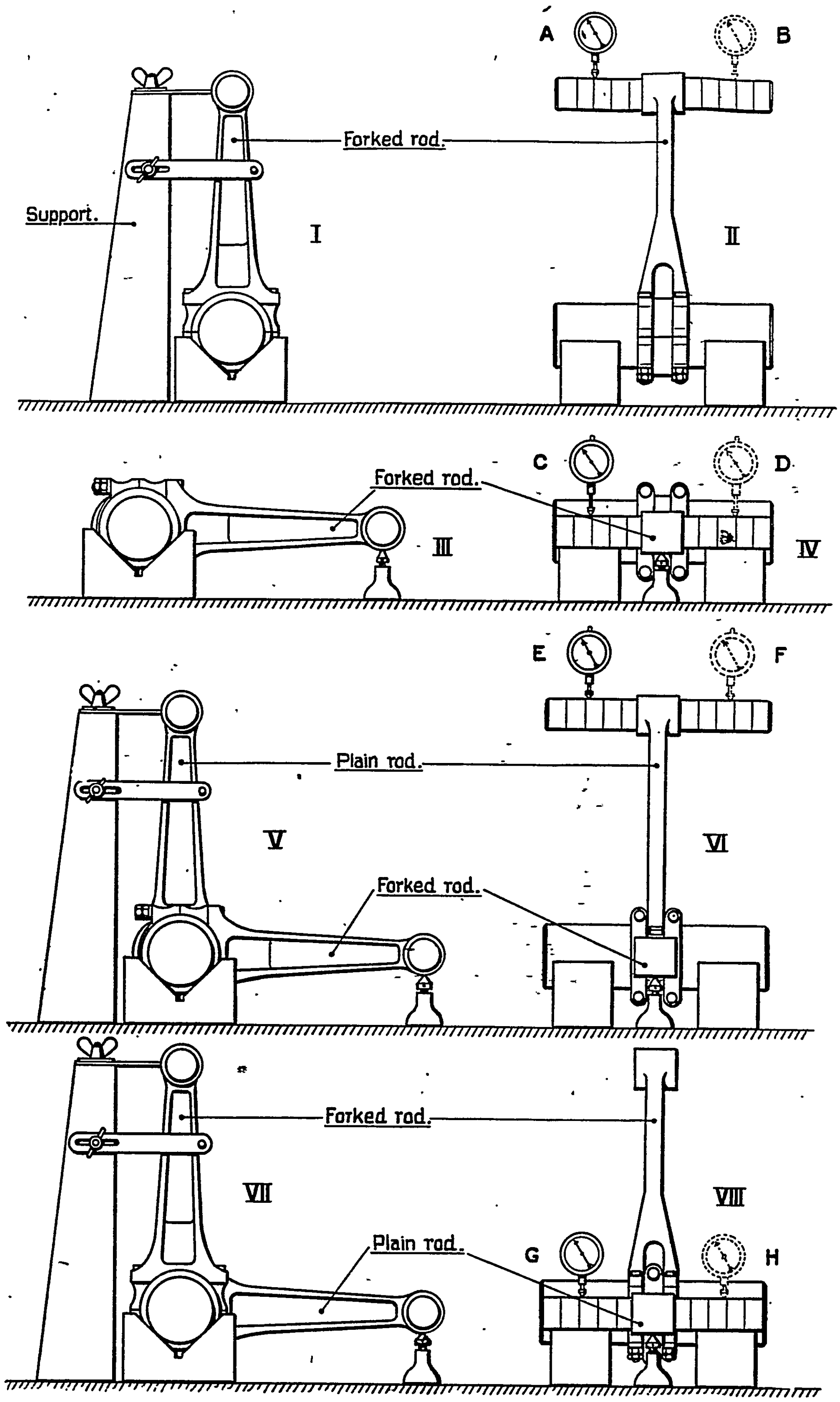


Fig. 9.—Alignment tests for forked and plain connecting rods

Forked and plain connecting rods

13. The forked and plain rods are mounted on a bearing block (see fig. 2). The bore of the bearing block is metalled to form the crank pin bearing and a central band of bearing metal is depositied around the exterior of the block to form a bearing surface for the plain rod. The necessary rigs are illustrated in fig. 9.

Tests for forked rod

14. The tests for the forked rod, see fig. 9, are as follows:—

(i) Fit the bearing block to the forked rod and tighten up the securing nuts to their normal tension, inserting packing as required.

(ii) Insert the appropriate mandrel in the bore of the big-end bearing.

(iii) Mount the assembly on V-blocks and test the mandrel for parallelism to the table.

(iv) Insert a mandrel in the gudgeon-pin bearing of the forked rod, rotate the rod so that it is pointing vertically upwards and allow the small end of the rod to rest against a support, as shown in sketch I.

(v) Proceed to take dial readings at each end of the smaller mandrel at positions A and B, as shown in sketch II, without disturbing the first setting of the dial. The positions where these readings are taken should be observed. The difference in the readings should be calculated per inch length of mandrel, thus denoting the error due to lack of parallelism. Make a note of these readings.

(vi) Rotate the rod until it lies in an approximately horizontal plane, i.e., parallel to the table. The toolmaker's jack may be placed under the overhung portion of the rod to act as a support, see sketch III.

(vii) Take dial readings at each end of the small mandrel at positions C and D, as shown in sketch IV and note the difference, i.e., the amount of error due to twist. Calculate the error per inch length of mandrel and note this on the record sheet. Compare the readings obtained with the permissible tolerance as detailed in the Volume II, Part 2, of the particular engine handbook and if the rod is not within these limits it should be rejected.

Tests for plain rod

15. The following tests should now be carried out on the plain rod without dismantling the forked rod assembly:—

(i) Mount the plain rod in its normal position on the bearing block and insert the mandrel in the gudgeon-pin bearing of the plain rod.

(ii) Support the rods, as shown in sketch V, and proceed to take dial readings as before on this rod at positions E and F in sketch VI.

(iii) Rotate the rod to the position shown in sketch VII and proceed to take dial readings on the small-end mandrel as at G and H in sketch VIII, which will denote the amount of twist in this rod in relation to the bearing block.

Master and two articulated connecting rods

16. The complete connecting-rod assembly of this type is shown in fig. 3 and comprises a master rod and two articulated or side rods hinged to the master rod by wrist-pins fixed in lugs integral with the big-end. A number of alignment errors will possibly be experienced when testing these rods and any error which exceeds the permissible tolerance as detailed in the Volume II, Part 2, of the particular engine handbook will necessitate the rejection of the rod. In addition to the two mandrels required for the big-end and small-end of the rods, a special mandrel should be ground at one of its ends to fit into the lugs of the master rod, i.e., wrist-pin housing. In this respect the shape of the wristpin ends can be taken as a guide. The other end of the mandrel should be ground parallel and marked in inches along its length.

Test for parallelism—Master rod

17. The master rod is tested for parallelism, see fig. 10, as follows:—

(i) Assemble the rod in the normal manner and insert an appropriate mandrel in the bore of the big-end bearing.

(ii) Mount the assembly on V-blocks and test the mandrel for parallelism to the table.

(iii) Insert a mandrel in the gudgeon-pin bearing of the rod and rotate the rod until it is pointing approximately vertical. Support the rod as shown in sketch I.

(iv) Proceed to take dial readings at each end of the small-end mandrel as at A and B in sketch II, without disturbing the first setting and note the positions at which these readings are taken. Calculate the difference between the measurements per inch length of mandrel; this denotes the lack of parallelism.

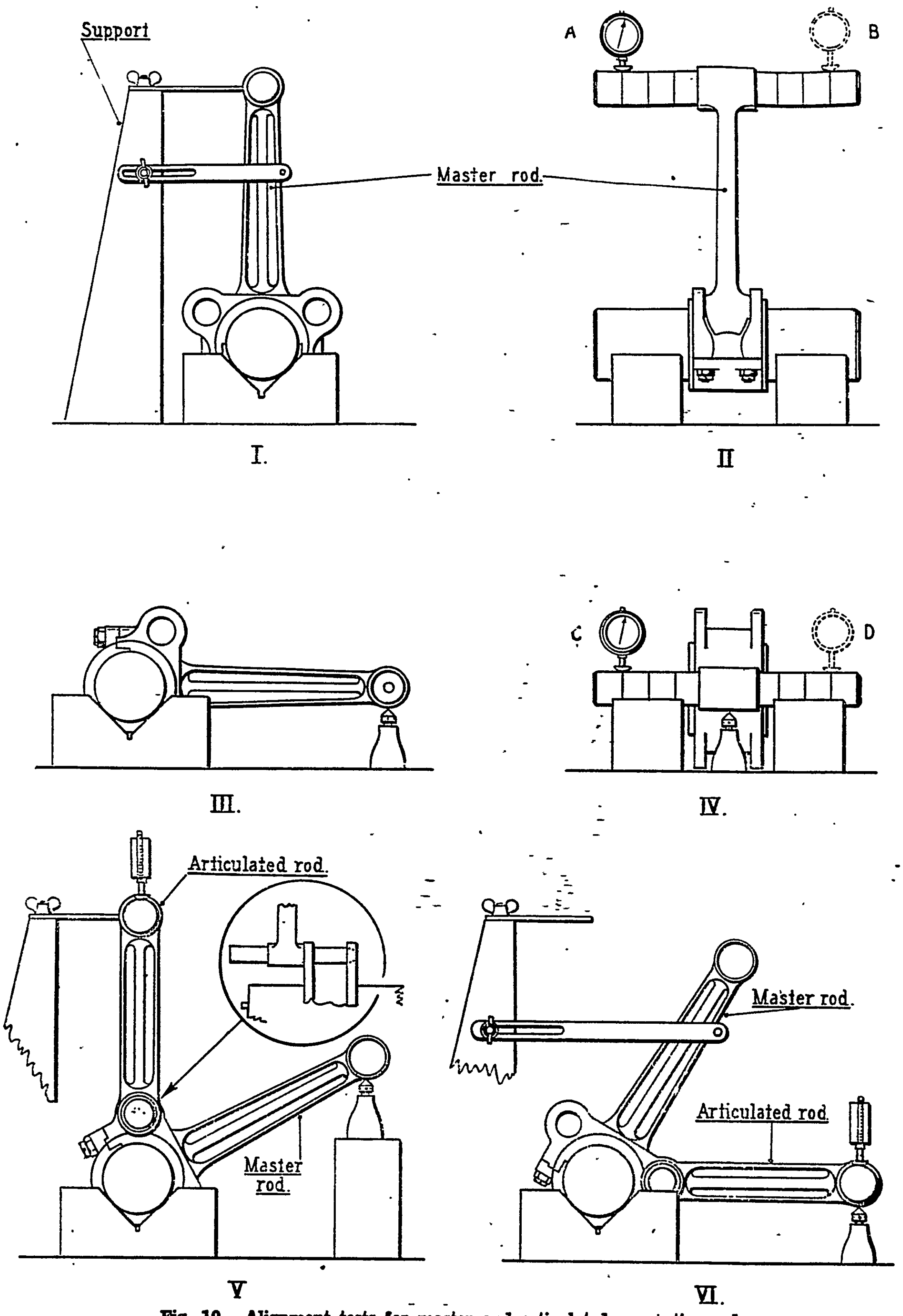


Fig. 10.—Alignment tests for master and articulated connecting-rods

Test for twist—Master rod

18. The master rod is tested for twist as follows:—

(i) Rotate the rod until it is in the position shown in sketch III; the small end may be supported by a toolmaker's jack.

(ii) Take dial readings at each end of the small-end mandrel, noting the positions at which these readings are taken and calculate the error per inch length of mandrel; this denotes error due to twist. These positions are marked C and D in sketch IV.

(iii) Remove the mandrel from the gudgeon-pin bearing.

Tests for parallelism and twist—Articulated rods

19. The two articulated rods are each tested for parallelism in a similar manner. The test is as follows:—

(i) Insert the special mandrel into the appropriate lugs in the master rod big-end bearing and mount an articulated rod on the protruding end of the mandrel—see inset of sketch V.

(ii) Insert the parallel mandrel used in the previous tests in the articulated rod gudgeon-pin bearing.

(iii) Rotate the assembly so that the articulated rod is pointing vertical and support the small-ends of the rods as shown in sketch V.

(iv) Take dial readings at each end of the mandrel in the gudgeon-pin bearing as before and note the readings per inch length of mandrel. This will denote the error due to lack of parallelism of this rod.

(v) Rotate the assembly until the articulated rod is parallel with the table as shown in sketch VI.

(vi) Take dial readings at each end of the small-end mandrel and note the error per inch of its length; this will denote the error due to twist. Repeat the foregoing operations for the other articulated rod.

Master and articulated connecting rods

20. By referring to figs. 4, 5 and 6, it will be observed that there are three other types of assemblies which involve a master and a number of articulated rods. In each assembly the articulated rods are mounted on a master ring in a similar manner, i.e., hinged by means of wrist pins fixed in the lugs of the master ring. The master rods differ from one another as follows:—

(i) Fig. 4 shows a master rod which is integral with the master ring, the latter being in one piece and the big-end bearing is in the form of a bush.

(ii) Fig. 5 shows a master rod which is integral with one portion of the master ring, the ring being split to take the two half shells of the big-end bearing.

(iii) Fig. 6 shows a master rod which is mounted on the master ring by means of two anchor-pins. The master ring in this type is split to take the two half shells of the big-end bearing.

21. The alignment tests for the assemblies mentioned above are separated into groups as follows:—

(i) Master rod integral with master ring.

(ii) Master rod separate from the master ring.

(iii) Articulated rods.

Master rod integral with the master ring

22. The alignment tests for this type of master rod—see fig. 11—are carried out as follows:—

Test for parallelism

(i) Insert an appropriate mandrel in the big-end bearing of the rod and mount the assembly on a pair of V-blocks.

(ii) Test the mandrel for parallelism to the table.

(iii) Insert a mandrel in the gudgeon-pin bearing and rotate the latter until it is pointing vertical and support the rod in this position, as shown in sketch I.

(iv) Proceed to take dial readings at each end of the small-end mandrel at positions A and B, shown in sketch II, and note the readings obtained. The positions where these readings are taken should also be observed. Calculate the error per inch length of mandrel; this denotes the lack of parallelism.

Test for twist

(v) Rotate the rod to the position shown in sketch III, i.e., horizontal to the table; the small end of the rod may be supported by a toolmaker's jack.

(vi) Proceed to take dial readings at each end of the small-end mandrel at positions C and D in sketch IV, and calculate the error per inch length of mandrel; this denotes the error due to twist.

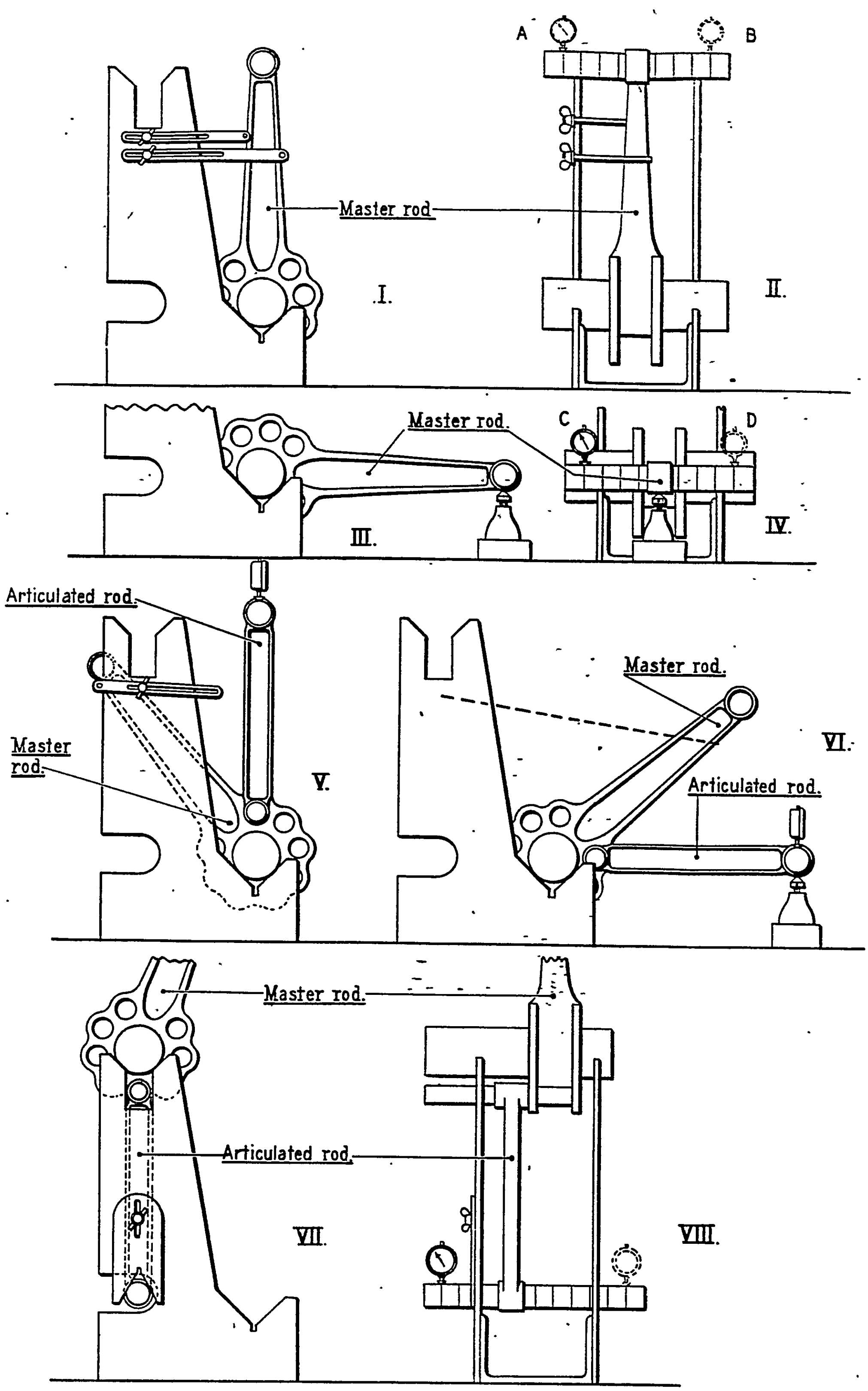


Fig. 11.—Alignment tests for master and articulated connecting-rods

Master rod separate from master ring

23. To enable this type of rod to be satisfactorily tested for alignment, three mandrels are required, two for the anchor-pin housings and one for the gudgeon-pin bearing. The tests are as follows:—

Test for parallelism

(i) Mount the rod on a pair of V-blocks, the mounting mandrel being inserted in the outer anchor-pin housing. Test the mandrel for parallelism to the table.

(ii) Insert a parallel mandrel in the gudgeon-pin bearing and rotate the rod so that it is vertical; support the rod in this position.

(iii) Take dial readings at each end of the upper mandrel as at positions A and B in sketch II, and calculate the error due to lack of parallelism per inch of length mandrel.

Test for twist

(iv) Rotate the rod until it is horizontal with the table and support the overhung portion of the rod in this position—see sketch III.

(v) Take dial readings at each end of the mandrel, as at positions C and D in sketch IV, and calculate the amount of error due to twist per inch length of mandrel.

(vi) Remove the mandrel from the outer anchor-pin housing and insert it in the inner anchor-pin housing and repeat the tests.

24. The foregoing tests will determine whether the rod is serviceable or not as regards parallelism and twist and should be carried out as a preliminary before assembling the rod in the master ring. When assembling the rod in the master ring, care must be taken to ensure that the anchor-pins are drawn right home in their sockets. After assembling, the master ring and the rod should be temporarily marked with paint to denote the position of assembly; in no circumstances should the components be scratched or centre-punched. The rod should now be retested for lack of parallelism and twist as follows:—

(i) Insert a mandrel in the bore of the master ring and mount the assembly on a pair of V-blocks; test the mandrel for parallelism to the table.

(ii) Insert a mandrel in the gudgeon-pin bearing and rotate the rod so that it is pointing vertical. Support the rod as shown in sketch I.

(iii) Take dial readings at each end of the small-end mandrel as at positions A and B in sketch II, and calculate the error per inch length of mandrel; this denotes lack of parallelism.

(iv) Rotate the rod until it is horizontal with the table. Support the overhung position of the rod—see sketch III.

(v) Take dial readings at each end of the small-end mandrel at positions C and D in sketch IV and calculate the error per inch length of mandrel; this denotes the amount of twist.

25. The latter tests will determine the acceptability of the rod in relation to the master ring. If the results are satisfactory and the bare rod was found serviceable after the tests detailed in para. 23, the master ring will be at fault and the following tests cannot be carried out satisfactorily. If the master rod is correct, the alignment tests for each of the articulated rods should follow.

Articulated connecting rods

26. The alignment tests for the articulated rods are similar for each of the connecting rod assemblies shown in figs. 4, 5 and 6. Owing to the wrist-pins being positioned around the master ring, some difficulty may be experienced in supporting the master rod during the tests. The double V-block shown in fig. 11 is suggested to overcome these difficulties and the item should be made up locally by using a piece of channel sectioned steel of suitable width and welding two side members to the flanges of the joist. The accuracy of the "Vees" is important and therefore it is desirable to shape these first, then rivet them in the correct position with countersunk rivets and finally weld the edges; any surplus metal should be removed.

Test for parallelism

(i) Mount the master rod on a pair of V-blocks and test the mandrel for parallelism to the table.

(ii) Insert a mandrel in the wrist-pin housing next to the master rod and mount an articulated rod on the overhung portion of the mandrel.

(iii) Insert a mandrel in the gudgeon-pin bearing and rotate the articulated rod so that it is pointing vertical, support the rods as shown in sketch V.

(iv) Proceed to take dial readings at each end of the upper mandrel as at positions A and B in sketch I, and calculate the amount of error, due to lack of parallelism, per inch length of mandrel. Reverse the articulated rod on the lower mandrel and repeat the previous operation. Whichever position shows the smallest error should be noted and the rods temporarily marked accordingly with paint.

Test for twist

(v) Fit the wrist-pin end of the articulated rod on the appropriate mandrel in the better position as determined from the previous tests and rotate the rod so that it is horizontal to the table, supporting the rods as necessary—see sketch VI.

(vi) Proceed to take dial readings at each end of the mandrel in the gudgeon-pin end of the rod, as at C and D in sketch IV, and note the amount of error per inch length of mandrel, this error denotes twist.

27. The other articulated rods are tested in a similar manner, but it is advisable to remove the articulated rod which has been tested from the master ring before commencing to test another articulated rod. Sketches VII and VIII show the assembly set up for test on the upper V-blocks.

Testing crankshafts

28. Crankshafts can be tested for parallelism and twist in a similar manner to that described for connecting rods, i.e., by mounting the shaft upon a pair of V-blocks and then taking readings on each journal and pin when their vertical and horizontal axes are respectively parallel to the marking-out table. It must be remembered that due allowance must be made for any existing taper or ovality of the journals and pins.

Single-throw crankshafts

29. Single-throw crankshafts are either made in one piece or built up, illustrations of which are shown in figs. 12 and 13. Particular care must be taken in assembling the built-up type before the alignment tests are carried out, in this respect, reference to the engine handbook is essential. The following tests are necessary to determine the serviceability of the component:—

(i) Alignment throughout its length.

(ii) Tests for parallelism and twist of the pins in relation to the axis of the shaft.

30. Throughout the tests, suitable supports should be provided under the crankwebs in order that the shaft may be steadied while dial readings are being taken. Narrow V-blocks are desirable for mounting the crankshafts and care should be taken that the shaft does not "ride" on its radii, otherwise the readings will be inaccurate.

Alignment test

31. This test is carried out as detailed below:—

(i) Mount the shaft on V-blocks placed under the two main journals or under the main journal inner races, if these have not been removed, so that the axis of the shaft is parallel to the marking-out table, as confirmed by a dial indicator and the shaft is able to swing clear of the table—see figs. 16 and 17. If the inner races of the ball bearings have not been removed the V-blocks should be placed under these parts.

(ii) Rotate the shaft slowly through one revolution and test for truth by taking readings at the extremities of the shaft. If the readings show that the shaft is out of alignment, the root of the bend can generally be found by taking further readings at other points on the overhung portion of the shaft.

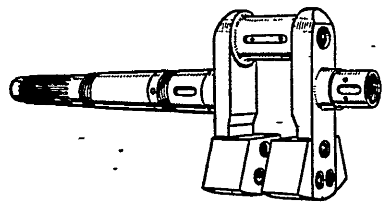


FIG.12. ONE-PIECE SINGLE-THROW CRANKSHAFT.

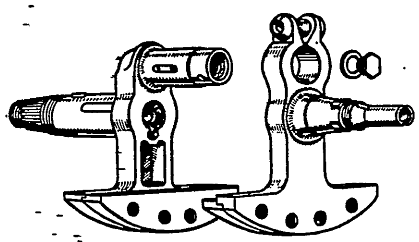


FIG.13. BUILT-UP SINGLE-THROW CRANKSHAFT.

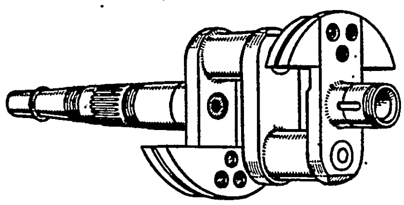


FIG.14. TWO-THROW CRANKSHAFT.

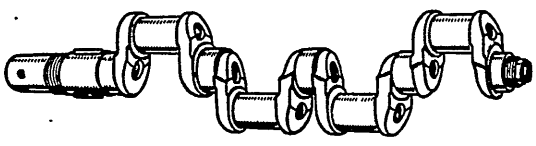


FIG.15. MULTIPLE-THROW CRANKSHAFT.

Fig. 12 to 15.—Types of aero-engine crankshafts

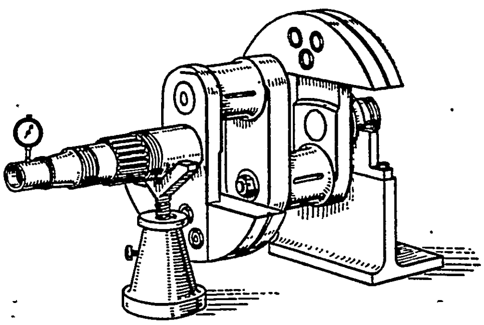


FIG. 16. ONE-PIECE TWO-THROW CRANKSHAFT.

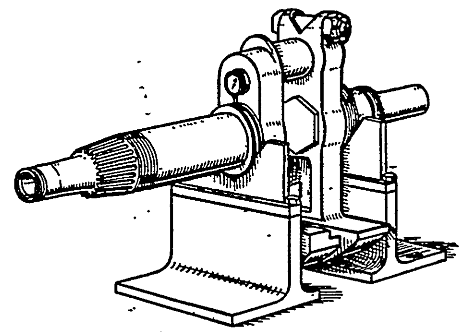


FIG. 17. BUILT-UP SINGLE-THROW CRANKSHAFT.

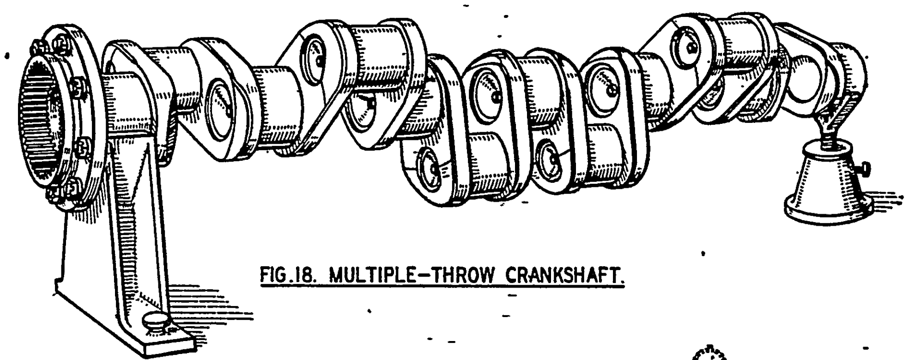


FIG. 18. MULTIPLE-THROW CRANKSHAFT.

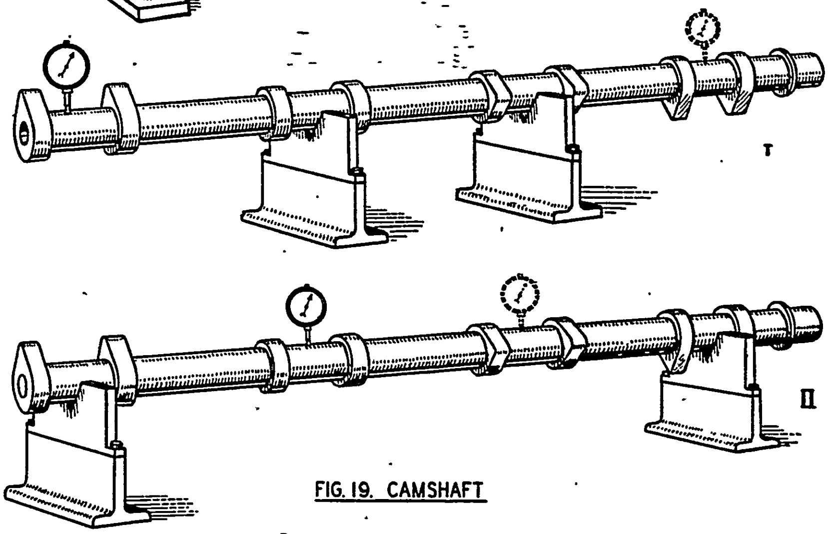


FIG. 19. CAMSHAFT

Fig. 16 to 19.—Alignment tests

Test for parallelism of crankpin

32. This test should immediately follow the test previously described, i.e., whilst the shaft is mounted on the V-blocks, this avoids having to reset the shaft in relation to the table. The test is as follows:—

(i) Rotate the shaft so that the crankpin is on its B.D.C., as confirmed by a dial test indicator,

(ii) Proceed to take dial readings at each end of the crankpin. The contact point of the. indicator should be kept clear of the radii of the pin and the axial distance between the points where the readings are taken should be approximately three inches.

(iii) Rotate the shaft through 90 degrees and repeat operation (ii). If an oil groove is machined along the pin, as shown in the illustrations, the readings should be taken clear of this area.

Multiple-throw crankshafts

33. Two types of multiple-throw crankshafts are shown in figs. 14 and 15, one having two throws and the other having four throws. Two alignment tests are necessary for each type of shaft—(i) journals and (ii) crankpins.

Crankshaft journals

34. The crankshaft journals should be tested for lack of alignment and for twist as follows:—

(i) Mount the two end journals of the shaft on V-blocks placed on a marking-out table—see fig. 18. The blocks must be sufficiently high to enable the shaft to rotate on its axis, this involves the use of packing or parallel blocks when small V-blocks are used.

(ii) Adjust the V-blocks so that the axes of the end journals are parallel with the marking out table, as confirmed by dial indicator, the dial readings should show constant for all positions of the shaft if the journals are not oval. All dial readings should be taken at a point on the periphery well clear of the radii at the end of the journals.

(iii) Take dial readings at each end of the centre journal when the adjacent crankpins are at T.D.C., B.D.C. and at approximately 90 degrees from these positions. The readings obtained will vary under certain conditions, e.g., deflection or bow and ovality of pins. The direction of ovality found should be checked against the dial reading before distortion can be said to exist and its amount measured.

(iv) Test the other journals in a similar manner to that previously described. By making a comparison between the various readings, the exact position and extent of bowing (if present) can be determined. A tabulated chart will be found useful when carrying out the above test and this information will also be of value should the shaft require regrinding.

Crankpins

35. The crankpins should be tested for parallelism and twist immediately after the journals have been tested, i.e., before the shaft is moved from the V-blocks. The dial readings should be taken at positions three inches apart on each crankpin when the latter is at its respective B.D.C., and at 90 degrees from this position. To permit each pin to lie in a similar position it is desirable to place a small toolmaker's jack under the balance weights while dial readings are being taken; this also assists to steady the shaft.

Testing camshafts

36. Each camshaft should be tested for alignment to ascertain the presence of any errors due to bending, allowance being made for any existing taper or ovality of the journals. The test is carried out as follows:—

(i) Mount the camshaft upon a pair of V-blocks placed under the end journals and test these journals to ensure their axes are parallel to the table—see fig. 19.

(ii) Rotate the shaft and take dial readings at each end of the centre journal. The direction of any high points of the journals should be marked with indelible pencil.

(iii) Mount the camshaft upon the same V-blocks placed under the centre journals and take readings on the centre journals, marking the high points as before. The foregoing tests will not denote the amount of twist which may be present.

P5032 M /1322 9/44 5250 C & P Gp. 1

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 7 to A.P.1464C, Vol. I and concerns Part 2, Sect. 2.
Insert this chapter.

RESTRICTED
(For official use only)

CHAPTER 6

AERO-ENGINES—CARBURETTOR SERVICING

LIST OF CONTENTS

Introduction

1. Servicing operations on carburettors, in accordance with current authorised procedure, should where possible be confined to a self-contained bay in which the necessary special tools and test equipment are readily available. Precautions must be taken against fire, observing the relevant instructions given in Air Publication 957—Fire Manual.

2. Aero-engine carburettors vary considerably in design and for this reason it is essential that only those operations detailed in the particular handbook and in relevant Vol. II leaflets, are effected by Units. Servicing operations are generally confined to partial dismantling, cleaning, viewing, authorised replacements, minor adjustments and tests, assembling and final testing.

3. Before commencing work on a carburettor, reference should be made to the handbook concerning the constructional details and the precautions to be observed during the various operations. It should be realised that the removal or alteration of certain components entails the use of special test-rigs before the carburettor can be used again; therefore such operations as dismantling the mixture or boost control capsules or alterations to the linkage, etc., should not be commenced unless the necessary test-rigs and skilled personnel are available.

Removing carburettor from engine

4. Before a carburettor can be removed from an engine, a number of control rods and pipe-lines have to be disconnected. Great care should be taken during these operations to prevent any alteration in the adjustment of the controls and, when uncoupling the pipe-lines, the unions should be prevented from turning while the union nut is slackened. The clips on hose connections should be slackened sufficiently to allow the hose to be withdrawn easily over the lipped end of the union. The air intake and the filter should also be removed after disconnecting any stay rods that may be fitted.

Dismantling

5. Where dismantling operations are authorised, partitioned trays should be made up locally for the reception of all components of one carburettor, thus preventing loss or the intermixing of parts of a similar nature; for large intricate modern types of carburettors the trays can be arranged in tiers. A carburettor must not be gripped in a vice under any circumstances and great care should be taken to avoid damaging the protective coatings on the various components. A suitable rig on which a carburettor can be mounted when dismantling and assembling can also be made up locally by units, to suit the particular type of carburettor. The rig should be made from ¼ in. steel plate drilled to fit the carburettor flange bolts or studs, and fitted with a swivelling bracket in the centre by means of which the plate can be mounted on an angle iron upright bolted to a base-plate. The base-plate can be bolted to a bench or held in a vice.

6. Dismantling operations will vary according to the type of carburettor. As already stated, particular attention should be given to instructions in the relevant handbook regarding those components which may be dismantled and those which must not be removed or adjusted. Some screws may be peened or riveted over at the end of the threads by the manufacturers and care must be taken to remove all the deformed thread before removing the screw. Special tools provided for carburettor dismantling should always be used; mating or meshing parts not marked should be labelled suitably or marked, by means of an electric etching pencil or by an indelible pencil, in order to avoid confusion when re-assembling. All used tabwashers, gaskets and joint rings should be

rejected and replaced by new ones of the approved material and thickness at each complete overhaul. Any jets or screws that are tight in their threads should be eased backward and forward and penetrating oil should be applied; on no account should these parts be forcibly removed.

7. Mixture and boost control capsules should be handled carefully to avoid distorting the metal bellows; any linkage on these controls should not be disturbed. Wedges or the tip of a screwdriver must not be used for separating carburettor components or the joint faces will be distorted.

8. Care should be taken to prevent damage to the floats, pump mechanism and chokes. Cork floats should be handled carefully, otherwise the fuel-proof coating will be damaged (see para. 12).

Cleaning

9. Dismantled parts should be cleaned in clean petrol, using a small bristle brush and a syringe. Compressed air or the syringe can be used for blowing through jets and fuel ducts, etc., except where diaphragms are fitted as these would be damaged even by low pressures. Rags of a fluffy nature must not be used and it is preferable to allow parts to drain off rather than risk small pieces of rag adhering to the surfaces. All joint faces should be cleaned free from jointing material taking care not to damage the faces by removing any of the metal.

Viewing

10. After the carburettor has been dismantled and cleaned, the various parts should be viewed as follows:—

(i) Examine the body castings for corrosion, cracks, signs of warping, loose studs and general soundness.

(ii) Examine all internal screw threads and the threads on studs, screws and bolts. Examine all oil ways for leakages, or for foreign matter where the throttle is oil-heated, also check the relief valve.

(iii) Examine joint faces for high spots or foreign matter. Any irregularities should be removed by careful hand-scraping.

(iv) Examine the throttle spindle and bushes for signs of wear and excessive end clearance.

(v) Examine the throttles for tightness on the spindle and check twin throttles for alignment. The throttles should not be removed unless they are distorted or worn. In the event of their removal it should be noted that the screws securing them to the spindle are peened over. New screws should always be fitted when re-assembling the throttles.

(vi) Examine jet valves, and test for fuel-tightness by first removing the respective jets and then filling the float chambers with fuel. Test the accelerator piston and mixture control pistons for freedom of action.

(vii) Test the mixture control valves for fit by the application of a marking medium.

(viii) Examine the needle valve and seat and, if worn, both should be replaced by new ones. A new needle should not be fitted to an old seat and *vice versa*, nor should a needle be ground-in.

(ix) Examine the float fulcrum-screws and bearings for wear also the float arm for wear and signs of distortion. In instances where the clearance between the float and the roof of the float chamber is given, and cannot be measured directly, this should be checked by assembling the parts concerned temporarily, with a piece of plasticine or similar material interposed between the two components.

(x) Examine all levers and their shafts, whether pinned or clamped, and ensure that there is no lost motion.

Repairs

11. Beyond the replacement of certain parts and attention to the fitting and adjustment of others as detailed in the relevant handbook, little else can be done by Units in the nature of structural repairs.

Floats

12. Modern types of carburettors are equipped with cork floats built up of laminations of close grained cork, riveted to a metal fulcrum lever and impregnated with a fuel-proof dope to prevent the ingress of fuel into the grain of the cork which would cause the floats to become fuel-logged, with the result that they would become unstable in service. Cork floats which are damaged or showing signs of structural breakdown should be rejected as unserviceable. Dark patches appearing in the neighbourhood of a crack indicate the percolation of fuel.

13. Slight shrinkage of the cork laminae may occur in use or during storage, resulting in surface wrinkles in the dope coating. These wrinkles can be ignored unless they penetrate through the coatings of dope to the cork.

14. A fuel-logged float will cause flooding of the carburettor, therefore before any attempt is made to adjust the fuel level, it should be ensured that the float is in a serviceable condition. Should the float structure be defective in any way it should be returned to Stores as unserviceable and replaced by a new one.

Re-doping cork floats

15. Where facilities do not exist for the return of damaged floats to the manufacturer, floats which have been in service for some time or those with damaged coatings may be re-doped in the damaged area or all over. The dope should be either L7339, Stores Ref. No. 33B/605, or D454, Stores Ref. No. 33B/607, and should be used with solvent spirit No. 681, Stores Ref. No. 33B/606, or thinners T.10, Stores Ref. No. 33B/608. Three ½-in. soft fibre brushes will also be required, one for removing dust, the second for removing grease and the third for actual doping operation. Each brush must be used exclusively for its particular duty and should be marked accordingly.

16. The work room where the doping is to take place should be free from draughts or dampness, and the temperature should be maintained within the range of 13° C. to 19° C. Both the floats and the dope should be allowed to attain the work room temperature for at least an hour before doping.

17. The old dope should be stripped by brushing with solvent spirit D454 or Thinners T.10, until it is all removed after which the float should be suspended on a wire passed through the fulcrum-pin hole and allowed to dry. When dry any veins or small holes in the cork should be filled with dope and allowed to dry until the whole surface is even, after which the float should be given fifteen separate coatings, the float straps or fittings having been removed. Each coat should be applied evenly and quickly and allowed to dry before the succeeding coat is applied. The straps or fittings must be re-attached, care being taken not to damage the dope covering during the riveting process. Any small cavities between the float straps and the floats must be filled-in by applying coats of dope as necessary. Any dope on the straps themselves being subsequently removed.

18. A float that is chipped or cracked need not be completely stripped but should be rubbed down to the cork in the damaged area by means of fine sandpaper, after which the affected parts should be cleaned. The area should then be re-doped as described above until it is level with the surrounding coating.

19. Should white patches be observed forming on the float as the dope dries, this indicates that the doping conditions have not been followed correctly and will necessitate re-doping after stripping the faulty coating.

Assembling

20. The sequence of assembling operations will be found in the relevant handbook, wherein the details of tests to be made as the operations proceed are given. Absolute cleanliness is essential and all jets and ducts should be finally cleaned by an air blast except, as already mentioned, where diaphragms are fitted. It is of the utmost importance when parts are being assembled that all particles of metal and other foreign matter adhering to parts are removed. When drain plugs, unions, screws or jets are screwed into position it should be ensured that no foreign matter, removed by the cleaning action of the threads, is allowed to remain in the carburettor. Any leather pistons should be smeared lightly with pure castor oil before they are inserted in position; no other kind of oil should be used for this purpose and care should be taken not to fold back the edges of the cup washers. In carburettors where jet orifices are needle controlled, the amount by which the needle protrudes through the jet when correctly adjusted should be ascertained and checked.

21. All locking devices, joints and washers should be renewed by similar items of the same thickness and material as those originally employed. Jointing compound should not be used except when authorised, and where its use is approved it should be applied sparingly otherwise it may foul the internal mechanism. Care should be taken when tightening the nuts of flange studs and bolts, to avoid distorting the flanges; the nuts should be screwed down finger-tight, then gradually and evenly tightened by a spanner. All parts should be locked as assembling proceeds unless it is anticipated that adjustment may be required during subsequent tests.

22. The jets should not be altered in any way by reaming, peening, etc., and whenever such alteration is suspected and at complete overhauls, the jets should be checked for calibration as detailed in A.P.1464B, Vol. I, Part 2, Sect. 3, Chap. 11. When the jets are to be fitted in the carburettor a light application of engine oil (D.T.D.109) should be made to the threads. The fuel level should be checked after assembling the components of the lower half of the carburettor. For this purpose

a test tank and a pipe-line will be required. The tank should be arranged so that the head of fuel, measured from the level of the needle-valve seat, can be varied between 2·5 ft. and 12 ft. The tank and the pipe-line should be of adequate sizes to enable a flow test to be made satisfactorily when all the carburettor jets and plugs are removed. The fuel level in the carburettor should be adjusted to that specified for the particular type, and the needle valve should remain fuel-tight up to a maximum head of 12 ft. The fuel level is usually measured from the joint face of the float chamber at a fuel pressure of 2 lb./sq. in. or, at a 6-ft. head. The free flow of fuel is rated in gallons per hour at a given static head of fuel. Tabwashers are usually provided in various thicknesses for the purpose of effecting the fuel level adjustment and for locking the needle-valve seat in position after tightening down.

23. When the level has been adjusted correctly, the halves of the carburettor should be fitted together taking care that the flange faces are kept parallel. Plain washers should be fitted on the studs before the spring washers. It should be ensured that the joint faces meet squarely when the nuts are tightened. After the carburettor has been assembled and before it is filled with fuel, the throttle should be checked for throttle load, range of opening and ease of movement and, if any tightness occurs, the fault must be found and remedied; the throttle loads over the range of movement are generally specified for each type of carburettor. The jet plugs should then be removed from the base and filtered fuel run through the carburettor to remove any dust or foreign matter which may have collected in the interior, after which the plugs should be replaced in position and all open orifices blanked off by the standard equipment until the carburettor is to be installed on the engine. All working parts of the carburettor including the throttle linkage system, tappets and cams, etc., should be lubricated and, if the carburettor is to be stored, suitable precautions should be taken against corrosion by the use of an approved inhibitor.

Calibration of jets

24. The calibration of a jet is the means whereby the flow characteristics of the jet are determined by comparison with a master jet of which the flow rate is accurately known. By this means the performance of carburettors used on engines in service will conform to that of the type carburettor so far as the jets are concerned, irrespective of whether the jets are of the fixed or adjustable type. Jet calibrating machines have been introduced which supersede the lengthy and erratic methods of timing the flow-rate in c.c. per min. and obtaining the correct size by trial and error. The different types of machine are described and the methods of using them are given A.P.1464B, Vol. I, Part 2, Sect. 3, Chap. 11.

P5033 M /1324 9/44 5250 C & P Gp. 1

SECTION 3

LUBRICATING SYSTEMS

LIST OF CHAPTERS

Note.—*A list of contents appears at the beginning of each chapter*

CHAPTER 1

LUBRICATING SYSTEMS—GENERAL

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The general arrangement of aero-engine oil systems varies on different types of aircraft and aero-engines; the principle of the systems and several components are, however, common to all and although there are variations in the sizes of such components, servicing operations will be similar. The information contained in this chapter is of a general character and should be read in conjunction with the relevant aircraft and engine handbooks where any specific details will be found concerning the layout of the particular oil system components, working pressures, oil temperature ranges, etc.

2. The dry-sump system of lubrication is used in all aero-engines. From the main oil tank, oil passes through a filter and is forced into the engine bearings by means of a pressure pump. After passing through the bearings it runs down the inside of the crankcase and collects in reservoirs or sumps from which the oil is returned to the oil tank via an oil cooler or its associated by-pass by means of scavenge pumps. The scavenge pumps have a greater capacity than the pressure pump thus maintaining the sump in a relatively dry condition and preventing oiling-up of the engine. Spring-loaded check valves are fitted in the circuit in some instances where the oil tank has a positive head, in order to prevent flooding and so eliminating the use of a stopcock in the oil feed except when cleaning the tank. It should be remembered that when such a stopcock is fitted it should be wired in the open position except when it is actually in use during servicing operations.

3. When auxiliary pipe-lines are led to oil-operated components such as the two-speed supercharger or certain types of variable-pitch airscrew, the feed is taken from the pressure pump, but for heating purposes, e.g. the carburettor throttle, the oil feed is taken from the delivery side of the scavenge pumps. The pressure of the oil is regulated at the upper limit by means of one or more relief valves, one being fitted at the delivery side of the pressure pump, others where required to effect a reduction in pressure for auxiliary pipe-lines. Oil cleaners and filters are included at various points in the system, usually in the tank sump, in the pressure pumps supply, and at the suction side of each of the scavenge pumps. Information on refilling oil systems is given in the relevant aeroplane handbook, Vol. I.

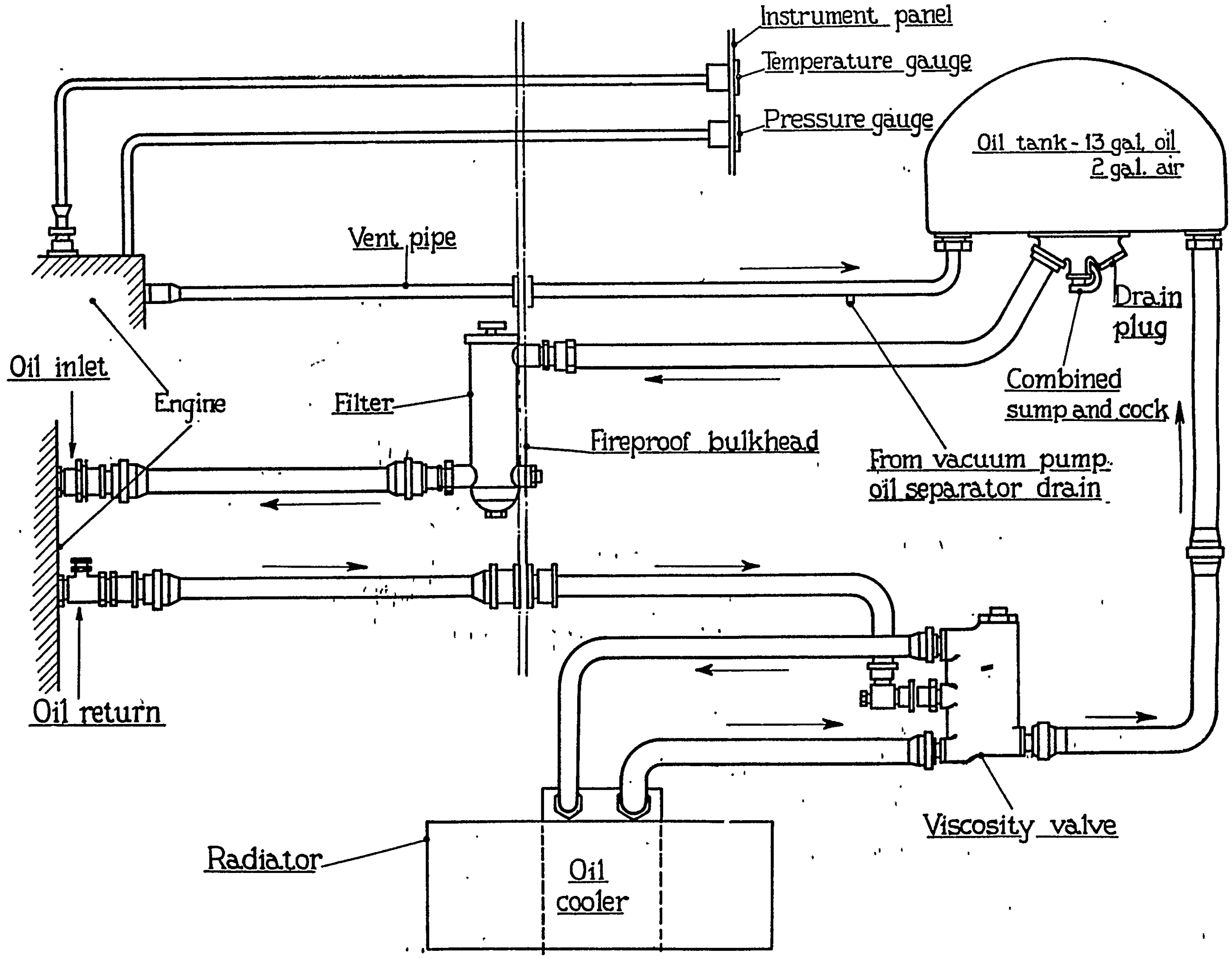


Fig. 1.—Diagram of typical oil system

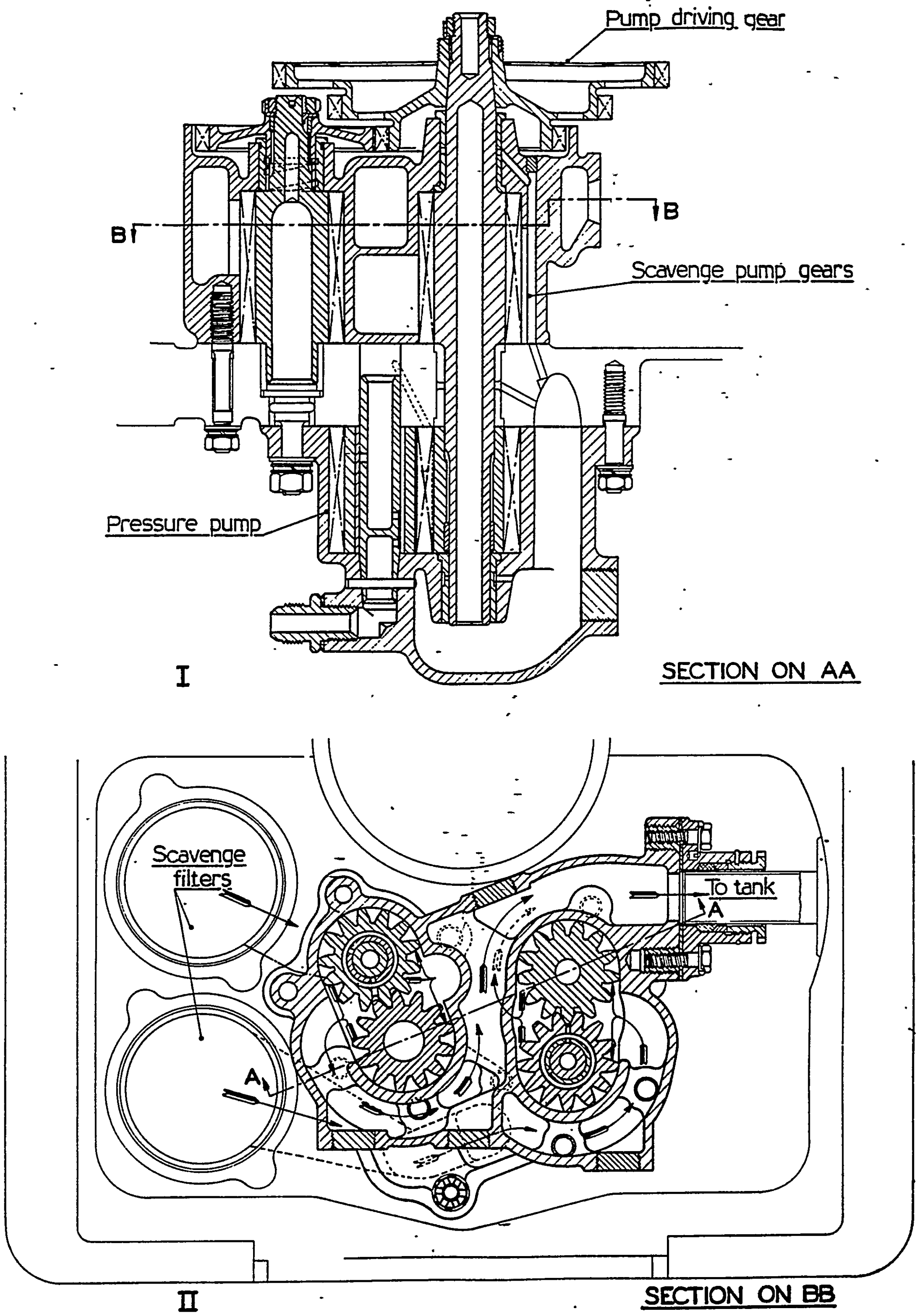


Fig. 2.—Aero-engine oil pump

Typical layout of oil system

4. A typical oil system is shown in fig. 1 from which will be seen the direction of oil flow and the position of the components in the circuit. In this system oil from the tank is forced under pressure to the engine bearings, etc., from whence it drains into the engine sump. The oil is then picked up by the scavenge pumps and passed through an oil cooler or a by-pass back to the oil tank, so completing the cycle. The by-pass valve is incorporated in the oil cooler inlet so that cold oil can pass directly to the tank without circulating through the cooler, thus enabling the oil to warm up more quickly. A thermometer is fitted with its bulb in the oil stream of the inlet to the engine, provision being made for the fitting of an additional thermometer in the pipe-line at the scavenge pump outlet for use only when required for test purposes.

Oil system components

5. Oil tanks are constructed from sheet metal and are suitably baffled in the interior to prevent surging of the oil during flight. An air space is provided, approximately equal in volume to the oil capacity of the engine, and petcocks are fitted at the nett capacity level when the filler cap is above this level in order to avoid over-filling; a graduated dipstick is provided for each oil tank. In some oil tanks a separate compartment is formed, in which only a small amount of the main body of oil is in circulation until the oil warms up, thus permitting a quick take-off from cold. A detachable drain sump is fitted near the outlet pipe connection and a filter and drain cock are provided in order that the tank can be rapidly and completely drained when in the fuelling position; in some instances the filter is removed from below, whilst in others, a rod is provided by means of which the filter can be withdrawn from above. As previously stated if a stopcock is fitted in the outlet, it must be wired in the open position except during maintenance operations.

6. A.G.S. screw-type filler-caps are usually fitted except in instances where the tank has a long filler neck, when the quick-release type filler-cap is used to prevent undue strain on the relatively weak neck. Vents with detachable covers are provided for inspection and cleaning of the tank interior.

7. Oil tanks may be provided with some form of external protection, primarily against leakage caused by bullets or shell splinters. The protection is usually in the form of laminations of rubber enclosed in a strong canvas jacket surrounding the tank. In the event of a leak the oil percolates into the rubber which begins to swell in the vicinity of the leak and, because of the constricting action of the canvas jacket, a pressure builds up between the jacket and the tank shell so forcing the rubber into the hole and effectively stopping further leakage at that point. The protective covering is similar to that employed for fuel tanks and information on the various types of covering is given in A.P.1464D, Vol. I, Part 2, Sect. 5.

Oil pumps

8. The oil pumps generally consist of a combined pressure pump and two scavenge pumps having a common drive. The two scavenge pumps maintain ample suction to keep the engine sump relatively dry whilst the pressure pump forces oil from the oil tank to the bearings. The pumps are of the gear type, the tips of the teeth being chamfered in some instances for the purpose of relieving the pressure of the oil trapped between the gears, as shown in fig. 3. In the illustration of a typical oil pump for an in-line engine (see fig. 2) the scavenge pump gears are above those for the pressure pump and the scavenge pump filters are incorporated in the pump body casting.

High initial oil pressure valve

9. In some types of radial aero-engines a high initial oil pressure by-pass (see fig. 3) is provided on the oil pump. The function of this valve is to increase the oil pressure to the bearings automatically when first starting up and to supply oil to an auxiliary oil-feed jet in the top of the crankcase from where oil is directed on to the connecting rod bearings and cylinder walls. The oil pressure may rise to as much as 200 lb./sq. in , but it should rise steadily at first up to 150 lb./sq. in. at oil temperatures below + 15°C. When the engine oil reaches a temperature of 30°C to 35°C the valve goes out of action and the pressure regulation is taken over by the relief valve.

Oil coolers

10. Various types of oil coolers are employed on different types of installations on aircraft, and descriptions and information on the repair and servicing of oil coolers will be found in subsequent chapters in this section. Some coolers are mounted in a separate cowl and others are mounted together with the radiator. Provision is generally made for the attachment of some form of relief valve in order to prevent the cooler from sustaining damage caused by the building up of excessive pressure in the cooler.

Oil filters

11. Oil filters are usually of the cylindrical type having a gauze element, approximately 40 mesh, suitably reinforced to prevent collapse under pressure or suction. Some filters are designed to fit in the tank outlet and others as separate units are inserted in the pipe-line and mounted on the fireproof bulkhead or some similar position. Gauze type filters are also employed at the suction side of the scavenge pumps. In all types, the filter element can be withdrawn readily for cleaning purposes without draining the system and without leaving sludge behind in the oil-ways. On certain types of radial engines a separate sump is positioned between the two lower cylinders, and oil drains into it from the crankcase and reduction gear; such sumps are usually divided into compartments to form a filter chamber in which a detachable filter element is housed.

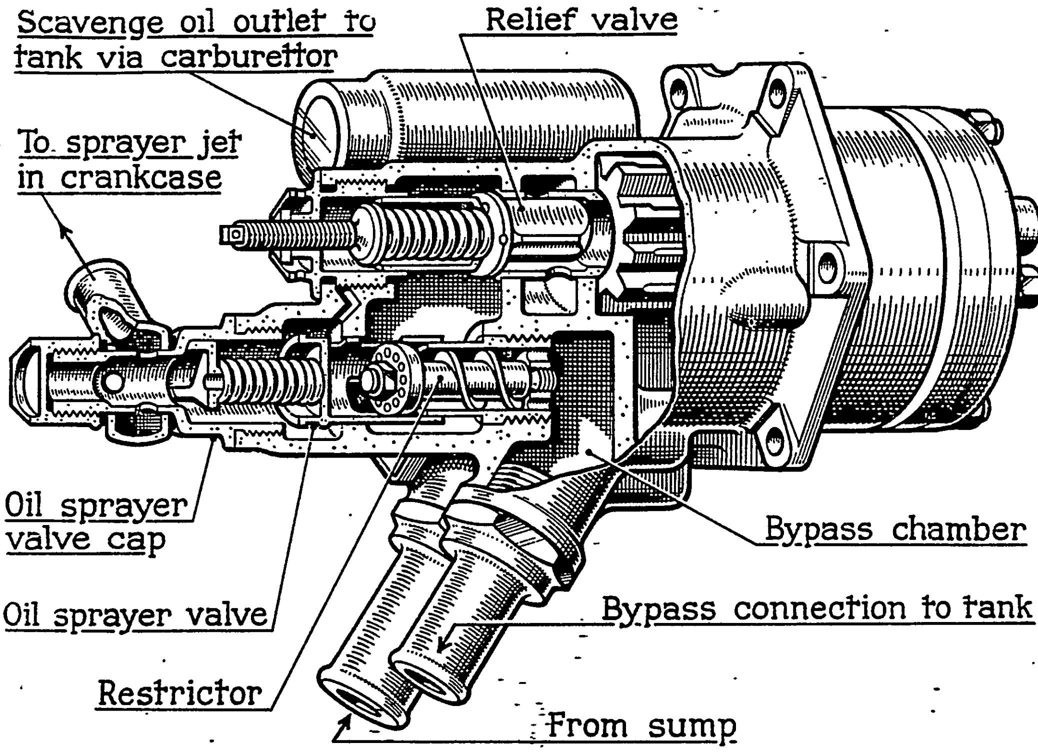


Fig. 3.—Oil pump and high initial oil pressure valve

Relief Valves

12. Relief valves are fitted in oil systems for the purpose of preventing excessive pressures from building up in the oil ways and for compensating for variations which would otherwise occur caused by changes in engine speed or in the viscosity of the oil. Additional relief valves may also be fitted to an engine for the purpose of effecting a reduction in the oil pressure when branch oil feeds are taken to certain auxiliaries such as the reduction gear, fuel-pump gland, electric generator and the supercharger drive gears. A relief valve may also be fitted in a pipe-line carrying the hot oil returning from the engine to the cooler for the purpose of heating the carburettor throttle valves. When a number of relief valves are employed these are generally arranged in a group at the outlet side of the pump.

13. There are two types of relief valve in general use, one being fitted with a spring-loaded disc on a flat seat and the other having a spring-loaded plunger on a 45° seat. Means of adjustment is generally provided by a screwed sleeve which bears on the top of the coil spring, and which is secured by means of a locknut, wired and sealed. Some types of relief valves (see fig. 4) have a small by-pass hole which permits sufficient quantity of oil to pass and prevent starving of the pipe-line and the bearings.

Oil pipe-lines

14. The pipe-lines in oil systems consist of metal piping and flexible tubing joined together in some instances by means of metal couplings, in others by rubber hose and clips (see fig. 5); the

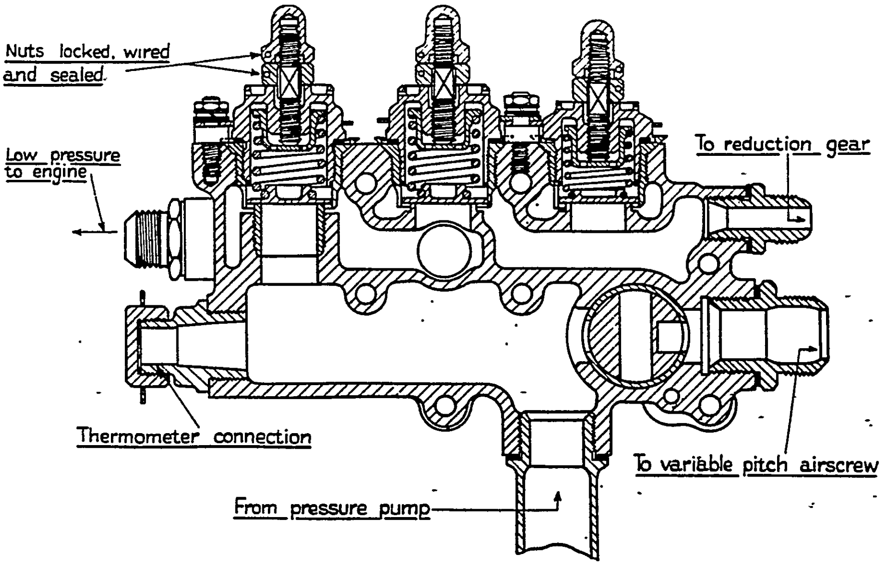


Fig. 4.—Typical arrangement of relief valves

flexible tubing is generally employed for the final connection to the engine. The pipe-line is supported on the structure of the aircraft along the whole length by clips and all joints in the line are bonded and locked by means of locking wire. Each pipe is marked by means of a black band for identification (see A.P.1464D, Vol. I, Part 2, Sect. 3, Chap. 2). Soft soldered joints are not permissible forward of the fireproof bulkhead. Metal tubing in oil systems should not be bent to a radius of less than

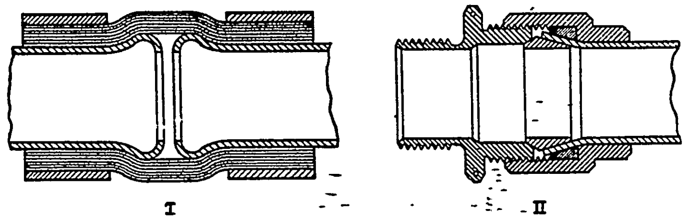


Fig. 5.—Types of oil-pipe couplings

four times the diameter. Approved oil-pipe materials used on different types of aircraft are as follows:—

Material	*Specification*
Copper	B.S.–T7
Stainless steel	D.T.D.97 or 207
Tungum	D.T.D.253
Light alloy	D.T.D.310

Copper tubing

15. When copper tubing is used it must be 20 s.w.g. and in its fully annealed state; the tubing should be bent or formed in its cold state as issued, and subsequent heat treatment of the tubing must not be applied. Re-bending after the initial bending has been completed is not permitted. Copper pipes sometimes have their fittings silver-soldered or brazed on, and when a new pipe-line has to be made up, care should be taken to ensure that the jointing process adopted is identical with that originally used. It is most important that the tubing is bent as near to the correct shape as possible before fittings are attached, in order to obtain the correct length, after which the silver soldering or brazing operations may be completed.

Stainless steel pipes

16. Stainless steel pipes are used in certain instances in oil systems and where a pipe of this material is used, the reference number will be found in Vol. III of the relevant aircraft handbook; such pipes are not normally made up by Units. If it is found that a stainless steel pipe does not fit correctly in the prescribed position and further bending operations are necessary, so altering the general shape of the pipe, a replacement pipe should be fitted. A pipe must not be forced into position or drawn up to the couplings by the union nuts and left in a state of tension. Stainless steel pipes in oil systems should be pressure tested internally to 100 lb./sq. in. when immersed in water as laid down in Spec. D.T.D.1008. It is of the utmost importance that when stainless steel pipes are used in conjuction with rubber or rubber-proofed fabric the pipe should be protected by the application of pigmented oil varnish (Spec. D.T.D.62 or D.T.D.260) to those parts of the pipe over which the connections make contact. In instances where the working of stainless steel tubing is permitted, any necessary application of heat should not be made to one part of the pipe, but the whole length should be heated at an even temperature. The pipe should be evenly heated to a temperature of 550°C. after the work is completed.

Light alloy tubing

17. Light alloy tubing anodically treated is employed in the oil pipe-lines of some aircraft and care should be taken not to remove the anodic coating by heating, scraping, or buffing, unless the tube is to be re-anodised when the work is completed. Whilst it is the practice, when light alloy tubing is used for certain other purposes, to coat the tubing internally and externally with aeroplane varnish it is of extreme importance that tubing so coated should not be used in oil systems. Only specified couplings may be used with light alloy tubing, and contact with fittings made from brass, copper, tungum or steel should be avoided. Approved packing for use between clips and light alloy tubing are varnished langite, systoflex and red fibre (Spec. D.T.D.37A).

Tungum tubing

18. Tungum tubing (Spec. D.T.D.253) is supplied in the annealed state and can be bent cold; for sizes up to ⅜-in. diameter, filling is not required during bending operations. A suitable packing for use between the mounting clips and tungum tubing is tinned brass gauze (80 mesh).

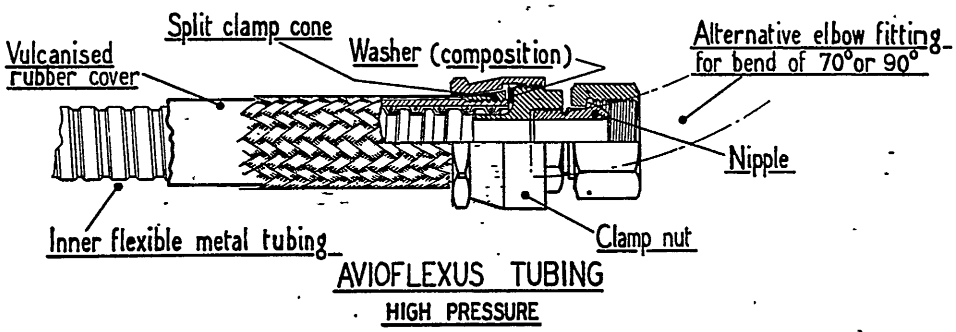


Fig. 6.—Type of flexible tubing

Flexible tubing

19. Several types of flexible tubing are used in oil systems and in order to differentiate between them and similar tubes used in fuel systems those employed in oil systems are pigmented black. These tubings are made in such a manner that the interior walls are impervious to the action of the oil and capable of withstanding the heat and pressures involved to the degree stated in the relevant specification. The end connections (see fig. 6) are made to suit the A.G.S. fittings and it is important when tightening or slackening the union nuts to avoid twisting the tube; two spanners, one on the union nut and the other on the hexagonal portion of the coupling, should always be used. Care should also be taken when fitting replacement tubes, not to reduce the radius of bends over the safe limit. The original layout of the system should be followed and the tubing protected and supported as detailed in the approved drawings for the particular aircraft. Protection should also be given against chafing on adjacent metal fittings, etc.

General

20. Details for the inspection and maintenance of the oil system of a particular aircraft will be found in the relevant aircraft handbook, Vols. I and II. During routine servicing, cleanliness must be observed throughout every operation; oil filters and cleaners, tanks and oil coolers should all be maintained in a clean serviceable condition and free from corrosion. Wherever possible the use of paraffin for cleaning and testing the components of oil systems should be avoided, because of the liability of subsequent corrosion. When the use of paraffin cannot be avoided the component should be dried and flushed out with flushing oil or engine oil. Oil coolers should always be flushed through with engine oil after testing for flow rate with paraffin.

Priming

21. After filters, cleaners, pipe-lines, etc., have been removed from the oil system for any reason, they should be primed with clean engine oil when they are to be replaced in position. Where several components have been dismantled and when an engine is newly installed the whole system should be primed. This priming should be effected with engine oil at a temperature of 60°C. at a pressure slightly below that at which the relief valve is set to open; 60 lb./sq. in. will usually be found sufficient. The amount of oil required for priming the engine alone will vary according to type, but it is usually from half a gallon to one gallon. If a variable-pitch airscrew control is fitted, the control valve should be closed to the coarse-pitch position, in order to prevent the oil escaping into the v-p. airscrew oil circuit. A priming connection is usually provided at the oil pressure gauge pipe coupling on the engine and this should be the last pipe-connection to be made before running the engine. Should more than four hours elapse before the engine is started it must be reprimed.

22. Oil-soaked felt pads are used on some types of aero-engines for lubricating the valve rocker arm. These pads require soaking periodically in engine oil at a temperature of 50°C. for a period of at least one hour. They should not be washed when dirty but must be replaced by new ones.

Jointing materials and packings

23. Particular care should be taken to ensure that only the approved jointing materials indicated in the Schedule of Spare Parts of the relevant aircraft handbook, Vol. III, are used in oil systems. The material should be capable of withstanding the effects of contact with hot oil under pressure without disintegrating; furthermore, it should not have any corrosive effect upon the mating metal faces.

Cleaning oil filters and oil cleaners

24. Oil filters and cleaners should be cleaned periodically and the elements replaced by new ones as laid down in the relevant handbook, Vols. I and II. Further information will also be found in A.P.1464, Vol. II leaflets.

Oil coolers

25. Information on oil coolers will be found in Sect. 3, Chap. 6, 7, and 8 of this volume.

Oil pumps

26. The oil pumps should be maintained in a serviceable condition and at overhaul should be dismantled and viewed for wear or other defects. The schedule of fits and tolerances laid down for the particular type of pump should be strictly observed and any damaged parts, or those worn outside the limits, should be replaced by new ones or by salvaged components on which new metal has been deposited by an approved process.

27. Excessive end-float of the gear wheels in the pump can be reduced by lapping the end faces of the casing, taking great care to ensure that the faces are square with the pump bore, ensuring also that the original minimum clearance is retained; the depth of the pump casing must not be reduced below the minimum new dimensions when the end-float of the gear wheels is being corrected by this method.

28. When gear-type oil pumps are to be dismantled it should be ascertained, before taking the wheels out of mesh with one another, that the meshing teeth are marked in order that they can be re-engaged with the same teeth in mesh, both when the pump is viewed for wear and when re-assembling.

29. After oil pumps have been dismantled for overhaul they should be tested for flow-rate with unrestricted delivery, also against a pressure specified for the type of pump. Information on the test rig and the conditions of tests is given in Volume II of the relevant engine handbook.

Oil tanks

30. Oil tanks, both main and auxiliary, should be kept clean, free from corrosion and leakages. Information on the repair of tank-shells and protective coverings is given elsewhere in this publication.

31. When assembling or removing such tank fittings as pipe unions, drain plugs, etc., the sleeve or ferrule on the tank into which the fittings are screwed should be held firmly on the hexagonal flange by means of a spanner, pressure being applied to oppose the direction of pull of the other spanner during tightening or slackening.

32. Vent pipes and orifices should be kept free from obstruction. Only approved jointing material or jointing components should be used when re-making a joint on a tank fitting. Packing strips used between the tank and its straps should also be of approved material only.

Bonding

33. The oil system should be correctly bonded as described in A.P.1464D, Vol. I, Part 2, Sect. 1, Chap. 5. The bonding points for a particular system are indicated in the relevant aircraft handbook, Vol. I.

P5047 M /1325 9/44 5250 C & P Gp. 1

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 9 to A.P.1464C, Vol. I and concerns Part 2, Sect. 3
Insert this chapter.

CHAPTER 2

VISCOSITY VALVES

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Clarke viscosity valve

1. This type of viscosity valve (see fig. 1) is fitted to aircraft oil-coolers of various types, and operates as a combined oil-pressure relief valve and automatic oil-feed control to the cooler. Two valves are embodied, one for each of these functions, both communicating with a common inlet orifice, each having its own outlet. The valve inlet is connected to the pipe-line from the engine oil-outlet whilst the two valve outlets are connected to the oil cooler and the return pipe-line, respectively. Of these two outlets, that to the oil cooler is controlled by a spring-loaded piston valve and the one to the by-pass by means of a spring-loaded mushroom-headed valve.

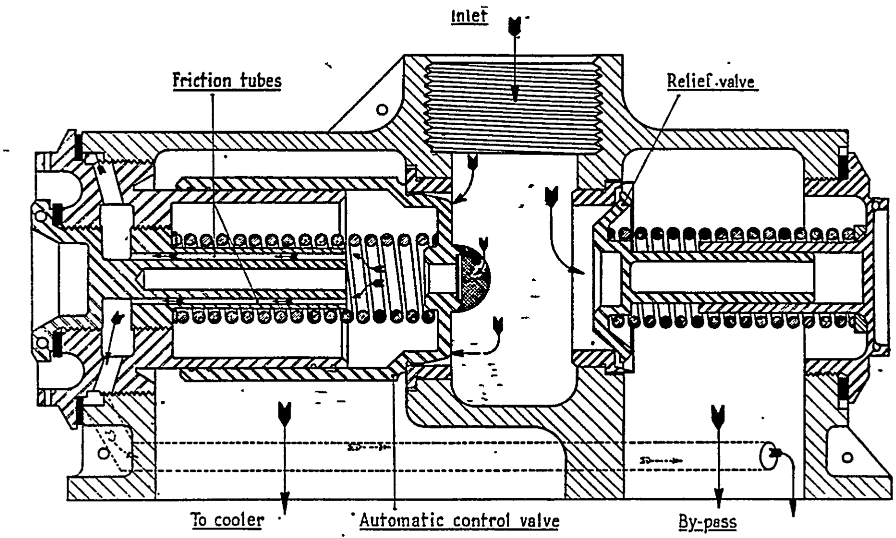


Fig. 1.—Section showing directions of oil flow

Construction

2. The complete valve consists of a housing in which two valves are housed, axially in alignment, each controlling the flow path of the engine oil from the scavenge pumps according to the pressure and viscosity of the oil in circulation. The pressure-relief valve is held on its seat, which is a press-in fit in the body, by means of a coil spring and is guided by a screw-in sleeve in which the hollow stem of the valve can slide freely. The automatic control valve is of a more complex design and incorporates an arrangement of small oil ducts or fluid-friction tubes open at one end to the oil inlet, via a gauze covered hole in the crown of the piston-type valve, and open at the other end, to the outlet to by-pass via a duct in the valve housing. The control-valve piston fits over a sleeve extension of the end-cap on which it slides freely under the action of the spring or of the oil pressure.

Operation

3. The operation of the viscosity valve depends upon the pressure of the oil and its viscosity. The valve is positioned in the pipe-line between the scavenge pumps and the oil cooler and, when

the engine is first started, both valves then being closed, oil passes through the gauze-covered hole in the end of the automatic control valve into the interior of the piston and sleeve and into the friction tubes. The oil is relatively viscous and because of the restricted oil flow through the friction tubes, pressure builds up in the inlet orifice. As a result the pressure in the inlet and on both valve heads increases and, because the oil in the control valve piston prevents it from opening, the relief valve comes into operation, by-passing the oil cooler. As the oil circulates through the engine and becomes warmed up, it passes more freely through the friction tubes and oil ducts and relieves the back pressure on the interior of the control valve, thus allowing it to open. The warm oil now passes directly to the oil cooler and the pressure on the relief valve is thereby reduced and so it closes gradually.

4. The pressure relief valve opens at 30 lb./sq. in. and the automatic control valve begins to open at an oil temperature of 55° C. and is fully open at 75° C., when used with oil to Specification D.T.D.109. It should be realised that should the viscosity of the oil be decreased by use or by dilution, the automatic control valve will operate at correspondingly lower temperatures. When the valve is in use it effects a gradual blending of the hot and cold oil.

Servicing

5. The servicing for this type of valve consists of cleaning, viewing and testing. The adjustment of the automatic control valve is effected by the manufacturers and should not be altered. Both valves can be removed by unscrewing the end-caps from the housing. The relief valve should be cleaned and examined to ensure that the valve stem is free in its guide and that the valve head has been seating correctly. The valve springs should be examined and if defective replaced by new ones. The control valve should be washed in clean paraffin, when it should be ensured that both the filter in the piston crown and the oil ducts are quite clean. The control valve piston should slide freely on the sleeve extension and the annular grooves in both these components should be free from foreign matter. When assembling the valves, clean oil should be applied to the working parts. The spring seat washers should be in the correct positions and the end-cap joint washers in a serviceable condition. The screw threads on the control-valve cap should be perfectly clean otherwise when the valve cap is screwed into the body, dirt may collect in the annular oil duct which is formed at the end of the internal threads. The caps should be locked by means of locking wire after the valve has been tested.

Testing

6. For the purpose of testing the valve, oil (D.T.D.109) should be pumped under pressure through the valve from a tank in which the oil can be gradually heated. A return pipe-line should be arranged from the valve cooler-outlet to the tank. The oil should be circulated and a pressure of 30 lb./sq. in. applied, upon which the relief valve should open. When the action of the relief valve has been checked the oil pressure should be reduced to approximately 25 lb./sq. in. and maintained at that value, whilst heating the oil until it reaches a temperature of 55° C. When the temperature of the oil reaches this value the automatic control valve should begin to open and allow oil to flow through to the outlet which is normally connected to the cooler. The oil should then be heated further, when the oil pressure should fall steadily until the oil has reached a temperature of 75° C., at which temperature the valve should be fully open, and as a result, the pressure will settle down again and remain constant.

7. If the results of the above tests are not satisfactory the complete valve should be returned to Stores as unserviceable and replaced by a new one.

P5049 M /1327 9/44 5250 C & P Gp. 1

CHAPTER 3

OIL CLEANERS—VOKES

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. Vokes oil cleaners are employed in the oil circulating systems of certain aircraft and are usually included in the engine lubricating oil systems, and gun turret oil circuits. The oil cleaners are made in various types similar in construction and operation, all using the same type of filter element, but varying in the size of the element and container according to the grade of oil to be handled. Each type of cleaner is designed to clean a particular grade of oil, and is available with alternative connections for port or starboard mounting with all components interchangeable, *i.e.*, parts taken from a L.H. cleaner can be used in a R.H. cleaner and *vice versa.*

2. The oil cleaning operation is effected by deflecting the oil in circulation into a filter element housed in a container, this filter arresting and retaining any solid foreign matter contained in the oil. The design of the oil cleaner allows for the removal and replacement of filter elements to be made without disturbing any pipe-line connections, and also for the insertion of a cleaner unit into any size pipe-line up to $\frac{3}{4}$ in. B.S.P. Information on the construction and maintenance of these cleaners is given in this chapter; details as to the periods between cleaning and replacement of the filter element will be found in the Servicing Schedules in Vol. II, Part 2, of the relevant aircraft handbook.

CONSTRUCTION AND OPERATION

Construction

3. The oil cleaner (see fig. 1) comprises a filter element housed within a container which is provided with inlet and outlet connections. The container is a pressed steel cylinder enclosed at one end by a die-cast head held in position by a clamp-ring. The filter element consists of a perforated sheet-brass cylinder mounted between plates which enclose the cylinder ends, the perforated cylinder enclosing an inner fabric gauze, which effects the oil cleaning operation. One end plate is fitted with a tube forming the oil inlet into the filter element; a bridge piece attached to the tube, anchors a bolt connecting the plates together. The filter element is held in the container on a large coil spring which retains the inlet tube in position in a port cored in the top-head. A cork ring is fitted over the inlet tube and makes an oil-tight joint between the top plate of the filter element and the underside of the top head casting, pressure being applied by the coil spring on the bottom plate of the filter element (see fig. 1).

4. The head casting is a domed, flanged fitting incorporating inlet and outlet ports tapped $\frac{3}{4}$ in. B.S.P. for connecting the cleaner to an oil pipe-line; the underside of the flange is machined to form a seating for a gasket. The container is a sheet metal pressing fitted with a drain plug, the mouth being beaded over to form a flange intended to be clamped against a gasket in the top-head. The clamp ring fits over the container, and lugs cast integral with the ring are tapped $\frac{1}{4}$ in. B.S.F. for the insertion of the setscrews which effect the clamping operation.

5. The inner gauze is a three-ply fabric gauze, made up by inserting a layer of cotton fabric between two layers of fine mesh wire gauze. The gauze is corrugated during manufacture to increase the filtering area available inside the cylinder, and the ends are joined together with a spring clip. The perforated cylinder is built to the size required from 24 s.w.g. perforated sheet brass, the perforations being 8 to 1 in. The end plates are annular rings of channel section made from 24 s.w.g. sheet brass. The inlet tube is made from 1¼ in. o/d brass tube; the holes drilled in the wall of the tube (see fig. 1) are the by-pass outlets.

Operation

6. The cleaner is fitted into an oil pipe-line with the inlet port facing the flow of oil in circulation. Oil entering the inlet port of the cleaner is led into the inlet tube of the filter element; the oil then circulates around the inside of the filter element to pass through the gauze and perforated cylinder into the container which is directly connected to the outlet port in the top-head. This operation ensures that any solid foreign matter contained in the oil in circulation is retained inside the filter element and remains here until the filter element is removed for cleaning. If the filter is allowed to become choked, a relief valve prevents a stoppage in the oil supply by by-passing the filter element described in the next paragraph.

7. When the gauze in the filter element is clean and offers no resistance to the oil in circulation, the coil spring in the bottom of the container maintains an oil-tight joint between the inlet port into the filter and the outlet port from the container, by forcing the cork ring joint against the underside of the top-head (see fig. 1). When the gauze is choked with foreign matter, a pressure builds up, and compresses the coil spring until the holes drilled in the wall of the inlet tube are in alignment with the underside of the top-head. When the filter element is in this position a direct path is established between the inlet in the top-head and the outlet from the container; the filter element is by-passed, and the filtering operation discontinued, ensuring that the flow-rate is maintained and preventing a dirty filter element from contaminating the oil in circulation.

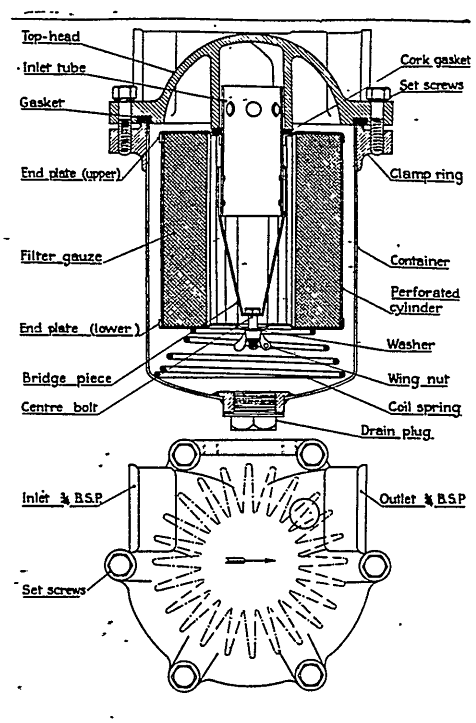


Fig. 1—Vokes oil cleaner

SERVICING

Cleaning

8. The filter element must be cleaned periodically by removing the cleaner from the oil pipe-line and extracting the accumulations of dirt from inside the filter element. It is essential that replacement gauzes are fitted to the filter at the prescribed periods indicated in Vol. II of the relevant aircraft handbook. The gauze inside the filter element can be cleaned with paraffin; the operation of cleaning a filter element is described hereunder:—

(i) The cleaner must be isolated from the oil circuit.

(ii) Remove the drain plug from the bottom of the container. A suitable vessel in which to catch the oil from the container must be available before removing this plug.

(iii) The container should be removed from the head by unscrewing the setscrews from the clamp ring, after which the filter element should be withdrawn and dismantled by unscrewing the wing nut from the bottom plate.

(iv) Remove the gauze from the perforated cylinder, then unroll the gauze ofter removing the spring clip.

9. All the components should be thoroughly cleaned by washing in paraffin or petrol, then drying all the parts, with the exception of the perforated cylinder, with soft clean rag. The perforated cylinder should be allowed to drain and dry out naturally. Normally, a new gauze is inserted at each cleaning operation, but in circumstances where replacement gauzes are not available, or when the gauze has not been in service for the prescribed period, it can be cleaned by scrubbing with paraffin,

using a soft bristle brush, and examining each corrugation as it is cleaned, for breaks or holes in the gauze or fabric. Damaged sections will have to be repaired or replaced according to circumstances; the methods of effecting repairs are outlined under appropriate headings in this Chapter.

10. When all the components have been thoroughly cleaned, the cleaner should be reassembled. The sequence of operations for effecting this is as follows:—

(i) Insert a new gauze inside the perforated cylinder. If a cleaned gauze is being replaced, connect the ends of the gauze together with the spring clip before inserting it inside the cylinder.

(ii) Place the gauze and perforated cylinder into the end plates and connect the plates together by tightening the wing nut on the bolt protruding through the bottom plate.

(iii) Place the coil spring inside the container (see fig. 1) and mount the filter element on top of this spring. Place the clamp ring over the container ready for connecting to the top-head.

(iv) Enter the inlet tube of the filter element into the port cored in the top-head to receive it and ensure that the cork ring will make a seal against the underside of the top-head. Clamp the container into position by inserting the setscrews through the top-head into the clamp ring, and then tightening the setscrews.

(v) Replace the drain plug in the bottom of the container.

(vi) Open the valves isolating the cleaner from the pipe-line, to allow the oil to be circulated through the cleaner in order to test the top-head joint.

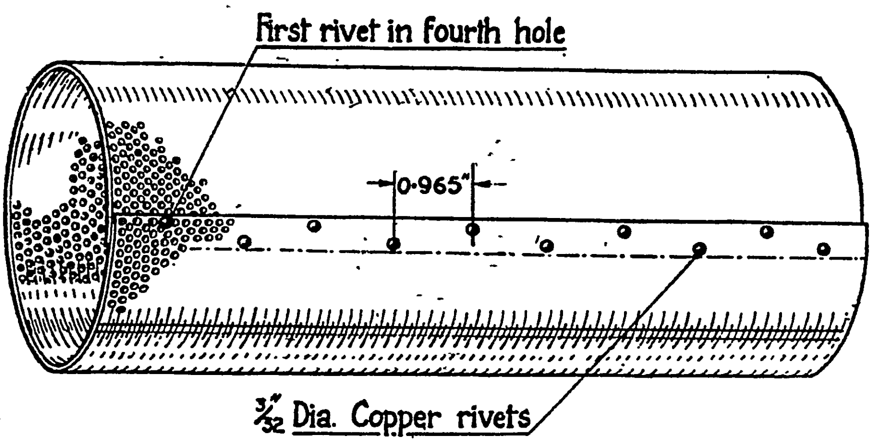


Fig. 2.—Arrangement of rivets in repaired filter

Repairing

11. The design of the cleaner allows replacements to be made to any part of the cleaner without complications, but in circumstances where permanent repairs are necessary, reference to the engine handbooks and Vol. II of the relevant aircraft handbook will provide the necessary information as to what constitutes an econominal repair. When a cleaner has been removed from an oil circuit for reconditioning, permanent repairs to the various components can be effected by carrying out the following operations, after first removing the container and filter element from the top-head, as indicated in para. 8, in order to ascertain the nature and extent of the damage to be repaired:—

(i) *Top-head.*—Examine the top-head for any defects that may prevent an oil-tight joint being made; if the cover is deformed as a result of over-tightening the set screws, or if cracks or holes are present from any other cause, a new cover should be fitted as these covers cannot be repaired economically.

(ii) *Container.*—Examine the container for any dents or holes which can cause the container to leak, and also for breaks in the flange which could prevent an oil-tight joint being made when the container is clamped against the gasket in the top-head. All dents must be carefully hammered out; any perforations found should be covered with patches cut to size from suitable gauge sheet brass, the patches being either riveted or soldered in position. The container is made from 20 s.w.g. mild steel tinned sheet, and care must be taken when effecting these repairs to ensure that a protective anti-corrosive coating is applied to any surfaces exposed during the repair operation.

(iii) *Clamp-ring.*—Examine the clamp-ring for any defects which could prevent it holding the container to the top-head. If any serious defects are noted a new ring should be obtained as these rings cannot be repaired economically.

(iv) *Perforated cylinder.*—Examine the perforated cylinder for dents or holes, and also for breaks in the ends which could prevent an oil-tight seal being made when the cylinder is clamped to the end plates. All dents must be hammered out and the holes covered with patches made from similar perforated plate, or from 22 to 24 s.w.g. sheet brass, soldered in position. If a patch covers more than one square inch perforations should be made in the patch using a $\frac{1}{16}$-in. drill. In cases where the longitudinal seam of the container is soldered, and this has parted, the repair should be effected by riveting instead of soldering. The seam should be thoroughly cleaned of all solder, and then riveted as shown in fig. 2. Ten round head copper rivets $\frac{3}{32}$ in. dia. by $\frac{1}{8}$ in. long (A.G.S.397) will be required along the joint.

(v) *End plates.*—Examine the end plates for any dents which could prevent an oil-tight seal being made when they are clamped to the cylinder. Unless the damage is confined to dents which can be satisfactorily hammered out, new end plates should be obtained.

(vi) *Filter gauze.*—Always use a new gauze when effecting repairs to this type of cleaner.

(vii) *Miscellaneous.*—New gaskets must always be used when effecting permanent repairs. The remaining components of the cleaner, *i.e.*, the setscrews, wing nut, and drain plug should be examined to ensure that they are serviceable, replacement parts being obtained when necessary.

Temporary repairs

12. In an emergency where the inner filter gauze is seen to be damaged, and replacement gauzes are not immediately available, repairs can be effected by removing the damaged sections, or covering the sections with patches cut to size from similar material. The following are the operations for effecting temporary repairs:—

(i) Remove the gauze from the cleaner as detailed in para. 8 (vi).

(ii) Examine the gauze carefully for breaks or holes, and cover all damaged sections with patches cut to size from similar material, sewing the patches firmly in position. If the damaged area is confined to two or three corrugations the repair can be effected by cutting out the particular sections and sewing the ends together again.

(iii) Replace the gauze as detailed in para. 10 (i).

Testing

13. When all repairs have been completed and the cleaner re-assembled as detailed in para. 10 the cleaner must be subjected to an air-pressure test before it can be passed back into service. The test procedure and equipment required for testing oil cleaners is as follows:—

(i) *Air test.*—The approved test is to immerse the cleaner in a tank of water and subject it to an internal air pressure test not exceeding 120 lb./sq. in. for a period of three minutes.

(ii) *Air test equipment.*—The equipment required for testing oil cleaners, comprises a water tank, large enough to allow the cleaner to be immersed for testing an air compressor or air equipment for maintaining a pressure of 120 lb./sq. in. inside the cleaner, and fittings for connecting the air supply to the cleaner inlet and for plugging the cleaner outlet.

14. When the cleaner has been tested and proved satisfactory, it should be thoroughly dried out and labelled to denote that it is available for service, having passed the prescribed tests on a given date. Cleaners not required for immediate use must be blanked off with fittings listed in Airframe handbook, Vol. III, Schedule of Spare Parts, for this purpose, and returned to Stores.

P5051 M /1329 5250 9/44 C & P Gp. 1

RESTRICTED (For official use only)
R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS
This is A.L. No. 11 to A.P.1464C, Vol. I and concerns Part 2, Sect. 3
Insert this chapter.
AIR MINISTRY
May, 1944

CHAPTER 4

OIL CLEANERS—TECALEMIT

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. Tecalemit oil cleaners are made in two types, viz., A and B, which cover ranges of medium and high-pressure requirements respectively for the oil systems of various types of aero-engines. In both types of cleaner a composite felt filter element is housed in a cast cylindrical container fitted with a balance valve and provided with an inlet and an outlet. The oil cleaner is normally included in the pipe-line between the scavenge pumps and the oil tank, but in certain installations an additional cleaner is included in the oil circuit between the high-pressure oil pump and the bearing feed pipe. The actual location of the cleaner in the oil circuit and its position on the aircraft will be found in the relevant aeroplane handbook, Volume I, whilst the inspection periods at which the oil cleaner should be examined and cleaned is laid down in the Servicing Schedule, Vol. II, Part 2, of the particular aeroplane handbook. Descriptions of these two types of oil cleaner and information on their maintenance are given in the following paragraphs. The cleaners and spares are listed in A.P.1086, Part IIA, Sect. 27A.

DESCRIPTION

Type A oil cleaner

2. The Type A oil cleaner (see fig. 1) is designed to cover a range of normal working pressure up to 100 lb./sq. in. and has a maximum flow rate of 300 gal. per hour when used with oil (D.T.D.109B) at normal working temperatures. The cleaner has a cast cylindrical body made of aluminium alloy, machined and anodised and fitted with a spigoted end-cover; the cover is held in position by means of four steel wing-screws and made oil-tight by a langite gasket, the threaded bosses for the wing-screws being reinforced by steel bushes internally threaded to fit the screws. A spring pressure-plate incorporating a balance valve is positioned on a slotted boss at the centre of the inner side of the cover by means of a sleeve which is cut away to provide a dog-type engagement. The pressure-plate is spring-loaded by two coil springs fitted with end caps which, when in position, engage with recesses arranged diametrically opposite one another on the pressure-plate face and at the same time with hollow bosses integral with the cover.

3. When the oil cleaner is assembled the pressure-plate bears on and closes the end of the filter element, the opposite end of which seats on the lower inner face of the housing. At this end of the housing an oil outlet is provided through a drilled and internally threaded central boss which is open to the interior of the filter element; the oil inlet is formed by means of a hollow boss positioned on the side at the lower end of the housing with which it is integral and communicates with the annular space surrounding the filter element within the cleaner housing.

4. The filter element is cylindrical in shape, approximately two diameters in length, and formed in deep, evenly spaced corrugations running lengthwise. The filtering medium is made from a type of felt specially developed for the purpose and built up around a coarse wiremesh former. The interior of the filter element is supported further by means of a strong coil spring which effectively prevents collapse of the element under working oil-pressures, the effect of which is increased as the felt becomes choked in use. For the purpose of identification the felt in this type of cleaner is white in colour when new.

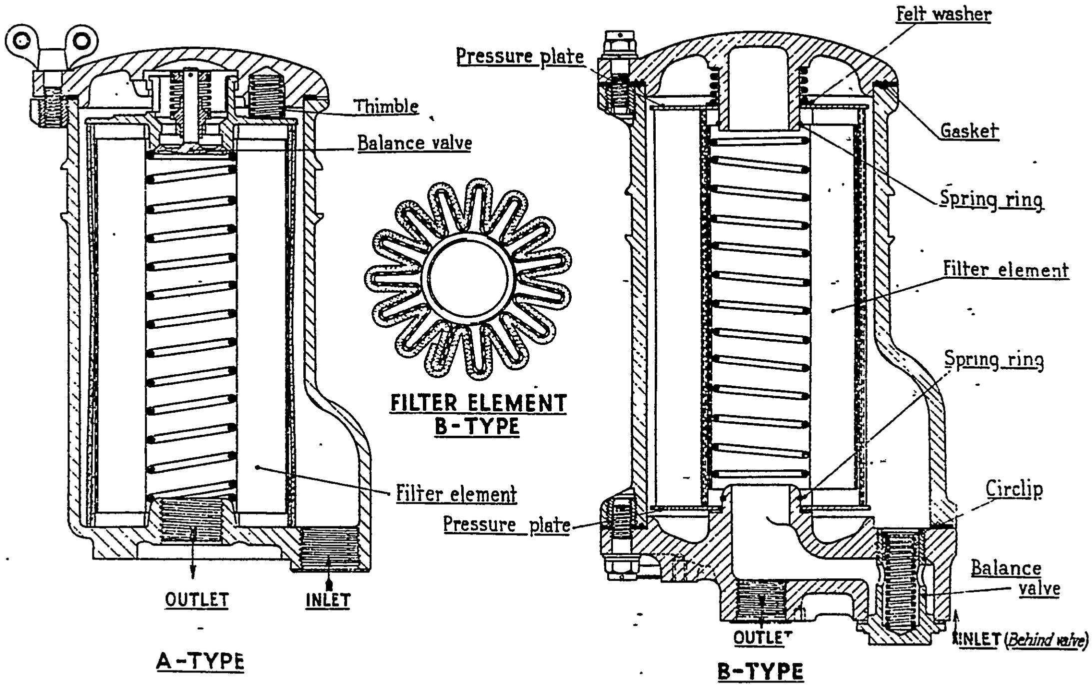


Fig. 1.—Aero-engine oil filters (Tecalemit)

Type B oil cleaner

5. The Type B oil cleaner (see fig. 1) is designed to cover a range of normal working pressures up to 250 lb./sq. in. and has a maximum flow-rate of 300 gal. per hour when used with oil (D.T.D.109B) at normal working temperature. The body casting or housing is a similar construction to that employed for the Type A oil cleaner, already described in para. 2, but is of course heavier in order to withstand the higher pressures involved. Two end-covers are fitted, each being secured in position by means of six steel hexagon-headed setscrews, special gaskets being employed at the spigot joint faces in order to ensure that they are oil-tight. The lower-end-cover incorporates the inlet and outlet which are arranged similarly to those in the Type A cleaner, with the essential difference in this type that the balance valve is fitted in an oil duct arranged between the inlet and outlet orifices. The upper cover is provided with an integral hollow boss at the centre of the inner side on which a spring-loaded pressure-plate enclosing the end of the filter element is retained by a spring ring. A felt ring interposed between the coil spring and the pressure-plate prevents leakage of uncleaned oil from the exterior to the interior of the filter element.

6. The filter element for the Type B oil cleaner is similar in design to the one fitted in the Type A cleaner, described in para. 4, with the exceptions that the felt is coloured blue for identification purposes and is formed in one thick layer.

Operation of oil cleaners, Types A and B

7. In operation both types function in the same manner, oil entering the cleaner and circulating around the filter element, both ends of which are closed. The pressure exerted by the oil from the pump is sufficient to force the oil through the filtering medium to the interior of the element, from which the oil is free to pass to the outlet; any foreign matter in the oil is meanwhile retained on the exterior corrugated surface of the filter element. When the oil is cold, or when the filter element becomes choked with dirt, pressure builds up around the outside of the filter element and the balance valve opens, so permitting the oil to pass directly to the outlet by short-circuiting the filter element.

SERVICING

General

8. The following information is generally applicable to both these types of oil cleaner unless otherwise stated; the periods given for cleaning and replacement of filter elements are those recommended under normal circumstances but it should be understood that the instructions laid down in the relevant aeroplane handbook Servicing Schedule, Vol. II, Part 2, are to be strictly observed.

9. The filter element should be withdrawn and cleaned after every 30 hours running time; it must be replaced by a new one, after cleaning five times, *i.e.*, at 150 hours, also at which period the balance valve should be removed, dismantled and cleaned as described in the appropriate paragraph below.

Dismantling

10. For the purpose of dismantling the oil cleaners for cleaning, the top end-cover should be removed first, after which the filter element can be withdrawn. In addition, on the Type B cleaner only, it is necessary to unscrew the balance valve from the lower end-cover at the 150 hour period inspection. On the Type A cleaner the valve is embodied in the top cover and will therefore have been removed together with the cover; if it should be required to drain this type without removing it from the aircraft, the inlet pipe coupling should be removed from the underside of the cleaner. When the balance valve is to be dismantled, this should be effected as follows according to the type:—

(i) *Type A balance valve.*—This valve is carried on the pressure-plate which must first be removed from the end-cover. For this purpose the spring caps should be lifted, by means of two screwdrivers, out of the recesses in the pressure-plate, which should then be rotated through an angle of 45° until the dogs are disengaged. The valve can be removed from the plate after the removal of the cotter in the valve stem.

(ii) *Type B balance valve.*—This valve is housed within a cage which screws into the base of the cleaner and, in order to remove it, the locking wire, securing the end-cover bolts and the hexagonal head of the cage, should be removed and the cage unscrewed. The spring-loaded piston valve can then be withdrawn from the cage after the removal of the circlip which will be seen in the end of the cage.

Cleaning

11. The metal components of the filter should be cleaned in paraffin, care being taken not to damage or remove the protective coatings. A soft bristle brush should be used to apply the paraffin, and rag of a non-fluffy nature should be used for drying the parts.

12. The filter element can be cleaned in a trichlorethylene degreasing plant, but if this is not available the element should be immersed in clean petrol and the dirt removed by means of a soft bristle brush. Under no circumstances should a wire brush or a scraper be used or the element will be irreparably damaged. An element in which the felt is defective or damaged should be rejected and replaced by a new one.

Examining and testing balance valves

13. The balance valves should be examined and tested before they are replaced in position in the cleaners, as follows:—

(i) *Type A.*—The Type A valve should be examined for distortion and if either the head or stem is bent, the valve should be replaced by a new one. A light application of marking should be made on the valve seat and the valve face tested for seating; if the seat faces are not satisfactory the valve should be carefully lapped in, using crocus powder or metal polish as the abrasive. All traces of the lapping medium should then be removed from the valve faces,

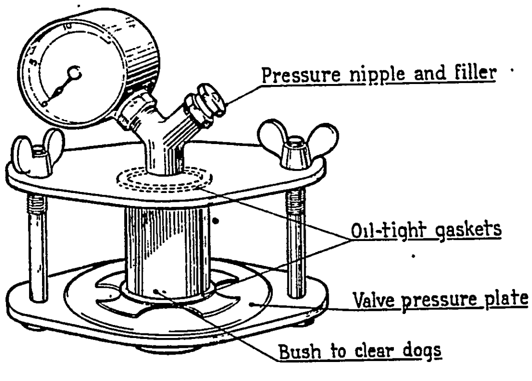


Fig. 2.—Rig for testing balance valve—Type A

after which the valve should be assembled and tested in a rig, which can be made up locally, similar to the one shown in fig. 2. The test rig should be assembled in the pressure-plate, ensuring that the joints between the flange plates and the cylinder are air-tight, without using undue pressure which might distort the valve pressure-plate. For the purpose of the test the oil gun adaptor should be removed and the cylinder should be filled two-thirds full of oil (D.T.D.109B). The adaptor should then be replaced and pressure applied gradually by means of a Tecalemit pressure oil gun through the adaptor until at 10 lb./sq. in. ± 2 lb./sq. in. the balance valve should just begin to lift from its seat and allow a slight leakage of oil. If the valve opens at a lower pressure a small adjustment can be made by stretching the spring slightly, otherwise it should be replaced by a new one.

(ii) *Type B*.—The Type B valve should be cleaned and the spring and piston examined for wear or damage, and if found to be defective they should be replaced by new ones. No pressure test is necessary for this type of valve; it should, however, be ensured that the piston is quite free in the cage and that it does not stick in any position. Care should be taken when fitting or removing the circlip to avoid distorting it, also to make sure when it is fitted that it lies snugly in its groove.

Assembling

14. The cleaners should be assembled according to type in the reverse order given for dismantling; the following points should be noted for use during assembling operations:—

(i) Strict cleanliness should be observed throughout the assembling operations, all components being kept dry and free from dust.

(ii) No difficulty will be experienced in assembling the balance valve Type B, but when the Type A valve and pressure-plate are fitted to the top cover, the operation will be facilitated by the use of a square steel plate fitted with four dowel pegs which engage with the cover screw-holes. This rig will allow the springs to be compressed while the spring cups are being guided squarely into the two bosses on the cover; care should be taken to see that the dogs and slots are in alignment and that when the pressure-plate is rotated through an angle of 45° the dogs engage correctly. When the pressure on the plate is released it should be ensured that the spring cups rest in the recesses in the pressure-plate.

(iii) Before the filter element is replaced in position in the Type B cleaner it should be ascertained that both the felt rings (see fig. 1) behind the pressure-plates are in position and in a serviceable condition.

(iv) When assembling the end-covers the joint faces should be clean and the gasket should be in a serviceable condition. It is important to ensure that the correct gasket for the type of cleaner is fitted; for Type A the gasket is a cork composition—langite, whilst for Type B a synthetic rubber gasket is used. Both these types are available as spares. Before tightening the bolts, the spigot should be entered squarely into the body, and, in the case of Type A cleaner, the wing bolts should be tightened by hand in the order 1, 3, 4, 2; the hexagon-headed screws in the Type B cleaner should be tightened evenly in the order 1, 5, 3, 6, 2, 4, a spanner being necessary in this instance.

Pressure testing assembled cleaner

15. When the cleaner is assembled, after it has been completely dismantled, it should be subjected to an oil pressure test, for which purpose the cleaner should be filled with clean oil and the outlet blanked off. The inlet should be coupled to a suitable oil-pump and the following pressures applied to the cleaner without any sign of leakage:—

(i) *Type A*.—200 lb./sq. in. applied for 15 minutes.

(ii) *Type B*.—350 lb./sq. in. applied for 10 minutes.

16. During the pressure test, should any leakage be observed which appears to be caused by porosity, or fracture of the casing or cover, the defective component should be replaced by a new one. A leaking joint should be examined carefully before fitting a new gasket to ensure that the leak is not the result of a distorted cover or damaged face joints.

Locking and blanking

17. After the pressure test has been completed satisfactorily the cover screws should be secured by means of a length of 16 s.w.g. copper wire. The wing-screws on the Type A cleaner should be wired in pairs; in Type B the wire should pass through the heads of each set of the six screws and in addition at the lower end-cover the valve cage should be wired to the nearest screw head. Unless the cleaner is to be placed in service immediately the inlet and outlet should be blanked off by means of the fittings provided.

P5053 M /1331 9/44 5250 C & P Gp. 1

CHAPTER 5

OIL DILUTION SYSTEM

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The oil dilution system has been introduced as a means of facilitating the starting of aero-engines during cold weather by reducing the effort which would otherwise be required to turn them when starting under such conditions. The system is based on the principle that, within practical limits, satisfactory lubrication can be obtained by cold oil thinned with fuel so long as the correct lubricating viscosity is preserved. In addition to easier starting, a flow of lubricant is assured to all parts of the engine practically at normal working pressure, immediately after the start.

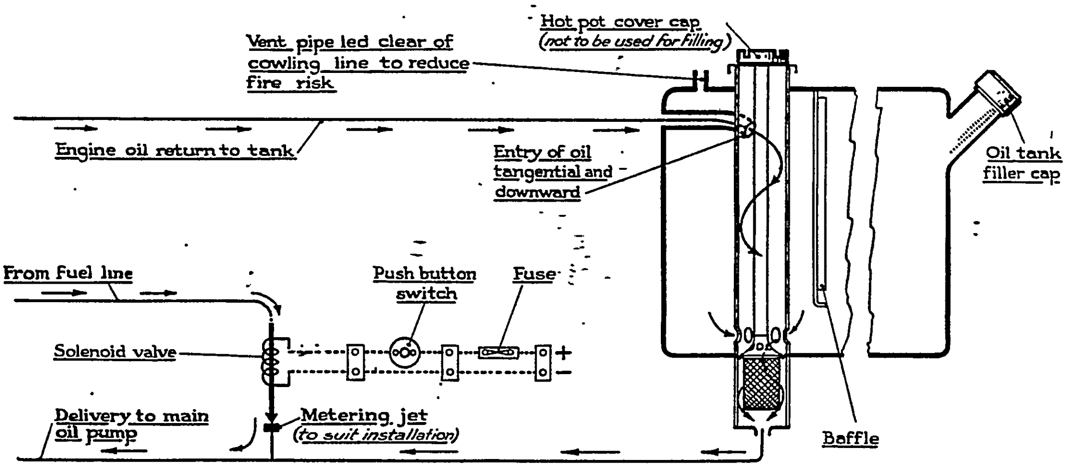


Fig. 1.—Typical layout of oil dilution system

2. The system (see fig. 1) comprises an interconnecting pipe-line from the delivery side of the fuel pump or reducing valve to the suction side of the oil pump, a solenoid valve controlled by means of a push-button switch from the cockpit, and a metering jet incorporated in the valve-outlet to regulate the flow of fuel. Fuel is thereby admitted for a specified period to the engine oil in circulation, immediately before the engine is to be stopped for any length of time during which the oil may cool to a temperature low enough to cause difficulty in normal starting. The dilution period will vary from one to about four minutes according to the lowest temperature to be anticipated under the prevailing operating conditions, the arrangement of the installation and the type of engine. Where periods are not laid down, the shortest possible period of dilution consistent with ease of starting should be the general rule.

3. Over-dilution, should this accidentally arise, will result in low oil pressures which will not have any serious effects on the engine, provided that the oil pressure is above the minimum allowed. Over-dilution can only occur when the operating instructions are not carefully followed, or in the event of the solenoid valve leaking or the push-button sticking in the ON position. The excess fuel will be evaporated rapidly by the heat of the engine and the only precaution to be taken when over-dilution is suspected is to warm up thoroughly until normal oil pressure is established.

4. In order to ensure that the dilution is confined as far as possible to the engine oil which is in circulation, a well or hot pot is formed in the main oil tank into which the oil which has circulated through the engine is returned by the scavenge pump. The level of the oil in the hot pot is maintained by the entry of oil from the surrounding oil tank. The diluent is eliminated by distillation when the engine is subsequently started up from cold, the greater part evaporating during the first 10 minutes. After a period varying from 15 to 30 minutes all effects of the dilution will have been eliminated.

5. In aircraft in which the oil tank is not fitted with a hot pot, or when the hot pot is not entirely suitable for oil dilution purposes, the system can still be used with advantage as regards ease of starting. In such circumstances, a short period of dilution will be specified in the relevant aircraft handbook, Vol. I, in order that dilution of the bulk of the oil in the tank may be avoided. Care must also be exercised during the warming-up period because of the risk of loss of oil pressure resulting from thick oil in the main tank or hot pot.

Operating the system

6. Before the dilution system is put into operation, the specific instructions giving the correct dilution period for the particular type of aircraft should be read; this information will be found in the relevant aircraft handbook, Vol. I. The following is the sequence of operations to be observed when using the system:—

(i) Whenever possible the oil tank should be topped up prior to dilution, but if this is impracticable, the topping up should be left until immediately before or after starting as this prevents cold undiluted oil from finding its way into the hot pot where, owing to its greater density, it would displace the diluted oil and thus prevent a free flow of oil after starting.

(ii) It is desirable that the engine and the oil shall be cool before the dilution operation is started, as otherwise the fuel is liable to be evaporated from the oil and the maximum benefit not obtained. It is recommended that the oil temperature should be between the range of 10° to 45° C. at the start of the operation. Although the full benefit of oil dilution can only be obtained when it is performed as recommended, it is emphasised that considerable assistance to starting will still result if, for operational reasons, the dilution has to be effected at higher oil temperatures.

(iii) After the engine has cooled it should be started and run up to 1,000–1,200 r.p.m., when the solenoid valve control switch should be pressed for the period given in the relevant aircraft handbook, Vol. I. During very cold weather at temperatures of −10° C. and below, the specified period of dilution may be increased by one or two minutes if found necessary.

(iv) While pressure is still retained on the switch the engine should be stopped in accordance with the procedure laid down in the relevant aero-engine or aircraft handbook. The valve control switch should not be released until the engine has stopped.

Explanatory notes on operation

7. In addition to the sequence of operations given in the preceding paragraph, certain conditions may arise which the following notes are intended to cover:—

(i) The beneficial effects of dilution will be increased if, after the diluting operation, the engine is first allowed to cool thoroughly and is then started and run for a period of thirty seconds, the dilution control switch being pressed during this period. During this short run, diluted oil is distributed to the cylinder walls and other engine parts which, at the time of dilution operation, are normally so hot as to evaporate the fuel. This method can be advantageously employed when for operational reasons the major dilution operation has been effected at high temperatures.

(ii) After dilution has been completed, the engine can be left for two or three days even in cold weather, without the usual frequent running up, until the next start is made. Starting the engine, at any time after dilution, is performed in the normal manner.

(iii) If after being diluted the engine is subsequently started for the purpose of running it on the ground only, after which it is then to remain idle for some time, the oil dilution operations should be repeated before closing down, but only for a quarter of the normal period; this will replace the fuel eliminated by the ground run.

(iv) Take-off may be made as soon as the oil pressure is normal and the oil and coolant temperatures are at least the minimum laid down in the relevant aircraft and aero-engine handbooks.

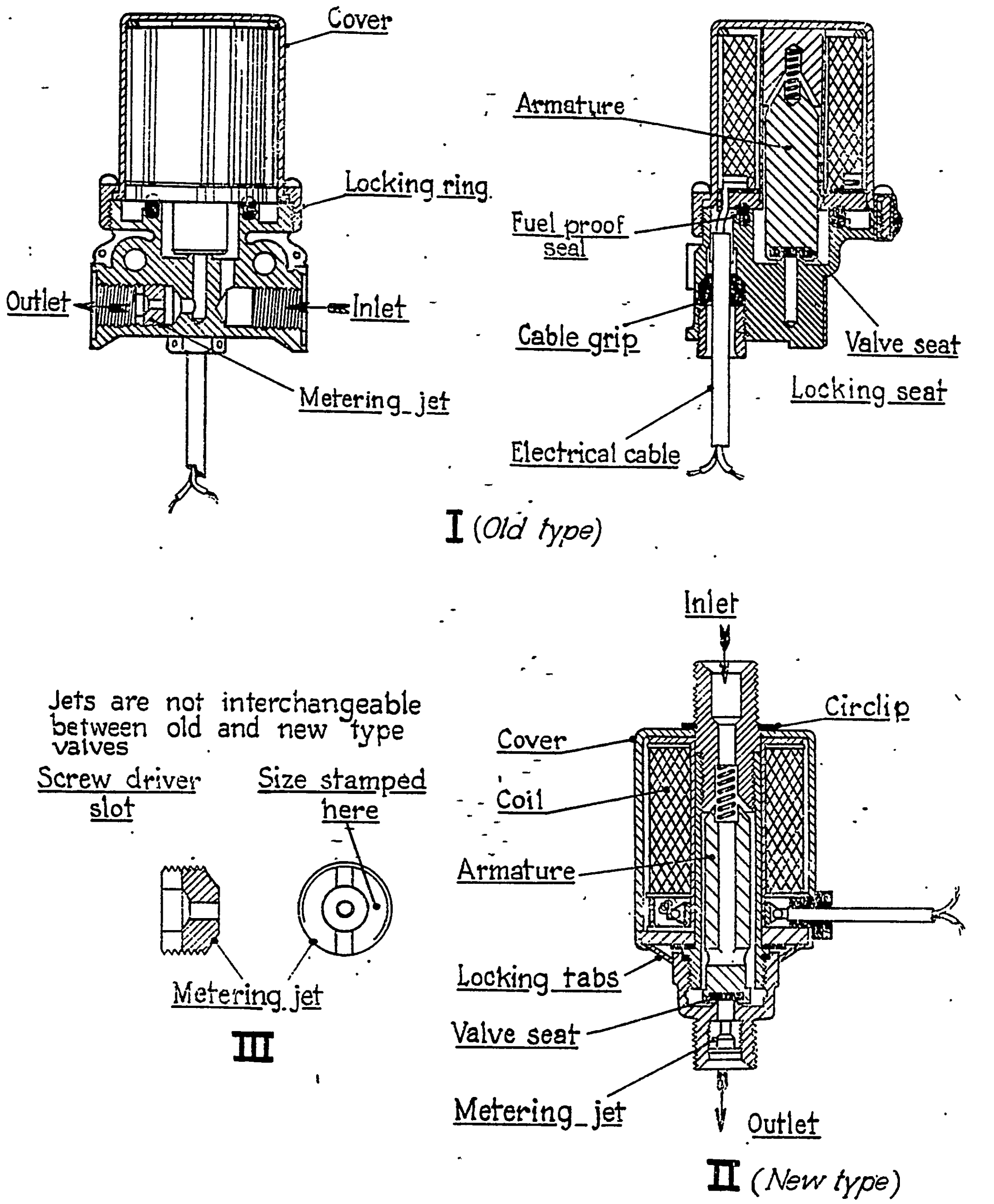


Fig. 2.—Types of solenoid valves

(v) The diluent has a cleansing effect upon the interior of the engine; therefore, when the system is installed and used on other than new engines, the filters must be cleaned more frequently until conditions are restored to normal.

(vi) Under conditions where sharp night frosts are to be expected, whatever the day temperature, the dilution system should be operated in the normal manner at the end of each day's flying, in order to prevent the bursting of flexible pipes, couplings and oil coolers.

Solenoid valve

8. The solenoid valve assembly is made in two types (see fig. 2) one having the fuel line arranged at a right angle to the solenoid and armature, the other later type being arranged axially. Each type is wound in accordance with the voltage on which it is required to operate (12 volts or 24 volts), the operating voltage of each being stamped on the body. The armature is spring-loaded to the closed position and carries a valve, the seat being in the body midway along the fuel duct. A metering jet is fitted in the outlet to suit the particular installation in which the assembly is incorporated and for this purpose jets are made for each type in various sizes; the jets are not interchangeable between the two types of valve. The solenoid is included in the electrical circuit of the aircraft and is operated by means of a spring-loaded switch from the pilot's cockpit; it should be remembered however that the dilution system cannot function unless the engine is running.

Hot pot

9. The hot pot is embodied in the oil tank and forms a compartment within the main body of the tank. The oil inlet from the scavenge pumps is directed into the top of the hot pot in such a manner as to separate the air. The outlet to the main oil pump is at the lower end of the hot pot, and holes in the lower wall which are shielded by a gauze wire, allow the cool oil in the main tank to replenish the hot pot without disturbing the circulation of the hot oil. By this arrangement the diluted oil circulates through the hot pot and does not mix to any appreciable extent with the main bulk of the oil in the tank.

Servicing

10. For the servicing of the oil dilution system, the solenoid valve and the pipe-lines should be examined at the inspection periods laid down in the Maintenance Schedule in the relevant aircraft handbook, Vol. II, when the following points should be observed:—

(i) It should be ensured that the solenoid valve operates with an audible click when the push-button switch is pressed.

(ii) It should be verified that the switch push-button is free in its guide and has no tendency to stick in the ON position.

(iii) The pipe-line and couplings should be maintained in a leakproof condition.

(iv) The oil tank filter should be kept clean.

(v) A solenoid valve which appears to be defective should be removed, dismantled and cleaned. The valve seat face should be examined, and if in a serviceable condition the valve should be assembled, the electrical connections being checked for tightness at the same time. The functioning of the unit can be tested on the bench at the same fuel pressure and the same voltage as specified for the particular installation, when it should be ensured that the valve is fuel-tight in the closed position and that the flow rate is consistent with the size of metering jet fitted in the outlet.

(vi) The oil filters in the engine should be cleaned frequently when the system is first installed in engines which have been in use some time since overhaul.

Jets and valves

11. The following list gives the types of valves and their associated jets:—

				Stores Ref. No.
Solenoid valve (*old type*)		12 volt	...	5U/1513
		24 volt	...	5U/1514
Jets	1	0·046 in.	...	5U/10
	2	0·070 in.	...	5U/11
	3	0·089 in.	...	5U/12
Solenoid valve (*new type*)		12 volt	...	5U/1566
		24 volt	...	5U/1567
Jets	1	0·046 in.	...	5U/1559
	2	0·070 in.	...	5U/1560
	3	0·089 in.	...	5U/1561

P5055 .M /1333 9/44 5250 C & P Gp. 1

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 13 to A.P.1464C, Vol. I and concerns Part 2, Sect. 3
Insert this chapter.

CHAPTER 6

OIL COOLERS

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Function of oil coolers

1. Modern aero-engines develop high powers, and are extensively cowled to reduce head-resistance to the aircraft. These characteristics and the fact that the aircraft is sometimes employed in very hot climates tend to cause the lubricating oil to become overheated. This necessitates the introduction of a cooling device in the oil pipe-line of the aircraft at a position between the engine scavenge oil pump and the oil tank. By this means surplus heat can be dissipated and the oil returned to the engine at the approximately correct temperature. Oil coolers employed on aircraft are air-cooled and it is therefore important that the aerodynamic resistance be kept as low as possible. To obtain maximum cooling, the coolers are generally mounted in the slipstream of the propeller.

A.M. TYPE A.325 COOLER

2. The Air Ministry type A.325, Mark V oil cooler is shown in fig. 1. The main members of the cooler are a number of fins or cooling elements assembled on two parallel connecting tubes, the fins being separated from one another by means of intermediate spacing rings, thus providing an air-space between each two fins. This air-space is further increased by local flattening of the fins, thereby increasing the surface of the hot oil exposed to the metal fin. An odd number of fins are employed in making up an oil cooler of this type because the oil flows through the fins in series and must emerge at the outlet connection which is situated on the side opposite to that of the inlet. The number of fins will vary according to the type of aircraft and aero-engine.

Fins

3. Each fin is made of sheet tinned brass (26 s.w.g.) in two halves, distance pieces being interposed between the halves so as to form a hollow centre. The construction is clearly shown in fig. 1. Internal duralumin rings, drilled with 14 holes of ¼ in. diameter, are fitted near the ends of the fin and form the inlet and outlet orifices respectively. The halves of each fin are assembled with the rivet distance pieces and internal rings in position and the whole is then riveted together, washers being placed under the heads and the burred-over portion of the rivets. The outer edges of the fin

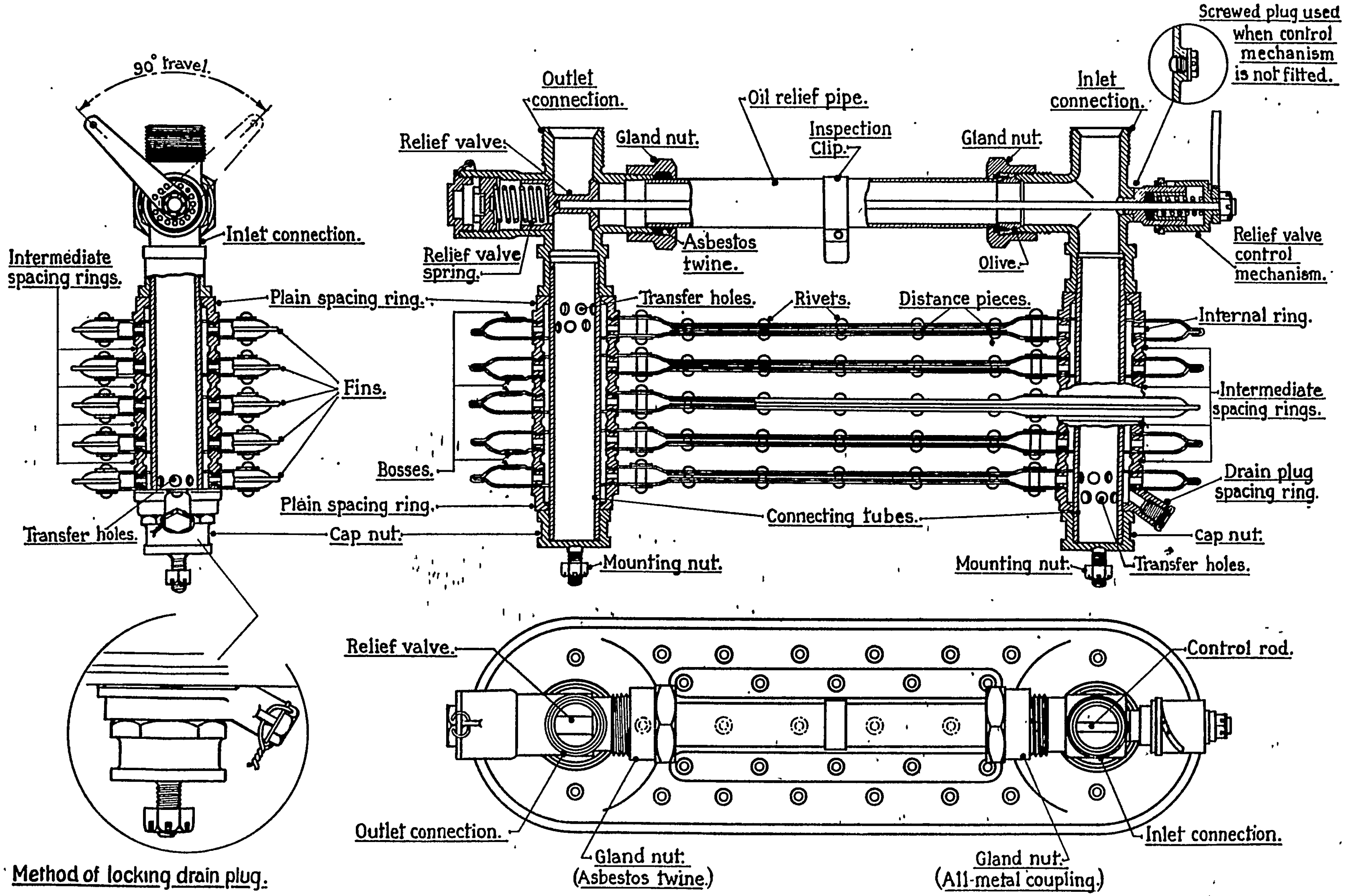


Fig. 1.—Oil cooler, A.M. Type A.325

are formed by means of a paned-down seam as shown in the illustration, after which the fin is flooded with solder. The latter is kept in a molten state by a gas blow-pipe which distributes the solder around the rivets and seam, the surplus solder being wiped off with a clean rag. After completion, each fin is independently tested to an internal pressure of 25 lb. per sq. in. Besides being structural members, the distance pieces break up the oil flow and conduct the heat to the surface of the fin. Each fin has a cooling surface of approximately 145 sq. in.

Connecting tubes

4. The two vertical connecting tubes are similar in construction and are made of mild steel. The tubes are threaded at both ends for a distance of about ¾ in. for the accommodation of the inlet and outlet connections at one end, and the cap nuts at the other end. The tubes are drilled at one end only with 14 holes of ¼ in. diameter in two rows, the edges of the outer holes being approximately 1 in. from the ends of the tubes.

Relief pipe

5. To allow for cold weather conditions when the oil has a high viscosity, a relief pipe is incorporated between the inlet and outlet connections where, by means of a spring-loaded relief valve, the flow of oil automatically short-circuits the cooler until the oil is warm enough, and consequently sufficiently fluid, to flow through the holes in the connecting tubes. The relief pipe is bell-mouthed at one end and forms part of a standard all-metal coupling, and the other end of the pipe is parallel and fits in the gland of the outlet connection. Asbestos packing is provided in the gland to make an oil-tight joint. Some such arrangement is necessary to allow for expansion of the pipe on heating. An inspection clip is positioned on the pipe.

Relief valve

6. The spring-loaded relief valve fitted to the outlet branch of each cooler is of the usual mushroom type. The valve is supplied set generally at 15 lb. per sq. in. and sealed by the makers and should not require any adjustment during service. This pressure, however, may be of a different value to suit particular requirements; see appropriate aircraft handbook. Occasions may arise, when the aircraft is flying at a high altitude and also when the engine is being warmed up on the ground, which necessitate the short-circuiting of the oil to avoid excessive pressure in the fins. This condition is effected on some coolers by fitting a control mechanism operated from the pilot's seat. The mechanism consists of a spring-loaded rod which is inserted in the relief pipe, the inner end of the rod being positioned in the head of the relief valve. The outer end of the rod is integral with a sleeve mounted on a barrel screwed into the inlet connection. A spiral groove is cut on the outside of the sleeve in which two keys slide, thereby permitting the sleeve to move laterally over the barrel and to hold the relief valve open to any degree. A handle is mounted on the sleeve and is provided with a fine adjustment to allow it to be placed in any desired position to suit the requirements of the particular aircraft. The handle has a range of 90 degrees travel, which lifts the valve from its seat approximately ⅜ in. When this mechanism is not fitted a screwed plug is substituted. By removing this plug and inserting a long rod through the relief pipe, the relief valve can be tested to ascertain whether it is functioning satisfactorily.

Oil coolers fitted with extensions

7. Oil coolers are sometimes fitted with extensions to bring the fins further away from the side of the aircraft and thus increase the cooling efficiency of the inner fin. The extension is obtained using a longer connecting tube and inserting a special two or four element spacing ring in place of the plain spacing ring (see fig. 3). Coolers of this type are given a double part number. The first portion of the number denotes the number of fins and the second portion the length of the connecting tube employed in the particular cooler. Thus a 5/7 cooler means that there are five fins on a seven fin connecting tube. To make up for the difference in length, a special spacing ring, equivalent in thickness to two fins plus an ordinary spacing ring, is introduced between each connection and the inner fin.

Dismantling

8. The following is the sequence of operations for dismantling the cooler:—

(i) Mount the cooler on a fixture similar to that shown in fig. 4. The fixture is made from a piece of 4 in. × 4 in. × ½ in. angle iron about 18 in. long. Two $\frac{5}{16}$ in. clearance holes should be drilled through the upper face and also two holes shaped to suit the heads of the special bolts (see para. 15), both pairs of holes having a pitch of 12 in. It is intended that the fixture shall be bolted to the side of the bench.

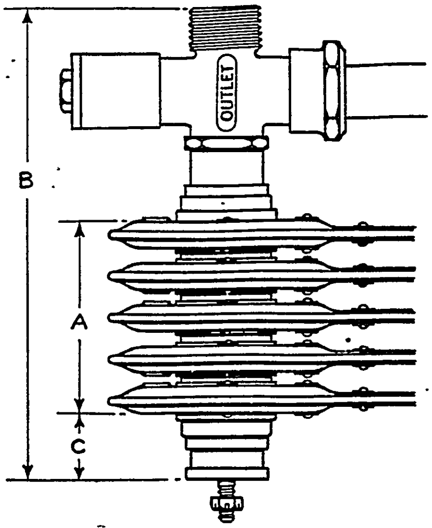


Fig. 2.—Cooler assembled without special spacing ring

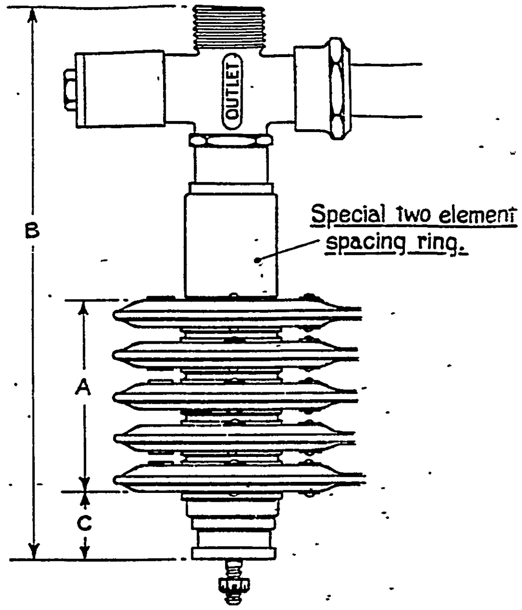


Fig. 3.—Cooler assembled with special two element spacing ring

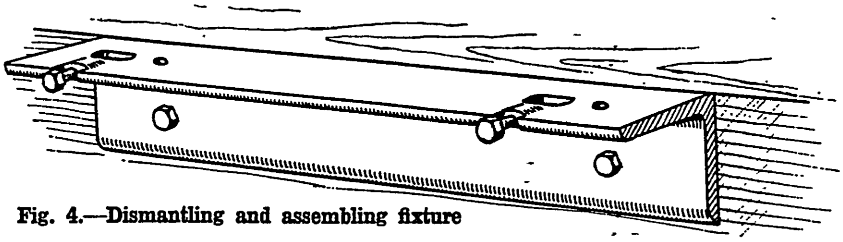


Fig. 4.—Dismantling and assembling fixture

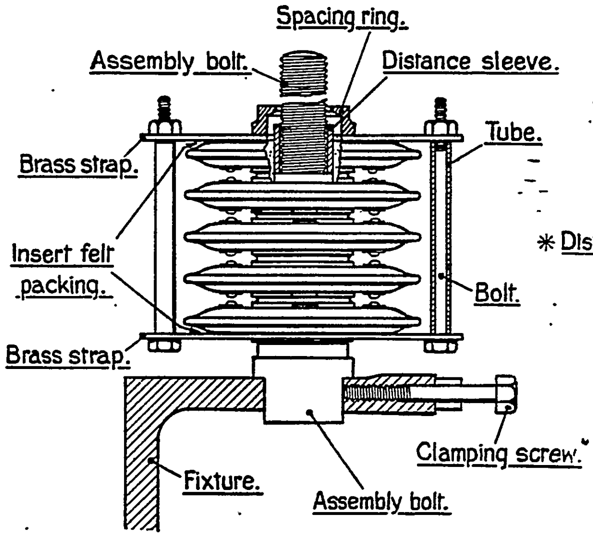


Fig. 5.—Clamping device for fin assembly

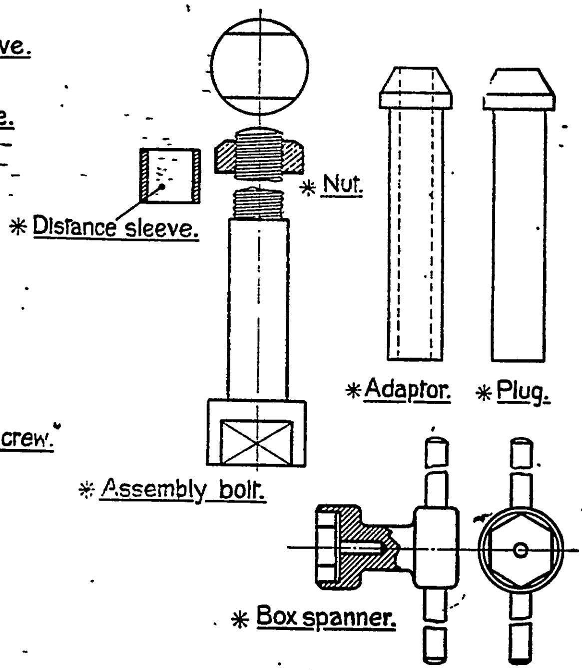


Fig. 6.—Assembling and dismantling tools
*Available (A.P.1086)

(ii) Unscrew the gland nuts from the inlet and outlet connections and remove the asbestos packing from the gland. The relief pipe can then be removed by withdrawing it into the gland of the outlet connection, thus allowing the olive to be removed from the inlet connection. The olive, gland nuts, etc., should be replaced on their respective connections.

(iii) Unscrew the connections from the connecting tubes. If a branch is tight, the connecting tube should be held by applying a spanner to the cap nut. Should the connecting tube become unscrewed from the cap nut, the tube can be unscrewed from the connection by first warming the latter in hot oil, holding the tube between wooden vice clams (similar to V-blocks) and applying a spanner to the hexagon on the connection. If both connections are tight, i.e., both tubes unscrew from their cap nuts, care must be taken when disconnecting the second tube to prevent the fins from falling to the floor.

(iv) Remove the fins and spacing rings and place the components on a bench in their various groups.

(v) Examine the fins for damage and the threaded parts for signs of stripping and picking-up. Either of these defects necessitate rejection of the part concerned. Indentations in the fin are liable to cause a fracture to develop whilst the cooler is in service and stripped threads cause oil leaks.

Cleaning

9. No difficulty should arise in the cleaning of the majority of the components, as this can be done with an engine cleaning brush and paraffin. Emery cloth should not be used as a cleaning agent as there is a risk of disturbing the solder round the rivets and seams on the fins, and such action would also destroy the anodic film on the duralumin components. To clean the insides of the fins, they should be first soaked in hot water for about half-an-hour and then emptied. The cooler should then be thoroughly flushed through with clean hot water, first in the direction of flow and then in the opposite direction, and finally washed in paraffin. If the insides of the fins appear to be in a very dirty condition they may be flushed through with dope solvent after the soaking operation and then rinsed in paraffin. Soda should not be used as a cleaning agent owing to its tendency to cause corrosion through small quantities remaining in crevices, etc. Subsequent flushing with hot water will not entirely eliminate the presence of the soda. Any paraffin remaining in the fin will be removed during the tests described later. The relief valve should be thoroughly syringed with paraffin to remove any sludge, etc., without breaking the maker's seals. During the cleaning the relief valve should be lifted from its seat so that any foreign matter will be removed by the syringing operations.

Repairs

10. The fins having been riveted and soldered during their manufacture, cannot be extensively repaired. Fins which are distorted must be rejected. Small leaks, however, can be remedied with a hot soldering iron, using the standard soldering compound as the flux. Fluxite will not be found satisfactory for repairs to fins. Each fin should be examined for surplus solder on the intermediate spacing ring seats. If solder is present, it may be removed by means of a hot soldering iron and then wiping with a clean rag. It is important that these seats make full contact with the spacing rings.

11. Components with stripped threads cannot be satisfactorily repaired and it is therefore necessary to scrap the part concerned and fit a new one. Rounded or burred-over corners of nuts can be rectified by using a smooth file, providing the defect is not severe.

Assembly

12. The correct method of assembling the various components is of great importance and for this reason it is imperative that the fins are assembled in the proper order, otherwise there will be a serious restriction of oil flow. No jointing compound or other material is permitted between mating surfaces—all joints are metal to metal.

13. Absolute cleanliness is essential and each component should be again washed with paraffin, then drained and wiped with a clean rag immediately prior to assembly. It must be remembered that a small piece of grit or other foreign matter between two mating surfaces is sufficient to cause a leak from the cooler. During the assembly operations, it is important that the two dimensions indicated by the letters A and B in fig. 2, are checked for accuracy. The table below gives the correct number of fins employed in the respective coolers, together with these dimensions.

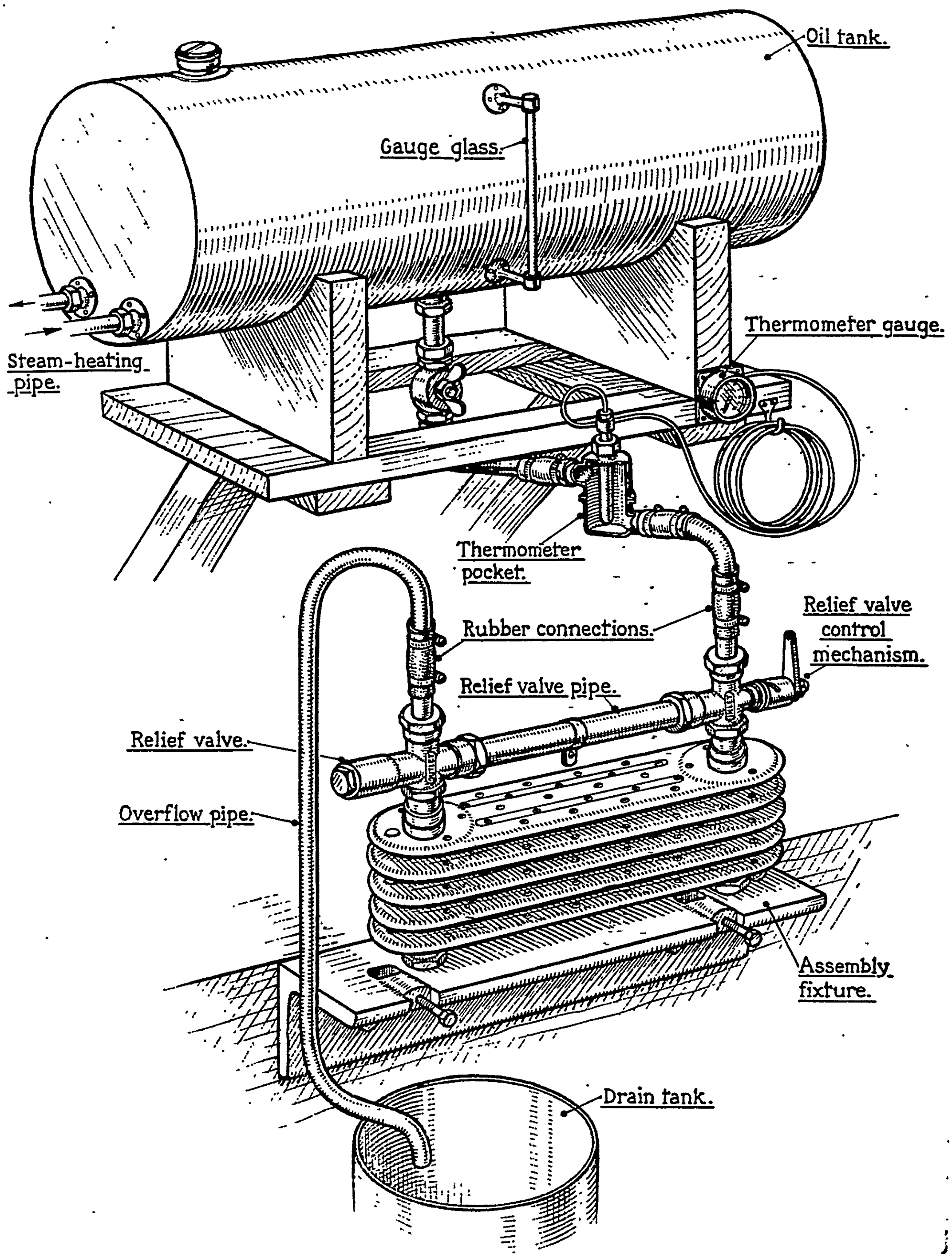


Fig. 7.—Test plant for oil coolers

Table No. 1

Mark of cooler	Number of fins	Dimension A in inches	Dimension B in inches
III	3	$1\frac{31}{32}$	$7\frac{13}{32}$
V	5	$3\frac{9}{16}$	9
VII	7	$5\frac{5}{32}$	$10\frac{19}{32}$
IX	9	$6\frac{3}{4}$	$12\frac{3}{16}$
XI	11	$8\frac{11}{32}$	$13\frac{25}{32}$

14. When a special spacing ring is used, the dimensions A and B indicated in fig. 3 will be as stated in the following table. The lengths of the two element and four element special spacing rings are $2\frac{1}{8}$ in. and $3\frac{3}{4}$ in. respectively.

Table No. 2

Cooler number	Number of fins	Connecting tube as used with cooler	Dimension A in inches	Dimension B in inches
3/5	3	Mark V	$1\frac{31}{32}$	$9\frac{17}{32}$
5/7	5	„ VII	$3\frac{9}{16}$	$11\frac{1}{8}$
7/9	7	„ IX	$5\frac{5}{32}$	$12\frac{23}{32}$
9/11	9	„ XI	$6\frac{3}{4}$	$14\frac{5}{16}$

Note.—The dimension C indicated in figs. 2 and 3 will remain constant for all coolers of this type, i.e., $1\frac{3}{8}$ in. The $\frac{5}{16}$ in. B.S.F. mounting studs are approximately $\frac{3}{8}$ in. long.

15. The correct assembly of the various components employed in building up a standard cooler is shown in fig. 1 and the utmost care must be taken to avoid incorrect assembly. Before commencing to build up a cooler, the operator should check the components in accordance with the list given at the end of this chapter. Two special bolts and distance sleeves, see fig. 6, are provided to facilitate the assembly of the cooler, and these should be mounted on the fixture and secured in position by means of the set bolts. The components should then be passed over the bolts in the following order:—

(i) Plain spacing rings, one on each bolt. Where one of the rings is provided with a drain plug, this ring should be fitted to the inlet side of the cooler.

(ii) First fin with its circular boss (fig. 1) uppermost on the outlet side. This boss is plain and must not be confused with the inspection bosses as the latter may be found on either end of the fin.

(iii) Intermediate spacing rings, one on each bolt.

(iv) Second fin with its circular boss on the underside, i.e., facing the boss on the first fin.

(v) Intermediate spacing rings, one on each bolt.

(vi) Third fin with its boss uppermost on the outlet side.

(vii) Plain spacing rings if a Mark III cooler is required, otherwise, intermediate spacing rings should be mounted and so on until the desired number of fins and rings have been mounted. It must be remembered that the boss on the last fin must face upwards and be followed either by plain spacing rings or by special extension spacing rings.

16. The nuts should now be tightly screwed on the special bolts, first ensuring that the intermediate spacing rings are central on the fins. On tightening down the nuts, the flanges on the fins will conform to the shape of the rims on the rings and a good mating surface will be made before the final assembly. The use of the special bolts permits the application of a greater load than would be possible with direct assembly on the connecting tubes.

17. The fin assembly should now be lightly clamped together as shown in fig. 5 and the nuts removed from the special bolts. The reason for clamping the fins and intermediate spacing rings is to retain the relative positions of the mating surfaces. Remove the fin assembly from the bolts and note the positions occupied by each of the spacing rings, as it is desirable for these to be replaced in similar positions in the final assembly. Remove the special bolts and replace the nuts and distance

sleeve on them. Place the cap nuts in position and screw them up, using the box spanner supplied, as shown in fig. 6, so that the rows of holes on one tube are farthest from the nut end, i.e., outlet side, and then unscrew each cap nut two or three turns, *but not more than this amount.* It is essential at this stage to check the lengths of the screwed portions of the tubes to ensure that the transfer holes will correctly register with the holes in the internal rings in the fins.

18. Mount the cap nuts on a fixture similar to that shown in fig. 4, using the mounting studs and nuts to secure the cap nuts temporarily to the fixture. Screw the connecting tubes to their full extent into the cap nuts and pass the plain and drain plug spacing rings over the connecting tubes; the drain plug spacing ring should be on the inlet side of the cooler. Mount the fin assembly over the tubes, ensuring that the lowest fin makes a good seating on the spacing rings, then tighten the mounting stud nuts. The upper row of holes on the outlet tube should now show clear of the rim on the upper fin, see fig. 1. Pass the plain or special spacing rings over the tubes, as before, and screw the inlet and outlet connections on the ends of the tubes, thereby drawing all joints together. The connections should be first screwed up finger tight and then finally tightened by means of a spanner until the screwed portions of the tops of the tubes are fully contained in the connections, or alternatively the connections are bedding down on the upper spacing rings. Care should be taken to ensure that the connections are in alignment to receive the relief pipe.

19. Insert the parallel end of the pipe in the outlet connection, the olive in the inlet connection, smear the threads with graphite grease and screw up the gland nuts with the fingers. This will check the alignment of the branches. Finally tighten up the gland nut on the inlet branch with a spanner. Unscrew the gland nut on the outlet branch and wrap a few turns of asbestos twine coated with graphite grease around the pipe, then replace and tighten the gland nut.

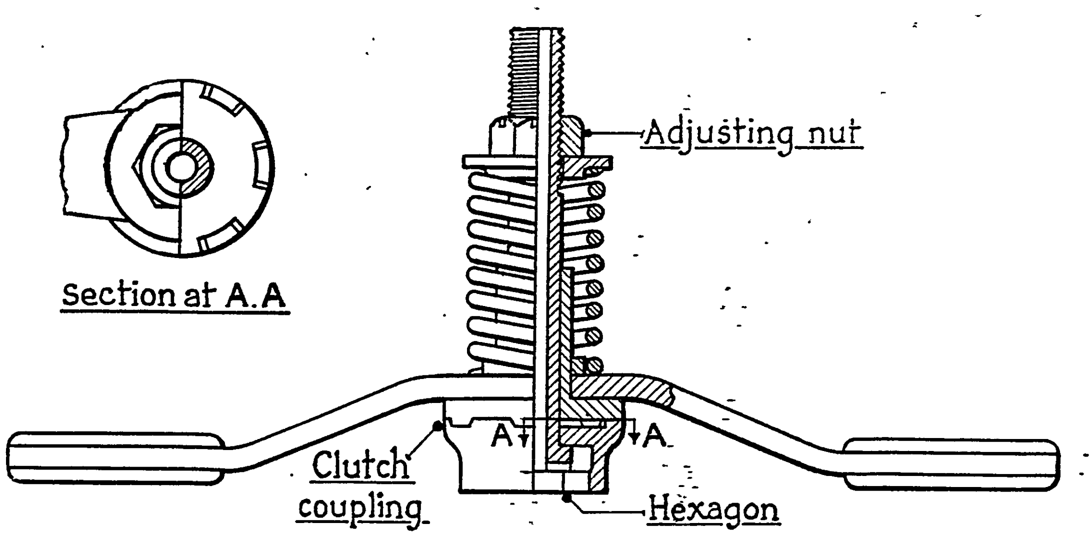


Fig. 8.—Spring-loaded spanner

20. Remove the clamps from the fin assembly and the complete cooler from the fixture. On the bottom ends of the tubes assemble the case-hardened gauge nuts, after the cap nuts have been removed, and tighten them up to the full extent with the special spring-loaded spanner; gauge nuts and spring-loaded spanner are listed in A.P.1086, Section 27A. This spanner (see fig. 8) comprises two H.T.S. couplings, i.e., upper and lower, in the form of a dog clutch. The upper coupling has an extension secured to a duralumin handle, whilst the lower coupling is governed by a spring, which is adjusted so that this coupling will slip when a tangential load of 80 lb. is applied at a radius of 7½ inches along each handle; when issued, the spring adjusting nut is locked at this setting.

21. In instances where the connecting tubes protrude beyond the faces of the gauge nuts, the surplus material should be cut off and the ends faced up with a file—see sketch I of fig. 9. The gauge nuts should then be removed, the cooler scrupulously cleaned to ensure that no swarf or filings remain, the screwed caps re-assembled and fully tightened by means of the spring-loaded spanner. If the ends of the connecting tubes stop short inside the gauge nuts for a distance exceeding 0·1 inch—see sketch II of fig. 9—the particular combination of connecting tubes, fins and spacing rings must be considered unsatisfactory for assembly, owing to the combination of extreme limits

prevailing throughout. In those circumstances the assembly should be reconsidered with the use of, say, 50 per cent. fins and spacing rings of low limits. Finally, if tests do not immediately follow the assembling operations, the inlet and outlet connections should be suitably blanked off to prevent the entry of foreign matter.

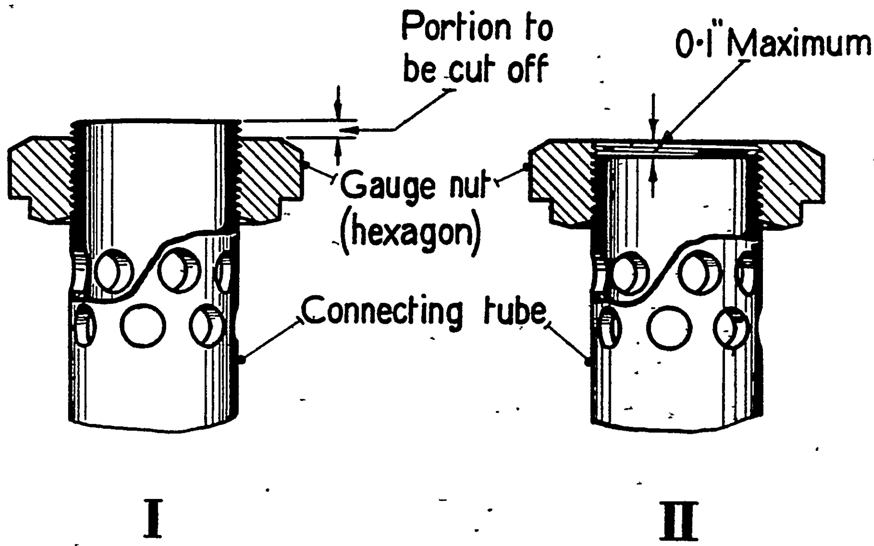


Fig. 9.—Application of gauge nut

Testing

22. Two tests are necessary to ensure correct functioning of the cooler; these tests are described below. A suggested plant lay-out suitable for making the tests is shown in fig. 7 and consists of a steam-heated oil tank having a drain cock and pipe for direct connection to the oil cooler. A thermometer bulb should be inserted in a pocket (shown in section in the illustration) formed in the pipe line in such a manner that the oil will flow completely over the whole length of the bulb and ensure the temperature of the oil being correctly registered on the gauge. Particulars regarding oil thermometers will be found in Air Publication 1275. An overflow pipe should be arranged to convey the oil from the cooler outlet to a drain tank. Units not equipped with a steam-heating plant may utilise either of the portable oil tanks, heater type. (See A.P.1464G, Part 2, Sect. 3, Chapter 3 for these tests.)

Flow test

23. The cooler should be mounted on the fixture and the coupling adaptor, see fig. 6, inserted in the inlet connection. The adaptor should then be connected to a tank containing oil at a temperature of 40° C. (104° F.), which should be allowed to flow freely through the cooler, the oil from the outlet branch being collected in a drum or other vessel—see fig. 7. Whilst the oil is flowing through the cooler it should be observed that the temperature of each fin increases in succession, commencing with the fin farthest from the connections. This will indicate that there are no restrictions and also that the fins have been assembled in the correct sequence. The outer fin will become warm within a few seconds and when the temperature of the inner fin has reached approximately the same value as the outer fin and the flow has been maintained throughout, the test can be regarded as satisfactorily passed.

Pressure test

24. Without removing the cooler from the fixture, the outlet connection should be blanked off with its plug and nut (see fig. 6), the drain plug removed and a pressure gauge connected in place of it. Hot oil at a temperature of 40° C. (104° F.) must now be applied to the cooler at a pressure of 25 lb./sq. in. The outside of the cooler should then be wiped clean and an examination made for leaks. Any leakage between the fins and the spacing rings may possibly be remedied by further tightening the cap nuts after the oil pressure has been released. It is unlikely that any faults will be found in the fins themselves as they are tested during manufacture, as previously stated.

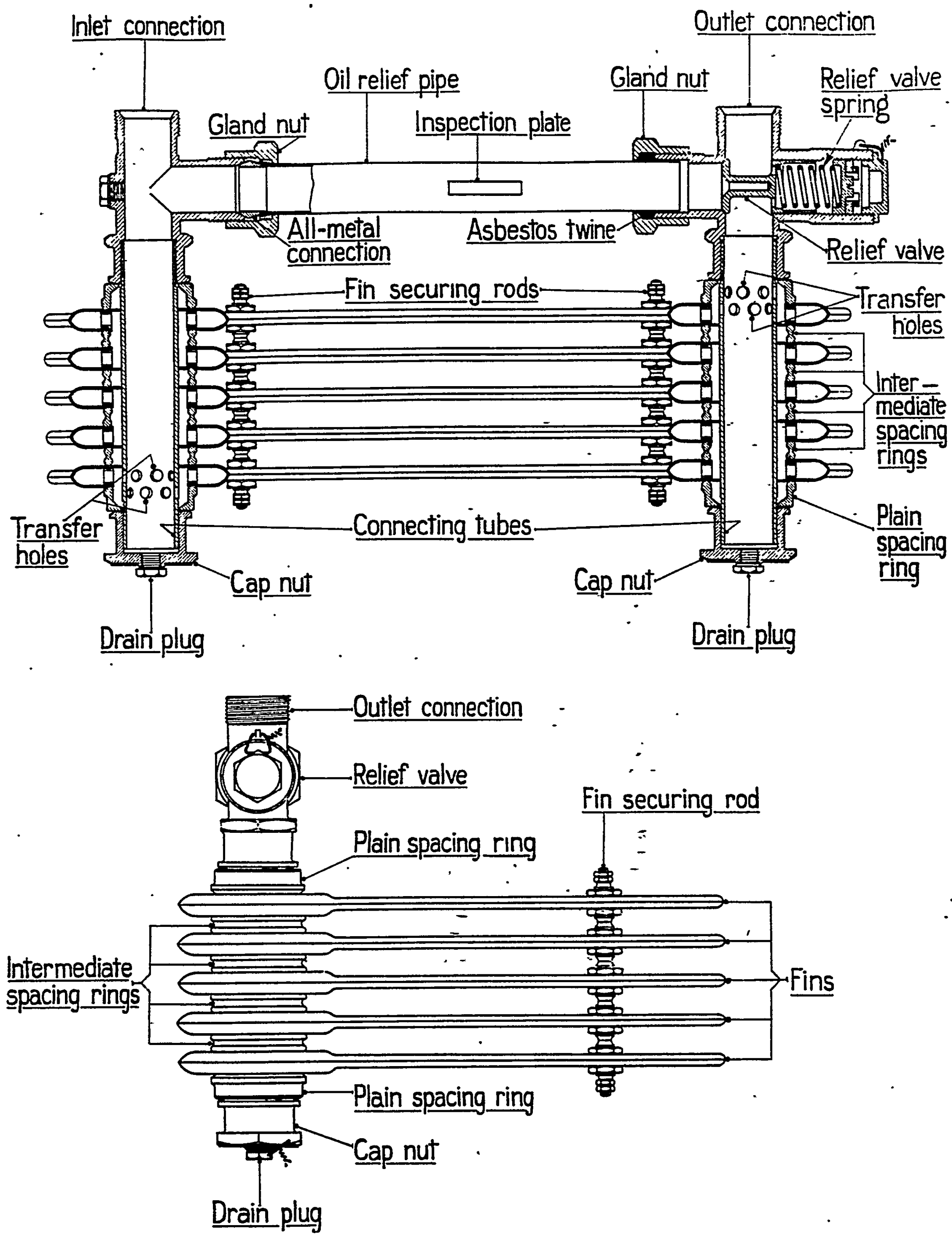


Fig. 10.—U-type oil cooler fin assembly for U.B.S. type

Storage

25. After the completion of the tests the drain plug should be locked as shown in the inset in fig. 1 and the exterior of the cooler washed in paraffin and dried with a clean rag, after which it should be labelled to indicate that it has passed the prescribed tests. If soldering flux has been used in the repair of the cooler it should be filled with oil, lubricating, D.T.D.109, and all open orifices blanked off; this precaution will apply also to new oil coolers installed in airframes or in store when they have not been in service.

OIL COOLERS—TYPES A.802, A.826 AND A.867

26. These coolers are generally referred to as the U-type, on account of the shape of the fins or cooling elements employed in their construction. The principal difference between these fins is the material from which they are made, i.e. brass sheet (A.802), P.M.G. sheet (A.826) or M.G.7 sheet (A.867). In these coolers, the fins are shaped in the form of a letter U to provide an increased cooling surface with a reduction in air-drag as compared with the A.M. type A.325 cooler. Fig. 10 shows an example of a U-type cooler, from which it will be observed that a number of components are similar to those employed in the A.325 type cooler, e.g. connecting tubes, branch connections, relief valve, etc.

Fins

27. The construction of a U-type fin is shown in fig. 11. The thickness of the sheet material is dependent upon the material used in making the two halves, which have distance pieces interposed between them so as to form a hollow centre. The halves are assembled with distance pieces, internal rings and fins spacers in position and the whole assembly is then riveted together, the rivets passing through the bores of the distance pieces; washers are placed under the heads and the burred-over portion of the rivets on the brass and P.M.G. fins, the outer edges are sealed by means of turned-over and soldered joints—see sketch I of fig. 11. After this operation the riveted areas are flooded with soft solder, the surplus solder being wiped off with a clean rag. Red fibre joint washers are introduced in the M.G.7 fins to make an oil-tight seal, whilst the seam between the two halves of the fins is completed by butt-welding—see sketch II of fig. 11. The function of the distance pieces (rivets) is to break up the oil flow and conduct the heat to the surface of the fin. Owing to the overhang of the fin from the connecting tubes, two fin spacers—see sketches I and II—are fitted to each fin through which a rod passes, two nuts being employed on the ends to secure the fins together. A spacing ring with drain plug is not generally fitted to these coolers, but each connecting tube cap is provided with a plug (⅛ in. B.S.P.) for draining purposes. Coolers for certain aircraft, however, are provided with a spacing ring having a drain plug, the component being fitted as in the A.325 type cooler. Other coolers have this component interposed between the fin and the branch connection on the outlet side. This latter arrangement is employed only when the cooler is mounted in an inverted position.

28. The total cooling surface of each fin is approximately 205 sq. in., but the actual cooling surface will depend upon the position the cooler is mounted on the aircraft, i.e. the amount of fin surface which is shrouded by the fairing of the fuselage. All fins after assembly are pressure tested—90 lb./sq. in. for brass and P.M.G. fins and 25 lb./sq. in. for M.G.7 fins.

Connecting tubes

29. The description given in para. 4 applies to these coolers. The tubes are interchangeable between the A.325 and the brass and P.M.G. U-types of coolers, according to the mark of the cooler.

Relief pipe and valve

30. These components are interchangeable between the A.325 and the U-types of coolers and are described in paras. 5 and 6 respectively. In some coolers the control mechanism for the relief valve is not always fitted, in which case, a plug (⅛ in. B.S.P.) is substituted in the threaded hole of the branch connection. Certain U-type coolers are also assembled without a by-pass pipe and relief valve.

Oil coolers fitted with extensions

31. The information given in para. 7 equally applies to the U-type coolers.

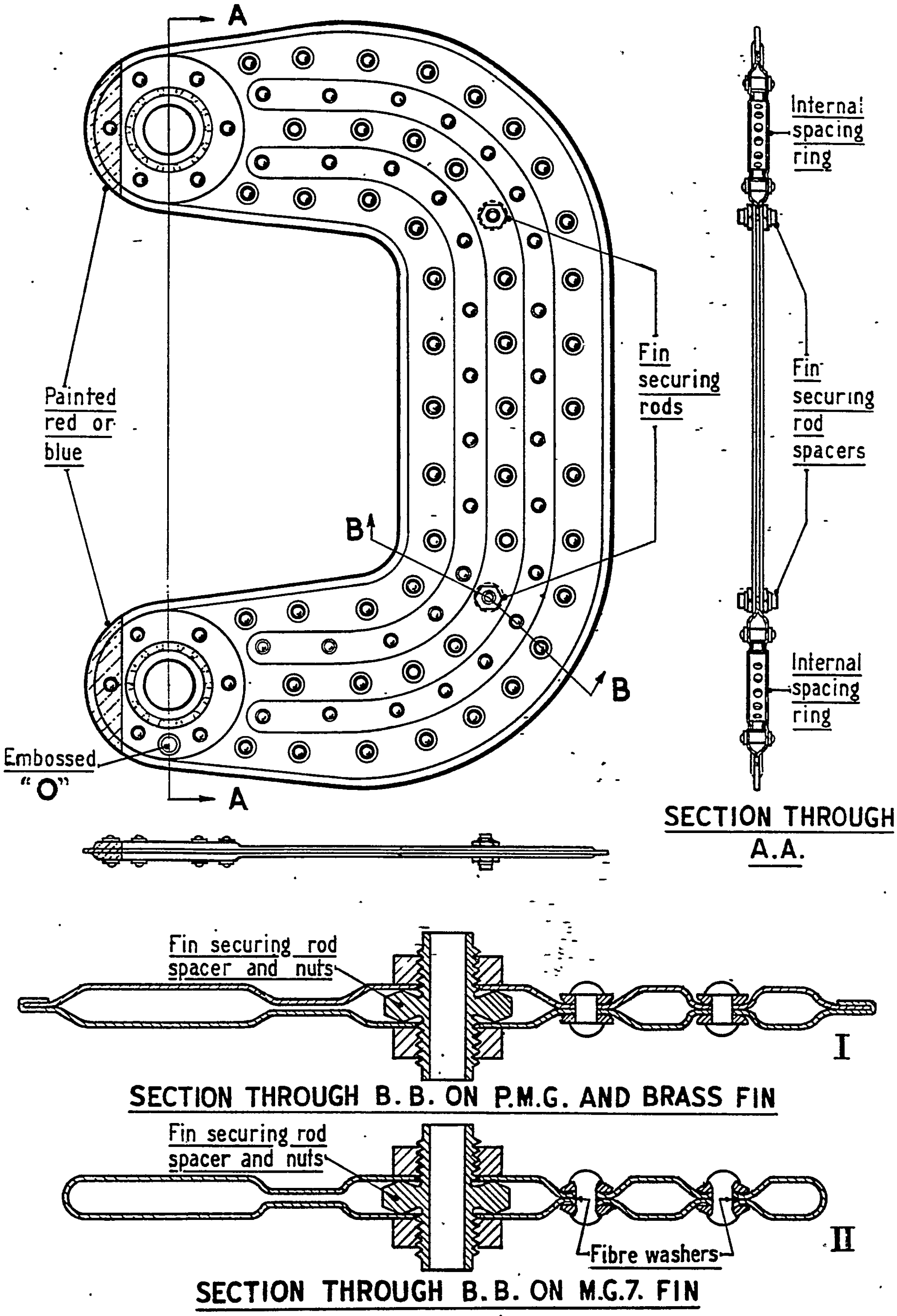


Fig. 11.—U-type oil cooler fin assembly

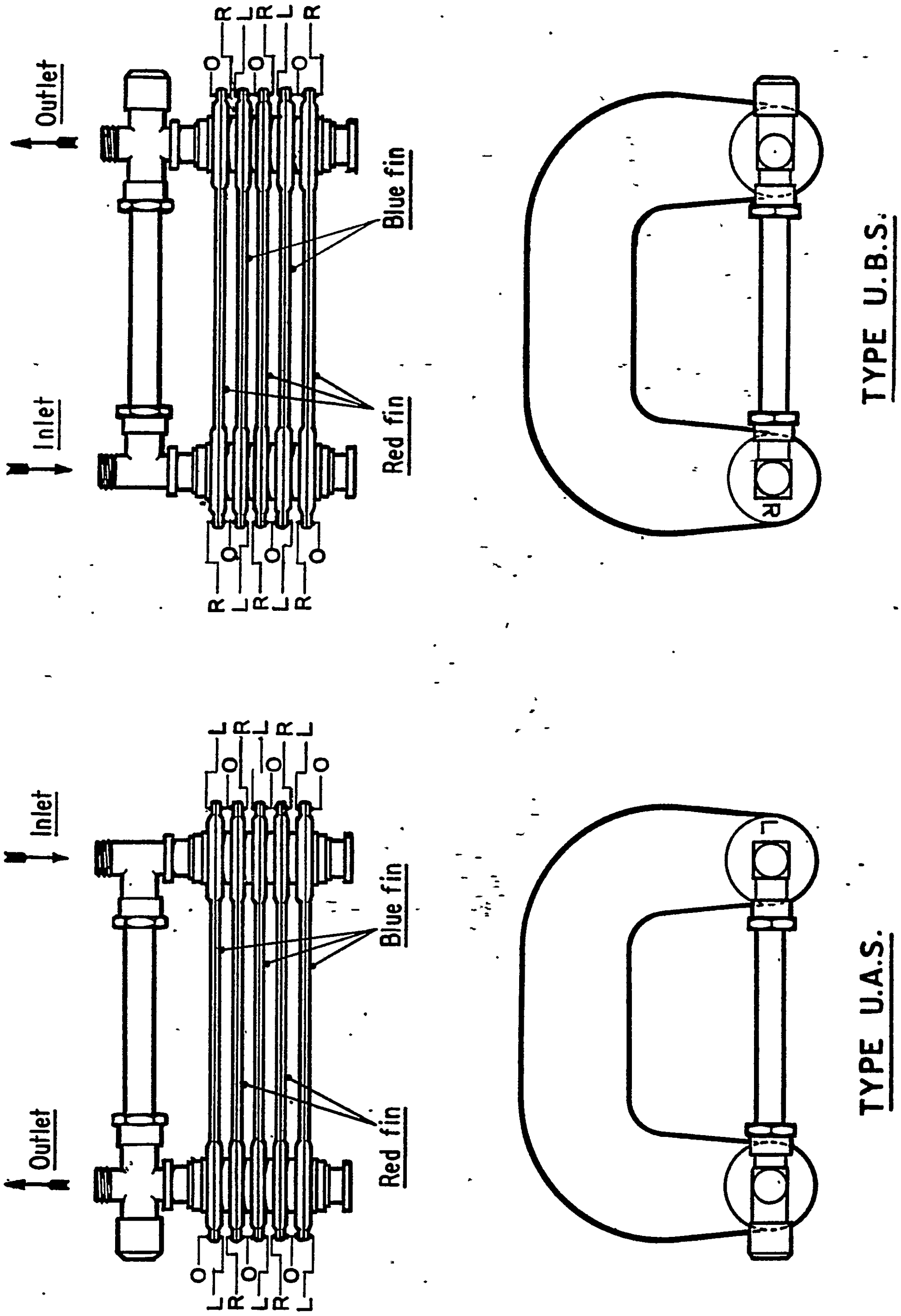


Fig. 12.—U-type oil cooler assemblies

Dismantling

32. The following is the sequence of operations for dismantling the cooler:—

(i) Mount the cooler on a fixture similar to that shown in fig. 4, by removing the drain plugs and substituting bolts with longer threads (⅛ in. B.S.P.). The fixture is made from a piece of 4 in. × 4 in. × ½ in. angle iron about 18 inches long. Two clearance holes should be drilled through the upper face of the fixture and also two holes shaped to suit the heads of the special bolts (see para. 15), both pairs of holes having a pitch of 12 inches. It is intended that the fixture shall be bolted to the side of the bench.

(ii) Unscrew the gland nuts from the inlet and outlet connections and remove the asbestos twine from the gland. The relief pipe can then be removed by withdrawing it into the gland of the outlet connection, thus allowing the olive to be removed from the inlet connection. The olive, gland nuts, etc., should be temporarily refitted on their respective connections.

(iii) Unscrew the connections from the connecting tubes. If a branch is tight, the connecting tube should be held by applying a spanner to the cap nut. Should the connecting tube become unscrewed from the cap nut, the tube can be unscrewed from the connection by first warming the latter in hot oil, holding the tube between wooden vice clams (similar to V-blocks) and applying a spanner to the hexagon on the connection. If both connections are tight, i.e., both tubes unscrew from their cap nuts, care must be taken when disconnecting the second tube to prevent the fin assembly from falling to the floor.

(iv) Unscrew the locknuts from the fin securing rods. Note the relative positions of the red and blue fins (see fig. 12) and remove the fins and spacing rings and place the components on a bench in their various groups.

(v) Examine the fins for damage and the threaded parts for signs of stripping and picking-up. Either of these defects necessitates rejection of the part concerned. Indentations in the fin are liable to cause a fracture to develop whilst the cooler is in use, and damaged threads cause oil leaks.

33. It will be observed that the fins employed are made in two types, i.e. left and right-hand which facilitates handed coolers being assembled when required. The left-hand fins are marked blue and the right-hand fins marked red. In addition the right-hand fins are stamped "R" and the left-hand fins are stamped "L", and each fin has an embossed "O" which enables an external check of the series flow of the oil through the cooler. The embossed "O" may also have an additional impression, namely "θ" if the fin is made of P.M.G. sheet, and "7" if the fin is made of M.G.7 sheet; brass fins (tinned) have no additional marking. The handed coolers are designated U.A.S. and U.B.S.

Cleaning

34. The cleaning operations described in para. 9 apply to U-type coolers, and in addition, care should be taken not to remove any of the blue or red marking from the fins. If this cannot be avoided or the marking has already been removed, the fins should be re-marked with air drying enamel of appropriate colour.

Repairs

35. Instructions regarding the extent to which repairs can be done are given in paras. 10 and 11.

Assembly

36. A method of assembling the various components and the precautions to be observed are given in paras. 12 and 13; the tables No. 1 and No. 2 do not apply to the U-type cooler.

37. An alternative form of assembling fixture which can be made locally is shown in fig. 13. This fixture consists of a piece of angle-iron (for bolting to the bench) on which two sliding supports (angle-iron) each having a clamping device can be adjusted. Two screwed sockets (as shown in the inset) should be made to form adaptors for the inlet and outlet connections. The sockets should be first screwed on the connections and then bolted to the fixture, and the by-pass pipe fitted as described in para. 19. The clamping devices should now be swung over the sleeve portion of the gland nuts, and tightened. All components should now be wiped clean. The cooler must be assembled in the following sequence, assuming that a U.A.S. Mark V cooler is required:—

(i) Connecting tubes, one in each branch connection. With the inlet tube on the left, its transfer holes should be uppermost, whilst the transfer holes of the outlet tube should be adjacent to the branch connection.

(ii) Plain spacing rings, one on each tube.

(iii) Blue fin
(iv) Red fin
(v) Blue fin
(vi) Red fin
(vii) Blue fin
} Assembled with intermediate spacing rings interposed between the fins and the respective markings of the fins as shown in fig. 12.

Note.—The transfer holes of the inlet tube should now be clear of the rim of the last fin as shown in fig. 14.

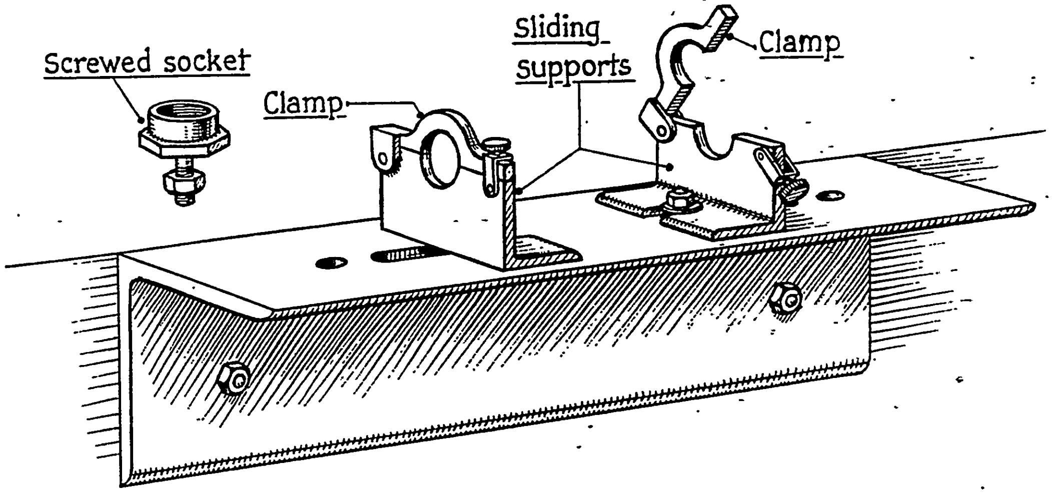


Fig. 13.—Assembling fixture

(viii) Plain spacing rings, one on each tube.

(ix) Fin securing rod. Fit the locknuts and tighten, so as to secure the fins together.

(x) Cap nut, one on each tube. Ensure that all intermediate spacing rings are central and correctly bedded down on the fins. Tighten the cap nuts with the spring-loaded spanner.

(xi) Drain plugs, one in each cap.

38. If a U.B.S. Mark V cooler is required, the sequence of assembly is as follows:—

(i) Connecting tubes, one in each branch connection. With the outlet tube on the left its transfer holes should be adjacent to the branch connection, while the transfer holes on the inlet tube should be uppermost.

(ii) Plain spacing rings, one on each tube.

(iii) Red fin
(iv) Blue fin
(v) Red fin
(vi) Blue fin
(vii) Red fin
} Assembled with intermediate spacing rings interposed between the fins and the respective markings of the fins as shown in fig. 12.

Note.—The transfer holes of the inlet tube should now be clear of the rim of the last fin as shown in fig. 14.

(viii) Plain spacing rings, one on each tube.

(ix) Fin securing rods. Fit the locknuts and tighten, so as to secure the fins together.

(x) Cap nut, one on each tube. Tighten the cap nut with the spring-loaded spanner.

(xi) Drain plugs, one in each cap.

39. When larger coolers are required, additional fins must be assembled in pairs as adopted for the second and third fin of the particular type. If a Mark 5/7 cooler is required, for example, a special two-element extension spacing ring (see fig. 3) must be fitted instead of the plain spacing ring mentioned in paras. 37 (ii) or 38 (ii).

Testing

40. The flow and pressure tests stated in paras. 22 to 24 should now be made to ensure correct functioning of the cooler, but the pressure to be applied is 25 lb./sq. in. for A.867 cooler (M.G.7 fins), and 90 lb./sq. in. for A.802 cooler (brass fins) and the A.826 cooler (P.M.G. fins). The working pressure for the A.867 type cooler is 15 lb./sq. in. and for the A.802 and A.826 types is 50 lb./sq. in. The pressure gauge should be secured in the hole normally occupied by the plug in the inlet branch connection. When the relief valve control mechanism is fitted, the gauge may be fitted in either drain plug orifice.

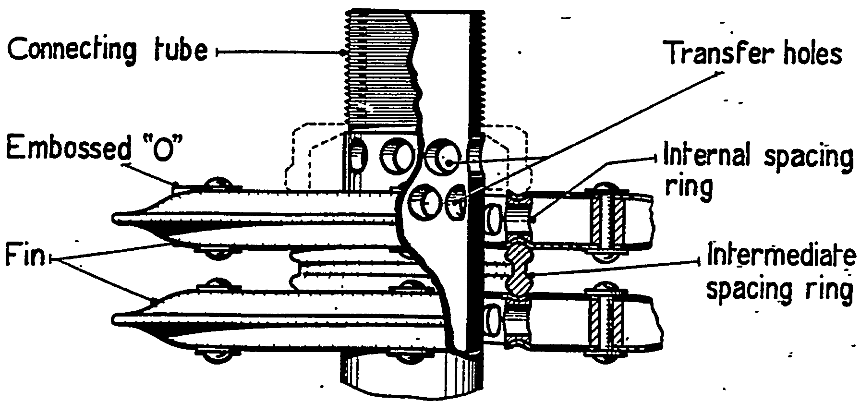


Fig. 14.—Connecting tube assembly, outer end

41. After completion of the flow and pressure tests, the drain plug must be locked as shown in the inset of fig. 1.

42. The whole cooler should now be thoroughly washed down with paraffin and finally dried off with a clean rag. All open orifices are to be suitably blanked off if not intended for immediate use and the cooler labelled to the effect that it has passed the prescribed tests. The precautions given in para. 25 for storing coolers in the filled condition should be observed where applicable.

LIST OF COMPONENTS FOR OIL COOLERS, AIR MINISTRY TYPE A.325

The following list of components is given for information purposes only. In ordering spares for oil coolers, the appropriate section of A.P.1086 (Priced Vocabulary of R.A.F. Equipment) must be used.

Stores Ref.	Nomenclature	Mk. V	Mk. VII	Mk. IX	Mk. XI	Mk. 5/7	Mk. 5/9	Mk. 7/9	Mk. 7/11	Mk. 9/11	Mk. 9/13	Mk. 11/13
Section 27A												
600	Caps, connecting tubes ...	2	2	2	2	2	2	2	2	2	2	2
	Connections:—											
601	Inlet, with plugs fitted and nipples loose	1	1	1	1	1	1	1	1	1	1	1
602	Outlet, with relief valve and gland nut	1	1	1	1	1	1	1	1	1	1	1
850	Controls, relief valve—complete with operating lever and pin unfitted	1	1	1	1	1	1	1	1	1	1	1
851	Levers, operating ...	1	1	1	1	1	1	1	1	1	1	1
852	Packings, gland ...	1	1	1	1	1	1	1	1	1	1	1
853	Pins, operating lever ...	1	1	1	1	1	1	1	1	1	1	1
603	Fins, complete	5	7	9	11	5	5	7	7	9	9	11
604	Pipes, oil relief—with collar and outer sleeve	1	1	1	1	1	1	1	1	1	1	1
843	Plugs, drain	1	1	1	1	1	1	1	1	1	1	1
	Rings, spacing:—											
842	Drain	1	1	1	1	1	1	1	1	1	1	1
605	Intermediate	8	12	16	20	8	8	12	12	16	16	20
606	Plain	3	3	3	3	1	1	1	1	1	1	1
	Special—											
871	Two element	—	—	—	—	2	—	2	—	2	—	2
1006	Four element	—	—	—	—	—	2	—	2	—	2	—
	Tubes, connecting:—											
608	5 fin	2	—	—	—	—	—	—	—	—	—	—
609	7 fin	—	2	—	—	2	—	—	—	—	—	—
610	9 fin	—	—	2	—	—	2	2	—	—	—	—
611	11 fin	—	—	—	2	—	—	—	2	2	—	—
—	13 fin	—	—	—	—	—	—	—	—	—	2	2

P5059 M /1335 9/44 5250 C & P Gp. 1

AIR MINISTRY *May, 1944*

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 14 to A.P.1464C, Vol. I and concerns Part 2, Sect. 3.
Insert this chapter.

CHAPTER 7

OIL COOLERS—ROBERTSON

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The Robertson oil cooler is made in a range of sizes to meet the different requirements of various types of aircraft. The types of coolers are, in general, similar in construction and operation, *i.e.*, each cooler is built to the size required from standard unit sections, the sections comprising a bank of tubes connected in the complete cooler to end covers incorporating inlet and outlet connections. The number of sections employed in any particular type of cooler depends on the working temperature of the engine of the aircraft and the volume of oil to be cooled to a specified temperature. Each cooler is mounted on the aircraft in an air duct; oil that has been heated by the engine is forced through the cooler, the cooling process being effected by the circulation of the oil through the air-cooled tubes. A full description of the oil cooler, together with information on the maintenance and repair of its components, is given in the following paragraphs.

Types of Robertson oil coolers

2. There are four types of Robertson oil coolers in use, built up with three, four and six unit sections, respectively; a modification of the three unit section cooler allows two or more coolers of this type to be mounted in series on certain aircraft. Details of the various types of coolers are as follows:—

(i) *R.H.5/29.*—This type of cooler is built up with four unit sections. An oil pressure relief valve is normally incorporated and adjusted to operate at a pressure of 35 lb./sq. in. This type is intended to be mounted in a wing of an aircraft, the inlet to the air duct being inserted in the leading edge.

(ii) *R.H.5/33.A.*—This type is built with three unit sections and suitable end covers; a relief valve is not employed. Twin coolers of this type are, in certain instances, fitted to particular engines and mounted in air ducts outside the engine nacelles.

(iii) *R.H.5/33.*—This type of cooler is similar in construction to the R.H.5/33.A., except that round section tubes are used in its construction. This cooler has been largely superseded by the R.H.5/33.A, but it is still used on certain types of engines.

(iv) *R.H.5/34.A.*—This type is built with six unit sections. A relief valve is generally incorporated, adjusted to operate at a pressure of 25 lb./sq. in. This type is intended to be mounted at the rear of the engine, the inlet to the air duct being inserted in the slipstream.

DESCRIPTION AND OPERATION

Construction

3. The unit sections of the coolers are, except in type R.H.5/33, built up from a number of anodically treated aluminium tubes of oval section, the rounded ends of which are fitted into aluminium end plates, the tubes being swaged to the round section at each end during the course of manufacture. When the tubes are in position in the end plates, aluminium nipples (see fig. 1) are

inserted in the tube ends and expanded in a press, thereby securing the tubes to the end-plates. Each complete tube block is arranged for series flow through the unit sections; the directional circulation of the oil through these unit sections, is effected by deflectors fitted in the collector covers. The collector covers are magnesium castings, the deflectors being cast integral with the covers; the number of deflectors in any particular cooler varies in accordance with the number of sections in the cooler. (See fig. 1.)

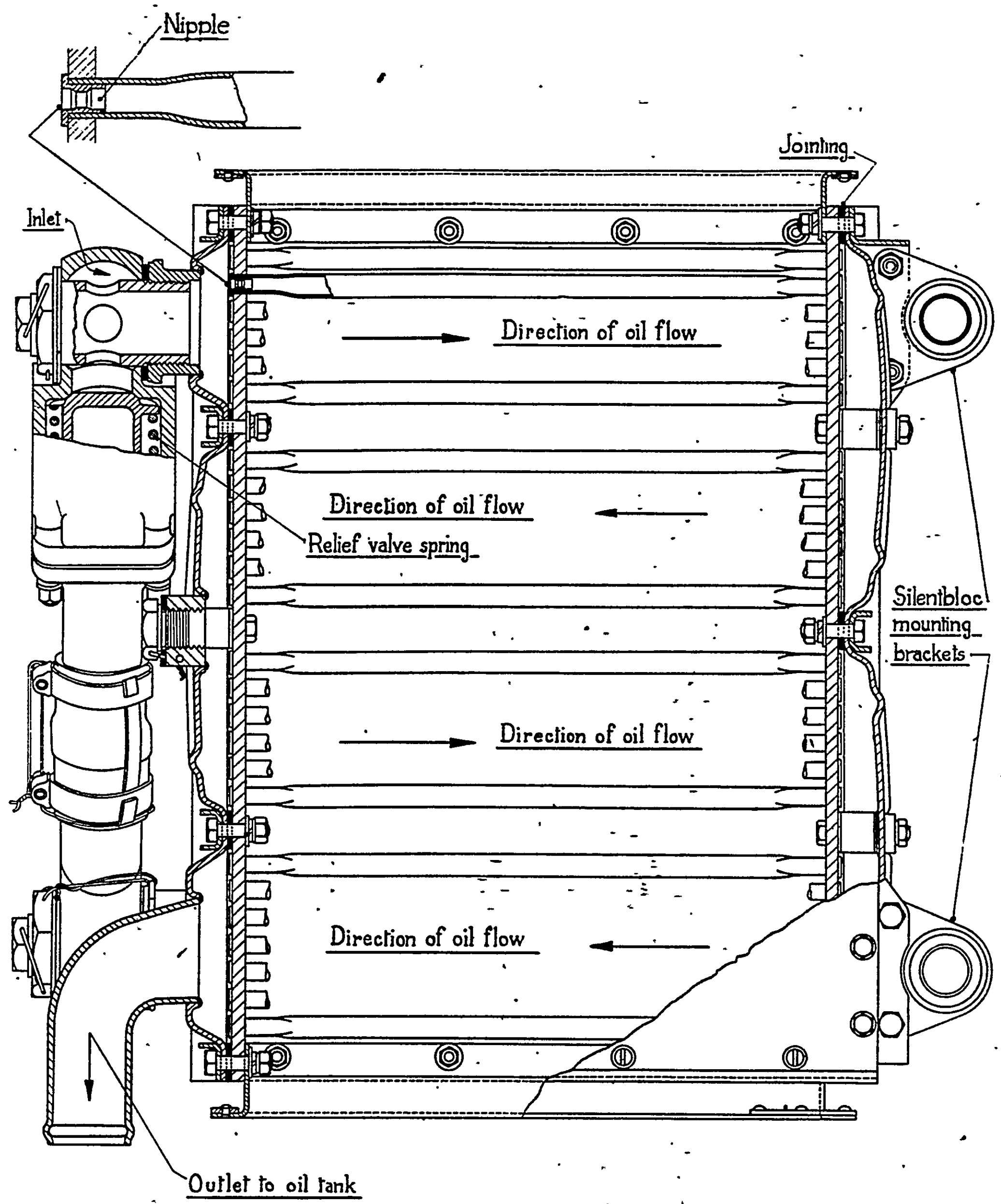


Fig. 1.—Oil cooler, Robertson Type R.H.5/29

4. Inlet and outlet pipe couplings are welded to the collector covers, and an oil pressure relief valve is connected between the inlet and outlet sections to allow a direct flow of oil from the scavenge pump to the oil tank when this valve is opened. The operation of the relief valve is dependent on the viscosity of the oil in circulation; if the oil in circulation is cold its viscosity is high, consequently it will not flow easily and a pressure is built up inside the cooler and, in order to protect the cooler from damage that would be sustained should the cooler be subjected to excessive pressures, the relief valve

is adjusted to open at a safe pressure, when the oil is by-passed through the valve. The opening of the relief valve also ensures that cold oil which does not require cooling is not circulated through the cooler, but is delivered directly to the storage tank on the aircraft with no change in temperature. In certain installations a viscosity valve is incorporated in the relief valve mechanism to ensure that the cooling process is not applied to the oil in circulation, until the rise in temperature has reduced the degree of viscosity of the oil. Gaskets are fitted between the tube block and the collector covers. Side plates are fitted on all models, and the inlet and outlet connections on the collector covers are suitable for coupling to 1 in. i/d rubber hose.

SERVICING

General

5. In order to ensure efficiency in operation particular attention must be paid to the servicing of these types of oil coolers. Details of the plant required to carry out the various routine servicing operations are given below; the periods at which these examinations must be made will be found in the maintenance schedules in Vol. II, Part 2, of the relevant aircraft handbook. The routine servicing operations consist of (i) regularly cleaning the interior of the tubes; (ii) checking the flow rate through the cooler to ensure there are no obstructions inside the cooler; (iii) examining the tube block for leaks during the cleaning operation and (iv) effecting the necessary repairs and replacements of new parts.

Cleaning

6. Coolers should be cleaned internally by pumping paraffin through the cooler in order to remove any solidified oil or foreign matter adhering to the tube walls. It is important that the tubes are kept clean, because the presence of any impurities in the system seriously restricts the flow of oil through the cooler and reduces the cooling area available, causing a corresponding loss of efficiency in the cooler. Details of the plant required to effect the cleaning operation and method of using it are as follows:—

(i) *Cleaning plant.*—A layout of the plant necessary to enable cleaning and flow testing operations to be effected is illustrated in fig. 2. This consists of a main tank, a hand or motor driven pump and a header tank, with pipe-lines connecting the pump to the tanks and the cooler to be cleaned. A tray in which the cooler is mounted is provided with a drain to the main tank to avoid loss of paraffin.

(ii) *Cleaning tubes.*—To clean the cooler it will be necessary first to remove the side plates from each end in order to expose the tubes. The cooler should then be mounted in the tray and the cooler inlet coupled to the header tank outlet pipe. The main tank should be filled with paraffin, which should be circulated through the header tank into the cooler until all the oil is removed from the interior of the cooling tubes; this can be ascertained by observing the condition of the paraffin leaving the cooler.

(iii) *Cleaning relief valve.*—Care must be taken when dismantling the oil pressure relief valve not to alter the tension of the valve spring. The valve seats can be examined and cleaned after removing the hexagonal fitting from the top of the valve casting, the cleaning of the faces of the valve being effected with soft clean rag. When replacing the valve in position make certain the stem works freely in its guide, any high spots should be eased, taking care not to damage the valve. When the valve is clean and free in its guide, the hexagonal fitting should be replaced in position and locking wires inserted through the holes provided for this purpose.

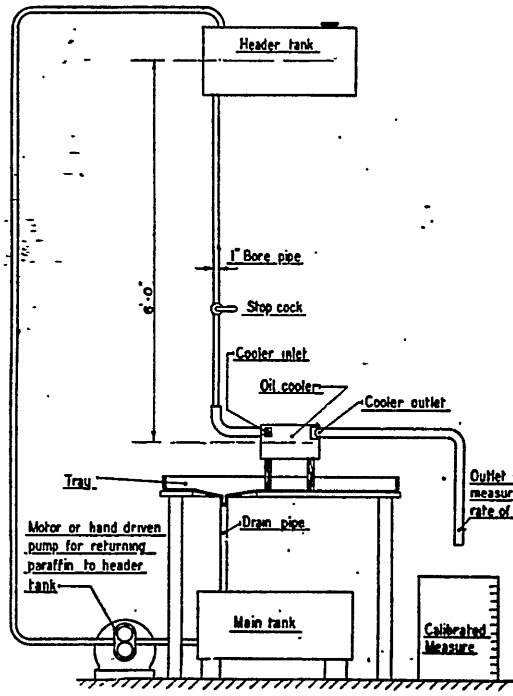


Fig. 2.—Cleaning and flow testing plant

Testing

7. Testing the flow-rate through the cooler and testing for leaks, is effected by using the cleaning plant described in para. 6 (i), in the following manner:—

(i) *Connecting the cooler.*—A layout of the plant required is illustrated in fig. 2. Connect the inlet of the cooler to the header tank outlet and connect the outlet of the cooler so that it discharges into a calibrated measure, care being taken to ensure that the fittings used will not restrict the flow of paraffin through the cooler. Fill the header tank with paraffin and shut off the pump supplying the header tank.

(ii) *Flow test.*—The flow-test is intended to indicate the number of gallons of paraffin per min. that can be circulated through a cooler from a tank mounted six feet above the cooler. The flow-test is made by first priming the cooler by allowing paraffin to pass through it from the header tank until there is a steady flow, free from air, and then noting the number of gallons passing through the cooler in a given time. This is accomplished by checking with a stop-watch the number of seconds it takes to fill a calibrated measure, calculating the flow-rate per minute from the figures obtained. The figures given below refer to the average flow-rate that should be obtained through the various types of coolers using the method given above; the maximum permissible reduction in flow-rate is 10 per cent.

(*a*) Type R.H.5/29 ... ... 16 galls. per min.
(*b*) Type R.H.5/33 ... ... 13·85 galls. per min.
(*c*) Type R.H.5/33A ... ... 13·3 galls. per min.
(*d*) Type R.H.5/34A ... ... 9·8 galls. per min.

(iii) *Test for leaks using cleaning plant.*—When testing the cooler for leaks, the paraffin should be circulated through the cooler as described in para. 6 (ii) for cleaning, and the tube block examined for signs of leakage from damaged tubes, tube ends, cover joints and couplings. Leakage may occur at the cover joints, caused by shrinkage of the gasket, in which case the joint bolts should be carefully tightened. If the leakage continues, or a leak is located elsewhere in the cooler, the cooler should be removed from the test stand, thoroughly dried out, and the necessary repairs effected as outlined under appropriate headings in this chapter.

Blanking after test

8. After the tests have been completed, the cooler should be flushed out with flushing oil or oil lubricating D.T.D.109 and thoroughly drained and if it is not required for immediate use, the inlet and outlet fittings should be suitably blanked off with cork or wooden plugs in order to prevent the ingress of foreign matter, after which the coolers should be labelled to indicate that they have been cleaned and have passed the prescribed tests on a given date. Coolers being packed for shipment are to be blanked off with the proper fittings listed in the Airframe handbook, Vol. III, Schedule of Spare Parts.

Repairing oil coolers

9. The general construction of these coolers allows for complete faulty sections to be removed and replaced without complication but, in cases where tubes are to be replaced, special tools, as listed in A.P.1086, are necessary for the operation. Additional tools may be required to effect repairs to coolers installed on certain types of aircraft, and in such instances the additional requirements are listed in the relevant Airframe handbook, Vol. III, Schedule of Spare Parts. Temporary repairs can be effected in emergency by sealing the ends of the damaged tubes with moulded rubber plugs. Oval section tubes are now standardised on all coolers except type R.H.5/33, but in circumstances where round tubes only are available as spares, these tubes may be used for effecting repairs without seriously impairing the efficiency of the cooler, but the number of such tubes inserted in a complete cooler normally using oval section tubes should not exceed 10 per cent. of the total.

Temporary repairs

10. Temporary repairs to damaged or faulty tubes in these coolers can be effected in an emergency by inserting moulded rubber plugs in the ends of the damaged tubes; the number repaired by this method in any complete cooler should not exceed 30. These plugs, see fig. 3 (III), fit into the connecting nipples and are inserted by means of plug inserting pliers, see fig. 3 (III). These pliers force the rubber plugs into the tube ends, completely sealing faulty tubes, but new tubes must be inserted at the first opportunity. The plugs may be inserted according to the position of the damaged tubes. Tubes in an outer tube row can be repaired without removing the collector covers, the sealing operation

being effected from the inside or *air* side of the tube block. In cases where the tube to be plugged is situated in an inner tube row and is not accessible from the inside of the tube block, it will be necessary to remove the collector covers and insert the plug from the outside or *oil* side of the tube block.

(i) *Removal of damaged tube for plugging operation.*—Before inserting the moulded rubber plugs, the faulty tube must be removed to expose the nipple ends. The tube can be removed by passing a piece of Bowden wire around the tube midway between the end plates, then gripping the ends of the wire firmly by means of a piece of wood, pulling the wire until the tube breaks off at each nipple. Normally, the action of pulling the tube at the centre will cause it to break close to the plate at each end exposing the nipple in a manner suitable for inserting the plug. It is possible, however, when a tube is locally weakened or damaged, that a portion of the tube will protrude above the edge of the nipple; this must be cleared away to permit the use of the insertion tool. Care must be taken, if pliers are used to extract the piece of tube not to damage any of the surrounding tubes, as these tubes are anodically treated to prevent corrosion, and damage to this anodic film will set up corrosion almost immediately.

(ii) *Inserting a plug in an outer tube row.*—When inserting a plug in an outer tube row from the *air* side of the end plate, a rubber plug must first be eased into the holder of the insertion tool, see fig. 3 (III), then, with the spigot of the tool in position in the nipple, the plug can be introduced by closing the lever arm of the tool. It should be noted that a plug is required for each nipple exposed in the end plates by the removal of damaged tubes.

(iii) *Inserting a plug in an inner tube row.*—In cases where the faulty tubes are not accessible from the *air* side of the end plate, the collector covers must be removed by removing the flange bolts. When the collector covers are removed the faulty tube ends can be sealed with rubber plugs using the pliers in the manner described in para. 10 (ii). When the plugs are inserted by this method it is not necessary to remove the damaged tubes from the cooler; these can be left until new replacement tubes are inserted.

(iv) *Test.*—Temporary repairs can be tested as outlined in para. 7 (iii) using the cleaning plant for the purpose. The plugging of tubes will tend to restrict the flow-rate; the maximum permissible reduction in flow-rate allowed is indicated in para. 7 (ii).

Permanent repairs

11. Permanent repairs involve the replacement of damaged tubes by new ones and can only be effected by using special tools. The coolers have to be dismantled and they must be subjected to an air test before being passed as serviceable. The plant required to enable tests to be made to permanent repairs consists of:—

(i) A water tank, large enough to submerge the cooler completely in order that it may be subjected to an air-pressure test; facilities should be available for heating or maintaining the water at a temperature of approximately 40° C. (104° F.), which is the normal working temperature of this type of cooler.

(ii) Facilities for applying and maintaining an internal pressure of 50 lb./sq. in. inside the cooler, comprising an air pump with connections and equipment for connecting the cooler inlet to the compressed air supply and for plugging the cooler outlets.

Test

12. The approved test is to immerse the complete cooler in a bath of hot water maintained at a temperature of approximately 40° C. whilst subjected to an air-pressure test of 50 lb./sq. in. for a period of five minutes. If no leakage is noted during this test, the cooler must be thoroughly dried out and wiped over with a paraffin soaked rag to remove stains, and be labelled and blanked off as described in para. 8.

Tools

13. The special tools (see A.P.1086) necessary to enable tube repairs to be effected on this type of cooler are:—

(1) Guiding tool.
(2) Locating tool.
(3) Hand drifting tool.
(4) Nipple extractor.
(5) Nipple expander.
(6) Plug insertion pliers.
(7) Alignment key.
(8) Spanners 2 B.A., 4 B.A., and 2 B.A. universal tube spanner.
(9) End plug.

Repairs to tube block

14. To effect repairs to the tube block, first remove the cover plates to expose the tubes and subject the cooler to the air-pressure test outlined in para. 12. For this preliminary test the pressure should be applied slowly, the object being to reveal the leakage source. Should leaks be traced to damaged tubes or connecting nipples their position should be carefully noted. If a thin strip of metal having one true edge is inserted between the tube rows, and held up to the end plate it will assist in tracing leaks by isolating the source of the air bubbles. When all leaks have been located and their positions noted, the cooler should be disconnected from the air supply and be carefully dried out.

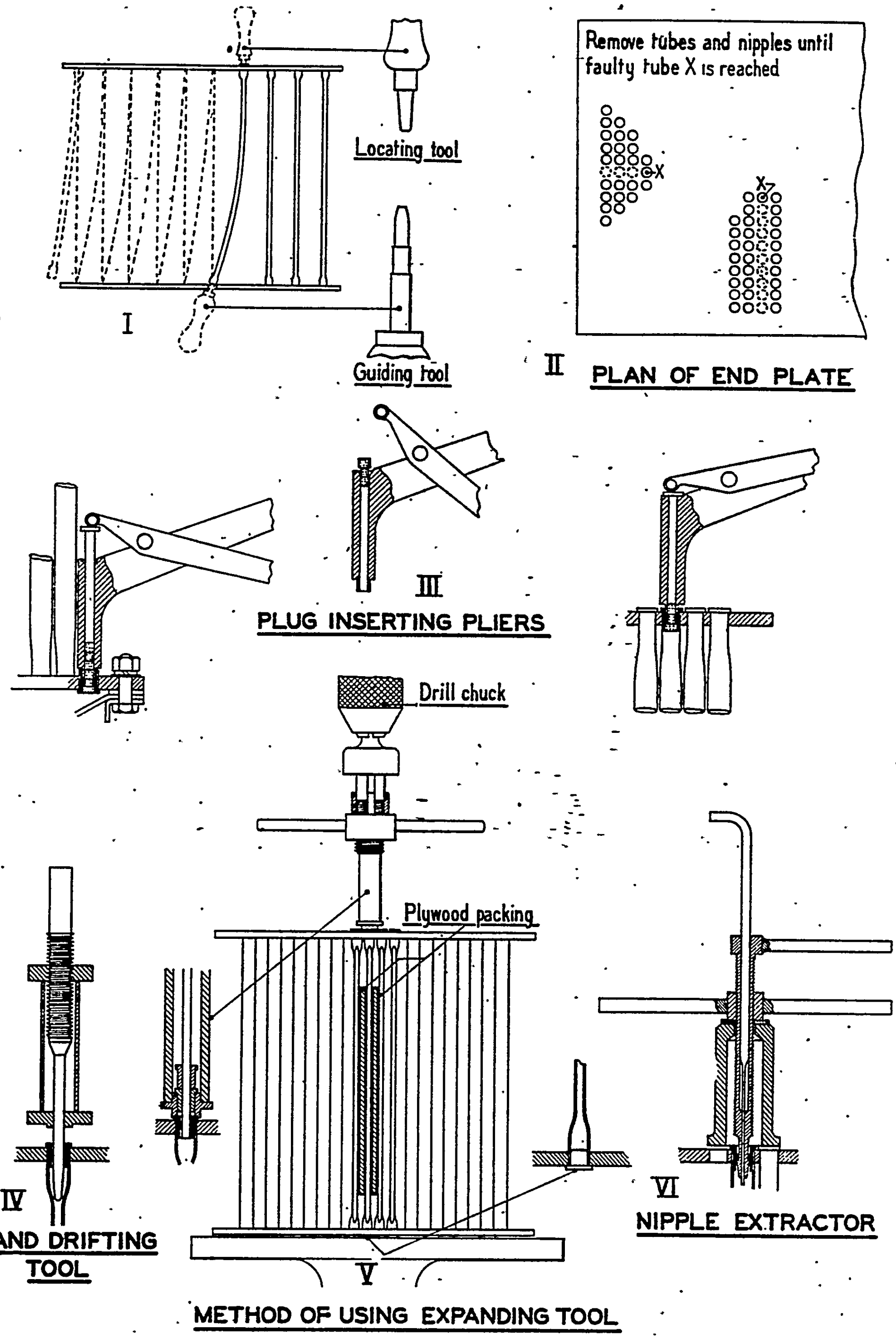


Fig 3.—Special tools

Leaks caused by slack tube nipples can generally be remedied by first removing the collector covers, then expanding the defective nipples, using the hand drifting tool, see fig. 3 (IV); if it is found impossible to stop the leaks by this method the damaged tubes must be removed and replaced by new ones. It should be noted that in some instances leaks which may appear to be at the nipple joint may be caused by damaged or faulty tube ends.

15. If the tube to be replaced is situated in an outer tube row it will be readily accessible for removal, but should it be in one of the inner rows it will be necessary to remove a line of tubes to make a path for the removal of the faulty one. When removing and inserting the tubes it should be noted that, because of its oval section, the tube will bend more readily in one plane than the other, and advantage should be taken of this fact when inserting new tubes. Fig. 3, sketch II, shows two examples of tube replacements to inner tube rows.

Removal of connecting nipples

16. In order to remove tubes without damaging them, it is necessary to extract the nipples which secure the tubes to the end plates, for which purpose the nipple extractor tool (see fig. 3, sketch VI) should be used in accordance with the following sequence of operations.

(i) The nipple extracting tool head should be inserted in the bore of the nipple to be extracted; the enlarged head of the tool is thereby contracted and passed through the centre bead inside the nipple.

(ii) The collet on the tool should then be expanded by pressing the expander down; with the tool in this position, the nut should be screwed down until it bears on the face of the washer.

(iii) The extractor body should seat on the heads of the nipples surrounding the one to be extracted, with the head of the collet expanded inside the nipple, in such a manner that its enlarged end is bearing on the beading inside the nipple. The nipple can then be withdrawn by tightening the nut.

(iv) When both the nipples have been extracted from the tube ends, the tube can be removed by pushing it through the end plate, using the locating tool as illustrated in fig. 3 (I) until one end of the tube is free; the free end should be flexed until it is in line with the next hole. The guiding tool is inserted in this hole to guide the tube, and the tube is eased forward from the other end by the locating tool until the tube ends are flush with the outer faces of the end plates again. From this position the tools are changed to opposite hands, and the tube is eased through until it projects $\frac{3}{16}$ in., leaving the other end clear of the inside of the plate; the free end is again flexed until it is in line with the next hole, the operation of threading from one hole to another being continued until the tube can be removed from the block.

Insertion of new tubes

17. The insertion of new tubes can only be effected by the correct use of the locating and guiding tools (see fig. 3, sketch I). The locating tool should be inserted in the tube end, the guiding tool being placed in the first tube hole. It will be found that the tubes are sufficiently flexible to enable them to be threaded into position, using the guiding tool to keep the tube central. Care should be taken when flexing the tubes during this operation, otherwise they will collapse. When the first tube has entered in the first hole in the end plate, the tube should be pushed through until the end projects a distance of about $\frac{3}{16}$ in. The guiding tool must now be transferred to the opposite hand, when it will be found that, after removing the locating tool, the free end of the tube will just clear the inside of the end plate, allowing it to be flexed until the end is in line with the second hole. The guiding tool is then inserted through the second hole and into the tube end, after which the tube is eased forward from the other end by means of the locating tool, until the tube ends are flush with the outer faces of the end plates. From this position the tools are again changed to opposite hands and the tube eased through until it projects $\frac{3}{16}$ in., the operation of threading from one hole to another being continued until the tube is in the required position, this operation being repeated until all the new replacement tubes and the remaining sound tubes are in the block. Any which are not correctly aligned should be turned until they are in line with the other tubes, using an alignment key for the purpose, inserting the blade end of the key into the tube end, when the tube may be turned in the required direction.

Fitting nipples

18. When all the new tubes are in position, nipples should be fitted to each tube end. This is effected by using the expanding tool (see fig. 3, sketch V), which consists of a central draw rod having an enlarged end which is held in the chuck of a drilling machine, using the machine as a press. Several nipples are threaded on the central draw rod of the tool and then inserted, one at a time, into the

tube ends. When a nipple is in position in a tube end, the enlarged end of the draw-rod is pulled through the bore of the nipple, thus expanding the nipple into the tube. Nipples are fitted as follows:—

(i) Insert the expanding tool in the spindle of a drilling machine, and secure the spindle in such a manner that it will not rotate, the drilling machine being used as a press for this operation.

(ii) Thread six nipples on the draw rod, insert it into the tool, and screw it into the boss of the four-pronged nut.

(iii) In preparing a nipple for expansion, the slotted washer must be in position. To release this washer, the nut adapted to take a tommy bar should be screwed down the body of the tool to allow the four-pronged nut to fall. When the slotted washer has been removed, the succeeding nipple should be dropped until it rests on the enlarged end of the draw-rod; the washer is then replaced behind the head of the nipple. If the tommy bar nut is now screwed upwards until it is finger-tight, the nipple is ready for insertion into the tube block.

(iv) The tube block must rest squarely on the drilling machine and be moved in such a position that the nipple on the draw-rod of the tool is in a direct line with the tube in the end of which a nipple is to be inserted.

(v) To prevent movement of the tube when the nipple is inserted, an end plug having a slightly thicker head than a standard nipple is provided. This end plug is pushed into the lower end of the tube and, because it has a thicker head than the surrounding nipples, the end thrust arising from the insertion of the nipple is transmitted directly to the table of the drilling machine, thus preventing any movement of the tube. Care must be taken to ensure that the head of the end plug is bearing on the solid surface of the drilling machine.

(vi) With the tube block in position, the drilling spindle can be brought down until the nipple enters the tube end. It should be noted that it is only necessary to apply sufficient pressure to ensure the shoulder of the nipple is bearing evenly on the end plate, any excess pressure will only bend the plate.

(vii) To expand the nipple after insertion in the tube end, the nut adapted to take the tommy bar is screwed upwards, forcing the enlarged end of the draw-rod through the bore of the nipple, thus expanding the tube into the end plate wall.

(viii) The nipple insertion and expansion operation should be repeated until all the tubes are secured to the end plates. The tube block should then be cleaned by blowing through the tubes with compressed air to remove any particles of aluminium, etc., that may be left in the tube block.

19. When the repairs to the tube block are completed the collector covers should be fitted, the cooler air-tested for leaks (see para. 12), and the flow-rate tested (see para. 7 (ii)). Coolers fitted with an oil-pressure relief valve should be tested to ensure this valve will not open until the pressure, stamped on the name plate, is applied to the cooler inlet. When the cooler is proved satisfactory the side plates should be replaced, and the cooler labelled to denote that it is available for service, having passed the prescribed tests on a given date. Coolers not required for immediate use must be blanked off with the fittings listed in Airframe handbook, Vol. III, Schedule of Spare Parts, and be returned to stores.

P5061 M /1337 9/44 5250 C & P Gp. 1

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 15 to A.P.1464C, Vol. I and concerns Part 2, Sect. 3

Insert this chapter.

RESTRICTED
(For official use only)

CHAPTER 8

OIL COOLERS—SERCK TYPES

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The Serck oil cooler (see fig. 1) for aircraft is of the drum type and comprises a tube block mounted within a casing through which oil is forced to take an indirect path through the block by means of a series of carefully arranged baffles. When the oil is cold most of it passes right round the block without circulating through the tubes and then, as it warms up and the viscosity is reduced, it is gradually passed through the tubes. A by-pass valve is fitted to the cooler which may be a simple spring-loaded type operated by the increase in pressure caused by the viscosity of the oil at low temperatures or it may be a thermostatically operated valve designed to open at a predetermined temperature; a viscosity valve may alternatively be used which by-passes the oil in increasing amounts as the viscosity increases and vice-versa. The oil circulating around the tube block during the initial warming up transmits heat to the oil in the tube block thereby assisting circulation.

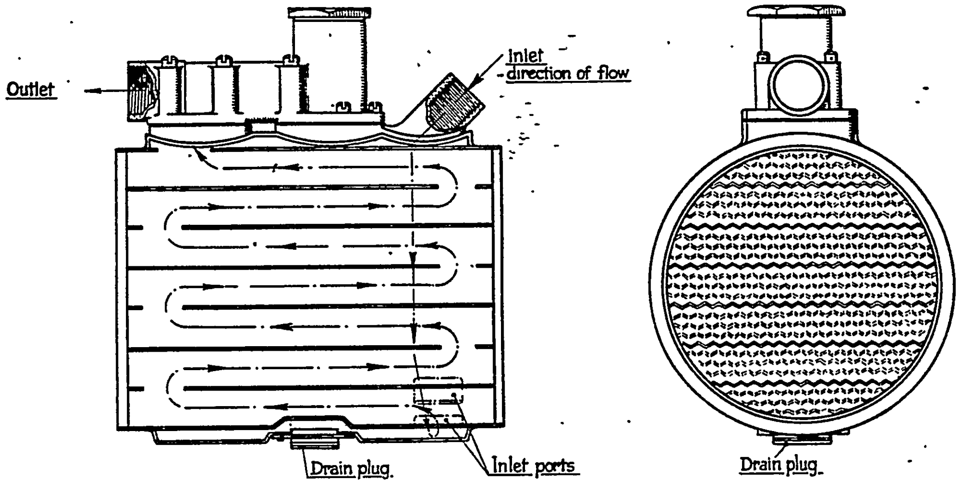


Fig. 1.—Serck oil cooler, showing baffles and direction of oil flow

Construction

2. The tube block is built up of a number of round tubes expanded at the ends to an hexagonal shape and divided into groups by means of baffles so providing separate flow paths for the oil with communicating ports at alternate ends. The positions of the baffles are plainly visible on examination of the tube block face, the number of baffles fitted varying with the size of the cooler.

3. During manufacture the tubes and baffles are built up in a special clamp and the ends are then dipped in a bath of molten solder. After this operation the tube block is soldered into position in the sheet-brass casing or jacket. The valve mounting is a gun-metal casting brazed to the casing and machined to fit the valve face.

SERVICING

4. During servicing operations care should be taken to avoid damaging the tube block or the casing. The general principles of repair are similar to those for the repair of radiators in aero-engine cooling systems as described in other sections of this publication, see List of Chapters. The by-pass valve incorporated in the cooler should be maintained according to the type of valve employed. Any packing or insulating strip removed when the cooler is dismantled from the aircraft should be retained unless it is damaged or worn, in which case new strips of the same material should be obtained.

5. In certain installations where the by-pass valve is positioned below the cooler the valve cap functions also as a drain plug, and if care is not taken when it is removed during draining operations the valve and spring may fall out. When the cap is being replaced the spring should be positioned between the valve and the cap, otherwise the cooler will not function correctly.

Cleaning

6. The cooler should be kept clean and free from foreign matter, internally and externally. The exterior should be washed by means of a strong jet of paraffin or water directed through the tubes in the reverse direction to that of air flow after which the honeycomb should be examined to ensure that the tubes are clear; any foreign bodies wedged in the tubes should be carefully removed. Internal cleaning should not be necessary as this is effected by the regular changing of the engine oil during routine inspections. If, however, the presence of foreign matter is suspected the cooler should be cleaned out by means of paraffin from a supply having a 6 ft. head connected to the outlet in order to obtain a flow reverse to the normal. After long service a thin film of carbon becomes deposited on the interior of the tubes but as this does not affect the efficiency of the cooler to any appreciable extent no attempt should be made to remove it.

Temporary repairs

7. A leak at the tube ends can be repaired by soldering, when it should be ensured that the solder runs into the joint. If the solder does not run freely after the application of the flux and soldering iron, one or more of the tubes should be removed in order that the end can be re-tinned.

8. In an emergency a tube which is leaking along the tube, away from the ends, can be repaired quickly by inserting a short wooden plug or a piece of asbestos string in each end of the tube, and then floating a thin layer of solder over it in order to seal it. Such a repair should be regarded as an emergency measure only and the faulty tube should be replaced by a new one as soon as possible.

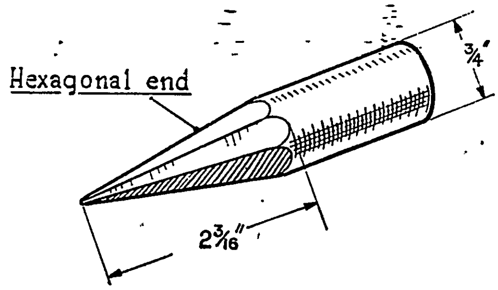


Fig. 2.—Steel bar for heating tube ends

Permanent repairs

9. In order to repair a cooler in which some of the tubes are damaged and are leaking, the faulty tubes should be replaced by new ones. The tubes should be removed by means of two heated hexagonal rods (see fig. 2) which should be inserted one in each end of a tube to melt the solder, pressure being applied to one rod so as to force the tube through the block. When the tube has been released at the hexagonal ends the projecting end of the tube can be gripped and extracted by means of a pair of pliers which have been filed or ground on the jaws to fit the tubes (see fig. 3).

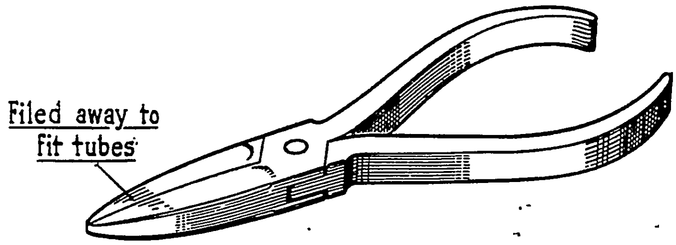


Fig. 3.—Pliers for extracting unsweated tubes

10. The new tubes should be tinned at the ends and inserted in the blank spaces in the tube block after which the ends should be expanded by means of an hexagonal taper drift until the tube end fits snugly into the space between adjacent tubes. The replacement tube or tubes should then be soldered in position, care being taken to prevent flux from entering the tube block in excessive quantities. After the operation has been completed the cooler should be thoroughly washed out in hot water, then dried thoroughly and flushed out with engine oil.

Testing after repair

11. In order to test a cooler after repair the outlet should be blanked off and the inlet connected to an air supply at a pressure of 70 lb./sq. in. The cooler should then be submerged in water at a temperature of 40° C. for a period of at least 15 minutes whilst the air pressure is applied, without signs of leakage.

12. A flow test should also be made under a 6 ft. head by means of a similar test rig to that described in Chapter 7 of this Section. During the test, paraffin should be used and the following flow rates should be obtained according to the type of cooler:—

Types S	*Flow rate—gal. per hour* Min.	Max.
59—3C	432	480
69—3C	432	480
89—525R	337	348
99—4C	432	465
109—4C	465	490
1011—4C—525R	327	348
1111—4C—525R	327	360

13. When the coolers have been tested and are found to be satisfactory the paraffin should be allowed to drain out after which the coolers should be flushed out with engine oil in order to remove all traces of paraffin and so reduce any possibility of internal corrosion. If the coolers are not to be fitted immediately or are to be stowed for some time the inlet and outlet orifices should be blanked off by means of the fittings provided, after filling with oil, lubricating, D.T.D.109. New oil coolers in store or installed in airframes should also be filled but serviceable coolers removed from aircraft after flight need not be filled.

P5063 M /1339 9/44 5250 C & P Gp. 1

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 16 to A.P.1464C, Vol. I and concerns Part 2, Sect. 3.
Insert this Chapter.

RESTRICTED
(For official use only)

CHAPTER 9

RELIEF VALVES—ROBERTSON

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Type R.V. 2

1. The type R.V. 2 relief valve (see fig. 1) comprises a body built up in two parts, a spring-loaded piston and a screwed-sleeve union fitted with a lock-nut. The two parts of the valve body forming the inlet and outlet respectively are spigoted at the joint and are held together by means of studs and nuts. The piston slides in the outlet half of the body and seats on the interior of the inlet half, being normally held in the closed position by means of a coil spring which bears on a flange on the piston and valve body respectively. Slots are machined in the walls of the piston through which the oil flows from the inlet to the outlet when the valve is lifted from its seat by the pressure built up in the oil system. The pressure at which the valve opens is generally indicated on a name-plate attached to the valve body and depends upon the strength of the spring.

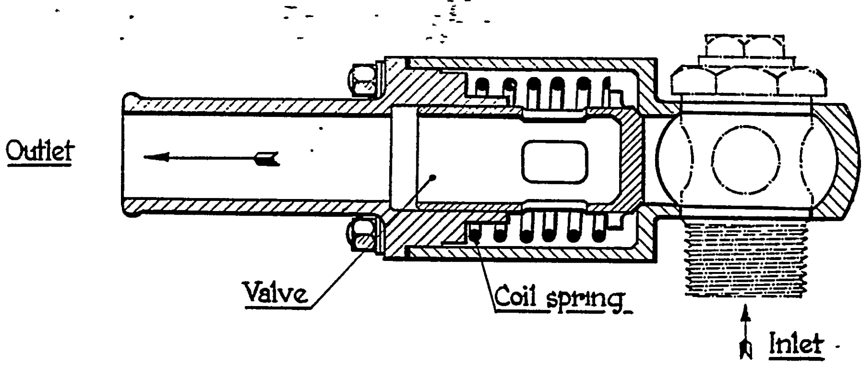


Fig. 1.—Relief valve, type R.V.2

Type R.V. 6

2. The type R.V. 6 relief valve (see fig. 2) has a body cast in one piece embodying the inlet and outlet flanges which are arranged at a right angle to one another. The valve body houses a spring-loaded piston, the crown of which closes the inlet orifice, the spring being held in compression against

the inner flange of the piston by means of an end cap which is secured to the valve body by means of four studs and nuts. Holes are drilled in the wall of the piston, of such a size that when the valve is in operation and the oil is cold and therefore viscous, the opening of the valve is retarded.

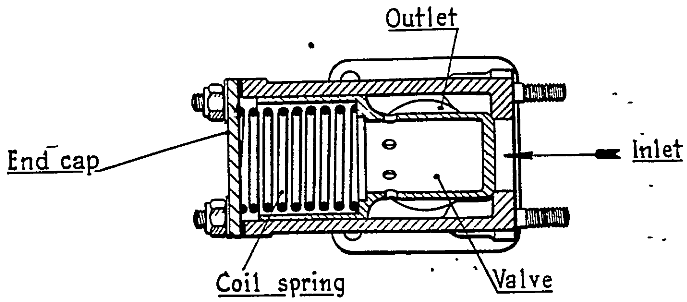


Fig. 2.—Relief valve, Type R.V.6

Servicing

3. The relief valves should be maintained in an oil-tight condition and examined periodically at the inspection periods specified in the Maintenance Schedule of the relevant aircraft handbook, Vol. II, Part 2. The valves should be tested according to the type as outlined below, each valve being subjected to a pressure test and a flow test; for the purpose of the tests a supply of heated oil under pressure which can be regulated within the limits specified below, will be required:—

(i) *Pressure test.*—The valve inlet should be coupled to the oil supply and the outlet fitted with a drain pipe leading to a suitable receptacle which will hold the oil which passes through the valve during the tests; the temperature of the oil supply should be 80° C. ± 3° C. The pressure should be applied gradually whilst it is allowed to build up from zero until the valve lifts, which should be at a pressure between the limits of 32 to 36 lb./sq. in. for the R.V. 2 type and 24 to 27 lb./sq. in. for the R.V. 6 type.

(ii) *Flow test.*—During the flow test the oil should be maintained at a temperature of 80° C. ± 3° C. and the valve should be coupled to the supply in a similar manner to that employed in the pressure test. The following are the correct test pressures and flow rates for each type of valve:—

(*a*) *R.V. 2 type.*—At a pressure of 40 lb./sq. in. the flow rate past the valve should not be less than 170 gal. per hour (1 gal. in 21·2 sec.). The pressure should then be progressively reduced from 40 lb./sq. in. to 20 lb./sq. in. when the oil flow rate past the valve should not exceed 5 gal. per hour (1 qt. in 3 min.).

(*b*) *R.V. 6 type.*—At a pressure of 35 lb./sq. in. the flow rate past the valve should not be less than 200 gal. per hour (1 gal. in 18 sec.). The pressure should then be progressively reduced from 35 lb./sq. in. to 15 lb./sq. in. and at this lower pressure the flow rate past the valve should not exceed 5 gal. per hour (1 qt. in 3 min.).

Faulty valves

4. Valves which are found to be faulty by the above tests, the correct test pressures and flow rates not being obtained, should be dismantled and a new spring of the correct type fitted. If the lower flow rate (obtained after progressively reducing the pressure during the flow test), is more than the amount stated in the preceding paragraph for the particular type of valve, the valve faces and the seat should be examined and, if worn or not seating correctly, the valve should be lightly lapped in, using metal polish applied to the seat only; a piston which is deeply ridged on the seat should be exchanged for a new one. A piston that tends to bind should be examined for high spots which should be eased by means of a scraper, after it has been ensured that the tightness is not the result of a damaged relief valve body. When re-assembling the valve, joint washers of the same type and thickness as the original should be used.

P5065 M /1341 9/44 5250 C & P Gp. 1

SECTION 4

DE-ICING EQUIPMENT

LIST OF CHAPTERS

Note.—*A list of contents appears at the beginning of each chapter.*

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 17 to A.P.1464C, Vol. I and concerns Part 2, Sect. 4
Insert this chapter.

RESTRICTED
(For official use
use)

CHAPTER 1

DE-ICING EQUIPMENT FOR PROPELLERS

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. De-icing equipment for propellers provides means for maintaining a film of de-icing fluid on the blade surfaces of a propeller during flight under conditions conducive to the formation of ice. The fluid has a freezing point of about —40° C. and it prevents heavy ice formation on protected surfaces by mixing with the water or ice deposits, reducing the freezing point of the mixture to a temperature lower than any likely to be encountered during normal flight. In addition the de-icing fluid is highly penetrative and, when applied to a blade surface on which ice has already formed, percolates under the ice which is thereby loosened sufficiently to be thrown off centrifugally.

List of components for propeller de-icing

2. Propeller de-icing equipment consists generally of the following components, details of which are given in subsequent paras.:—

(i) De-icing fluid tank.
(ii) Filter.
(iii) Electrically driven pump with rheostat control.
(iv) Slinger ring with feed pipes.
(v) Spinner.
(vi) Check valves.
(vii) Pipe-lines and connections.

Layout of components

3. The equipment comprises an electrically driven pump delivering de-icing fluid from a tank to the feed pipes of a slinger ring mounted on the propeller hub. The outlets of the feed-pipes are arranged in alignment with the leading edge of each blade and the de-icing fluid is distributed over about one-third the length of the blade, the remaining two-thirds being kept free from ice by virtue of the increased temperature resulting from drag and by the increased effect of centrifugal force. The propeller hub is protected from ice accretion by means of the spinner. The delivery rate of de-icing fluid under normal conditions is approximately two pints per blade per hour, which amount may be varied by the pilot according to the severity of the icing conditions. A typical installation of propeller de-icing equipment is shown in fig. 1, from which it will be seen that the rheostat control is affixed to the starboard side of the instrument panel whilst the tank, filter and pump are mounted in the root of the starboard wing.

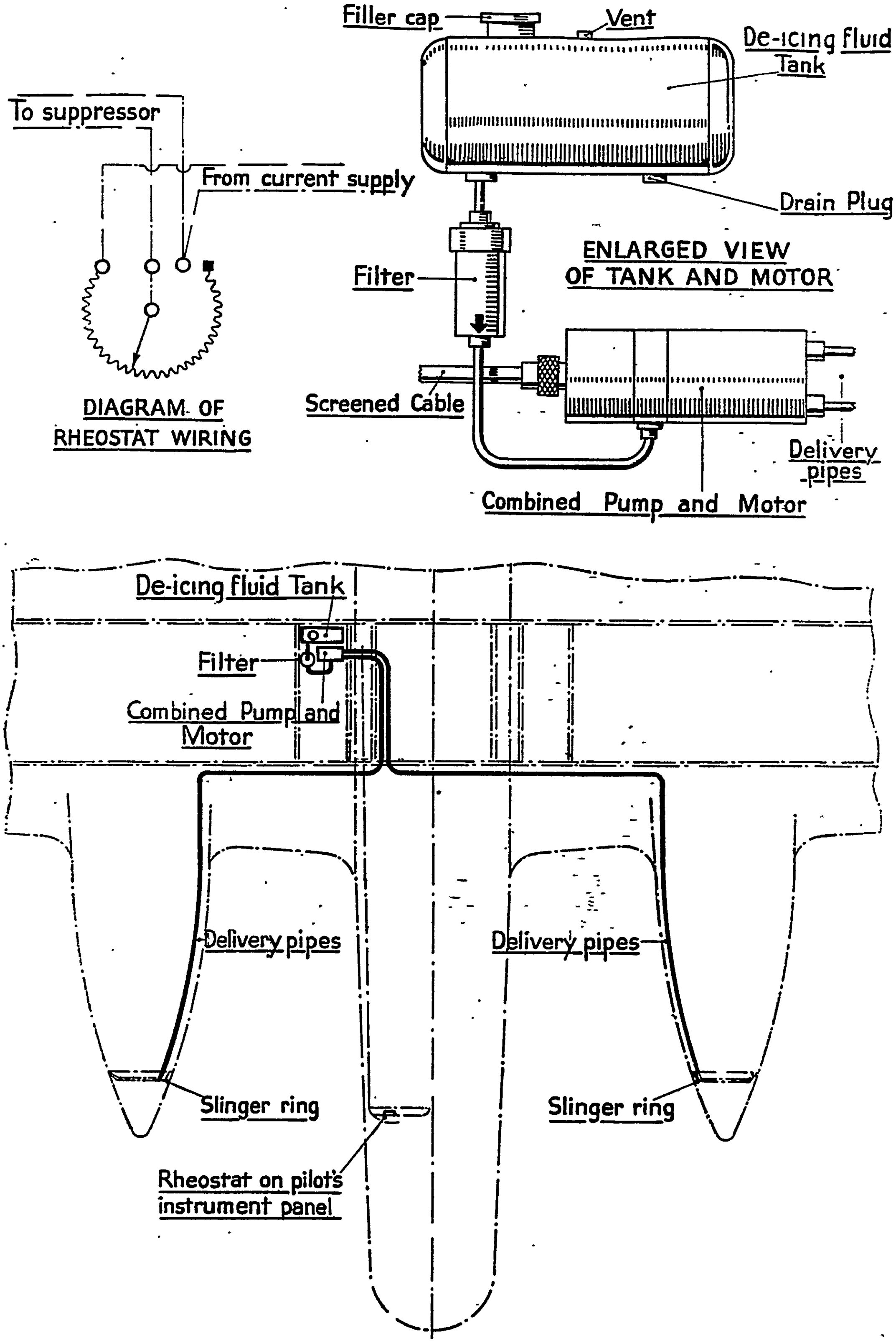


Fig. 1.—Typical arrangement of propeller de-icing installation

DESCRIPTION OF COMPONENTS

De-icing fluid tank

4. The de-icing fluid tank is of welded cylindrical construction and is provided with a filler cap, a vent-pipe and a drain plug; a dip stick is attached to the filler cap. The capacity of the tanks on various systems will vary according to the requirements of the installation and the estimated duration of the period over which the de-icing equipment is likely to be in operation.

Filter

5. The filter consists of a cylindrical wire gauze element in a cylindrical container having inlet and outlet connections. An arrow marked on the container indicates the direction of the flow and when the filter is mounted should be pointing downwards. The filter element has a flange which is clamped against a shoulder in the container when the upper end cap is screwed into position.

Diaphragm type pump

6. This type of pump, shown in fig. 2, is fitted with twin diaphragms each having independent inlet and delivery valves and ports. The two diaphragms are formed by laminated sheets of fabric-reinforced Neoprene which, in operation, are flexed against the pressure of coil springs by two cams driven through a 40 to 1 worm reduction gear by an electric motor. The worm reduction gear is enclosed in an oil reservoir having a filling plug. Oil is distributed to all moving parts, except the motor bearings, by the pumping action of the diaphragms, the undersides of which communicate with the oil reservoir. The diaphragms are clamped between the main housing and a valve-block, a synthetic rubber gasket being provided at the joint faces. The diaphragms are supported on each side by means of dished washers and are attached to push-rods which slide in the main housing. Spring-loaded ball valves retained by screwed caps are provided in the inlet and delivery passages above each diaphragm, both inlet valves having a common inlet port, while the delivery valves are provided with separate delivery ports. The springs of inlet and delivery valves are not interchangeable (see para. 29 (i) (*b*)).

7. The pump motor is series wound and is provided with a screened cable gland fitting, the supply leads being connected inside the motor. The base has four mounting lugs and the pump is mounted in a horizontal position about 6 in. below the bottom of the de-icing fluid tank and on a level with or below the slinger rings. The outlet pressure should not exceed 10 lb./sq. in. Non-return valves are usually fitted in systems in which this type of pump is used. The pump is not self-priming and must be primed when first installed and whenever the tank runs dry, by slackening off the screwed caps of the inlet valves until fluid exudes while the motor is running. The output for each delivery may be varied between 2 and 5 quarts per hour by means of the rheostat in the motor circuit. Different types of motor are used for 12 and 24-volt operation respectively.

Gear-type pump

8. This type of pump (see fig. 3) supersedes the diaphragm type, and comprises a central gear wheel keyed on a motor driven shaft and meshing with two outer gear wheels. The gear wheels are a running fit at their outer peripheries in circular openings in a centre plate secured between a housing and a ported top plate by six bolts. The circular openings in the centre plate constitute the only bearings for the gear wheels.

9. The top plate is provided with three ports each fitted with an adaptor for the pipe couplings. The central or inlet port communicates, through ducts drilled obliquely in the top plate, with ports in the centre plate and with the teeth of the gear wheels. The two outer ports are independent delivery ports and communicate with the teeth of the gear wheels so that each delivery port receives an equal amount of fluid.

10. The pump housing screws on to a worm gear casing attached by screws to the motor body. The pump shaft is driven through a universal joint by means of the 4 to 1 single reduction gear. The wormwheel of the reduction gear is made from bakelized fabric and is mounted on a bronze boss secured to the shaft by means of a set-screw. The shaft is supported in two self-lubricating plain bearings. The worm is generally keyed to the armature shaft, but in some instances the worm is integral with the shaft. A steel ball, socketed in the end of the worm shaft and the end of an adjusting screw, takes the end thrust, although in some instances a ball-race may be provided for this purpose.

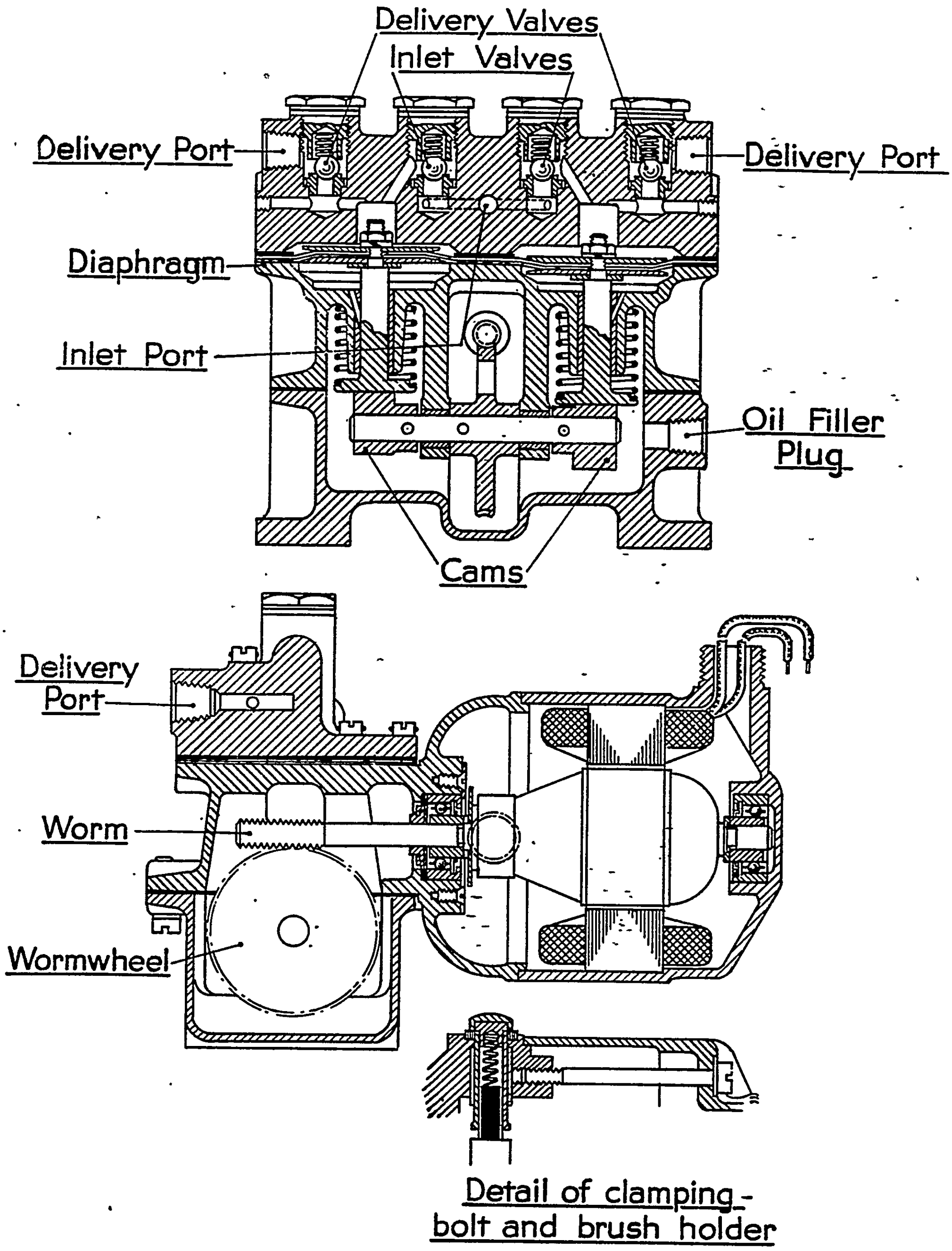


Fig. 2.—Propeller de-icing fluid pump, diaphragm type

11. The pump motor is a two-pole series wound machine ventilated by a fan mounted on the armature shaft. A screened cable gland is provided in early issues for the supply leads which are coupled to internal connections; in later models a plug and socket external connection is provided. Small covers are attached to each side of the motor housing over brush-retaining screws. The complete pump is secured to a base plate, mounted horizontally when installed in the aircraft. Earlier issues of gear type motors were produced in different types for 12 and 24-volt operation respectively; these types have now been superseded by a single universal type operating on 12 or 24 volts with a rheostat resistance of 8·5 ohms of 20 ohms respectively. In the maximum speed position no resistance is

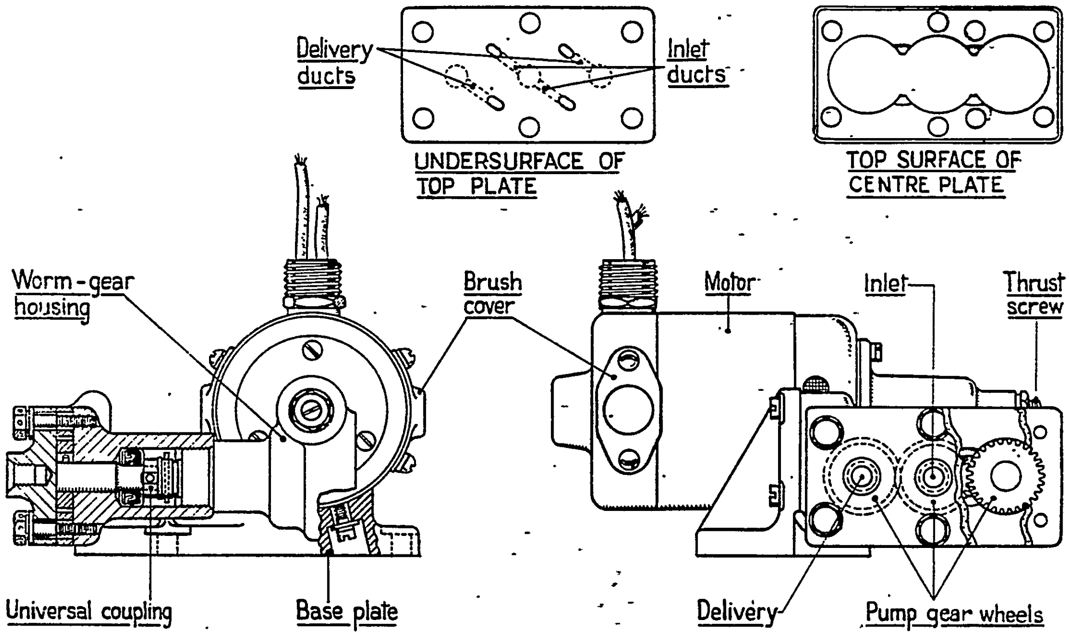


Fig. 3.—Propeller de-icing fluid pump—gear type

in circuit in either case and the motor runs at twice the speed on 24 volts as on 12 volts The maximum power consumption of the motor is approximately 36 watts and the delivery at each outlet may be from 2 to 6 quarts per hour on 12 volts and 2 to 12 quarts per hour on 24 volts. The speed of the pump shaft at maximum capacity is less than 300 r.p.m. The pump is self-priming against a maximum suction lift of 10 feet but a lift of 3 feet is not exceeded in practice.

Piston-type pump

12. In the piston type pump shown in fig. 4, a motor (1) drives through double reduction gearing, a cam (2) having a cam groove (3) which engages with rollers on the pistons (4), which operate in cylinders (5) thereby pumping de-icing fluid from a chamber (6) in an inlet block (7) having an inlet connection (32) through the hollow pistons and inlet valves (8) into the compression space (9), to be expelled through delivery valves (10) to one or more delivery outlets (11). The motor reduction-gear housing (12), inlet block (7), pump body (13) and end cover (31) are secured together end-to-end to form a cylindrical unit, all the joint faces being spigoted and dowelled. The gear housing is secured to the motor by four screws, access to which can be obtained only after removal of the pump unit and inlet block.

13. The double reduction gear comprises two worm gears (17), (18) and (20), (21) and spur gears (23), (24), the pump shaft (25) being in alignment with the motor shaft (16). The worms and the spur wheel (23) are of steel, the wormwheels and the spur wheel (24) being of tufnol. The worm (17) and the cam (2) are pinned to their shafts, all the remaining wheels being splined and a push fit on their shafts. The upper bearing of the transverse shaft (19) is adjustable for end play by means of a screwed sleeve (24) having castellations which engage with a locking plate (25). The locking plate is secured by a screw (26) which passes through a slot in the plate whereby the sleeve can be locked in any position within the range of movement allowed by the slot.

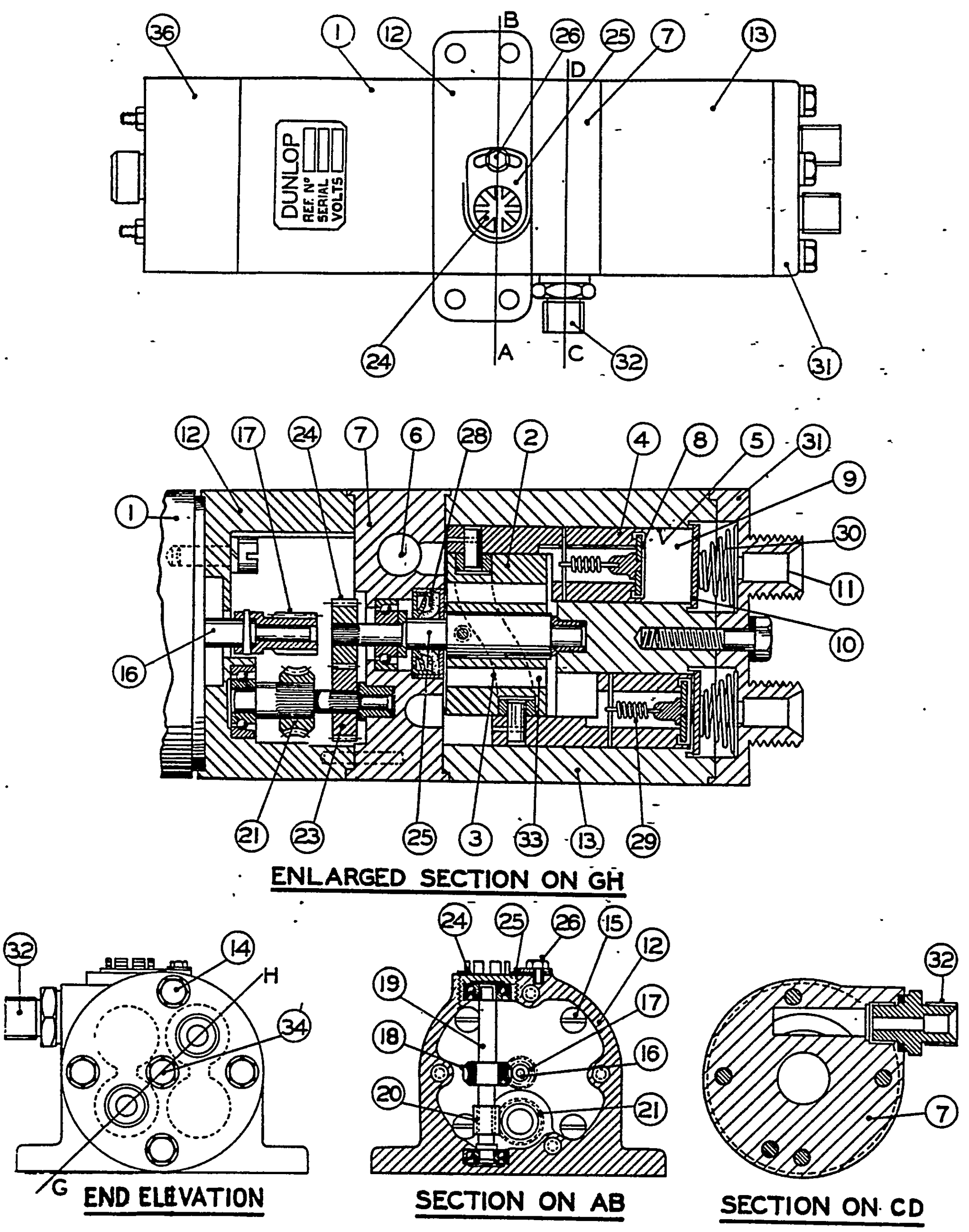


Fig. 4.—Propeller de-icing pump—piston type

14. The pump shaft (25) is provided with a seal (28) to prevent the pump from drawing air or oil from the gear housing (12). The piston-crowns are formed by the spring-loade dinlet-valve discs (8). The delivery valve discs are retained on their seats in the cylinder heads by volute springs (30), recessed in the end cover (31) which has an independent delivery connection (11) for each piston. The inlet and delivery valve discs are in some instances of tufnol and in others are of brass with rubber seats vulcanised to them.

15. The end cover is secured to the pump body by a short central bolt (34), four long bolts (14) holding the remaining parts together; three of the long bolts pass through the end cover, pump housing and inlet block and then screw into the gear housing. The fourth bolt passes through the end cover and pump body and screws into the inlet block in order that these three parts may be held together prior to assembling the inlet block on the gear housing.

16. Although the pump has four cylinders, some of them may not be used in certain installations The pump shown in fig. 4 has two cylinders in commission and two independent delivery outlets. Other models employ a single cylinder and outlet, and other use all four cylinders with four independent outlets. Any cylinders which are not required are blanked off by the cover plate.

17. In operation, fluid enters the inlet block (7) via the inlet connection (32) and passes through the chamber (6) and apertures (33) in the cam (2) to the interior of the pistons (4). During the downward stroke of the pistons the inlet valves (8) open and the fluid passes into the compression space (9). During the upward stroke, the inlet valves close whilst the delivery valves (10) open and allow the fluid to be expelled to the pipe-lines through the delivery outlets (11). The pump is usually mounted horizontally, but when mounted vertically, the motor is arranged to be uppermost in order to avoid the possibility of fluid leakage into the motor.

18. The pump motor is series wound and is provided with a detachable end cover (36). In the type illustrated in fig. 4, removal of the end cover exposes the terminals and brush gear; in some designs, however, access to the brushes is obtained by removal of a separate cover band with a toggle clip.

19. All models of this type of pump can deliver against a head of 15–20 lb./sq. in., the maximum delivery and current consumption being as stated in the table in para. 31.

Slinger ring and spinner

20. The slinger ring and spinner vary according to the design of the propeller and for a full description of these parts reference should be made to A.P.1538, Vol. I. One form of installation of the slinger ring and spinner on a variable pitch propeller is shown in fig. 5, in which the slinger ring is shown secured to the rear of the propeller, and the feed pipes can be seen extending from the slinger ring to the leading edges of the propeller blades, the spinner being attached to the front of the hub.

Pipes and connections

21. Aluminium pipes of ¼ in. o/d and 22 s.w.g. are used throughout the installation. Pumps of the diaphragm and gear type are provided with adaptors to suit A.G.S. metal couplings.

Non-return valves

22. Spring-loaded non-return valves are in some instances provided in the delivery pipe-lines near the slinger ring outlets to prevent loss of fluid by syphoning action when the pump is not in operation. The non-return valve comprises a spring-loaded ball, housed in a light alloy body marked

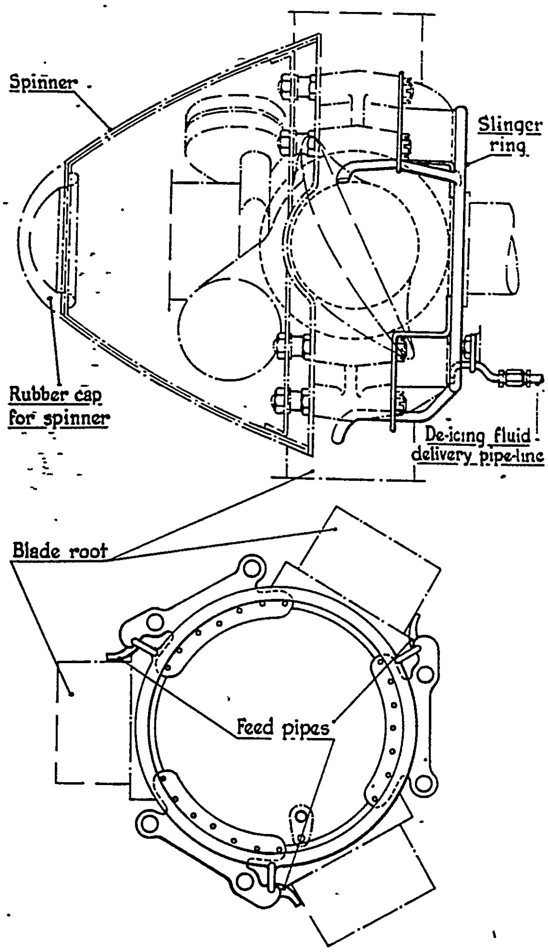


Fig. 5.—Arrangement of fluid feed to propeller blades

with an arrow indicating the direction of flow, and fitted with pipe couplings. The pressure at which the valves open is slightly in excess of that exerted by the static head of fluid as determined by the height of the supply tank above the level of the slinger rings, and may be up to 8 lb./sq. in. In instances in which the supply is not mounted at a higher level than the slinger rings, the valves are usually set to open at a pressure of 1 lb./sq. in. In installations using diaphragm and piston-type pumps, non-return valves are not usually provided since syphoning is prevented by valves embodied in these pumps. Gear-type pumps, however, do not embody non-return valves, and installations using these pumps always require non-return valves fitted in the pipe-line.

Rheostat

23. The rheostat is totally enclosed in a metal case provided with a screwed fitting for a screened cable gland. In some propeller de-icing installations the rheostat may be mounted on a panel with other controls. The control knob has an OFF position to serve as a switch, the rheostat being of the rotary type, having a radial contact arm sliding over a resistance wound on a circular ceramic former. Some rheostat dials are marked OFF—FAST—SLOW or alternately OFF—SLOW—FAST; in the former, clockwise rotation of the knob first switches the motor full on and further rotation inserts a gradually increasing resistance. This is the sequence in which the motor should be brought into operation when first encountering icing conditions. In the OFF—SLOW—FAST sequence the motor starts slowly on full resistance and its speed is gradually increased as the knob is turned clockwise. The rheostat has three terminals so that connection can be made to either end of the resistance wire to correspond to the sequence of the dial marking. The rheostat should be inserted in the positive cable of the circuit.

SERVICING

De-icing fluid

24. After each flight in which the de-icing equipment has been used, the propeller, hub and slinger ring should be washed down and all traces of the de-icing fluid removed. The tank should be replenished with de-icing fluid to Specification No. D.T.D.406A.

Periodical inspection

25. The supply tank should be examined periodically for signs of corrosion and at the same time any sludge which is present should be drained and the tank rinsed with methylated spirits. The outlets at the slinger ring should be examined to ensure that the orifices are not restricted. The pipe-lines should be examined for leaks and the couplings tightened if necessary. A leak can be readily detected by the presence of glycerine residue.

Cleaning filter

26. After every ten hours running of the de-icing equipment the filter should be dismantled and then cleaned by washing in methylated spirits, after which the delivery rate of the pump should be tested *in situ* (see para. 28).

Cleansing the system

27. If the system is not to be used for some time, the tank should be drained and then filled with clean methylated spirits. A suitable vessel should be placed under the slinger rings and the pump operated until the tank is empty. This will cleanse the system of all gummy deposits and leave it clean and ready for use when next required.

Testing the pump in situ

28. The pipe coupling nearest to each slinger ring, or any other convenient connection, should be uncoupled and graduated measuring vessels should be held under the open ends of each delivery pipe to receive the liquid. An ammeter should now be fitted in the motor supply circuit. Before making the test, compressed air should be blown through all the pipe-lines, including the vent pipe, to ensure that no obstruction is present; the filter should be cleaned, and an examination made for leaks, after which it should be ascertained that the electrical wiring is in order and the supply voltage adequate. The pump should then be operated, the fluid delivery rates and ammeter readings noted. If the current exceeds the rated value (see para. 31), or if the delivery rate is more than 10 per cent. below the rated value, the pump should be removed from the installation and dismantled reconditioning it as described in paras. 29 and 30 and then tested on the bench as described in para. 31.

Dismantling pumps

29. The pumps should be dismantled as follows:—

(i) *Diaphragm type pump.*—

(*a*) The screws around the upper and lower flanges of the body should be removed and the base cover and upper chamber detached from the body.

(*b*) The screwed caps over the ball valves in the upper chamber should then be removed and the ball valves and springs withdrawn. The inlet and delivery valve-springs are not interchangeable and should therefore be labelled accordingly. The inlet valve springs have 14 turns of 0·014 in. dia. wire and a free length when new of $\frac{17}{32}$ in. while the delivery valve springs have 12 turns of 0·020 in. dia. wire and a free length of $\frac{3}{4}$ in.

(*c*) The nuts in the centre of the diaphragms should be removed and the diaphragms, complete with reinforcing plates and washers, should be lifted carefully off the push-rods.

(*d*) The three parallel pins holding the cams and wormwheel on their shaft should be tapped out with a suitable drift, and the shaft withdrawn from its bearings; the wormwheel will also be freed during this operation.

(*e*) The motor brushes should be removed by unscrewing the caps at the side of the motor and withdrawing the brushes.

(*f*) The motor should be dismantled by removing the two long screws passing through the stator into the gear housing and the stator withdrawn from the housing. The outer bearing will slip out of the stator during this action, leaving the armature supported on its inner bearing in the gear housing. To detach the stator completely, the leads should be disconnected from the brush holders and the flanges separated.

(*g*) In order to withdraw the armature completely, the small screws securing the bearing retaining plate to the gear housing should be removed, whereupon the armature, complete with worm and bearing, can be withdrawn.

(ii) *Gear-type pump.*—

(*a*) Before separating the pump-plates, stencil or similar marks should be made across one side of the plates and body to ensure that the plates can be subsequently re-assembled in the same relative positions.

(*b*) The six bolts securing the top plate to the pump body should be removed, and the top plate detached by sliding it laterally over the underlying centre plate.

(*c*) The outer gear wheels should be suitably marked to indicate their position in the assembly, after which they should be removed together with the centre plate. During manufacture the gear wheels and centre plate are matched by selective assembly; care should therefore be taken not to confuse the wheels and plates of different assemblies.

(*d*) The pump body should now be unscrewed from the worm-gear housing, which should then be detached from the motor which is held by three screws.

(*e*) The carbon brushes should be removed from the motor by unscrewing the two caps at the side of the motor and withdrawing the brushes.

(*f*) The motor can now be further dismantled by removing the two long screws passing through the stator from the worm-gear end after which the stator should be detached from the worm-gear housing.

(*g*) To dismantle the worm-gear, the end cap should be removed by releasing its spring retaining ring.

(*h*) The wormwheel should be removed from its shaft by removing the hexagonal socket grub screw in its boss, using a hexagonal key which can be introduced through a hole in the housing normally plugged by a screw. If a suitable key is not available, one can be made by filing a hexagon to fit the socket, at the end of a piece of steel rod of suitable size. The grub screw is of hardened steel and grips on a flat on the shaft, therefore the screw should be completely removed before attempting to move the wormwheel boss. The parts are a tight fit and the application of heat to the bronze boss of the wormwheel, by means of a soldering iron, will probably be found necessary both in the removal of the grub screw and the shaft.

(iii) *Piston-type pump.*—

(*a*) Commencing at the pump end of the unit, the four long bolts and the central short bolt should be removed allowing the various parts of the unit to be separated. During the operation the pistons and the small phosphor bronze rollers on the piston pins will be released, together with the delivery valve discs, therefore care should be taken not to lose any of these rollers or damage the delivery valve discs.

(*b*) The inlet valve discs should be removed from the pistons by pushing out the cross-pin over which the inner ends of the phosphor bronze valve springs are hooked.

(c) The tufnol spur wheel should be carefully withdrawn from the pump shaft and the latter removed from the inlet block, after which the cam should be removed from the pump shaft by extracting the pin which is inserted through the cam and the shaft.

(d) The four screws inside the gear housing should now be removed and the gear housing separated from the motor, taking care not to damage the wormwheels.

(e) To dismantle the reduction gear, the castellated sleeve should be removed and the transverse shaft withdrawn complete with worm and wormwheel, inner ball races and caged balls.

(f) The countershaft should be lifted out of the motor housing together with the gear wheels, inner ball race and caged balls.

(g) The gear wheels are a splined push fit on their shafts and can be removed if necessary for replacement purposes by applying steady axial pressure.

(h) In order to gain access to the brushes and commutator, the end cover or the cover band should be removed as the case may be; in the former the brushes should then be released by extracting the split pins from the brush holders, whilst in the latter types the brushes can be withdrawn after removal of the cover band. In replacing the cover band, care should be taken to ensure that the insulation strips inside it register with the brush slots in the housing, otherwise the band will not seat correctly.

Cleaning and re-assembling pump

30. After the pump has been dismantled, the components should be cleaned. The valves, diaphragms, pistons, etc., should be cleaned in methylated spirits, while the gears and bearings should be cleaned in paraffin. After cleaning and viewing, defective parts should be rejected and replaced by new ones. All ball-bearings should be lubricated on re-assembling with anti-freezing grease, (Stores Ref. 34A/49), thinned slightly with anti-freezing oil, (Stores Ref. 34A/43). Gears and plain bearings should be lubricated with anti-freezing oil only. Unless otherwise stated below, re-assembly should be carried out in the reverse order to the dismantling (see para. 29), the following details being observed according to the type of pump:—

(i) *Diaphragm-type pump.*—In tightening down the flanges on either side of the gear housing, the central screws should be tightened first, working outwards to the end screws. When assembling operations are completed the base chamber should be filled with anti-freezing oil, (Stores Ref. 34A/43), to the level of the filling aperture.

(ii) *Gear-type pump.*—The markings made prior to and during dismantling operations should be checked to ensure that the parts occupy their original relative positions, it being remembered that the recessed face of the centre plate is the one in contact with the top plate. In tightening down the six bolts which hold the top plate to the body, the centre pair should be tightened down before the outer pairs. Great care should be taken to ensure even tightening, otherwise distortion will result, with the risk of seizure. Tightening should be effected whilst the pump is running, if possible, when uneven tightening will be indicated by a slowing down of the motor pump. The worm-gear housing should be filled with anti-freezing grease, (Stores Ref. 34A/49).

(iii) *Piston-type pump.*—This type of pump should be re-assembled as follows, and new gaskets made from paper jointing should be used at all the spigoted joint faces:—

(a) The delivery valve discs should be placed on their seats in the pump body, and the ported end-cover, complete with valve springs, should be attached in its correct position on the pump body by means of the short central bolt.

(b) The inlet valves should be fitted to the pistons by pushing the pins through the hooked ends of the springs while the latter are held in tension.

(c) The cam should be positioned on the pump shaft and re-pinned, the shaft then being mounted in the inlet block and the tufnol spur wheel pressed on to the outer end of the shaft.

(d) The pistons, complete with rollers, should be held in position around the cam and entered into the cylinders. During this operation the inlet block should be pushed fully home and the assembly held together by inserting the shorter of the four long bolts into the appropriate hole in the cover plate and pump body and screwing it into the inlet block.

(e) The reduction gear should be assembled and its housing attached to the motor by the appropriate screws, after which the housing should be filled with anti-freezing grease, (Stores Ref. 34A/49).

(f) After placing the dowel in position, the gear housing should be assembled on the inlet block. The countershaft must be entered carefully into the plain bearing in the inlet block and the gear wheels turned gently to allow them to mesh. When this operation is completed the three remaining long bolts should be screwed in position and tightened carefully.

Bench test of pump

31. After assembling the pump it should be tested by means of the test apparatus (see figs. 6 and 7), as follows:—

(i) *Pressure test.*—In the pressure test-rig shown in fig. 6, the delivery from each outlet is controlled by a stopcock in order to obtain the desired back pressure. The pump should be

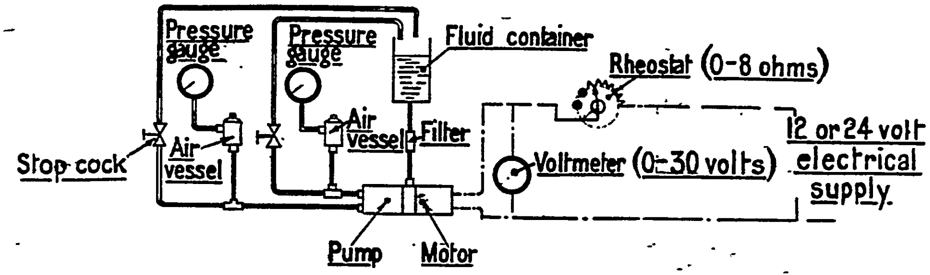


Fig. 6.—Pressure test-rig for propeller de-icing fluid pump

allowed to run for five minutes with the rheostat adjusted to give a voltmeter reading of exactly 12 or 24 volts as the case may be, when both pressure gauges should show 15–20 lb./sq. in. back pressure. During this period the back pressure should not fall, nor should the pump show any sign of distress.

(ii) *Delivery test.*—In the delivery test-rig shown in fig. 7 it will be seen that each outlet delivers to a graduated measuring glass against a static head of 10 ft. The rheostat should be

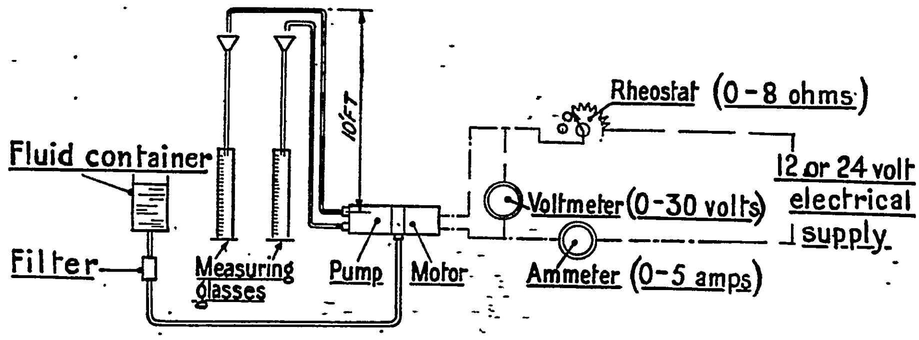


Fig. 7.—Delivery test-rig for propeller de-icing fluid pump

adjusted to give a voltmeter reading of exactly 12 or 24 volts as the case may be. The rate of flow should be timed over a convenient period, say of ten minutes, and the ammeter reading noted. During the test, the current consumption of the motor should not exceed the values in the following table at the corresponding rate of flow:—

Type of pump	Maximum delivery at each outlet: quarts per hour	Current consumption of motor in amps.	
		12-volt motor	24-volt motor
Diaphragm type	5	2	1
Gear type	12	—	1½
Piston type—			
Mk. I (12 volts only, two deliveries)	6	3·9	—
Mk. II (single delivery)	7·5	1·8	0·9
Mk. II (two deliveries)	7·5	2·2	1·1

Faulty operation of pump

32. Any trouble experienced with diaphragm and piston type pumps will most probably be due to dirty or defective valves. These should be dismantled and cleaned as described in paras. 29 and 30.

33. Gear-type pumps are susceptible to damage by the presence of any foreign matter in the pumped fluid and quite small particles are sufficient to cause seizure. If seizure occurs or is suspected, the motor should be switched off immediately, otherwise the armature and field windings may be burnt out. In the event of a seizure the pump should be dismantled and cleaned, as described in paras. 29 and 30, and at the same time the system should be thoroughly cleaned and the tank flushed to ensure that the seizure will not be repeated.

34. If the failure of the motor is not due to pump seizure, the leads from an external supply, of appropriate voltage, should be connected directly across the motor terminals. If the motor now starts, the external wiring circuit is at fault and should be checked and the fault corrected. If the motor does not start, the brushes should be examined, cleaned, and replaced by new ones if necessary. It should be verified that the brushes are bedding correctly and are free in their holders, also that the springs are in a serviceable condition. The commutator should be cleaned with a petrol-soaked rag (this will involve dismantling the motor on certain early types of pump motors). The field coils should be tested for open circuits and insulation resistance. If all appears to be satisfactory the correct voltage supply should again be applied to the motor. If it still fails to start, the armature is at fault and should be replaced by a new one.

Replacement pump outlets

35. In some instances pumps may be fitted with more than one delivery outlet. When the number of outlets on a pump exceeds the number of feeds required on the aircraft for the propeller, those outlets not required should be by-passed into the delivery pipe or pipes in use; such outlets should not be plugged unless the pump is of the multi-outlet gear type, in which case any outlet may be plugged provided that the gear wheel, feeding that outlet, is first removed.

Flow distribution test

36. The correct distribution of the de-icing fluid on the surface of the propeller blades is obtained during the installation of the equipment and should not normally need adjustment. If the slinger ring has been disturbed, however, the following test will determine whether the flow is evenly distributed or not:—

(i) The surface of the propeller blades should be whitewashed and allowed to dry, after which the propeller de-icing equipment should be operated whilst the aircraft is in normal flight at cruising speed with the propeller blades set in the cruising position. The de-icing fluid will stain the whitewash and give an indication of its distribution over the blades, which should be examined immediately on landing.

(ii) The fluid should be distributed uniformly over each side of the blade and if this is not the case, the feed pipe should be carefully set towards that side of the blade which has received the smaller supply and the test repeated until a satisfactory result is obtained. When correctly positioned, the outlets will usually be at the thrust side of the blade just at the rear of its leading edge.

P5067 M /1343 9/44 5250 C & P Gp. 1

This leaf issued with A.L. No. 18
May, 1944

CHAPTER 2

DE-ICING EQUIPMENT FOR INDUCTION SYSTEMS

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. De-icing equipment for aero-engine induction systems includes heating arrangements and de-icing spirit injection equipment for carburettors, alternative hot and cold air intakes, and ice guards for air intakes, all of which are described in detail in this chapter.

De-icing arrangements for carburettors

2. Carburettor de-icing is effected by the application of heat, with or without injection of an alcohol de-icing spirit into the throttle barrel. The spirit mixes with water and lowers the freezing point thereby melting the ice completely or converting it to a mush which can be carried along by the fuel stream to warmer parts of the inlet manifold. The application of heat to the carburettor

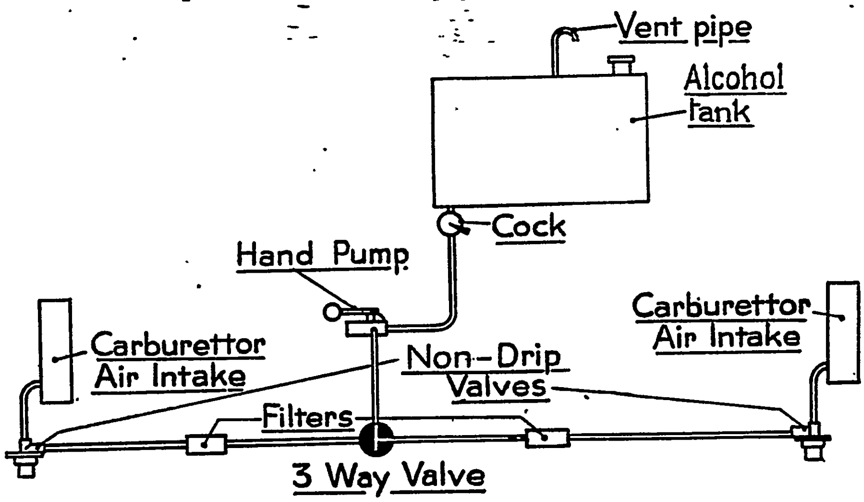


Fig. 1.—Layout of equipment—hand pump

prevents ice accretion on the heated parts, and if sufficient heat can be applied to the parts most affected, the carburettor is regarded as normally ice-free and is not equipped with a de-icing spirit injection device. Carburettors may have heat applied to the throttle butterfly only; to the throttle barrel only; or to both the butterfly and the barrel, heat being applied by circulating the scavenged lubricating oil from the engine crankcase through a hollow throttle or through a jacket surrounding the barrel. Alternatively, in some liquid-cooled engines, the coolant may be circulated through the barrel jacket. Details of particular carburettor heating arrangements will be found in the relevant engine handbooks, Vols. I. Of the various systems adopted, only those carburettors in which the throttle butterfly is directly heated are regarded as normally ice-free. Types of carburettors not provided with direct throttle-butterfly heating are now provided with de-icing spirit injection equipment.

DE-ICING SPIRIT INJECTION EQUIPMENT FOR CARBURETTORS

General

3. De-icing spirit injection equipment for carburettors comprises an electrically or hand-operated pump, delivering de-icing spirit from a supply tank to jets suitably disposed in the air intake in such a manner that jets of the spirit will be directed towards the carburettor throttles.

Layout of equipment

4. A typical layout of the de-icing spirit injection equipment in which a hand-operated pump is used, as fitted on a twin-engined aircraft, is shown diagrammatically in fig. 1. The de-icing spirit supply tank is mounted in the port-engine nacelle and is connected by means of pipe-lines to a single hand pump in the pilot's cockpit. When the pump is operated, de-icing spirit is drawn from the tank and forced to a three-way valve, the two outlets of which are coupled by the 20 s.w.g. $\frac{1}{4}$ in. o/d aluminium pipe-lines to injection jets positioned in the air intakes of the respective engines. By means of the three-way valve the pilot can direct the flow of de-icing spirit to either or both the carburettors. Syphoning is prevented by means of non-drip valves provided in each delivery pipe. In the installation shown in fig. 1 two filters are provided, one in each delivery pipe; in other instances a single filter is arranged between the pump and valve. Some installations have separate hand pumps for each engine, in which case the three-way valve is not fitted. An installation in which an electrically driven pump is employed is shown diagrammatically in fig. 2. A complete arrangement such as that shown is arranged in each engine nacelle.

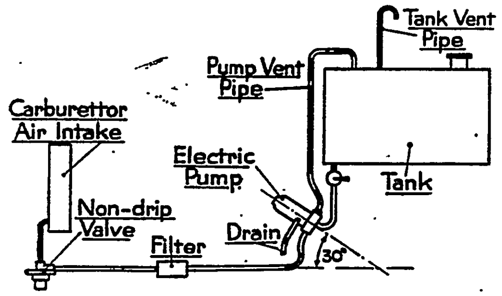


Fig. 2.—Layout of equipment—power pump

De-icing spirit tank

5. The capacity of the tank is generally limited in all cases to two gallons per engine which is sufficient for 30 minutes continuous operation at maximum delivery rates. The quantity of de-icing spirit normally required for efficient operation is about five per cent. of the fuel flow to the engine. The tank is provided with a vent pipe clipped near to the adjacent fuel tank vent pipe.

Pumps

6. The pumps are either hand-operated or electrically driven, hand pumps being most generally adopted, the electric pump usually being installed when there is insufficient room in the cockpit to accommodate and operate a hand pump. The types of pumps employed are described in the following sub-paras.:—

(i) *Hand pump.*—The hand pump illustrated in fig. 3 comprises a diaphragm which is mounted between the flanges of the two portions of the pump housing and which can be flexed by operating a hand lever. One side of the diaphragm is open to an inlet valve, whilst the other side is open to a delivery valve, a relief valve being arranged between the two valves. The diaphragm is formed of layers of Neoprene-coated silk supported between steel plates, the outer plate being flat and the inner slightly dished. The inlet and delivery valves are identical in construction but are assembled and mounted right and left-hand to suit the direction of flow. Each valve comprises a stainless-steel disc held onto a nickel-bronze seat by a spring bearing against a cage secured to the seat. The valve seats and the cages are each secured in position by circlips. The relief valve comprises a caged spring-loaded ball of $\frac{5}{16}$ in. dia., no adjustment being provided for the spring. The valve cage screws into a housing which is screwed into the partition between the valve compartments. The screwed cap of the ball cage is locked by a spring arranged between the cage cap and the plug. The pump body is formed of two aluminium castings between the flanges of which the diaphragm is clamped. Inlet and outlet unions, screwed ¼ in. B.S.P., extend radially from the inlet and delivery compartments and the housings can be bolted together in six different relative positions 60° apart, whereby the unions

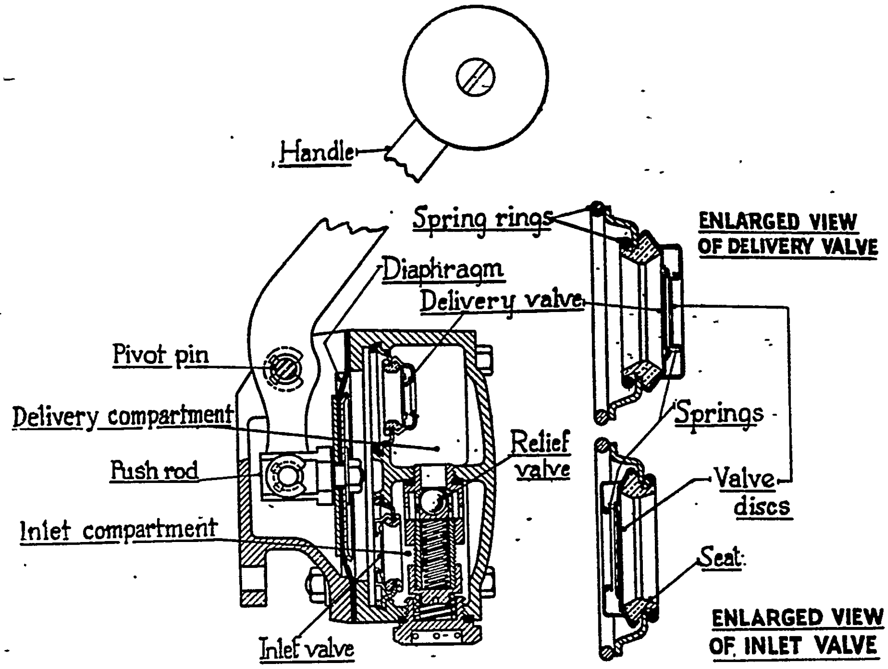


Fig. 3.—Carburettor de-icing pump (hand operated)

can be arranged conveniently in relation to the handle. The handle is pivoted on a pin in the housing, and is coupled to the diaphragm push rod. The delivery of the pump should be at least 5 gal. per hour when operating against a back-pressure of 5 lb./sq. in. at 60 strokes per minute.

(ii) *Electric pump.*—The electrically-driven centrifugal pump shown in fig. 4 is built up in sections screwed together, comprising a pump body, gland-block, motor stator and cover. An aluminium impellor is screwed onto the lower end of the armature spindle and rotates in a volute chamber formed in the pump body, which has ¼ in. B.S.P. inlet, outlet and vent connections. The vent connection communicates with a space round the eye of the impeller and serves to prevent the formation of a vapour lock. This pump is similar to the immersed type fuel pump with the exception of the gland which is illustrated in fig. 4. The pump is usually installed just below and as near as possible to the de-icing fluid tank so that suction lift is reduced to a minimum and is inclined at 30° to the horizontal to facilitate gland drainage. The pump should deliver a minimum of 5 gal. per hour against a pressure of 5 lb./sq. in., the motor speed being 12,000 r.p.m. and the current consumption 2 amps at 12 volts.

Time-lag switch

7. When an electric motor is used to drive the pump, a time-lag switch is usually fitted which automatically breaks the circuit (see fig. 5) after a predetermined interval. The switch (see fig. 6) comprises a push button, depression of which pivots a contact-bridge across contact plates connected to the leads. The push-button has a return spring, the action of which is retarded by the formation of a partial vacuum between the inside of the button and a U-leather piston secured to a metal post on which the button slides. Air returns slowly into the exhausted space through an orifice controlled by a tapered adjusting screw, the setting of which determines the period during which the contacts remain closed. When the button approaches the OFF position, the piston uncovers an additional

hole in its side thereby allowing the button to be returned quickly at the end of the stroke by the spring, the contacts then being snapped open by a spring surrounding the pivot pin of the contact bridge. The push-button, mounting-flange and rear cover are three separate components held together by screws.

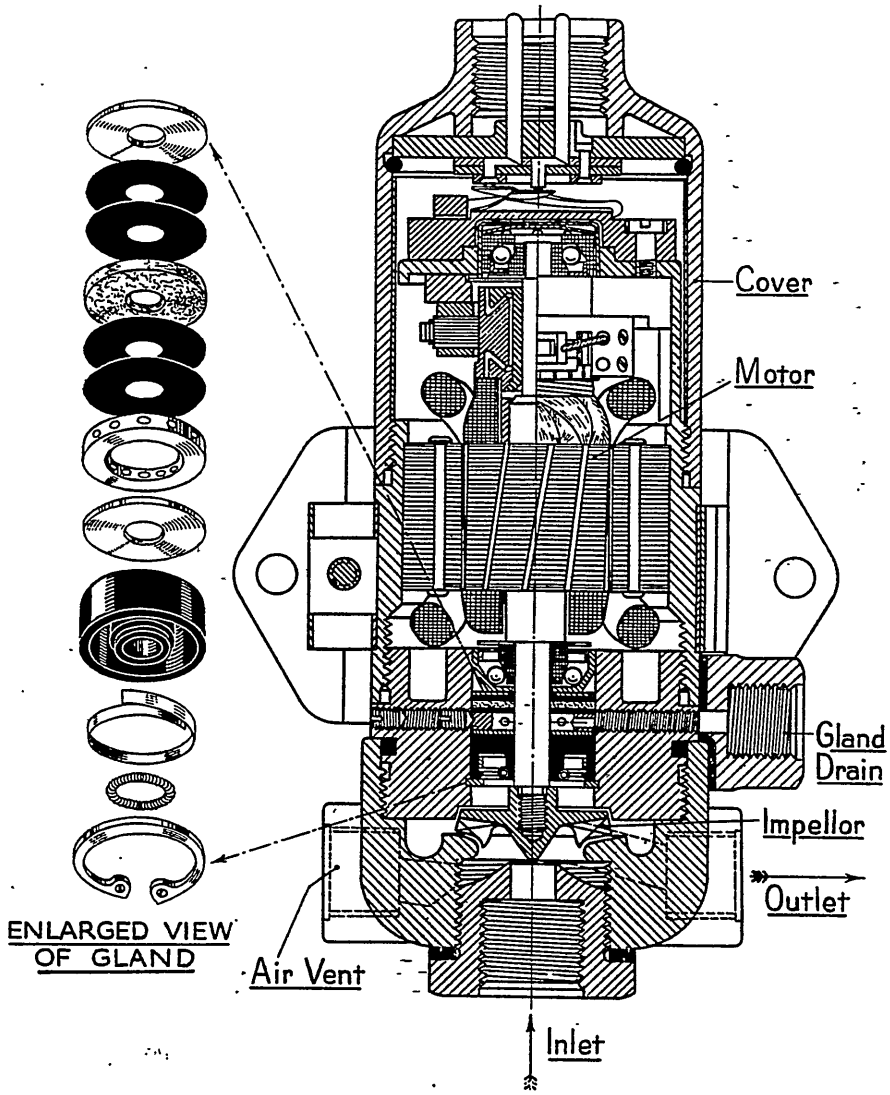


Fig. 4.—Carburettor de-icing pump (electrical)

8. The adjusting screw can be directly turned by means of a screwdriver, no locking device being provided. The adjustment is usually made at ground level to allow the switch to remain in

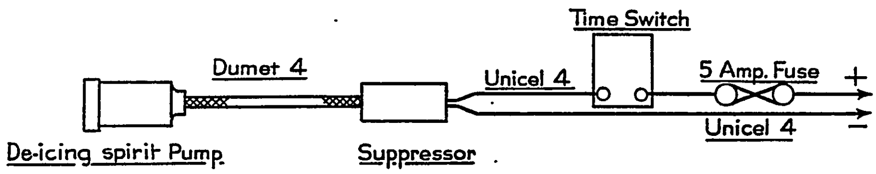


Fig. 5.—Wiring diagram—carburettor de-icing pump

the ON position for a period of one minute, a setting which, at 20,000 ft., gives an open period of half a minute.

Filter

9. The type of filter used in the system has ¼ in. B.S.P. connections at each end of its cylindrical body. Unscrewing the inlet end from the body gives access to the gauze filter element. The body is marked with an arrow indicating the direction of flow.

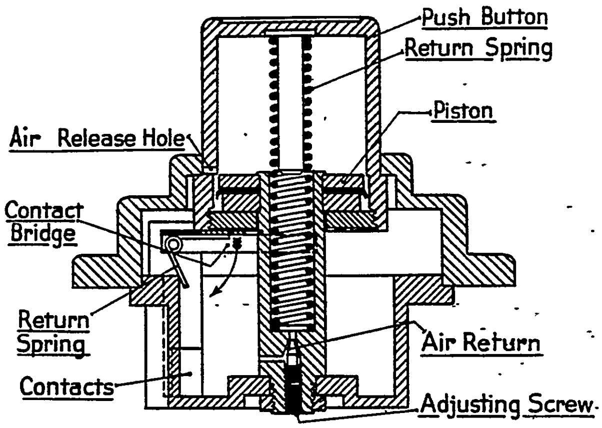


Fig. 6.—Time-lag switch

De-icing spirit injection jets

10. A typical arrangement of de-icing spirit injection jets in an engine air intake for one type of carburettor is shown in fig. 7. The jets comprise a U-shaped pipe supported in a plate bolted in the intake flange and having a central double-banjo union attached to an inlet connection which is

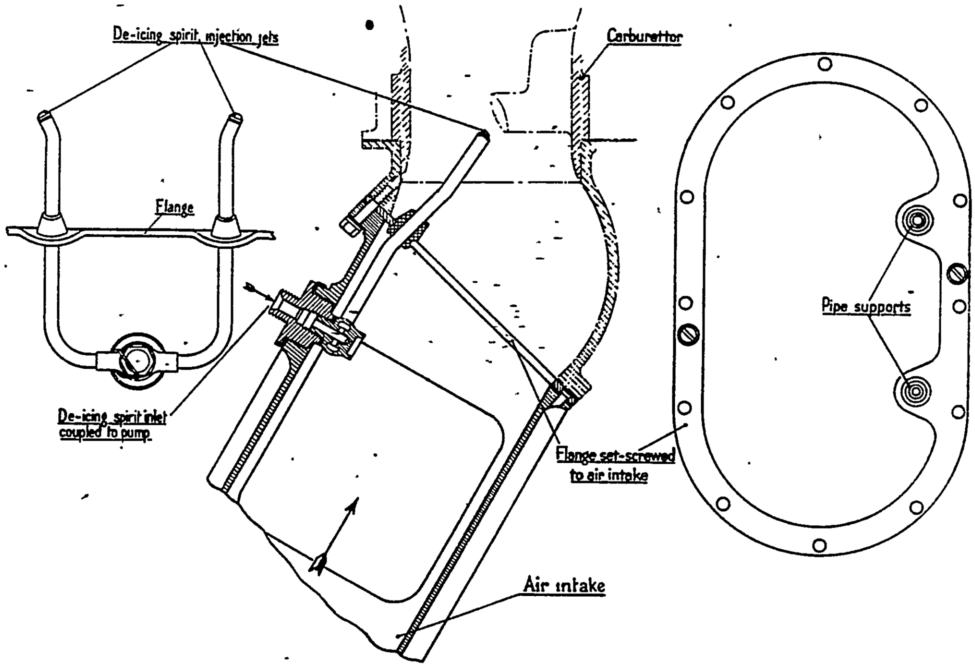


Fig. 7.—Arrangement of de-icing spirit injection jets in aero-engine air intake

screwed into the air intake. Metering jets, designed to give the correct rate of flow and back pressure are brazed to the ends of the branch pipes and are usually set to direct the spray of de-icing spirit toward the carburettor throttles. The size and setting of the injection jets should not be altered. In the case of down-draught type carburettors, the de-icing spirit injector comprises a single tube, extending across the air intake, having metering jets which spray the spirit downwards into the air stream.

Valves

11. The non-drip valve prevents leakage of liquid when the pump is not working and comprises a spring-loaded Neoprene diaphragm held onto a seat which is closed against the static head. When the pump is started, the spring yields at a predetermined pressure, allowing the diaphragm to flex away from the seat and permit the flow of de-icing spirit to the injection jets. The loading is not adjustable, the valve being usually designed to open under a minimum pressure of 4 lb./sq. in. and close under a maximum pressure of 2½ lb./sq. in.

12. The three-way valve is a simple plug cock and is used in installations such as that shown in fig. 1, for directing the de-icing spirit from a single pump to either engine as desired.

SERVICING

Periodical inspections

13. At the periodical inspections laid down in the relevant aircraft handbook, Vol. II, the following points should be observed:—

(i) The inside of the tank should be examined at intervals for traces of corrosion, when sludge should be drained away and the tank flushed out with alcohol.

(ii) The system should be carefully examined for leaks, and it should be remembered that, in view of the small capacity of the tank and the nature of the spirit, a leak would seriously deplete the supply, and increase the risk of fire.

(iii) After each flight in which the equipment has been used, the tank should be refilled with the approved grade of de-icing spirit, Stores Ref. 34A/104 (D.T.D. Spec. 386).

(iv) The filter should be dismantled and cleaned in alcohol periodically. The pipe-lines and vents should be cleaned by blowing compressed air through them.

(v) At periods laid down, or sooner if an obstruction is suspected, the air intake should be removed from the carburettor and the injection jets cleaned by blowing through them in the reverse flow direction.

(vi) If the delivery appears to be below normal, the pump should be tested as described in paragraph 17 below.

Testing pump *in situ*

14. For the purpose of testing the delivery of the pump *in situ*, the delivery pipe should be disconnected from the pump and a test-rig should be fitted on the pump outlet in place of the delivery pipe. The test-rig can be made up and should include a screw-down cock for providing variable back-pressure, a pressure-gauge on the inlet side of the cock, suitable connecting pipes and a metal coupling for screwing onto the pump, whilst a graduated measuring vessel should be arranged under the outlet from the cock. When the pump is motor driven an ammeter should be connected in the motor circuit for the purpose of the test, and where hand pumps are used they should be operated at 60 working strokes per minute. Before commencing the test, the filter should be cleaned and compressed air should be blown through the vent-pipe and supply-pipes to ensure that no obstruction is present. The pump should then be operated, the cock adjusted to give a minimum back-pressure of 5 lb./sq. in. and the delivery rate timed. This should not be less than one quart in three minutes whilst the current consumption of the electric pump should not exceed 2 amps. at 12 volts. If these conditions are not satisfied, the pump should be removed from the aircraft and dismantled as described below.

Dismantling hand pump

15. The hand pump should be dismantled by removing the six diaphragm-clamping bolts, and separating the two body-castings; after unscrewing the centre nut and washer from the push-rod the diaphragm can then be removed. The inlet and delivery valve cages should be withdrawn by removing their respective spring rings and the valve disc and seat detached from the valve cages by removal of the smaller spring rings. The relief valve should be dismantled and for this purpose the plug and locking spring should be removed and the spring cap unscrewed. The relief-valve spring, sliding cup, and the ball will then fall out of the cage, which should be unscrewed from the housing.

Dismantling electric pump

16. The electric pump should be dismantled in the following manner:—

(i) All the screwed body parts are locked by grub-screws bearing on the threads. These should be removed before attempting to unscrew the motor body components.

(ii) The gland drain connection should be removed by unscrewing the two small screws securing it to the lower bearing housing, whereupon the pump chamber can be unscrewed.

(iii) The motor end-cover should be unscrewed and, holding the exposed end of the armature lightly with the fingers, the impellor should be unscrewed (R.H. thread) from the armature spindle, using a light finger grip only. Shims are fitted in some instances behind the impellor and these should be retained.

(iv) The lower bearing housing should be unscrewed from the motor, while the gland, outer bearing race and rollers are left in the housing. The armature should now be withdrawn, complete with inner races, after first removing the brushes from their holders.

(v) To remove the gland assembly from the block, the circlip should be sprung out of its groove and the U-sectioned Neoprene ring complete with springs and upper washer, should be withdrawn. To release the aluminium ring, the blanking screws around the lower bearing housing should be removed and the grub-screws at the inner end of three of the screw holes should be slackened back. The aluminium ring, Neoprene, felt and steel washers can then be withdrawn from the housing.

(vi) To remove the insulated disc carrying the contact pins from the upper end of the motor cover, the spring retaining ring should be removed and the disc will then fall out of the cover.

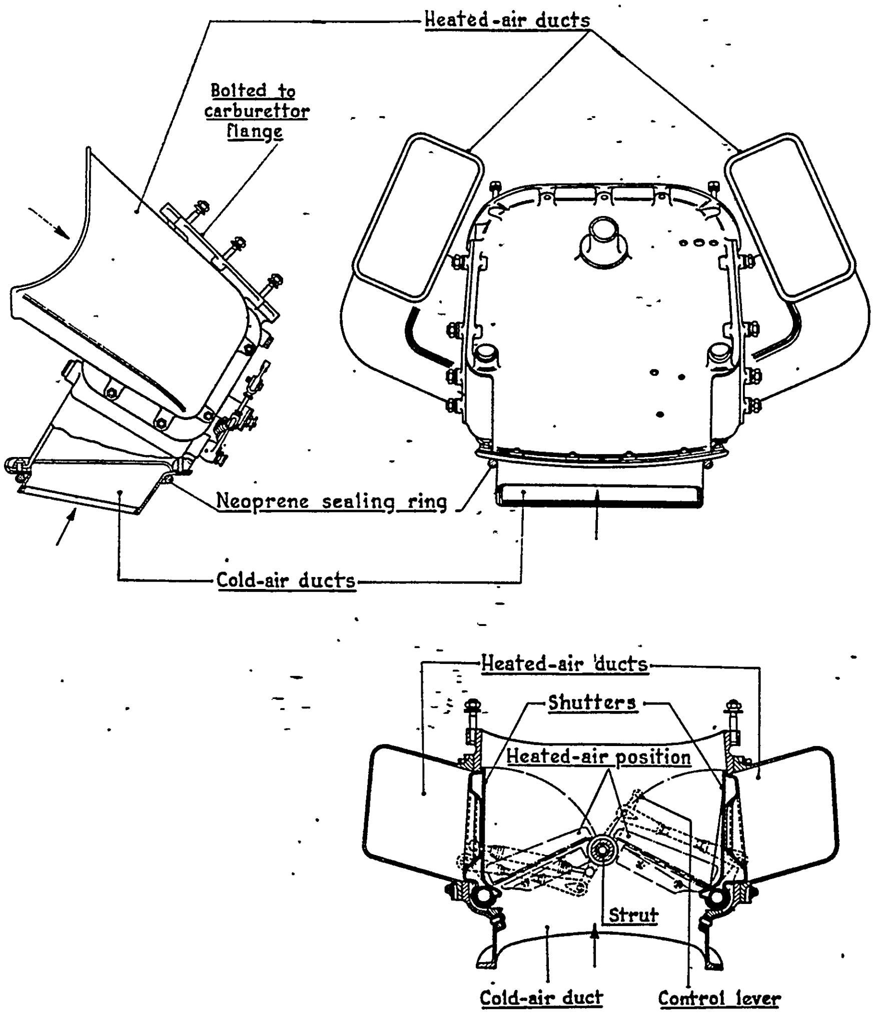


Fig. 8.—Alternative heated air-intake—updraught

Cleaning and re-assembling pumps

17. When the electric pump is dismantled, its parts, excluding motor parts, should be cleaned in alcohol, when it should be ensured that all ports and passages in the pump body are clean and free from obstruction. The bearings of the electric pump should be lubricated with anti-freezing grease (Stores Ref. 34A/49), thinned slightly with anti-freezing oil (Stores Ref. 34A/43). The commutator and brushes should be cleaned with a petrol-soaked rag. Any worn parts such as carbon brushes

and ball bearings should be replaced and the pump should be re-assembled in the reverse order to that given for dismantling in the preceding paragraph. After re-assembling the pump, it should be tested on the bench using either the test-rig described in para. 17, or the test-rigs for the airscrew de-icing pumps described in Chapter 1.

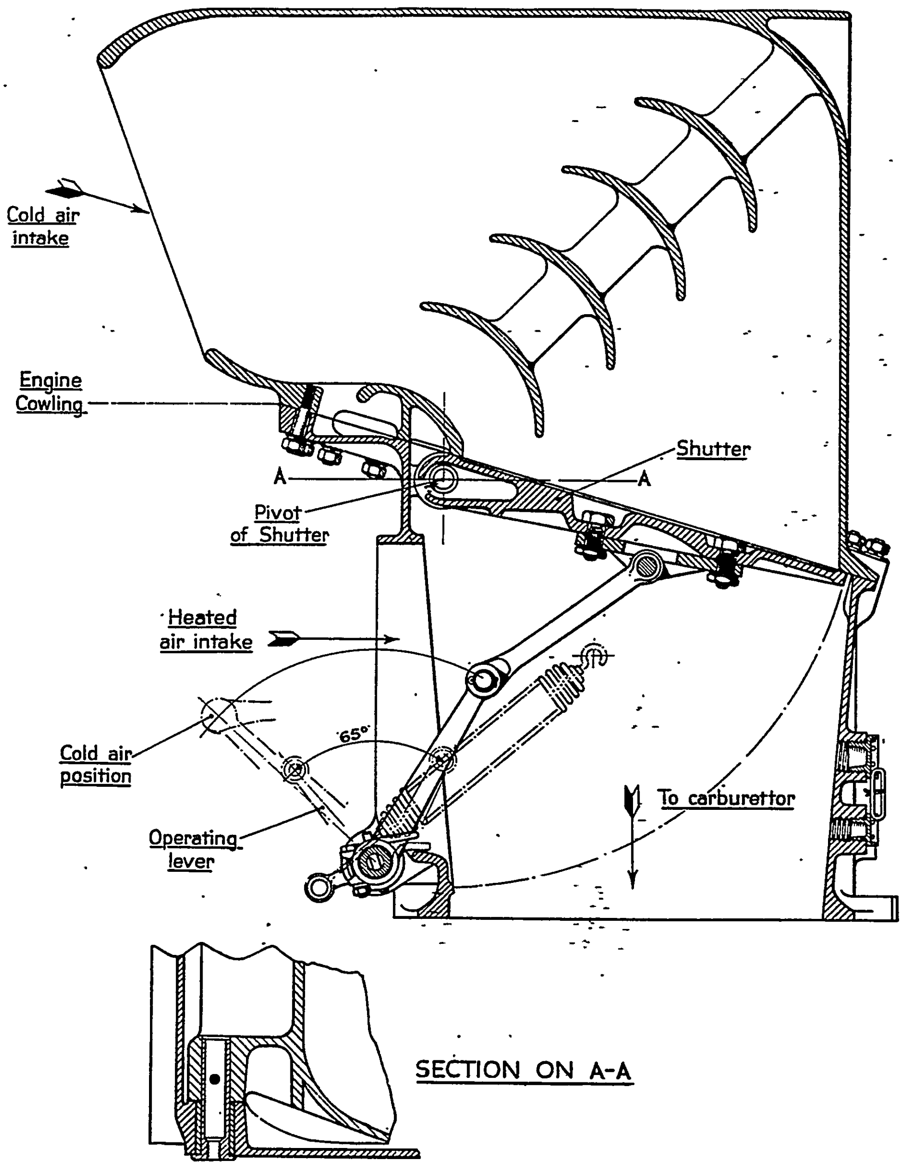


Fig. 9.—Alternative heated air intake—downdraught

Pump motor

18. In the case of motor failure, or excessive current consumption, after ascertaining that the supply and wiring are not defective, the motor cover should be removed and the commutator and brushes cleaned with a petrol-soaked rag. The brushes should be examined and if worn should be replaced by new ones. It should be verified that the brushes are free in their holders and their springs in a serviceable condition. If this fails to remedy the fault, the motor should be dismantled and the field coils tested for electrical continuity and insulation. If the field coils are satisfactory, the fault is probably in the armature which should be replaced by a new one.

ALTERNATIVE HOT AND COLD AIR INTAKES

General

19. Air intakes for aero-engines are provided with alternative hot and cold air supplies so enabling the pilot to change from a cold to a heated air intake whilst flying under conditions conducive to the formation of ice in the engine induction system. The carburettor air intake is usually provided with one or more shutters, operation of which closes the cold air intake and at the same time opens one or more ducts through which warm air is drawn from the neighbourhood of the engine cylinders.

Updraught air intake

20. A hot and cold air intake for an updraught type carburettor fitted to an air-cooled radial engine, is shown in fig. 8. The heated air intake has two ducts, the inlets of which are disposed near two adjacent engine cylinders, whilst the cold air intake, having one duct, projects outside the engine cowling and fits into a streamlined air intake which faces forward (not shown), a Neoprene sealing ring being provided at the base of the duct. Control is effected by means of a pair of interconnected shutters which, in the cold air position, close the heated air ducts and permit a free passage to the cold air. In the hot air position, shown in dotted lines, the shutters are pivoted together to close the cold air duct and permit free passage to the heated air. In this position the shutters rest on Neoprene-lined seats inside the intake, so forming an airtight joint which prevents entry of cold air. As a precaution against damage to the shutters which might otherwise be caused by a backfire, they are made of mild steel, strengthened by dishing, and rest at their outer edges on a reinforcing strut extending across the intake.

Downdraught air intake

21. An alternative air intake for the downdraught type of carburettor fitted to an air-cooled radial engine is shown in fig. 9. The hot and cold intake ducts are respectively inside and outside the engine cowling and are controlled by a single pivoted shutter which simultaneously closes one duct and opens the other.

Alternative intakes embodying filters

22. Some alternative hot and cold air intakes are especially designed to incorporate an air filter.

Control

23. The hot and cold air intake is controlled by a lever mounted near the pilot and operating through the usual transmission devices. A helical tension spring is usually provided on the air intake, tending to open the shutter or shutters to cold air. In the downdraught intake shown in fig. 9, the helical tension spring is assisted by a pair of helical torsion springs on the spindle of the operating lever.

Servicing

24. Servicing of the intake will be limited to the application of a little anti-freezing oil at periodic intervals to the pivots of the shutters and operating lever. Some intakes are provided with grease-gun nipples at all the pivots for lubrication purposes. At major inspections the shutters should be examined for distortion and the pivots and Neoprene-lined seats should be examined for wear. Distortion may be occasioned by engine backfires, and if the distortion is such as to interfere with the functioning of the shutters the intake should be replaced by a new one and the damaged intake should be returned to Stores as unserviceable.

R.A.E. ICE GUARDS FOR AIR INTAKES

General

25. Ice guards for the air intakes of aero-engines are available for the majority of service aircraft. An ice guard consists of a wire-mesh arranged in front of the forward-facing cold air intake so as to consitute a leading surface upon which ice forms when the aircraft is flying under icing conditions. If the conditions are sufficiently severe, the ice formation will cover the entire surface of the ice guard, whereupon the latter becomes a solid cap which shields the interior of the intake from the airstream, with the result that ice formation in the intake is effectively prevented. In addition, the ice guard protects the air intake against the entry of stones, leaves, twigs, and, in tropical countries, locusts. Since ice guards are fitted externally, the presence of any such foreign matter is readily detected by personnel servicing the aircraft and can easily be brushed away prior to each flight.

Types of ice guard

26. Two types of ice guard are in service, the gapped type, and the gapless type. In the gapped type ice guard (see fig. 10), a gap is provided between the ice guard and the mouth of the air intake, and the guard overlaps the air inlet. With this arrangement the intake can continue to draw air around the sides of the ice guard and through the gap after the guard has become completely covered

with ice. For engines provided with a cold air intake only, the gapped type ice guard is the only type which can be used, because when the ice guard is iced over, the gap provides the only path for air supply to the carburettor.

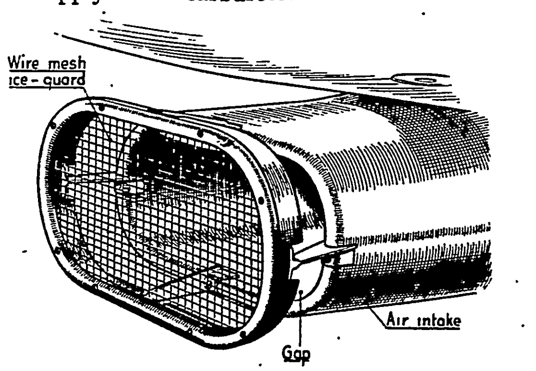


Fig. 10.—Gapped type ice guard

27. In some types of engines provided with alternative hot and cold air intakes, it is not essential to provide a gap between the intake and the guard, since the pilot would normally change over to the heated air intake before icing conditions were encountered. In such cases, although the gapped type ice guard is sometimes used, the tendency is to use a gapless type (see fig. 11) in which the ice guard is mounted directly on the mouth of the air intake. The function of both types is to prevent the formation of ice on the shutters which control the heated air intake, and to limit ice accretion to an external point where a change to a warmer level would melt it quickly.

28. In certain types of engines provided with the alternative hot and cold air intakes it has been found necessary to use a proportion of cold air with the heated air in order that the engine should not operate on heated air alone, and in such instances it is necessary to provide a cold air intake which is free under all conditions. Whilst it would be possible to use a gapped type ice guard, the air intake is usually arranged too far forward to permit a guard of this type to be mounted in front of it. An arrangement of a gapless type ice guard to fulfil these requirements is shown in fig. 12; the intake is of the downdraught type and is faired into the leading edge of the top of the engine cowling. The wire-mesh ice guard is attached directly to the mouth of the intake, and a panel is cut out of the engine cowling inside the intake and forward of the engine cylinders. When the ice guard is covered with ice, the intake continues to draw cold air from under the engine cowling through the panel.

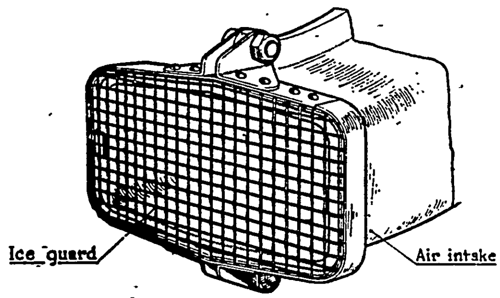


Fig. 11.—Gapless type ice guard

29. Some engines are provided with a cold air intake which is built into the radiator, and with this arrangement an ice guard is not used.

Construction of ice guard

30. The mesh of ice guards has been standardised as 4 mesh per inch, the wire being high tensile phosphor-bronze. The mesh is pulled taut before being soldered within a metal frame in such a manner that the full strength of the wire is available to resist air and vibratory forces on it. In the gapped type ice-guard shown in fig. 10, the frame is clamped between the two parts of a divided frame of synthetic material, a cork gasket being provided at the mesh-side of the metal frame. The parts of the frame are secured together by countersunk screws and attached to the mouth of the intake by suitably shaped metal brackets secured by screws to the frame and intake. In the gapless type ice guard shown in fig. 11, the guard is mounted in a divided metal frame which is clamped onto the intake mouth by two bolts passing through lugs on the intake.

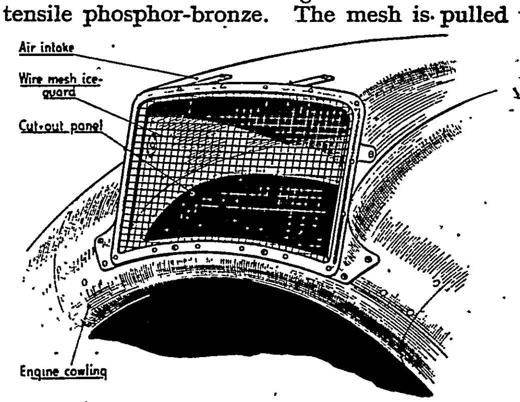


Fig. 12.—Gapless type ice guard with cut-out panel

Servicing

31. After each flight, the ice guard should be inspected and any twigs, leaves, grass, etc., removed. Care should be taken not to displace the wires of the guard mesh relatively to one another, otherwise the holes will be enlarged and the effectiveness of the guard reduced. In the case of accidental damage or incipient corrosion, the guard should be removed and replaced by a new one. Corrosion is particularly dangerous in view of the possibility of the wire mesh becoming detached from the frame and being carried into the engine supercharger, in which case serious damage might result.

P5069 M /1345 10/44 5250 C&P Gp. 1

SECTION 5

COOLING SYSTEMS

LIST OF CHAPTERS

***Note.**—A list of contents appears at the beginning of each chapter*

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 19 to A.P.1464C, Vol. I and concerns Part 2, Sect. 5
Insert this chapter.

RESTRICTED
(For official use only)

CHAPTER 2.

AERO-ENGINE COOLING SYSTEMS—SERVICING

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The efficiency of a properly designed aero-engine cooling system depends mainly on the thoroughness of the servicing. The information given in this chapter is of a general nature because each type of cooling system has its own peculiarities, and local conditions must also be taken into consideration. This chapter, should therefore, be read in conjunction with information contained in the relevant aircraft handbook and further augmented by reference to Vol. II leaflets and personal experience. The routine servicing instructions for cooling systems are laid down in the relevant aircraft handbook, Vol. II, Part 2.

2. In the cooling systems of all types of liquid-cooled aero-engines, Ethylene Glycol is used either in an approved form alone, or mixed to a specific percentage with water; the resulting liquids are termed "Coolants". The use of ethylene glycol is essential to prevent the cooling system from freezing up during service in cold climates and also during long glides at great altitudes. In order to avoid any risk of confusion a liquid-cooled aero-engine must not be referred to as "water cooled", whatever coolant is used. The cooling systems of Service aircraft may be broadly classified in two main categories, namely:—

(i) Those using coolant consisting of 30 per cent ethylene glycol (D.T.D.344, or D.T.D.344A) mixed with 70 per cent water. In this category are included the earlier types of liquid-cooled aero-engines in which the coolant circulates at atmospheric pressure, and the latest types where the whole cooling system is under a controlled internal pressure.

(ii) Those using coolant consisting of ethylene glycol without water. (D.T.D.344, or D.T.D. 344A.)

CORROSION

General

3. One of the principal defects experienced in cooling systems is the corrosive action of the coolant on the various metals used in the system. This corrosion continues all the time the coolant

is in the system, whether the engine is standing idle or is in constant use. Since leaking radiators or coolant pipes, resulting from such corrosion action, may well cause the loss of an aircraft, it is of primary importance that corrosion be reduced to a minimum.

Corrosion inhibitor

4. Ethylene glycol in its pure form (D.T.D.116A) does not contain a corrosion inhibitor and when used as a coolant, alone or mixed with water, will itself attack the solders in the radiators. If used for any length of time ethylene glycol becomes acidic; its corrosive effect is thereby increased and the various metals in the cooling system, especially mild steel, are also affected. It is therefore necessary to protect the cooling system components subject to attack by adding an inhibitor (Triethanalomine Phosphate). Ethylene glycol containing this substance is now the standard used in the Service for all liquid-cooled aero-engines, either neat or as a 30/70 per cent coolant, according to the requirements of the particular cooling system. Ethylene glycol containing corrosion inhibitor is available to the Service to specifications D.T.D.344 and D.T.D.344A. Both specifications include the addition of the inhibitor, but D.T.D.344A, which is a more recent specification, contains 0·2 per cent more of the inhibitor than D.T.D.344. Ethylene glycol to either specification may be used, but it is preferable that D.T.D.344A is used in the preparation of the 30/70 per cent coolant.

COOLING SYSTEMS USING 30/70 PER CENT COOLANT

5. Where coolant having an admixture of water is used in aero-engine cooling systems, unless suitable precautions are taken, trouble will occur in service because of the deleterious effects of impurities contained in most supplies of water. It is therefore preferable that, whenever possible, distilled water should be used in the preparation of 30/70 per cent coolant. The usual sources of supply of water and the methods of employing them are described in the following sub-paragraphs:—

(i) *Distilled water.*—As already stated, wherever possible distilled water should be used in making up the coolant and every care taken to keep it free from contamination. Containers used for storing distilled water should be reserved for this purpose alone and should never be used for holding any other liquid. Whenever the containers are to be filled they should be first washed out at least four times with distilled water. Any funnels or pipes which may have to be used should be washed out with the same care. Receptacles holding distilled water should always be kept covered to prevent the entry of impurities and the absorption of gases from the atmosphere.

(ii) *Mains water.*—Where distilled water is unobtainable local mains water is the better alternative, but as such water has an appreciable degree of hardness, calcium and magnesium salts will be precipitated when the water is heated to boiling point, thus causing furring of passages and reservoirs in the cooling system. Hitherto, the practice had been to obtain the hardness figure of the mains water to be used, and then to add a definite amount of Tartaric acid in order to precipitate the impurities before using the water in the preparation of 30/70 per cent coolant. The inhibitor included in the present standard glycol (D.T.D.344 and D.T.D.344A) is itself an efficient water softener, and with its introduction, the need for any further water-softening process has been removed.

(iii) *Rain water.*—Rain water, though by nature purer than mains water, is usually collected from roofs of buildings and may have become seriously contaminated with camouflage paint, etc. It should not be used if distilled or mains water is procurable.

(iv) *Chlorinated water.*—It is possible that only chlorinated water may be available, in which case it should be de-chlorinated either by boiling or by adding Sodium Hyposulphate or Sodium Sulphite (see A.P.1086), in the proportion of ½ oz. to 100 gal. of chlorinated water. In an emergency where only contaminated supplies of water are available and no proper treatment can be given, it is important that an aero-engine cooling system, in which such water has been used as part of the coolant, should be drained and thoroughly flushed with clean water at the first opportunity. The system should be refilled with clean coolant correctly prepared.

Mixing 30/70 per cent coolant

6. Where distilled water is used in the preparation of 30/70 per cent coolant, and provided that all the apparatus is clean, the mixture may be transferred to the aero-engine cooling system immediately after being thoroughly stirred and tested for specific gravity (see para. 7). The water content of the coolant when not distilled will be of various degrees of hardness, and a settling period will be necessary to ensure that the calcium and magnesium salts, precipated by the inhibitor, are allowed to subside. For this purpose a settling tank is necessary. The tank should be supported above ground level and fitted with a large-bore drain-cock in the base of the tank, so that sludge and sediment may be easily removed. For drawing off the pure coolant, a second drain-cock should

be fitted in the side of the tank at a sufficient height from the bottom to prevent any sediment passing out with the coolant. Alternatively, the clean coolant may be syphoned out of the tank through a pipe, the submerged end of which is supported some distance from the bottom of the tank. The coolant should be allowed to stand in the tank for at least four hours after mixing before being transferred to the cooling system. After each tankful of coolant has been used the tank should be thoroughly cleaned out and flushed with clean water.

Testing specific gravity of 30/70 per cent coolant

7. The strength of the solution is tested by taking its specific gravity by means of a suitable hydrometer (see A.P.1086), but special precautions must be taken to ensure that each hydrometer reading taken is representative of the whole bulk of the solution. Because of the possible variation of the purity of ethylene glycol (D.T.D.344 or D.T.D.344A), it may be found that the specific gravity of the coolant when made up in the proportions of 30 per cent glycol to 70 per cent water may not conform to that indicated in fig. 1. After making up the coolant it should be well stirred and a sample taken without delay in a clean glass or other suitable vessel, and the specific gravity measured. The hydrometer reading must be taken at the meniscus or the base of the curve formed by the liquid on the stem of the instrument and, at the same time, the temperature of the sample should be taken in degrees Centigrade by means of a reliable thermometer. Reference to the graph (fig. 1) will show whether the hydrometer reading is the correct one relative to the temperature of the mixture. The curve in the graph is intended to indicate the particular hydrometer reading that must be obtained at any given temperature. If the hydrometer reading obtained is too low, more ethylene glycol is required to be added to the mixture in the container; if the reading is too high the addition of more distilled water is necessary. The hydrometer and thermometer test should be repeated on samples until the concentration is correct, special care being taken to stir the liquid each time water or ethylene glycol is added and to wash the testing vessel before each test, thus avoiding errors in obtaining readings.

30/70 per cent coolant in use

8. It is essential that the correct specific gravity of the coolant in use should be maintained and, as evaporation resulting from high engine temperatures or prolonged use will affect the strength of the coolant, samples must be drawn from the cooling system periodically and tested. Any evaporation that takes place is almost entirely that of the water, and consequently the specific gravity of the mixture will tend to increase. If, as the result of a test on a sample drawn from the cooling system, it is found that the specific gravity of the coolant is incorrect, the whole of the coolant must be drawn from the system and the specific gravity adjusted by the method described in para. 7. If samples of coolant are found to be so discoloured as to indicate the presence of an excessive amount of rust, the aero-engine should be run up and opened out to full ground level power for 30 seconds, in order to circulate the coolant thoroughly, after which the cooling system should be drained immediately. The liquid should be allowed to stand in the settling tank until the impurities have subsided, after which the coolant should be adjusted to the correct strength and returned to the cooling system after this has been flushed through with clean soft water.

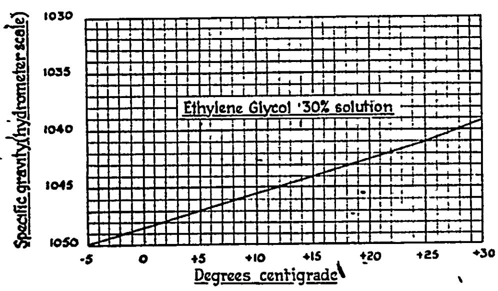


Fig. 1.—Graph, indicating specific gravity of 30/70 per cent coolant at various temperatures

Aircraft delivered from contractors

9. The cooling systems of aircraft which are delivered by air to Units direct from contractors may not contain coolant to Service standards. The cooling systems of all such aircraft should be drained, the coolant examined and treated in accordance with the directions given in the preceding paragraphs.

Foaming of coolant in engines

10. Foaming of the coolant in aero-engines gives rise to very serious consequences. The trouble usually occurs when the coolant temperature has risen to 80° C. under running conditions, large quantities of foam being formed and then lost via the header tank relief valve. It will readily be appreciated that, in conjunction with the consequent reduction in the quantity of coolant available, the fact that foam rather than liquid is being circulated through the system seriously reduces the

cooling efficiency of the coolant, resulting in overheating and consequent damage to the engine. Foaming of the coolant may result in the loss of as much as 4 to 6 gallons from the cooling system of a typical single engine on an operational flight of 6 hours' duration.

11. It has been proved by experiments that, where coolant is kept scrupulously clean, foaming cannot take place. Foaming appears to be the result of a very fine dispersion or colloidal suspension of impurities in the coolant. Such fine impurities may have been introduced during mixing in the tanks, or may be a result of corrosion within the cooling system itself. Coolant which becomes discoloured during use should be treated with suspicion and if very obviously dirty should be discarded. *Suspected coolant should not be rejected lightly.* Whilst some trouble caused by foaming has been experienced in the Service, this cannot be said to have reached any serious proportions, and only where strong evidence as to the foaming propensities of the coolant has been definitely established under running conditions, should it be discarded.

12. Evaporation of water from 30/70 per cent coolant causes an increase in the concentration of impurities present in the system. When draining the cooling system for correction of the specific gravity of the coolant by the addition of water (see para. 8) the opportunity should be taken to examine the coolant for signs of foaming. When foaming in a coolant system has been definitely established, there is only one sure method of dealing with the trouble, namely, the cooling system must be drained, washed out with water, and refilled with new coolant.

13. Where evaporation of the water content of the coolant has occurred, on no account must the cooling system be topped up with water alone. If this is done, any impurities in the water, such as those which give rise to permanent or temporary hardness, will be precipitated, causing sludging, and also greatly increasing the possibility of foaming. In an emergency when there is no time to drain the cooling system and to refill with the correct coolant, the system should be topped up with clean coolant or, if this is not available, with neat ethylene glycol (D.T.D.344, or D.T.D.344A).

Draining the engine coolant system

14. When it is necessary to drain the coolant from the cooling system, the following is the procedure to be adopted. The engine should be run up until the coolant has reached a temperature of 85° C. The engine should then be switched off and the hot coolant immediately removed. This ensures that any sludge or sediment in the coolant is first thoroughly agitated and then cleared from the cooling system. When it is seen that the coolant is dirty, and it is considered advisable to flush the system for this reason, it should be refilled with distilled water, or the softest water obtainable, and the engine run up again until the temperature of this water reaches 85° C., upon which it should be drained off at once. If the water drained from the system is very dirty, the process should be repeated until clear, and the cooling system filled finally with clean coolant. In all such operations the apparatus used must be kept clean.

Safety precautions

15. Personnel should exercise great care when draining an engine cooling system to avoid getting splashed with hot coolant, as the resulting burns are both painful and serious. The fumes given off by the hot coolant should not be inhaled where this can possibly be avoided. The 30/70 per cent coolant and neat ethylene glycol coolant, whether hot or cold, have a deleterious effect on rubber and similar materials. This is an additional reason for avoiding splashing and awkward handling of the fluid. Any rubber components, such as tyres, electrical cables, etc., which have unavoidably come into contact with coolant should be wiped dry at once.

Salvage of coolant

16. All coolant removed from a cooling system and which is considered to be unfit for further use, or is known to be contaminated, should be returned to Stores in salvage drums for despatch to the manufacturers who can reclaim such coolant no matter in what condition it has come from the engine.

COOLING SYSTEMS USING ETHYLENE GLYCOL WITHOUT WATER

17. Those aero-engine cooling systems using neat ethylene glycol must always use inhibited ethylene glycol to Specification D.T.D.344 or 344A.

18. Ethylene glycol tends to decompose in use, due to the repeated heating to normal engine temperatures, and evidence of this will be shown by foaming; foaming may also be caused by dilution with water or by contamination with oil, or by the presence of dirt. Because of the higher operating temperatures of ethylene glycol, care should be taken to ensure that water is not inadvertently introduced either directly or indirectly into the system, as, for example, when cleaning and flushing

radiators, etc., otherwise loss of coolant will take place as a result of foaming and water vapour locks will be formed in the system, resulting in serious overheating of the engine. When foaming occurs, the ethylene glycol should be replaced by new liquid, the old being drained from the system into proper containers (see A.P.1086) and returned to Stores to be freed from water and impurities. Used ethylene glycol should always be conserved and only clean approved types of containers suitably labelled should be employed for this purpose.

19. There is no simple method of determining the water content of ethylene glycol when slight decomposition or dilution with water has taken place, apart from observing when foaming occurs. The presence of larger quantities of water can be determined by taking the specific gravity of a sample of the liquid. The specific gravity of pure ethylene glycol at 60° F. (15·6° C.) should not be less than 1·115; at the same temperature, a hydrometer reading indicating a specific gravity of 1·10 would represent about 10 per cent dilution. A 70 per cent dilution would give a reading of 1·044 as indicated in fig. 1.

20. The boiling point of ethylene glycol is 195° C. and its freezing point is minus 17° C.; it can, therefore, be used to advantage in extreme climates. Care should be taken when handling it to prevent any from being splashed on rubber components, on which it has a deleterious effect. When draining cooling systems containing pure ethylene glycol which is still hot, it should be remembered that serious scalding may ensue from personal contact with the fluid.

Thermostatic control

21. Most cooling systems are fitted with thermostatic control and pressure relief valves (see relevant aircraft and engine handbooks, Vol. I). These components should be examined and tested at the inspection periods laid down in Vol. II, Part 2, also whenever signs of overheating persist after routine maintenance operations have been completed. The cause of sudden rises in the temperature of the cooling system should be investigated without delay. When radiator shutters are fitted their operation should be observed from fully open to fully closed positions ascertaining at the same time that the control is locked in intermediate positions.

Header tanks

22. Certain cooling systems include a header tank which should be removed, cleaned and examined at the inspection periods. If any sign of corrosion is present action should be taken without delay either by repair or replacement. Inlet and outlet venting valves, where fitted, should be periodically cleaned and then tested for operating pressures, which should be in accordance with those given in the relevant aircraft handbook, Vol. I; defective valve springs should be replaced by new ones of the correct type and compression values.

Filling cooling systems

23. Certain cooling systems of aircraft have occasionally failed to function efficiently as a result of filling operations. The failures are principally due to air-locks which cause the level of the coolant to fall as the air-locks are dispersed during flight; the engine then has insufficient coolant for the system to function correctly. The design of the piping layout, especially when a retractable radiator is employed, has considerable effect in the formation of air-locks. The approved methods of filling cooling systems are generally stated in the relevant aircraft handbooks. When a system is being filled, the coolant must not be pumped too quickly when hot coolant is used. The following is the sequence of operations for filling where specific instructions are not available:—

(i) *System with retractable radiator.*—

(*a*) Lower the tail of the aircraft to the ground.

(*b*) Wind the radiator down to its lowest position and see that the drain plug is screwed up hard and is locked.

(*c*) Open all vent cocks (see aircraft handbook for position) and fill the system with the proper coolant. The filling must be done through a fine mesh strainer at the highest point in the system. Close the vent cocks as the coolant issues from them, but not before.

(*d*) Wind the radiator up to its highest position.

(*e*) Run the engine in a similar manner to that laid down in the aircraft handbook for warming up; this will disperse any trapped air.

(*f*) Stop the engine and check the level of the coolant. It will probably be found that the level has dropped and in these circumstances the system should be "topped-up" with the proper coolant.

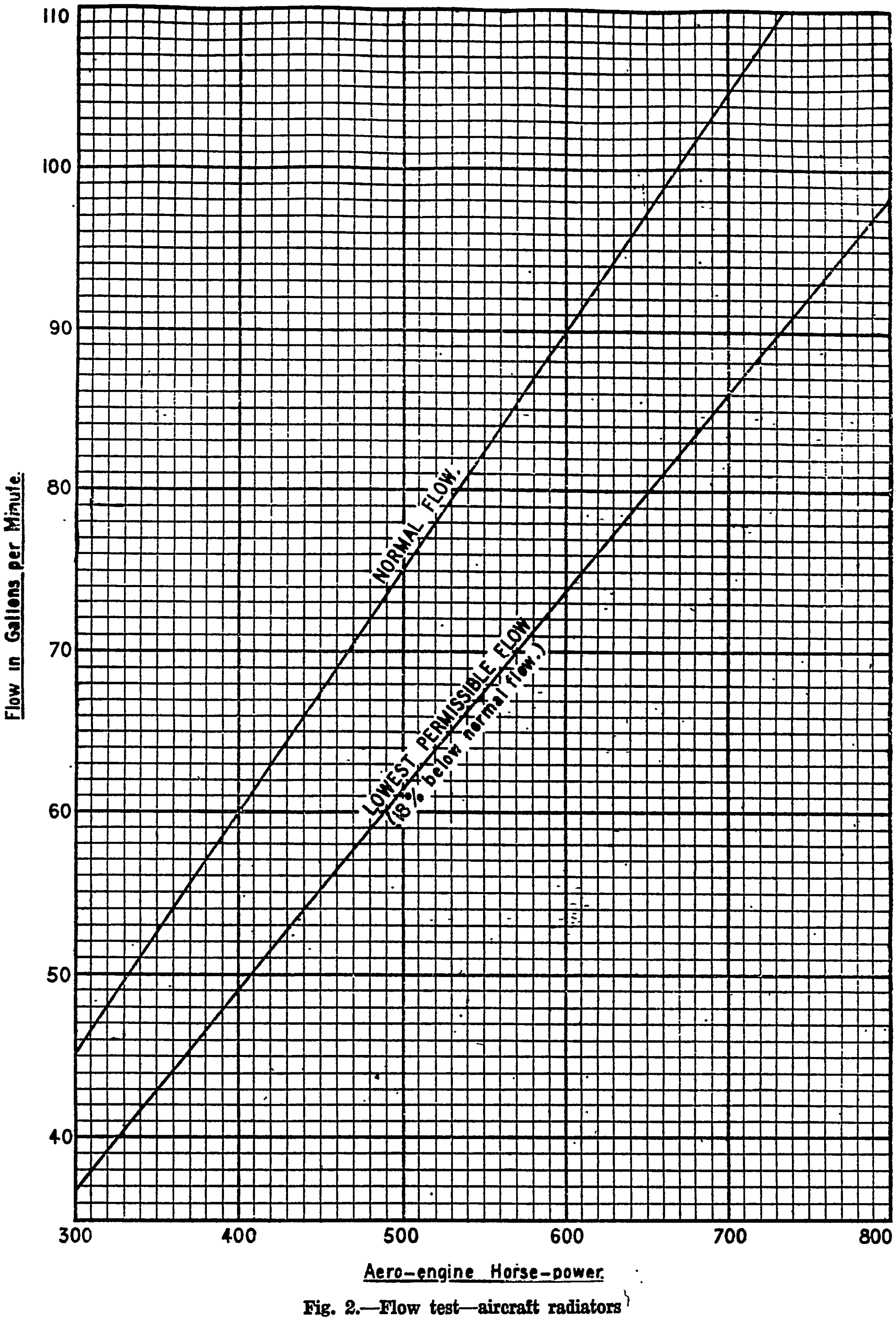


Fig. 2.—Flow test—aircraft radiators

(*g*) Wind the radiator down to its lowest position and again run the engine for a few minutes. With the engine running, raise the radiator to its highest position until the coolant reaches its correct temperature (see relevant engine handbook). Stop the engine. A momentary rise in temperature may occur when suddenly throttling down, owing to the temporary slowing down of the circulation of the coolant.

(*h*) Check the level of the coolant and "top-up" as necessary.

(ii) *System with fixed radiator.—*

(*a*) Lower the tail of the aircraft to the ground and see that the drain plug is screwed up hard and is locked.

(*b*) Open all vents (see aircraft handbooks for positions) fill the system with the proper coolant. The filling must be done through a fine mesh strainer at the highest point in the system. Close the vents as the coolant issues from them, but not before.

(*c*) Run the engine in a similar manner to that laid down in the aircraft handbook for warming up; this will disperse any trapped air.

(*d*) Stop the engine and check the level of the coolant. If the level has dropped, "top-up" the system with the proper coolant.

(*e*) Run the engine until the coolant reaches its correct temperature (see relevant engine handbook). Stop the engine. A momentary rise in temperature may occur when suddenly throttling down, owing to the temporary slowing down of the circulation of the coolant.

(*f*) Check the level of the coolant and "top up" as necessary.

Flow test of radiators in aircraft

24. The purpose of flow-testing a radiator is to ascertain whether there is any obstruction due to scale formation, pieces of rubber, etc., in the water spaces between the radiator tubes. The test may be made, in some instances, without removing the radiator from the aircraft, first draining the system and then breaking the radiator inlet and outlet water branch pipe joints. The branch pipes should be coupled to long lengths of tubing. The tubing on the inlet branch must provide the 7-ft. head of water which is necessary for this test and, therefore, will require supporting in a vertical position. The tubing at the outlet branch should be long enough to permit the overflow of water to be led clear of the aircraft. Suitable clips should be used to make the rubber joints, unless special adaptors have been made up in the unit. The use of a large funnel fitted with a strainer will be found of assistance when filling the radiator. Soft water preferably should be used for the flow test. The test consists of timing (with a stop watch) the filling of a large drum of known capacity or a calibrated measure, after the full flow of water has been attained. The actual flow in gallons per minute is then calculated; for instance, if a 20-gall. drum is filled in $10\frac{2}{5}$ sec. the rate of flow will be $\frac{20 \times 5 \times 60}{52} =$ 115·38 gall. per min. Reference to fig. 2 will determine whether the flow-rate is below the minimum authorised, which is 18 per cent below the normal flow. An aircraft radiator should normally pass a flow of water of 15 gall. per min. for each 100 h.p. of the engine on which it is employed. If the rate of flow is below the low limit, the radiator should be removed from the aircraft and returned to the workshop for necessary action. The radiator may be boiled in water (caustic soda or washing soda should not be used) for an hour, and then flushed through with hot water in the reverse direction to the normal flow. If this operation does not increase the flow-rate, the radiator should be returned to the depot in order that the four bottom rows of tubes can be removed to permit access to the sediment.

Temporary repairs to radiators

25. As an emergency measure only, a leaky radiator may be temporarily repaired by using the standard leak-stopping compound listed in A.P.1086. This compound is supplied in $4\frac{1}{2}$-oz. and 9-oz. tins, and normally, for small leaks, the contents of the 9-oz. tin will be sufficient for each eight gallons of cooling capacity, but larger proportions may be added if required. The compound consists essentially of an organic liquid containing resinous matter, partly in solution and partly in suspension. When the compound is mixed with hot water the solid particles separate out and, on boiling the liquid, the particles become coarser, eventually forming soft masses which fill up small holes in the cooling system at which a leak is occurring.

26. To effect a temporary repair, the coolant, if other than water, is drained from the system and replaced by soft water, the special coolant being stored in suitable containers. The engine is then run long enough to raise the temperature of the water to 90° C., the necessary amount of com-

pound is then added and the engine run at half ground-level speed until the leak ceases. If soft water is not available, the necessary amount of leak-stopping compound may be added to the existing coolant and the remainder of the procedure followed. The addition of leak-stopping compound to coolant (water or otherwise) causes considerable frothing and subsequent loss of liquid. During flight, therefore, the temperature of the coolant treated with leak-stopping compound should not be allowed to rise higher than 10° C. below boiling point, as indicated on the radiator thermometer gauge (see A.P.1275, Vol. I). As the use of this compound is only to be regarded as an emergency expedient, permanent repairs or replacements must be effected at the earliest opportunity. Before permanent repairs are commenced, radiators in which leak-stopping compound has been used must be flushed through with soft water in the reverse direction to normal flow in order to remove all traces of the compound from the cooling surfaces; the contaminated water or coolant is to be discarded.

Permanent repairs to radiators

27. For information on permanent repairs to aircraft cooling systems, reference should be made to Chapter 5.

Marking of piping

28. All pipes in aircraft cooling systems must be marked to indicate their application, in accordance with the information given in A.P.1464D, Vol. I, Part 2, Sect. 3, Chap. 2.

WATER JOINTS

General

29. Particulars regarding the maintenance of special types of joints employed in cooling systems will be found in the relevant aircraft handbooks. The most commonly used type of joint is one in which two metal pipes are joined by means of a length of rubber tubing, the ends of the tubing being compressed by encircling adjustable clips (see fig. 3). As a general rule this type of joint should be tightened up when first fitted and tightened again, after the engine has been run, whilst the cooling system is still hot. As a result of the continual expansion, contraction and deterioration of the rubber tubing, the joints should be examined frequently and kept tight and free from oil or grease. A bead of liquid may be found at some joints but this should not be regarded as a leak, unless it takes the form of frequent and continual dripping.

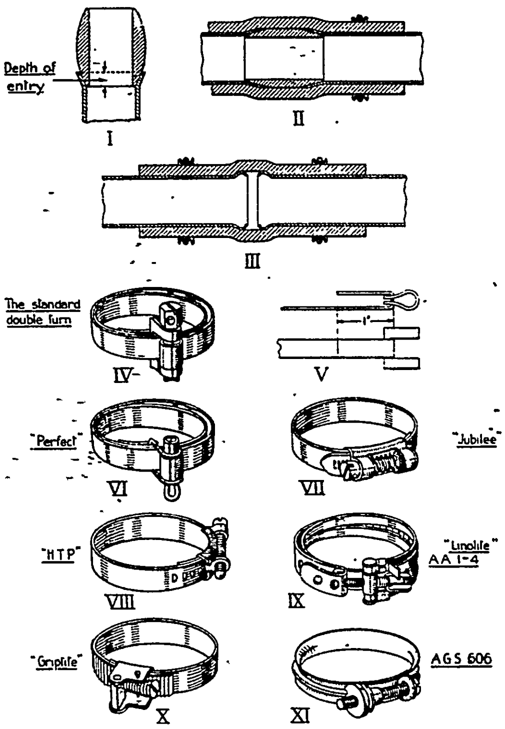


Fig. 3.—Water joints and clips

Making a joint

30. When making a joint of the type mentioned in the preceding para., the pipe ends should be square with the axis and either flanged for use without an olive (see fig. 3) or expanded for use with an olive. In both instances the sharp edges should be rounded off and a clearance should be left between the ends of the pipes, sufficient in one instance to allow the olive to be held without undue springing and in the other to prevent contact between the pipe ends due to flexing.

31. The ends of copper pipes should be tinned to a suitable length for the protection of the pipe against the corrosive action of rubber on copper. The ends of stainless-steel pipes should be protected by the application of a coat of pigmented oil varnish.

32. The correct depth to which an olive should enter a properly expanded pipe-end varies for pipes of different diameters and should be as follows:—

Pipe. Diameter	*Olive. Depth of entry*
$\frac{1}{4}$ in. to $\frac{7}{8}$ in.	$\frac{1}{8}$ in.
1 in. to $1\frac{5}{8}$ in.	$\frac{5}{32}$ in.
$1\frac{3}{4}$ in. to 2 in.	$\frac{3}{16}$ in.
Over 2 in.	$\frac{7}{32}$ in.

33. When assembling a joint in which an olive is to be used the rubber tubing should be passed over the expanded end of the pipe, the olive placed in position and the rubber tubing then pushed back over the joint into its correct position. Certain types of hose clips must not be sprung over the rubber tube, therefore they should be placed loosely in position on the pipe ends before inserting the olive. It is essential that all mating surfaces are perfectly clean when making a joint employing nipples, olives, etc. The clips should be fitted at each end of the rubber tubing and tightened; if necessary, fabric or copper gauze should be wrapped around the rubber tubing over the full length of the joint, to ensure that the clips will grip securely. *Insulation tape, leather, etc., must on not any account be used for this purpose.* Each pair of clips should be tied together by means of locking wire as shown in fig. 4, after they have been re-tightened whilst the cooling system is hot, as described in para. 29. In most instances, the heads of the clip screws are drilled for the reception of the locking wire but, where no such provision is made, the locking wire should be passed behind the ends of the screws in a similar position to that indicated in the illustration; other types of clips can be secured in a similar manner. Care must be taken after a joint has been disturbed to ensure that any bonding on the joint is replaced in position in a tight and serviceable condition.

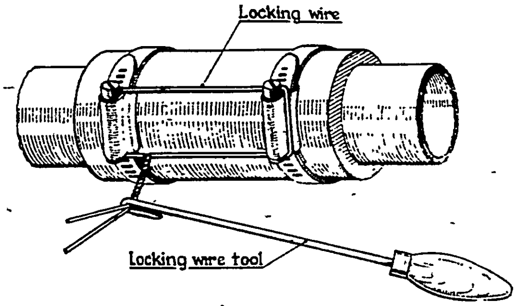


Fig. 4.—Arrangement of locking wire on hose clips

WATER CONNECTION CLIPS

Ring clip

34. The ring clip (see fig. 3, sketch XI) consists of a split brass-channelled band, encircled by a tempered steel ring which fits into a recess formed in the brass band, the ends of the steel ring being looped to take an adjusting screw and nut. In use, the clip is first opened out by unscrewing the adjusting screw until the ring can be slipped over the rubber tubing; the rubber tubing is then pushed over the pipe end, and the clips positioned on the ends of the rubber tube. By tightening the adjusting screw, the band is reduced in diameter and the rubber tube is compressed. If, when tightening the adjusting screw, the looped ends of the steel ring meet, the clip is too large for the tubing and a smaller clip must be obtained. Ring clips are available in sizes ranging from $\frac{5}{16}$ in. to $3\frac{1}{2}$ in. in increments of $\frac{1}{16}$ in.

Note.—This type of clip must not be sprung over the rubber tubing when making a joint or the clip will be distorted at the curved ends, resulting in a defective joint. Care should be taken to ensure that the nut is in correct engagement with the steel ring.

Single band-type clips

35. Single band clips of the Jubilee type (see fig. 3, sketches VII, VIII and X) are available in various sizes to cover a wide range of pipe diameters. They can be removed and replaced without serious distortion, but must not be used on piping of light alloy or thin section because of the risk of distorting the piping due to over-tightening. Clips of this type each employ a screw, mounted in a small bracket fixed to one end of the clip, whilst the other end of the clip is formed with a series of evenly spaced serrations or slots which engage with the screw threads for adjustment and tightening purposes.

Double turn band clip

36. The double turn band clip (see fig. 3, sketches IV and VI) is intended for use with standard internal diameter rubber tubing of various thicknesses. The clip consists of a length of steel strip, forming a double band, secured at one end to a fitting (clip) which positions the split pin on to which the other end of the band is wound. The band is made up to suit requirements from a roll of steel strip and the whole is assembled as explained in the following sub-paragraphs. The length of steel strip required for any particular size of rubber tubing can readily be determined by making two turns round the outside of the tubing and allowing, in addition, 1 in. for securing to the clip, plus $\frac{3}{4}$ in. for attachment to the split pin. When a number of these clips of similar dimensions are required, it is advisable in the first place to construct a pattern which can be fitted to the joint, in order to obtain the correct length, before cutting the lengths of steel strip from the roll. The correct method of making up this type of clip after cutting off to length is as follows:—

(i) Secure one end of the strip by bending it, 1 in. from the end, over the clip through an angle of 180°, as shown in fig. 3, sketch V.

(ii) Pass the free end of the strip once round the rubber tubing and under the split pin, then again round the tubing and through the slot in the pin.

(iii) Turn the head of the pin slowly by means of a small tommy bar whilst there is still some slack left in the strip, so that this slack is wound *under* the pin until the whole band is tightened on to the tubing.

The joint will not be satisfactory if:—

(*a*) The strip is passed once only round the rubber tubing.
(*b*) The strip is not entered through the pin slot in the correct direction.
(*c*) The strip is pulled taut before turning the head of the pin or by winding the strip over the pin instead of under it.

37. The head of the pin may be rotated with a tommy bar or spanner. If the tommy bar is used, care must be taken to see that the end of the bar does not protrude through the hole, and so damage the rubber tubing. To loosen the clip sufficiently to break the joint, it is necessary only to turn the pin in an anti-clockwise direction, when the clip may be dismantled by extracting the pin.

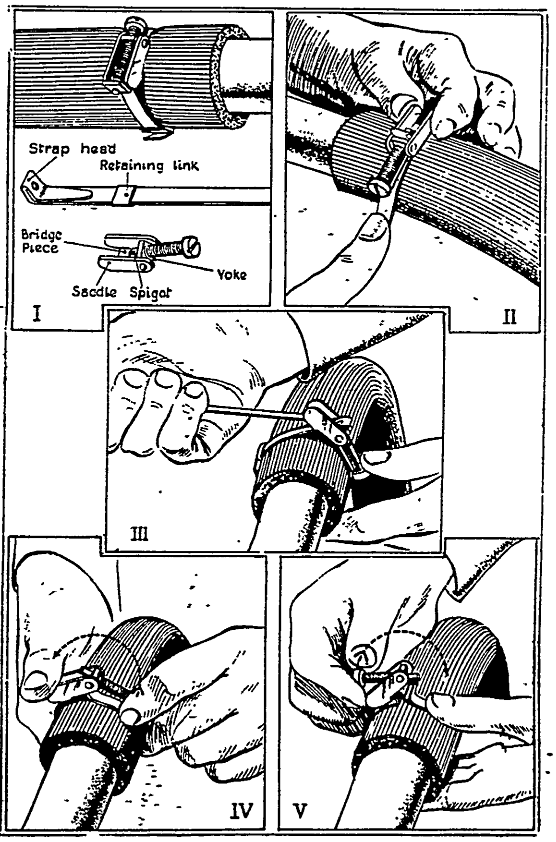


Fig. 5.—Fitting Linolite C.C. hose-clip

Examination of rubber tubing

38. It is sometimes found that certain rubber joints in aircraft cooling systems deteriorate more rapidly than others. If the periodical inspections appear to indicate that a length of rubber tubing is beginning to deteriorate at a joint, the rubber tubing should be removed and cut open, in order to ascertain the true condition of the rubber. It is possible in this way to form an opinion as to the "safe" period between the renewal of tubing at these particular joints and, by comparing the external appearance of the rubber with the condition of the rubber as revealed by cutting open, it is possible in due course to judge the serviceability of a rubber joint by external examination only.

Linolite C.C. hose-clips

39. The Linolite C.C. hose-clips (fig. 5, Sketch I) have been introduced in three sizes and will gradually supersede the types previously used, except the Jubilee type which is for general purposes and is the only clip to be used for Avimo couplings. The number of types of hose-clips is thus reduced to two, which are to be considered standard. The Linolite C.C. clip is made of mild steel, cadmium-plated, and is of the single-turn band type. The head of the band or strap is doubled back over a square flat washer and spot welded during manufacture, at the same time the holes in the strap are punched from both sides into the hole in the square washer, thus retaining it in position and forming a reinforced end. A retaining link is fitted to the strap for the reception of the tail-end of the strap when the clip is assembled, and the join in the link should always be positioned next to the hose. Straps are available in three different lengths, covering hoses of the following ranges of outside diameters:—$\frac{3}{8}$ in. to 1 in.,—1 in. to 3 in.,—3 in. to 6 in.

40. The strap is provided with a saddle having a fixed bridge-piece and a swivelling yoke into which a spigot-ended screw is fitted. The head of the screw is provided with a screw-driver slot and the first thread is upset to prevent the screw from coming out of the yoke, when unscrewed to the full extent. The saddle is available in two sizes, namely A—large, and B—small. The small size (B) with a 2 B.A. screw fitted is used only for the $\frac{3}{8}$ in. to 1 in. range; the large size (A) has a $\frac{1}{4}$ in. B.S.F. screw and is used for the other two ranges, 1 in. to 3 in. and 3 in. to 6 in. No attempt should be made to fit the small bridge-piece and yoke to the large sizes of straps or tearing of the strap will occur near the head also sufficient travel will not be obtained to enable the clip to be tightened. The following is the method of fitting a clip:—

(i) The hole in the strap-head should first be engaged with the spigot-end of the saddle screw which should be screwed out as far as the first thread (see Sketch II).

(ii) A retaining link should then be slipped over the free end of the strap and held approximately in its final position at about 120° from the saddle (see Sketch III), the join in the link being positioned so that it will be next to the hose.

(iii) With the head of the screw facing the operator, the free end of the strap should be passed round the hose, through the opening in the saddle (between the yoke and the fixed bridge-piece) and pulled as tightly as possible, after which the end of the strap should be bent back over the bridge-piece. The clip should now be reasonably tight on the hose, without obvious slack.

(iv) The free end of the strap should then be threaded through the retaining link and bent back again, the end of the strap being cut off to a convenient length (see Sketch I). *Note.*—It is important when the clip is tightened, to ensure that the end of the strap at the head is on or passed over the bridge of the saddle.

(v) The clip should be tightened up by means of a screw-driver. If, while being tightened the head of the strap does not ride smoothly over the bridge of the saddle, the head of the screw should be forced downwards in order to raise the strap-head clear of the obstruction; the clip screw can then be tightened to the requisite tension.

Removal and re-fitting of built-up clip

41. Once the clip is fitted to the hose it can be readily removed during dismantling operations, by slackening the screw back to the first thread, when the strap-head should be pushed off the spigot-end of the screw. The screw should then be pushed towards the strap-head until the spigot end of the screw rests on the top of the head (see Sketch IV) after which the head of the screw should be raised and the yoke and saddle levered clear of the strap head. The clip will now be completely released.

42. When refitting a built-up hose clip it should be positioned on the hose and, with the spigot end of the screw resting on the top of the strap-head (see Sketch V), the bridge-piece should be levered over by means of the screw and the spigot end of the screw engaged with the hole in the strap-head. The clip should then be tightened to the requisite tension.

Note.—Hose-clips which are required to be fitted in difficult positions in confined spaces should be made up first on a mandrel of the same outside diameter as the hose for which the clip is required.

P5071 M 1347 9/44 5250 C & P **Gp.1**

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 20 to A.P.1464C, Vol. I and concerns Part 2, Sect. 5.
Insert this chapter.

RESTRICTED
(For official use only).

CHAPTER 5

AIRCRAFT RADIATORS

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. Radiators are essential parts of the cooling system of water-cooled engines. As an aircraft radiator must be of light construction, it follows that it is somewhat fragile and easily damaged. Repair and inspection of radiators are therefore specially important, particularly when it is remembered that a defective radiator is quite sufficient to cause a forced landing.

2. The purpose of a radiator is to deprive the engine cooling fluid of heat. During the development of automobile radiators many different types were tried, most kinds depending upon the circulation of the water through a large number of metal tubes, which in many instances were fitted with fins or gills to increase the radiating surface. These early types gave way to a design, called the honeycomb radiator, which is entirely different in principle and is adopted for all aircraft radiators. In this type, short horizontal tubes with both ends open are soldered together leaving a narrow water space surrounding each tube. The cooling fluid is thus compelled to flow in a large number of shallow streams taking a zig-zag path. Air passing through the open tubes rapidly cools the fluid, owing to the very large surface of water in contact with the tubing.

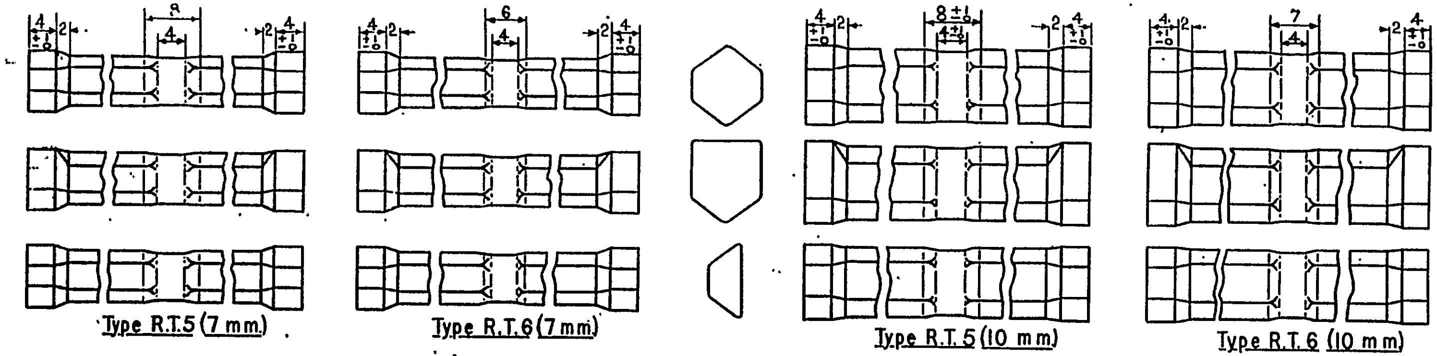


FIG.1. STANDARD TUBES.

Note:- Dimensions in millimetres.

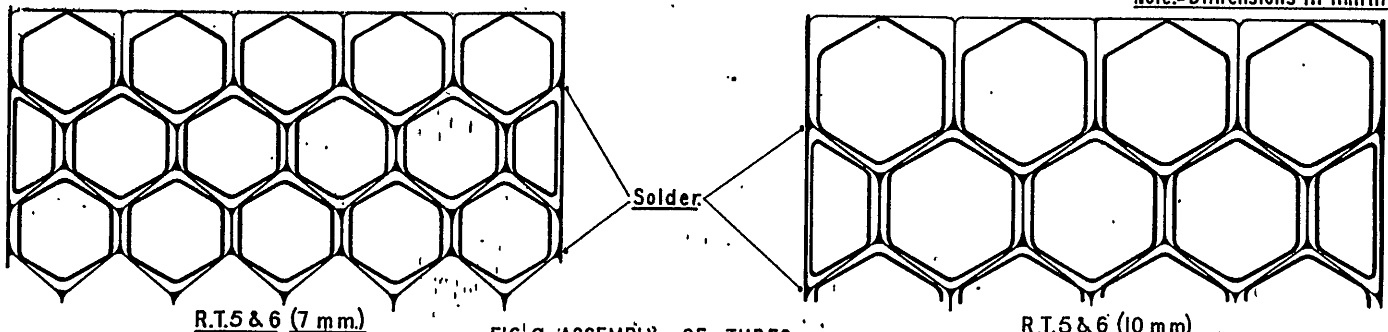


FIG. 2. ASSEMBLY OF TUBES.

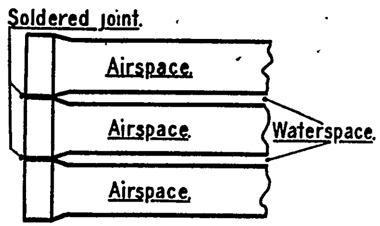


FIG. 3. SECTION THROUGH THREE TUBES.

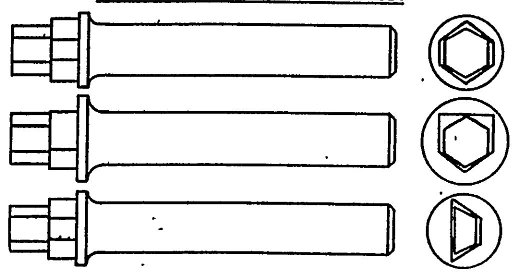


FIG. 4. FORMING TOOLS.

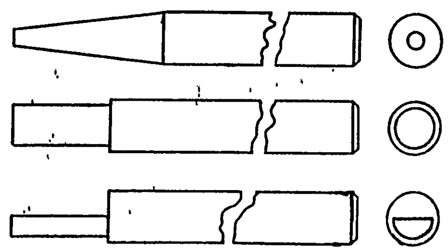


FIG. 5. STEEL RODS.

Fig. 1 to 5.—Aircraft radiator components and tools

3. The normal type of radiator is composed of a "tube-block" comprising a number of soldered-up tubes as described, held in a thin metal frame which includes an open water space over the tube-block and another water space below the block. The size, shape and general design of the radiator will vary according to the engine power and airframe design. The tubes themselves are made from solid drawn brass tubing of 7 mm. or 10 mm. diameter, the thickness of the wall being only 0·005 in. The bodies of the standard tubes are generally hexagon-shaped, although some radiators will be found with circular bodied tubes. The ends of the standard tubes in both instances are expanded into irregular hexagons as shown in sketch I of fig. 1, but two alternative shapes are formed in some tubes to allow them to be used at the margin of the tube-block—see sketches II and III of fig. 1. Enlarged views of the arrangement of the tubes are shown in fig. 2, in which it will be noticed that the correct assembly avoids horizontal channels, but gives vertical channels nearly double the width of the inclined ones. Where long tubes are employed, bulges are provided at predetermined positions so that the tubes may be supported, thereby preventing sagging. Fig. 3 shows the side view of three tubes sweated together.

Repair of radiators

4. The remainder of this chapter deals with such repairs as are likely to be carried out in the Service. In addition, some information is given as to the inspection processes carried out during the manufacture of radiators.

Equipment

5. *Dipping bath.*—A bath of molten solder will be required for dipping the tube-block, the size of the bath varying according to the extent of the repairs being undertaken in the Unit. For repairs involving the resoldering of a complete tube-block, a tank large enough to take the end of the block will be required; for less extensive repairs, a smaller one will be sufficient. The depth of the bath should be about two inches. The solder in the bath is liable to lose some of its tin content after repeated heating, and for this reason the contents of the bath should be periodically changed. The temperature of the bath should be controlled by means of an index pyrometer. The latter may also be employed to indicate when the solder becomes deficient in the tin content, this being indicated by the fact that a considerably higher temperature over the normal working temperature (i.e. 200° C.) will be required to give proper fluidity when the solder is deficient of tin.

6. *Solder and flux.*—During the construction and repair of radiators, only Grade B solder British Standard Specification No. 219B, together with the flux, Specification No. D.T.D.81, must be used; these are available to the Service and listed in A.P.1086 under the headings "Tinmen's Solder (Grade B)" and "Soldering Solution", respectively.

7. *Water bath.*—A bath containing hot water should be provided on the bench in close proximity to the repair operations, so that no time will be lost in transferring the tube-block or tube after it has been in contact with the flux.

8. *Heating stove.*—A suitable tinman's stove, heated by either gas or coke, is required for heating the soldering irons.

9. *Soldering irons.*—As small soldering irons soon lose their heat, it is desirable to use a large iron with a long tapered nose suitably "tinned".

10. *Jigs.*—A number of locally made jigs will be found convenient to hold a tube-block during the various repair processes. Fig. 8 shows a typical jig which comprises two metal straps of channel form, four pieces of plywood, two long bolts and nuts and a number of small wooden wedges—see para. 26.

11. *Forming tools.*—A number of steel forming tools should be made up, the ends of the tools being shaped similar to, but smaller than, the expanded ends of new tubes—see fig. 4. The object of these forming tools is to dress up the deformed ends of the tubes, if required, after the repair process has been finished. Only light hand pressure is required; excessive pressure is liable to split the corners of the tubes.

12. *Steel rods.*—Tapered steel rods, as shown in fig. 5, will be necessary for removing a single defective tube from the tube-block. If one of the steel rods is provided with a shoulder as shown in the illustration, it may be effectively used for the operation described in para. 24. Sometimes long rods are employed which protrude through each end of the tube, thereby allowing an operator to push one end and pull the other in the operation of removing a single tube.

13. *Wire clips.*—A number of pieces of soft wire will be found useful for identifying the tubes which are observed to be leaking under test, the wire being bent over with the fingers and squeezed against the sides of the tube ends. This method will be found more efficient than employing an indelible pencil, as the pencil marking will run when in contact with water.

14. *Testing equipment.*—The standard equipment for testing radiators is illustrated in fig. 6. This installation is designed to maintain a constant 7 ft. total head of water during the flow test. It will be readily understood that, providing the header tank is kept full to capacity, on opening the gate-valve in the supply pipe and the bib-cock in the outlet pipe, a supply of water at a constant pressure is passed to the radiator. To obtain the constant pressure the inflow through the gate-valve must be sufficient to supply the required quantity to the radiator under test, and at the same time cause a slight overflow from the header tank into the open tun-dish; the overflow should be kept to a minimum by adjustment of the gate-valve.

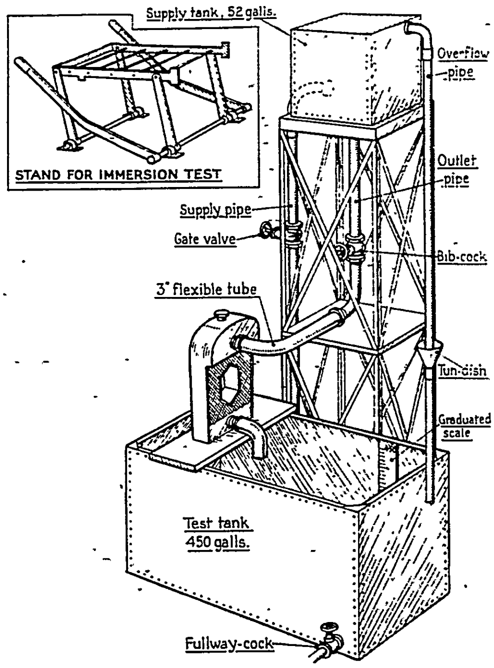


Fig. 6.—Standard installation for testing radiators

15. The capacity of the test tank provided for the purpose of receiving and measuring the water passed through the radiator is 450 gallons. This is sufficient to enable all types of radiators in general service to be flow tested. It should be noted when taking readings from the test tank, that when the water is released by means of the fullway-cock the tank is not completely drained, and in order to allow for this the graduated scale provided is so arranged that the zero mark includes this residual water. When testing a radiator a plank should be placed across the test tank to support it; the radiator should rest on its edges and not on the tubes. The size of the flexible tube employed to connect the radiator to the outlet pipe of the installation should not be less than 3 in. diameter; this size is adequate for the flow of water required by all types of service radiators and will allow for friction caused by any roughness in the bore of the pipe. Similarly the size of any outlet pipe or tube attached to the radiator, to give a clear discharge into the test tank, must not be less than 3 in. diameter, and the end of it must not extend to a distance exceeding 1 ft. below the outlet of the radiator. A suitable heating apparatus should be arranged in a position close to the testing installation, and a thermometer provided for ascertaining the temperature when hot water is being used. To facilitate handling the radiator during the immersion test, a stand similar to that shown in the inset of fig. 6 will be found useful; the stand may be made up from strip steel and bolted to a wooden frame, or secured to the bottom of the test tank.

Process inspection during manufacture

16. Some particulars are given below of the precautions found necessary during the process of manufacture of aircraft radiators, in order that the service engineer may be guided thereby with regard to the execution of radiator repair work.

(i) Absolute cleanliness and thorough washing of the casing and tube-block are necessary throughout the various operations.

(ii) The dimensions are checked and particular care exercised that the tubes are correctly assembled in the blocks, and that there are the correct number of tubes in each row and also the correct number or rows of tubes.

(iii) The water spaces between adjacent tubes must not be less than the minimum specified. This is ascertained as far as the marginal tubes are concerned, by direct measurement. In the main body of the tube-block, however, this can only be done by counting the number of tubes in a length of say twelve inches, in all directions and calculating an average width of water space between the tubes.

(iv) The depth of solder-dipping is checked to ensure that this is not less than 3 mm. and not more than 4 mm.

(v) Each tube-block is weighed before and after solder-dipping each side, and comparisons are made between each one of a batch of similar tube-blocks to ensure that no loose solder is present in any one of them.

(vi) The operation of loading the tube-block in the casing is specially supervised to ensure that the marginal soldering is satisfactorily carried out. This is particularly important, as no check upon the marginal soldering can be made upon a completed radiator.

(vii) Completed radiators are weighed in their dry state, and then the first radiator of any batch is checked for capacity.

(viii) Various tests, see paras. 36 to 41, are given to each radiator.

Repairs

17. All copper piping and bent and welded steel fittings must be subjected to the appropriate heat-treatment before assembly on the radiator. The radiator tubes having been already heat-treated at their ends and bulges, no further heat process is required before they are used. All lap joints forming the corners of the tanks must be of double "L" form (unless the drawings state otherwise), both plates being sweated together on two sides of the angle forming the corner.

18. As the bodies of the tubes are shaped either hexagonal or circular, it is desirable that the inserted tube is the same form as the one removed. The difference in the tube shape may be recognised by looking through the individual tube, and noting whether the body is hexagonal or circular; the inspection may be aided by the use of a light background. Tubes removed from unserviceable radiators may be used to effect repairs. Before the tubes are used, they must be thoroughly cleaned and examined for signs of corrosion. Dirty brass may be cleaned by immersion in a mixture of nitric acid, 2 parts, sulphuric acid, 1 part, water 5 parts. After immersion, the part must be immediately washed in hot water to remove the acid and then wiped dry. This operation is not, of course, a remedy for corroded tubes.

19. No plugging of tubes is permitted. Any tubes which leak at points other than soldered joints must be replaced. Particular care must be exercised at all times to avoid, as far as possible, the entry of solder into the radiator.

20. The greatest care must be exercised when handling radiators, and whenever possible the radiators should rest on their sides on wooden blocks covered with felt packing. If it is essential for the radiator to be horizontal during the repair process or test the radiator should be supported on a stand having a stout wooden batten across its upper face or on a frame so that the weight of the radiator is taken on the edges of the casing and not on the tube ends.

21. It should be ascertained from the aircraft log book whether the radiator has been temporarily repaired with leak stopping compound, in which case the radiator should be flushed through with hot water in the reverse direction to normal flow. This will loosen the masses of compound which may have adhered to the cooling elements.

22. It must be remembered that after any repair has been completed, the affected area must be immediately cleaned out (see para. 34) and the radiator subjected to the appropriate tests.

23. If it is necessary to remove a portion of the casing to effect a repair, the opportunity should be taken to examine the outer surfaces of the radiator tubes for signs of corrosion. Details are given hereunder of some common radiator repairs.

24. *Removing a single tube from a tube-block.*—Assuming that the radiator has been emptied of water, support it in a vertical position, i.e. with the tubes horizontal. Heat the steel rods to a dull red (about 500° C.), and insert the rods in the ends of the defective tube, one at each end; the rods should not touch the interior of the tube ends. The radiated heat will be sufficient to bring the solder to a plastic state within a few seconds. Care should be taken not to extend the time of application of the rod owing to the liability of the solder around other tubes becoming fused. Quickly remove the rods and push out the defective tube from the tube-block with a suitably shaped piece of wood. If a shouldered rod has been used for the heating process, the tube can be pushed out with the shoulder on the rod.

25. *Inserting a single tube.*—After removing the defective tube, clean off all blobs of solder on the tube ends in the space left by the removed tube. This can be done with a hot soldering iron or a steel rod, inserting the tool in the hole for just sufficient time to melt the solder, and immediately wiping away the blobs with a clean rag attached to a stick. The greatest care is essential during this operation to avoid disturbing the other tubes at their soldered joints. Take a new tube of suitable shape and correct length, and fit each end into the spacing in the radiator for which it is intended. It may be necessary slightly to deform the ends of the new tube to permit an easy entry. Dip the end of the new tube in the flux, then into the dipping tank to a depth of 3 mm. (not exceeding 4 mm.), and immediately transfer the tube to the hot water tank to remove the excess of flux. These operations

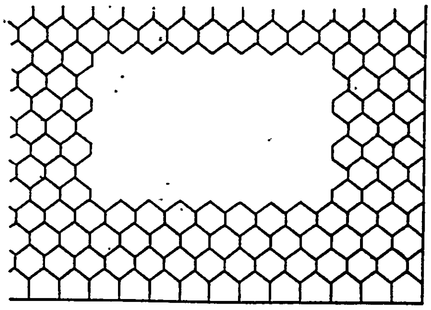


FIG.7.

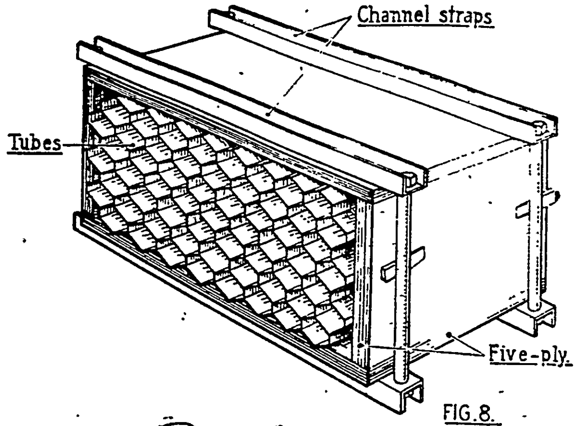


FIG.8.

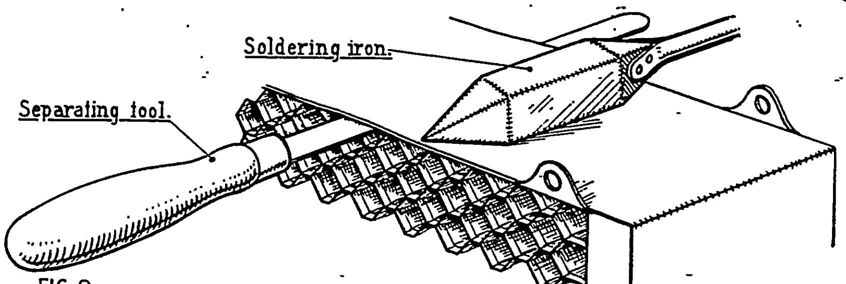


FIG.9.

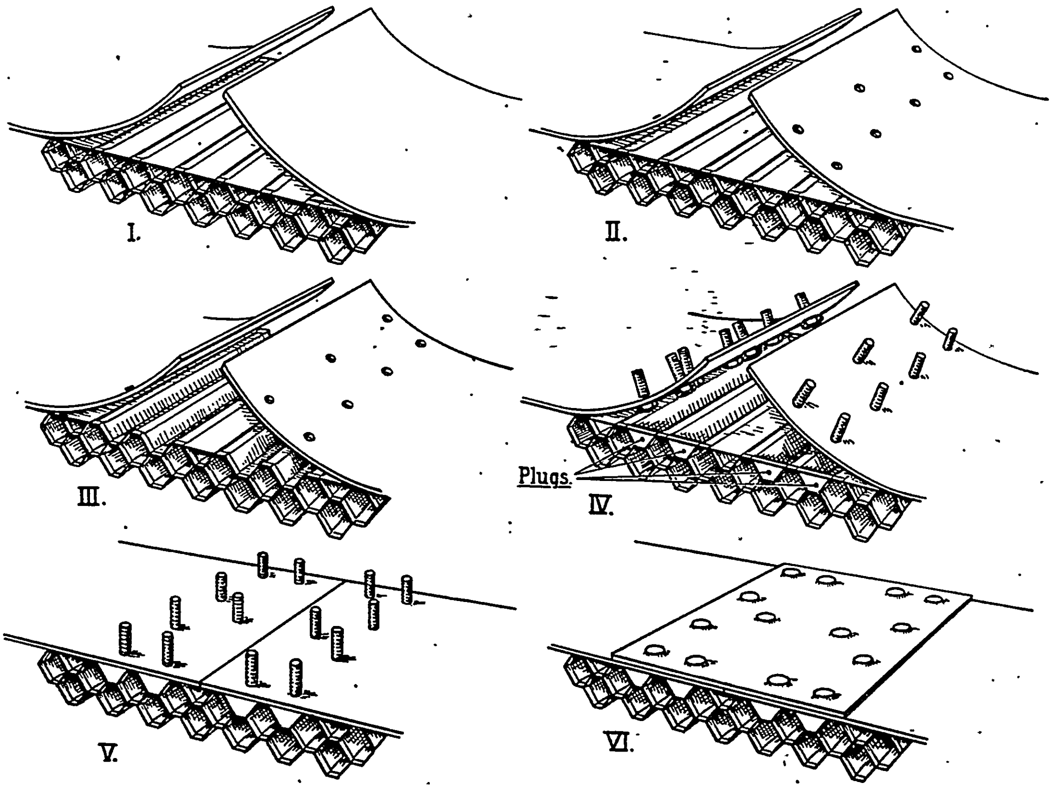


FIG.10

Fig. 7.—Tube-block with section removed
Fig. 8.—Tube-block section in jig

Fig. 9.—Separating casing from tube block
Fig. 10.—Repairing split in casing

should be done in quick succession. Wipe the tube perfectly dry with a clean rag. Remove the surplus solder from the tube end by heating it in a clear flame (brazing lamp) until the solder just melts, and then wipe the end of the tube with a clean rag. This treatment should then be repeated for the other end of the tube. Insert the tube in position in the radiator and apply the point of the soldering iron around the ends of the new tube for a few seconds to just melt the solder. Use no flux. A common mistake is often made when sweating the tubes by inserting the end of the soldering iron inside the tube end. This is unnecessary as the application of the iron to the tube end is sufficient to melt the solder on the expanded portion, and cause it to flow over the faces to be joined. If necessary, the appropriate forming tool can then be lightly worked into the ends of the new tube to re-form their shape. Wash the area around the replaced tube, or where facilities exist, spray the area with hot water to remove any foreign matter. Place a piece of soft iron wire in the new tube—see para. 13—so as to mark the repaired position. This area can be given special attention during tests described in para. 36 to 41.

26. *Removing a number of tubes from a tube-block.*—Proceed to remove the tubes, one by one, on the margins of the defective area and remove the loose section of tube-block. It will be found convenient for the opening thus formed to be made roughly square or oblong in shape—see fig. 7. Then clean the exposed surfaces of the tubes in the orifice as detailed in para. 25. Assemble the appropriate new tubes in a jig—see fig. 8, so as to form a section of tube-block which will fit into the orifice formed, less one row of tubes on each side. Care should be taken in tightening up the jig to prevent distortion of the tubes. Small wooden wedges should be carefully inserted between the bolts and the plywood packing pieces to keep the latter rigid. Dip one end of the tube-block section into the flux to a depth of 3 to 4 mm. Remove the section and immediately immerse it into the dipping-bath to the same depth and then plunge it into the hot water bath. Tin the other end of the tube-block section in the same way. Then place the tube-block section on a draining board, and dress up the ends of the tubes with an appropriate forming tool.

27. *Fitting a new tube-block section in the radiator.*—Place a row of tubes along the bottom side of the orifice in the radiator tube-block. Dismantle the jig and insert the tube-block section in position. The tubes will probably require a certain amount of deformation to permit mating-up. Proceed to join up the section to the remainder of the tube-block by soldering as explained in para. 25. A row of tubes can then be inserted and soldered up first at one side of the section, then the other side. Dress up the tube ends as required with the forming tools. Wash the repaired area with hot water, or, if convenient, spray with hot water. Mark the repaired area with wire so that special attention may be given during the tests.

28. *Removing a whole tube-block from a radiator casing.*—Apply a hot soldering iron to the edges of the radiator so as to melt the solder joining the marginal tubes to the casing. Use a piece of hacksaw blade (with teeth removed) or thin steel between the tubes and the casing as a separating tool, to follow up the soldering iron—see fig. 9.

29. *Repairs to tubes adjacent to the casing.*—If the radiator is defective where the marginal tubes are soldered to the casing, the defect can generally be overcome by the usual process of soldering, but care must be taken to avoid disturbance of other soldered joints. A temporary repair can be made by soldering over the ends of the defective tube, but this method should only be permitted in emergency.

30. *Single splits in the casing.*—A satisfactory method of repairing a single split in the casing is as follows. In order to prevent the split extending further, drill small holes at the extreme ends of the split, care being taken not to puncture the tube-block. The holes must be clean and should therefore be drilled with a sharp drill. Prepare a suitably shaped patch of thin brass sheet, and solder it to the casing in the usual manner. At least one inch of overlap should be arranged around the defective area.

31. *Star-shaped splits in the casing.*—If the split is small it may be repaired as above, but if the split covers a large area, a method of repair is as follows—see fig. 10:—

(i) Separate the casing from the tube-block in the vicinity of the split as shown in sketch I, and cut away the defective portion.

(ii) Drill two rows of staggered holes (using No. 22 drill) as shown in sketch II. The rows should be about 1½ in. apart, and so arranged that they will coincide with the centres of the marginal tubes.

(iii) Remove the marginal tubes which coincide with the drilled holes as shown in sketch III, care being taken not to disturb the soldered joints of the adjacent tubes.

(iv) Thin down the heads of a number of No. 4 B.A. bolts. Insert the bolts in the casing and solder them in position, care being taken to keep the solder clear of the threads—see sketch IV.

(v) Cover both sides of the casing with solder, care being taken to protect the threads as before.

(vi) Prepare suitably-shaped brass plugs, about ¼ in. long, and solder these in position so that they will form a blanked marginal tube—see sketch V.

(vii) Cut a patch of material similar to that of the casing, and cover one side of the patch with solder. Drill the patch, using a paper template taken over the protruding bolts.

(viii) Thin down a number of No. 4 B.A. nuts and fit the patch in position, the soldered side being towards the tube-block—see sketch VI.

(ix) Screw down the nuts and flood them with solder. Cut off any projecting ends of the bolts. In applying the soldering iron to get an even flow, the patch will become sweated to the casing at the overlapped joint.

(x) Solder the sides of the patch to the tube-block.

32. *Splits affecting a supporting bracket.*—If the area of the split casing affects a supporting bracket, the defective area should be removed and the repair carried out as detailed above, the greatest care being observed when replacing the patch, to ensure that the supporting bracket is in its correct position. This may be checked after the patch has been bolted down on the casing by supporting the radiator on its brackets and testing the alignment. It may be necessary to rig up some form of jig to secure correct positioning of the bracket.

33. Defects in the casing must be rectified to a condition demanded for new radiators as far as general soundness is concerned.

Cleaning out radiators before repair

34. The flushing of hot water through a radiator will not entirely remove all the particles of foreign matter, flux, etc., which may have accumulated. It has been found that a low percentage caustic soda solution is more effective, and can be used without any ill effects if the remnant is immediately neutralised by an acid wash. The procedure for cleaning out radiators by this method is as follows:—

(i) Invert the radiator.

(ii) Rinse it through carefully with a solution of 2 per cent. caustic soda in water that is nearly boiling. Repeat the rinsing several times.

(iii) Wash it through immediately the rinsing operations are completed with an acid wash comprising 0·75 per cent., by weight, chromic acid (CrO_3) plus 0·5 per cent., by weight, phosphoric acid syrup and the remainder water. This solution should be just warm and the operation should be repeated several times.

(iv) Finally wash the radiator through with clean water sufficiently to remove all traces of the solution used above.

Cleaning and examining radiator after repair

35. After a radiator has been repaired by methods entailing the use of flux, all traces of the flux should be removed by washing the parts of the radiator affected in a 2 per cent. solution of hydrochloric acid and water, followed by a thorough washing in clean water sufficient to remove all traces of the acid wash. The radiator should then be thoroughly examined for freedom from foreign matter, loose pieces of solder, etc. The inlet, outlet and vent pipes should be checked to ensure that they are free from obstruction. Pipe ends for rubber tube connections should be tinned and well rounded to prevent subsequent cutting into the rubber. Any solder found on screw-threads should be carefully removed.

TESTING OF RADIATORS

36. After completion of the repairs and cleansing operations, the radiator should be sealed with metal caps sweated over the orifices, one sealing cap being fitted with a screwed adaptor for connecting a foot pump or other air pressure supply. The radiator must then be subjected to the following tests, a record of which should be noted on Form 760 or 1083 as appropriate. The radiator must be tested to the pressure given in the Vol. II of the particular aircraft handbook, or to the pressure stated on the identification plate sweated on the radiator. Where no specific instructions are promulgated, the standard pressure is 6 lb. per sq. in.

First cold water pressure test

37. The radiator should be filled with cold water and then subjected to the appropriate pressure for a period of not less than 30 minutes, during which time there must be no leakage at any point. Alternatively, the same air pressure may be imposed upon the radiator, and the entire radiator submerged in water for the purpose of ascertaining any leakage. For this test it is advisable that the radiator rests upon wooden supports in the testing tank to avoid damage. If leakage takes place, the position should be marked and the radiator emptied and repaired as required and then re-tested.

Hot water pressure test

38. For this test, the radiator should be emptied and completely filled with hot water at a temperature of not less than 85° C. and the appropriate air pressure applied for at least ten minutes during which no leakage should occur.

Second cold water test

39. After the previous test, the radiator should be emptied and the cold water test repeated for a period of five minutes at the standard pressure.

Distortion of radiators after pressure test

40. The principal dimensions of the radiator should be measured before, during and after the pressure tests to ensure that no permanent distortion has taken place in excess of the specified limits.

Flow test

41. Normally the flow test should be made by using the standard equipment illustrated in fig. 6 and described in para. 14 and 15, but in some instances the test can be made with the radiator mounted in the aircraft. The latter method of flow testing is described in Chapter 2, para. 24. When employing the standard test equipment the radiator must be supported in a position corresponding to its normal position when mounted in the aircraft, i.e. a radiator that is mounted vertically in an aircraft must be flow tested in a vertical position; it must not be tested horizontally, nor may it be reversed so that the outlet opening is used as the inlet. *It is essential to ascertain during test that the radiator is kept full to capacity and that no air is trapped in any part of the system.* Prior to the actual test the system should be operated and the water flow adjusted by means of the gate-valve in the supply pipe, to ensure a satisfactory overflow into the open tun-dish. The test tank should then be drained by means of the fullway-cock, or if this is unnecessary, the reading on the graduated scale should be noted. Serviceable radiators should pass, during the flow test, 15 gallons of water per minute for every 100 h.p. of the engine with which they are to be employed; the minimum permissible flow is indicated in the diagram fig. 2, Chap. 2.

Radiators not in use

42. Honeycomb radiators when not in use, are liable to deterioration due to internal corrosion. In order to prevent such deterioration, all honeycomb radiators in store or installed in air frames or power plants, and serviceable radiators which have been removed from aircraft, must be kept filled. Fin and tube or secondary surface radiators must be drained, sealed and stored empty.

42A. The coolant pipes should be disconnected and sealing plugs for the inlet and outlet branches, etc., should be made up locally if standard caps are not available, after which the radiator should be filled with a 30 per cent. ethylene glycol mixture and sealed within 24 hours of receipt. When suitable, the liquid filling may be used as part of the first charge of the cooling system when the radiator is installed or it can be used for filling other cooling systems.

42B. Radiators are to be emptied and sealed for transport in this country, but for transport overseas they are to be kept filled, special sealing plugs being provided for this purpose; standard wooden packing cases are to be used for the transport of radiators overseas.

Marking radiators

43. After each test the radiator should be marked to denote that it has satisfactorily passed the particular test. The marking should be done by applying a small blob of solder near the filler cap, a metal stamp then being pressed into the solder whilst it is in a plastic state. After the radiator has passed all its tests a small brass plate should be soldered close to the manufacturer's marks or subsequent test marks, indicating the Unit by which it was reconditioned and the date. All open orifices should be closed with soldered sealing caps.

44. Radiator tube-blocks should only be covered with the authorised paint, and never with a metallic paint such as aluminium paint, as this would act as an insulator of heat. The paint may be applied with a brush, only one coat being required. The paint is quick-drying and after about eight hours attains a satisfactory hardness. An alternative method of applying the paint is by spraying, which provides a thin coat evenly distributed.

GALLAY HONEYCOMB RADIATORS

Introduction

45. Radiators of the honeycomb type having a non-standard tube-block have recently been introduced. These radiators have been designed to withstand the corrosive action of the cooling medium, e.g. ethylene glycol, and are in general use in the Gallay cooling system "E", but in some instances the block design has been incorporated in replacement radiators for standard types. The simplicity of the block formation has facilitated manufacture and repair of these radiators, but the extent to which repairs can be undertaken by all Units whilst the radiators are in service is limited. The repair schemes given in para. 47 are intended as an aid to maintain the serviceability of radiators, but in instances where the schemes are inadequate the radiators should be returned to depot as unserviceable. Prior to commencing any repairs the construction of the radiator should be clearly understood.

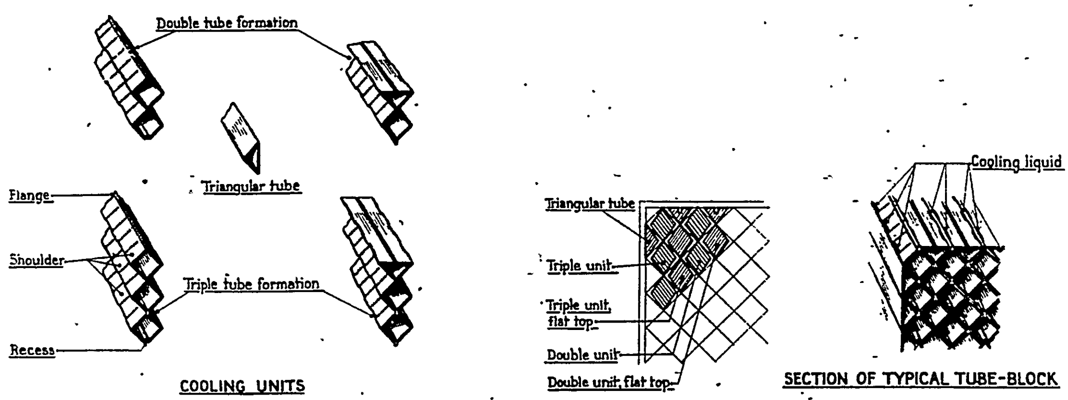


Fig. 11.—Gallay radiators—formation of tube-block

Construction

46. The construction of this type of radiator is similar in principle to that of a standard honeycomb type in which the "tube-block" and the shell or case are built up to shape and soldered together. In this type the tube-block is built up from groups of cooling units in place of the standard tubes. The cooling units are manufactured from cupro-nickel alloy in several distinct tube formations, as illustrated in fig. 11. They are pressed from the strip alloy, shaped and seamed; the seams being finally tinned as a means of sealing them. Each cooling unit is provided with a number of shoulders which are spaced along the tubes in such a manner that, when the block is assembled, the shoulders butt against those adjacent and so form orifices through which the cooling medium circulates. A section of a typical group of cooling units as assembled in a radiator is illustrated in fig. 11. It will be seen that the tubes of the cooling units forming the top and bottom of the block are flattened to facilitate the attachment of the shell, also that single tubes of triangular section are used to form the flat sides of the block. The upper and lower tubes of the intermediate cooling units are in one instance slightly recessed, while in the other the seam forms a flange, so that when a group is assembled the flange of one unit is positioned in the recess of the adjacent unit.

Minor repairs

47. The general construction of the block allows faulty cooling units to be removed and replacements made without complication, but there is a grave risk of further damaging the block during this operation which should not be attempted by Units other than Repair Depots. Repairs which may be undertaken whilst the radiators are in service are limited to those which will rectify slight damage or minor leakages of the shell or casing, the temporary sealing of cooling units by means of repair pieces supplied and the fitting of repair tubes to the cooling units. These repairs are as follows:—

(i) *Repairs to shell.*—A radiator shell or casing which has sustained damage causing leakage or weakness to the construction, may be repaired externally by means of patches. The patch used should be of the same gauge and made up of similar material to that of the damaged part. Grade B solder may be used to effect this repair, which on completion may be considered permanent. When dealing with a leaking case the patch should be heavily soldered, and be of sufficient size to cover an area well in excess of the damaged portion, so allowing for the slow corrosive action that will take place internally during further service. On completion of the repair the radiator should be tested in accordance with the instruction given in paras. 36 to 41, and the usual anti-corrosion methods applied externally.

(ii) *Repairs to block.*—Two methods of repairing the tube-block are clearly illustrated by fig. 12. For both methods it is necessary to identify the faulty cooling units before the repair can be made. This should be done by carefully scraping away the paint around the affected area and if necessary some of the solder joining the cooling units, until their formation is clearly seen (see fig. 11). In effect both methods of repair are similar, i.e. the tubes of a defective cooling unit are blanked off to prevent leakage of the cooling medium. Thus in the case of a unit of triple tube formation, the three tubes must be blanked off while a unit of double tube formation will only require the two tubes blanked off. The two methods are as follows:—

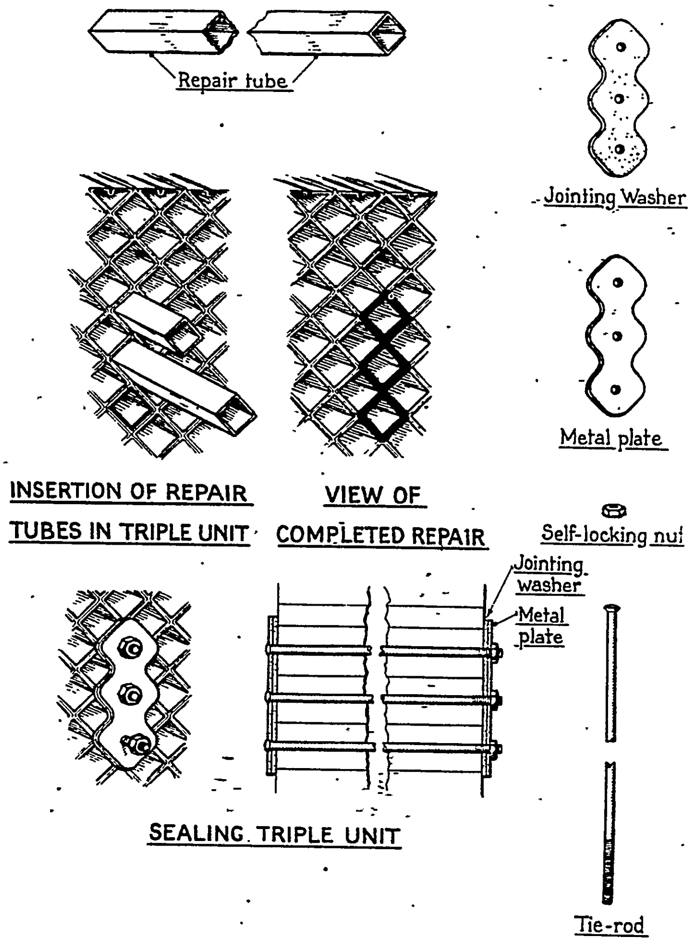


Fig. 12.—Gallay radiators—repair schemes

(*a*) *Sealing of cooling units.*—This repair should be treated as a temporary measure and used to cover the period which may elapse before it is convenient to remove the radiator from the aircraft. It must be realised that when this method is used the airflow through the cooling units concerned will be completely blanked off, therefore the number of units so treated must be limited, depending on the type of aircraft and the conditions in which it is operating, to prevent impairing seriously the efficiency of the radiator. The method of making the repair is very simple and is clearly illustrated in fig. 12. The repair pieces illustrated are available on demand; no substitutes should be used as the pieces have been chosen and treated to withstand the corrosive action of the cooling medium. When making the repair care must be taken to prevent damaging the cooling units by over-tightening the self-locking nuts, which should be tightened only to a degree sufficient to stop leakage. If during further service, leakage caused by shrinkage, etc., should take place, the nuts may be tightened to rectify the fault. On completion of the repair the rods should be cut off flush with the tops of the nuts, and the area concerned repainted.

(*b*) *Repair tubes*.—This repair (see fig. 12) consists of inserting specially drawn square tubes, of light gauge cupro-nickel, into the air orifices of faulty cooling units, and sealing the ends by soldering. Grade B solder may be used for the purpose, and various lengths of repair tubes are available on demand. This method may be considered as a permanent repair, and has the great advantage of allowing several cooling units to be sealed without appreciably decreasing the efficiency of the radiator. To make the repair, tubes of the same length as those of the cooling unit should be inserted carefully, as shown in the illustration, after which the ends should be expanded slightly to improve the fit, and then soldered at both ends. Sufficient solder should be used to seal the joints completely and at the same time allow for the slow corrosive action that will take place during further service. After repairs the radiator should be tested in accordance with instructions given in paras. 36 to 41, and if passed as serviceable the usual anti-corrosion action should be applied to the area concerned.

Major repairs

48. The practices and methods in general use at Repair Depots for the building up of tube-blocks and repairing radiators of the standard type are applicable in general to this type. The building up of a complete block or of a group of cooling units is greatly facilitated in this type because the tubes are already formed into cooling units and the flanges and recesses assist in retaining the units in position during the operation (see fig. 11). It is essential, however, when building up a block or replacing units, to ensure that the tubes of the units are alike with regard to the shoulder formation, also that they are correctly positioned, so that the orifices required for the circulation of the cooling medium are correctly formed. In addition it must be realised that the cooling units are pressed from the strip alloy during fabrication, and are consequently of a very flexible nature. This feature whilst facilitating the building up of a new block or group of units, necessitates care when handling and storing units to prevent distortion or other damage being sustained. The precaution especially applies when replacing units during repair, as the forcing of a unit into position may cause damage to adjacent units which will not be visible during the operation. The cooling units shown in fig. 11 are available on demand in various lengths to suit the block depths of the radiators in service; if necessary cooling units may be cut down to size, but this should be avoided if possible to prevent wastage.

MORRIS FIN AND TUBE RADIATOR

Introduction

49. The Morris fin and tube radiator is made in different types for various type of aircraft but all are the same in principle. They are generally constructed in a unit consisting of two tube blocks having a common bottom tank and separate top tanks, one of the latter being fitted with an inlet pipe and the other with an outlet; in this construction the coolant passes down the tubes on one block and up the tubes of the other. In the cases of cross-flow radiators one tube block fitted with end tanks is used. For the purpose of repair it is essential that the construction of the radiator should be understood and a brief description of one type is given in the following para.

Construction

50. The main feature of this type of radiator is in the arrangement and construction of the tubes in the tube block (see fig. 13). These are of flat section, made from light-gauge sheet copper 0·006 in. thick and arranged in rows in the tube block, edge-on to the air stream. The tubes are mechanically supported internally by means of corrugated strips of thin sheet copper passing through the whole length of the tubes, whilst the exteriors are finned by corrugated sheet copper strips 0·004 in. thick, stamped out to fit over the tubes. The tube ends fit into end plates, to the flanges of which the tanks are soldered, after the whole tube block has been tinned by dipping in a bath of molten solder. Additional strength is given to the tanks by means of interior ribs arranged lengthwise and by tie bolts mounted in metal channels which are soldered to the end plates between the separate rows of tubes; the nuts fit into cupped recesses in the tanks into which they are subsequently soldered.

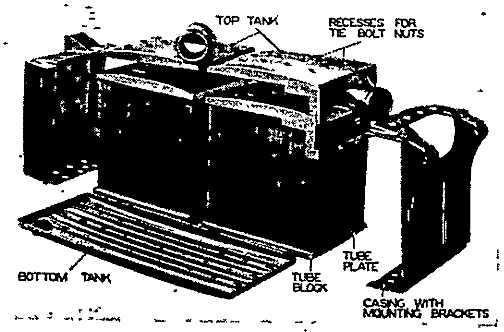


Fig. 13.—Construction of fin and tube type radiator

51. The radiator sides are enclosed in casings which form part of the air duct and which carry the radiator mounting brackets. The end casings and the top and bottom tanks are all soldered in position on the tube blocks. It will thus be realised that as the whole tube block with end tanks complete is dipped in a solder bath it is not possible as a repair job to remove the end tanks and block a defective tube from each end, or to insert a new tube, therefore, repairs are confined to approved methods of patching the end tanks and to blocking damaged tubes by the methods described in subsequent paragraphs.

52. The repair of damage to this type of radiator which is generally mechanical damage to the matrix or the tanks can be conveniently divided into two categories. (i) Emergency repairs. (ii) Workshop repairs. The first category is purely for use in emergency, and the second, whilst not being perfect, because of the limitations imposed on repairs by the construction, may be regarded as more or less of a permanent nature subject to it passing the flow-test and the pressure test.

Equipment

53. The equipment and material required for the repairs to the tubes in categories (i) and (ii) mentioned in the preceding paragraph is as follows:—

Nomenclature.

Tube piercing tool } *See* fig. 14
Wooden plugs (emergency repair) }
Solder, Grade B
Solder, $\frac{1}{8}$ in. dia. rod
Brass or copper rod, $\frac{1}{8}$ in. dia.
Soldering iron
Flux, D.T.D.81
Blow lamp or gas blow-pipe

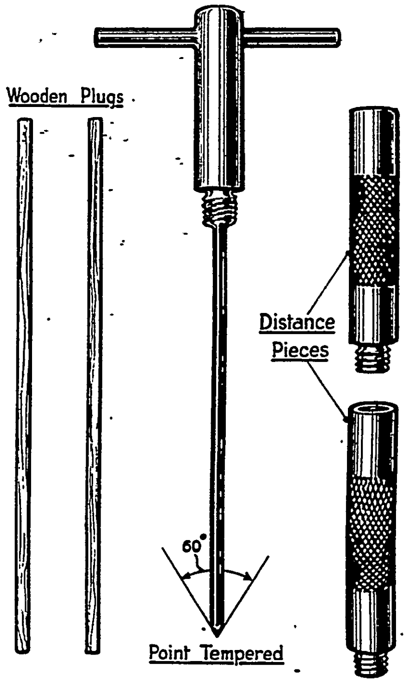


Fig. 14.—Piercing tool

Emergency method of repair to tubes

54. This method of repair to damaged tubes up to a limit of 10 per cent of the total number of the tubes, is to enable the aircraft to be flown back to its base under reduced power and is to be regarded as a temporary expedient only. The repair consists of plugging leaking tubes by means of wooden plugs which can be inserted if necessary to a depth of two tubes, with the radiator *in situ* without draining the coolant below the level of the damaged area, to which it will probably have drained already.

(i) The tubes should first be examined around the damaged area for the number of tubes involved and the depth to which the damage extends. If more than 10 per cent. of the tubes are damaged and leaking, it is useless to attempt to repair it by this method.

(ii) Having noted the tubes that require plugging each tube should be pierced at two points by means of the piercing tool. These points should be one on each side of the damaged portion of the tube, about one inch from the damage and in a sound portion of the tube (see fig. 15).

(iii) In order to pierce a tube in the first row, the first distance-piece or sheath should be removed from the piercing tool and, at the position selected on the edge of the tube, the point of the tool should be centred and then tapped through the tube by means of a light hammer until the shoulder on the distance piece just touches the fins.

(iv) If a tube in the second row should be damaged, the second distance piece must be

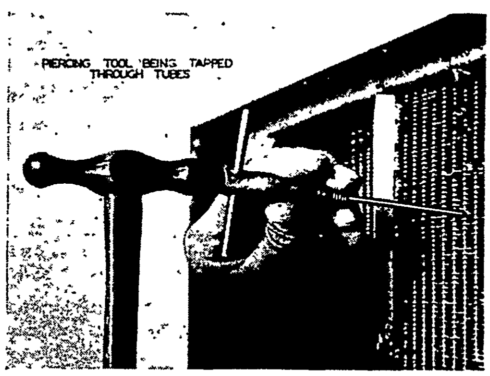


Fig. 15.—Piercing radiator tube

removed from the tool after piercing the tube in the outer row in line with the damaged tube. The tool can then be pushed through the first tube and driven through the tube in the second row until the shoulder on the tool just touches the fins. The tool should then be carefully withdrawn by a twisting and pulling action, care being taken meanwhile to avoid any side pressure on the tool that would tend to enlarge the hole.

(v) Round wooden plugs should then be tapped into position (see fig. 16) in the pierced damaged tubes until the plugs abut against the undamaged tubes behind, in the second or third row according to whether one or two rows have been pierced.

(vi) The piercing and plugging operations should be repeated for all the similarly damaged tubes, one plug being inserted on each side of the damage on each tube, working if necessary on both sides of the block. All the protruding ends of the wooden pegs should be carefully trimmed off by a sharp knife, level with the fins (see fig. 17).

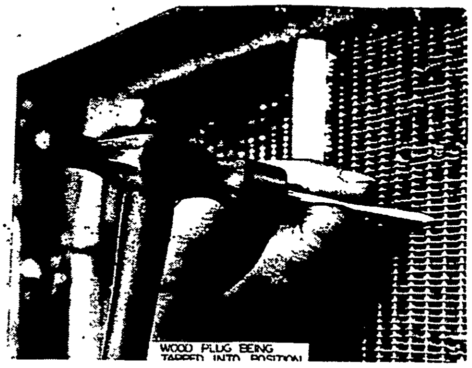


Fig. 16.—Wooden plug being tapped into position

(vii) The cooling system should be refilled with coolant, after it has been ascertained that all damaged tubes have been plugged, and the plugged tubes and other parts of the radiator examined for leaks. Some of the wooden plugs may leak slightly at first, but normally this ceases when the wooden plugs swell after making contact with the coolant.

(viii) If one or more of the plugs leak persistently, an additional plug should be similarly inserted in the tube towards the tank side of the faulty plug, and about half an inch away from the faulty plug. Inserted plugs should be positioned as near to the damaged area as possible in order to retain a sufficient length of tube for the purpose of subsequently effecting a more permanent repair as outlined below.

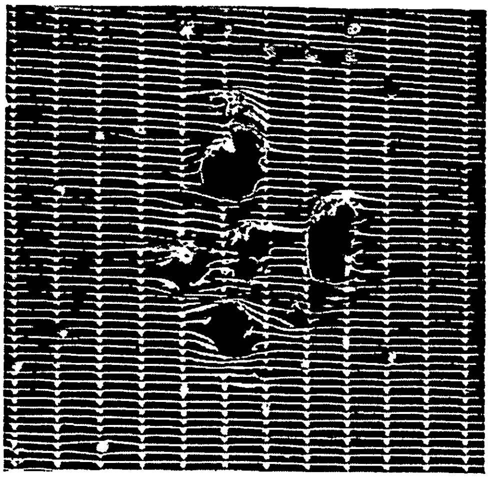


Fig. 17.—Wooden pegs inserted around damaged area and trimmed off

Workshop repairs

55. The repairs to be made in workshops to the radiator tubes may be regarded as permanent, provided that the tubes affected are confined to the outer rows only and that not more than 5 per cent. of the total number of tubes in the radiator require plugging. Damage to the tanks and casing can be repaired by normal patching methods already described in A.P.1464D, Vol. I, Part 2, Sect. 5; repairs entailing the removal of the tanks should not be undertaken, however, and such radiators should be returned to Stores as unserviceable. The method of repairing damage tubes, subject to the limitations mentioned above, is as follows:—

(i) Convenient points should be selected on each side of the damaged section of the tube and two holes made close to one another at each point, by means of the piercing tool on which one distance piece has been fitted. If the damaged tube has already been plugged with wood as already described, the two holes must in each case be pierced towards the tank side of the wooden plugs (see fig. 18), about $\frac{1}{2}$ in. away from the wooden plugs.

(ii) Metal plugs should be made up, $2\frac{1}{4}$ in. long and $\frac{1}{8}$ in. dia. from copper or brass rod which should be carefully tinned and smoothed off to size; rods of solder of the same size should also be prepared.

(iii) One of the tinned rods should be dipped in flux and inserted in the hole nearest the tank and a piece of the $\frac{1}{8}$ in. dia. solder rod placed in the adjacent hole, at the same time applying flux by means of the solder rod whilst the tube block is arranged on the bench with the solder rod uppermost (see fig. 19). A blow-pipe or blow-lamp flame should then be lightly played around the two rods with a view to heating them evenly until the solder rod just melts and runs down on to the metal rod and without over-heating the fins or tubes. Great care is necessary during this operation to ensure that all the solder rod has melted and has run down on to the tinned metal rod and the surrounding inner surface of the tube, thus forming a sweated joint.

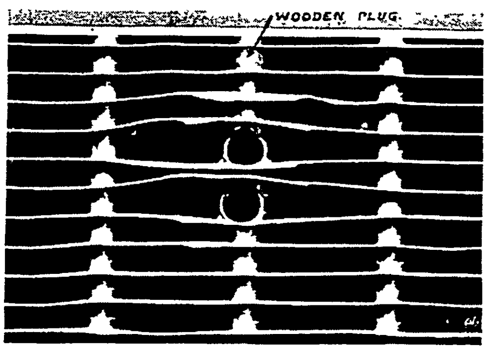


Fig. 18.—Two holes pierced for soldered repair

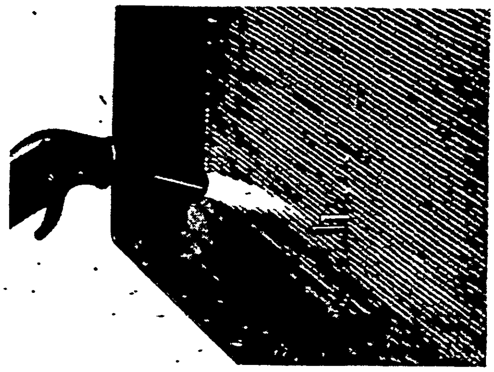


Fig. 19.—Copper rod and solder rod in position for sweating

Cleaning after repair

56. After the radiator has been repaired by soldering, suitable precautions should be taken against corrosion which would be caused by flux. If only one or two tubes have been repaired, it will be sufficient to wash the radiator in hot water, but in instances where several tubes have been soldered, the radiator should be cleaned as described in para. 34 of this Chapter.

Pressure test

57. After cleaning, the radiator should be pressure-tested in accordance with the method described in para. 36 to 41 of this Chapter. The applied air pressure should be 50 lb./sq. in.

Flow test

58. The flow test for the repaired radiator should be in accordance with that detailed in para. 41 of this Chapter. The minimum flow-rate obtained should not be less than 10 gal. per 100 h.p. of the engine on which the radiator is employed.

P5057 M /1349 9/44 5250 C&P Gp.1

SECTION 6

FUEL SYSTEMS

LIST OF CHAPTERS

***Note.**—A list of contents appears at the beginning of each chapter*

AIR MINISTRY
May, 1944
R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS
This is A.L. No. 21 to A.P.1464C, Vol. I and concerns Part 2, Sect. 6.
Insert this chapter.
RESTRICTED
(For official use only)

CHAPTER 2

FUEL PRESSURE REDUCING VALVE—AMAL

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. Fuel pressure reducing valves are necessary in some fuel systems in order that the correct fuel pressure is maintained at the carburettor. The average pressure is standardised at 1·90 lb./sq. in. irrespective of the delivery pressure from the pump or tank, provided that this is within the range of 4 to 20 lb. sq. in. Reducing valves are made in different sizes covering delivery rates up to 390 gal. per hour and increased fuel pressures as required.

Description

2. The body of the reducing valve (see fig. 1) is in two parts each having a circular flange held together by six bolts. A spring-loaded Neoprene diaphragm is held between the flanges, the centre portion of the diaphragm being free to flex under the action of its spring and the valves. Two valves are situated in the lower half of the body between the inlet and outlet connections which are arranged diametrically opposite one another. The lower of the two valves, through which the fuel passes first, is of the piston type and controls the pressure throughout the greater part of its range of movement;

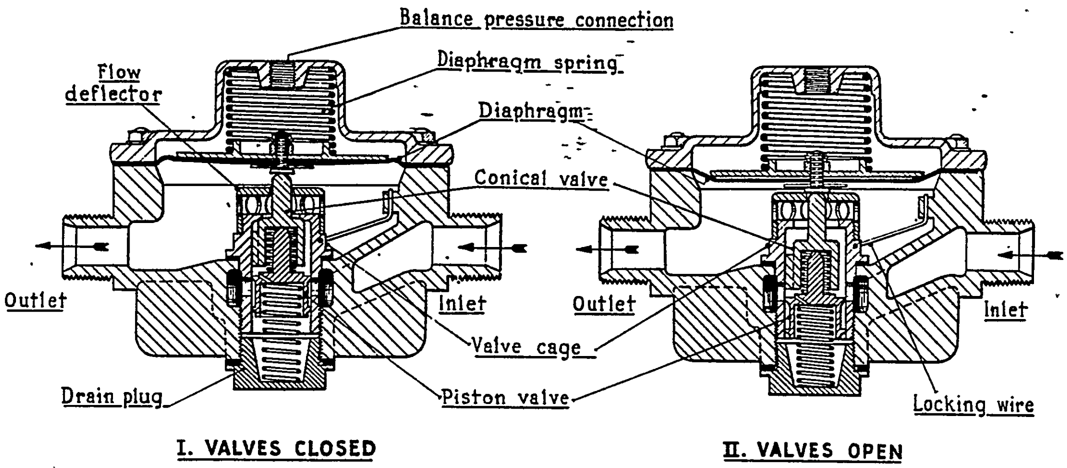


Fig. 1.—Fuel pressure reducing valve

above the piston valve is a conical valve which comes into operation when the piston valve covers the ports and definitely cuts off the flow of fuel. Both valves are spring loaded and the conical valve can function under the reaction of its spring independently of the piston valve should this fail—e.g. by sticking. Normally both valves operate together, both being raised by the piston-valve spring until the stem of the conical valve abuts against the head of the screw in the centre of the diaphragm.

The diaphragm spring is housed in the upper part of the body, and bears through the medium of the spring plate and the diaphragm centre bolt on the top of the conical valve, normally keeping both valves open against the pressure of their springs. When fuel enters the valve chamber and passes through the valves, the pressure which builds up on the underside of the diaphragm compresses the diaphragm spring thus relieving the pressure on the conical valve stem and so allows the valves to move upward towards their closed positions under the action of the piston-valve spring. Partial closing of the piston valve reduces the fuel flow and the pressure on the diaphragm so that the diaphragm spring reacts and opens the valves for the fuel flow to continue at the point of balance between the springs, which gives the regulated pressure required at the carburettor. Any increase in pressure above the point of balance will result in both valves being closed and an entire cessation of fuel flow until the balance is again restored. The balance of the piston valve is maintained under pressure by the provision of two holes which communicate between the top face and the spring recess. Above the diaphragm housing is a vent hole which is connected by an air pipe-line to the air intake of the carburettor so providing the necessary balance effect to compensate for differences in air-intake pressure at different altitudes.

Construction

3. The lower half of the body has a projecting boss internally threaded to take a screw-in drain plug, which serves to support the piston-valve spring; a valve cage, incorporating two valve seats also screws into the opposite end of the boss. An annular recess in the bore of the boss is provided into which the fuel first flows from the inlet and from which it passes through ports in the valve cage to the outlet when the piston valve is open. The lower part of the cage constitutes the piston valve seat, the valve having two annular knife edges to reduce friction which might cause the valve to stick; in the upper end of the cage is the seat for the conical valve, above which, in the larger types, is a deflector plate to prevent the formation of a jet of fuel which would exert a pressure on the diaphragm and thereby upset the balance of the valves. The valves are of stainless steel, this material also being used in the small type of reducing valve for the cage; in the large type of reducing valve however the cage is made from phosphor-bronze. The spring of the piston valve is inside the hollow piston body whilst that for the conical valve is between the valve head and the top of the piston valve. In the small type of reducing valve a stem, on the top of the piston, guides the conical valve which can lift and close independently of the piston valve—e.g. should this stick in the open position—but cannot move downwards to open without also pushing downwards and opening the piston valve. In the large type of reducing valve three vanes are formed around the skirt of the conical valve, guiding it in the cage.

Installation

4. The reducing valve is usually installed within one foot of the carburettor and on a level with the float chamber. When these conditions are not satisfied, friction in the pipe-line and acceleration forces during aerobatics and take-off seriously affect the operation of the valve. While the valves will function constantly, mounted in the aircraft in almost any attitude, the diaphragm should preferably be horizontal and never at an angle of more than 45° to the horizontal. The reducing valve may also with advantage be mounted upside down, the drain plug being uppermost to provide a self-flushing effect, as a precaution against sediment. The pipe-lines should be kept free from kinks and acute bends.

Servicing

5. The drain plug should be removed for complete draining whenever the fuel filters are cleaned during routine inspections unless the reducing valve has been mounted with the drain plug uppermost, when this draining becomes unnecessary. At major engine inspections the reducing valve should be dismantled and examined for (i) damage or cracks in the body, (ii) deterioration of the diaphragm, (iii) tightness of the conical valve seat. Defective parts should be replaced by new ones, the diaphragm being exchanged every 1,000 hours running time unless signs of failure are observed during previous examination.

Dismantling

6. The sequence of operations for dismantling the valve is as follows:—

(i) Remove the bolts holding the halves of the body together, from the circular flange joint; separate the two parts, then carefully remove the diaphragm.

(ii) Unscrew the drain plug and withdraw the valves with their springs from the cage.

(iii) Remove the locking wire from the valve cage and unscrew the cage from the body.

(iv) After their removal from the cage, the valves may be separated and their springs removed.

(v) The diaphragm can be removed from the spring plate, if necessary, by releasing the nut on the central screw.

Assembling

7. When the reducing valve is being assembled, strict cleanliness is essential throughout the operation. Any new parts which are to be fitted should be tried in their working positions and compared with the part which they are to replace. No jointing compound should be used on the joint faces. The following is the sequence in which the valve components should be assembled:—

(i) The diaphragm unit should be built up on the central bolt, the diaphragm washer being placed first on the bolt between two fibre washers, followed by the diaphragm, the annular depression in which should face the bolt head; another fibre washer should then be placed next to the diaphragm succeeded by the spring plate and the nut, which should be tightened and pinned. If the pin hole does not register with the castellations in the nut, an additional fibre washer should be fitted.

(ii) The valve cage should be fitted with a serviceable joint washer and the valves and their springs inserted in the order shown in fig. 1, then, holding the cage and the body in an inverted position, the cage should be screwed into the body.

(iii) Test the valves, which should be quite free to spring up and down in the cage, then fit the drain plug and test the valves again for freedom of movement by pressing down the end of the conical-valve stem. The drain plug and the cage should be locked by means of locking wire, the ends of that for the cage being bent down clear of the diaphragm.

(iv) Insert the bolts in the flange on the lower half of the body ensuring that they seat correctly. Apply a thin coat of vaseline to the joint faces of the diaphragm and thread it on to the bolts, the spring seat being outward. Place the diaphragm spring in position, then fit the upper half of the valve body. Tighten the flange nuts down evenly.

Testing

8. The pressure reducing valve, fully assembled, is tested by coupling a filtered fuel supply at 4 lb./sq. in. to the outlet. The flow from the inlet is then momentarily checked to enable the conical valve to seat, when any leakage may be observed (permissible limit—one drop per minute). The head of the fuel supply is then progressively reduced until, at a certain pressure, the conical valve opens and allows fuel to flow from the inlet, thus enabling the pressure at which the valve operates to be checked. If during the test a rod is passed through the balance pressure connection, the diaphragm can be gently depressed and released, when the conical valve will be opened and closed, so giving a further check on the functioning of the valve. A pressure reducing valve which does not satisfy the conditions of the test should be returned to Stores as unserviceable, after ensuring that failure is not caused by dirty valve seats. No attempt should be made to grind or lap the valves.

P5075 M /1851 9/44 5250 C & P Gp. 1

SECTION 7

AIR FILTERS AND SUPERCHARGERS

LIST OF CHAPTERS

***Note.**—A list of contents appears at the beginning of each chapter*

P5037 M /1313 9/44 C & P Gp. 1

CHAPTER 2

VOKES AIR FILTER

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The Vokes air filter (see fig. 1) is fitted to the carburettor air intake of various types of aero-engines and is designed to remove all dust and other injurious foreign matter from the air passing to the carburettor. The filter is constructed in streamline form and comprises an outer casing, a filter element and an air chamber. All the components of filters of the same type are interchangeable, except the air chamber which incorporates a flange by means of which the filter is attached to the carburettor intake; the air chamber, therefore, is peculiar to the type of carburettor to which it is fitted. Provision is made for the ejection of surplus fuel from the bottom of the air filter by means of two venturi elbows while any solid matter is blown through a hole below the hinge at the rear end of the casing. Cleaning operations are facilitated by the provision of a hinge and dowelled joint in the outer casing which is made in halves thereby giving easy access to the filter element.

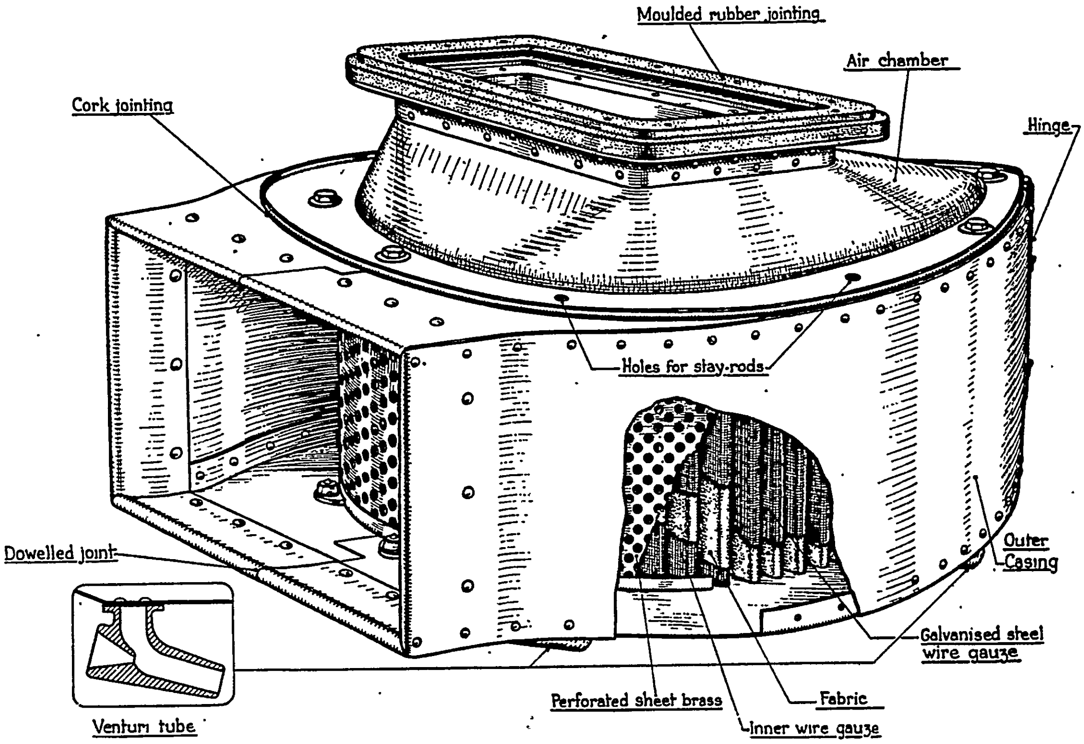


Fig. 1.—Vokes air filter

Construction

2. A general idea of the construction of the Vokes air filter will be obtained from fig. 1. It will be seen that the outer casing is built up in two parts, each riveted to upper and lower flanges to which the air chamber and the lower cover are bolted; the material used for the casing is aluminium alloy (18 s.w.g.). The air chamber is provided with a flange by means of which the filter is attached to the carburettor air intake; a moulded neoprene jointing allows a limited amount of movement between the components whilst maintaining the air-tight joint. Stay rods fitted between the filter and the aeroplane structure, provide the necessary amount of rigidity and alignment when the air filter is installed. The filter element is built up, between two channel section end plates, from layers of galvanised steel wire gauze and fabric, bound at the edges with copper gauze and formed into a number of deep regular corrugations. The gauze is protected on the outside by means of a perforated brass case which entirely surrounds the gauze. At the lower end of the casing two venturi-type fuel ejectors made from magnesium alloy are provided for the purpose of draining surplus fuel that might otherwise collect in the filter.

SERVICING

General

3. The air filter should be maintained in a clean and serviceable condition and for this purpose it should be cleaned and examined periodically. The periods at which the filters should be cleaned vary considerably, because of the different climatic and ground conditions in which the aircraft is operating, therefore, local instructions will be given by Officers Commanding Royal Air Force Stations regarding the cleaning periods to be observed. Care must be taken throughout to preserve the protective coatings on filter components, and in instances where the anodic coating has been partly removed from the outer casing a coat of air-drying enamel should be applied.

Cleaning

4. In order to clean the air filter the outer casing containing the filter element should be removed from the air chamber which should be allowed to remain in position on the carburettor air intake. The four nuts should first be removed from the stay rods and then the screws should be removed from the lower flange of the air chamber thereby releasing the casing and the filter element. The eight bolts securing the filter element to the underside of the casing should now be removed after which the casing can be opened out on its hinge, thereby allowing the filter element to be withdrawn.

5. After the filter element has been removed from the casing all the air filter components should be washed in clean paraffin. It should be ensured that the air and drain holes in the fuel ejectors are free from obstruction. A bristle brush should be used when washing the filter element and it should be left to drain after shaking off as much of the paraffin as possible.

Examining components

6. When all the filter components are cleaned they should be examined for any defects. Dents should be removed and any holes or cracks in the outer casing should be marked for repair. The filter element should be examined closely in order to ensure that there are no tears in the gauze. All cork gaskets should be examined and any which are defective should be replaced by new ones.

Priming filter element

7. After the filter element has drained off sufficiently it should be primed by immersing in a bath of engine lubricating oil to Specification D.T.D. 472 in order to saturate the inner layer of fabric after which the element should be allowed to drain. Only the correct type of oil should be used for this purpose, otherwise the efficiency of the filter will be impaired and damage may be sustained by the engine.

Repairing components

8. After the air filter components have been viewed, any which are defective should be repaired or replaced by new ones. The following information will be found useful when repairs are to be effected:—

(i) Dents on the outer casing should be carefully hammered out and any cracks or holes should be covered with patches neatly riveted in position; patches should be cut to size from 18 s.w.g. sheet aluminium.

(ii) No attempt should be made to repair damaged ejectors; they should be replaced by new ones.

(iii) The perforated sheet brass around the filter gauze should be free from dents, cracks or large holes. Patches, cut from 24 s.w.g. sheet brass, should be soldered over damaged portions and in instances where a patch covers an area of more than 1 sq. in. it should be perforated by means of a $\frac{1}{32}$ in. drill.

(iv) New filter gauzes and cork gaskets should be fitted to all air filters undergoing repair except in an emergency, when new parts are not available. Clips are available for the purpose of blanking off a damaged corrugation in the filter element gauze in an emergency, but this must be regarded as a temporary expedient only. When these clips are fitted they must be placed over the affected corrugation on the gauze immediately under the perforated cover and in no circumstances should a clip be fitted on the inner corrugations.

(v) Jointing compound should be applied to the end plates when fitting a new gauze and care should be taken to ensure that the gauze beds down evenly into the channel when the nuts are tightened.

Assembling

9. The air filter should be assembled, after all components have been reconditioned and the filter gauze primed, in the following sequence of operations:—

(i) Insert the tie bolts in the channel of the filter element bottom cover and secure them in position by means of the hexagon nuts.

(ii) Apply a coat of an approved jointing compound to the channel and then fit the gauze filter over the tie bolts and into the channel.

(iii) Place the perforated brass cover round the outside of the gauze filter ensuring that the edge fits inside the outer rim of the channel.

(iv) Apply a coat of approved jointing compound to the channel of the top end plate of the filter element and place it in position over the upper threaded portions of the tie bolts.

(v) After ensuring that the gauze filter and the perforated brass cover are both in the channels of the end plates, the hexagon nuts should be screwed down on the tie bolts while the jointing compound is still wet.

(vi) The outer casing should now be opened on its hinge as far as possible. Then place a cork gasket on the upper end plate of the filter element and insert the element and the gasket between the top and bottom plates of one half of the opened streamline casing until the holes register in the three components.

(vii) After ensuring that the filter element is in the correct position the screws of the lower part of this half of the outer casing should be inserted through the casing and into the lugs on the filter element.

(viii) The outer casing should then be closed taking care that the cork gasket on the filter element fits under the top plate of the casing. The remainder of the screws should now be inserted in the underside of the outer casing.

(ix) The outer casing and the filter element should now be supported and offered up to the air chamber whilst the flange screws are inserted; care should be taken to ensure that the cork gasket is in its correct position between the outer casing and the air chamber flange before the screws are tightened. If the air chamber has been left in position on the carburettor the stay rod nuts can now be fitted and carefully tightened.

Storage after reconditioning

10. When an air filter is not required for immediate use it should be labelled to indicate that it has been completed and that the filter element has been primed, after which it should be stored in a clean dry place. If the air filter is to be stored for more than a few days or is to be packed for shipment the inlet and outlet should be blanked off by means of the fittings listed in the Schedule of Spare Parts in the relevant airframe handbook, Vol. III.

P5079 M /1353 9/44 5250 C & P Gp. 1

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—AERO-ENGINES AND POWER PLANTS

This is A.L. No. 23 to A.P.1464C, Vol. I and concerns Part 2, Sect. 7
Insert this chapter.

RESTRICTED
(For official use only)

CHAPTER 3

VOKES DRY-ELEMENT AIR FILTERS

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. Vokes dry-element air filters are fitted to the carburettor air intakes of aero-engines for the purpose of removing all injurious foreign matter from the air passing to the carburettor. There are two designs of this type of dry-element air filter, one is fitted outside the engine cowling and is constructed in streamline form with the air inlet at the forward end of the housing, while the other is a built-in construction mounted on the engine side of a detachable panel in the cowling, its air inlet being arranged outside the cowling and facing forward. The filter element in both types is rectangular in shape and is built up from layers of fabric gauze and compressed cotton fibre formed into a number of deep regular corrugations and enclosed in a former. Both types of filter can be mounted above or below the engine, according to requirements, but in all cases the disposition of the filter element in its housing is such that the inlet air always passes through the filtering media from the underside, thus preventing the accumulation of heavy particles of foreign matter on the filter element which might damage it or reduce its efficiency. Access to the element of the external type filter for cleaning and replacement purposes, is given by a hinged section which is normally retained in position by two screws, whilst for the interior type filter, access is gained by first removing the detachable cowling panel and then unscrewing the filter element retaining screws.

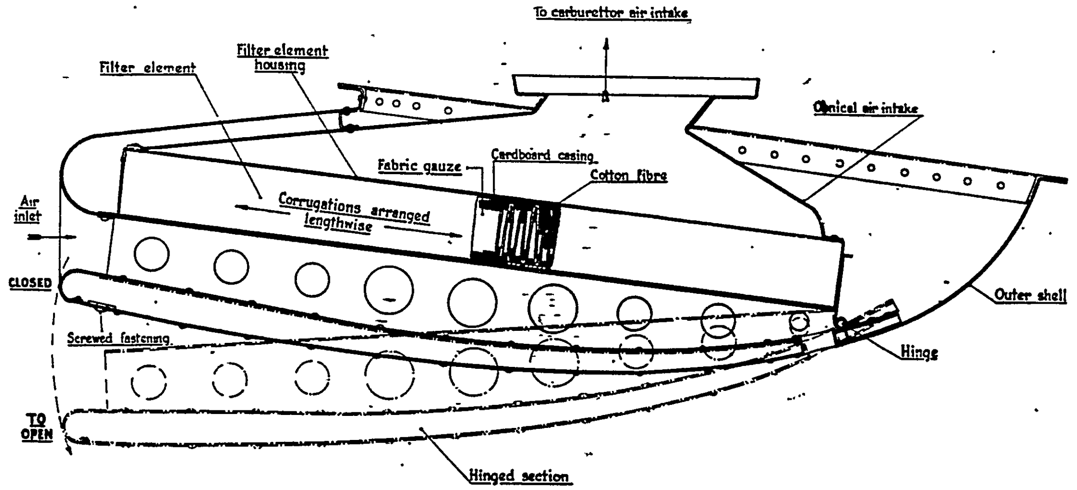


Fig. 1.—Vokes dry-element air filter—external type

CONSTRUCTION

External type

2. The external type filter (see fig. 1) comprises an outer shell of streamline form, and an inner housing for the filter element, the two parts being riveted together for rigidity. The outer shell is provided with a flange, by means of which the filter is secured to the aircraft, and the shell has a hinged section which normally retains the filter element in position. Provision is made for the ejection of heavy particles of foreign matter by means of three slots positioned at the after end of the hinged section. The filter-element housing is provided with a conical air duct which is connected to the carburettor, a rubber joint ring being interposed between the carburettor and the filter to form an airtight joint whilst allowing a limited amount of movement between the two components for alignment purposes. The filter element comprises a layer of closely pressed cotton fibre interposed between two layers of fabric gauze, which are formed into a number of deep regular corrugations, the whole being housed in a compressed cardboard former.

Built-in type

3. The built-in type of filter (see fig. 2) comprises a filter element housing, which is secured by screws to the inboard side of a detachable panel in the engine cowling. This panel forms the filter air-inlet and faces forward, and is attached to the airframe by means of quick-release fasteners. The air passing through the intake is evenly distributed over the whole of the surface area of the filter element by means of suitable vanes or deflectors riveted to the filter housing, whilst a similar set of deflectors is fitted on the delivery side of the filter to prevent the formation of eddy currents in the carburettor air intake. A semi-rotary flap valve is provided in the inlet-air duct to enable air to be drawn from the inboard or outboard side of the engine cowling, as required. The flap valve is operated from the pilot's cockpit, usually by means of a small hydraulic control, the piston-rod of which is connected to a lever secured to the flap-valve spindle. A sliding joint between the filter and the carburettor air intake forms an air-tight joint whilst allowing a slight amount of movement between the two components. The filter element is of a similar construction to that described in para. 2, as used in the external type filter. Access to the filter element for cleaning and replacement purposes is obtained by first detaching the engine cowling panel and then removing the screws which secure the inlet deflector-assemblage to the filter housing.

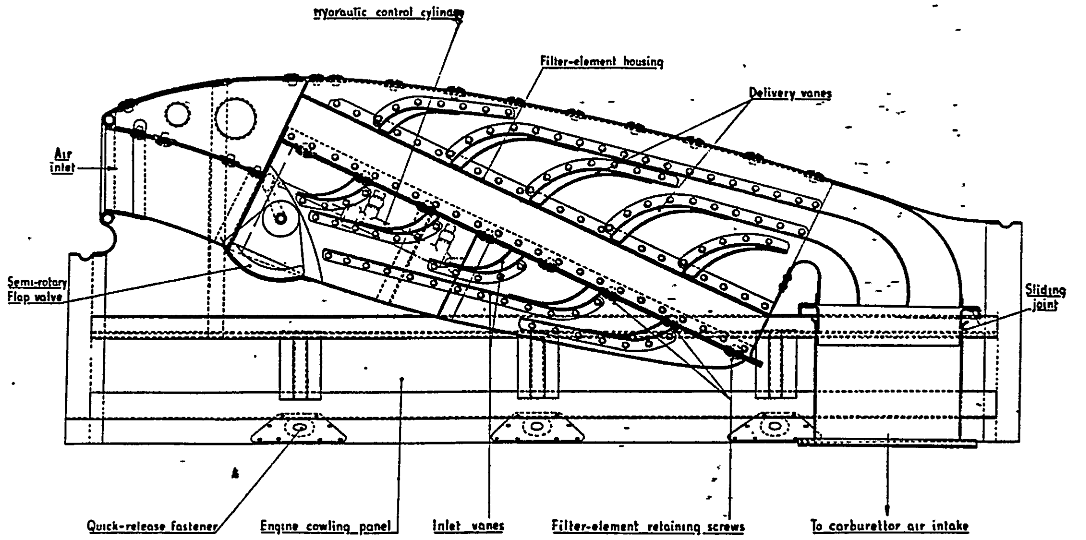


Fig. 2.—Vokes dry-element air filter—built-in type

SERVICING

General

4. Both types of air filter should be maintained in a clean and serviceable condition and for this purpose they should be cleaned and examined periodically. Care should be taken to prevent the accumulation of heavy particles of foreign matter in the filter housing, particularly in instances where built-in type filters are fitted. In common with all air-filters, the periods at which the filter element should be cleaned vary considerably according to the climatic and ground conditions under which the aircraft is operating, therefore local instructions will be given by Officers Commanding Royal Air Force Stations, regarding the cleaning periods to be observed. Care must be taken to preserve the protective coatings on the filter components and in instances where the anodic coating has been partly removed from the outer casing, a coat of air-drying enamel should be applied. Dents in the outer casing should be carefully hammered out and any cracks or holes should be covered with 18 s.w.g. sheet aluminium patches, riveted in position.

Cleaning and replacing filter element

5. In order to clean the filter element in instances where the external type of air filter is fitted, the two screws which retain the lower part of the filter housing in position should be removed. The lower part of the housing can then be lowered downwards on its hinge (*see* fig. 1) and the filter element withdrawn. To gain access to the filter element of the built-in type of filter, the cowling panel should first be detached, after which, the screws securing the inlet deflector assemblage to the filter housing, should be removed, when the filter element can be withdrawn. The element in both types of filter should be cleaned by jarring them on a flat surface such as a bench top, care being taken to ensure that the air-delivery side of the element is upwards during the operation and that the cardboard former is not damaged or distorted. The element should then be further cleaned by means of a strong jet of compressed air directed on to the delivery side of the element. Under no circumstances should cleaning fluids be used to clean the filter elements in the dry-element type air filters nor should they be allowed to come into contact with oil. If the filtering media has come into contact with oil, or is clogged with oily dirt, the element should be replaced by a new one of the correct type. After cleaning, the element should be replaced, care being taken to ensure that it has been replaced correctly as indicated by the word "INLET" on the cardboard former, which should face the air inlet orifice. If a filter element has sustained damage it should be replaced by a new one of the correct shape.

P5077 M /1355 9/44 5250 C & P Gp. 1

CHAPTER 5

AUTOMATIC ALTITUDE CONTROL FOR AERO-ENGINE SUPERCHARGERS

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

1. The purpose of the automatic altitude control is to relieve the pilot of the necessity to change over from lower to higher super-charge and vice versa. Control is obtained by a combination of an altitude operated switch and an electro-pneumatic ram. In operation, the switch closes the electrical circuit at a pre-determined altitude and energises a solenoid incorporated in the ram which is operated on the inward stroke by the admission of compressed air when the valve is opened by the action of the solenoid; the return stroke, when the altitude is decreased, is effected by a coil spring. The particular arrangement of the components of the automatic control to the supercharger will be found in the relevant aero-engine handbook, Vol. I. The switch and ram are described in detail in the paragraphs which follow.

Altitude switch

2. The altitude switch (see fig. 1) comprises an outer casing of light alloy formed into two compartments, one of which houses a spring-loaded metal bellows and the other an electrical trip-switch controlled by atmospheric pressure acting through the medium of the bellows. One end of the bellows is anchored to the housing and the other end is free to extend, carrying with it a central spindle which is guided axially on ball-bearings in a sleeve. The air is evacuated from the bellows during manufacture and, at atmospheric pressures below a pre-determined altitude, the bellows remain closed against the action of the coil spring. At the desired altitude the bellows extend and carry the central spindle outward in its guide, so operating the switch.

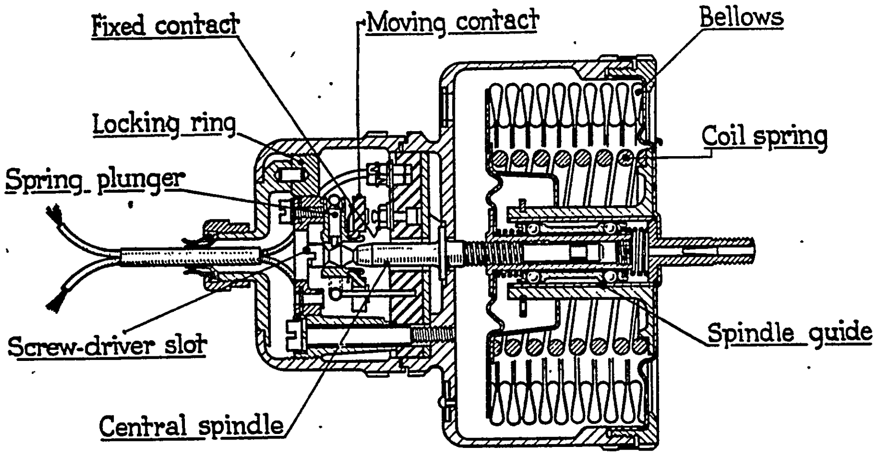


Fig. 1.—Altitude switch

3. The switch is actuated at the end of the central spindle in which two V-shaped grooves are machined and in which three spring plungers engage alternatively, according to the position into which the spindle is moved by the bellows. The purpose of the spring plungers is to enable a positive snap-action of the switch contacts to be obtained on either side of a dead-centre thereby opening or closing the electrical circuit of the aircraft in which these components are wired. Below the desired altitude the switch contacts remain open and the solenoid is inoperative, but at and above the altitude, the switch contacts close and the solenoid becomes energised.

4. The altitude at which the switch is desired to operate can be varied by rotating the central spindle by means of a screw-driver, a slot being cut in the end of the spindle for that purpose. Clockwise rotation will give a decrease in altitude by reducing the compression on the coil spring within the bellows and, conversely, operation at increased altitude will be obtained by an adjustment of the spindle in an anti-clockwise direction.

5. There is a difference allowed between the altitude at which the switch contacts close and that at which the switch operates again to open the contacts; for example, in one particular setting the switch operates to give a closed circuit at an altitude of 15,250 ft. and operates again to re-open the circuit at 14,750 ft. The means by which this altitude lag is varied is provided in the form of an adjustable locking ring locked in its correct position by three cheese-headed screws; anti-clockwise rotation of the ring delays the action of the switch and vice versa. All the necessary adjustments are made by the manufacturers and, except in an emergency, should not be disturbed.

6. Holes are provided in the casing to allow free communication with the external atmospheric pressure; the entry of dust into the switch and bellows housing is prevented by a gauze fitted under the name-plate.

Electro-pneumatic ram and switch circuits

7. The electro-pneumatic ram comprises an arrangement of solenoid-operated valves controlling the inlet and exhaust ports to and from a spring-loaded ram. The solenoid is included in the electrical circuit of the aircraft in conjunction with the altitude switch described in the foregoing paragraphs. When the predetermined altitude is reached, the switch contacts close, the solenoid then becomes energised and admits compressed air into the cylinder, behind the piston, thus operating the ram

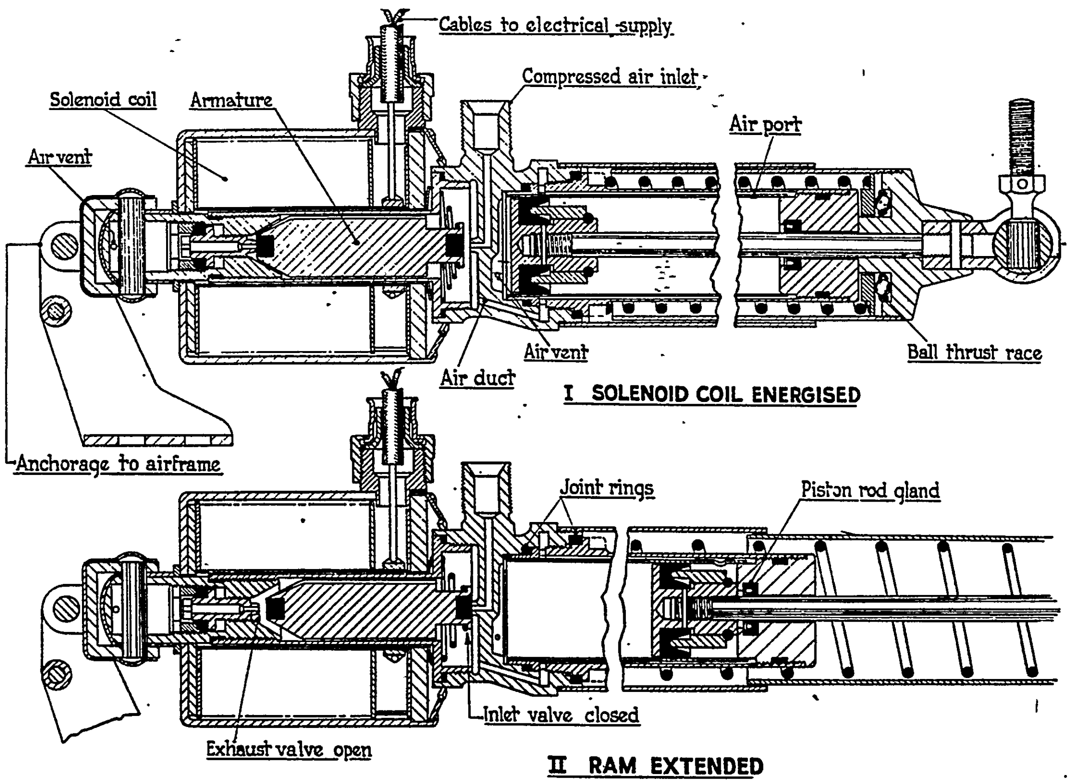


Fig. 2.—Electro-pneumatic ram

and any external mechanism to which it may be connected (in this instance the supercharger). When the altitude is reduced to the lower level at which it comes into operation, allowing for the lag given by the switch mechanism, the contacts open, so releasing the solenoid. When the solenoid is released the ram returns to its extended position under the action of its spring, the compressed air being exhausted to atmosphere.

Components of electro-pneumatic ram

8. The electro-pneumatic ram (see fig. 2) consists of two main components, namely, the solenoid-operated valve and the pneumatically-operated ram. These components are described in the following sub-paragraphs:—

(i) *Solenoid.*—The solenoid coil and armature are housed within a cylindrical metal case and the whole assembly is mounted on a casting in which the air inlet connection and air ducts are formed. The armature is free to move endwise axially and it carries a rubber valve at each end, the one at the inner end mating with a valve seat formed on the compressed-air inlet duct, the other end engaging with the exhaust duct seat. The solenoid armature is spring-loaded to the inlet valve closed position and, when the coil is energised, the armature is drawn in along the central sleeve, so opening the inlet valve and closing the exhaust. The exhaust air passes through an air vent hole drilled in the mounting eye of the ram by means of which the complete assembly is anchored to the airframe, at the end of the solenoid.

(ii) *Ram.*—The ram and cylinder are connected to the valve duct casting at the opposite end to the solenoid with which it is axially in line. The assembly consists of a piston attached to a rod mounted in an air-tight gland and passing through an end-cap which screws into the inner of two tubular guides. The end-cap takes the thrust of the return spring, through the medium of a ball thrust race, the opposite end of the spring bearing against the cylinder mounting sleeve. Within the mounting sleeve is the cylinder proper and, between the two, a clearance is provided to form an air duct through which air passes from the compressed air supply to the piston via radial holes in the outer end of the cylinder. The piston and the piston rod are rendered air-tight by U-section packing rings. Joint rings are fitted at the junctures between the air duct casting and the cylinder. A vent hole leading to atmosphere is provided at the head of the ram cylinder formed by the air-duct casting, in order to prevent back pressure against the action of the piston when it is forced inward on the air pressure stroke.

Servicing

9. For servicing purposes, the complete ram is regarded as a sealed unit. For test purposes, the electrical resistance of the solenoid should be 38 ohms for 12-volt coils and 150 ohms for 24-volt types. Air pressure tests should be made at a pressure of 5 lb./sq. in. above that of the compressed air service in the aircraft. During inspections it should be ensured that there is no lost motion in the anchorage of the ram to the airframe or the linkage to the controlled mechanism.

10. Air leakage from the vent at the mounting eye when the solenoid is not energised will indicate a faulty inlet valve, but when the coil is energised a leakage at the same vent will indicate a faulty exhaust valve. Leakage of air at the central vent near the inlet connection will, when the coil is energised, indicate a faulty piston ring.

P5073 M /1357 9/44 5250 C & P Gp. 1