Nicholas Cale.

RESTRICTED

December, 1947

AIR MINISTRY

Amendment List No. 31
to
Air Publication 1464C
Volume I

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

PART 2
Sect. 3

(1) List of Chapters. Delete the title of Chap. 8 and write "A.L.31" in the outer margin of the page opposite the amendment.

(2) Chap. 8. Remove and dispose of the entire chapter.

Sect. 5

(3) List of Chapters. Delete the title of Chap. 5 and write "A.L.31" in the outer margin of the page opposite the amendment.

(4) Chap. 5. Remove and dispose of the entire chapter.

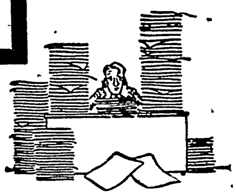
When you have done this make an entry in the Amendment Record Sheet at the beginning of the book.

ENGINEER

RTP3278/4500/12/47

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
1 to 24	Incorporated	MAY, 1944
Sept 44 25.	M. Titterington	31.3.45
26 Dec 44		
27 " "		
28 Sept 44	W. Cranley	17-4-45
29 Oct 44		
30 June 45	M. M. Gallagher	18/1/46

A.L. No.	AMENDED BY	DATE

(Continued overleaf)

AMENDMENT RECORD SHEET
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A.L. No.	AMENDED BY	DATE

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R.A.F. ENGINEERING—GENERAL ENGINEERING
This is A.L. No. 1 to A.P.1464B, Vol. I
Insert these leaves.

AIR MINISTRY
May, 1944

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.

(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 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. 1464B—R.A.F. ENGINEERING

GENERAL ENGINEERING

- **VOL. I**
  - **PART I**
    Principles of general engineering
    - Sect. 1—Statics
    - Sect. 2—Dynamics
    - Sect. 3—Hydraulics
    - *(continued)
  - **PART 2**
    Miscellaneous general engineering subjects
    - **SECT. 1**
      General
    - **SECT. 2**
      Hand tools
    - **SECT. 3**
      Workshop equipment and plant
      - Chap. 1—General
      - Chap. 2—Station workshops
      - Chap. 3—Crack detection—Metals and alloys
      - *(continued)
    - **SECT. 4**
      Materials and how to work them
      - Chap. 1—General
      - Chap. 2—Timber
      - Chap. 3—Metals and alloys
      - *(continued)
    - **SECT. 5**
      R.A.F. engineering standards and specifications
      - Chap. 1—General
      - Chap. 2—Standard colour scheme and index
      - Chap. 3—B.S. specifications
      - *(continued)
    - **SECT. 6**
      Special rivets, bolts, fasteners and nuts
      - Chap. 1—General
      - Chap. 2—Rivnuts and Tools
      - Chap. 3—Dzus fasteners
      - *(continued)
  - **PART 3**
    List of general engineering publications
- **VOL. II**
  - **PART 1 (Leaflets)**
    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.*

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	Aeroplane 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				
1464A	4	4	2	Aero-engines—Viewing procedure (New title:—Aero-engines—Viewing and viewing procedure)	1464C	2	2	4

LIST OF CHAPTER REFERENCES—CONTD.

Old ref.				Chapter Titles	New ref.			
Vol. I	Part	Sect.	Chap.		Vol. I	Part	Sect.	Chap.
1464A	4	4	3	Aero-engines—Alignment tests	1464C	2	2	5
1464A	4	5	6	Carburettor maintenance (New title:—Aero-engines—Carburettor servicing)	1464C	2	2	6
1464A	5	1	2	Aeroplane 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 machines	1464B	2	3	8
1464B	3	3	5	Chobert riveting tool	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
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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

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Vol. I	Part	Sect.	Chap.		Vol. I	Part	Sect.	Chap.
1464B	5	2	4	De-icing equipment for aero-engine induction systems (New title:—De-icing equipment for induction systems)	1464C	2	4	2
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. I			
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	(Old title) Fuel oil and water pumping equipment (New title) Replenishment equipment on airfields—General	1464G	2	3	1
1464B	8	7	2	Delivery nozzles	1464G	2	3	6
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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
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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. I			
1464B	8	9	5	Compressed air operated oil primer	1464G	2	5	7
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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
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1464B	8	10	13	Accumulator trolley—Aero-engine electric starting	1464G	2	5	14
1464B	8	10	14	Aero-engine starting accumulator charging sets (Stores Ref. 42U/10, 42U/12 and 42U/16)	1464G	2	5	15
1464B	8	10	15	Aero-engine starting accumulator charging set (Stores Ref. 42U/500)	1464G	2	5	16

NOTES 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.

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FOR LIST OF ASSOCIATED PUBLICATIONS SEE PART THREE OF THIS VOLUME

R.A.F. ENGINEERING

GENERAL ENGINEERING

LIST OF PARTS

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

PART 1 *Principles of general engineering (to be issued later)*

PART 2 *Miscellaneous general engineering subjects*

PART 3 *List of general engineering publications (to be issued later)*

PART 2

MISCELLANEOUS GENERAL ENGINEERING SUBJECTS

LIST OF SECTIONS

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

SECTION 1	Miscellaneous general engineering subjects—general (*to be issued later*)
SECTION 2	Hand tools (*to be issued later*)
SECTION 3	Workshop equipment and plant
SECTION 4	Materials and how to work them
SECTION 5	R.A.F. engineering standards and specifications
SECTION 6	Special rivets, bolts, fasteners, and nuts

SECTION 3

WORKSHOP PLANT AND EQUIPMENT

LIST OF CHAPTERS

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

CHAPTER 1	Workshop plant and equipment—general (*to be issued later*)
CHAPTER 2	Station workshops
CHAPTER 3	Crack detection—metals and alloys
CHAPTER 4	Spraying equipment
CHAPTER 5	Spraying technique
CHAPTER 6	Electric brushing machine A1/MY
CHAPTER 7	Tru-loc cable end-fitting swaging machine
CHAPTER 8	Tube bending machines
CHAPTER 9	Chobert riveting tools
CHAPTER 10	Measuring instruments and appliances
CHAPTER 11	Jet calibrating machines
CHAPTER 12	De-greasing by trichlorethylene process (A.L.27

CHAPTER 2

STATION WORKSHOPS

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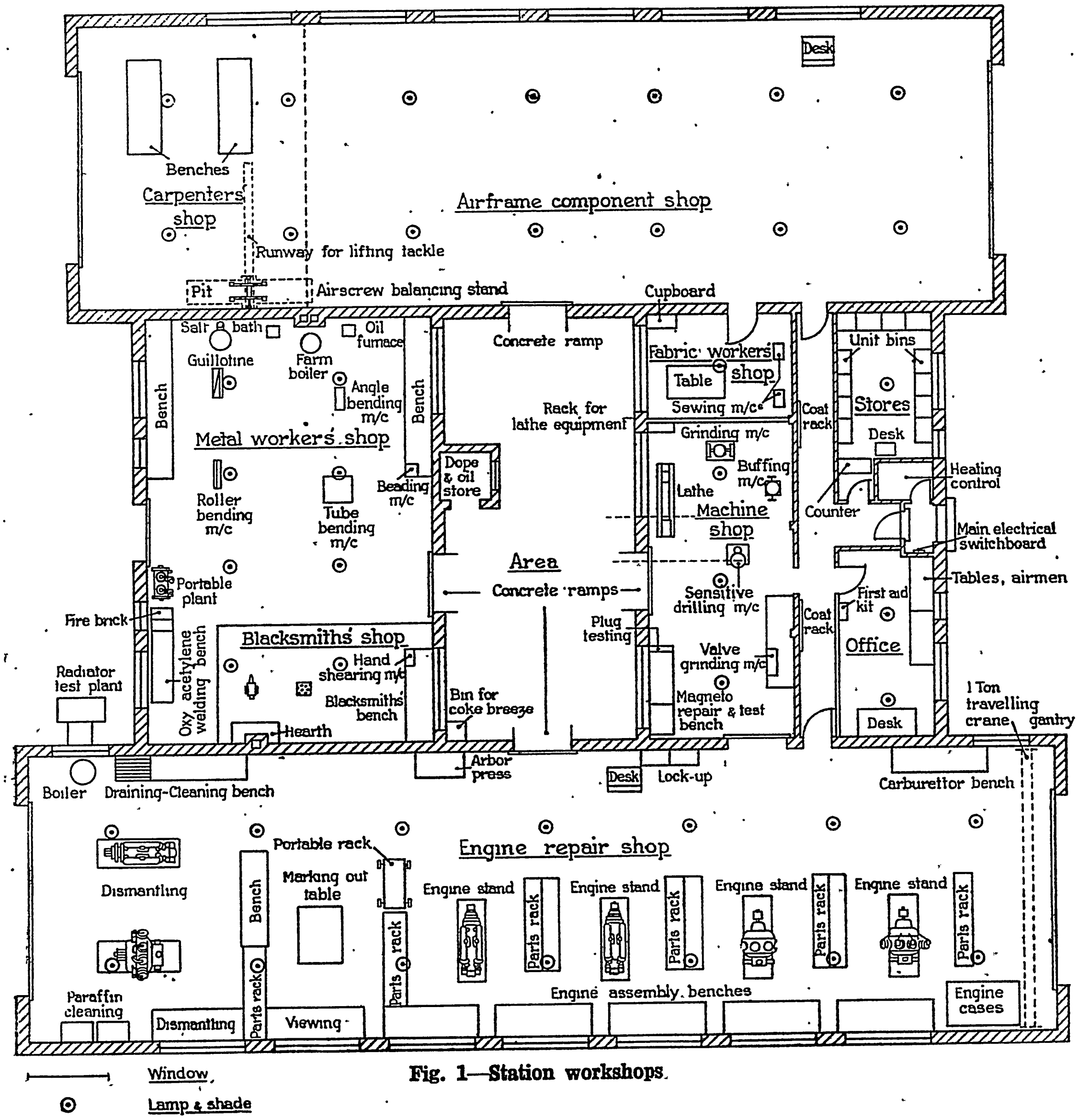

Fig. 1—Station workshops.

CHAPTER 2

STATION WORKSHOPS

General

1. Station workshops should be laid out and supervised in such a manner that all work undertaken in the shops will follow the approved working procedure as described in this and other chapters of this publication. A standard type station workshop has been introduced and in order to ensure that all station workshops conform to type as nearly as possible, the following description of a typical station workshop is given with a plan of the layout. This description deals first with the workshops and the layout of the Directorate of Works fixtures, followed by the recommended layout to be adopted in the disposition of available equipment with observations on the use of each shop. Although there are variations in the size, shape and relative positions of the separate shops at some stations, the main features described in this chapter apply to all station workshops.

Typical layout

2. A typical layout of a station workshop is indicated in fig. 1, in which the positions of the various shops are shown and the arrangement of the main items of equipment. Lighting and heating are supplied from a central source in the station. The electricity supply is led into the workshops to a main switchboard situated in a recess in the outer wall of the office whilst the heating supply is connected in a valve room placed on the opposite side of the entrance. These connections are outside the workshops entrance door in order that they may be accessible from the outside when the door is locked. Sub-fuses and switches are placed in each shop, with plug-in switches at various points to provide for the use of portable hand-lamps, electric drills, etc. The electric power supply is led to a distribution box in the machine shop from which it is taken to the separate machines. The heating of the shops is effected by means of single column type radiators spaced around the shops, each radiator being fitted with a control valve. The heating temperature of the workshops is regulated thermostatically. The central area which is enclosed by the workshop buildings is accessible to all shops. The separate shops are dealt with in the following sub-paragraphs:—

(i) *Engine repair shop.*—The engine repair shop is spanned by a hand-operated 1-ton travelling crane which may be traversed the full length of the workshop in such a manner that engines may be picked up at either main entrance and placed in any intermediate position. The doors in each end of the shop are of the sliding folding type giving a clear entry 20 ft. wide × 17 ft. high. Fitters standard type metal covered benches are placed opposite each window; the benches are recessed to allow clearance for the heating radiators which are placed below each window. Adjustable workshop lamps are mounted on wall brackets near the vice positions; these lamps may be extended to a maximum length of 2 ft. 6 in. and movement allowed by the universal joints permit the light to be projected on to the work at the required angle. Four plug-in switches are provided around the shop so permitting the use of inspection lamps, electric drills, etc. The roof lamps are controlled by seven switches, one switch for each pair of lamps.

(ii) *Airframe component shop.*—The airframe component shop is similar in construction to the engine repair shop. One end of this shop is allotted for use as a carpenters' shop.

(iii) *Carpenters' shop.*—The carpenters' shop is situated as shown in the plan, but as no partition separates it from the remainder of the airframe component shop, the space occupied may vary according to the amount of work in either shop. The equipment supplied consists of two carpenters' benches.

(iv) *Fabric workers' shop.*—The fabric workers' shop is a small workroom 10 ft. 6 in. × 15 ft. 3 in. placed conveniently near the airframe component shop.

(v) *Metal workers' shop.*—The metal workers' shop is allotted for the use of the metal workers including blacksmiths and welders. The sheet metal workers are provided with two benches underneath which are cupboards for the safe keeping of fluxes, solder, etc. There is a flue at each end of the workshop to take the fumes from the farm boiler heater and the blacksmiths' hearth. The blacksmith and oxy-acetylene welder, each provided with a fitter's standard bench, occupy one end of the workshop for a distance of 15 ft.; this portion of the shop floor is made up of rolled fine ashes. Sliding doors 7 ft. high × 6 ft. wide are placed in each side wall.

(vi) *Machine shop.*—The machine shop is arranged as shown in the plan, for the reception of machinery and for the benches, to be provided, on which magneto repairs and valve grinding may be undertaken. Three doors open into this shop so facilitating communication with the workshops.

(vii) *Stores and office.*—The stores and office are placed one on each side of the front entrance and adjacent to the workshops. The heating system valve room is built into part of the stores and the main electrical switchboard is recessed into the outer office wall. The office floor is laid with linoleum.

(viii) *Dope and workshop oil store.*—A small outbuilding is provided in the area for the purpose of the safe storage of dope, oil for workshop use, paraffin, etc.

WORKSHOPS, EQUIPMENT AND WORKING PROCEDURE

General

3. The standard type station workshops are intended to be used and equipped in the manner described in the following paragraphs. The equipment required will vary according to the type of aircraft held on the station, but the general principles will apply to all workshops. Standard tool kits and lock-ups are available for workshops and also for workshop personnel according to trade; these kits are listed in Air Publication 1086 and are in accordance with scales given in Volume III of Air Publication 830. Equipment which is general to all shops, such as ladders of various types, portable hand trollies, general purpose fixed trestles, lifting tackle, etc. should be obtained and kept in a position where they will be accessible without causing obstruction.

Squadron hangar for workshop use

4. In order to ensure that the greatest advantage is obtained from the workshops, full use should be made of the allotted space in the Squadron Hangar. Aircraft to be repaired in the workshops should be taken on charge by the Engineer Officer and dismantled in the squadron hangar as required. Component parts for repair should be taken to the workshops concerned, whilst the fuselage remains in the hangar. Lockups are provided and these should be utilised for the safe keeping of instruments, etc. during the period that the aircraft is under repair. Repairs that may be completed without dismantling major components should be undertaken in the hangar. After repair in the workshops, components should be returned to the squadron hangar for assembling, doping and rigging operations. For the purpose of dismantling and assembling aircraft components in the squadron hangar, tail and plane lifting gantries will be required in some instances. Jacking trestles, axle trestles, fixed trestles, jacks, platform ladders, plane storage racks, portable storage racks and inspection platforms should be obtained as required; a description of this equipment is given in Air Publication 1464G, Volume I, Part 2, Section 5, whilst information regarding special equipment which is available according to type will be found in the relevant aircraft handbook. Equipment will be required for the doping scheme laid down in Volume II leaflets of this Air Publication. Portable air compressors are available for operations such as tyre inflation and spraying, whilst hot air blowers are available for dope drying, etc.

Engine repair shop

5. The engine repair shop should be so arranged that the sequence of operations is followed as described in A.P.1464C, Vol. I, Part 2, Sect. 2. The separate bay system should be adopted as standard with any slight modifications that may be necessary when different types of engines are dealt with; the layout of the complete workshop is shown in fig. 1. The separate bays should be made up as follows:—

(i) *Engine dismantling.*—Engine dismantling operations should be done in the dismantling bays according to the methods laid down in A.P.1464C, Vol. I, Part 2, Sect. 2. A fitter's standard metal covered bench with vice is provided and sufficient space to accommodate two engines and stands is allotted. Drip trays should be used underneath engines whilst dismantling. A portable storage rack should be used for the reception of dismantled parts to be passed for cleaning.

(ii) *Engine cleaning.*—Cleaning operations should be undertaken according to instructions given in A.P.1464C, Vol. I, Part 2, Section 2. A hot-water boiler, two paraffin tanks, a draining rack and cleaning bench comprise the main items required; the layout of this equipment is shown in fig. 1. After the parts are cleaned they should be handed over to the viewing bay, complete in groups of components, for which purpose a portable rack should be provided.

(iii) *Viewing.*—A bay is provided where viewing operations may be undertaken. Two benches, two part racks, a marking out table and viewers' instruments should be obtained. The viewing procedure and the instruments required are described in A.P.1464C, Vol. I, Part 2, Section 2. The marking out table should be placed in a central position in the bay. A bench and a part rack should be obtained for the reception of parts from the cleaning bay and a portable type rack should be provided and arranged to receive parts that have been viewed, whilst a fixed rack should be used for the reception of rejected parts. Special lighting has been provided in this part of the shop (see para. 33).

(iv) *Engine assembling bays.*—The assembling bays are laid out as shown in fig. 1 with the engine stands in a central position and part racks on either side, opposite the fixed benches supplied. Slatted footboards should be provided at the benches, by means of which small adjustments for difference in height of personnel may be made. Drip trays should be used when possible underneath all engines that are being assembled. Engine tool kits, jigs and gauges should be supplied according to the type of engines held on the station. Further information regarding engine assembling equipment will be found in A.P.1464C, Vol. I, Part 2, and in detail in the relevant engine handbook.

(v) *Carburettor bay.*—The carburettor bay is situated in the engine repair shop. A fitter's standard metal covered bench with vice should be provided for the purpose of dealing with carburettors according to instructions in A.P.1464C, Vol. I, Part 2, Section 2, and in appropriate aero-engine handbooks. Fuel feed pumps may also be dealt with in the carburettor bay. Light wooden trays should be made up locally with suitable partitions in each tray to accommodate a dismantled carburettor or fuel feed pump, in order to avoid the loss of small parts as they are dismantled. The necessary test equipment should be provided as required.

Airframe component shop

6. The airframe component shop is provided for the repair of such components only as main planes and tail units. This shop should be kept as clear as possible to facilitate the work in hand and any plane racks and trestles that are not in use, or completed components, should be removed and stored in the squadron hangar. No doping other than for small patching operations should be undertaken in this shop. Portable benches are available for use in this workshop as required. The equipment will include a portable flight desk, main plane repairing trestles, storage racks, adjustable tail trestles and portable wooden benches. A propeller metal balancing stand with centring cones to suit the type of propeller concerned should be obtained and placed in the position indicated in fig. 1; this apparatus is fully described in the A.P. "1538" series.

Carpenters' shop

7. The carpenters' shop occupies a position at one end of the airframe component shop, and is equipped with carpenters' benches and general purpose trestles. This shop is intended for handwork only, and machined timber of which the demand must be anticipated in varying types and cross-sections cut to size should be requisitioned from depots and held in the main stores until required by the workshops. This workshop is not partitioned off but will generally occupy a space 30 ft. × 20 ft.

Fabric workers' shop

8. The fabric workers' shop should be kept solely for the purpose of dealing with fabric and allied materials, cutting out, machine sewing, etc. The main items of equipment required comprise a work table, a sewing machine and a chair. No equipment or material should be stored in this shop other than that necessary for the work in hand. Authorised work on parachutes and safety harness may also be undertaken in this workroom in accordance with the methods laid down in Vol. II leaflets of the A.P. "1182" series.

Metal workers' shop

9. The metal workers' shop should be laid out as shown in fig. 1. The manually-operated metal working machines should be so situated that ease of access is permitted to each machine and at the same time ensuring that personnel may walk past with safety and without interfering with the operator. The work undertaken in this workshop varies and should be dealt with in the appropriate part of the shop as indicated by the layout of the equipment (see fig. 1). The blacksmiths and welders should occupy one end of the shop and one half of the remaining portion should be suitably equipped for repairing fuel tanks, radiators, oil coolers, and the like, the other half being allotted for the use of the sheet metal workers doing such work as panel beating, riveting, and the authorised fabrication of light metal fittings. The following sub-paragraphs deal separately with the equipment required by each group in this workshop:—

(i) *Metal working equipment.*—Four benches equipped with vices are supplied in this workshop. Two of these benches are fitted with cupboards which are built in beneath them for the reception of such items as fluxes, solder, mallets, etc. The other two benches are the fitters' standard metal-covered type fitted with revolving head vices for the use of the blacksmiths and welders. Two muffles heated by means of 5-pint blowlamps should be obtained for various heating processes, also a salt bath suitable for the heat treatment of duralumin rivets.

A 30-gall. farm boiler is supplied for the purpose of washing fluxes from work which has been soldered or welded. Tinmen's stakes, mandrels, shears and various soldering irons are available as listed in Air Publication 1086. Lead blocks and sand bags, which may be made up locally, should be provided. The manually operated machine tools supplied comprise a roller bending machine, a 36 in. guillotine, a 30 in. angle bending machine, a beading and swaging machine, and a tube bending machine with $\frac{1}{4}$ in. to $\frac{7}{8}$ in. formers; these should be positioned as shown in fig. 1. Riveting sets suitable for solid and hollow type riveting, a portable electric drill and a breast drill should also be obtained for use in this workshop.

(ii) *Blacksmiths' equipment.*—The blacksmiths should be provided with a portable type hearth, an anvil, a swage block and a standard metal-covered bench equipped with combination vice and shearing machine. Other equipment such as sledge hammers, tongs, setts, fullers and hardies, as listed in Air Publication 1086, are available. An oil bath and water trough should be obtained for heat treatment and slaking purposes, whilst sand and slaked lime should be supplied for use in annealing operations. A bin should be used for the storage of coke breeze which should be kept outside the workshop.

(iii) *Oxy-acetylene welding equipment.*—A portable plant is provided for oxy-acetylene welding purposes and a fixed working position is allotted in a portion of the blacksmiths' shop. A standard metal-covered bench and a vice is supplied; part of this bench top should be protected by means of fire-bricks or slabs. A cupboard should be provided, in which goggles not in use may be stored safely, fluxes kept dry and welding rods kept free from corrosion. A metal stand should be made up to hold the blowpipe when necessary whilst work is in progress. Gas cylinders not in use should be stored in the approved manner. Welding equipment is dealt with fully in Air Publication 880. The regulations contained in para. 24 of this chapter should be observed.

Machine shop

10. The machine shop should be laid out as shown in fig. 1. The positioning of the machine tools should be done carefully in order to ensure that each machine may be used to full advantage and not limited by the close proximity of a wall or another machine. Tools and appliances for each machine should be obtained and kept in suitable racks. The main items in this shop should be arranged in accordance with the information contained in the following sub-paragraphs:—

(i) *Lathe.*—The lathe should be placed near the window with only sufficient clearance from the wall to allow for cleaning. The tailstock end should be as far away as possible from the end wall consistent with the lighting at the face plate. It should also be ensured that a clearance is allowed for the overhang of long lengths of material which may project through the lathe hollow spindle when end-facing or parting-off. Suitable receptacles should also be provided for the metal cuttings, scrap, etc.

(ii) *Drilling machine.*—The utility of the sensitive drill will be increased if the machine is placed in such a manner that long spars or similar objects to be drilled can project through the area door-way as indicated in fig. 1.

(iii) *Buffing and grinding machines.*—The buffing machine and the grinding machine should be fixed with sufficient clearance around each to permit access to both sides of the wheels. The wheels should not be in a direct line with the operator of any other machine; this is necessary in order to prevent injury by work accidentally thrown across the shop by the wheels when in use. The buffing machine polishing bobs, mops and brushes, buffing mediums, etc., should be placed on a rack on the wall near the machine. The stand type grinding machine should be fitted with two wheels, one for rough grinding and the other for finishing; a suitable receptacle for holding water should be kept near the machine for cooling purposes whilst grinding hardened steel tools.

(iv) *Magneto repair and test bench.*—One end of the machine shop should be equipped with fitters' standard benches in order that magneto repairs and valve-grinding may be undertaken therein. The sparking plug testing machine can be conveniently placed on the end of the bench provided for magneto repairs, but operations involving the use of petrol for plug cleaning should not be done in this shop owing to the risk of fire. A magneto testing set should be obtained and installed as indicated in fig. 1.

(v) *Valve grinding machine.*—The valve grinding machine should be secured to fitters' standard metal covered bench so providing for valve face grinding operations. The machine is electrically driven, and the current for the electric motor should be taken from the plug-in-switch, situated near the bench, using an extension lead. Portable hand racks should be made locally for the purpose of holding a complete set of valves and so keeping them together (see A.P.1464C, Vol. I, Part 2).

Stores

11. The store-bins should be placed around the walls and full advantage should be taken of the height of the room when placing them in position. These bins are available in various unit lengths and heights, as listed in Air Publication 1086. A small desk will be necessary for the use of the store-keeper. A hinged counter should be used for the issue of stores and so positioned as to prevent unauthorised entry of personnel.

Office

12. The office should be provided with tables, chairs, a desk and a filing cabinet. A telephone is installed for the use of the engineer officer. The first aid outfit should be kept in the office in a prominent position.

Area

13. In order to give easier access of trollies, etc. to the area, it may be necessary to make up a ramp to reach the height of the step of each workshop around the area.

MAINTENANCE OF WORKSHOPS AND EQUIPMENT

Maintenance of workshops

14. The maintenance of all workshops will be facilitated if portable equipment, surplus material and personal belongings not actually in use are removed from the working positions. Shelves, benches, floors, etc., should be swept daily. Tools, gauges and jigs should be returned to the tool stores or tool kit boxes after use. Suitable receptacles should be provided for rubbish and metal scrap, and all rubbish should be removed daily from the workshops after cessation of work; rubbish of an inflammable nature should be disposed of by burning in a safe place as laid down in the Royal Air Force Fire Manual, A.P.957. The floors should be kept clean and free from oil and grease. Sliding door runners and guides, door hinges, and window fastenings, should be examined periodically to ensure that they are secure and working freely. Any defects in the workshop building or fixtures should be reported to the Section Officer of the Directorate of Works without delay.

Maintenance of equipment

15. All equipment should be kept clean and free from corrosion and in a good state of repair. The fixtures and equipment supplied by the Directorate of Works are maintained and repaired by them. Other equipment should be maintained in good condition and returned to Stores when unserviceable. Painted equipment should be renovated when the paintwork becomes damaged. Cleaning, adjusting and lubrication of equipment and machinery should be attended to systematically by competent personnel; before commencing any of these operations to power-driven machinery, attention should be given to the precautions contained in para. 25 of this chapter. The following points should be noted:—

(i) *Benches.*—Benches should be kept in a clean condition; the metal covered and the portable types cleaned with paraffin rag, and the plain wooden benches by means of a stiff brush and by scraping if necessary. Punching operations should not take place on the bench tops without some form of protection for the bench surface such as a piece of hardwood or a lead block. Care should be taken to prevent nails and pieces of metal from becoming embedded in the bench surface. The portable type benches should be examined periodically and all nuts checked to ensure that they are tight; the wheel bearings should also be lubricated.

(ii) *Vices.*—Vices should be wiped over frequently, using an oily rag for the purpose. The moving jaw should be withdrawn to the limit of its movement in order that the screw bearings and the thread may be lubricated. The jaw-insert screws and the bolts securing the vice to the bench should be tightened occasionally. Vice handles should be kept free from rust in order that they may slide freely in use.

(iii) *Engine stands.*—Engine stands should be cleaned frequently and kept free from corrosion. Bolts should be checked for tightness and, when not in use, any loose packing blocks, etc., should be attached to the stand until required for use.

(iv) *Lifting tackle.*—Lifting tackle should be cleaned, lubricated and maintained as laid down in Vol. II leaflets of this Air Publication.

(v) *Marking out table*.—The marking out table should be kept perfectly level with the supporting stands taking the weight evenly. Any raised portions, the result of surface abrasions, should be removed without delay by means of a flat scraper. The table should be tested for warping when installed and then periodically, using a 6 ft. steel straightedge; if warped, the table should be returned to stores as repairable and replaced. The table should be kept clean and free from corrosion, and a wooden cover should be provided to protect the surface when not in use.

(vi) *Metal workers' equipment*.—The hand-operated metal working machines should be lubricated, kept in adjustment and free from corrosion. Blow-lamps should be kept clean and filled with fuel to the correct level as described in para. 21 of this chapter. The blacksmiths' hearth should be kept free from clinker and fine ash and cleaned periodically. The fan bearings should be lubricated prior to each occasion the hearth is used.

(vii) *Portable oxy-acetylene equipment*.—The oxy-acetylene equipment should be maintained in good condition as described in the Welding Manual (Air Publication 880) and as laid down in Vol. II leaflets of this Air Publication. Gas cylinders should be marked plainly, "full" or "empty" as the case may be, using tie-on labels for this purpose.

(viii) *Lathe*.—The lathe should be kept clean and all bearings and working surfaces lubricated. After use, all metal cuttings and cutting lubricant should be removed from the lathe bed and the saddle; the saddle should be traversed by hand the full length of the bed until it is seen that the oil applied to lubricate the lathe bed is free from particles of metal, etc. Cutting tools should not be allowed to remain in the tool post after use. Other lathe equipment such as face plates, chucks, centres and tool holders should be kept clean and stored in a rack.

(ix) *Drilling machine*.—The drilling machine should be cleaned and lubricated periodically. A piece of planed hardwood should be kept on the table to protect the machined face whilst drilling sheet metal, etc. Table clamping-screws should be slackened several turns occasionally, to enable the threads and thrust faces to be lubricated.

(x) *Buffing machine*.—The buffing machine should be cleaned and lubricated frequently. The wheels and mops in use should be kept dry and free from oil or grease.

(xi) *Grinding machine*.—The grinding machine should be kept clean and as free from abrasive as possible. The bearings should be lubricated frequently but care should be taken to avoid oil or grease coming into contact with the emery wheels. The water provided for cooling purposes should be changed frequently. The tool-rests should be kept in adjustment at a position as near as possible to the emery-wheels. The wheels should be trued up, as required, by means of an emery-wheel dresser and the tool-rests reset; the resulting abrasive should be carefully brushed off the machine after the operation is completed.

(xii) *Drives, electric motors*.—Electric motors used for driving machine tools and portable apparatus should be kept clean and free from dust both internally and externally. Bearings should be lubricated but care should be taken to avoid over-lubrication as the surplus will be carried to the armature and to the commutator. Immediate attention should be given to motors showing signs of overheating or excessive sparking. Only authorised personnel are permitted to attend to defects which may arise in connection with electric motors, switches, cables or fuses.

(xiii) *Workshop tool kits*.—Fitters' tool kits and engine service kits should be kept clean and in a serviceable condition; any tools that are provided with separate divisions in trays should be replaced in the tray after use.

(xiv) *Measuring instruments and appliances*.—Measuring instruments and appliances are dealt with in detail in A.P.1464B, Vol. I, Part 2, Sect. 3. This equipment should be stored in the workshop lock-up and placed in the charge of a senior N.C.O. It is necessary to check all instruments periodically in order to ensure that they are accurate in use.

(xv) *Drills and reamers*.—Drills, reamers, etc., should be maintained in good condition and frequently checked for accuracy. Defective tools should not be used but returned as unserviceable. Twist drills should be accurately ground to a gauge and, when not in use, kept in a graded drill stand. Reamers should be kept in partitioned boxes or laid in grooved trays cut to receive each size of reamer. The cutting edges of reamers should be ground only in a tool grinding machine. Expanding reamers should be set to a standard size and any variation from this size should be made only by a senior N.C.O.

(xvi) *Jigs, gauges and special tools*.—Jigs, gauges, etc., should be protected against damage and corrosion and should be kept in labelled wooden boxes when practicable; the labels should indicate the special purposes only for which the tools may be used.

LIGHTING AND HEATING OF WORKSHOPS

General

16. The installation and maintenance of workshop lighting and heating systems are under the supervision of the Directorate of Works (see Air Publication 855); many duties however are the direct responsibility of the workshop personnel and it may be necessary in cases of emergency for operating personnel to give immediate attention to either of these installations. The layout of both should be thoroughly understood and the precautions laid down to prevent fire, damage and injury strictly observed; the following points should be noted:—

(i) *Lighting.*—Workshop lighting is supplied by means of roof lamps for general lighting and by means of adjustable workshop lamps and inspection hand lamps for local lighting as required. The main electrical switchboard is situated in such a position that access to it is obtained from outside the workshop doors after they have been locked. Lamp wattages are fixed according to a schedule and lamp replacements should be made by lamps of the same power as those removed. Sub-fuses and distribution boards are usually placed in each workshop, a separate board being provided for the power connections. Tapping points for portable equipment are provided in each workshop, of the plug-in-switch type. Further information on general lighting is given in paras. 33 and 34 of this chapter.

(ii) *Heating.*—Workshop heating is usually effected by means of hot water radiators of the single column type. These are spaced around the walls with flow and return pipes coupling them to the heating plant which may be within the building or some distance away. The temperature should be kept as near constant as possible and for this purpose modern systems include thermostatic control. The temperature desired will be dependent on the type of work being done and normally should be in the region of 58°–62° Fahrenheit; any wide divergence from this range should be notified to the Section Officer of the Directorate of Works, who is responsible for the maintenance of the heating system. Leaks in the radiators and pipe-lines should also be reported. Care should be taken to obtain economical and efficient heating service by conserving the radiated heat within the workshop, as far as possible consistent with proper ventilation. Precautions must be taken to prevent leaks or other damage to radiators, etc., which may be caused by contact with heavy objects. Inflammable, volatile or rubber materials should be kept away from the pipe-lines in order to prevent loss and deterioration due to heat, and to reduce the risk of fire.

SAFETY PRECAUTIONS TO BE TAKEN IN THE WORKSHOPS

General

17. The safety precautions adopted should prevent as far as possible any injury to personnel or damage to property. There are a number of risks to be considered such as those caused by fire, acids, machining, electricity and explosive gases. Orders are laid down to cover various risks and these must be adhered to, as for example those in the Royal Air Force Fire Manual, Air Publication 957. A list of general safety precautions should be summarised and posted on the workshop notice board, and attention drawn to special risks by means of suitable notices placed near the danger points. Although some precautions may appear to be elementary it should be remembered that many accidents are the result of over-confidence. In all cases of personal injury first aid treatment should be given immediately, and proper medical attention obtained as soon as possible. The box or cabinet containing first aid appliances and an instruction chart should be placed in a prominent position in the office. The nature of the contents should be clearly indicated and, whenever any of the items are used, replacements should be made without delay. Suitable equipment is available as indicated in Air Publication 132. In workshops where acids are handled, additions to the outfit should be made in the form of approved neutralising agents such as those which should be available for use where accumulators are charged (see the A.P. "1095" series).

Fire precautions

18. Adequate precautions should be taken against fire as laid down in the Fire Manual, Air Publication 957. The following remarks are not intended to over-rule existing regulations, but to draw attention to possible fire risks appertaining particularly to workshops.

(i) *Waste.*—Receptacles containing waste paper and oily rags, or rags impregnated with spirit, dope, varnish and paint are prolific sources of fire and it is desirable that metal containers only are used; these substances should be separated from other rubbish. Smoking is prohibited in workshops. Attention is drawn to the possibility of spontaneous combustion, caused by the tight packing of oil rags, etc., in the containers. All waste oil and combustible rubbish should be removed from the workshops on cessation of work for the day, when it should be burned in a safe place or otherwise carefully disposed of.

(ii) *Cleaning.*—The use of petrol in the workshop is permitted only for such special purposes as cleaning magneto parts during overhaul and then only in quantities up to half a pint. Petrol should not be used in engine cleaning tanks or mixed with the paraffin. On no account should petrol or any other inflammable liquid be poured down a drain, as this may cause a serious explosion. Paraffin cleaning tanks should be placed in such a position that an outbreak of fire at this point could be isolated; a metal cover should be provided to fit over the bath for use in case of fire, and also to reduce the possibility of accident when the bath is not in use. Processes involving the use of heat or naked flames should be undertaken only at a safe distance from all inflammable material or vapour.

(iii) *Magnesium alloys, etc.*—The working of magnesium alloys, electron, etc., requires special care in order to reduce the risk of fire because under certain conditions these materials are readily combustible. When machining these metals fine cuts should be avoided, the tool used should be sharp, with generous clearance, and low cutting speeds employed. When grinding, special wheels should be kept for use on these metals; they should be clearly marked for identification purposes. Metal particles should not be allowed to accumulate or remain on the clothing and as a precaution, a rubber apron is recommended for the use of operators. Prior to dressing the wheels they should be free from metal dust. During hand finishing processes glass-paper should be used in preference to emery cloth. To extinguish a fire involving magnesium alloys, dry sand or earth should be applied to smother the flames, alternatively, dry cast iron cuttings may be used if available in sufficient quantities; water should not be used for this purpose as hydrogen gas is generated when water comes into contact with these metals when burning, and combustion is thereby accelerated.

(iv) *Fuel tanks.*—In order to avoid the risk of fire in the vicinity of petrol fumes, only special types of hand inspection lamps may be used, i.e. those designed for this purpose and listed in Air Publication 1086. For petrol tank inspection a suitable lamp is also available and no other type should be used for this purpose. Reference should also be made to A.P.1464D, Vol. I, Part 2, Sect. 5, regarding tank repairs and the precautions to be observed.

(v) *Acids.*—Acid should not be retained in any building other than the authorised store, or where its use is necessary for some process. The floor should be sprinkled with sand; sawdust should not be used for this purpose. If the acid is kept in containers these must be tightly closed, and should a leak be detected, the container should be removed outside the building and its contents transferred to a sound container. A good supply of sand and a shovel should always be available for use in emergency.

(vi) *Doping.*—Fabric-covered aircraft components that have been recently doped should not be dusted or brushed until the metal parts have been earthed and precautions taken as described in para. 30. Care should be used when employing electric water heaters or any electrical equipment in the vicinity of dope shops in order to minimise the risk of fire.

(vii) *Alumino-thermic soldering irons.*—Alumino-thermic soldering irons should not be lighted inside a building or taken inside whilst the tablet is burning, nor within a distance of 15 yards from aircraft or inflammable material. These irons are issued to the service for use in emergencies only and should not be employed in other circumstances.

(viii) *Sodium-filled exhaust valves.*—There is a risk of fire and injury to personnel in the handling of sodium-filled exhaust valves during breaking down processes; this operation is only to be effected by authorised Units, according to the procedure laid down in Vol. II leaflets of this Air Publication.

Electrical precautions

19. Precautions should be taken to guard against the possibility of accidents where electric light and power systems are installed, particularly when the supply current is at a pressure exceeding 125 volts alternating current or 250 volts direct current. In instances where the pressure is 650 volts or over, notices should be displayed, clearly marked "High Voltage"; this applies especially to positions where any contact with live conductors is possible. Personnel operating electrical apparatus should be instructed in the use of such apparatus including the methods to be employed in case of emergency. Main switches should be clearly marked so that they are readily located in an emergency. The following list of precautions is given to indicate possible sources of danger and to reduce risks to a minimum:—

(i) *Electrical fires.*—On any outbreak of fire in connection with electrical supplies or equipment, the current should if possible be cut off at the main switch. The method of dealing with electrical fires as laid down in the Fire Manual, Air Publication 957, must be strictly observed.

(ii) *Damp conditions.*—Damp conditions and steam are liable to cause leakage of current from electrical apparatus; approved apparatus only should be used in these circumstances and all earthing wires must be checked frequently. It is advisable for the operator who is using electrical apparatus in damp conditions to stand on a dry wooden platform.

(iii) *Earthing.*—It should be ascertained that all electrical equipment, portable or otherwise connected to workshop supplies is earthed efficiently.

(iv) *Defects.*—All electrical equipment, particularly flexible wires, extension cables, switch plug connections, etc. should be examined frequently for defects. Loose connections should be tightened by authorised personnel and any defective parts replaced without delay. Flexible cables for hand lamps and portable apparatus should be examined to ensure that the cables are supported at each end in such a manner that no tension is applied to the terminal connections.

(v) *Oil on rubber insulation.*—Rubber components should be kept free from oil, otherwise the insulating properties will become impaired. In the case of unavoidable contact, the oil should be wiped off immediately and french chalk applied to the portion of the cable affected.

(vi) *Carbon dust.*—The brush gear of rotary equipment should be examined periodically and any carbon dust that has accumulated carefully removed, otherwise sparking and current leakage may occur.

(vii) *Fuses.*—Sub-fuses may be repaired by competent personnel but main fuses must be repaired by the Directorate of Works personnel. When a fuse has "blown", the current supply should be cut off before any attempt is made to repair the defect, and it should be ascertained that the replacement is of the correct amperage. During the repair of any fuse it is inadvisable to touch any bare metal within the fuse box. Fuse box covers should be replaced when repairs are completed satisfactorily

(viii) *Equipment voltage*—Before any new electrical equipment is connected to a supply circuit it should be ascertained that the voltage required for such equipment is the same, within approved limits, as that of the supply current

(ix) *Heating apparatus.*—Electrical heating apparatus such as glue kettles, soldering irons and immersion water heaters, should be switched off immediately after use. Water heating appliances should not be allowed to boil dry, and suitable notices should be placed over the switches connected to such heating appliances to remind personnel of the necessity for switching off.

(x) *Screw-cap lamps.*—To prevent danger to personnel from shock due to contact with the lamp screw of 150 to 500-watt lamps fitted with Edison screw caps, precautions should be taken to ensure that the supply of current is disconnected before any attempt is made to replace or remove a lamp from the holder or to insert a new lamp. In instances where a switch plug connection is fitted this must be removed.

(xi) *Overheating.*—Electrical equipment showing signs of overheating should receive immediate attention; the equipment may be overloaded, and unless this condition is relieved there is risk of fire. Air-cooled motors should have a free flow of air, which must not be obstructed by covering the air ducts or enclosing the motor for guarding or other purposes. Overheated wiring may be the result of using wire of too small a section to carry the load applied.

Accident precautions

20. Precautions should be taken to prevent accidental injury to personnel or damage to property, and should include efficient supervision with the provision of necessary guards and fences at danger points. The workshop should be kept free from tools and material not in actual use; ropes and inspection lamp leads in use should be so placed that there is no possibility of anyone falling over them. When it is necessary to leave any equipment projecting into a gangway, it should be made plainly visible by means of some noticeable material such as white rag or paper. Similar precautions should be taken when a tie-rod or any other object is projecting at eye level. Inefficient workshop lighting may contribute towards accidents, therefore the recommendations contained in para. 33 should be noted. The following sub-paragraphs contain information regarding specific risks relevant to service workshops:—

(i) *Working at a height.*—When working at a height any ladders or platforms employed should be firmly fixed and tools placed in such a manner that there is no possibility of their dropping and causing injury or damage. Tools in actual use should be held by means of strong cord when this is practicable; the cord should be tied at one end to a fixed object, or to the wrist of the operator, and should be of sufficient length only to allow free movement. Safety belts are available for the use of personnel who are working on the planes or structure of seaplanes or amphibians, whether afloat or ashore.

(ii) *Pressure risks.*—When operating hydraulic presses, hand-operated arbor presses and air compressors, special attention is required to prevent the building up of excessive pressures and to avoid mechanical failures which would cause damage and injury. Pressure release valves on hydraulic or pneumatic appliances should be tested frequently to ensure that they are functioning correctly. If there is any possibility of the collapse of work or supports when using presses, suitable guards should be placed in position to prevent any damage by parts that may otherwise be projected across the workshop.

(iii) *Bench work.*—Heavy coil springs should not be compressed in a bench vice but by means of a special rig. Hardened steel-headed hammers should never be struck together or used to strike any hardened steel, such as drills, files, etc., as there is a danger of injury from steel splinters. Care should be taken when filing to ensure that the handle of the file is a tight fit on the tang, so preventing the possibility of the handle becoming detached with consequent risk of injury to the operator.

(iv) *Goggles and respirators.*—Goggles should be worn by personnel engaged in grinding or chipping operations to prevent abrasives or pieces of metal injuring the eyes. During welding processes tinted goggles of the approved type must be used. Dope and paint spraying respirators are available for use during the application of dope, etc. (see para. 30 (vii). Respirators should be worn if the time taken for the process be more than a few minutes when materials such as bonded asbestos brake linings are being ground; as a temporary measure a damp cloth tied round the mouth and nose of the operator will serve for this purpose. Respirators must be worn during sand-blasting operations (see Vol. II leaflet, A.P.1464/D.112).

(v) *Exhaust fumes.*—The inadvertent inhaling of injurious fumes should be guarded against by efficient ventilation; exhauster fans and cowls should be used, if necessary, especially where large acid containers are exposed as in the case of electro-deposition processes. Exhaust fumes from M.T. vehicles or any internal-combustion engine should not be discharged into a workshop; these exhaust fumes are injurious to health and if inhaled in enclosed spaces may have fatal results. M.T. vehicles should not be allowed to remain in the workshop, or at the entrance with the engine running, during loading or unloading operations.

(vi) *Use of heat.*—The application of heat in workshop processes in many instances requires care, especially when the reaction of the particular material to be heated is not fully understood. Allowance should be made for the effects of expansion and contraction, also for possible changes in the structure or composition of the materials. Before heat is applied to any tubular work which is sealed at each end, as in the case of some brazed work, examination should be made to ensure that there is a suitable vent to permit the escape of air or steam. During any operation involving the use of molten metal, the greatest care should be taken to prevent contact of such metal with oil, water or moisture, especially when pouring the metal, otherwise gases will be formed which may cause an explosion resulting in injury to the operator.

(vii) *Heat screening.*—Fire-bricks, metal screens, sheet asbestos cord may be used to screen objects from the heat of a flame. Stone, ordinary bricks or concrete should not be subjected to heat as there is a danger of these materials splitting with considerable force. Portable heating apparatus having a pressure fed flame, such as an oxy-acetylene blowpipe, should be suitably guarded or used in such a manner that the flame is not pointing towards a glass window or in the direction of any person or any inflammable material in close proximity to the flame.

(viii) *Poisonous fumes.*—The fumes given off from zinc when this metal is volatilised by heat are injurious to health and should not be breathed during operations that entail the heating of alloys with a zinc content, as in brazing, or when heating galvanised iron. Similarly, inhaling the fumes of burning lead base paints should be avoided. All processes during which harmful gases are evolved should be done in such a position that the fumes cannot affect personnel employed in other working stations.

(ix) *Cleanliness.*—Precautions should be taken with regard to the cleanliness of personnel handling lead, lead oxides or paints, mineral oils, dope and cellulose enamel, acids, sodium-cyanide and other harmful materials. The hands should be washed in running water as soon as possible after contact with any of the above. Food should not be eaten or placed near any of these materials.

Paraffin brazing lamp precautions

21. In order to minimise the risk of accidents which are attendant upon the improper use and neglect of paraffin brazing lamps, the following instructions should be observed:—

(i) *Filling.*—It should first be ascertained that the lamp is filled to the correct level with clean paraffin. The lamp should not be filled beyond three-quarters of the container capacity and it is essential that only paraffin be used; in no circumstances must petrol or other spirit be used in the container. The chief trouble experienced in the use of blow lamps is due to foreign matter choking the nipples or jet orifices. It is essential therefore that a funnel fitted with a fine gauze strainer be used during filling operations. The filler cap should be tightened only by hand.

(ii) *Lighting.*—Before lighting the lamp the nipple should be cleaned by inserting a cleaning needle of the correct type in the nipple orifice; no other wire or instrument should be used for this purpose. The lighting cup should now be almost filled with methylated spirit and ignited, care being taken that the air release valve is open and the flame regulator valve closed. Petrol may be used in the lighting cup when methylated spirit is not available. When the vaporiser is thoroughly heated, the release valve should be closed and the regulator valve opened to a position varying from one to two turns. On operating the plunger pump a clean blue flame should be produced at the burner and an auxiliary light should be to hand in case the flame in the lighting cup be burnt out prematurely. If the lamp burns with a yellow flame or emits jets of flame when first lighted it indicates that the vaporiser is insufficiently heated, in which case the regulator valve should be closed immediately and the air release valve opened, until the vaporiser has been heated further. Lighting operations will be facilitated by shielding the burner from cold air currents, for which purpose a metal screen should be used, large enough to prevent the possibility of long jets of flame damaging surrounding objects when air pressure is first applied. The vaporiser must not be heated by means of another blow lamp or by application of heat other than that described above.

(iii) *Flame regulation.*—The flame is regulated by the air pressure that exists in the lamp fuel container and by the regulator valve. The pressure is decreased by releasing the air valve and increased by means of a plunger pump. In no circumstances must the pressure in the fuel container exceed 45 lb. per sq. in. Working pressures of from 20 lb. to 30 lb. per sq. in. are sufficient to produce the maximum heat of which the lamp is capable. To extinguish the lamp the regulator valve should be closed and the air release valve opened fully.

(iv) *Using lamps.*—Care must be taken when more than one lamp is in operation to prevent the flame of one lamp playing even momentarily on any part of the other lamp. Precautions should be taken to avoid damaging the vaporiser whilst the lamp is in use, and the flame hood should not be removed when the lamp is at working temperature. After use the lamps should be allowed to cool off, when they may be cleaned before storing. The successful use of these lamps depends to a great extent on paying strict attention to their maintenance. Considerable difficulty will therefore be avoided if the nipples are kept clean and the various parts renewed as necessary.

(v) *Testing.*—The pressure gauge should be tested at frequent intervals to ensure that it is in working order.

(vi) *Inspection.*—As an additional precaution the senior technical officer of the unit concerned is to ensure, by periodical inspection, that all blow lamps are maintained in a serviceable condition.

(vii) *Brazing lamps, Type B.*—A number of type B brazing lamps have been issued fitted with a pump which is so arranged that the valve at the bottom of the barrel can be screwed down when the lamp has been started, to prevent leakage into the pump barrel. This valve should be retained in the closed position, except when the pump is being operated. Care is to be taken to ensure that the pump handle is unscrewed to the limit before pumping, as failure to do this will cause damage to the non-return valve, with a subsequent risk of fire, should fuel collect in the pump barrel. It should be also ensured that the cap nut at the top of the pump barrel is secure and that the grub screw securing this nut is screwed home, otherwise damage may occur to the threads.

Salt bath safety precautions

22. Personnel should be careful whilst using salt baths to avoid contact with the molten salts as its appearance gives no indication of the high temperature; splashing of the salts should be avoided. The heat should be gradually applied, as the solidified salts do not make contact with the container as a result of the contraction that takes place when cooling after use. The hard top surface should be broken as the salts become heated in order to release air lock that may exist below the crust. Any object placed in the bath must be perfectly clean and dry. The heater flame should be under constant observation and the regulator valve turned off if the flame is extinguished. In the event of fire the workshop should be vacated immediately and the fire dealt with from outside the building. Any burns received by contact with the salts must be given immediate medical attention.

Blacksmiths' shop precautions

23. Accidents in the blacksmiths' shop are usually caused by heated metal, splinters from

hardened steel, faulty hammers, work held insecurely in tongs, or from such causes as those indicated in the following sub-paragraphs:—

(i) The coke breeze used in the hearth should be free from foreign matter such as slate or stone that may explode when heated.

(ii) Care should be taken in lighting the fire to avoid heavy accumulations of inflammable vapour in the cowl such as that given off by heated paraffin, and in instances where paraffin is used it must not be poured on to the breeze; a small piece of oily rag is usually sufficient to start the fire in normal circumstances, aided by gentle application of the air blower.

(iii) Work that has been heated and thrown on to the floor to cool should be marked plainly with white chalk to indicate that the item is "black hot". Tongs and other tools that are in frequent use should be cooled in the water trough immediately after use.

(iv) During case-hardening operations, where sodium cyanide is being used, care should be taken to avoid inhaling the poisonous fumes evolved during the process.

(v) Setts and other tempered steel tools used should only be hardened by competent personnel and steel should not be hammered cold unless it has been ascertained that the temper has been drawn.

(vi) Sledge hammer heads should be examined frequently to ensure that they are secure on the shafts, and that the shafts are free from damage; defective hammers should not be used until the faults are rectified.

Oxy-acetylene welding precautions

24. Oxy-acetylene welding and cutting apparatus should be used according to the methods laid down in the Welding Manual, Air Publication 880. The following precautions to be adopted apply to the equipment in use in the service, and should be regarded as a general guide to operators with a view to preventing damage and injury resulting from misuse of such equipment:—

(i) The generator house for low-pressure acetylene supplies, and where any gas cylinders are stored, should be well ventilated and a notice board, as laid down in the standard rules for oxy-acetylene welders, exhibited.

(ii) Leakages of oxygen or acetylene should be located and remedied immediately; tests for leakage should be made with soapy water. Oil should not be used for this or any other purpose in connection with oxy-acetylene equipment, nor should any jointing material of any description be used for making joints.

(iii) The identification colour for oxygen cylinders is black and cylinders painted black must not be filled with air, or used for any other purpose than that for which they are intended.

(iv) Connections for cylinders which do not fit easily should not be forced and all connections should be free from dirt or oil.

(v) Rubber tubing which conveys either oxygen or acetylene should be secured by means of approved clips, and wire must not be used for this purpose. The tubing should be kept free from oil or grease.

(vi) The blowpipes should not be used unless the operator is wearing goggles of the approved type, the lenses of which should be returned as unserviceable when they become badly pitted.

(vii) Blowpipes must either be put in the case or hung up on a suitable holder, and flux tins when not in use should be closed. Cylinder valves should be closed and the pressure in the regulators released when left unused for any length of time.

(viii) Fire buckets and appliances must be easily accessible and in case of fire the operator should, if possible, close the cylinder valves.

(ix) Oxygen valves must be opened very slowly, otherwise the pressure reducing valve may fracture and inflict serious injury on the operator.

(x) Hydraulic valves used with low-pressure acetylene supplies should be free from obstructions. They should be tested before commencing work, also after a back-fire. Purifiers in use with these supplies should, if possible, be placed within the workshop as too low a temperature impedes the correct working of this component.

(xi) When lighting back occurs from the jet there is a possibility of a leakage occurring along the acetylene feed tube at a joint or a weak place, the tube should therefore be inspected to ensure that such a point is not alight after a back-fire. The rubber tubing used for the oxygen and the acetylene feeds should not be patched. Defective tube ends should be cut off immediately any signs of deterioration are evident at these positions.

Machine shops safety precautions

25. Safety precautions applicable to the machine shop apply to all types of workshops equipped with line shafting, machine tools, appliances with independent drive, or any power driven machinery.

Personnel employed in such workshops must be instructed in the method of stopping the machinery in an emergency. The workshop floor should be kept free from oil, grease or any objects, such as pieces of round section metal, on which operators may slip. The following regulations apply to all Royal Air Force machine shops and must be strictly observed:—

(i) Suitable fences or expanded metal screens are to be fitted to electric motors or other power units when these are installed in such a manner that any part thereof is at a height of less than 6 ft. 6 in. above the floor level, or when they are otherwise accessible.

(ii) Guards must be used in instances where main drive or countershaft belting approaches within 7 ft. of the ground level in a fairway or open gangway, or in positions used by operators when making adjustments, etc., also where there is a space not permanently screened off to prevent unauthorised access of personnel.

(iii) Any shafting or countershafting that is erected at a height of less than 7 ft. from the floor level is to be enclosed or screened by fencing.

(iv) Final belt drives from countershafts to machine tools situated in such positions as described in sub-para. (ii) are to be guarded where any belting approaches within 5 ft. 6 in. of the floor level; this distance is measured from the floor to the belt in a vertical plane at the extreme point of the machine immediately under the belt.

(v) Flywheels and any exposed gearing or transmission shafting incorporated in a machine at a height of less than 6 ft. 6 in. from the ground level to any part of such component, when situated in conditions as stated for shafting in sub-para. (ii), must be suitably fenced or guarded.

(vi) Gear trains of machine tools are to be fenced by guards or screens fixed to the machine or to the floor in such a manner as to be readily detachable for the purpose of gear changing, but secure against accidental movement.

(vii) Guards and fences must be in position at all times when the machine shafting or belt is in motion and only removed for the purpose of authorised inspection and adjustment of machinery.

(viii) Machine tools employing a traversing table or tool carriage, e.g. planing and shaping machines, are to be installed in such a position that the table or ram at each end of the maximum travel positions are not less than 18 in. from any fixture that is not a part of the machine.

(ix) Machines, line shafting and countershafting must not be lubricated or cleaned whilst in motion, and cleaning operations are not to be commenced on a machine the line shaft of which is running until the final drive belt to the machine has been removed.

(x) Belt striking gear operated by hand controls must be so adjusted that any tendency of the gear to move will be towards the off position. Line shaft belts must not be removed or replaced whilst the machinery is running and, when changing the belt positions on a speed cone drive, the machine must be stopped and the change made by hand.

(xi) Lathe face plates, driving plates, chucks, etc., are to be mounted or removed with the mandrel at rest. These fittings must not be braked by hand in order to bring the mandrel to rest after switching off.

(xii) Clothing worn by personnel working in the machine shop should be close fitting at such positions as the sleeves, and loosely tied scarves or articles of clothing that are liable to be caught in a machine or shafting should not be worn.

(xiii) The floor immediately around all horizontal milling machines should be maintained in good condition and kept free from loose material. Suitable measures must be taken to prevent the floor from becoming slippery.

(xiv) The lighting at the machines should be good, and where artificial lighting is provided the lighting points should be so placed or shaded that direct rays of light will not impinge on the eyes of the operator whilst he is operating the machine.

(xv) The cutter or cutters of horizontal milling machines must be fenced by a strong guard, properly adjusted to the work, which shall enclose the whole cutting surface excepting such parts necessarily exposed for the milling operations. This regulation does not apply to milling cutters used on a spindle which exceeds $2\frac{1}{2}$ in. dia., or on an arbor which exceeds 2 in. dia. at the place where the cutter is mounted. Exception is also made in the following cases:—

(a) Making tools, jigs, or gauges for use in the workshop.

(b) Accurate operations where the traverse is being worked by the operator.

(c) Internal and thread milling.

(d) End milling other than face milling.

(e) Automatic hobbing, profiling, and gear cutting.

(xvi) The guards should be provided with adequate side flanges or should extend on each side of the cutter or cutters to the end of the arbor or arbor support, or to a distance not less than half the diameter of the cutter. This type of guard must be used as stated for all cutters except those used for face milling.

(xvii) Each horizontal milling machine must be provided with an efficient starting and stopping appliance, and the control of this appliance must be in such a position that it is readily and conveniently operated by the operator.

(xviii) When cutting lubricants are used on a horizontal milling machine, suitable safety arrangements should be made to enable the operator to apply the lubricant or to adjust the supply pipe, and suitable means for removing the cuttings should be provided.

(xix) The guards or other appliances required by these regulations must be maintained in an efficient state and must be constantly retained in position while the milling cutter is in motion, except when the tool setter is setting up the machine.

(xx) Personnel employed on a horizontal milling machine must use, and maintain in proper adjustment, the guards or appliances provided in accordance with these regulations.

Woodworking machinery safety precautions

26. Particular care is necessary in the use of woodworking machinery, in order to avoid accidents to personnel. Personnel of the woodworking trades only, above the classification of aircraftsman, 2nd class, are to be allowed to use woodworking machinery. Permission for an airman to work on a specific machine must only be granted by the appropriate specialist officer after he has satisfied himself by personal investigation that the airman is competent to operate the machine. It is essential that the machines are maintained in good condition, that cutters are secure and correctly sharpened, and that the guards and fences supplied with each machine are used and properly fixed. Especial care is necessary in securing the blades of planing machines to the rotating spindle and absolute cleanliness is essential before inserting the blades; the clamping screws must be tightened carefully without over-tightening and they must be checked frequently for tightness. The following list of causes of accidents is given as a guide for the prevention of injury to operators:—

(i) Over-confidence of the operator, lack of general experience, or insufficient knowledge of the particular type of machine.

(ii) Guards and fences removed or carelessly set in position.

(iii) Operators using their hands too close to cutters instead of feeding the work into the machine by means of another piece of wood.

(iv) Using the machine for an operation for which it is not designed, and overloading the machine.

(v) Attempting to work with defective or improperly adjusted cutters.

(vi) Machining timber which has not been previously examined and prepared.

(vii) Using a machine on small items that should be worked by hand.

(viii) Insecure foothold whilst leaning over a machine, caused by pieces of wood, shavings, etc., on the floor.

Lifting appliances precautions

27. In order to safeguard against the possibility of accidents due to failure or misuse of lifting appliances, the correct use and periodical inspection of such appliances are essential. In addition to the information given herewith, further information on the use and care of lifting tackle, types of special engine slings, and safe working loads will be found in Volume II leaflets of this Air Publication. All lifting tackle should be returned as unserviceable immediately any signs of deterioration are noticed, e.g. frayed strands or defective splices in ropes or wear and damaged links in chains. Over-

loading should be avoided at all times. Suspended objects should not be left unattended and personnel should never pass directly underneath. The following points should be noted:—

(i) *Chains.*—Chains should not be subjected to shock loads or hammered. When used for slinging purposes protection should be given to links against sharp edges, by means of wood or sacking. Chain slings should not be shortened by tying the chain into a knot, as this method is unsafe and may result in permanent injury to the chain. A chain should not be considered serviceable when the diameter of the link material is reduced by wear to an amount exceeding 10 per cent. Chains should not be dragged on the floor or thrown down from a height; in the latter case the chain would be liable to failure caused by the resulting crystallisation of the link material. Chains should not be exposed to extremes of temperature for long periods; the strength of a chain diminishes rapidly at temperatures exceeding 600° Fahrenheit, whilst low temperatures tend to make the chain brittle especially at weak places, when notched or damaged in use.

(ii) *Safe working loads for chains.*—The following table gives the safe working loads for ordinary short link steel chains of various link material diameters. The maximum safe working load for a long link chain should be two-thirds of that for a short link chain with link material diameter of the same size. A reduction in the safe load must be allowed for, as shown in fig. 2, according to the sling angle used when lifting.

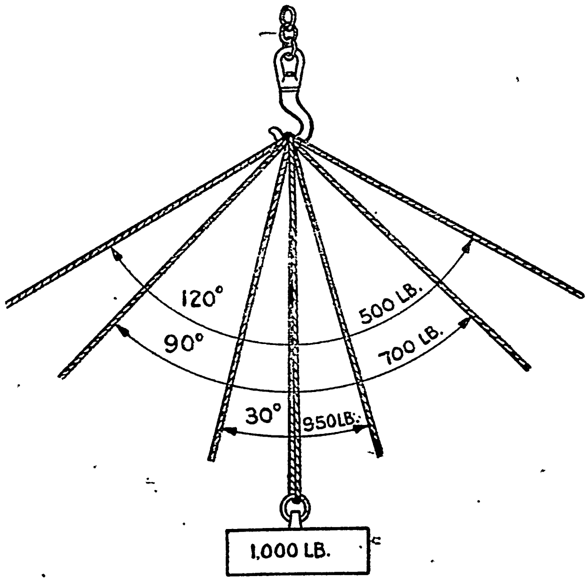

Fig. 2.—Diagram of proportional loads and sling angles

Diameter in inches of link material	Maximum working load in lb.	Diameter in inches of link material	Maximum working load in lb.
$\frac{1}{4}$	650	$\frac{9}{16}$	3,360
$\frac{5}{16}$	1,100	$\frac{5}{8}$	4,200
$\frac{3}{8}$	1,500	$\frac{11}{16}$	5,040
$\frac{7}{16}$	1,900	$\frac{3}{4}$	6,720
$\frac{1}{2}$	2,550	1	7,840

(iii) *Wire ropes.*—Wire ropes should be examined frequently for defects such as frayed strands and ends. They should be kept free from corrosion, and care should be taken to avoid kinks and knots. Protection should be given against sharp edges and rubbing or fretting should not be permitted when a wire rope is in use. When used as a sling the angle of spread should be taken into account as indicated in fig. 2. The following table indicates the average safe working load for galvanised steel wire ropes of various sizes as listed in Air Publication 1086:—

Safe loads for single galvanised steel wire ropes
Factor of safety allowed = 6

Circum. in inches	Breaking strain lb.	Safe load lb.
½	2,016	336
¾	4,256	710
1	6,720	1,120
1¼	10,752	1,790
1½	15,904	2,650
2	29,568	4,928
2½	45,024	7,504
3	66,752	11,125

(iv) *Hemp and manilla ropes.*—Ropes made of these materials should be inspected frequently for frayed ends, frayed strands, and weak splicing. Ropes should not be allowed to come into contact with acids, nor should they be subjected to heat. Protection should be given against the cutting action of sharp edges. The allowances indicated in fig. 2 for various sling angles should be observed. The following table gives the average maximum safe working loads that may be lifted whilst using tarred hemp ropes of various sizes; for a cotton rope the safe load will be half of that indicated for a hemp rope of the same circumference:—

Safe loads for single hemp and manilla ropes
Factor of safety allowed = 6

Circum. in inches	Hemp (tarred) lb.	Manilla and hemp (untarred) lb.
1	112	150
1½	224	250
2	350	400
2½	650	750
3	950	1,090
3½	1,120	1,280
4	1,400	1,650

Air compressor precautions

28. Air compressors are a source of accidents when not properly serviced. During their servicing it is important to ensure that any water and vapour (which is present in the system be drained frequently, otherwise the combination of oil-mist and water-vapour that is formed during the operation of the compressor unit may be ignited by the heat which is generated, thereby resulting in an explosion. The risk of an explosion will be reduced by using a lubricating oil of a high flash point in the compressor crank case and by removing frequently the carbon deposits from the valve heads and piston top, etc. Fixed pipe lines should be so arranged that there is a gradual rise from the air container to the extreme tapping points. Water must be prevented from collecting in any part of the system. All connectors to flexible extensions should be firmly secured to prevent the possibility of adaptors being blown out whilst in use. The safety valve should be tested frequently at the recommended pressure to which it has been adjusted, and the pressure gauge also checked periodically to ensure correct functioning.

Caustic soda precautions

29. Caustic soda should be carefully handled and contact with this substance avoided, especially when it is moistened or when decomposition has taken place and there is a collection of liquid caused by absorption of moisture from the air. The following precautions should be observed when handling caustic soda:—

(i) The approved protective clothing should invariably be worn.

(ii) A vessel of dilute vinegar and a vessel containing a weak saline solution consisting of one teasponnful of salt to one pint of water should be kept ready to hand.

(iii) Should any part of the skin or clothing come into contact with the substance, the part affected should be washed with vinegar solution without delay.

(iv) If the mouth or eyes are affected they should be washed with a weak vinegar solution or the saline solution.

(v) Should any of the substance be swallowed, a weak solution of vinegar and water should be administered immediately, but on no account should the saline solution or anything which may cause vomiting be given. In every case a medical officer should be sent for at once.

Doping precautions

30. During the process of doping aircraft components an explosive mixture of gases is formed in the spaces enclosed by the fabric and this mixture may retain its explosive character for three or four days. Even when the usual precautions are taken against the risk of fire the possibility of an explosion exists under certain conditions, particularly when aircraft are dusted too soon after doping. The dusting of aircraft, especially in a warm, dry atmosphere, induces an electrostatic charge of high voltage on the fabric and metal parts. This charge may cause a spark which may ignite the explosive mixture in the aircraft if unconnected metal parts of the aircraft approach each other, or when the metal parts are brought close to earth, or close to other conductors of high capacity such as metal parts of another aircraft. In order to obviate this and other dangers the precautions given below, together with those relating to the ill-effects of inhaling the gases given off during doping operations and in Vol. II leaflets should be observed:—

(i) Before doping, all metal parts of the aircraft including the control cable must be connected together with copper wire if they have not been previously bonded.

(ii) Before dusting aircraft that have recently been doped, the metal parts must be connected to earth; the metal framework of the building or a metal water-pipe will serve for this purpose.

(iii) It is important that the connections be made in such a way as to give good electrical contact which cannot break if the aircraft is removed.

(iv) Doping operations must not be commenced on an empty stomach.

(v) Food must not be eaten in the doping rooms, nor may personnel remain there during the time allowed for meals, and dope must be removed from the hands before a meal is eaten.

(vi) Doping must be commenced at that portion of the work which is nearest the exhaust fans and must proceed away from that point; personnel must not stand between the exhaust fans and the work while it is drying; the safest position is near the fresh air inlets.

(vii) Respirators must be worn by personnel when spraying dope as laid down in A.P.1464/D.111.

Chromium-plating precautions

31. Where chromium plating is undertaken precautions should be taken to prevent personal contact with the acid. Operators of this process should be provided with rubber gloves, rubber boots and rubber aprons, and supplies of hot running water should be available for washing purposes. An efficient air current should be provided by mechanical means to draw injurious vapour away from the plating vat and clear of all personnel. The floor in this position should be impervious to water and should be swilled down daily. The first-aid box should contain suitable ointment and waterproof plaster in case of injury to operators; medical examination should be given every 14 days.

Anodic process precautions

32. Precautions should be taken where this process is in operation according to the instructions in para. 31 on chromium plating. The electrolyte must not be allowed to come into contact with the skin nor should the fumes be inhaled; any irritation of the skin should be reported to the medical officer immediately. Although the operating voltage required is relatively low, the conductor bars should not be touched whilst the current is switched on, and the current should be switched off before removing jobs from the electrolyte.

Workshop lighting

33. The efficient lighting of the workshop, by daylight and artificial light, is of primary importance. The main objective is to ensure a sufficiency of light at all times, with absence of glare and elimination of shadow, to a degree economically practicable. Considerable saving of artificial light can be effected by carefully positioning the various working stations and frequently cleaning windows, etc. Whitened interiors properly maintained assist in the reflection of all light, artificial or daylight. In instances where sunlight is too brilliant and causes glare, a system of blinds should be utilised to obscure the light, or, as a temporary measure, glass may be whitewashed, this latter material having the advantage of being readily removed. Artificial lighting should be arranged to give a good general effect over the whole area of the workshop, while localised illumination should be employed to assist at the various working stations, as required. In addition, portable illumination, i.e. hand inspection lamps, torches, etc., should be provided for use as occasion demands. The disposition of the various illuminating points together with the use of suitable lamps, reflectors and shades, are primary factors with regard to lighting efficiency and economy; an indication in this direction may be obtained from the following information:—

(i) *Lighting layout.*—It will be seen on examination of the list below that particular workshops are given a recommended intensity of light in foot-candles with the type of reflector that should be used for specified types of work. The higher figures given in the list for the workshops concerned should be adhered to where possible both for general and local lighting. From the number of foot-candles indicated in the list, the graph II of fig. 4 should be utilised to find the area in square feet which can be illuminated to the desired intensity by a lamp of the wattage shown on each curve. Examples are given in dotted lines from 12 foot-candles, which cut through the wattage curves of 100, 150, 200 and 300 watts; horizontal lines taken from these points of juncture to the vertical scale of area values will indicate the area per unit point of illumination, which in the examples are 70, 100, 150 and 220 sq. ft., respectively. The square root of any area so found will give the required spacing of lamps, and by referring to fig. 3, graph I, the recommended height and the type of reflector can be determined from the spacing so obtained.

List of recommended light intensities

Type of work or shop	Recommended foot-candles		Type of reflector	
	General	Local	General	Local
Carpenters'	8–15	—	Dispersive reflector	—
Cellulosing	7–15	25–50	Well glass	Projector well glass
Fine bench work	—	25–50	—	Adjustable workshop
Foundries	5–15	—	Concentrating dust-proof	—
General engineering ...	7–13	15–25	Dispersive or concentrating	Adjustable workshop
Machine shop	5–15	25–50	Dispersive	Adjustable workshop
Ordinary bench work ...	—	7–20	—	Adjustable workshop
Plating	5–10	—	Well glass	—
Polishing	8–15	—	R.L.M. dustproof	—
Metal workers'	8–25	20–25	Dispersive	Adjustable workshop
Blacksmiths'	3–10	—	Dustproof Dispersive	—
Stores	2–6	—	Distributing	—

(ii) *Correct illumination.*—For the correct disposition of lamps of suitable types giving the requisite intensity of illumination for the whole of the workshop, the following recommendations ensuring the greatest economy and utility will be found useful. The light intensity given is that obtained at the working level, which may be defined as being approximately 3 ft. above the floor level of the average workshop; the actual intensity of light reaching the working plan is from 60 per cent. to 80 per cent. utilisation efficiency. The loss in efficiency is due to light going up and sideways and to differences in reflector efficiencies. The intensity of the illumination can be conveniently based on the unit of a foot-candle (see fig. 4) or on a basis of watts per square foot as given in the tables below.

Table I

Utilisation efficiency	80 per cent.	70 per cent.	60 per cent.	50 per cent.	40 per cent.
Lamp watts	Foot-candles—230-volt lamps At 1 watt per square foot				
40	8·2	7·1	6·1	5·1	4·1
60	9·2	8·0	6·9	5·7	4·6
75	9·7	8·5	7·2	6·0	4·8
100	10·5	9·2	7·9	6·6	5·2
150	10·8	9·4	8·1	6·7	5·4
200	11·2	10·1	8·7	7·2	5·8
300	13·5	11·0	9·4	7·8	6·3
500	16·9	11·8	10·1	8·4	6·7
750	18·1	12·7	10·9	9·0	7·2

Table II

Watts per sq. ft.	0·5	0·75	1·0	1·25	1·5	1·75	2·0	2·5	3·0	3·5
Lamp watts	Foot-candles based on 60 per cent. utilisation efficiency. 230-volt lamps.									
40	3·0	4·6	6·1	7·6	9·2	10·7	12·3	15·3	18·4	21·5
60	3·4	5·1	6·9	8·6	10·3	12·0	13·8	17·2	20·7	25·1
75	3·6	5·4	7·2	9·0	10·9	12·7	14·5	18·2	21·8	25·4
100	3·9	5·9	7·9	9·8	11·8	13·8	15·8	19·8	23·7	27·7
150	4·0	6·0	8·1	10·1	12·1	14·2	16·2	20·3	24·3	28·4
200	4·3	6·5	8·7	10·8	13·0	15·2	17·4	21·7	26·1	30·4
300	4·7	7·0	9·4	11·8	14·1	16·5	18·9	23·6	28·3	33·0
500	5·0	7·6	10·1	12·7	15·2	17·7	20·3	25.4	30·4	35·5
750	5·4	8·1	10·9	13·6	16·3	19·0	21·7	27·2	32·7	38·1

(iii) *Limiting factors.*—There are certain factors which may limit the dimensions of a lighting installation, one instance being the height available above the working plane; in such a case the spacing will be determined by the height shown in fig. 3, (see examples C and D) while the square of the spacing so obtained will give the area illuminated per point. The wattage required (see fig. 4) to give the correct lighting in foot-candles is found by taking a horizontal line from the corresponding area marked on the graph scale to a point immediately over the requisite number of foot-candles; the curve nearest to this point will represent the wattage of the lamp. Other deciding factors are the varying lengths and widths of workshops and the wattage of the lamps available. Lamps of high candle power should be so shaded that no part of the filament may be seen at an angle of less than 20 degrees to the horizontal plane, by any person employed within a distance of 100 ft.; in the case of any person employed within 6 ft. of the light source it is recommended that the angle be not less than 30 degrees. Direct reflection from highly polished surfaces such as aluminium or steel into the eyes of personnel should be avoided by the provision of adequate shading.

Maintenance of lighting systems

34. To retain the efficiency of a lighting system proper maintenance of the fittings, etc., must be regularly observed. The following points should be carefully noted:—

(i) All electric lamps, fittings, reflectors, etc., should be examined periodically and cleaned. Lamps should be removed from their holders and the glass bulbs washed in soapy water and carefully dried with clean rag; reflectors must not be wiped with oily rag as the oil will burn on to the surface, thereby leaving a hard deposit with consequent loss of efficiency in light reflection.

(ii) The average useful life of the filament of an ordinary electric lamp is approximately 1,000 hours, at which point the current consumption increases and the lighting efficiency decreases. When this point is reached it is more economical to replace the lamp than to leave it until the filament finally burns out. All damaged and burnt-out lamps should be replaced by lamps of the correct voltage and wattage as soon as possible.

(iii) Electrical wiring, fuses, switches, etc., should be examined periodically and any defects rectified immediately by authorised personnel. Suspended lamps on flexible wiring should not be raised to a higher position by tying knots in the wire, but should be carefully suspended by approved methods. The flexible leads of portable equipment should be protected from contact with sharp metal edges and from heat; if laid on the floor during use, adequate protection should be provided to prevent damage to the wire insulation or core, caused by wheeling portable cranes or engines stands, etc., over them. After use the cables should be carefully coiled prior to storage.

(iv) Repeated failure of fuses in the electrical circuit indicates an overload, faulty equipment, defective wiring or the presence of moisture. The defect should be traced without delay and remedied by competent personnel.

(v) The fastenings of heavy lamp fittings should be frequently examined and any defective parts replaced; this especially applies where such fittings are permitted to swing freely, and where they are exposed to corrosive agents, e.g. to sea air at coastal stations.

(vi) Economy in the consumption of current must be practised at all times. Constant supervision should therefore be exercised in order to prevent waste caused by the unnecessary use of lighting and electrical equipment.

(vii) Sub-switches in the various workshops should be switched off before the main supply is switched either on or off, in order to relieve the load on the main switch.

Portable electrical installations

35. Portable electric generating sets are available to the service for the supply of power and light. Early types are of different voltages, but 230-volt alternating current generating sets are now standardised, thus enabling apparatus already employed with normal 230-volt supplies to be retained. The information given in this paragraph is intended as a guide in the various applications of portable sets, and to electric lighting and power plants generally:—

(i) *Application of power.*—Portable generating sets may be utilised for the supply of power and light for workshop use, airfield floodlighting, land beacons, battery charging, etc. Small direct current (D.C.) generating sets are available for the purpose of charging batteries, and these are described fully in the A.P. "1095" series. An alternating current (A.C.) generator cannot be used directly for charging purposes but the A.C. current may be rectified first and then used; metal rectifiers are available and listed in Air Publication 1086. A.C. generators are used mostly for the supply of power for lighting, heating and driving electric motors. The actual power output will be less than the rated output according to the nature of the load; the difference is due to the effects of resistance, capacity and induction as present in induction type motors. A circuit consisting of lighting is practically non-inductive, and the power factor for the true output may be taken as 0·95 of the rating; for power motor supplies the average value will be 0·80 and for motors and lights together 0·85. Power rating is dealt with in the following sub-paragraph.

(ii) *Power rating.*—The power rating of a D.C. generator is usually given in kilowatts (K.W.) and of an A.C. generator in kilo-volt-amperes (K.V.A.). The unit of electric power is the watt and one watt is the work done during one second by a current unit (one ampere) against a resistance unit (one ohm); see para. 39. The electrical horse power is equal to 1·34 times the rating in kilowatts and 746 watts is the equivalent of one mechanical horse power. The standard frequency for alternating current is 50 cycles per second. A.C. generators may be single, two, or three phase according to the design and the circuit; in three phase circuits each supply wire is used as the return for the other two. For the types of generators indicated, the amperage of the output for a known voltage may be obtained from the formulae given below, when the load is non-inductive, such as lighting:—

Direct current ... ... $\dfrac{\text{K.W.} \times 1{,}000}{\text{voltage}}$

Alternating current:—
Single phase ... ... $\dfrac{\text{K.V.A.} \times 1{,}000}{\text{voltage} \times 1}$

Alternating current:—
Two phase ... ... $\dfrac{\text{K.V.A.} \times 1{,}000}{\text{voltage} \times 2}$

Alternating current:—
Three phase ... ... $\dfrac{\text{K.V.A.} \times 1{,}000}{\text{voltage} \times \sqrt{3}}$

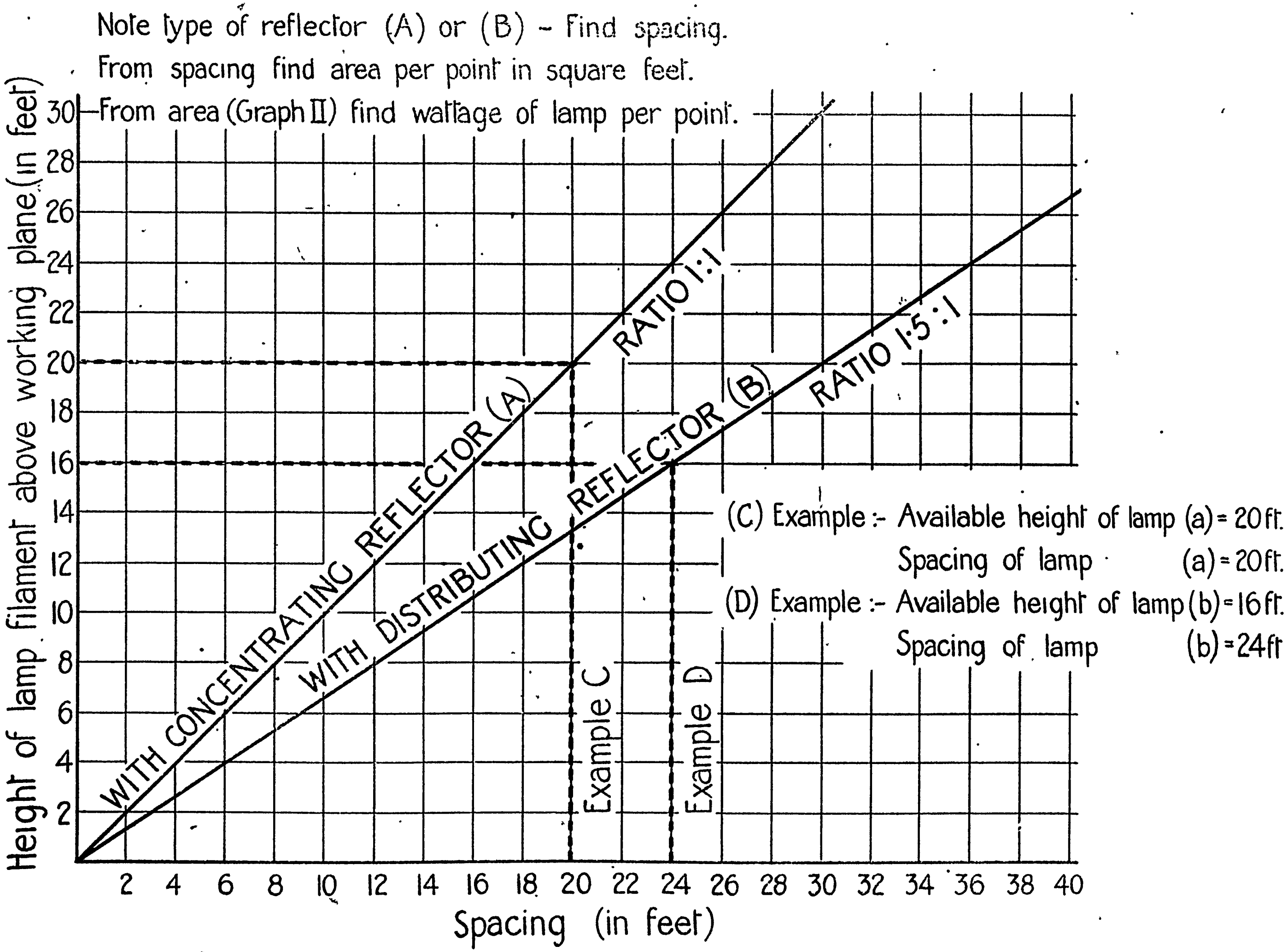

Fig. 3.—Mounting heights of lamps for uniform lighting

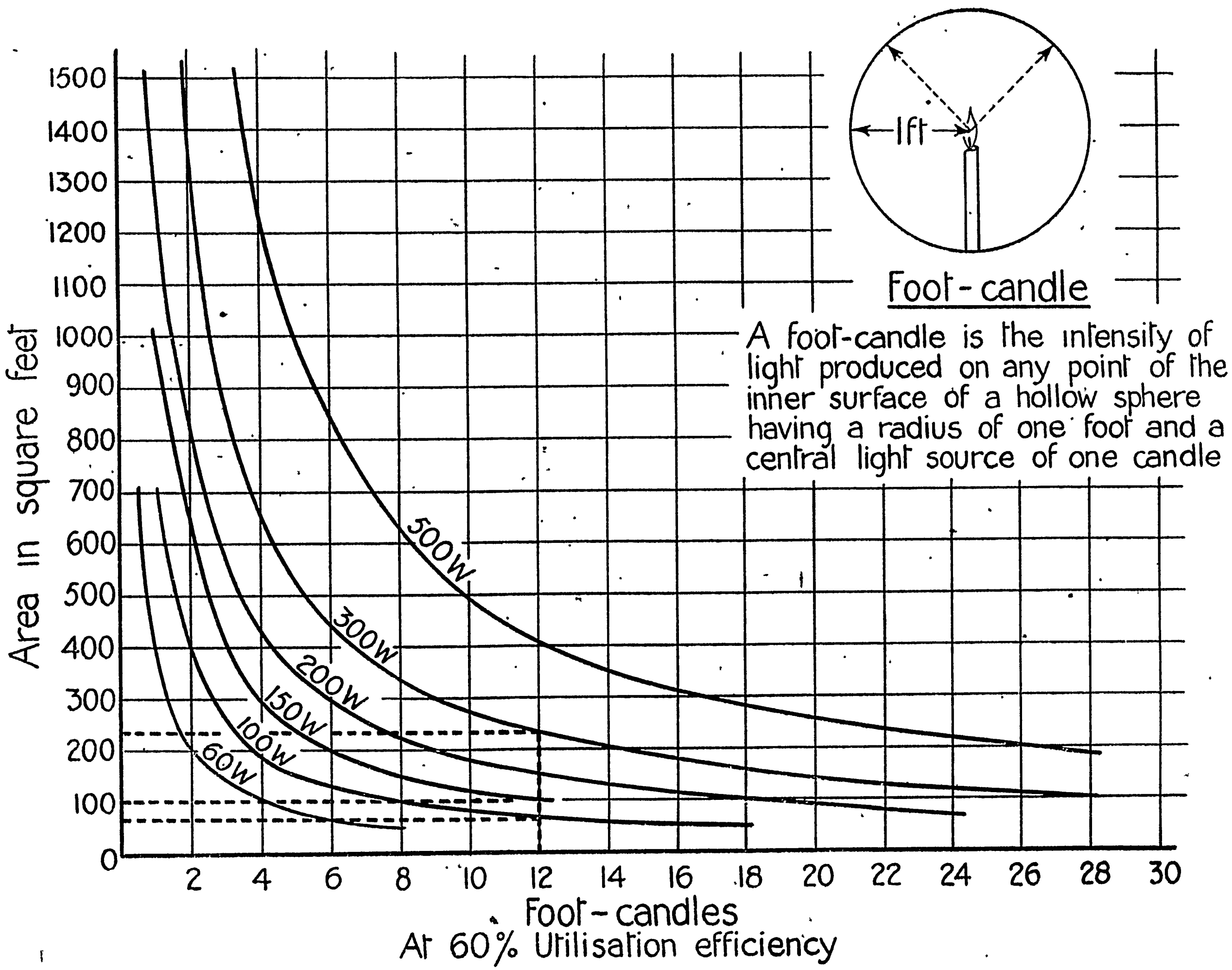

Fig. 4.—Relation between area and illumination

(iii) *Distribution of power.*—In order to ensure the efficient distribution of current it is essential that the cables used are of a sufficiently large cross sectional area to carry the current required at any point. For a given amperage a cable size may be selected from Table III below. The current carrying capacity of cables listed in Air Publication 1086 is also given in that publication together with the core sizes. The lamps or motors that are included in a circuit should be protected by means of fuses of the correct amperage at suitable distributing points, whilst the whole system should be protected by means of main fuses. Fuses should "blow" at double the normal maximum current which is being carried for amounts up to 50 amperes and at one-and-a-half times the normal current for supplies of 50 to 100 amperes, whilst for amounts over 100 amperes one-and-a-quarter times the normal supply should be allowed. Sizes of copper wire for use as emergency fuses are given in Table IV. The voltage of lamps or any apparatus used in an installation should be the same as that of the generator; as a rule the generator voltage may be slightly higher in order to compensate for a drop in the voltage due to resistance in the cables. The number of lamps of different wattages that constitute a full load for given outputs is given in Table V.

Table III

Cable sizes for load in amperes

Current in amps.	Size of cable	Current in amps.	Size of cable
3	1/036	37	7/052
5	1/044	46	7/064
5	3/029	53	19/044
10	3/036	64	19/052
15	7/029	83	19/064
24	7/036	97	19/072
31	7/044	118	19/083

Note.—The No. before the stroke in the cable size represents the number of wires forming the cable. The No. after the stroke indicates the diameter of each wire and should be read 0·036 to 0·083 in.

Table IV

Sizes of copper fuse wires (emergency)

Fusing current in amperes	Dia. in in.	S.W.G.
1	0·0021	47
3	0·0044	41
5	0·0062	38
10	0·0098	33
15	0·0129	30
20	0·0156	28
25	0·0181	26
30	0·0205	25
50	0·0288	22
70	0·0360	20
100	0·0457	18

Table V

Engine B.H.P.	Generator K.W.	Number of lamps			
		25 W	60 W	100 W	150 W
5	3	100	40	25	16
7	4½	150	60	35	24
10	7	230	90	60	35
20	14	450	180	120	70

Power, general requirements

36. The power required for workshops will vary considerably according to the size of the installation and the type and efficiency of the layout. Machine tools which are provided with individual drive electric motors require a reserve of power for which an allowance must be made in power calculations. The information given below is based upon the average requirements of machine tools and lighting as applicable to the service. In practice it has been found that for the purpose of driving a generator an allowance of one brake horse power should be made for each 600 watts output.

37. *Power, station workshop requirements.*—The following particulars are given to indicate the usual requirements of a station workshop. The total consumption of current will be approximately 13 K.W. and a 14 K.W. generating set would therefore supply such a station workshop easily.

Lighting:—

No. of lamps	*Wattage*	*K.W.*
24	25	0·660
12	60	0·720
12	100	1·200
28	150	4·200
		6·780

Power:—

Load	*K.W.*
$6\frac{3}{4}$ in. centre lathe	2·0
Buffing machine	2·0
Grinding machine	0·5
Sensitive drilling machine	0·5
Portable drilling machine	0·5
Electric soldering irons	0·2
Glue kettles	0·3
	6·00

38. *Power, machine tools, individual drive.*—The average power required by machine tools fitted with individual electric motor drive is given below for each type of machine. The power values given are applicable to machines used for normal purposes, but in the case of high speed work, or machining such exceptionally hard material as manganese steel, then the power required will be 50 per cent. higher in each case than the appropriate average value given here:—

Type of machine tool	*Size*	*Electrical H.P.*
Boring:—		
Machine, horizontal	4 in. spindle for bores up to 20 in. dia.	7·5
	6 in. spindle for bores up to 30 in. dia.	10·0
Drilling:—		
Machine, sensitive	to $\frac{1}{2}$ in. dia. drill	0·75
Radial	3 ft. arm	3·0
Radial	4 ft. 6 in. arm	5·0
Vertical	24 in. up to 2 in. drill	5·0
Grinding machines:—		
Tool grinding, stand type	10 in. wheels	2·0
	12 in. wheels	3·0
	18 in. wheels	5·0
Cylindrical grinding	10 in. to 12 in. × 2 in. wheel	5·0
	14 in. × 2 in. wheel	7·5
	18 in. × 2 in. wheel	10·0
Lathes:—		
Engine lathe, general purpose	7 in. centre	3·0
	12 in. centre	7·5
	18 in. centre	15·0
Milling machines:—		
Plain	24 in.	7·5
Plain	36 in.	10·0

Type of machine tool	*Size*	*Electrical H.P.*
Planing machines:—		
Double tool	24 in. × 24 in.	10·0
	36 in. × 36 in.	15·0
	48 in. × 48 in.	25·0
Shaping machines:—		
	12 in. stroke	3·0
	18 in. stroke	5·0
Slotting machines:—		
	6 in. stroke	3·0
	8 in. stroke	5·0
	12 in. stroke	7·5
Gear cutting machines:—		
	36 in. × 9 in.	3·0
	48 in. × 10 in.	5·0

39. *Electrical units and formulae.*—The following information will be found useful in obtaining electrical unit values as required, by the application of Ohm's law when the information given above is insufficient for the work in hand:—

(i) The current in an electrical circuit varies directly as the electro-motive-force (E.M.F.) and inversely as the resistance of the circuit. The unit of current is an ampere (I), the unit of resistance an ohm (R), and the unit of pressure (E.M.F.) is a volt (E); thus

$$I = \frac{E}{R},\ R = \frac{E}{I} \text{ and } E = IR.$$

(ii) The power (P) in a circuit is the product of the E.M.F. (E) and the current (I), and the unit of power is the watt. For large power outputs the kilowatt (1,000 watts) is used as a unit of power.

From the above it will be seen that $P = EI$

and as $I = \frac{E}{R}$ then $P = E \times \frac{E}{R}$, or $P = \frac{E^2}{R}$; also $E = IR$, so that $P = IR \times I$, or $P = I^2R$

Note.—This application of Ohm's law is true when applied to direct current supplies only and not to alternating current, as induction, capacity and resistance each affect the power output (see para. 35).

(iii) In order to determine the brake horse power required to drive a generator of a known output, the output in KW × 1·34 will give the electrical horse power, and this divided by the generator efficiency will give the B.H.P. required (see Table III, para. 35).

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AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—GENERAL ENGINEERING
This is A.L. No. 3 to A.P.1464B, Vol. I and concerns Part 2, Sect. 3
Insert this chapter.

CHAPTER 3

CRACK DETECTION—METAL AND ALLOYS

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General

1. As a result of the general application of highly stressed metal and alloy components in the construction of the various mechanical designs, especially in regard to aircraft and aero-engines, it is imperative that a thorough examination of the material used should be made *both* before, during and after manufacture to ascertain that the material is free from cracks. This examination should also be made while the components are in service, during overhaul and in instances where there is a likelihood of damage having been caused by corrosion, accident or failure of a subsidiary component, etc.

2. It has been found that in many instances minute cracks, which can be regarded as providing a point of concentration of stress, are present in the material of a component. These cracks are sometimes discernible with the aid of a microscope but can in most cases be traced by a process of crack detection. Fatigue cracks and consequent failure of highly stressed components often have their origin in these minute cracks. It is therefore of the greatest importance that extreme care should be taken when operating the various processes of crack detection. This chapter describes the processes permissible for use in the service. It is assumed that all components to be tested have been thoroughly cleaned, degreased, etc., in accordance with service procedure.

CHALK TEST OF METALS AND ALLOYS

3. A satisfactory method which can be generally applied for the detection of cracks in metals and alloys is known as the chalk test. There are two processes for this test, i.e. hot and cold. The hot test is the more satisfactory but, owing to the equipment required, it can only be applied to the smaller components. Briefly, the test consists of immersing the component in a bath of hot fluid, removing and drying it, covering with french chalk and then allowing it to cool off. The principle of the process is that on immersion in the hot fluid the material will expand and allow the fluid to enter any cracks that may be present. On cooling off, the material will contract and force the fluid out of the cracks and at the same time stain the french chalk. The mark so made indicates the presence and location of cracks or porous material.

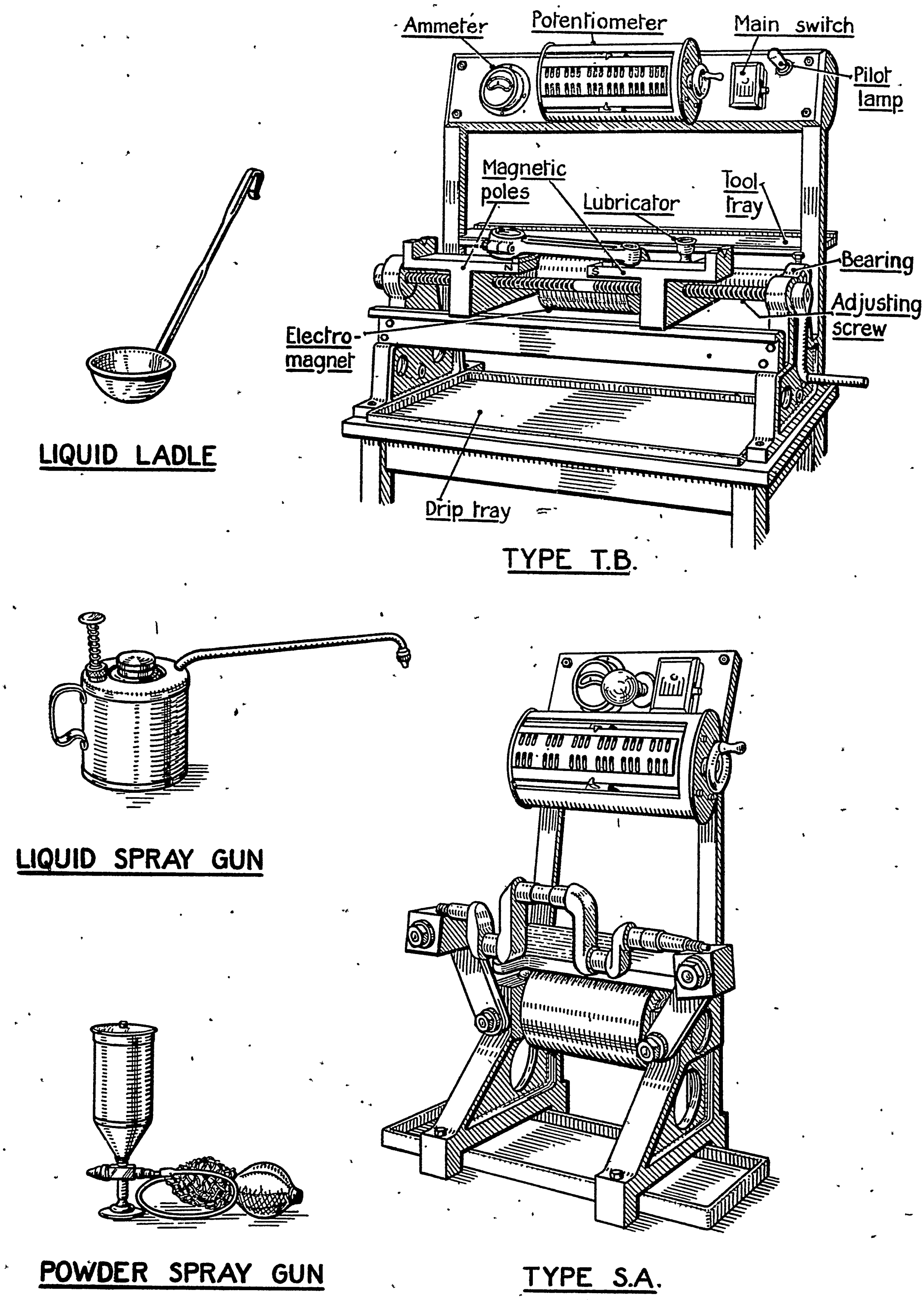

Fig. 1—Crack detectors—electro-magnetic

4. The cold test can be used on the larger components and in many instances can be applied to them without dismantling. This test consists of cleaning the material with a fluid (mixture of paraffin and oil), wiping it dry and then painting on a mixture of french chalk and methylated spirits. The principle of the process is that cleaning fluid will be retained in any cracks that may be present, while the methylated spirit will evaporate leaving a thin deposit of french chalk which in turn will be marked by the fluid retained in the cracks, so indicating the location of cracks or porous material.

Hot fluid chalk test

5. *Apparatus required and fluid used.*—The apparatus required and fluid used for the hot fluid chalk test is as follows:—

(i) A steam heated tank or bath with a capacity of 10 to 15 gallons; the tank should be equipped with a heating device capable of controlling the temperature of the fluid.

(ii) A flat tray approximately 4 ft. × 2 ft. 6 in., and 3 in. deep; a standard drip tray (see A.P.1086) can be employed for this purpose.

(iii) A mixture of paraffin (3 parts) and lubricating oil, D.T.D.109 (1 part). A sufficient quantity of fluid should be mixed to suit requirements.

(iv) Finely ground and perfectly dry french chalk.

6. *General procedure.*—The general procedure for the hot fluid chalk test is as follows:—

(i) Heat the fluid— in the tank or bath and maintain it at a temperature of 90 degrees centigrade (194° F.).

(ii) Spread a thick layer of french chalk over the bottom of the large tray.

(iii) Immerse the components to be tested in the hot fluid and leave them until they reach the same temperature as the fluid (90° C.); a number of components can be tested at the same time (dependent on size).

(iv) Remove components from the fluid and wipe them perfectly dry with clean rag; this operation must be done as quickly as possible in order to retain the heat.

(v) While still hot roll the components in the french chalk until they are completely covered with it.

(vi) Remove all surplus french chalk from the components by lightly tapping them on a bench or wooden block.

(vii) Stand the components on one side until they cool off, when they should be thoroughly examined. In the event of porous or cracked material the french chalk will become yellowish in tinge around the faulty area.

Cold fluid chalk test

7. The cold fluid chalk test should be employed when dealing with components that are too unwieldy to be immersed in a fluid bath, also in instances where a suspected area is inaccessible and the component cannot be readily dismantled. The process has a very wide application in regard to general engineering, but it is of the greatest importance that tests should be carefully undertaken and if at all doubtful applied several times to the same area; this is to prevent condemning serviceable components which for some other reason may have retained oil or fluid which has marked the french chalk, and by so doing given a false impression.

8. *General procedure.*—The following is the general procedure for the cold fluid chalk test:—

(i) Mix a quantity of paraffin (3 parts) and lubricating oil, D.T.D.109 (1 part); sufficient to meet requirements.

(ii) Make up a mixture of methylated spirit and finely ground french chalk to a consistency that, when painted on a surface with a brush, will leave a thin coating of french chalk after the spirit has evaporated.

(iii) Thoroughly wash down the area to be tested with the paraffin/oil fluid, and carefully dry off with clean rag.

(iv) Using a brush carefully paint the area concerned with the methylated spirit and french chalk mixture. Allow to dry.

(v) A careful examination should now be made. Signs of porous material or cracks will be indicated by the french chalk, which will become yellowish in tinge around the affected area.

General

9. The electro-magnetic process of crack detection necessitates magnetising the material concerned and can therefore only be applied to ferrous metals. The process can be widely applied in service depots, but special equipment and detecting agents are required. Briefly, the process consists of highly magnetising the item to be tested and then observing any disturbance of the magnetic flux due to cracks or faults. This is achieved by means of a controlled electro-magnet, the two poles of which are so designed that when a steel or iron component is laid across them it will complete a closed magnetic circuit of low inductance. Whilst in this state a detecting agent, in the form of a liquid or powder, is poured or sprayed on to the material. If a crack exists the lines of magnetic force will be broken and will emerge on to the surface of the material, forming opposite poles and causing granules (incorporated in the detecting agent) to adhere to the edges of the crack. It has been found that if this process is correctly applied, cracks which are imperceptible through a magnifying glass can be clearly defined.

Equipment

10. Fig. 1 illustrates two types of electro-magnetic crack detectors together with a non-magnetic (brass) ladle and spray guns for use with the detecting agents. The principle of detection and method of operation of both types is similar, but the adjustment of the magnetic poles and the size vary considerably. A brief description of the two types is given in paras. 11 and 12.

11. *Type T.B. crack detector.*—This apparatus (see fig. 1) is intended for use when testing items of various shapes, and lengths to a maximum of 62 in. The construction consists of a steel framework, which can be mounted on a table or bench, carrying the electro-magnet in the centre. The two pole limbs of the magnet are supported by bearings at each end and are mounted on a hand-operated adjusting screw. Each pole limb is provided with V-blocks, and bearing plates to which various jigs may be bolted to suit the work in hand. The rear portion of the framework consists of two uprights carrying a tool tray and an instrument board which contains a main switch, potentiometer and an ammeter. A drip tray situated between the feet of the apparatus is provided to collect the detecting liquid as it is poured or sprayed during test.

12. *Type S.A. crack detector.*—This crack detector (see fig. 1) is similar in construction to the type T.B. described above but is much smaller and only capable of testing items to a maximum length of 24 in. Also the method of adjusting the pole limbs is different. In this case the pole limbs consist of two vertical swinging arms carrying adjustable pole blocks at the ends. The method of adjusting the pole arms and blocks is by securing nuts which are clearly shown in the illustration. For repetition work the pole arms can be fitted with jigs of various designs to suit items being tested, or a brass block may be screwed on to the side of one pole block so that an air gap of definite length is maintained.

13. *Installation of equipment.*—The crack detectors should be erected on a strong wooden table or bench in a position free from draughts and where a good light is available. A large lamp with a reflecting shade should be placed immediately above the apparatus where the items are tested. On no account must the apparatus be installed on an iron floor or an iron-covered bench, or in close proximity to steel joists etc., running in such a manner that they tend to interfere with the magnetic flow. The apparatus when in operation must be placed at a good distance from delicate instruments, clocks etc., in order to prevent the powerful magnetic field from upsetting their mechanism. Personnel should remove watches and similar articles from their pockets prior to operating or approaching the apparatus when in use.

14. *Maintenance.*—The apparatus and the area surrounding it should be kept clean at all times. The drip trays supplied should be carefully placed to collect the detecting liquid which, apart from salving for re-application, if allowed to accumulate around the apparatus will be detrimental to its efficiency; this also applies to the detecting powder. All bright parts of the apparatus should be carefully wiped and kept clear from corrosion. The working parts such as adjusting screws and bearings should be suitably lubricated. All electrical contacts should be periodically examined, cleaned and tightened. The lead screws of the potentiometer and the pivots of the gear wheels should be lubricated frequently to enable them to work freely. The contacts on the wire-wound resistance coil (potentiometer) should be examined periodically and a small amount of vaseline applied, to enable them to pass freely over the wire without cutting or damaging it. When lifting heavy items on to the crack detector care must be taken to ensure that they do not come into contact with the instruments or the casing of the electro-magnet; these parts can be easily damaged by careless handling of heavy test items.

Operation of electro-magnetic crack detector

15. To obtain the best results when operating this apparatus it is of the greatest importance that the correct degree of magnetism is applied to the item under test (see para. 16). The positioning

of the work on the apparatus prior to testing will greatly depend upon the circumstances, i.e. size and shape of the item concerned, but a general guide in this direction will be found in the typical test examples given in para. 25. Prior to setting up the work and making the test, the general observations given in para. 21 should be read. To prevent condemning serviceable material and components only competent personnel should be employed and under strict supervision. On the other hand, the test must be carefully done in order not to miss any cracks, especially in highly stressed components. The procedure for operating the electro-magnetic crack detectors is given here:—

(i) Before setting up any work on the apparatus the main switch must be in the "off" position and the potentiometer sliders set at the central (zero) position.

(ii) Set up the work in the apparatus. The best position will depend on the circumstances of individual cases, but if possible the area to be tested should lie level or slightly tilted to facilitate the flowing of the detecting agent. The work should be placed across the magnetic poles so that reasonable contact is made with each pole. In instances where there is only a small area of contact between the work and the magnetic poles, the magnetic conductivity should be improved by placing iron packing pieces round the ends of the work and resting on the pole plates. For repetition testing iron jigs should be made up and screwed to the pole plates, to suit requirements. A jig constructed of material which is a non-conductor of magnetism (brass, etc.) can often be used to great advantage in repetition work; this jig forms a permanent air gap and thus, if correctly proportioned, will ensure the desired degree of magnetism being applied to similar items. The correct proportions of the jig can be easily determined by experiment (see Adjustment of magnetic strength, para. 16).

(iii) After positioning the work to the best advantage the electro-magnet should be energised by placing the main switch in the "on" position. The correct degree of magnetism should now be applied to the work by means of the potentiometer (see para. 16) and a trial of the detecting agent. When satisfied that this has been attained to the best advantage, all settings should be left and the current cut off by the main switch. The work should be wiped down prior to making final tests.

(iv) Make the final test by re-energising the electro-magnet, and apply the detecting agent as described in para. 18; several tests should be made and if the result is at all doubtful the work should be set up again in a different position and the test procedure recommenced.

(v) After making tests all items that have been magnetised should be de-magnetised as explained in para. 20.

16. *Adjustment of magnetic strength.*—The current reading of the ammeter is a direct measure of the amount of magnetism applied. This amount can be adjusted by means of the potentiometer to suit the length and section of the item on test, i.e. by turning the handle of the potentiometer the sliders are moved outwards from the central (zero) position to any desired position within the capacity of the windings; the greater the movement of the sliders from the central (zero) position so the more magnetism is applied, which will show as a corresponding increase on the readings of the ammeter. No definite position can be given for the various lengths and sections of items, owing to the variation in length of magnetic conductivity and other features which govern the reluctance of a magnetic circuit, but the best adjustment of the potentiometer will be readily found by experiment.

17. If too great an amount of magnetism is applied to a section of an item on test there is a likelihood of the magnetism extruding outside the surface of the material. This state will be indicated by an application of the detecting agent, the granules of which will, more or less, adhere all over the surface of the material in the form of a scale or fur. The correct degree of magnetism should be such that this state is just avoided. On the other hand, should the amount of magnetism be too weak the lines of magnetic force will tend to curve round any cracks (that may be present) internally without reaching the surface of the material, failing to attract the granules of the detecting agent, and leading to the possibility of the cracks being missed. To minimise this risk several tests should be made with varying potentiometer settings; this of course does not apply to repetition work where the correct setting is known.

Detecting agents

18. There are two detecting agents for use with the electro-magnetic process of crack detection, i.e. liquid and powder. The indication of cracks given by both methods is similar, but the application varies. The liquid method is in most instances the more economical and easier to apply. A description of the application of the two methods is given here:—

(i) *Liquid method.*—This method can be applied with either the spray gun or ladle illustrated in fig. 1. On opening a new container of the liquid which has been standing for a long period it will be found that there is a thick sediment which has become a cake at the bottom. This must be mixed with the free solution before application; a piece of dry wood should be used to prise the sediment free from the bottom of the container, the sediment should be broken up and the whole stirred until well mixed. When applying the liquid for test purposes the use of too thick a solution should be avoided. The liquid should flow gently and evenly over the surface of the test material. The best procedure is if possible, to employ the ladle in the following manner:—Thoroughly stir the liquid with the ladle, which must be perfectly clean and free from sediment, and while gently stirring pour the contents of the ladle slowly over the surface of the item on test. When searching for minute cracks, especially in small components, it is often preferable to use the liquid spray gun illustrated in fig. 1. It is, however, essential in all instances that the liquid is of such a consistency that when poured or sprayed over the item on test it will, with the exception of the granules attracted, flow freely off the item and leave it quite clear; to assist this action the surface of the item concerned should have been arranged with a slight tilt as explained in para. 15, sub-para. (ii). If the liquid is correctly applied any cracks will show up as a definite black line generally rather rough in character.

(ii) *Powder method.*—It will be found that with certain items such as rough castings or forgings that this method is preferable to the liquid method. To apply the powder detecting agent the powder spray gun illustrated in fig. 1 should be used. The gun should be approximately half filled with powder, and then held over the area concerned with the nozzle downwards. It should then be gently shaken and at the same time the rubber bulb gently squeezed. A small quantity of the powder will then be ejected in the form of a spray which should be directed on to the desired area. The nozzle of the gun should not be held too close to the work so that the powder falls and is not blown on to it. The surplus powder should now be blown away (a small bellows will facilitate this operation) when any cracks present in the material will be revealed in a similar manner to those indicated by the fluid method.

19. *Maintenance of detecting liquids.*—The detecting liquid is an expensive item and should therefore be used with due consideration regarding economy. If kept clean and in the correct proportions it can be used many times and over a considerable period. It is important to remember that each container of the liquid is definitely proportioned regarding sediment (granules) and free liquid and should be constantly stirred when in use to avoid the contents from becoming too thick through loss of the free liquid. The drip trays provided for collecting the liquid during the pouring or spraying operations should be kept perfectly clean at all times. After continuous testing the drip tray will become full when it should be slightly tilted and the sediment brushed to one corner, where together with the free liquid it can be returned to the container. Should there be any oil, grease or foreign matter, which cannot be removed, in the liquid the whole should be thrown away to prevent contamination of the remaining liquid in the container. The lid of the container should always be replaced after use and reasonable precautions taken to prevent foreign matter from entering the container; this especially applies to water or moisture which has a particularly detrimental effect to the quality of the liquid.

Demagnetising after test

20. It is necessary for many reasons that items should be demagnetised after test. For all practical purposes this operation can be done with the existing equipment, but in instances where it is necessary to remove absolutely all traces of permanent magnetism, as in the case of drills, taps, etc., special equipment is required. It is advisable unless such equipment is available that these items should not be subjected to the electro-magnetic process. To demagnetise with the existing equipment the following procedure should be followed:—

(i) At the conclusion of a test, prior to switching off the apparatus the potentiometer sliders should be returned to the central (zero) position. At this position a certain amount of residual magnetism is present in the item on test, the amount being dependent on the grade of material and degree of magnetism that has been applied to it.

(ii) With the apparatus still switched on, move the sliders of the potentiometer in an opposite direction to that used for the application of magnetism, and bring them back again to the central (zero) position. Repeat this movement several times reducing the amount of travel each time until finally bringing the sliders to rest at zero. When this final movement is reached the apparatus should be switched off.

(iii) Remove all demagnetised items from the vicinity of the apparatus before again switching on, or they will tend to become re-magnetised by stray influence.

General observations

21. The following general observations are made to help in the detecting of cracks but in many instances individual attention and forethought must be given to the item concerned. The design

of highly stressed and other components should be carefully considered to decide at which point stress has taken place, and a very careful search made at these points to reveal minute cracks. The detecting agents will often show as blurred marks when testing with the electro-magnetic process. These marks should not necessarily be regarded as denoting cracks as they are often caused by the distortion of the magnetic field where sharp corners occur, or where a severe change in section of the material is encountered; if any doubt exists the item should be wiped dry, arranged at another angle on the apparatus and if necessary several tests repeated.

22. It should be observed that cracks in general are of two definite kinds, i.e. those due to stress as a result of use, and those due to stress set up during the process of manufacture. The former category is productive of the most definite form of crack where the material tends to part along the surface, as a preliminary to a complete fracture, and this form of crack is in many instances absolutely invisible. These cracks when revealed by the electro-magnetic process rarely follow a straight or direct line but take a sinuous form which cannot be easily mistaken during test. A tool mark is generally indicated by a straight line which will run right around the bar. In cast iron and similar brittle ferrous metals the cracks are usually very sinuous in character and often terminate and restart in an adjacent parallel path.

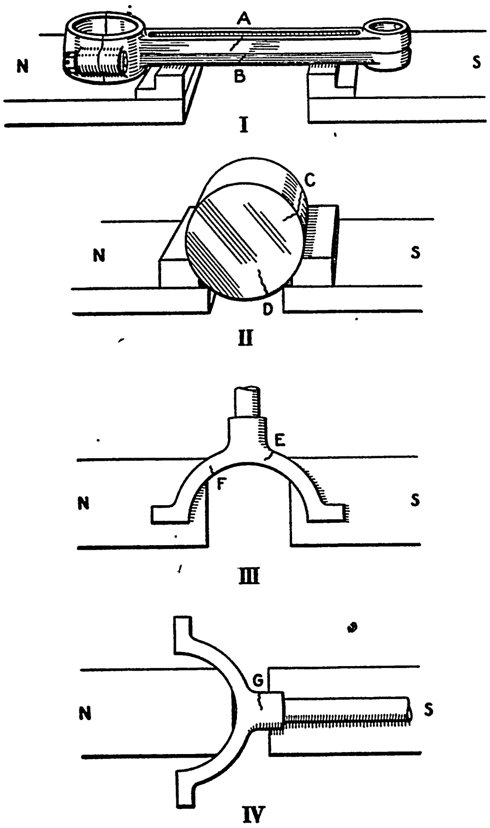

Fig. 2—Electro-magnetic crack detection—typical examples of tests

23. In the case of unused manufactured items cracks are often more difficult to detect as they are usually the result of imperfect heat treatment or a similar process. Heat treatment may set up internal stress and produce minute fissures which are revealed under test in the form of line hair-line cracks on the surface of the material. These cracks usually occur in hardened steel items, e.g. at the roots of the teeth of hardened steel pinions. An item of this description should be tested by applying the magnetism locally to the area suspected. Grinding processes are often the cause of cracks (due to local heat) which are generally revealed in clusters. With drop forgings a seam is sometimes formed where the two halves of the die close on each other and as a result a fold is formed in the material, enclosing a cavity which under test will show up in a similar manner to a crack; the depth of this fault, which is usually superficial, can be determined by filing away the material to remove the fold and producing a smooth surface. Lapped or welded seams in tubes will be revealed under test in instances where the weld or lap is imperfect; in both these cases the tube should be placed on the testing apparatus so that the lines of magnetic force pass across the diameter and not along the length of tube.

24. To reveal cracks distinctly it is always advisable to place items concerned in such a position on the magnetic poles that any suspected cracks will be at right angles to the direction of the magnetic lines (see Typical test examples, para. 25, figs. 2 and 3). Cracks, however, will be revealed when parallel to the magnetic lines but not with the same intensity, and it is therefore advisable to test in both directions if possible. An indication of the depth of a crack will be given by the amount of built-up deposit (granules) upon it, i.e. the greater the deposit so the deeper the crack.

Typical examples of tests

25. Figs. 2 and 3 illustrate typical methods of testing for cracks with the electro-magnetic process. In the illustrations the magnetic poles of the detector are shown as N and S. The following is an explanation of the various sketches contained in the two illustrations:—

(i) *Fig. 2. Sketch I.*—This sketch illustrates a standard method of revealing transverse cracks in items of a straight nature. In the instance illustrated it will be seen that iron packing blocks have been used to make magnetic contact with the poles (N and S). The poles should be adjusted as far apart as possible so that the magnetic lines flow through the full length of the item. Cracks appear as shown at (A and B).

(ii) *Fig. 2. Sketch II.*—This illustrates the method of testing cylindrical items for radial (D) and longitudinal (C) cracks. Iron packing blocks are used to improve the magnetic contact with the poles. The items should be tested several times turning it slightly after each test.

(iii) *Fig. 2. Sketches III and IV.* This illustration is intended to give an indication of the method of testing odd-shaped items. The item should in the first place be tested as illustrated in sketch III to reveal cracks in the arms as shown at (E and F). The second test illustrated in sketch IV reveals cracks in the boss of the item as shown at (G). The rod of the item would, of course, be tested as illustrated in sketch I.

(iv) *Fig. 3. Sketch V.*—This illustration is again intended to give an indication for testing odd-shaped items, but with the addition of a jig bolted on to the pole (N) of the apparatus. This jig ensures good magnetic contact and would be of great advantage for repetition work. Jigs should be made of wrought iron and shaped to suit requirements. Cracks are shown in this illustration at (H and J).

(v) *Fig. 3. Sketch VI.*—This demonstrates the method of testing tubular items such as cylinder liners, etc. Bolted on jigs shaped to suit requirements are employed, which enable the item to be turned and at the same time make good magnetic contact during test. A crack is revealed at (K) in the illustration.

(vi) *Fig. 3. Sketch VII.*—This illustration indicates a method of testing small or very thin items, e.g. diaphragms, dies, etc., by immersion. A shallow brass tray is placed on the poles as illustrated. The tray is then partly filled with a thin mixture of the detecting liquid. The item to be tested is immersed in the liquid which is then gently stirred with a brush. If any cracks are present they will be revealed by the sediment (granules) in the usual manner. In this test the brass tray forms an air gap for the magnetic lines and the correct degree of magnetism to apply will be found by experiment and will depend on the size and thickness of the tray.

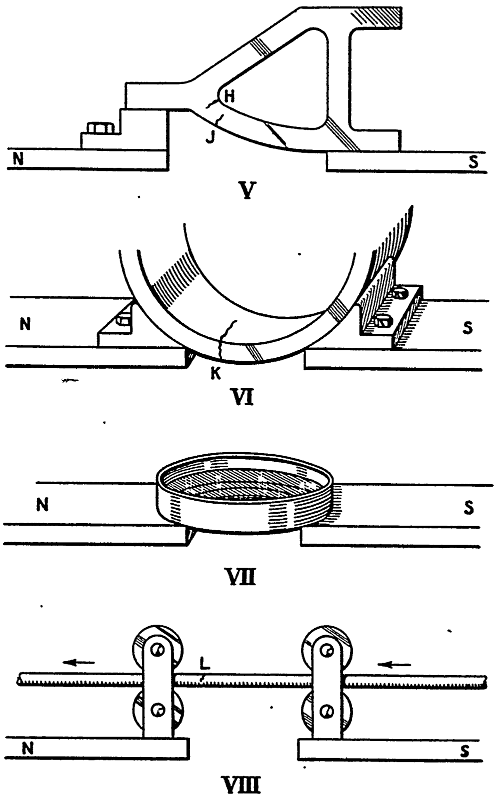

Fig. 3—Electro-magnetic crack detection—typical examples of tests

(vii) *Fig. 3 Sketch VIII.*—This illustration gives an indication of the method of testing rods, flying wires, etc., of a considerable length. Rollers should be fixed to the poles and the items on test drawn over them by hand. The rollers and fitting must be constructed of ferrous metal, and during test it must be ensured that the item concerned is making good magnetic contact while being drawn through them. When dealing with very long items or during repetition work an arrangement to provide a continuous flow of detecting liquid can readily be rigged up, but it must be taken into consideration that the detecting liquid will require constant stirring during test. In the illustration a crack is revealed at (L).

Johnson Fels method of crack detection

26. The Johnson Fels method of crack detection in ferrous metals, differs from those described in preceding paragraphs in that the specimens tested in the machine do not show an external field unless a crack is present and, when subsequently tested for residual magnetism they appear non-magnetic. The magnetic field is produced in the part which is to be tested by passing a heavy current

through it, from a suitable alternating-current supply, as an impulse of short duration and not a sustained flow.

27. After test, demagnetisation is only necessary in exceptional cases, dependent on the degree of hardness of the part although to some extent its shape will have some influence upon the length of time over which the magnetising effect will last. On steel with a low carbon content the effect will remain for approximately six hours, whereas in high carbon and certain alloy steels the effect may last for three months.

28. Coloured detector ink is employed as the medium by means of which any cracks or flaws are made visible in parts being tested. The ink carries very finely divided iron particles in suspension, which take up their position alongside any crack or flaw that may be present when the ink is poured over a test piece which has been magnetised in the machine. It should be noted that non-magnetic or feebly-magnetic ferrous alloys cannot be tested by this method.

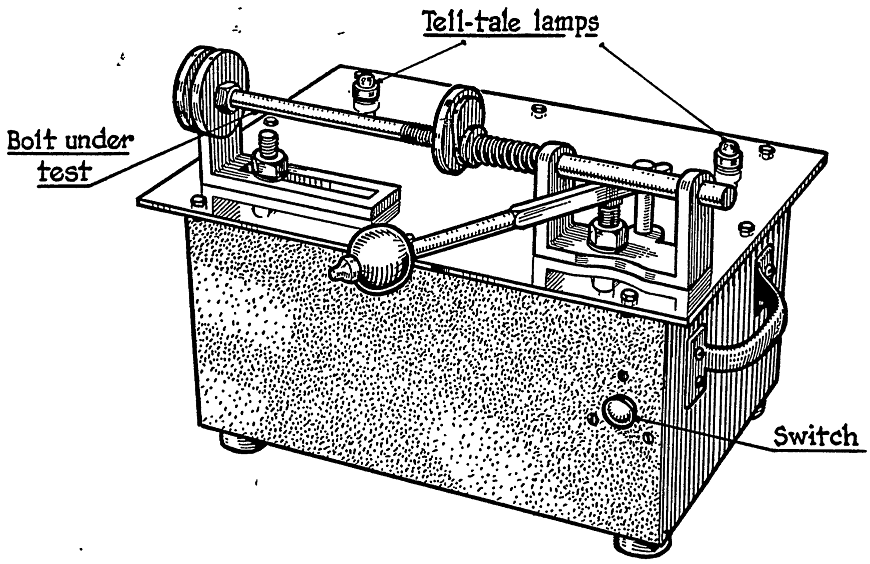

Fig. 4—Johnson Fels crack-detector fitted with spring-loading contacts

Description of crack detector, Johnson Fels type

29. Johnson Fels crack detector (see fig. 4) consists of a transformer and impulse coils housed within a heavy gauge sheet-steel case, having a top panel made from black bakelite. Two pilot lamps are fitted on the top of the panel and are included in the electrical circuit (see fig. 5), one, coloured red, warns the operator when the main current is switched on, and the other is green and indicates that the machine has magnetised the part correctly when the operating switch has been pressed in momentarily. The magnetisation is effected in approximately one second.

30. Two stout terminals are provided for the attachment of various fittings (see figs. 4, 6 and 7), by means of which electrical connection is made to test pieces of different shapes and sizes; the fittings may be provided with the detector in the form of clamps, cable connections, and spring-loaded sliding connections, or special adaptors to suit the work in hand may be made up locally.

31. The supply cable is three-core, externally steel-armoured and internally earthed, and is of a suitable length to plug in to a nearby 200/250-volt, 50-cycle single-phase A.C. power point. Handles are provided on the case by means of which the machine can be easily transported from one site to another.

Method of use

32. The method of using the Johnson Fels crack detector will depend upon the size, shape and carbon content of the parts to be tested, a large proportion of which will comprise steel components of aero-engines and airscrews. The general observations given in paras. 21 to 24 apply equally to this machine.

33. Attempts to find flaws and cracks should be made at right angles to the direction of a possible fault, except where the component to be tested is hollow or in the form of a ring; in such instances where it is possible to insert a brass or copper rod through the component across the detector terminals, any flaws which may be present will be disclosed, in all directions, in one magnetising operation.

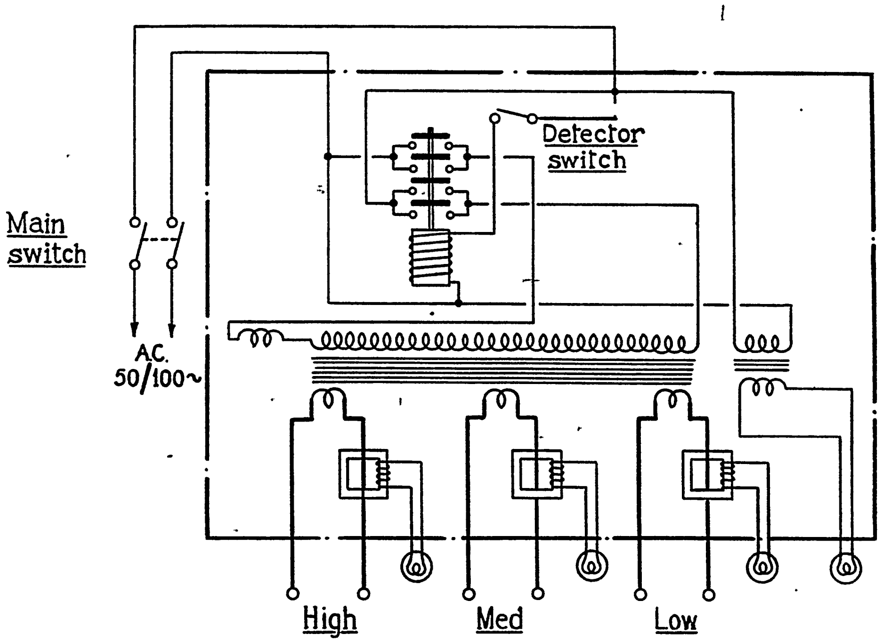

Fig. 5—Electrical circuit diagram, 3-point crack detector

34. Such components as gear wheels, ball races, gudgeon pins, milling cutters and any other parts of similar construction having a hole through the material should be magnetised on the movable bar fitting (see fig. 6). Small tubular test pieces which cannot be placed on the bar, should be threaded on to a stout piece of copper wire, which should be held at each end in the detector clamps. Bolts and similar parts can be quickly held in the detector by means of the spring-loaded plunger fitting (see fig. 4).

35. Long bars or tubes can be tested and examined in overlapping lengths along the bar or tube, in separate operations, until the whole length has been covered. The maximum length or diameter that can be tested in one operation depends to a great extent upon the carbon content; the higher the carbon content and the greater the degree of hardness, the greater the length or diameter that can be tested per operation.

36. When the component to be tested consists of a heavy crankshaft or similar object it may be supported without clamping, on V-blocks lined with brass or copper gauze, cable connections being made from the terminal posts on the detector to the V-blocks.

Clamping

37. It is of the utmost importance when testing components by means of the detector that all electrical contact surfaces on both the component and the detector fittings are clean and free from corrosion, scale, oil or grease, otherwise the magnetisation will be unsatisfactory. Except in

such instances as mentioned in the preceding paragraph and in the case of parts held in special jigs on the machine, copper clamps should be used to make good contact with the test piece; when electric cable is used in conjunction with the clamps it should be at least ¾ in. dia. It is essential in order to obtain satisfactory results that the area of contact should be at least ½ sq. in., and that the contact should be tight; point contact must be avoided.

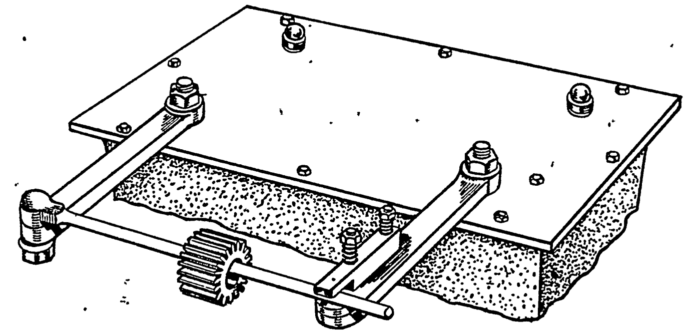

Fig. 6—Arrangement of rod fitting for pinions, rings, etc.

Operating the detector

38. After it has been ensured that the contacts are satisfactorily made the detector should be plugged in to the main electricity supply, which should be switched on. The red tell-tale lamp should now be alight, if not, the main feed should be checked and the fault remedied, after which the magnetising switch button should be depressed and released quickly. The green tell-tale lamp should now glow if the detector has magnetised the part correctly, if not, the contacts between the arms and the part to be tested should be cleaned, and the switch operated again.

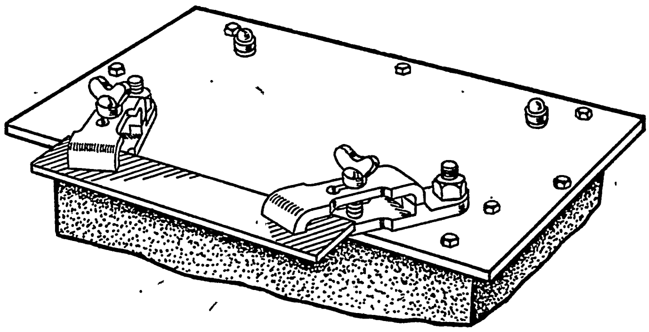

Fig. 7—Rig for clamping flat bar, wire, etc.

Application of ink

39. When the foregoing operation has been completed the part should be removed from the detector connections and immersed in an ink bath, or, if this is not possible, the ink should be sprayed or poured on it. Unless special equipment in the form of an ink bath and pump feed is available, the ink should be kept well-stirred before it is applied and a shallow tray should be used to catch the ink after it has been poured over the test piece. If there are any cracks at right angles to the direction of current flow in the part under test these will now be visible. When the formation of the part is such that cracks may be present in the same plane at a right angle to one another the magnetising operation should be repeated with the clamps arranged at 90° to the previous clamping position (see fig. 8); as already mentioned in para. 33 this does not apply to hollow objects or rings which have

been magnetised on the conductor bar of the ring jig (see fig. 6). If, after applying the ink, the marking should appear unsatisfactory for any reason, the suspected area can be cleaned and re-inked repeatedly, without re-magnetising.

40. In the cases of components having discoloured surfaces such as coil springs, stampings or forgings, any cracks may be made more plainly visible by the application of a thin coat of aluminium paint to the surface under test, before inking.

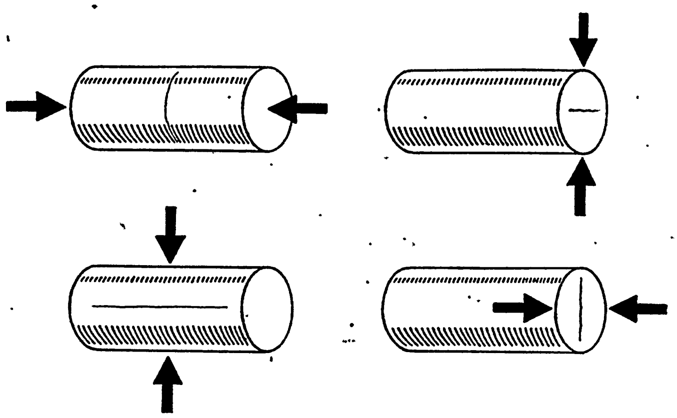

Fig. 8—Showing clamping points to disclose flaws at a right angle

Demagnetising

41. Components free from cracks and flaws, which have been magnetised on the Johnson Fels crack detector do not normally require demagnetising, because magnetism will only be present along a crack or faulty component. A magnetic field will be shown from tooth to tooth of a gear wheel or from one spline to another of a splined shaft, although when tested for residual magnetism the gear or shaft appear non-magnetic. As previously mentioned the magnetic effect may remain for a period of from six hours to three or four months and, if it is essential for some specific purpose that immediate demagnetisation is necessary, the component must be passed through a demagnetiser.

Maintenance of Johnson Fels crack detector

42. Necessary maintenance of the apparatus is limited to ensuring cleanliness of the contact surfaces on the terminal arms and clamps and serviceability of the supply cables and of the tell-tale lamps. The contact surfaces should be cleaned as necessary with a rag dipped in petrol. The supply cables should be examined periodically for signs of deterioration in the insulation and for security of the attachment of the plug, the pins of which should be cleaned as necessary. If either of the 6-volt tell-tale lamps fail to light when required, it should be examined for looseness in its holder or for faulty contact, and if still failing to light, checked for a faulty filament.

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AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—GENERAL ENGINEERING

This is A.L. No. 4 to A.P.1464B, Vol. I and concerns Part 2, Sect. 3
Insert this chapter.

CHAPTER 4

SPRAYING EQUIPMENT

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General

1. In order that spraying equipment can be used to the best advantage and without waste of effort, time and material, the correct type of equipment and the correct technique must be used. The equipment and material are listed in A.P.1086 and certain equipment, such as the pneumatic servicing trolley which supplies the pressure air is described in A.P.1464G, Vol. I, Part 2, Sect. 5. Chap. 12 and 13.

2. Spraying consists of atomising or breaking up a paint or dope stream into a spray by means of a spray gun which is the means of bringing compressed air and material together in the requisite proportions, according to the nature or viscosity of the material being used, and which ejects the spray and so deposits the paint or dope as a film on the surface to be covered.

3. There are numerous types of spray guns now in general use designed to meet the requirements of the Service and although they may differ in size and design, the fundamental principle is the same for all. An externally threaded connection for the reception of either the material hose or syphon cup is fixed under the body of the gun, and a further similar connection for the reception of the air pressure hose is provided under the grip.

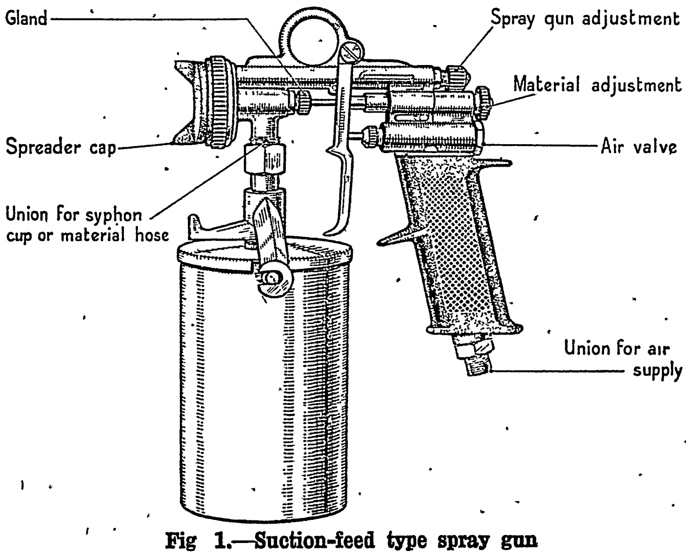

Fig 1.—Suction-feed type spray gun

4. Spray guns in the Service are capable of being fed (according to design) by either *suction* or *gravity* feed, when the gun is fed from a cup (see figs. 1 and 2) attached directly to the gun, or by *pressure* feed when the gun is fed with material through a hose from a separate pressure feed tank (see fig. 3) some distance away.

Suction feed and gravity feed

5. With the suction feed and gravity feed types, the spray gun is so designed that the compressed air, ejected through an annular orifice around the material nozzle, creates a small area of reduced air pressure or a state of partial vacuum at the fluid tip, which sucks out the fluid from a syphon or gravity cup attached to the gun. These types of feed are used where the area of the surface to be covered is small, such as when retouching, etc.

Pressure feed

6. With the pressure feed method (see fig. 3), a remote tank with a much larger capacity than the syphon cup is used, and the material is fed to the gun under pressure applied to the container whence it flows through a hose attached to the gun, the latter being adapted to take either the syphon cup or the hose end-fitting (see fig. 1). This method is used where the area to be covered is large, as it eliminates the necessity which would otherwise occur for constantly refilling the syphon cup with material. With a positive feed for the material, spraying can be speeded up and, in addition, the gun can be used in an inverted position.

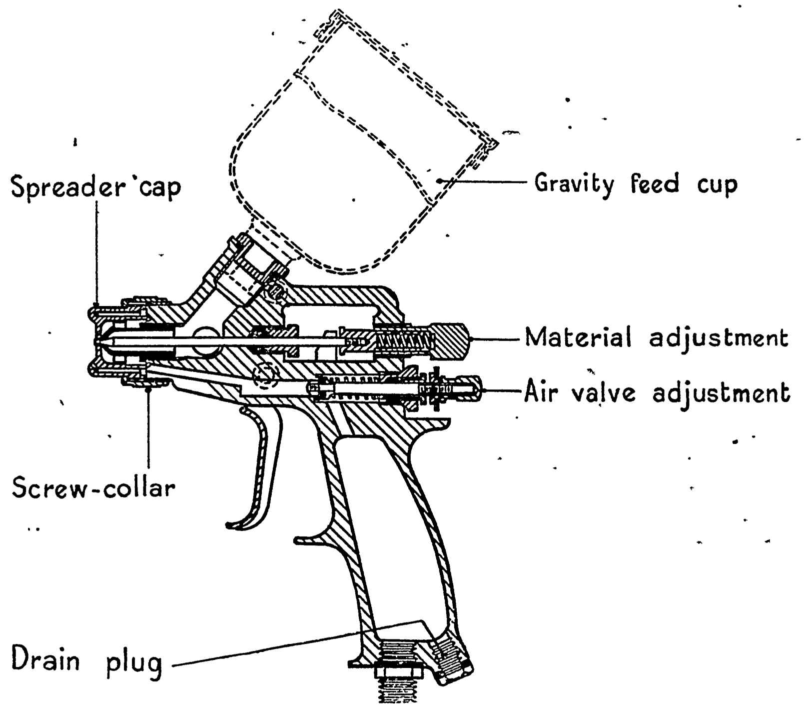

Fig. 2.—Gravity feed type spray gun

7. A combined air filter and pressure regulator, conveniently positioned in the air-line, extracts the oil and moisture from the compressed air.

The spray gun

8. Spray guns are designed to give a ready and easy control of spray pattern with varying spraying pressures and different materials without interrupting the spraying operation. The component parts of a general purpose gun such as is used in the Service is described in the following sub-paragraphs:—

(i) *The spray head.*—The spray head consists of a spreader cap which is screwed on to the nozzle at the ejecting end of the gun. The spreader cap is designed with two projections on the outer end face (see fig. 4) through which small air holes are drilled at an angle (spreader holes) so that when compressed air passes through them it converges towards the centre. In the centre of the cap is a larger hole into which the material nozzle projects leaving a small annular orifice around it through which air is ejected. The holes for both air and material may vary in size and number according to the type of gun.

gland and immediately behind the trigger. The air valve is opened by pulling the trigger and is closed by releasing it.

(vi) *Multiple jet spreader*.—A range of spreader caps with multiple jets for the better atomisation of the heavier bodied or more viscous materials are provided.

COMBINED AIR FILTER AND PRESSURE REGULATOR

9. In the process of compressing air, moisture and a certain amount of oil vapour from the compressor are liable to be carried into the air-line. To ensure that the air supply to the gun shall be clean and free from such vapour a filter is interposed between the air compressor and the gun or pressure tank.

10. The air filter and pressure regulator comprises a cylindrical metal container capable of withstanding a working pressure of 200 lb./sq. in. Enclosed in the cylinder are a stainless-steel ball-float and a lever pivoted to an arm on the valve housing and connected to the needle valve by a spring link. In its closed position, the valve is held on to its seat by the weight of the ball float and lever plus the working air pressure within. Water collecting in the trap raises the ball float, and compresses the valve spring till the coils are closed. When the buoyancy of the ball-float exceeds the pressure required to open the valve, the needle valve is snapped upwards from its seating by the action of the link spring under full compression. The water or collected moisture is then ejected from the trap until the level of the liquid is sufficiently low to enable the needle to re-seat and close the valve. This cycle is repeated automatically dependent on the rate of moisture collection in the trap. A gauze filter fitted to the needle-valve seat prevents the choking of the outside orifice by the entry of scale or dirt.

11. On some types, the filtration is effected by means of baffles and filter-pack whereby the moisture is extracted from the air passing through them. An air pressure regulator fitted to the air filter provides effective control of the air pressure at the gun. Gauges are fitted which indicate main line and regulated pressures, and valves provide outlets for pipe-lines to spray guns and other equipment. A drain cock is fixed at the lower end to allow the collected moisture to be periodically drained.

12. The air filter may, for convenience, be carried on the compressor unit trolley, but where possible it should be fitted as near as practicable to the spray gun or container and as remote as possible from the compressor, in order to reduce the possibility of condensation of moisture in the compressed air, at the gun end of the line, to a minimum.

Syphon cup

13. The syphon cup comprises a container which may be of one pint or one quart capacity and is provided with a quickly detachable lid which facilitates interchangeability from one cup to another when different colours are required, thus avoiding the necessity of cleaning the cup for each colour. The lid is provided with a union which screws on to the gun.

Pressure Feed Tank

14. A pressure feed tank (see fig. 3) consists of a steel container or tank which is heavily galvanised internally and externally. These pressure tanks hold the material to be sprayed and pressure air is delivered from the air compressor through a hose to the tank and through to the gun which is coupled by a hose to the tank. The material to be sprayed is thus forced out of the tank and delivered to the spray gun under pressure. The pressure tank provides a constant flow of material to the gun at a uniform pressure, and is normally supplied with a pressure regulator for the material-control, in which event the atomising air pressure will be controlled from the air filter and pressure regulator. An agitator for stirring the material is usually fitted. On the smaller types, the agitator is provided with a handle for turning by hand, but on the larger types the agitator is usually driven by a motor or a belt. A screw gland and packing around the shaft of the agitator prevents leakage of air. The tank cover is held down by quick-release clamping screws.

Functioning and adjustment of the spray gun

15. The air and material valves are controlled by the trigger which, when operated, opens the air valve slightly in advance of the material valve so that the air stream can atomise the fluid immeditately it emerges from the nozzle. Upon releasing the trigger, the material valve is closed slightly in advance of the air valve to ensure that all traces of material are blown from the nozzle. This effect is obtained by a clearance of approximately $\frac{1}{32}$ to $\frac{1}{16}$ in. allowed between the trigger and the end of the material valve. The various adjustments to the spray gun valves are described in the following sub-paragraphs:—

(i) *Adjusting flow of materibl.*—To adjust the flow of the material rotate the material adjusting valve (see fig. 4) in a *clockwise* direction to *decrease* the flow, and in an *anti-clockwise* direction to *increase* the flow.

(ii) *Regulating the air supply*.—To regulate the air supply to the spreader cap, screw-in the air adjustment valve in a *clockwise* direction to *reduce* the pressure, and in an *anti-clockwise* direction to *increase* the air supply. The air supply should be regulated with the trigger pulled back to its full extent.

(iii) *Valve glands*.—The material needle and the air valve spindle should be tightened up to prevent leakage which would cause intermittent spraying, but undue pressure must not be exerted—*finger tight* only—otherwise the needle and spindle will bind. The material nozzle, air valve body, spray head collar and union nuts, must be screwed home *tightly* and when using a container attached to the gun it should be ensured that the cover makes an air-tight joint otherwise intermittent spraying will result.

(iv) *Clearing air holes*.—The vent hole in the syphon cup must be kept clear to allow the air to take up the displacement of material. The holes in the spray head should also be kept clear, as the presence of foreign matter will affect the shape of the spray pattern. Do not attempt to clear obstructions from the air holes or vent hole by means of a hard implement, such as a wire or nail, or the holes may become enlarged or damaged; a pipe cleaner, a piece of thin soft wood or a broom bristle should be used instead.

(v) *Oiling*.—The fluid needle, air valve spindle and trigger-bearing screw require lubricating daily (see fig. 4). The material needle gland should be unscrewed occasionally and the packing softened with oil. The needle spring should be coated with light grease.

Adjustment of fluid and air pressure (with pressure feed tank)

16. The adjustments on the gun for the flow of material and the air pressure to the spreader cap have been described already in para. 15 (i), (ii). In adjustments for the material pressure there are two factors to consider, namely, the pressure maintained in the tank (material) and the size of the nozzle being used. There is no definite formula for determining how much pressure shall be maintained in the tank, as the requisite pressure varies with the viscosity of the material, the speed capacity of the gun, and the required thickness of film deposit. But, whatever the nature of the work in hand or the materials being used, the trigger should be regulated so that it is pulled back to its full extent in use. By this adjustment the results are more constant and the effort less fatiguing for the operator. For a general method of setting the equipment for average work and conditions, proceed in the following manner:—

(i) Set the material adjustment screw so that the first thread is exposed when the trigger is pulled back to its full extent. This setting brings the needle clear of the nozzle, thus ensuring a good spray pattern that might be distorted if operated with a restricted flow of material at the nozzle.

(ii) Set the atomising air pressure fairly low, say 35–40 lb. pressure and, commencing with no pressure in the container, adjust and increase the pressure until the desired amount of material is obtained for the work being sprayed and the speed of the operator. If too much material flows with less than 5 lb. pressure in the container, then it is advisable to fit a smaller sized material nozzle and needle.

(iii) When the required material flow has been obtained, adjust the atomising air pressure to the lowest possible pressure that will give the correct atomisation of the material being used.

(iv) If the work requires several overlaps and there is a possiblity of runs or sags forming, the atomising air only should be increased; this will dry out some of the solvent and the material will reach the surface in a drier state.

Preparing for operation

17. Before using dope or paint, *stir well and thoroughly mix* the contents in the container. The same care must be taken whether for brushing or spraying. The dope or paint should be strained if it contains any small lumps or skin. Before using any material pour a small quantity of thinners into the cup for testing purposes. If the spray is intermittent or the atomised stream irregular it may be caused by a loose union or connection. The air filter should be drained daily or more often if the atmosphere is humid by opening the drain cock fitted at the bottom of the filter. Check over all adjustments as indicated in paras. 22 and 23.

18. Always use the lowest pressure necessary to give good atomisation; an atomising pressure of within the range of 35 to 60 lb./sq. in. will be found sufficient to cover practically all materials in conjunction with a pressure of 5–10 lb./sq. in. in the pressure feed tank.

19. For testing the effects of adjustments made to the air and the material controls, especially with a new type of gun, an excellent method is to use water to acquire familiarity in the use of the gun and controls, as water causes no disfigurement of the surface sprayed, can be quickly wiped off and tends to clean the gun and avoids waste of material.

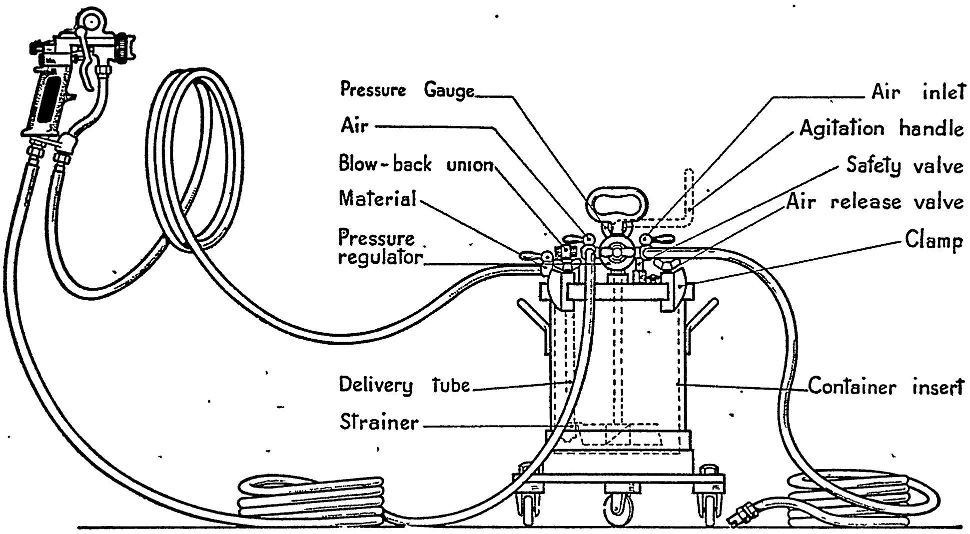

Fig. 3.—Pressure feed system

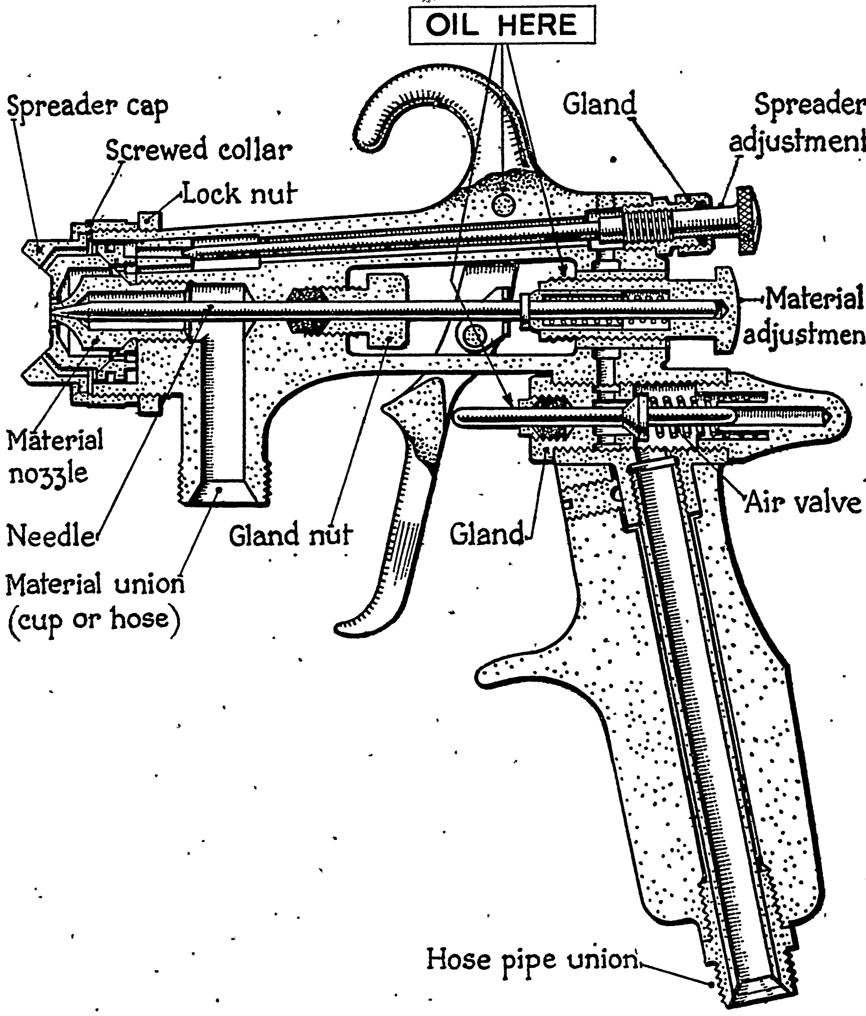

Fig. 4.—Sectional view of spray gun

(ii) *Material nozzle.*—The material nozzle consists of a sleeve jet made of hardened stainless steel with an orifice through its centre, through which the material is drawn or ejected. One end of the material nozzle is screw-threaded and fits into the gun body and, when the spreader cap is screwed into position the material nozzle is situated centrally in the centre hole of the spreader cap, as already stated, leaving a small annular air orifice around the tip and an air space between the conically-shaped body of the nozzle and the inner surface of the cap. At the inner end of the orifice in the material nozzle a seat is provided for the material needle and, by the adjustment of this needle, the material is metered through the nozzle as required.

(iii) *The material needle valve.*—The material needle valve comprises a spring-loaded needle of hardened stainless steel, one end of which is ground to a point, a knurled head being fixed at the opposite end for adjustment purposes. The needle point seats in the inner side of the hole in the material nozzle, thus controlling the flow of the material. The needle extends the whole length of the gun body, passing through a gland where it is fitted with a sleeve which is a sliding fit in the hollow adjusting screw, the head of which projects from the gun body; between the screw and needle sleeve is a coil spring. The sleeve has a collar which engages with the trigger for control purposes.

(iv) *The spreader cap adjustment.*—The spreader cap adjustment on certain types of gun consists of a spring-loaded needle valve, ground at one end for a seat in the air duct, passing through a gland and fitted at its opposite end with a head which projects at the rear end of the gun immediately above the material valve. This valve controls the air to the holes in the spreader cap, enabling adjustments to be made to obtain a desired pattern, varying from round to elongated patterns of different widths. In other types of spray gun, adjustment is made by rotating the spreader cap in a clockwise direction, when the valve gradually closes the air duct leading to the spreader holes so that air is being ejected only through the annular orifice around the fluid tip. In this position the spray issuing from the gun is truly conical and forms a round pattern varying in diameter according to the distance that the nozzle is held from the surface being sprayed. The nearer the gun is held to the surface the smaller the pattern and the thicker the film deposited; conversely, the further away the gun is held the larger the pattern and the thinner the film deposited. By rotating the spreader cap in the opposite direction, the air ducts to the spreader holes are gradually opened. The air being ejected from these holes converges into the central atomised stream and so causes elongation of the pattern, and the more the valve is opened the more elongated the pattern becomes as a result of the additional influence of the increased air stream converging on the central stream. For a horizontal elongation of the pattern the spreader holes on the cap will be vertical (see fig. 5). For a vertically elongated pattern the holes will be in a horizontal plane.

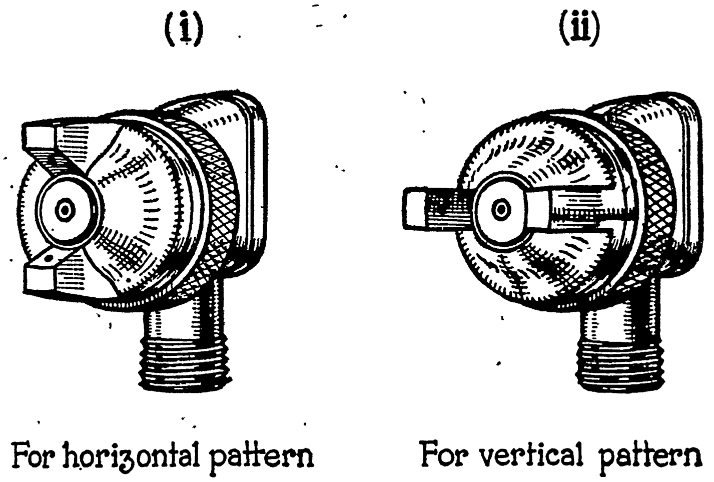

Fig. 5.—Nozzle setting for spray pattern

(v) *The air valve.*—The air valve consists of a spindle to one end of which a collar is fitted to take the thrust of the valve return-spring; the other side of the collar is ground at a suitable angle to form an air-tight seat in the air-valve body. Around the spindle is a gland and packing to prevent air leakage. The air-valve body is screwed into the gun body and is positioned behind the trigger below its fulcrum point with the head of the air valve immediately below the fluid valve, the opposite end of the spindle protruding from the

20. To test for correct atomisation of material, spray a pane of clear glass. This will reveal very clearly any imperfections of the spray pattern that may otherwise escape detection. The material should be wiped off the glass at each test before it dries.

Cleaning (syphon cup type)

21. Immediately after use, remove the material from the syphon cup—pour on a small quantity of cleaning solvent and replace the cup on the gun. Spray the solvent through the gun whilst holding a piece of rag alternately against and away from the nozzle. This forces the thinners back and forth through the ducts. Then clean out the cup. Alternatively, remove the cup or the material hose from the spray gun connection—whichever has been used—turn the gun upside down and pour the solvent down the material orifice (see fig. 6), in the meanwhile operating the trigger repeatedly to flush the ducts and clean the tip of the needle.

Note.—The solvent used in cleaning will be Brushwash cleaning liquid 33B/140 after using "C" type material, while for "S" materials primer thinner 33B/510 should be used.

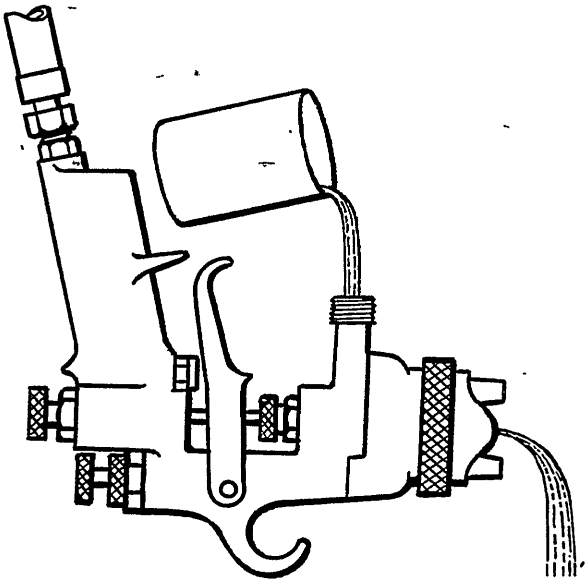

Fig. 6.—Flushing material ducts and nozzle

Cleaning (Pressure feed tank type)

22. When the pressure feed tank has been used, release the pressure in the tank by opening the relief valve mounted on the cover of the tank, then loosen the clamps which hold the cover in position. Hold a piece of rag over the holes in the air cap and pull the trigger. This forces the material in the gun and hose back into the container. Then remove the insert containing the material and replace with one into which the cleaning solvent has been poured. Replace the cover, close the relief valve and connect up the hoses as for spraying. Now spray the solvent through the gun which will clean the material hose and the gun.

23. On certain types of pressure tank a "blow back" union is provided to facilitate cleaning the hose. This consists of a two-way adaptor secured to the cover of the tank. To clean the hose proceed as follows:—

(i) Turn off all the cocks and release the air pressure from the tank.

(ii) Disconnect the material hose from the gun and couple to the respective union on the two-way adaptor.

(iii) Disconnect the air supply hose from the air inlet connection and couple to the other union on the two-way adaptor.

(iv) Open the fluid cock and turn on the air from the compressor; the air pressure will then force the material in the hose back into the container.

(v) To clean the hose and the gun with solvent proceed as described below.

Cleaning the spray gun

24. It may not be possible to clean the spray gun by the method already described in para. 21 and it will be necessary to remove the spreader cap and material nozzle if the material has at any time been allowed to dry in the gun. It may however be possible to avoid any dismantling if the nose of the gun is immersed for some time in a shallow tray of thinners or dope solvent. The gun should not be completely submerged, otherwise the packings will be dried out (see fig. 7).

25. If it should happen that the gun is left for two or three hours without cleaning, remove the material and replace with a small quantity of thinners, then hang the gun up on a wall bracket; the material will not then harden and it will be possible to clean the gun by spraying some of the thinners through it whilst repeatedly covering the air holes in the nozzle by applying the finger or a piece of rag intermittently.

Gland packing

26. The gland nuts should be unscrewed when no further adjustment is possible; the old packing should be removed and replaced by a three or four inch length of graphited asbestos string coiled round the respective needle. The gland nut should only be screwed up finger-tight, as excessive pressure will cause the needle to bind.

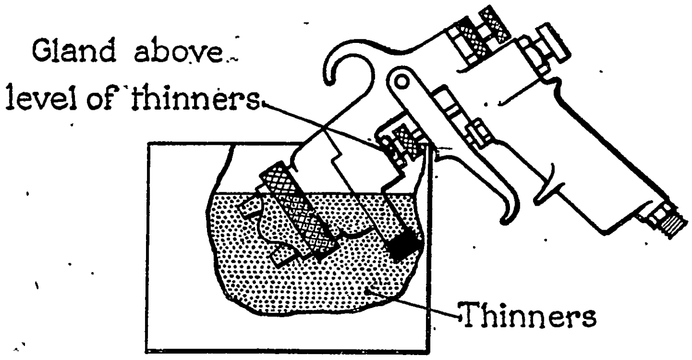

Fig. 7.—Immersion of spray gun head for cleaning

Removal of needle valves

27. The needle valves on normal types of spray gun can usually be removed after first unscrewing the adjusting screw and removing the spring. It may be necessary to slacken the gland nut if the needle is at all worn by use. Before replacing the needle in position it should be cleaned and lightly smeared with light grease.

Removal of material nozzle

28. The material nozzle is generally screwed into the gun body and is accessible, after the spreader cap has been removed, by unscrewing its collar or sleeve nut. Only the special ring spanner should be used when unscrewing or tightening the nozzle. Numbers or letters on the nozzle, spreader cap and needle indicate the relative sizes of each, according to the type of gun to which they are fitted.

Air hose

29. The air hose to the spray gun should be kept in good condition and should be supported as near to the gun as possible to relieve the operator of its weight and yet allow full and free movement. The hose should not be trodden under foot or run over by trolleys, etc. If any difficulty is experienced in obtaining good atomisation the size of the hose may be too small for the gun; it has been found that with a 25 ft. length of $\frac{1}{4}$ in. hose there is a pressure drop at the gun of 16 lb./sq. in., while for a similar length of $\frac{5}{16}$ in. hose there is a drop of only 5 lb./sq. in. The pressure should be checked at the gun by means of a suitable pressure gauge whilst the trigger is pulled.

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AIR MINISTRY
Sept. 1944

R.A.F. ENGINEERING—GENERAL ENGINEERING
This is A.L. No. 25 to A.P.1464B, Vol. I and concerns Part 2, Sect. 3
Chapter 5—*Remove* and *dispose* of the leaf bearing para. 1 to 10, and *substitute* this new leaf. Make an entry in the Amendment Record Sheet.

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CHAPTER 5

SPRAYING TECHNIQUE

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General

1. It is highly important that the operator should understand not only the nature of the materials and the mechanism of the spray gun, but also the technique of spraying in order to attain that degree of skill and proficiency necessary to obtain good results without wasting time and material. The necessary skill is acquired by constant practice and therefore, where possible, the same personnel should be allocated to all such work on the Unit.

Cleanliness

2. Cleanliness in spraying is essential; cleanliness of the work; cleanliness of the equipment and personnel cleanliness. If the work is not correctly prepared and thoroughly clean, the material will not adhere to the surface and peeling will result. If the equipment is not clean, the spray gun will not operate efficiently, resulting in considerable waste of time and material; containers which have coagulated material round the stoppers will also cause wastage. The operator should also give attention to personnel cleanliness in keeping the hands free from grease and material.

Precautions

3. Precautions should be taken against the risk of fire and explosion, and references to this will be found in the Vol. II Leaflets of A.P.830, in addition to recommendations for the storage of dopes, enamels, thinners, etc. (see also A.P.957—R.A.F. Fire Manual).

4. Information will also be found on the use of respirators for use when spraying in the Vol. II leaflets of this publication.

5. Precautions should also be taken to ensure that the source of air pressure is regulated to the correct value required by the spray gun. It should be ascertained at least once daily that the cut-off valve operates at the safe working pressure when a compressor is being used. It should also be ensured that water and oil vapour condensation is drained from the air container, the filter and the pipe-lines.

5A. Lead paint should not be used for any spraying operation except in a special compartment. This compartment should be provided with an efficient exhaust draught, and should be so equipped as to render it unnecessary for the operator to stand between the exhaust fan and the article which is being sprayed.

Atomisation

6. When the spray gun is in operation a stream of air and material is projected from the nozzle of the spray gun and the flow is unbroken until it reaches the objective surface when it is immediately spread in all directions close to the contour of the surface. The deflected air moving over the surface has a certain depth relative to its speed of projection, and the higher the air speed the greater the depth. It is therefore evident that all the air projected from the gun cannot actually come in contact with the surface, because most of it forms a moving layer of air of some depth which acts to a certain extent as an air cushion.

7. The material emerging from the material nozzle is suspended in the air stream, atomised, and carried along to the objective surface. The air stream travels slightly faster than the particles of material, but as these have a greater density than the air, they develop a certain momentum which carries them through to the surface; particles that have become too finely atomised however quickly lose their momentum and, being unable to resist the influence of the air stream deflected by the objective surface, are dispersed without being deposited on the surface.

8. If an excessive amount of spray mist is formed during spraying then it is evidence of over-atomisation, which results in waste of material representing a loss in some instances of as much as 25 to 30 per cent.

9. The following three fundamental principles must always be observed:—

(i) Use the least possible amount of air pressure that will give correct atomisation consistent with the viscosity of the material being used.

(ii) Hold the gun pointing at right angles to the surface being sprayed at any given moment.

(iii) Hold the spray gun at the correct distance (6 to 10 in.) from the surface being sprayed throughout each stroke (see fig. 1).

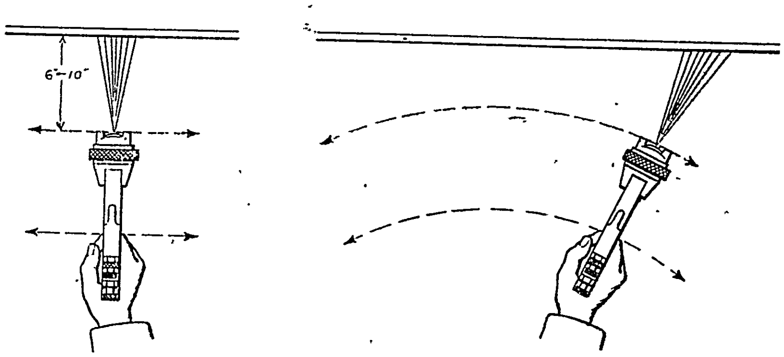

Fig. 1.—Holding the spray gun

Preparation of equipment for spraying operations

10. The following information applies to the general preparation for spraying, assuming that the gun is clean:—

(i) Select the correct material and thinners.

(ii) Strain the material and stir thoroughly.

(iii) Fill the container to a maximum of three-quarters full, or to a point that will leave a minimum in the container when the work is completed.

(iv) Ascertain that the following are of the correct size or are correctly adjusted:—

(*a*) Material valve needle to suit nozzle.

(*b*) Material nozzle—size varies for the type of feed and class of material; for example, viscous materials at high atomising pressures require a small nozzle; thin material applied at low atomising pressures will also require a small nozzle; large nozzles will be required for coarse materials.

(*c*) Spreader cap—size will depend on the volume of air and pressure available on the feed system used; on the type and volume of material to be sprayed; on the nozzle size selected, and on the size and nature of the work to be sprayed.

(*d*) Air valve.

(*e*) Trigger setting of both valves (air and material).

(*f*) Spray pattern (vertical or horizontal).

(*g*) Spray pattern width adjustment (when fitted).

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(v) See that the air hole in the syphon-cup lid is clear of obstruction or that the regulating valve in a pressure cup feed is closed before starting spraying.

(vi) Ensure that the compressed air supply is in order and the air filter drained.

(vii) Ensure that there is no leakage of air or material along the pipe-line, at the spreader cap or glands of the spray gun and at the container.

(viii) Check the atomising air pressure and, where a pressure feed tank is used, check also the material pressure. The latter will vary in direct ratio to the viscosity of the material in use

(ix) Mask all areas not requiring to be sprayed on the work.

(x) Obtain a respirator if the work is of sufficient duration to warrant its use.

Filling

11. In surfaces where there are lines of protruding rivet heads, countersunk screws or thin gaps between panels, these should be covered and smoothed off (prior to spraying) by means of a filler putty applied by a small thin-bladed putty knife. The putty should not be built up too heavily in one application but should be allowed to dry in successive layers; when dry the roughest parts can be smoothed down lightly with fine emery cloth. After the filling has been completed a priming coat should be applied and when this has dried the high spots should be flatted down using waterproof emery paper wrapped round a wooden hand block; plenty of water should be used to prevent the emery paper from becoming clogged.

12. In certain instances a line of rivet heads can be conveniently faired off by applying the filler and when it is dry a strip of thin canvas should be doped into position; another application of filler to fair off the strip followed by primer and flatting will complete the operation.

Procedure for retouching

13. When retouching damaged coatings, first obtain a good feathered edge by flatting the surface with emery paper, or, for very fine work—pumice, so that the edge of the coat of material cannot be detected by the sense of touch when the finger tips are passed lightly over it. Remove all traces of dust and grit with a clean duster, and remove any wax or grease by means of degreasing liquid (Stores Ref. 33B/510, 511, 512). Build up liberally with primer, extending in diminishing quantity beyond the feathered edges, then when dry rub down until level and smooth. Remove all dust or grit and apply finishing material; a mist coat of thinner will smooth out rough patches, after which apply the finishing coat.

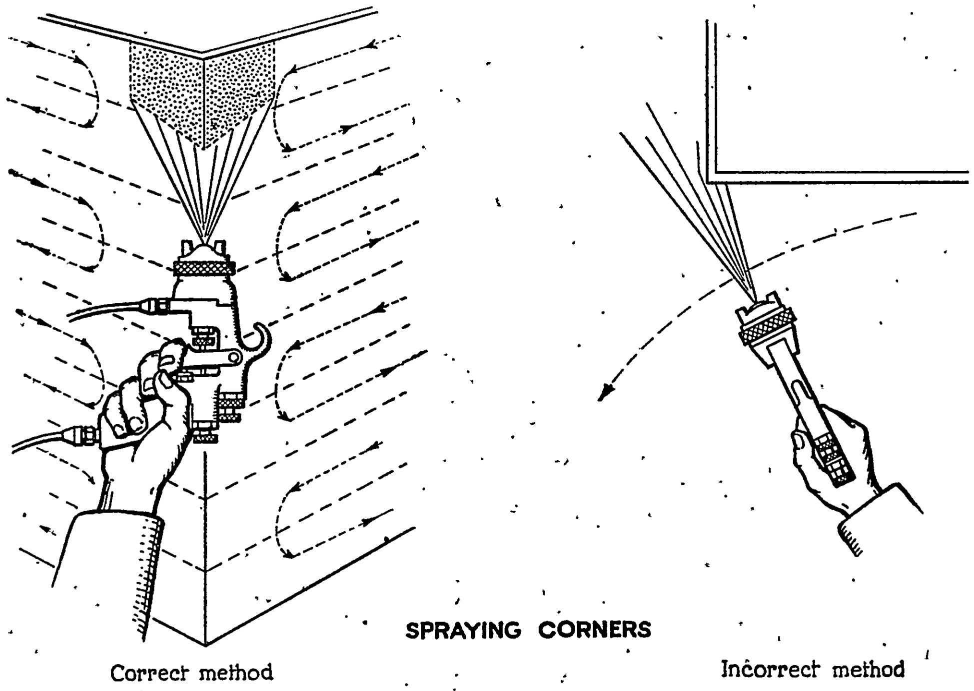

Fig. 2.—Spraying strokes

The operation of spraying

14. Assuming that all adjustments and preparation have been made correctly as already described, the actual handling of the spray gun is an art which is acquired by practice on the right lines. A good operator acquires a smooth even stroke, feathering off at the beginning and end of each stroke. The gun should be held square to the surface being sprayed throughout the entire stroke, and the operator must guard against the natural tendency to follow the arc of his arm reach, that is, by starting away from the work, swinging towards it and then pulling away at the end of the stroke (see fig. 1).

15. Before commencing to spray, the work should be carefully examined with a view to determining which way it can be sprayed by the least number of strokes; edges, recesses and protruding parts should be sprayed first so that the main surface will not be oversprayed. Corners should be sprayed to within one or two inches of the corner and then sprayed on the corner to include both sides at once (see fig. 2).

16. The spray gun should be triggered at the beginning and end of the stoke. At each end of the stroke the spray should be carried past the object being sprayed, but the trigger should be released at the point where it leaves the edge of the work. To pull the trigger back and keep it there for stroke after stroke is very wasteful of material.

17. During each successive stroke the spray gun should be pointed so that the centre of the spray follows the line along where the preceding stroke thinned off at the edge, thus ensuring even overlapping and a uniformly sprayed surface. The average arm-speed in spraying has been found to be 200/250 ft./min. Rapid or jerky strokes should be avoided.

18. Spraying must not be carried on to the point of fatigue, otherwise the work becomes erratic and causes loss of confidence which still further reduces efficiency, as good spraying is based on a self-confident mental attitude.

19. During spraying a good light is essential in order that the depth and condition of the sprayed material can be judged as it impinges on the work surface, whether it is over atomised, too thin or too heavy. Good lighting should be diffused and without glare and, for artificial lighting, fluorescent tubes are the best source of light.

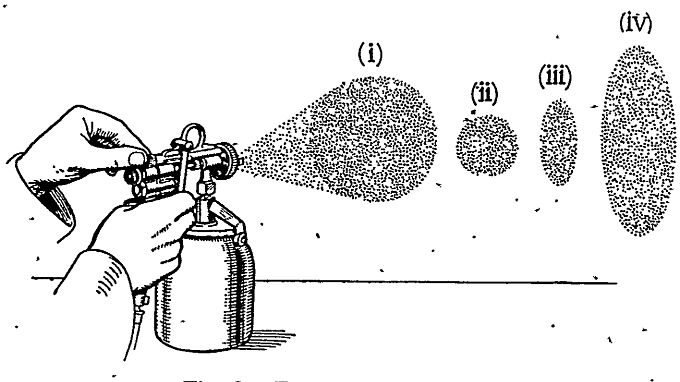

Fig. 3.—Types of spray patterns

Defective spray patterns

20. If the sprayed pattern is found to be defective, this can be caused by obstructions in the air holes in the spreader cap or in the air orifice in the centre of the cap. The atomisation may be incorrect, that is to say, the air and material not correctly balanced. The normal types of spray pattern are illustrated in the sketches in fig. 3 and the different types of imperfect patterns in fig. 4. The causes and effects are outlined in the following sub-paragraphs:—

(i) *Heavy top pattern* (see fig. 4 (i). Cause:—
- (*a*) Spreader cap holes partially clogged.
- (*b*) Obstruction on material needle tip.
- (*c*) Foreign matter on spreader cap seat or material valve seat.

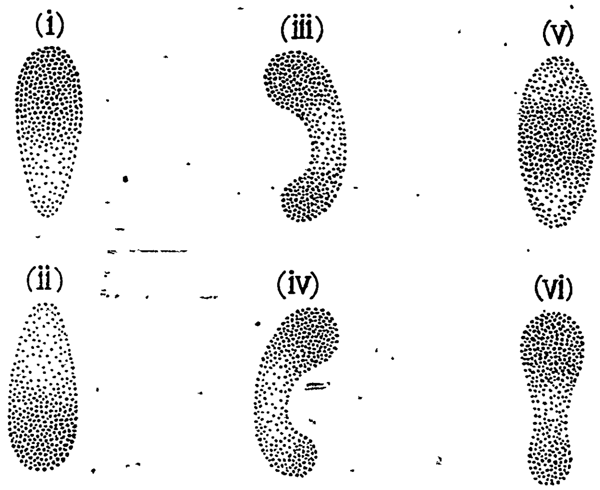

Fig. 4.—Defective spray patterns

(ii) *Heavy bottom pattern* (fig. 4 (ii)). Cause:—
- (*a*) Spreader-cap holes partially clogged.
- (*b*) Obstruction on lower side of material nozzle.
- (*c*) Foreign matter on spreader-cap seat or material nozzle seat.

(iii) *Heavy right-hand pattern* (fig. 4 (iii)). Cause:—
- (*a*) Right-hand spreader-cap hole partially clogged.
- (*b*) Foreign matter on right-hand side of material nozzle.

(iv) *Heavy left-hand pattern* (fig. 4 (iv)). Cause:—
- (*a*) Left side spreader-cap hole partially clogged.
- (*b*) Foreign matter on left-hand side of material nozzle.

(v) *Heavy centre pattern* (fig. 4 (v)). Cause:—
- (*a*) Too low a setting of spreader-adjustment valve.
- (*b*) Too high a fluid pressure for the spreader cap's normal capacity of the material pressure-feed relative to the air pressure.
- (*c*) Too large a nozzle for the material being used.

(vi) *Split spray pattern* (fig. 4 (vi). Cause:—
- (*a*) Material and air feeds incorrectly balanced.
- (*b*) Spray set too wide and material thin.

Note.—To determine whether the cause of a defective spray pattern is in the spreader cap or on the material nozzle rotate the cap one half turn and spray another pattern. If the defect is reversed the obstruction or cause is in the spreader cap; if the defect is not reversed the fault is in the material nozzle. Clean the spreader cap and check for fine burrs on the edge of the material nozzle or for dried material inside the opening. Check the air pressure and material pressure and adjust the spray-width till the desired spray is produced.

Orange peel effect

21. Orange peel effect (see fig. 5) may be attributable to one or more of the following causes:—

(i) Inferior quality of thinner or a thinner containing a high percentage of low boiling point solvent which will cause orange peel effect irrespective of efficiency of application.

(ii) The gun held too close to the surface, when the force of the air stream tends to disturb or ripple the surface.

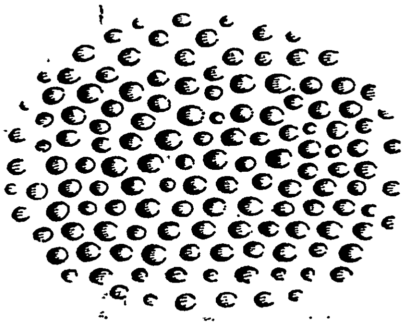

Fig. 5.—Orange peel effect

(iii) The gun held too far from the surface.

(iv) The material not thoroughly stirred and mixed.

(v) Currents of air in finishing room.

(vi) Incorrect relative humidity.

(vii) Insufficient atomisation caused by the air pressure being too low relative to the viscosity of the material. Multiple or larger orifices facilitate atomisation of heavy materials, but necessitate increased air flow to preserve the correct balance between air and material.

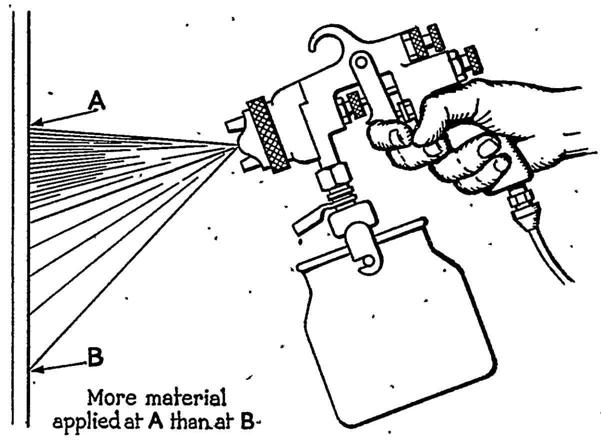

Fig. 6.—Tilting the gun

Streaks or runs

22. Streaks or runs in the coating may be caused as follows:—

(i) Tilting the gun (see fig. 6 and 7) and so spraying at an angle to the surface, causing the material to be unevenly applied with consequent waste.

(ii) Too much material applied to the surface. The speed of operation should either be increased or the fluid pressure reduced.

(iii) Runs are the result of the material being too thin.

Mist or fog

23. Mist or fog is due to over-atomisation and may be caused by any of the following conditions:—

(i) Too high an atomisation air pressure.
(ii) Incorrect size of spreader cap for the material being used.
(iii) Incorrect material nozzle for the material being used.
(iv) Material pressure too low (pressure feed tank).
(v) Spray gun held too far away from surface.

Jerky or fluttering spray

24. Jerky spray or fluttering may be caused by air leakage into the material line (see fig. 7) and may be due to any of the following causes:—

(i) Lack of sufficient material in the container.
(ii) Tipping the container at too acute an angle.
(iii) Obstructed material ducts.
(iv) Loose or cracked material tube in the cup.
(v) Loose material nozzle: dirty or damaged seat.
(vi) Material too heavy for suction feed.
(vii) Clogged air vent in the cup lid.
(viii) Loose or damaged coupling on the cup lid.
(ix) Loose needle-valve gland nut, or defective packing.

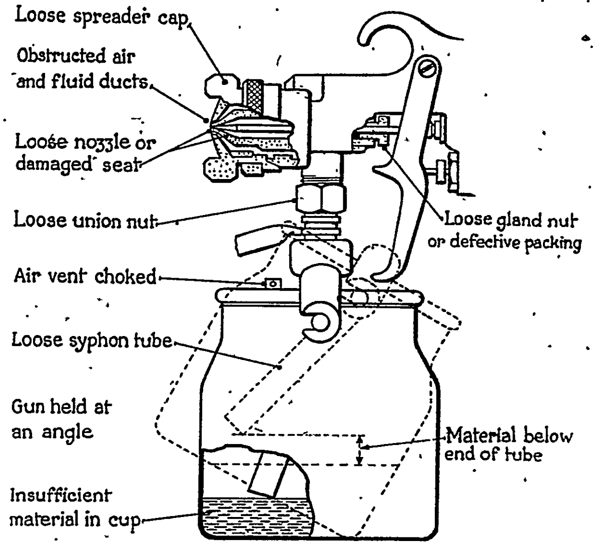

Fig. 7.—Causes of jerky or fluttering spray

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CHAPTER 6

ELECTRIC BRUSHING MACHINE—TYPE AI/MY

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General

1. The electric brushing machine (see Fig. 1) is a portable, four-speed flexible-drive machine which is adaptable for wire-brushing, grinding, drilling and polishing operations. The flexible shaft is driven by a ½-H.P. electric motor mounted on the underside of a base-plate, the whole being pivoted in a "U" bracket forming part of the stand. The speed of the flexible shaft can be varied progressively by means of two opposed-cone type pulleys, coupled by an endless rubber "V" belt. One of the pulleys is keyed to the motor armature shaft, and the other is coupled to the flexible drive shaft and mounted in a bracket on the motor base-plate. The flexible drive shaft is provided at the motor end with a drive connection and at the other end with an internally threaded union into which the various grinding and drilling attachments can be fitted.

2. The "U" bracket supporting the motor is provided with a boss at its lower end, machined to fit the upper end of the stand, which is fitted in turn to a conical base. A ball thrust-bearing is provided at the upper end of the column to enable the "U" bracket to swivel freely about the axis of the column. The base is mounted on a portable type stand fitted with castors, so that the machine can be readily moved when in operation, or from one working station to another. The castor stand is detachable and the base could if desired be mounted directly on a bench. The motor is controlled by means of an ON–OFF switch mounted on the upper side of the motor base-plate and a suppressor is fitted to the machine to prevent the motor from causing electrical interference to W/T apparatus. The various components of the flexible drive machine are described separately in paragraphs 3 to 7, while information is given on the operation and maintenance of the machine in subsequent paragraphs.

DESCRIPTION OF COMPONENTS

Motor

3. Three types of motor have been fitted to various issues of this type of brushing machine. All three types have a continuous rating of ½-H.P. at a speed of 2,800 r.p.m., and a brief description of each type, sufficient for maintenance purposes, is given in the following sub-paragraphs:—

(i) *Short-circuiting, brush-lifting type A.C. motor.*—This type of motor (see fig. 2) comprises an armature with a radial commutator, a cylindrical-type yoke, field coils, and two endshields. Each endshield is secured to the yoke by four screws, and each accommodates an armature ball-bearing retained in position by means of an inner and an outer bearing cap, both caps being held in position by means of four screws, which pass through the outer cap and endshield and are screwed into the inner cap. The inner cap at the commutator end of the motor has an extended sleeve which supports the brush gear. Incorporated in the armature is the short-circuiting, brush-lifting gear which is controlled by the centrifugal force acting on two pivoted weights mounted

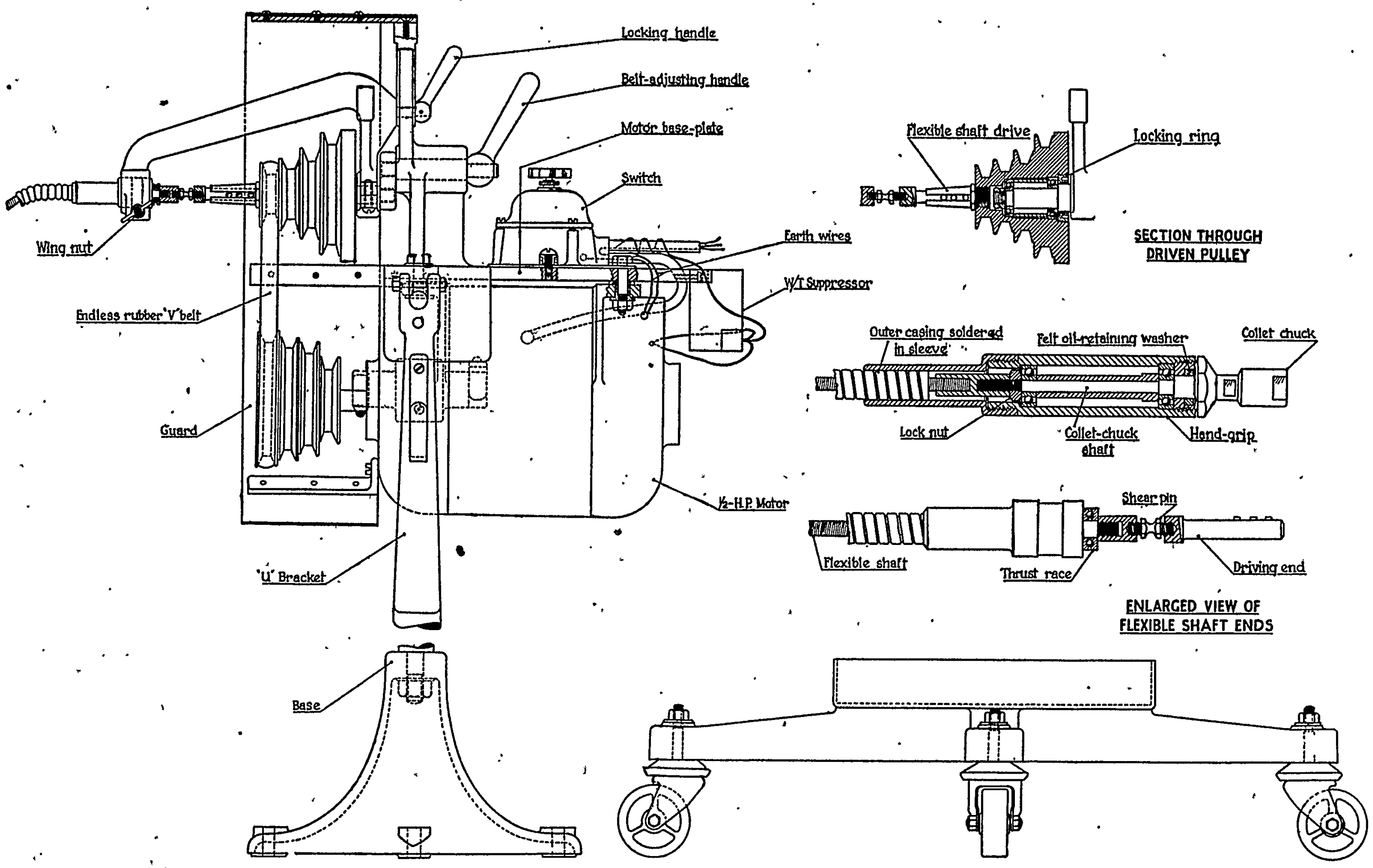

Fig. 1.—Electric brushing machine.

on the armature shaft. The purpose of the gear is to short-circuit the commutator segments and lift the brushes from the commutator face when the motor reaches a speed of approximately 1,200 r.p.m., enabling the motor to start as a repulsion motor and then to run under full load as an induction motor; the commutator segments are short-circuited by a number of copper strips which make contact with the inner ends of the segments under the action of centrifugal force (see fig. 2).

(ii) *Short-circuiting, brush-riding type A.C. motor.*—This type of motor is a repulsion-starting, induction-running motor similar to that described in sub-para. (i) except

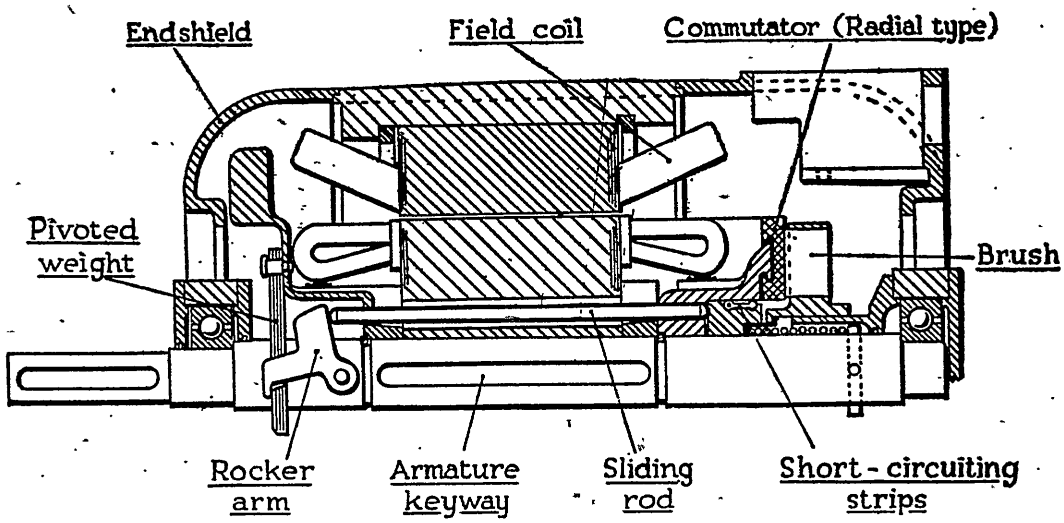

Fig. 2—Short-circuiting, brush-lifting type A.C. motor

that the brushes are not lifted when the commutator segments are short-circuited. The commutator is of the circumferential type and the short-circuiting copper strips are prevented from making contact with the ends of the commutator at motor speeds below 1,200 r.p.m. by means of a ring-type coil spring, but at higher motor speeds the force exerted by the copper strips overcomes the spring pressure and the strips short-circuit the commutator segments, thus allowing the motor to run as a squirrel-cage induction motor, the brushes being permanently shorted by means of a short length of insulated copper wire.

(iii) *Compound-wound D.C. motor.*—This type of motor comprises an armature provided with a cylindrical-type commutator, a yoke which houses both the series and the shunt-wound field coils, and two endshields which accommodate the ball-bearings supporting the armature. Each ball-bearing is retained in position in the endshield by means of an inner and an outer bearing cap, both caps being retained in position by means of four screws which screw into the inner cap. Provision is made for lubricating the bearings by means of a grease nipple fitted to each outer bearing cap.

Suppressor

4. The suppressor is inserted in the motor circuit for the purpose of preventing electrical interference to adjacent W/T apparatus. The suppressor consists of two condensers, each of 0·05 m.f.d. capacity connected in series across the two supply cable connections to the motor, the wire connecting the two condensers being earthed, as shown in fig. 3.

Switch

5. The motor control switch is a semi-rotary, single-pole type secured to the motor base-plate, insulation washers being provided where the holding-down screws pass through the switch body. The switch body is earthed by means of the earth wire in the three-core supply cable.

Operating-head drive

6. The drive for the operating heads incorporates a belt drive from the motor spindle, a shear

pin and a flexible cable enclosed in a metallic outer casing, each of which is described separately in the following sub-paragraphs:—

(i) *Belt drive.*—The belt drive consists of two 4-step cast-aluminium pulleys coupled by an endless rubber V-belt, one pulley being keyed to the motor armature shaft, and the other being mounted on ball-bearings supported by a bracket attached to an extension of the motor base-plate, and finally coupled to the flexible shaft driving the operating head. The driven pulley has four speeds of rotation, *viz*:—1,400, 2,500, 4,000 and 7,500

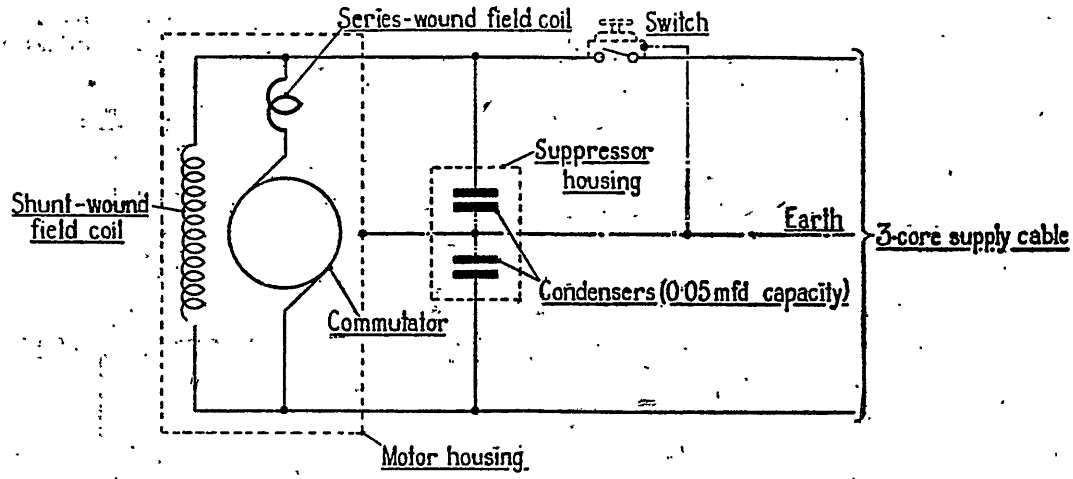

Fig. 3.—Circuit diagram

r.p.m. The tension of the belt can be adjusted by means of the belt-adjusting handle, which should be turned clockwise to increase the tension, and anti-clockwise to decrease the tension or to slacken the belt sufficiently to enable its position on the pulleys to be changed; a locking screw fitted with a handle is provided to lock the handle after it has been adjusted correctly. The outer end of the driven pulley is fitted with a slotted sleeve which accommodates the shear pin adaptor. A sheet-steel guard enclosing the belt and pulleys is supported on brackets secured to the motor base-plate.

(ii) *Shear pin.*—The shear pin is interposed between the driven end of the flexible shaft and the driven pulley in order to protect the machine and the flexible shaft from damage which would otherwise ensue should undue pressure be applied inadvertently to the operating head. The shear pin consists of a short length of hexagon steel rod provided with screw threads at each end, the centre being reduced to a diameter of $\frac{5}{32}$ in., which is just sufficient to withstand the maximum permissible torque. One end of the pin is screwed into a sleeve which is soft-soldered to the inner core of the flexible cable, the other end of the pin being screwed into the driving connection which engages with the slotted sleeve carried by the driven pulley.

(iii) *Flexible drive.*—Various sizes of the flexible shafts are available for use with the machine, the smaller sizes being used in conjunction with small size operating heads for light duties such as wire-brushing, grinding and polishing, whilst the larger size of shafts with large size operating heads are used for grinding, polishing, drilling, etc. All drives consist of an inner flexible cable which transmits the torque enclosed in an outer metallic casing, the inner cable being built up from several layers of high-tensile steel wire wound in alternate layers right and left-hand on a central core. The outer casing of the larger size flexible drive comprises two layers, the inner one being a flat steel strip wound spirally, over which the outer layer of interlocking strip steel covering is wound; in the smaller sizes of flexible shaft the inner layer is omitted from the outer casing. The driving end of the outer casing is secured in an extension of the driven pulley bracket, and a ball-bearing thrust-race is positioned between the end of the outer-casing of the shaft, and the sleeve carrying the shear pin. The other end of the flexible shaft is fitted with a sleeve for the reception of either a ball-bearing hand-grip or grinding and other attachments, the hand-grip being used on small shafts for holding small grinding and polishing heads. The motor end of the inner cable is soldered into the sleeve which carries the shear pin whilst the other end of the cable is soldered into a sleeve for the attachment of the various final drives.

Equipment

7. A description of the attachments which can be fitted to the larger size flexible drive together with a description of the hand-grip, grinding wheels and milling cutters used with the smaller size drive is given in the following sub-paragraphs:—

(i) *Hand-grip.*—Two sizes of hand-grip are provided for use with the flexible drive shafts, one for the large type and another for the small, each grip consisting of a sleeve, which screws into the outer casing of the flexible drive shaft and which is provided with a spindle mounted in two ball-bearings. In the smaller sizes, the spindle is integral with the collet chuck, but in the larger size the end is threaded ½ in. Whit. for the attachment of large grinding wheels, etc. A felt washer is provided in the hand-grip to prevent the escape of grease from the flexible drive shaft. The spindle in each hand-grip is screwed into a sleeve soldered on to the end of the inner cable of the flexible drive. Collets are available to suit operating head spindles of 6 mm. and ¼ in. diameter.

(ii) *Drilling attachment.*—This attachment is coupled to the larger size flexible drive shaft and consists of a worm, driven direct from the flexible drive shaft, and a worm wheel, housed in a casting provided with a supporting handle. A hand-operated extension screw used for exerting pressure on the drill point during drilling operations, and holes up to 1¼ in. diameter may be drilled with this attachment. The worm is carried in ball-bearings and a thrust-race is fitted on the motor side of the worm to prevent the flexible drive shaft from being subjected to end thrust; the worm wheel shaft is carried in two bearing bushes and a ball-bearing thrust-race takes the drill pressure.

(iii) *Right-angle drive attachment.*—This attachment is provided to facilitate grinding and polishing operations when using abrasive discs, felt and lambswool bobs, etc., on horizontal surfaces and it comprises a flexible drive shaft coupling, a right-angle bevel gear drive and a collet chuck. The gear shafts are mounted in ball-bearings and felt washers are provided to retain lubricant within the gear case.

(iv) *Ball-bearing extension handle.*—This attachment is provided for use when large grinding and polishing heads are employed in conjunction with the larger size flexible drive shafts, forming an additional hand-grip for the operating head. The handle consists of a knurled sleeve which houses a spindle and two ball-bearings, the spindle being provided with a screw thread at one end for attachment to a large grinding or polishing head.

(v) *Grinding wheels and milling cutters, etc.*—Various types of grinding wheels and milling cutters, wire brushes, etc. (see fig. 4) may be used on suitable attachments and these are provided with 6 mm. and ¼ in. diameter shanks to fit the collet chuck of the smaller size hand-grip. Typical grinding wheels and brushes are illustrated in fig. 4, together with the types of spindle which are used with felt, polishing and emery bobs, etc. Milling cutters are available in various types of "cut" to suit the material on which the tool is being used, the coarse type being used on soft metals such as light alloys and the fine types being used on materials such as steel and bronze.

(vi) *Spindles.*—Spindles are provided with a coarse taper thread at one end for the attachment of mops and bobs and the other end is machined to fit the collet chuck of the small hand-grip. Another type of spindle is provided with an end slot in which a piece of cloth can be held for the purpose of cleaning valve guides, etc.

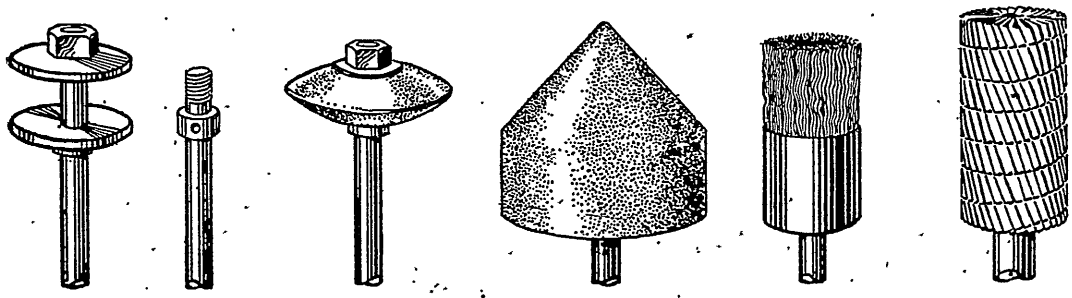

Fig. 4. – Type of spindles and attachments

OPERATION

General

8. Before connecting the brushing machine to the electricity supply it should first be ascertained that the voltage, etc., is the same as that indicated on the rating plate attached to the motor or stand. In the case of single phase A.C. supply, the voltage at the motor should not vary more than 5 per cent. above or below that stamped on the motor plate and if lengths of extension cable are used, it should be ascertained that they are of the correct capacity to carry the current without undue voltage drop. A standard three-pin plug is used for earthing the machine and no other earthing is necessary. Whilst in use the machine should be in a position to enable the operator to use the operating head without bending the flexible shaft unduly. When the machine is to be moved, the "U" bracket or the driven pulley support-bracket should be used as convenient handholds, and under no circumstances should the flexible drive or the electric supply cable be used for this purpose. The motor base-plate may be locked in any desired position in the trunnions of the "U" bracket by means of the lock-nuts provided. During the operation of the machine it should be ascertained that the flexible drive does not become overheated, particularly when high speeds are being used, also that no excessive local heating occurs at any point.

Changing speed of operating head

9. Four speeds of the operating head are provided to enable the different diameters of grinding and milling cutters, etc., to be used at the approximate cutting speed. To change speed the locking screw handle (see fig. 1) should first be released and then the belt-adjusting handle should be turned anti-clockwise to slacken the belt. The belt should then be moved to the appropriate pair of pulleys and the belt-adjusting handle turned in a clockwise direction until the belt is under slight tension; in no circumstances should the belt be over-tightened. The belt should normally be run as slack as is possible without undue belt slip, otherwise the motor bearings and pulleys will be subjected to excessive wear.

Speed and use of operating head

10. The most suitable speed of the operating head depends on the size and type of head and the material on which it is being used but, generally, the lowest speeds, *i.e.*, 1,400 r.p.m., should be used for milling cutters; medium speeds, *i.e.*, 2,500–4,000 r.p.m., for wire brushes, large polishing mops, sanding heads and grinding wheels from 4 in. to 6 in. diameter; and the high speeds, *i.e.*, 7,500 r.p.m., used only for small polishing mops up to 4 in. diameter and small grinding wheels. When using large sanding heads in conjunction with the right-angle drive attachment one side only of the head should be applied to the work. The use of a cutting lubricant is only necessary when using milling cutters, on materials other than brass and cast iron, suitable lubricants being chalk for steel or copper, and paraffin for light alloys.

SERVICING

General

11. The machine is to be kept clean and in a serviceable condition and lubricated periodically; care should be taken to ensure that particles of abrasive or metal cuttings are kept clear of the belt pulleys and the motor casing. Information on the servicing of the machine will be found in the following paragraphs.

ELECTRICAL EQUIPMENT

Motor lubrication

12. The motor bearings should be lubricated periodically with grease, high temperature (Stores Ref. 34A/89 or 34A/76) through the grease nipple provided on each outer bearing cap, care being taken to avoid over-filling; the bearings should be kept approximately two-thirds full, and this amount should not be exceeded. The bearing housings are charged with grease during assembly at the manufacturer's and this quantity is sufficient for approximately 12 months under normal working conditions. After a prolonged period of use the motor should be dismantled as described in para. 13 and the bearing housings cleaned out and then subsequently re-charged with grease.

Dismantling the motor

13 Care should be taken when dismantling the motor to ensure that all electrical connections are clearly marked before they are uncoupled, in order to prevent confusion on subsequent assembly. The supply cables should be disconnected at the junction box on the side of the motor after which the earth leads and the leads to the suppressor should be disconnected. The motor should then be removed from its base-plate by unscrewing the nuts on the four holding-down bolts, meanwhile supporting the motor until all four nuts are removed, to prevent damage being sustained by the

armature shaft and the bearings. To gain access to the interior of the motor for servicing operations, the four set-screws holding the endshield at the pulley end of the motor should be removed, and then the four screws securing the bearing cap at the other end should be unscrewed to allow the ball-bearing at the commutator end of the motor to be withdrawn with the armature shaft. The armature should then be removed with the endshield, care being taken to support the armature until it is clear of the pole pieces, to prevent damage to the armature, field coils and brush gear. The bearing-cap screws of the endshield on the armature shaft may then be removed for the purpose of cleaning and viewing the bearing housing. Worn or defective bearings should be replaced by new ones.

Commutator

14. The information given in this paragraph on the maintenance of the commutator applies to all types of motor which have been used on the brushing machine, Type AI/MY. The commutator should be cleaned periodically by means of a piece of soft cloth held on a piece of wood, against the surface of the commutator whilst the motor is running. If the commutator has become slightly roughened, it should be smoothed down by means of a piece of fine sand-paper attached to a piece of wood and held against the commutator whilst the motor is running, care being taken to avoid making contact with any live conductors. If the commutator is badly scored or worn unevenly, it should be re-faced in a lathe and then polished, care being taken to remove as little of the metal as possible. After re-facing the commutator, the mica insulation between the commutator bars should be carefully undercut and for this purpose a piece of thin hacksaw blade fixed in a holder will be found satisfactory; the mica insulation should not, however, be undercut in certain instances where the mica is intended to be flush with the commutator surface before re-facing. The edges of the commutator bars should be carefully chamfered after undercutting and the commutator surface highly polished in a lathe, by means of fine-grade glass paper, finally removing all dust from the grooves with a soft brush.

Brushes and brush gear

15. The brushes on all three types of motor should be inspected periodically to ensure that they are not unduly worn and that they slide freely in the brush-holders. Brushes which are worn down more than $\frac{3}{16}$ in. should be replaced by new ones of the correct grade. The normal brush pressure should be 3 to 4 lb./sq. in. New brushes should be correctly bedded to the commutator surface by first inserting a strip of fine-grade glass paper between the brush and the commutator, with the prepared side of the paper against the brush; emery paper should not on any account be used, as particles of emery may become imbedded in the brushes or commutator, thus causing sparking and rapid wear. The glass paper should be pulled through in the direction of armature rotation with the brush pressure applied, but the return stroke should be made with the brush lifted from the glass paper, then, lowering the brush, repeat the operation until a good surface contact is obtained between the brush and the commutator. After the brushes have been bedded by the method outlined above, the motor should be run for some time without load, in order that the surface contact will be further improved; before the load is then applied to the motor, a brush should be removed from its holder to determine the condition of the surface which should make as near as possible 100 per cent. contact. In both types of A.C. motor, periodical inspection should be made to ensure that the short-circuiting gear and the brush-lifting gear (where fitted) are free in action, particular care being taken to ensure that the short-circuiting strips are free to move outwards under the action of centrifugal force, otherwise the motor will run continuously as a repulsion motor and inefficient speed regulation and heavy current consumption will result. No carbon dust should be allowed to accumulate on the brush holders, commutator, or the adjacent insulating surfaces; dust may be conveniently removed by means of a jet of compressed air assisted if necessary by a soft bristle brush.

Renewal of ball-bearings

16. When the motor ball-bearings are to be replaced by new ones the pulley should first be removed from the armature shaft and then the motor should be dismantled as described in para. 13. The defective bearings should then be removed by means of a withdrawal tool. When the new bearings are being fitted they should be pressed on to the shaft in an arbour press, care being taken to ensure that the inner bearing caps are placed on the armature shaft before the ball-bearings are fitted. The motor should then be re-assembled as described in para. 17.

Assembling the motor

17. The information given in this paragraph on assembling the motor after it has been dismantled for maintenance operations will apply equally to all types of motor fitted on this type of brushing

machine. When assembling the motor all necessary precautions should be taken to prevent the ingress of foreign matter into the interior of the motor casing and ball-bearing housings. The endshield and bearing caps at the commutator end of the armature shaft should first be assembled, the bearing-cap screws being inserted through the outer cap and the central boss on the endshield, and then screwed into the inner cap thereby positioning the endshield on the ball-bearing. The armature should then be inserted in the yoke, care being taken to ensure that the armature or field coils are not damaged during this operation and that the armature has been inserted into the correct side of the yoke, as indicated by the relative positions of the junction box on the yoke and the pulley end of the armature shaft (see fig. 1). A long stud should then be screwed into one of the set-screw holes in the inner bearing-cap at the pulley end of the shaft to enable the inner cap to be held in position whilst the bearing-cap set-screws are being inserted. The endshield at the driving end of the armature shaft should then be fitted and the four set-screws inserted in each endshield and tightened up. Three of the bearing-cap set-screws should then be inserted in the cap at the pulley end of the armature shaft and tightened up after which the stud should be unscrewed and the other set-screw inserted and tightened up. After ensuring that the armature shaft will revolve freely, the pulley should be fitted to the armature shaft and the motor secured to the motor base-plate on the machine. The field coils and armature windings should then be tested for leakage to earth by means of a suitable bridge-megger, or, in instances where a megger is not available, continuity tests should be applied to the field coils, armature windings, etc., by means of a 40-watt lamp in series with the test leads plugged into a 230v. circuit. When tested by means of a megger the insulation resistance between the field coils or armature windings and earth should not be less than 2 megohms.

Belt and pulleys

18. The motor pulley and the driven pulley should be examined from time to time to ensure that the belt is not bearing on the bottom of the pulley grooves or showing other signs of wear such as fraying or cracking; if any of these defects is present a new belt should be fitted. If it is seen that a new belt bears on the bottom of the V-groove, a new pulley or pulleys should be fitted and the belt adjusted as described in para. 9. To fit a new belt, the flexible drive should first be removed by unscrewing the wing nut on the driven pulley support bracket and then the guard should be removed by unscrewing the retaining screws, thereby allowing free access to the pulleys. The driven pulley should now be removed from its shaft, first removing the locking ring, and then the shaft together with the ball-bearings. The new pulley should then be fitted to the shaft and the locking ring tightened securely.

Shear pin

19. To replace a damaged shear pin by a new one, the flexible shaft and casing should first be released from the driven pulley support bracket by unscrewing the wing nut. The halves of the shear pin should then be removed and a new pin fitted, care being taken not to damage the pin or the fittings into which it is secured. The flexible drive should then be replaced and the wing nut tightened.

Flexible drive

20. After approximately 50 hours running time or, if signs of overheating are noticed, the inner cable of the flexible shaft should be removed for cleaning and re-greasing. To remove the inner shaft from the flexible drive, the nut adjacent to the collet chuck on the handpiece should be unscrewed (L.H. thread) and the inner shaft withdrawn until the lock-nut on the collet-chuck shaft is visible; this lock-nut should then be slackened and the collet-chuck shaft unscrewed from the inner flexible shaft sleeve. The inner cable should now be removed from the motor end of the outer casing and the shaft components cleaned thoroughly, the outer casing being cleaned internally by pulling a piece of rag through it. After cleaning, the inner shaft should be coated evenly with grease to a depth of about $\frac{1}{16}$ inch and the components reassembled, the sequence of operations being the reverse to that described for dismantling.

Repairing flexible drive inner cable and outer casing

21. When the flexible drive is dismantled for cleaning and greasing, the inner flexible cable should be examined for signs of local wear and if this is excessive or the whole length of the cable has worn to such an extent that the outer layer of wire has become loose, the flexible cable should be replaced by a new one. If, however, the wear is localised the defective part should be removed and the ends connected in the manner described in sub. para. (ii). When it has been necessary to shorten the inner flexible shaft the outer casing should also be shortened a similar amount. The

normal procedure to be adopted for repairing the outer casing and the inner cable is described respectively in the following sub-paragraphs:—

(i) *To repair an outer casing.*—When an outer casing is damaged or broken, the defective part should be removed by cutting a section out of the casing. When repairing the larger size flexible drive it will be necessary to secure the inner spiral lining to the outer casing by means of a screw through the lining and casing. The ends of the screw should be riveted over and then filed flush, after which the casing ends should be thoroughly cleaned and soldered into a sleeve which just fits over the outside of the casing.

(ii) *To repair an inner flexible cable.*—When an inner shaft sustains any damage or localised wear it may be repaired in a similar manner to that described for the repair of outer casings. The damaged ends of the cable should first be thoroughly cleaned and then de-greased in a degreasing plant, after which the ends should be filed or ground square with the axis and slightly chamfered. The ends should then be soldered into a mild steel sleeve approximately 0·040 in. thick, the inside diameter of which is such that it fits neatly over the ends of inner cable. When the inner cable has been repaired it should be given a light coating of grease prior to replacing it in the outer casing.

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CHAPTER 7

TRU-LOC CABLE END-FITTING SWAGING MACHINE

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General

1. A hand operated swaging machine is used for fixing outer sleeves or hollow shanks to certain special types of control cables, by the application of an external squeezing action. The pressure is applied by a combined lever and cam acting through the medium of a pair of suitably shaped dies, the action being repeated at close intervals along the length of the cable end-fitting.

2. The machine can be used to swage the following types of end-fittings to control cables:—

(i) Threaded shank-type terminals
(ii) Eye-end shank-type terminals
(iii) Fork-end shank-type terminals
(iv) Rotatable shank-type terminals
(v) Ball-ends.

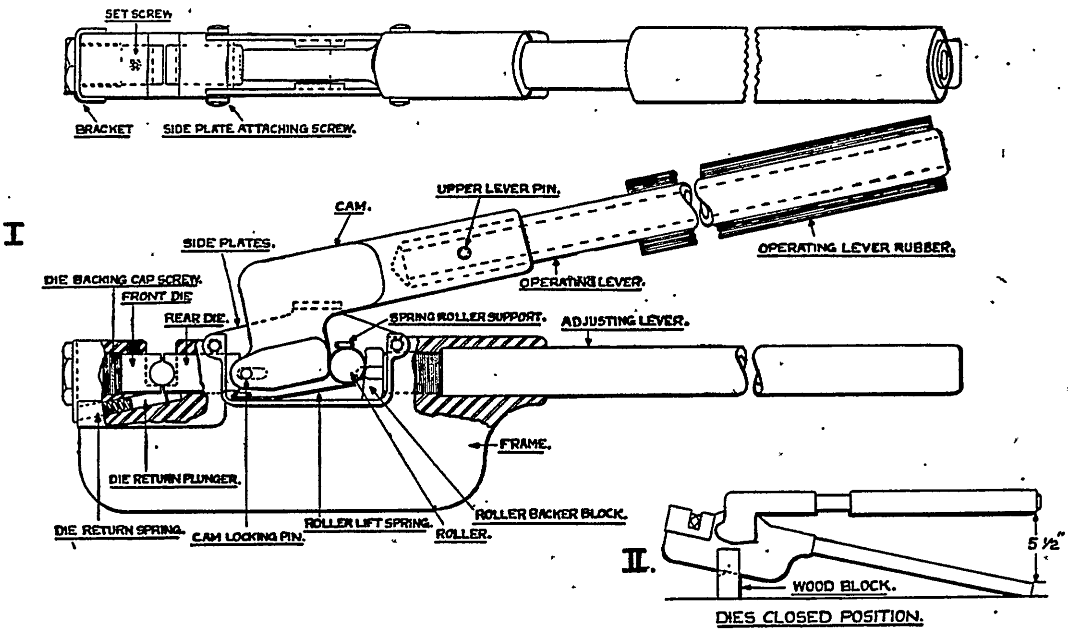


Fig. 1—Tru-loc cable end-fitting swaging machine

3. The machine can be used either on the bench or, if more convenient, on the aircraft with the cable *in situ*, and is particularly intended for use on the special control cables of certain aircraft where swaging is preferable to splicing. Some instances are detailed in the following list:—

(i) Gill controls
(ii) Throttle controls
(iii) Mixture controls
(iv) Airscrew pitch controls
(v) Carburettor heat controls
(vi) Aileron, elevator and rudder controls.

DESCRIPTION

Layout of machine

4. A sectional view of the swaging machine is shown in fig. 1. The steel frame has in its upper surface a recess, guarded by side plates, in which a cam can be rocked by means of its operating lever. The forward end of the cam is cylindrically shaped to engage a concave recess in the rear die against which it exerts a horizontal, forward thrust when the operating lever is pressed. The reaction to this thrust is taken by a roller which is held against the rear face of the cam by a flat spring, a roller backing-block, and a rotatable adjusting lever. The front die, held in position by a die backing cap screw and prevented from rotating by a setscrew, meets the swaging face of the rear die in a recess in the frame through which the work can be introduced. A die return plunger, spring-loaded, in an inclined cylindrical bore at the forward end of the frame, presses against the rear die and ensures that it returns with the cam after the working stroke is completed.

Interchangeable dies

5. A set of front and rear dies to suit cables of the following diameters is provided with each swaging machine:—

Dia. of cable	Die number	Cable strength
$\frac{1}{16}$ in.	24–M/25–M	5 cwt.
$\frac{3}{32}$ in.	26–M/27–M	10 cwt.
$\frac{1}{8}$ in.	28–M/29–M.	15 cwt.
$\frac{5}{32}$ in.	30–M/31–M	20 cwt.
$\frac{3}{16}$ in.	32–M/33–M	25 cwt.

Gauges

6. To guard against excessive squeezing of the cable and end fitting, a pair of plate gauges is supplied for each size of die. These gauges are marked "GO" and "NOT GO", and should invariably be used during the operation of the machine.

OPERATION

Setting up

7. The swaging machine when required in operation should be placed on a bench about 20 in. to 24 in. above floor level to enable the operator to apply the weight of his body on the lever to full advantage. The operating lever should be parallel with the edge of the bench, the frame with the dies being at the operator's left hand. This will bring the dies into the correct position for introducing and feeding the fitting to be swaged. A great increase in the speed of operation can be obtained if two operators are engaged, one to feed and rotate the fitting between the dies, the other to operate the handle.

8. The amount of squeeze transmitted to the dies is important. An adjustment which contributes to uniformity of results is provided in the form of the lower rotatable lever. Clockwise rotation of the adjusting lever forces the roller against the cam, lifting the operating lever and causing the dies to be brought together earlier in the downward, operating stroke. Anti-clockwise rotation of the adjusting lever allows the cam to settle lower, and the dies to meet later in the operating stroke. The correct adjustment is obtained when, with the dies together, a gap of $5\frac{1}{2}$ in. is measured between the ends of the operating lever and the adjusting lever (see fig. 1, Sketch II).

9. A wooden block is provided to support the frame of the machine. The block and the end of the adjusting lever are the only parts in contact with the bench during operation (see fig. 1, Sketch II).

Cutting the cable

10. During the swaging operation an elongation of the cable end fitting occurs. This should be taken into account when cutting the cable for existing conditions. The following allowances in length should be made for end fittings on cable assemblies, noting that two end fittings would double the amount to be deducted:—

For each end-fitting on	$\frac{1}{16}$ in. cable,	deduct	$\frac{1}{8}$ in.
,, ,, ,, ,,	$\frac{3}{32}$ in. ,,	,,	$\frac{1}{8}$ in.
,, ,, ,, ,,	$\frac{1}{8}$ in. ,,	,,	$\frac{3}{16}$ in.
,, ,, ,, ,,	$\frac{5}{32}$ in. ,,	,,	$\frac{7}{32}$ in.
,, ,, ,, ,,	$\frac{3}{16}$ in. ,,	,,	$\frac{1}{4}$ in.

Blind hole fittings

11. In fig. 2, Sketch I, the fittings marked Class A, B and D, have the cable hole drilled for a limited distance into the shank. It is important that the cable touches the bottom of the drill hole at the time of the first swaging operation. To ensure this the cable should be marked in accordance with the lengths given in the following table:—

Cable diameter	Depth of hole
$\frac{1}{16}$ in.	$1\frac{3}{64}$ in.
$\frac{3}{32}$ in.	$1\frac{17}{64}$ in.
$\frac{1}{8}$ in.	$1\frac{33}{64}$ in.
$\frac{5}{32}$ in.	$1\frac{49}{64}$ in.
$\frac{3}{16}$ in.	$2\frac{1}{64}$ in.

Note.—If the cable does not enter the hole to the point marked, the fitting should be examined to ensure that no foreign matter is present. If cleaning of the fitting fails to admit the cable to the full extent, the fitting should be rejected.

Clear hole fittings

12. The fitting marked Class C (see fig. 2, Sketch I) has the cable hole drilled right through the shank. The cable for this type of fitting should pass through the hole in the shank and extend beyond it by an amount equal to the diameter of the cable.

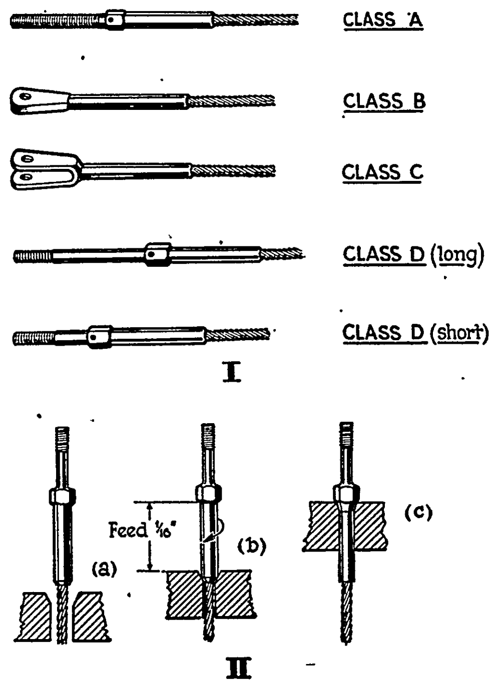


Fig. 2—Tru-loc swaged type terminals

Inserting dies

13. The following sequence of operations should be applied when inserting dies in the machine:—

(i) Remove die-backing cap-screw and bracket from front end of machine frame (see fig. 1.)

(ii) Apply heavy coating of extreme pressure grease (Stores Ref. 34A/54 or /72) to the outer surface and cam-end of rear die.

(iii) Insert the rear (long) die into the hole vacated by the die-backing cap-screw, making sure that the flat is on the underside.

(iv) Insert the front (short) die with the setscrew, the flat face being uppermost and the plunger groove downwards.

(v) Align the setscrew and the flat on the front die, and tighten setscrew.

(vi) Ensure that the die-return plunger and spring are in the inclined hole under the front die, then replace the bracket on the front end of the swaging machine.

(vii) Screw in and tighten the die-backing cap-screw in front of the machine.

(viii) Rotate the adjusting lever until the operating and the adjusting levers are $5\frac{1}{2}$ in. apart at their extreme ends (see fig. 1, Sketch II).

Examination of parts before swaging

14. The cable and end-fitting should be examined before swaging as follows:—

(i) Ascertain whether, if required, preliminary stretching of a flexible cable has been effected.

(ii) Measure the external diameter of the terminal shank, its length, the depth of hole and ensure that each connection is correctly mated to its particular cable.

(iii) See that the ends of the cable have been squarely cut and that the correct allowances has been made for stretching the fitting during swaging, as indicated in para. 10.

Swaging

15. With the swaging machine set up and the dies in position proceed as follows:—

(i) Insert the cable into the end-fitting.

(ii) Apply a few drops of oil to the cable and to the fitting to be swaged.

(iii) Open the dies by raising the operating lever.

(iv) Place the fitting and cable in the front die recess so that the end of the fitting is centred in the die. (See fig. 2, Sketch II (a).)

Note.—Always insert the end-fitting into the bell-mouthed side of the dies.

(v) Squeeze the end-fitting by pushing down the operating lever until the dies are completely closed.

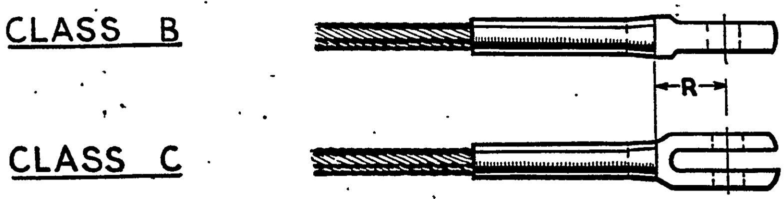
(vi) Open the dies by raising the operating lever sufficiently to rotate the end-fitting one quarter of a revolution and feed it $\frac{1}{16}$ in. into the dies. (See fig. 2, Sketch II (b).)

Note.—Where possible, rotate the end-fitting the opposite way to the lay of the cable. Otherwise, rotate the fitting one quarter of a revolution, in alternate directions, to each $\frac{1}{16}$ in. feed. Do not overfeed the end-fitting into the dies. To do so will call for a pressure in excess of the power range of the cam and lever.

(vii) Repeat operations (v) and (vi) until the correct length of shank has been swaged. Fittings marked Class A and D (see fig. 2) are swaged as far as the shoulder. The swaging lengths for Class B and C fittings are tabulated in fig. 3.

(viii) To finish the swaged tapered portion of the fitting, rotate and swage several time without feeding movement. (See fig. 2, Sketch II (c).)

(ix) When the swaging operation is completed, gauge the diameter of the cable end-fitting with the "GO" and "NOT GO" gauges supplied.



Cable dia.	Dimension R	
	Class B	Class C
$\frac{1}{16}$ in.	$\frac{21}{32}$ in.	$\frac{5}{8}$ in.
$\frac{3}{32}$ in.	$\frac{7}{8}$ in.	$\frac{3}{4}$ in.
$\frac{1}{8}$ in.	$\frac{29}{32}$ in.	$\frac{29}{32}$ in.
$\frac{5}{32}$ in.	1 in.	$\frac{31}{32}$ in.
$\frac{3}{16}$ in.	$1\frac{3}{32}$ in.	$1\frac{1}{8}$ in.

Fig. 3—Swaging lengths for Class B and Class C end fittings

Examination of parts after swaging

16. The cable and end-fitting should be examined after swaging, as follows:—

(i) If the shank of the fitting fails to enter the "GO" gauge, the amount of swaging is insufficient and further application of the swager should be made.

(ii) If the "NOT GO" gauge slips easily over the shank, it indicates over-swaging and consequent crushing or fracturing of the cable. In severe cases of over-swaging, both the cable and end-fitting should be rejected.

(iii) The increase in length of the fitting should be measured. This dimension will give an additional indication of the amount of swaging that has been applied. An insufficient increase in length suggests incomplete swaging, and undue increase in length suggests excessive swaging.

(iv) It should be ensured that the length of the cable in engagement with the shank is as originally intended. For blind-hole fittings the locating mark on the cable is used for this purpose.

(v) Notice that the lay of the cable is correct, and that the angle of the lay has not slipped during the swaging operation.

(vi) Measure the overall length of the cable assembly when tensioned by a load of 1 cwt. This should be to the length required in the installation.

(vii) Where possible subject the complete cable and end-fitting to a proof loading of 50 per cent of the ultimate strength of the cable.

Removal of dies

17. In order to remove the dies, turn the adjusting lever in an anti-clockwise direction until the operating lever and the adjusting lever come together, then remove the die backing nut and bracket from the front of the machine; loosen the setscrew above the front die and push both dies out of the machine with the die push-out rod provided.

SERVICING

General

18. The dies are the parts principally subjected to wear. A periodic examination should be made for scoring, pitting or corrosion of the working surface. The use of the plate gauges will show up any appreciable change that may take place in the profile of the dies.

Lubrication

19. It is important to keep the working surfaces of the rear die heavily coated with lubricant (Stores Ref. 34A/54 or /72).

20. The rear surface of the cam which contacts the roller should also be greased periodically and it should be ensured that all working parts are kept clean and free in operation.

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CHAPTER 8

TUBE BENDING MACHINES

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General

1. Tube bending machines are provided for use when bending metal tubing whenever there is a risk of the tube walls collapsing or rippling, a possibility which is greater for tubes of a light gauge when compared with the diameter, than with heavy gauge tubes of similar diameters. To prevent collapse of the walls of the tubing, the bending force and supporting pressure for a thin-walled tubing must be applied at a different position in relation to the bending point than for a thick-walled tube of the same outside diameter. As a result of this principle the pressure applied to the walls of thin tubing by means of a correctly designed tube bending machine is greater than that applied to the walls of thick tubing of the same outside diameter.

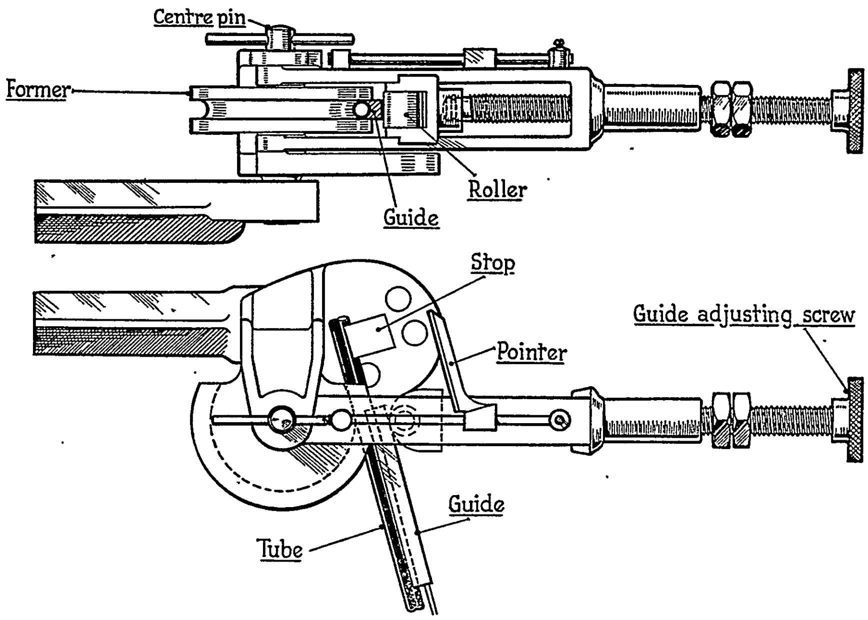

Fig. 1.—Tube bending machine, Type A2

Description

2. There are two types of bending machine in use in the Service, namely the A2 type (see fig. 1, Stores Ref. 3A/626) for bending tubes up to $\frac{7}{8}$ in. dia., and the larger C type (Stores Ref. 3A/642) for tube sizes from 1 in. to 2 in. dia. The two types are the same in principle, the major difference being that the operating lever of the C type is moved by a ratchet arm and pinion working on a circular rack which is mounted on a heavy cast-iron base. The A2 type is described in the following paragraphs.

3. The machine can be secured by bolts to the bench, or the underside of its base-plate may be gripped in a vice. Alternatively the hollow square-shaped lug provided may be held in a pipe vice.

Formers and guides

4. The machine is provided with a set of interchangeable circular formers, grooved to receive different diameters of tubing. The tube is forced round the former by means of a grooved guide which exactly fits the tube and former. A range of guides is provided to correspond with the range of formers. The following are the sizes of guides and formers provided with each type of tube bending machine:—

Machine type	O/d of tube	Outer radius of bend
Type A2 Stores Ref. 3A/626	$\frac{1}{4}$ in.	$1\frac{1}{4}$ in.
	$\frac{5}{16}$ in.	$1\frac{3}{8}$ in.
	$\frac{3}{8}$ in.	$1\frac{13}{16}$ in.
	$\frac{7}{16}$ in.	$2\frac{1}{8}$ in.
	$\frac{1}{2}$ in.	$2\frac{7}{16}$ in.
	$\frac{5}{8}$ in.	$2\frac{3}{4}$ in.
	$\frac{3}{4}$ in.	$3\frac{3}{8}$ in.
	$\frac{7}{8}$ in.	$3\frac{3}{4}$ in.
Type C Stores Ref. 3A/642	1 in.	$4\frac{1}{2}$ in.
	$1\frac{1}{8}$ in.	$4\frac{7}{8}$ in.
	$1\frac{1}{4}$ in.	$5\frac{1}{4}$ in.
	$1\frac{3}{8}$ in.	$5\frac{7}{8}$ in.
	$1\frac{1}{2}$ in.	7 in.
	$1\frac{3}{4}$ in.	$7\frac{3}{4}$ in.
	2 in.	$8\frac{1}{2}$ in.

5. From the above table it will be seen that each former provides for a mean radius of bend equal approximately to four times the diameter of the corresponding tube. The radius given may be regarded in each instance as the safe minimum for the diameter of tube concerned.

6. To remove and exchange the formers, the centre pin (see fig. 1) should be withdrawn and the former slid from between the forks of the bending lever arm. When replacing a former, care should be exercised to ensure that the centre pin is pushed right home before commencing bending operations.

7. Each guide is provided with a handle with which it can be conveniently inserted between the circular former and the roller (see fig. 1) after the tube to be bent has been laid in the groove of the former.

8. An adjustable stop (see fig. 1) is provided to withstand the thrust transmitted to the tube by the operation of bending. The position of the stop should be selected to suit the class of bend to be made.

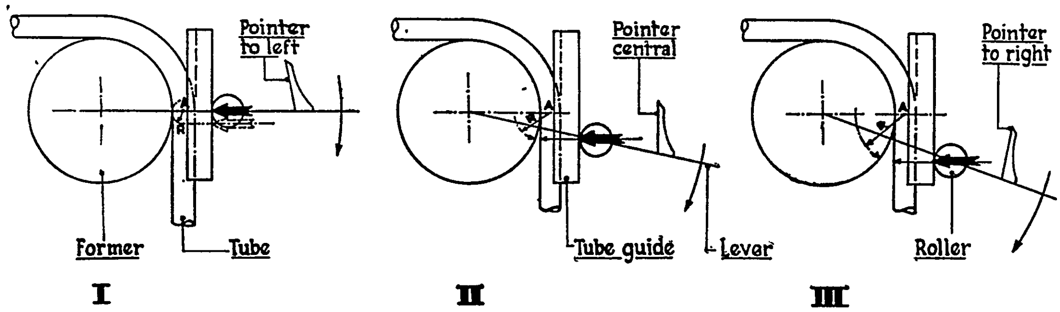

Fig. 2.—Roller settings for tubes of varying thickness

Operation

9. A roller is mounted in a slidable crosshead on the bending lever arm. Rotation of a knurled headed adjusting screw at the end of the lever causes the crosshead and roller to approach, or recede from, the guide and the former. The position taken up by the roller determines the point at which pressure will be applied to the tube (see fig. 2, Sketches I, II and III). A slidable pointer mounted on the bending lever arm, indicates the position of the roller in relation to the guide, tube and former in use on the machine. To use the pointer as an indicator of the roller setting it should be moved until its straight edge lies approximately over the centre of the tube to be bent. With the bending-lever arm pulled lightly towards the operator to take up any slack between the roller, guide, and tube to be bent, the angle of the pointer is noted in relation to the walls of the unbent tube. When the pointer is inclined to the left (see fig. 2, Sketch I) it indicates that the pressure applied to the tube through the roller and guide has approached the limiting position shown in fig. 2, Sketch I. In this position the radius R about which the tube will try to bend from the point A is a minimum and the force required to effect the bending is proportionately great. This is an extreme setting and is used for bending thin walled tubes without forming ripples on the inside radius of the bend. Fig. 2, Sketch III shows the roller withdrawn to allow the bending lever arm to swing forward sufficiently to tilt the pointer to the right. At this setting the radius R is large and the force required to bend the tube will be proportionately small, a condition suited to the bending of thick walled tubes which have less tendency to ripple or form flats. An intermediate setting, with the pointer lying parallel with the walls of the tube to be bent, is shown in fig. 2, Sketch II. This position will be correct for bending tubes with walls of average thickness. It should be noted that a setting similar to that shown in Sketch I should be used to prevent rippling of the inner radius, and the formation of flats on the outer radius of a tube; and that a setting similar to that shown in Sketches II or III should be used if undue squeezing of the tube occurs. The operation of bending must be effected by pulling evenly on the bending lever arm. The tube itself must not be assisted.

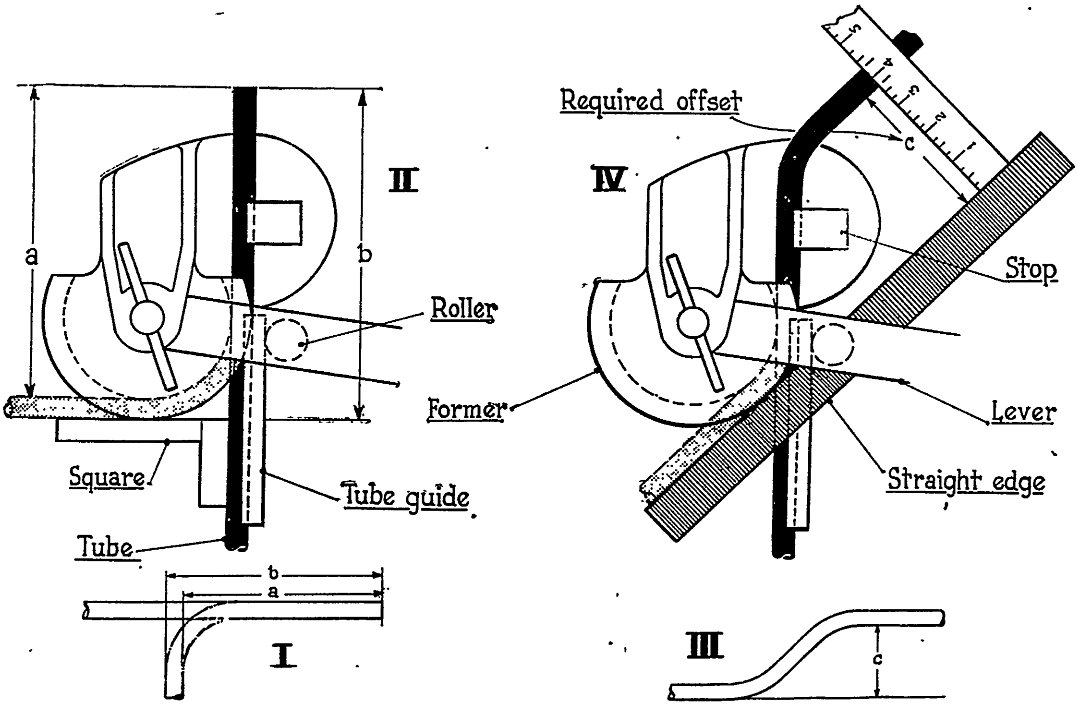

Fig. 3.—Bending tubes to measurements

Bending tubes to measurements

10. The U-section recess machined in the former is equal in depth to the diameter of the tube to be bent. This allows accurate bends to be made to specified dimensions (see fig. 3).

11. To bend a tube at a right angle so that the *outside* edge of the bent portion is a given distance from the tube end, this distance should be marked, with a pencil, on the straight tube at (b) (see fig. 3, Sketch I). With the stock of a set-square held against this mark, the tube should be inserted into the machine in a position such that the blade of the set-square touches the *outer* radius of the former (see fig. 3, Sketch II). In this position the tube will be bent to the required dimension.

12. To bend a tube at a right angle so that the *inside* edge of the bent portion is a given distance from the tube end, this distance should be pencil-marked, on the straight tube at (a) (see fig. 3, Sketch I). With the stock of a set-square held against this mark the tube should be inserted into the machine in a position such that the blade of the set-square touches the *inner* radius of the former.

13. To offset a tube to a specified distance by making adjacent left and right-hand bends (see fig. 3, Sketch III) the first bend (usually of 45°) is made on the bending machine in the normal way. Replace the tube in the machine in the position shown in fig. 3, Sketch IV, and lay a straightedge tangentially to the outer radius of the former and parallel with the part of the tube furthest from the operator. Adjust the tube until the distance between the straightedge and the parallel part of the tube is equal to the required offset (c). At this setting the second bend should be made.

14. When several tubes are to be offset to the same dimensions, the first tube should be marked where it touches the stop when set in position for the completion of the bend (see fig. 3, Sketch IV). Using this tube as a template, all the remaining tubes should be similarly marked after the first bending operation. No further measurement will be required.

Servicing

15. The machine should be kept clean and free from rust or corrosion. The roller should be lubricated and kept free to revolve in its mounting; the crosshead should be lubricated where it slides along the forked bending lever; oil should be applied to the threads of the roller adjusting screw. Guides and formers should be kept clean and readily available for use when required.

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CHAPTER 9

CHOBERT RIVETING TOOLS

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General

1. The Chobert riveting tool, type A (*see* fig. 1) is a single-acting, hand-operated machine which is used in the Service for minor riveting operations during the repair of riveted components of aircraft. Special types of hollow rivets are used with the machine, one rivet being inserted and headed at a time. It weighs approximately $2\frac{1}{2}$ lb. and has an overall length of 15 in. and is specially suited for use when only one side of the work is accessible, or in positions which are difficult of access. Interchangeable fittings are provided, by means of which the range of rivet sizes handled by the machine is extended; a detachable flexible extension is also provided in order that rivets can be fitted in positions where the riveting tool cannot be held in line with the axis of the rivets.

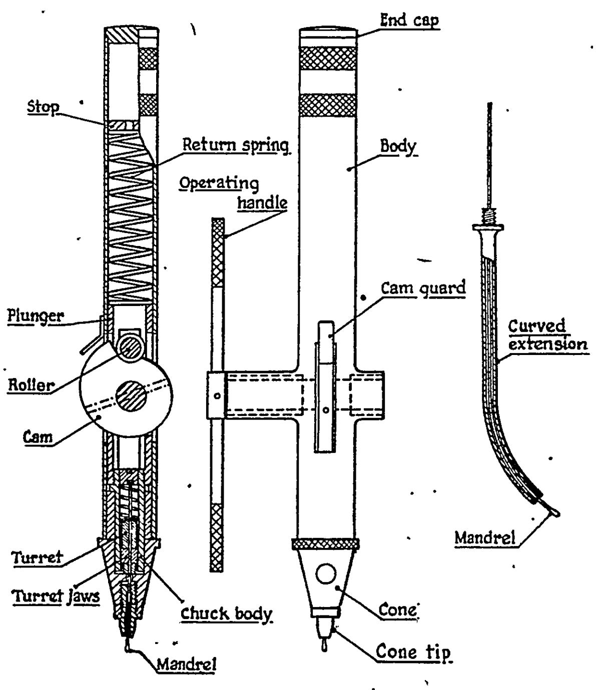


Fig. 1.—Chobert riveting tool, Type A

Description

2. The tool consists of a tubular body, knurled on the outside for convenience in holding, in which a cam-operated spring-loaded plunger is housed. The cam is fixed to a spindle mounted transversely on the body, a handle being provided on the spindle for the operation of the cam which engages with a roller attached to the upper end of the plunger. At the lower end of the tool, a chuck and cone are fitted to the plunger and body respectively, the cone being screw-threaded to receive the cone tips or alternatively

the extensions. The end fittings are interchangeable and are made in varying sizes to fit the rivets which are the deciding factor in the selection of the appropriate fittings to be used. Held within the chuck body are a turret and hardened-steel turret jaws and, when working on different sizes of rivets, these items and the cone tip require exchanging accordingly. The turrets differ only in the size of the bore which is larger for the $\frac{3}{16}$ in. to $\frac{1}{4}$ in. range of rivets than for the $\frac{1}{8}$ in. to $\frac{5}{32}$ in. rivets. The hardened-steel turret jaws are serrated and are carried by the turret in pairs, which are made in sizes corresponding to the three sizes of mandrel shanks. The mandrels have an enlarged pear-shaped end which, when drawn by the riveting tool through a rivet of special construction, forms a head on the rivet and clinches it; a single turn on the tool handle in a clockwise direction completes the operation.

Chobert rivets

3. The rivets inserted by means of the Chobert riveting tool are hollow and have a stepped or tapered bore which is capable of being expanded by means of the tool, so forming a head on the end of the rivet. The rivets are made in various lengths and diameters and have either snap or countersunk heads, the lengths of snap-head rivets being measured from under the head and countersunk head rivets over the head, in sixteenths of an inch, whilst the diameters are $\frac{1}{8}$ in., $\frac{5}{32}$ in., $\frac{3}{16}$ in. and $\frac{1}{4}$ in. In instances where additional shear strength or water-tightness is required, sealing pins, of the same materials as the rivets, are provided. The following details will be found useful when determining the sizes of drills and mandrels for use with the rivets:—

(i) *Rivet lengths.*—The correct length of rivet for $\frac{1}{8}$ in. and $\frac{5}{32}$ in. dia. taper-bore rivets is equal to the total thickness of materials to be riveted, plus 0·10 in. ± 0·032 in. For rivets of a larger diameter, the length should be equal to the thickness of the materials, plus a minimum of half the diameter of the rivet up to a maximum of one diameter. In the stepped bore type of rivet, the length is equal to the thickness of the materials to be joined, plus 0·08 in. ± 0·004 in.

(ii) *Drill and mandrel sizes.*—Chobert rivets are made with a tolerance of + 0·002 in. oversize and in order to obtain the correct clearance for rivets of various sizes the sizes of drills should be used as given in the following table together with the correct size of mandrel:—

Dia. of rivet	*Drill size* S.W.G.	Inches	*Mandrel dia.*
$\frac{1}{8}$ in.	No. 10	−0·128 in.	0·087 in. ± 0·001 in.
$\frac{5}{32}$ in.	No. 8	−0·160 in.	0·106 in. ± 0·001 in.
$\frac{3}{16}$ in.	No. 6	−0·192 in.	0·141 in. ± 0·001 in.
$\frac{1}{4}$ in.	No. 3	−0·252 in.	0·187 in. ± 0·001 in.

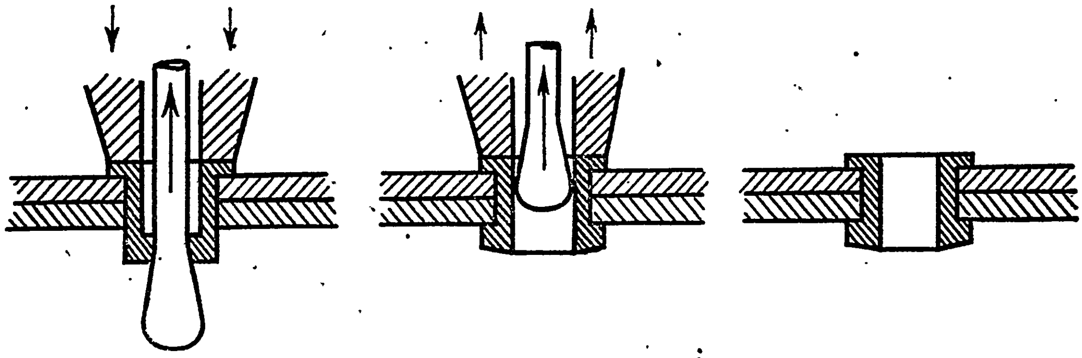
Length of mandrels—

For use with cone tip ... ... $3\frac{3}{8}$ in.

For use with 6 in. curved extension ... ... 9 in.

Operating the riveting tool

4. To operate the riveting tool, the appropriate sizes of turret, turret jaws, cone tip and mandrel for the rivet to be inserted, should be selected and fitted to the tool. The mandrel should be inserted or removed when the operating handle is in line with the body of the tool, at the beginning of the stroke; in this position the turret is in contact with the cone by means of which it is depressed, so releasing the turret jaws. When inserting the mandrel the appropriate rivet should first be



I.—Press tool downward II.—Pull tool away from work III.—Completed rivet

Fig. 2.—Formation of head on stepped-type rivet

threaded over the stem and the head of the mandrel lubricated with the special paste. The rivet should now be inserted in the rivet hole (see fig. 2) and pushed well home; the holes should be in alignment and on no account should an attempt be made to lever holes into alignment by means of the mandrel or the rivet.

5. End pressure on the rivet should be maintained whilst holding the tool steady and square to the face of the work, meanwhile turning the tool handle in a clockwise direction, then, when it is felt that the mandrel is gripped by the turret jaws and is being withdrawn through the rivet, the tool should be pulled away from the work during the remainder of the stroke, otherwise, when at the completion of the full stroke of the tool handle, the mandrel would strike the work and damage it. During the operation of the tool the following points should be observed:—

(i) Lubricate the head of the mandrel before threading the rivet on to the stem.

(ii) Keep the mandrel head polished, free from scores, and clear of metal swarf (see para. 7).

(iii) Ensure that the turret protrudes by the correct amount (see fig. 3).

(iv) Lubricate the taper bore of the chuck body to prevent the jaws from sticking.

(v) If the mandrel slips unduly, examine the turret-jaw serrations and the mandrel stem for wear, also check the turret protrusion.

(vi) The length of a working stroke is ½ in. and if the mandrel head projects for a greater distance, it will not be pulled clear of the rivet. In the event of a rivet being longer than ½ in. one working stroke should be completed, after which the tool should be pushed forward to enable the mandrel to be gripped higher up the stem, when a second turn of the handle will withdraw the mandrel completely. On the other hand, if the head of the mandrel does not project sufficiently, it will damage the cone tip at the end of the working stroke.

Maintenance

6. The riveting tool should be kept clean and in a serviceable condition and lubricated frequently when in use. New parts should be fitted when wear is indicated by slip and lost motion in the working stroke. The tool should be partly or wholly dismantled, according to its condition, then cleaned and examined, appropriate action being taken as required to remedy the defect. Details of maintenance operations required to remedy specified defects are given in the following sub-paras.:—

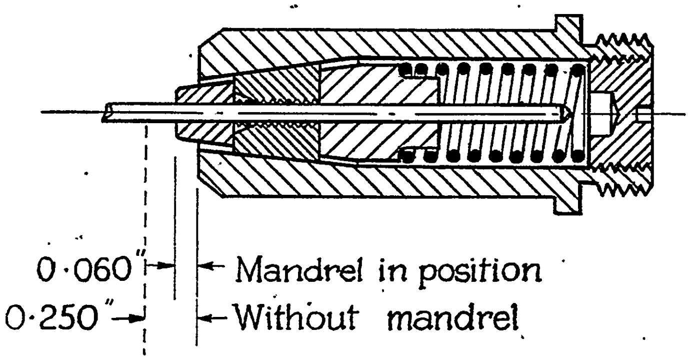


Fig. 3.—Correct turret projection

(i) *Dismantling.*—In order to dismantle the tool completely, the cone should be unscrewed from the body by hand and the chuck removed from the plunger. A serviceable mandrel should be inserted in the chuck, the turret checked for protrusion (see fig. 3), and worn parts noted for replacement purposes, after which the end plug should be unscrewed from the chuck, and the chuck spring, turret and turret jaws extracted. The plunger should not usually be removed, except for wear and breakages; for this operation, the sides of the cam at the largest radius should be gripped in a vice, the jaws of which are protected by tin or copper clams. The taper pin which secures the cam to the shaft should then be removed by means of a fine flat-nosed punch; the cam shaft, the plunger and its spring can now be withdrawn.

(ii) *Cleaning, examining and repairing dismantled parts.*—The dismantled components should be cleaned in paraffin and examined for wear. The turret-jaw teeth should be cleaned by means of a steel-wire brush, ensuring that they are free from particles of metal and, if it is seen that the teeth are badly worn, the jaws should be replaced by new ones. The jaws should be checked for side and end clearance which should be 0·006 in. and 0·020 in. respectively; excessive clearances will cause the jaws to stick in the chuck body. The upper edge of the jaws should be examined and if worn sharp, it should be stoned down to a slight radius to obviate any tendency for it to score the taper bore of the chuck body. The central hole in the cone tip should be slightly countersunk if worn to a sharp edge by the mandrel head. The taper bore of the chuck body should be polished free from corrosion and scores.

(iii) *Re-assembling.*—The riveting tool should be re-assembled in the reverse order to that given for dismantling. When the taper pin has been replaced in position in the cam, the ends should be smoothed off by means of a dead-smooth file or an oilstone. Care should be taken when screwing the chuck body into position, it should be screwed home by hand only, otherwise damage to the webs of the plunger will ensue. All working parts should be lightly lubricated when they are being assembled.

Mandrels

7. The mandrels should be kept in a servicable condition, the heads polished and free from scores. The heads should be polished in a revolving drill-chuck using a piece of fine emery cloth; the head should not be reduced to more than 0·005 in. undersize, and only that part of the head should be polished where scoring or swarf is present. The mandrel stem is produced during manufacture with a waved surface, in order that the turret jaws may take a firm grip on the mandrel during the working stroke; in some instances new mandrels may be slightly oversize on the stem and some difficulty will be experienced in extracting them. A mandrel will also be difficult to remove if the cone has become partly unscrewed from the body; in such instances the cone should be screwed into the body before attempting to remove the mandrel. Mandrels should always be extracted from the chuck by hand; pliers, etc., must not be used.

8. Mandrels are made of such a length that the end abuts against the plug in the chuck body, leaving the correct length projecting at the head. If for any reason a mandrel is shortened there is a danger of the head being withdrawn too far into the cone tip, where it will become wedged or broken. The end of the mandrel stem should be ground to a point at an angle of 60° when there is any difficulty in inserting it in the chuck.

Curved extensions

9. Curved extensions should be kept clean in the bore and lubricated periodically. They are normally curved to a 20 in. radius, and if bent more acutely, increased breakages of mandrels will result.

Chobert riveting tool, type R

10. The Type R riveting tool (see figs. 4 and 5) operates on the same principle as the Type A, but whereas the latter is only single-acting, the Type R has automatic rivet-feed. The number of rivets loaded at a time depends upon the length of the rivets required for use, a total length of $11\frac{3}{4}$ in. being available on a mandrel $18\frac{3}{4}$ in. in length for the accommodation of rivets placed end to end,

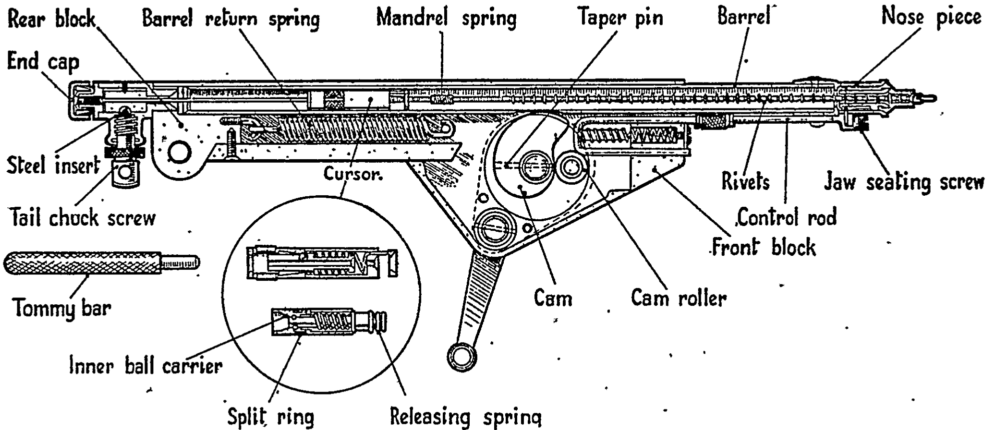


Fig. 4.—Early pattern Type R Chobert riveting tool

thus 94 rivets, $\frac{1}{8}$ in. in length, or 62 rivets, $\frac{3}{16}$ in. in length, may constitute one full load. The maximum length of single rivets handled by the tool is $\frac{1}{2}$ in. and the maximum diameter $\frac{1}{4}$ in. For rivets up to $\frac{3}{16}$ in. dia. it is possible on straightforward work to maintain a continuous production speed of over 1,000 rivets inserted per hour; with $\frac{1}{4}$ in. dia. rivets, however, this speed is reduced somewhat.

Rivet mandrel, and drill sizes for Type R riveting tool

11. The sizes of rivets, mandrels and drills to be used for riveting operations with the Type R tool are similar to those given in para. 3 for the Type A.

Description of Type R riveting tool

12. The Type R riveting tool comprises a metal casing which houses a cam-operated sliding

barrel, driven through a three-to-one reduction gear operated by hand from a cranked handle. A mandrel on which the rivets are carried passes through the barrel, where it is held in a chuck anchored at the rear end of the casing. At the front end of the barrel a two-jaw chuck is secured which slides on the mandrel with a rivet in front of the jaws of the chuck, when the tool is operated. Since the barrel moves in and out of the casing to which the mandrel is anchored, it will be seen that the rivet is pushed forward as the barrel moves outward and, the mandrel head being enlarged, the rivet is expanded as the rivet passes over the head.

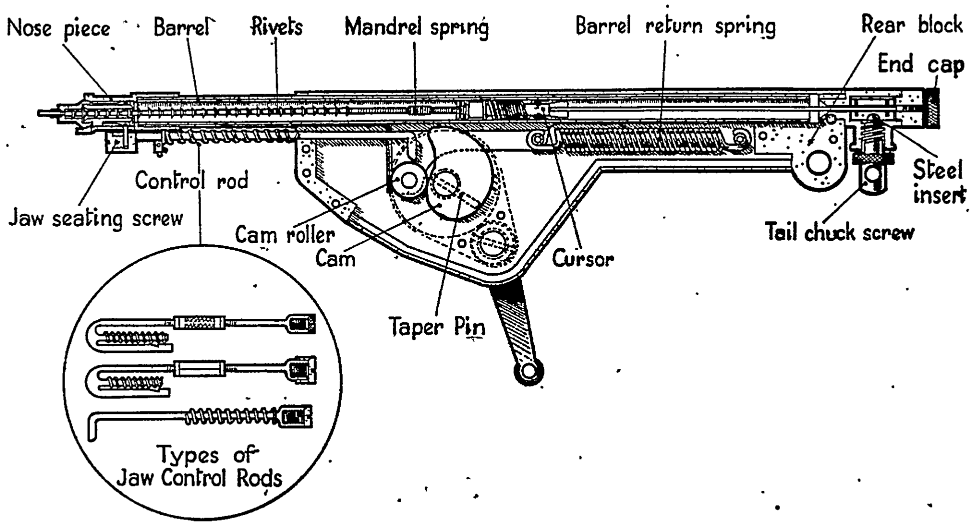


Fig. 5.—Type R Chobert riveting tool

13. A control rod (see inset in fig. 5) engages with the front jaws and with the barrel operating cam, so that the front jaws are opened to allow another rivet to feed forward on the mandrel by the action of a spring-loaded cursor or free-wheel slide. The cursor (see inset in fig. 4) is a sliding fit in the barrel and is free to be carried forward by any forward movement of the barrel, but is restrained by the gripping action of three balls in a tapered bore of the cursor body when the barrel returns under the action of its return spring.

14. The front chuck has a conical seat formed in the end of the barrel to accommodate the two jaws which fit over a guide-tube for the rivets (see fig. 6), the whole being encircled by a "figure 8" spring which serves to open the jaws when they leave the conical seat, and also provides a means of attachment to the control rod.

15. The rear chuck is operated by a square-headed screw, the head of which is drilled for the reception of a tommy bar. The inner end of the screw is fitted with a hemispherical hardened steel insert which engages with the jaws which are retained endwise in the tail piece by means of a screw-in plug. A handle is provided at the tail end of the tool by means of which it can be steadied whilst the crank handle is rotated.

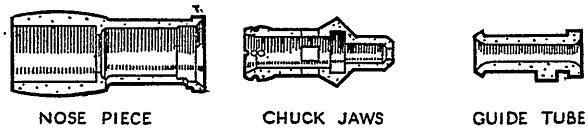


Fig. 6.—Details of front jaws

Preparation for riveting

16. After the rivet holes have been drilled and any burrs and metal cuttings removed from the holes, particularly between the sheets to be riveted, the work should be held together by means of sheet grippers. The work should be arranged with the rivet holes horizontal, but if this is not possible then the work should be positioned on a bench so that the operator can steady the butt of the vertically held tool against his shoulder at a convenient working height. Before the riveting tool can be used it should be loaded with rivets of the correct type, length and diameter to suit the

work in hand, and for this purpose the correlative mandrel, spring jaws, and guide tube should be selected and fitted to the tool as detailed below.

Removing and replacing jaws

17. The jaws are held together by a "figure 8" spring; they fit round the rivet guide tube and are marked to the diameter of the rivet with which they are intended to be used. The head of the rivet should be an easy fit in the guide tube, and for this reason guide tubes for use with snap or countersunk rivets respectively are different for $\frac{1}{8}$ in. dia. rivets.

18. To remove the jaws from the tool, the mandrel must first be removed (see para. 30) then, holding the crank handle in the position where the front jaws are just opening, the jaw-seat screw should be removed. The halves of the jaws should now be gripped through the aperture between them by the thumb and forefinger and pulled outward until the loop of the "figure 8" spring is seen to be out of the cup at the end of the control rod. The jaws should then be tilted (see fig. 7) when they may be readily removed.

19. To fit the jaws, the correct size of jaws and guide tube should be selected and, keeping the jaws open, they should be inserted into the nose piece by tilting them at an angle and then centralising them, when the loop of the "figure 8" spring should be seen to enter the cup at the end of the control rod. The jaw-seat screw should now be inserted loosely and the crank handle rotated clockwise to ensure that the jaws are seating correctly, then tighten the jaw-seat screw.

Loading the mandrel

20. The mandrel of the size to suit the rivets should be threaded with rivets with the rivet heads remote from the mandrel head to a length of not more than $11\frac{3}{4}$ in. After loading the mandrel with rivets a small quantity of lubricating paste should be smeared on the mandrel, and the rivets moved up and down with a rotary motion to ensure that the bores of the rivets are evenly lubricated. This lubrication of the mandrel is essential to prevent swarf building up on the head, so increasing the effort required to broach the rivets and resulting in mandrel breakages.

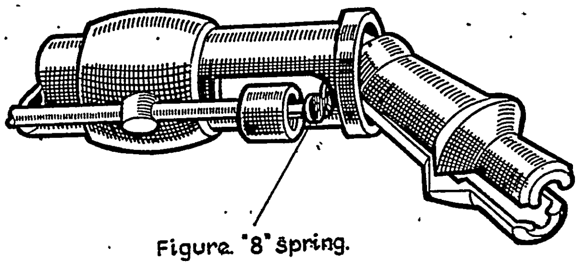


Fig. 7.—Removing front jaws

21. After lubricating the mandrel spring, it should then be placed over the tail end of the mandrel down to the rivets. The spring should slide freely on the mandrel without falling off; if the spring is too slack it should be bent slightly to make it grip the mandrel more firmly; on the other hand when the spring is too tight it should be straightened or exchanged for another one. If the larger end of a spring is distorted it should be rejected and a new one fitted, otherwise it will damage the releasing spring.

22. Springs for mandrels used with $\frac{3}{16}$ in. and $\frac{1}{4}$ in. dia. rivets have ends of the same diameter, but those for $\frac{1}{8}$ in. and $\frac{5}{32}$ in. dia. rivets have a larger diameter at one end. Springs for use with $\frac{1}{8}$ in. dia. snap-head rivets have a smaller intermediate collar than those used with countersunk rivets.

Fitting a loaded mandrel

23. To fit a loaded mandrel in the riveting tool the rear jaw-tightening screw should be slackened a quarter of a turn by means of the tommy-bar provided, then, holding the tool by the hand-grip, the crank handle should be gently rotated in an anti-clockwise direction until it will not turn any further, thus opening the jaws. The riveting tool should now be held in the left hand, the barrel being level with the operator's chest and inclined towards his face. With the tool in this position the tail of the loaded mandrel should be inserted through the partly opened jaws and through the central hole in the cursor. When the mandrel spring makes contact with the cursor, resistance is felt which should be overcome to force the cursor down the barrel. The tail of the mandrel is pushed through the hole in the end of the barrel into the chuck jaws.

24. The mandrel is correctly positioned in the tool when the jaws close approximately $\frac{3}{64}$ in. behind the head of the first rivet. At this position the crank handle should be rotated a quarter of a turn in an anti-clockwise direction and back again to ensure that the jaws open and close freely over the head of the first rivet. When the mandrel position has been adjusted correctly the rear jaw-tightening screw should be tightened firmly; if the mandrel slips, undue force should not be used but the tail jaws should be examined to ascertain whether they close freely or not, or for any damage sustained.

Operating the Type R riveting tool

25. With the work set up as described in para. 16, and the riveting tool loaded as described in paras. 20 to 24, the actual riveting operation may be commenced. For this purpose, when operating the tool in a horizontal position, it should be steadied by holding it against the left side of the operator, the left hand holding the hand grip. If, however, it is found to be more advantageous to arrange the work in a horizontal position, the operator should stand well over the work so that he can steady the butt of the tool against his shoulder.

26. It is of great importance to see that the tool is held normal to the surface being riveted; If the rivet is broached and the tool is not held firmly and squarely to the work there is a danger of breakage of the mandrel head as well as a badly formed rivet.

27. Before inserting the rivet in the hole the riveting tool handle should be rotated about a quarter of a turn in a clockwise direction to take up the play between the end of the jaws and the head of the rivet. This amount of a quarter of a turn is given as a guide and it may vary slightly with the type of rivet used; if the handle is taken too far expansion of the rivet will occur and this must be avoided.

28. The rivet should be inserted and pushed well down in its hole and, with the tool held firmly and squarely, the handle should be turned clockwise until the mandrel head has been pulled through the rivet; immediately resistance ceases, the tool should be withdrawn from the face of the work, otherwise damage to the mandrel and the work will be sustained when the head re-emerges.

29. When the riveting tool is away from the face of the work the crank handle should be rotated through two more complete revolutions, during which the jaws open, permitting the next rivet to emerge and the jaws to close again. The tool is then ready for the next hole, the cycle being repeated until the mandrel spring is seen to be emerging from the jaws, then the mandrel requires reloading.

Removing the mandrel

30. In order to remove an empty mandrel or one fully or partly threaded with rivets, the jaw tightening screw should be unscrewed a quarter of a turn by means of the tommy bar provided. The jaws should not be opened too much or the mandrel will not centralise itself when being replaced. The tool should be held by the hand-grip and the crank handle rotated in an anti-clockwise direction until it will not rotate any further, thus opening the jaws. The crank handle should be held in this position by the thumb of the left hand, and the mandrel withdrawn by pulling the head forward, pulling with it the cursor until the releasing spring (mounted on the end of the inner ball carrier) pushes against the restricted portion of the nose piece. The mandrel should then come away freely, but if not, do not persist in pulling; push it back a little way instead and then, giving the mandrel a slight twist, pull again.

Note.—The head of the mandrel must not be gripped by pliers or it will be damaged.

Notes for the operation of the riveting tool

31. To operate the Type R riveting tool as efficiently as possible the mandrel should be supplied to the operator already threaded with rivets and lubricated correctly. The mandrel head should be kept well polished and free from scores and swarf. Swarf is the result of the softer metal of the rivets building up on the mandrel head at the points of extreme pressure during the broaching operation, and should be removed by polishing the head of the mandrel by means of fine emery cloth while the mandrel is mounted in a lathe or drilling machine chuck. The head must not be reduced in diameter by more than 0·003 in.

Note.—The riveting tool handle must not be rotated in an anti-clockwise direction except as detailed in preceding paragraphs for specific purposes.

SERVICING THE TYPE R RIVETING TOOL

General

32. The riveting tool should be handled carefully, kept clean, and lubricated periodically and, provided that the operating instructions given in the preceding paragraphs are followed, very little other maintenance will be required. The faults detailed below, together with their causes and

remedies may, however, be found useful when the tool has been in use for some time or has been misused or damaged.

Defective automatic rivet feed

33. The rivets may fail to feed forward for a variety of reasons, a number of which are detailed below, with suggestions for rectifying the faults as they arise:—

(i) *Rivets tight on mandrel.*—This defect may be caused by lack of lubrication on the rivets and mandrel, or a bent mandrel. The remedy is obvious.

(ii) *Incorrect guide-tube for rivet head.*—It should be ensured that the correct guide-tube is fitted, as these are only to be used for countersunk or snap-head rivets of the same respective diameters. If the wrong size of guide-tube is fitted, change the jaw assembly and fit the correct guide-tube.

(iii) *Cursor choked with dirt or metal swarf.*—It may be possible to remedy this fault by washing the part in paraffin, at the same time ascertaining that the plunger is free in the body, and thus allowing the balls to rise and fall in the tapered portion of the cursor body. If it is found necessary to remove the cursor, the light-alloy handle and four short setscrews securing the tail assembly should be removed; it will then be found possible to withdraw the tail bracket and push out the cursor from the exposed end of the barrel, for which purpose the mandrel may be used. To replace the cursor, the above procedure should be reversed, taking care to see that the split ring is retained in its groove when the cursor body enters the barrel.

(iv) *Split ring detached from cursor body.*—This condition may be caused by attempting to load too many rivets in the mandrel; the total length occupied by rivets should not exceed 11¾ in. The end of the barrel has a wide chamfer into which a split ring should be guided if it should at any time be pushed clear of the barrel.

(v) *Cursor too slack in barrel.*—If the cursor is too slack in the barrel, this will be caused by a weak split ring, and can be remedied by fitting a new and stronger split ring. For this purpose the cursor must be removed as already detailed in (iii), the new ring fitted, and the whole re-assembled in the reverse order.

(vi) *Damaged or worn balls.*—If the rivet feed is defective as a result of wear or damage to the balls, these (of which there are three) should be replaced by new ones. To do this, first remove the cursor as detailed in (iii), then unscrew the cursor release spring and push the ball carrier out to the full extent. Remove the defective balls and replace by new ones held in position by means of petroleum jelly or yellow grease, after which re-assemble in the reverse order.

(vii) *Damaged barrel.*—If the barrel is damaged it should be exchanged for a new one, together with a new cursor and split ring, if these parts have also been affected, although it may be possible to make them serviceable by the removal of any burrs, etc., that would otherwise score the new barrel. In order to exchange the barrel for a new one, the front jaws and the tail assembly should be removed as described in (iii). The split pin and the six setscrews, together with the front block, should be removed, when it will be possible by means of a hook to lift the barrel return-spring free from its anchor pin; this anchor pin should not be removed on any account. It should now be possible to remove the barrel from the front end, but it may be found necessary to rotate the operating cam slightly to clear the return-spring. *The cam must not be rotated when the front block or the rear block is removed and the spring is still in position, or the barrel will be damaged.* The return-spring, cam roller, pin, and nose-piece should now be transferred to the new barrel, and the riveting tool assembled in the reverse order to that given for dismantling.

Failure of barrel to move forward when handle is rotated

34. This defect is caused by the shearing of the taper pin which secures the cam to the shaft, and a new pin must be fitted. To extract the defective pin, the dome nut and cranked handle should be removed; a slot is provided at the opposite end of the shaft to assist in unscrewing the domed nut. Next, the gear case, secured by two long setscrews, should be removed, after which the barrel should be dismantled as detailed in para. 33 (vii), then the shaft and cam can be withdrawn and the sheared portions of the taper pin punched out. When the new pin is fitted it should be ascertained that it is a good fit in the taper and, after it has been tapped home, the pin should not protrude at either end; the pin can be punched in or out through the opening left by the removal of the front block.

Sticking jaw-control rod

35. A sticking jaw-control rod may be the result of (*a*) wrongly adjusted jaws, (*b*) damaged control rod, (*c*) weak or damaged springs. The remedy for (*a*) is re-adjustment of the jaws. A damaged control rod (*b*) is usually caused by forcing the handle in an anti-clockwise direction; and

requires the rod to be either strengthened or, if badly damaged, replaced with a new one. For either purpose, the rod should be removed. A defective control rod spring (*c*) also entails the removal of the control rod, when the replacement spring can be slipped over the bent end of the rod. After dismantling for the defects (*b*) or (*c*) the riveting tool should be assembled in the reverse order to dismantling.

Sticking barrel

36. Sticking of the barrel is caused by damage sustained through dropping the tool, or by otherwise denting the casing. If any such damage has occurred the tool should be dismantled as far as necessary and the dents or high spots removed.

Shearing or bending of the mandrel at tail end

37. When this fault appears it may be caused either by the mandrel not centring in the jaws or by damaged jaws. In both cases the tail cap must be removed and the tail jaws examined to see that they operate correctly and are not closing on broken portions of the mandrel. Broken jaws should be replaced by new ones and bent mandrels straightened.

Slipping mandrel

38. If normal tightening of the rear jaw-tightening screw fails to hold the mandrel an attempt should not be made to effect a cure by overtightening; the jaws should be dismantled and examined. The jaws may fail to grip the mandrel tightly enough and allow slip to take place, for one or more of the following reasons:—

(i) *Undersize rivet holes.*—If the rivet holes in the work are undersize, excessive strain is imposed on the mandrel in broaching the rivet. It should be ensured that the holes are of the correct size as indicated in para. 3 (ii).

(ii) *Lack of lubricant.*—The mandrel and rivets should be lubricated as detailed in para. 20, using the correct high-pressure lubricating paste.

(iii) *Defective jaws.*—Worn or broken tail jaws will cause mandrel slip, and the only remedy is to remove the damaged jaws and replace by new ones.

(iv) *Defective insert pin.*—A damaged insert pin should be replaced by a new one and to do this the tail cap and jaws should be removed, after which the insert pin should be driven out of the jaw tightening screw by punching down through the centre of the screw, when the pin will drop out into the jaw housing. *An attempt should not be made (for any purpose) to remove the jaw tightening screw.* A new pin should be held over the end of the screw by a pair of pliers and punched back through the hole in the tail jaw housing. When this operation has been completed, assemble the tail jaws and replace the tail cap in position.

Riveting tool creaks when in operation

39. When obvious sounds of distress come from the tool when in operation, this may be due to a variety of reasons, of which any of the following may be responsible:—

(i) Rivets too hard.

(ii) Rivet holes undersize.

(iii) Rivet too short.

(iv) Lack of lubricant on mandrel.

(v) Mandrel head rough or scored.

(vi) Swarf on mandrel head.

Removal of jaw tightening screw

40. Type R riveting tools after Serial No. 860 may have the jaw tightening screw removed and, to do this, the tail assembly should be removed and dismantled as far as possible. The rivets securing the tail jaw housing should now be removed and the housing slipped off the tail block, after which the jaw tightening screw can be exchanged for a new one. The riveting tool should then be assembled in the reverse order to that given for dismantling. The new rivets fitted during this operation should be high tensile steel, as soft iron rivets will not stand the strain, and undue stress would be thereby imposed on the welded joints of the tail jaw housing.

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AIR MINISTRY
May, 1944

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CHAPTER 10

MEASURING INSTRUMENTS AND APPLIANCES

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General

1. The instruments and tools described in this Chapter are in general use throughout the service and, with a few exceptions, present no difficulty in manipulation. Certain instruments demand considerable skill in application, and a short description of each instrument is given to enable personnel to refresh their memories regarding the principles of construction of the instruments before using them. The descriptions and illustrations are not to be taken as authority for dismantling precision instruments. Adjustments should only be undertaken in exceptional circumstances and when experienced personnel and full facilities are available.

2. The accuracy of many contact measurements is mainly dependent upon the human element, i.e. the sense of touch or "feel". The latter can only be cultivated by continual practice in the correct manner of using the instrument. This sense of touch is most prominent in the finger-tips and therefore it is essential that all measuring instruments are held by the fingers wherever possible and in such a way that the finger tips are employed to bring the instrument in contact with the item being measured. It is important to remember that gripping an instrument tightly will greatly reduce the sensitiveness of the touch.

3. Some precision measuring instruments resemble each other in construction but, although they provide they same degree of accuracy,are graduated differently. It is essential that the operator observes certain precautions before using such instruments in order to avoid serious errors when interpreting the scale readings. As an example, some vernier calipers have the main scale marked in fortieths of an inch and the vernier scale marked with 25 graduations, whilst other vernier calipers have the main scale marked in fiftieths of an inch and the vernier scale marked with 20 graduations. (See para. 22.)

4. A large number of measuring instruments incorporate sliding members; the accuracy of such instruments depends upon the sliding member and the stationary member remaining parallel, or in some instances at right angles to one another. Burrs are soon formed on the corners of the slides, etc., if these instruments are allowed to come into forcible contact with other tools; this necessitates great care in handling, otherwise the instruments will give inaccurate results.

5. The majority of precision measuring instruments are originally supplied in cases or boxes and it is very desirable that these delicate instruments should be replaced in their respective containers immediately after use. If the instruments are not in continual use, it is desirable to coat them lightly

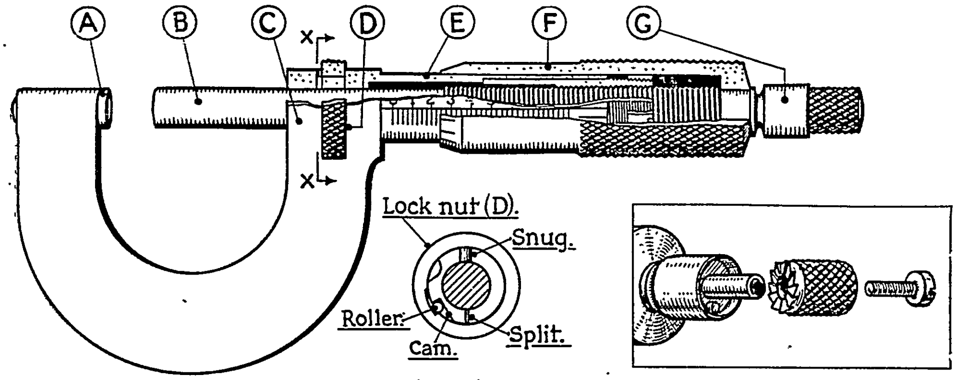


FIG. 1. OUTSIDE MICROMETER.

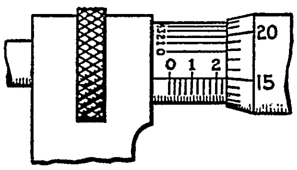


FIG. 2. VIEW SHOWING VERNIER SCALE.

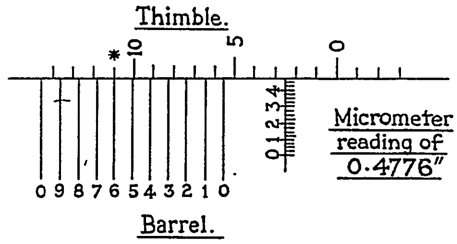


Diagram of vernier scale.

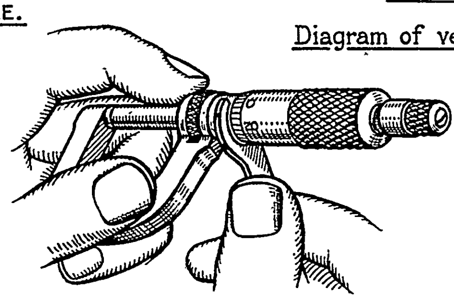


FIG. 3. ADJUSTING MICROMETER.

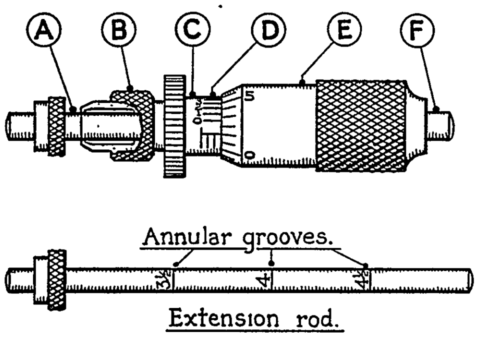


FIG. 4. INSIDE MICROMETER.

Fig. 1 to 4.—Micrometers

with rust preventive or to wrap them in grease-proof paper. The condition of an instrument or tool affects its accuracy; rusty or dirty tools, apart from being unsightly, will not give the same results as those which have been properly maintained. All working surfaces, slides, screws, etc., should be given a few drops of thin lubricating oil to prevent rust occurring and to reduce friction between the working surfaces.

Micrometer calipers

6. The micrometer caliper was originally invented about 1848, and it was first called a "screw caliper". Since that date may modifications have been introduced which have placed this instrument among those universally used where accurate measurements are essential. There are two main types of micrometer caliper, i.e., outside and inside; both types operate on precisely the same principles.

Outside micrometer caliper

7. An outside micrometer caliper is shown in fig. 1 and is used for measuring the external dimensions of an article when the latter is simultaneously in contact with the spindle (B) and the anvil (A). The anvil is mounted in one end of the U-shaped frame (C). The other end of the frame is integral with the barrel (E) on which a thimble or sleeve (F) can slide. Inside the sleeve and fixed to it, is the spindle having a portion of its length screwed with a V-thread of 40 threads per inch. The insi de of the barrel is suitably screwed to form a nut for the spindle which, when the sleeve is rotated, advances or withdraws the spindle to or away from the anvil. By means of a knurled lock-nut (D) the spindle can be locked in any position thereby making the instrument a fixed gauge. By rotating the lock nut, a split bush in the frame is contracted on the spindle, which also keeps the spindle in alignment. The instrument shown in fig. 1 is the English type in which the barrel is graduated longitudinally, in tenths of an inch and further sub-divided into fortieths of an inch. When the thimble is rotated through one complete revolution, the spindle will move a distance equal to $\frac{1}{40}$th (0·025) of an inch, which corresponds to the pitch of the thread on the spindle. The thimble is bevelled at one edge, the circumference of this edge being divided into 25 equal graduations, each fifth graduation being notated 0, 5, 10, 15, 20 respectively. When the thimble is rotated through a single division, the spindle will have moved forward through one-twentyfifth of a revolution or $\frac{1}{40} \times \frac{1}{25}$ of an inch, which equals 0·001 in.

8. It is essential that micrometers should be occasionally checked against the standard test-piece supplied with the instrument, care being taken that the faces of the anvil and the spindle are clean. The test-pieces are hardened and ground to diameters of 1 in., 2 in., 3 in., etc., $\pm$ ·0001 in. according to the size of the micrometer. An alternative method is to close the micrometer, when the zero line on the thimble should coincide exactly with the zero line on the barrel. Slight wear of the screw or nut, or inaccuracy of the instrument, can be generally eliminated by an adjusting device. Some micrometers are provided with a friction sleeve which can be turned by first slackening the locknut to relieve the roller from its cam (see view at X.X.) and then inserting a C-spanner in the recess in the barrel (behind the locknut) and turning the sleeve until the respective zero lines are in agreement—see fig. 3. When using a small micrometer, say one inch, for measuring work, the instrument should be held in one hand so that the first finger and thumb are in contact with the ratchet stop; the frame can be held securely in the palm of the hand by pressure applied by one or more of the remaining fingers, according to the construction of the instrument. This permits freedom of the other hand for holding the work. When measuring larger work, it is desirable that the object should be placed on the bench or marking-out table, or supported in some other manner and thus permit the frame of the larger micrometer to be held by one hand, while the other turns the ratchet stop to obtain the correct measurement. The most satisfactory results are obtained from micrometers having a ratchet stop. This device works on the pawl and ratchet principle (see sketch) and ensures that the object being measured is subjected to a standard gripping pressure. The non-ratchet type of micrometer entails considerable judgment to decide exactly how tightly to screw up the thimble.

9. It is sometimes desired to take readings to a limit of $\frac{1}{10000}$ in. (0·0001) and to do this, a micrometer having a vernier scale is necessary—see fig. 2. As applied to the micrometer, the vernier scale consists of ten divisions on the barrel, the sum of these divisions being equal to nine divisions on the thimble. To read the scales shown in the diagram adjacent to fig. 2:—

(i) Count the number of tenths of an inch on the main scale, i.e. 4 ... ... = 0·400 in.
(ii) Count the number of fortieths of an inch on the main scale, i.e. 3 ... = 0·075 in.
(iii) Count the number of thousandths of an inch on the thimble, i.e. 2 ... = 0·002 in.
The reading less the vernier scale ... ... = 0·477 in.

(iv) Add the vernier reading. It will be observed that the 6th line coincides with a line on the bevel scale. To the reading obtained in operations (i) to (iii) must be added $\frac{6}{10000}$ in. which will make the total reading of the scales in the diagram equal to 0·4776 in. For further explanation of the vernier scale—see para. 23.

Inside micrometer

10. The usual form of inside micrometer is shown in fig. 4. The instrument consists of a barrel (C) with one screwed end, on which is mounted a knurled nut (B) machined to form a split collet, the other end being bored and threaded to take the spindle. The thimble (E) and spindle (A) are similar to those of the outside micrometer, but the outer end of the thimble is machined down to form an anvil (F), the latter being hardened. The extension rods supplied with each inside micrometer are graduated by a series of annular grooves at ½ in. intervals, the latter being machined of a form and depth into which the clamping jaws of the collet (B) can spring. Care must be taken when inserting these rods that they are held by the clamping jaws in contact with the grooves, or the readings of the instrument will be incorrect. If the operation is done carefully, the closing of the jaws will be indicate by a soft click when they have entered the groove. These rods are hardened to obviate wear at their ends. Some inside micrometers are graduated with a vernier scale (D) similar to the outside micrometer and permit readings to be taken with an accuracy of 0·0001 in.

Three-point inside micrometer

11. This instrument, shown in fig. 5, is made in two types, i.e., English and metric and is used for measuring the internal diameters of circular sectioned orifices such as bores of cylinders. Each type of instrument is similar in construction but differs from the usual type of inside micrometer in that it ensures a true measurement of the bore of the orifice being obtained.

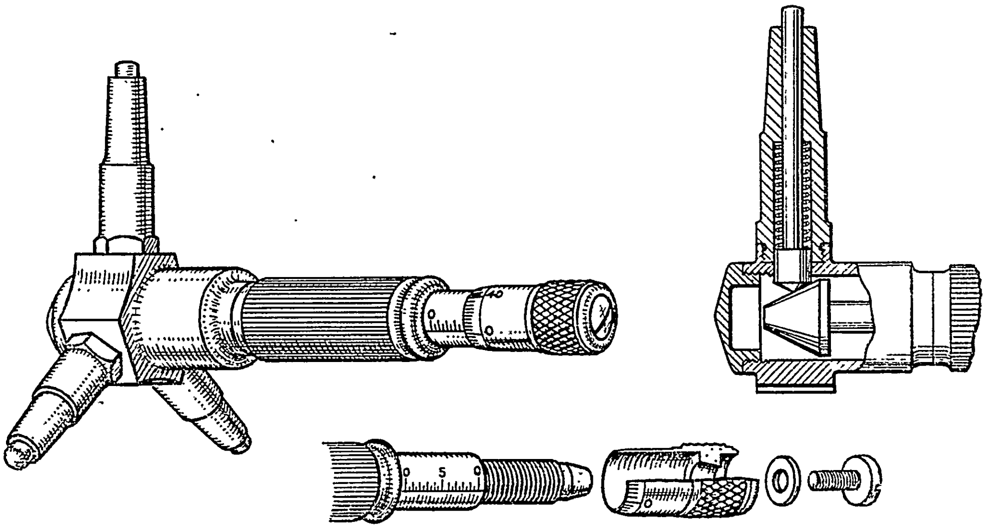


Fig. 5.—Three-point inside micrometer and details

12. The instrument consists of a stock and barrel in which a spindle is advanced or withdrawn by the rotation of a thimble in the usual manner. At one end of the spindle is a hardened cone on which bear the coned ends of three hardened steel plungers, set at 120° from one another and in the same plane. The plungers are kept in contact with the spindle cone by means of springs. As the spindle advances or withdraws an equal amount of movement is transmitted to each of the plungers. In the metric type, each plunger is advanced or retracted 0·25 mm. and as a result, the bore measurement is increased or decreased 0·5 mm. for each complete revolution of the thimble. The circumference of the bevelled edge of the barrel is divided into 50 equal divisions which permits readings having an accuracy of 0·01 of a millimetre to be obtained.

13. The metric type of three-point micrometer has a maximum range of ten millimetres, e.g., from 110 to 120 mm., and the English type has a maximum range of half an inch, e.g., from 2½ in. to 3 in. To provide greater ranges of measurement, alternative sets of plungers are supplied with the instrument and may be substituted for those originally fitted by unscrewing the housings. The plungers of each set are marked with the range of measurement that they cover, and it is essential

that they should be fitted as sets and also that the housings should be screwed up to their shoulders in their proper positions to give correct readings. The markings on the plungers must be taken into consideration together with the micrometer reading when determining the total reading of the instrument.

14. When using the instrument, two plungers are held against the wall of the orifice whilst the other plunger is brought up to the surface under measurement by turning the thimble. The same sense of touch, i.e., "feel" is required for the operation of this instrument as is needed for the more common type of micrometer.

15. Periodic checking for accuracy is desirable; any error can be adjusted by removing the screw at the end of the barrel, which will permit the latter to be removed and re-mounted in another position on its cone. Should the instrument become sluggish in its action, the fault may be rectified by removing the conical nut screwed in the end of the stock and applying thin machine oil or preferably clock or typewriter oil to the coned surfaces.

Cylinder gauge

16. Fig. 6 shows an instrument which is used for measuring the amount of ovality or machining errors in cylinder bores and similar work. The gauge consists of a T-shaped head or anvil in which

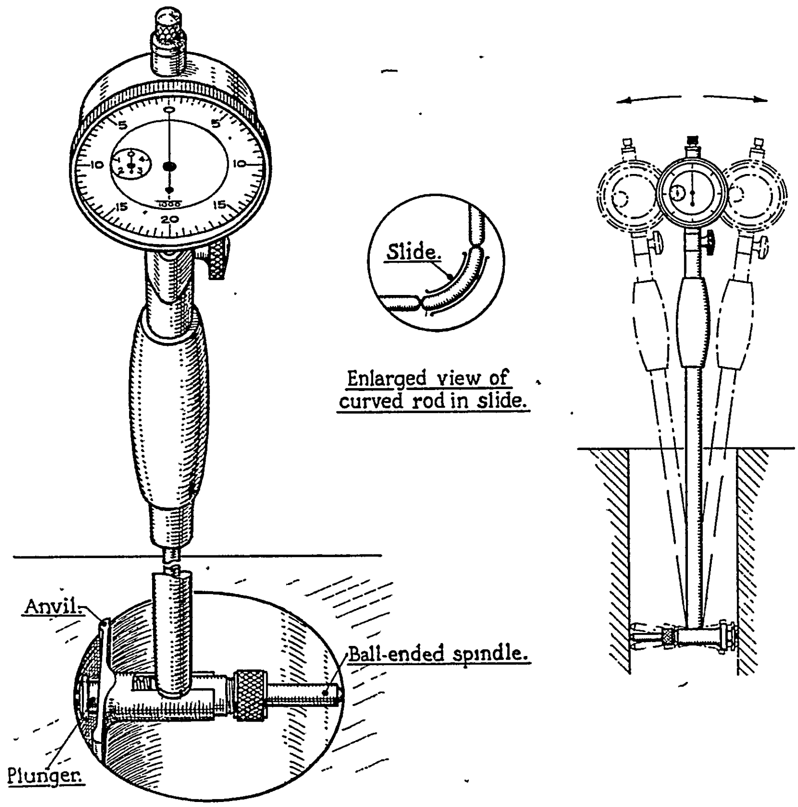


Fig. 6.—Cylinder gauge

a plunger, controlled by a spring, can be moved laterally. Inserted in each end of the plunger are spindles, one of which has a ball point and is located by means of a knurled nut, and the other is moveable and controlled by a light spring acting upon a collar which gives it a sensitive action. This ensures that internal measurements are taken across the diameter, and not across a chord of a circle within the range of the instrument.

17. Mounted at right angles on the plunger is a long hollow stem in which a rod extends throughout its length. The lower end of this rod bears against one end of a small curved rod, and

the upper end provides a point of contact for a dial indicator. The curved rod embraces an arc of approximately 90° and is controlled by a curved slide. The lower end of this rod bears against the inner end of the movable spindle. These three components are maintained in contact with each other by spring pressure, so that the movement is free from backlash and sliding contacts, which may give rise to errors as wear takes place. Any lateral action of the movable spindle will be directly transmitted to the upper end of the long rod.

18. Owing to the use of the curved rod for transmitting the movement, the range of the instrument, without changing the fixed spindle, is limited; the actual amount is approximately $\frac{50}{1000}$ in., or one-twentieth of an inch. Before using the instrument a dial indicator is mounted on the end of the stem, the contact point of the indicator being pushed in until it bears against the upper end of the long rod. A split collar and setscrew is provided to keep the indicator rigid. To permit the instrument to be used over a range of diameters, a set of spindles of various lengths is supplied together with a set of washers.

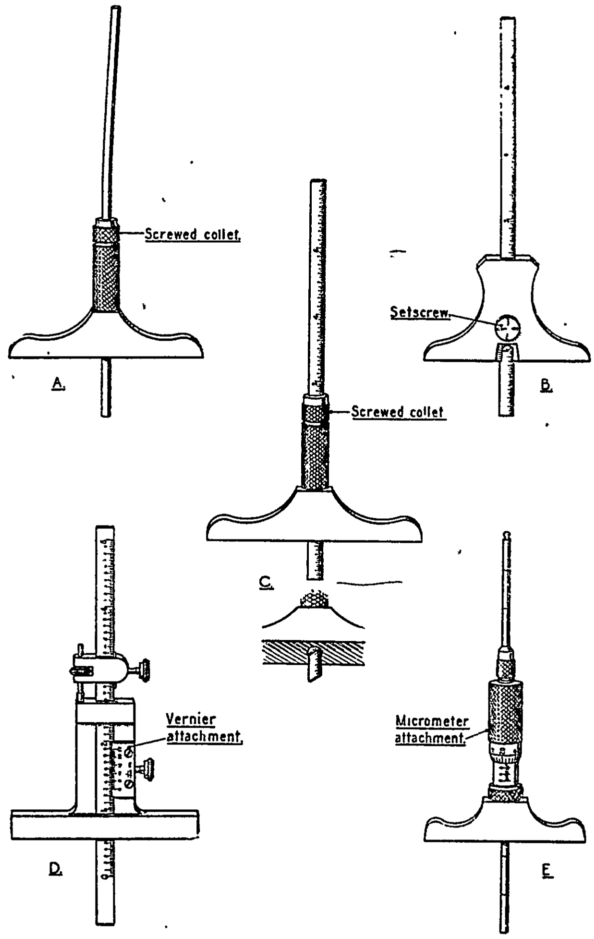


Fig. 7.—Depth gauges

19. *Method of using the instrument.*—First select a spindle appropriate to the bore to be measured and insert it in the end of the anvil. Next, adjust an outside micrometer to the "new size" as stated in the schedule of fits and clearances, if it happens to be an aero-engine part, or to the "lower limit" as stated on the drawing. The contact points of the instrument should then be placed between the jaws of the micrometer so that the spindle of the former is depressed say $\frac{20}{1000}$ in. and the knurled rim of the dial indicator turned so as to be reading at zero. Carefully disengage the micrometer. After this adjustment has been effected, the instrument should be inserted in the bore of the object to be measured, as shown in fig. 6. By moving the instrument up and down the the bore, a fluctuating reading will be observed on the dial according to the irregularities of the bore. A rocking movement should be given to the instrument just before readings are being taken, as shown in the dotted

vernier scale being equal to $\frac{19}{20}$ths. of one division on the main scale, i.e., $\frac{19}{20} \times \frac{1}{50}$th of an inch, the difference between the width of one division on the main scale and one division on the vernier scale is therefore $\frac{1}{1000}$ of an inch. If the zero line on the vernier scale is set exactly opposite to the zero line on the main scale, then the 5 line will be $\frac{5}{1000}$ in. from the 5 line on the main scale. This difference will increase throughout the main scale until the 20 line is exactly opposite the 19 line on the main scale. It is evident that any number of thousandths increase over the zero setting will bring that particular number on the vernier scale into line with a corresponding division line on the main scale.

To explain how to read the vernier, a concrete example is taken—see sketch I of fig. 9:—

(i)	Count the number of inches on main scale, i.e., 3	= 3·000 in.
(ii)	Count the number of tenths of an inch on the main scale, i.e., 5... ...	= 0·500 in.
(iii)	Count the number of fiftieths of an inch ($\frac{1}{50}$ in. = ·02 in.) on the main scale, i.e. 2	= 0·040 in.
	Total	= 3·540 in.

Therefore the jaws of the caliper are opened 3·540 in. plus the vernier reading.

(iv) Use a magnifying glass and carefully ascertain which line on the vernier scale most nearly coincides with a line on the main scale; in the illustration, this is line 6 as marked by the two stars. This represents $\frac{6}{1000}$ths of an inch (0·006 in.) which must be added to the sum of the readings previously obtained. The caliper jaws are therefore opened 3·546 in.

24. Some vernier scales are divided into inches, tenths and fortieths of an inch. The vernier scale in this case has 25 graduations equal to 24 divisions on the main scale. An example of this system of calibration is given in sketch II of fig. 9. The method of reading this scale is as follows:—

(i)	Count the number of inches on the main scale, i.e., 2	= 2·000 in.
(ii)	Count the number of tenths of an inch on the main scale, i.e., 5 ...	= 0·500 in.
(iii)	Count the number of fortieths of an inch ($\frac{1}{40}$ in. = ·025 in.) on the main scale, i.e., 3	= 0·075 in.
	Total	= 2·575 in.

Therefore the jaws of the caliper are opened 2·575 in. plus the vernier reading.

(iv) Add the vernier reading—the 12th line on the vernier coincides with a line on the main scale (two stars mark this position in the illustration) = 0·012 in. The caliper jaws are thus opened 2·587 in.

Universal scribing block

25. This tool is shown in fig. 10, and consists of a heavy base having V-shaped grooves accurately machined in its under surface and at the front end to enable it to be used against circular work as well as on flat surfaces. Two small push pins are fitted in the base which on being pressed downwards protrude through the bottom face so that the base can be located against a machined edge. A rocking bracket is pivoted to a spindle on the top of the base. The bracket, which is retained in a groove machined in the upper face of the base, can be raised or lowered by means of an adjusting screw fitted at the end of the bracket. A stiff spring is placed under the bracket, at the rear end, to prevent undesired movement. Mounted on the bracket is a rotating head having a spindle at one end and a screwed portion and knurled nut at the other end. Fitted on the spindle end is a sliding sleeve. A hole is drilled through the head and sleeve to take a long spindle. It will be observed that when the knurled nut is tightened up it draws the spindle through the sleeve thereby clamping the long spindle. A sliding attachment comprising a clamp, screw and nut is mounted on the spindle and a double pointed scriber passes through the clamp. The scriber is locked in a manner similar to the arrangement on the rocking bracket. For small work the spindle may be removed and the scriber inserted in its place. It will be seen that the scriber can be set in any position within the range of the tool. Fine adjustment is provided by the adjusting screw.

V-blocks

26. There are numerous types of V-blocks in use throughout the service, many of which have been made locally to suit special requirements—see sketches I and II of fig. 11. In this A.P., other forms of V-blocks may be suggested which can be made up by units to assist them in carrying out a specific operation. V-blocks are made of close grain cast iron. The standard V-block is shown in sketch III of fig. 11. All standard V-blocks are originally made in pairs, and it is essential that they should be suitably marked to avoid mixing.

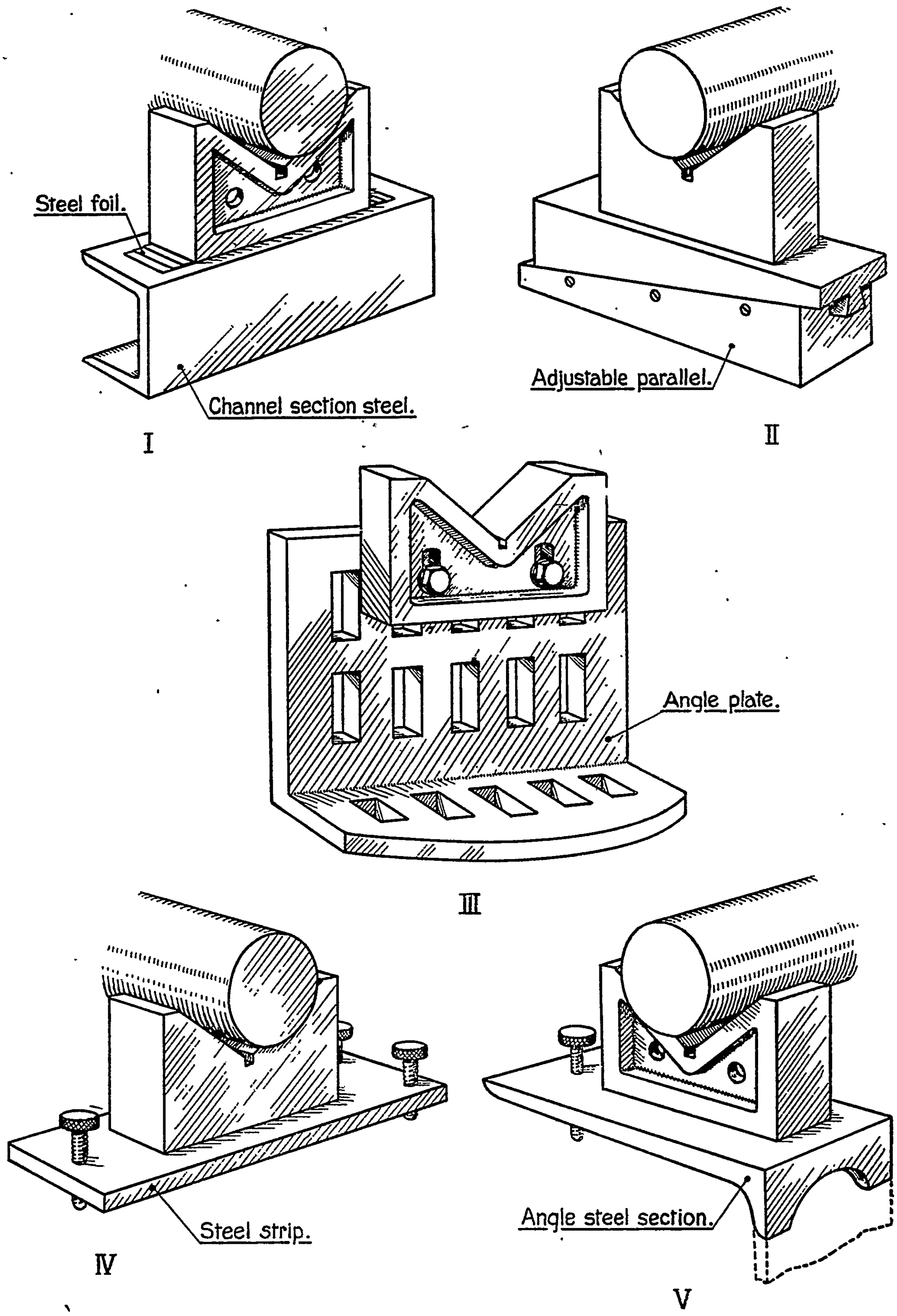


Fig. 12.—V-Blocks—methods of adjusting height

illustrations, but the instrument must be vertical when the reading is taken. The readings should be taken at several points around the circumference of the bore to ascertain the amount of ovality present.

Depth gauge

20. Depth gauges are used for measuring the depths of holes or recesses which cannot be conveniently measured with a steel rule. There are several types of depth gauges, their construction varying according to the degree of accuracy required—see fig. 7.

(i) *Type A.*—This tool embodies the principle of all depth gauges and comprises a steel stock having a hardened and ground flat face. The stock is drilled at right-angles to the face for the reception of a sliding steel rod, the latter being clamped in any desired position by a screwed collet. This tool is chiefly used for making comparisons between the depth of of holes or recesses, where the actual dimensions need not be ascertained.

(ii) *Type B.*—This tool is very similar to the previous type except that a narrow steel rule is fitted instead of the rod which can be clamped in position by a set-screw. The degree of accuracy depends upon the graduations on the rule.

(iii) *Type C.*—This type is similar to type A except that the narrow steel rule passes through a barrel in which a light spring tends to force the rule downwards, e.g., to the bottom of the hole. The barrel can rotate, which permits holes or recesses cut at an angle to be measured. A screwed collet locks the rule when required.

(iv) *Type D.*—This tool is fitted with a vernier scale and is capable of being used for very accurate work. The gauge can be employed to measure recesses with a degree of accuracy of 0·0001 in. The method of reading a vernier is described in para. 23.

(v) *Type E.*—This tool has a micrometer barrel attachment mounted on the stock. The tool shown in the illustration has three extension rods, any one of which can be inserted in the end of the spindle of the micrometer. This tool can be used for measuring very deep recesses or holes with an accuracy of 0·001 in. For method of reading a micrometer—see para. 7.

Vernier height gauge

21. This instrument is shown in fig. 8; it consists of a base having its upper and lower faces ground parallel to each other, and a steel rule graduated in inches, tenths and fortieths mounted at right angles to the base. One scale of the rule is used for internal measurements and the other scale, engraved on the reverse side, for external measurements. To provide for this condition the "internal" scale commences with the one-inch line instead of the usual zero line. Integral with the movable jaw is a vernier attachment similar to that described in para. 23. The movable jaw is machined parallel on both sides, and being at right angles to the main scale allows the instrument to be used for internal and external measurements. When the jaws are in contact the distance between the base and the outside of the movable jaw is exactly one inch—hence the difference in the starting points of the two main scales. An extension arm chamfered to a sharp edge is provided for clamping on the movable jaw. By this means, the instrument is instantly converted into a form of scribing block, in which the chamfered edge of the arm can be accurately set to any desired height for the purpose of scribing lines on work or for checking positions on a component.

Vernier caliper

22. The vernier caliper is shown in fig. 9 and is a combination of a graduated rule and two jaws, one jaw being integral with the rule and the other being movable. The movable jaw is provided with an attachment which enables it to slide on the edges of the rule and permits it to be located in any desired position by means of a setscrew. The illustration shows a form of this tool in which the main scale is divided into inches, tenths and fortieths of an inch and the vernier scale divided into 25 divisions. In order that this tool may be used for internal and external work, the jaws are machined to a definite width, e.g., $\frac{1}{4}$ in., and the back of the slide is marked with a scale allowing for the width of the jaws. Two small holes (marked X in the illustration) are drilled on the main scale and the slide attachment as an aid when setting dividers to an accurate measurement.

The vernier scale

23. The vernier scale, shown in sketch I of fig. 9, is mounted on the saddle piece of the caliper and slides over a main scale divided into $\frac{1}{50}$ths of an inch. The vernier scale is divided into 20 equal parts, each fifth division being numbered 0, 5, 10, 15 and 20 respectively. The total length of these 20 divisions is equal to the length of 19 divisions on the main scale. Each division on the

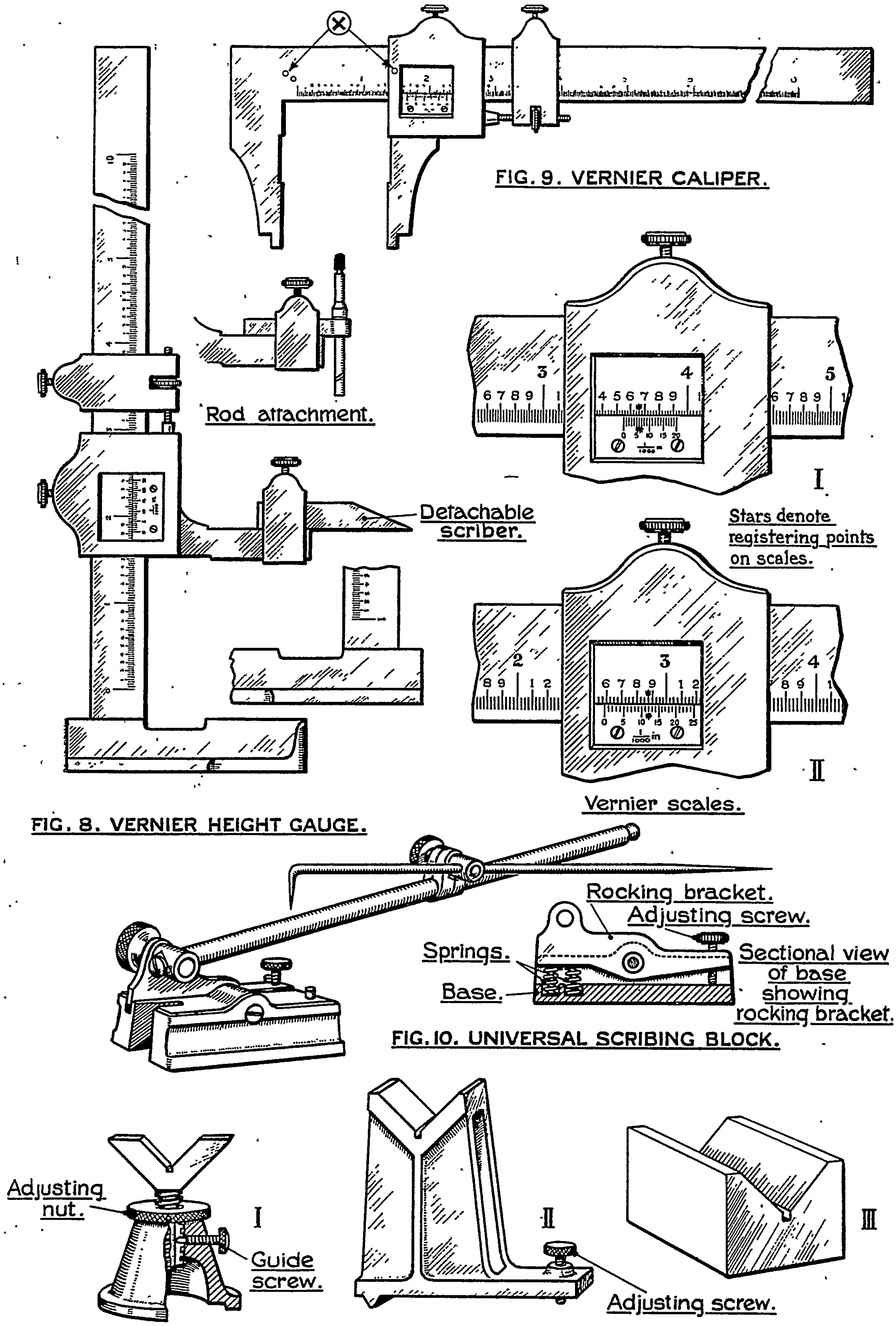


Fig. 8 to 11.—Height gauges, calipers, scribing and V-blocks

27. A useful form of V-block available for service use is known as a drill block. These blocks are made of cast iron and have grooves machined along each side for the reception of a steel clamp, the latter being used when it is necessary to secure a round object within the "vee" of the block. Overtightening the clamp screw should be avoided.

28. It is essential that all pairs of V-blocks should be periodically checked for accuracy both in the "vee" and the external surfaces. The "vee" should be machined centrally at 90 degrees, and the outside surfaces should be square with one another so that they may be used as parallel packing blocks if desired. When reconditioning these tools it is advisable to carry out the various operations simultaneously on each block of a pair; this can be done by securing the two together. If it has been found necessary to remove the markings in order to obtain a true surface or for any other reason, the blocks should be re-marked.

29. It is often necessary to mount a shaft or other circular object upon a pair of V-blocks so that the axis of the shaft is parallel to the upper surface of the marking-out table and at such a height that the shaft can be freely rotated. Several improvised rigs are shown in fig. 12, the equipment employed being generally available in all service workshops.

Parallel strips

30. These tools are generally made of pieces of hardened cast steel and are accurately machined in pairs, each strip having its opposite sides parallel to each other. The pairs are marked to denote their respective sizes to avoid having to measure them each time they are required for use. Parallel strips are employed beneath machined or ground surfaces for the purpose of raising them to a suitable height or to align the underside of a finished surface to an accurate surface such as a table or a plate.

Limit gauges

31. To permit interchangeability in the manufacture of similar components and to ensure parts being measured with the same degree of accuracy, various types of gauges are employed similar to those shown in fig. 13, these being known as plate, gap, plug, and ring gauges. In engine repair work it is often necessary to measure a number of components of a similar type to ascertain their degree of serviceability or selective assembly, and in some cases it is impracticable to use a precision instrument for the purpose. The first three types of gauge mentioned are usually double-ended, one end being slightly larger and the other end slightly smaller than the standard dimension. Plug gauges made under these conditions will permit the smaller end to enter a recess but the larger end will not enter—hence the popular name of "Go and not go" gauges. Plug gauges usually have two flat sides which enable them to be used for ascertaining whether a bore has been incorrectly machined or has worn oval. It is often necessary to ascertain the amount of wear or ovality of a component which has been used as a bearing or bush, e.g., valve guide or an aero-engine. The correct measurement across the axes of the component can be obtained by using a plug gauge having a cross-section as shown at A. The length of the gauge should be such that it will pass completely through the bore. The plate or gap gauge is made so that the larger end will pass over a given dimension but the smaller end will fail to do so. If a plug gauge (double-ended) is made say one inch in diameter plus 0·001 in. at one end and minus 0·001 in. at the other end, the difference between the two dimensions is known as the *tolerance*. The larger dimension is referred to as the ***high limit***, and the smaller dimension as the *low limit* of the gauge.

32. In practice these gauges are made either in cast steel and then tempered, or in mild steel and then case-hardened, after which they are ground and lapped. It is usual for double-ended gauges of these types to have one end longer than the other in order that the operator may immediately know which is the "Go" or "Not-go" end without having to examine the dimensions engraved on the gauge.

33. From the above it will be appreciated that properly dimensioned gauges will save considerable time when measuring machine parts. The extent to which such gauges may be made up by Units will depend upon the facilities available. Gauges are generally placed under three classes:—

(i) *Working gauges.*—Those which are used in the workshops during the manufacture of the component.

(ii) *Inspection gauges.*—Those which are used for checking the component after manufacture, e.g., in the View Room, or for checking a component for size ovality and wear, e.g., an engine part removed for examination, etc.

(iii) *Master gauges.*—Those used for checking the accuracy of gauges (i) and (ii).

34. Temperature plays an important part in the size of a gauge, and as far as possible they should be made and retained in a temperature of approximately 68° F. (20° C.), this being the common or average working temperature to which the gauges are ordinarily subjected in practice.

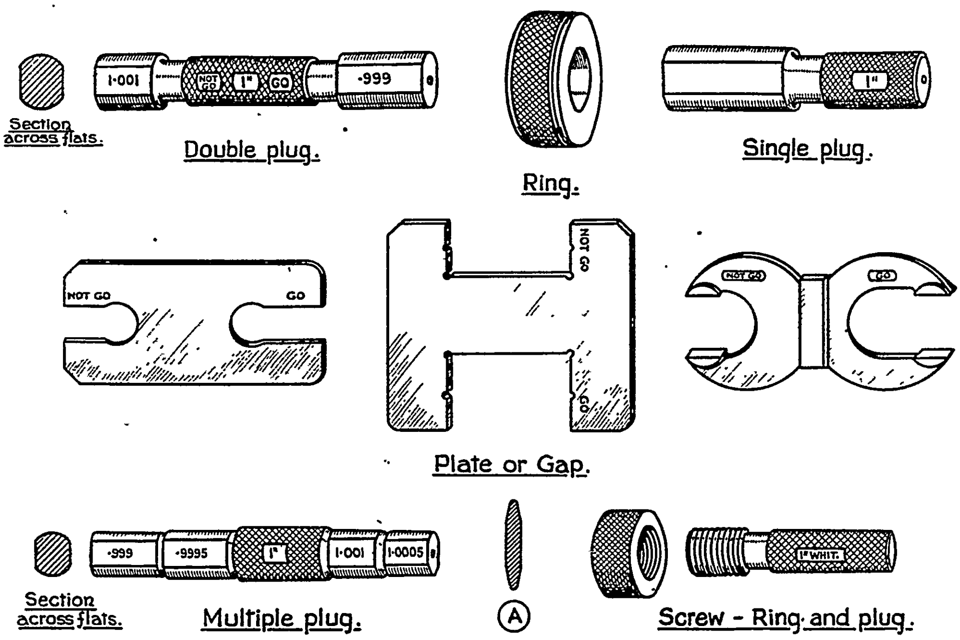
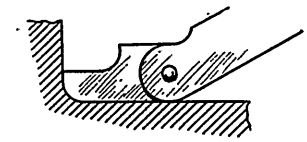
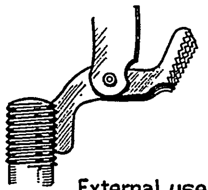


FIG. 13. LIMIT GAUGES.



Internal use of radius gauge.



External use of screw pitch gauge.

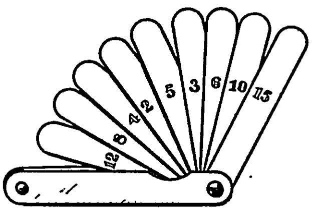
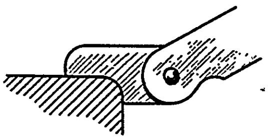
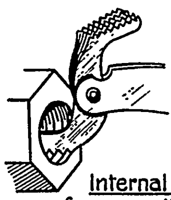


FIG. 14. FEELER GAUGE.



External use of radius gauge.



Internal use of screw pitch gauge.

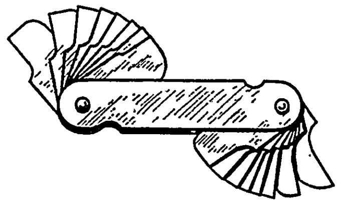


FIG. 15. RADIUS GAUGE.

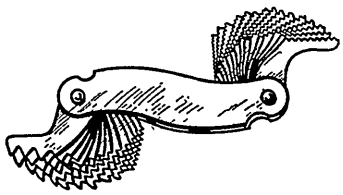


FIG. 16. SCREW PITCH GAUGE.

Fig. 13 to 16.—Miscellaneous types of gauges

Feeler gauge

35. The feeler gauge, sometimes called a thickness gauge, is shown in fig. 14 and consists of a number of leaves of thin steel which have been ground to definite thicknesses. Each leaf is suitably tempered and is marked with a number representing the thickness of the leaf in thousandths of an inch. The leaves are held in a metal case thereby protecting them from kinks. Any leaf can be removed by unscrewing the screwed pivot stud. Two types of this gauge are supplied for service use, (i) English—having leaves of thicknesses 2, 3, 4, 5, 6, 8, 10, 12 and 15 thousandths of an inch, and (ii) Metric—having 14 leaves of thicknesses from 0·05 to 1·00 mm. The object of the gauge is to provide a means of measuring clearances between two surfaces. Each leaf may be used singly or in combination with other leaves. Care should be taken to ensure the leaves are free from oil or dirt, especially when they are used in combination.

Radius gauge

36. The radius gauge is sometimes referred to as a fillet gauge, and is used to check the inside or outside radius of a part, e.g., pins, journals and bearings of a crankshaft. Fig. 15 shows a type of radius gauge and its uses. The service patterns are respectively (i) English—having a range of radii from (*a*) $\frac{1}{32}$ to $\frac{1}{4}$ in. and (*b*) $\frac{17}{64}$ to $\frac{1}{2}$ in. and (ii) Metric—having a range of radii from (*a*) 1 to 7 mm. and (*b*) from 7·5 to 15 mm.

Screw pitch gauge

37. A screw pitch gauge, as its name implies, is used for testing the pitch of a V-thread. In gauging a thread, the latter is first cleaned and then held up to the light and the gauge placed in position. The gauge consists of a number of leaves, each leaf being cut with "vees" at a certain number of teeth per inch. Each leaf is marked with a decimal figure which denotes twice the depth of the thread. This assists the operator to determine what size of drill is required to leave a full thread for a screw-cutting tap having the same pitch. The size of drill required will be that of the diameter over the crests of the threads, less this figure. Fig. 16 shows a type of screw pitch gauge and its use when checking the threads of a component. Three types of this tool are available for service use and cover most requirements, (i) British Association, i.e., B.A., (ii) Whitworth—having 30 pitches from $3\frac{1}{2}$ to 60 threads per inch and (iii) Metric—having 17 pitches from 0·5 to 7 mm. together with a centre gauge which can be used when grinding internal and external screwcutting lathe tools.

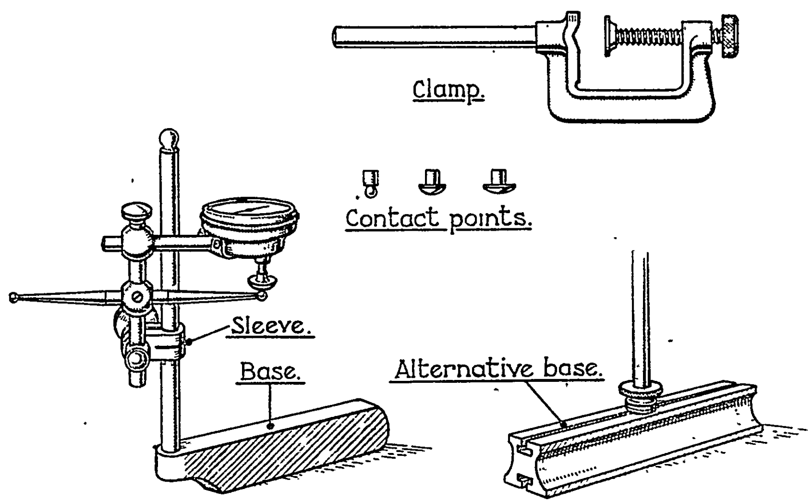


Fig. 17.—Dial test indicator

Dial test indicator gauge

38. This instrument is shown in fig. 17 and is used for determining the degree of accuracy of a flat surface or the truth of a rotating shaft. The instrument can also be used for taking comparative measurements between components. There are several varieties of the instrument but all types are designed to produce similar results. The instrument comprises a base on which is mounted a vertical spindle carrying a clamp or split sleeve. An additional hole is machined in the clamp to take a sliding

post. By tightening up the clamp screw, the clamp is located and at the same time the sliding post is secured. The other end of the post carries an arm on which the dial indicator is mounted. The dial gauge is graduated in thousandths of an inch, the graduations being widely spaced to permit lesser dimensions to be estimated. Some dials are graduated in half and quarter thousandths of an inch, and are generally used in View Rooms for inspection operations and also in the Grinding Bay where the machining limits are very fine; this type of indicator is not in general use in the service. The dial of the indicator may be turned by means of its knurled rim to bring the zero in any position. The contact points of the dial indicator spindle can be removed and different forms of points used. By bringing the contact point against an object with sufficient pressure to move the pointer one complete revolution and then setting the dial at zero, readings can be obtained for one complete graduation of the dial, either to the left or right of the zero graduation. It must be remembered that when circular rotating objects are being tested for alignment in relation to the axis of the object, the actual error will be half that registered on the dial. Fig. 18 shows a dial indicator mounted on a scribing block and illustrates how the dial indicator may be used in the absence of the complete instrument shown in fig. 17.

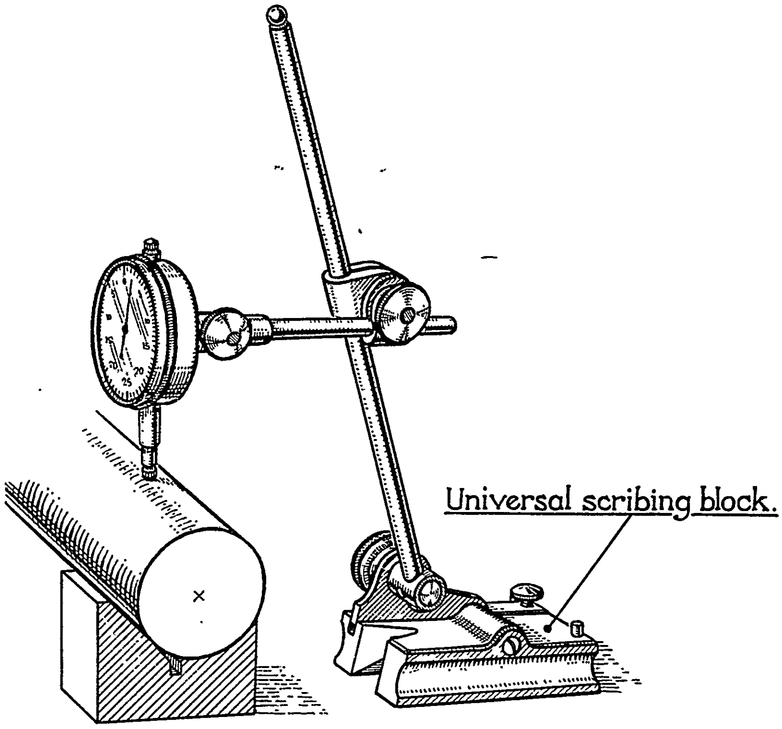


Fig. 18.—Dial indicator mounted on scribing block

Straightedge

39. This tool being made of steel throughout can be relied upon to retain its truth if care is taken during storage and in use. Long straightedges when not in use should either hang in a vertical direction or, if stored horizontally, be supported throughout its length. The tools should also be protected from damage caused by other metal parts coming into contact with them. Straightedges are used for testing the accuracy of long surfaces, and therefore their accuracy is essential. From time to time the tool should be checked for accuracy against a master surface table and any irregularities rectified as necessary. The 4-foot straightedge will be found most useful for all general purposes; straightedges in lengths up to 6 ft. are available. In some trades a wooden straightedge is employed, this tool being made of hard-wood and generally reinforced with metal strips at the ends and in other positions where excessive wear or damage is anticipated. Wooden straightedges are perfectly satisfactory for rigging and similar operations, but it is essential that they should be frequently checked for accuracy.

Parallel mandrels

40. These tools are generally made of mild steel and afterwards hardened; they are then ground to very fine limits. It is most important that mandrels should be used with care and when not in use they should never be allowed to lie haphazard on the marking-out table or bench. Suitably notched

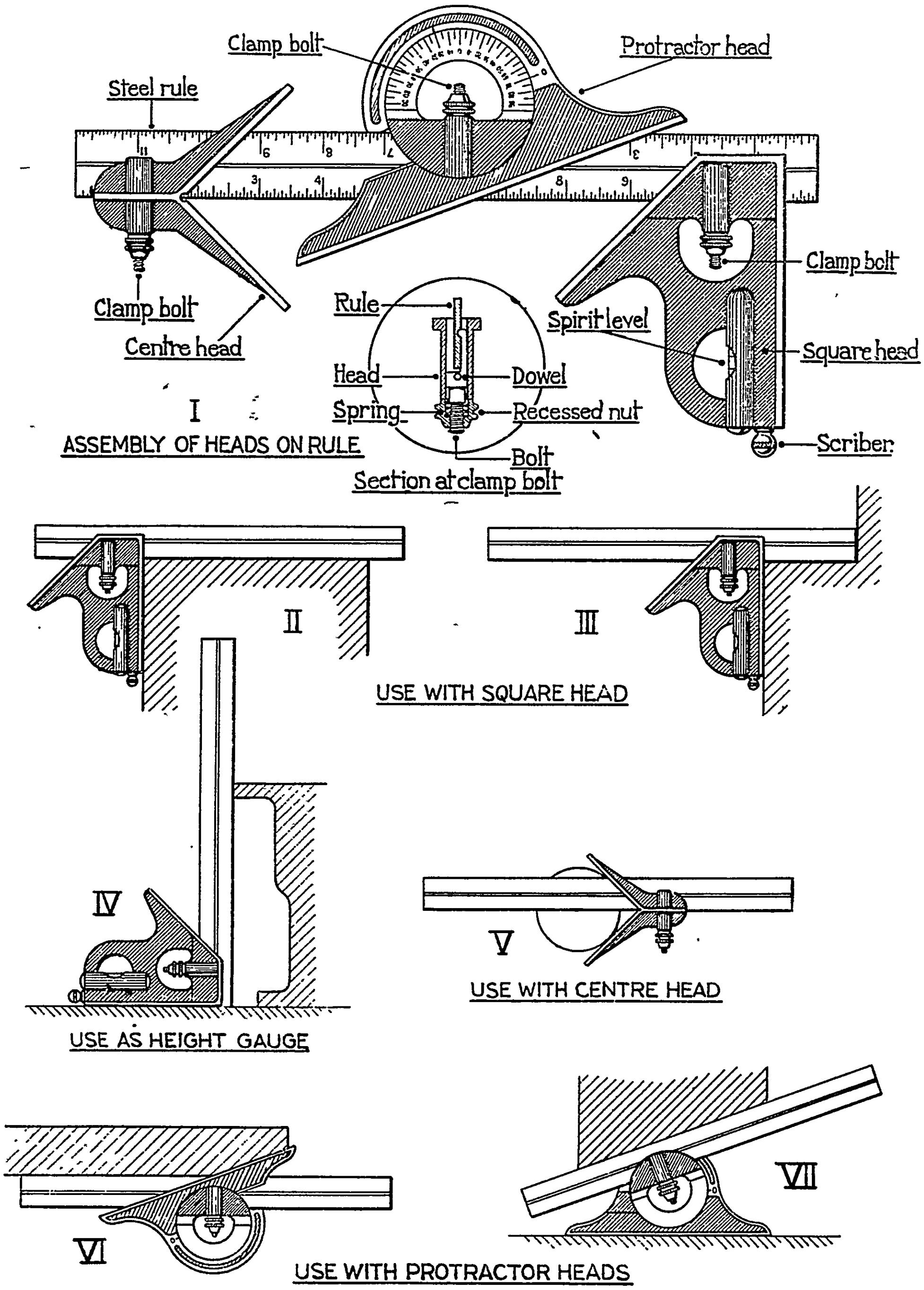


Fig. 19.—Combination set

wooden racks are suggested and the mandrels should always be coated with rust preventive, thick oil or vaseline when not in use, to prevent corrosion taking place on their ground surfaces. Various types of mandrel are in general use in the service and these will be described in connection with the particular operations for which they are used.

Combination set

41. The combination set shown in fig. 19, sketch I, consists of a graduated steel rule and three heads which enable the instrument to fulfil all the requirements of a square, set-square, height gauge, centre square, bevel, protractor, marking gauge and spirit level. The heads are made of cast iron or of malleable iron (drop-forged) and have their working faces ground accurately; the heads are about ½ in. wide. A slot is machined through each head for the reception of the rule and a clamping bolt and knurled nut (carrying a spiral spring) is provided so that the head can be secured in any desired position on the rule. If it is necessary to remove the bolt, care must be taken when replacing it to ensure that the dowel engages in its slot in the bolt hole. When not required, the heads can be removed, but care should be taken in replacing them to ensure that the end of the bolt engages in the concave groove machined in the rule. A brief description of the components is as follows:—

(i) *Steel rule.*—The steel rule supplied with the instrument is graduated in English, metric or combined English and metric measurements. The rule is hardened and this prevents the corners from wearing and destroying the graduations.

(ii) *Square head.*—The square head has one working face machined square and the other working face machined at 45° to the rule. This enables the instrument to be used as an adjustable try-square and a 45° mitre gauge. By sliding the head along the rule the instrument is converted into a set-square. A spirit level is incorporated in this head and is set accurately and secured in a protected position. A hardened steel scriber is also supplied and is frictionally held in a brass bush. Examples of uses with the square head are shown in sketches II, III and IV.

(iii) *Centre head.*—This head is used to determine accurately the centre of the end of a piece of round material—see sketch V. It will be observed that one edge of the rule always passes through the centre of the circular end of the material. The centre point will, therefore, be fixed by the intersection of any number of lines scribed with the centre head in different positions. The end of the bar should always be square before any attempt is made to determine the centre.

(iv) *Protractor head.*—The protractor head, as its name implies, consists of a double protractor reading from 0° to 180° in both directions. The protractor is carried on a revolving turret which can be secured in a similar manner to the other heads. Some protractor heads also incorporate a spirit level which adds to the usefulness of the instrument. The use of this head in conjunction with the rule serves the dual purpose of an adjustable mitre gauge and a bevel protractor. Examples of uses of this head are shown in sketches VI and VII.

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CHAPTER 11

JET CALIBRATING MACHINES

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General

1. Jet calibrating machines are employed for the calibration of carburettor jets to the standard set up by the National Physical Laboratory. The machines enable a comparison to be made quickly of the flow rate of the jet to be calibrated, with the flow rate of certain master jets, on the principle that the ratio of flow between one jet and another of the same design is always the same. The types of machine in use in the Service are described in the following paragraphs.

JET CALIBRATING MACHINE, MK. XB

2. A front view of this instrument is given in fig. 1, Sketch I, which shows that two gauges glasses, each with its own standard orifice, and two cocks and jet adaptors are employed. This is done in order to increase the range of jets that can be calibrated, the standard orifices being suitable for use with jets having a flow between 100 c.c. and 500 c.c., in the one case, and between 500 c.c. and 2,000 c.c. in the other. The above two sets of components, together with upper and lower tanks, hand air pump and tray, are all mounted on a vertical backboard. The instrument should be firmly fixed in a vertical attitude where it will be free from vibration, shock, direct sunlight and extreme variations of temperature, and at such a height that the scales may be read without errors due to parallax. The tray receives the fuel either as discharged from the jet under test or when filling the system, the filling being carried out by first filling the lower tank through the tray and then transferring the fuel from lower to upper tank by creating sufficient air pressure in the lower tank to lift the fuel to the upper tank. The fuel is drained through a filter in the tray comprising a disc of fine mesh gauze and then passes via a cock and pipe to a closed cylindrical tank having additional connections to the delivery side of the hand operated air-pump and to the return pipe which leads to the upper tank.

3. The air-pump is single acting and is furnished with the usual cup-type leather washer on the plunger. The upper tank is closed similarly to the lower tank except for a central cylindrical filter which screws into and seats on the adaptor for the cock (A) in the base of the tank. A dust cap with a small air-vent hole covers the protruding top of the filter. The fuel supplied from the lower tank is thus filtered before passing through the cock (A) and its appended pipe to the float chamber. This chamber houses a float and a needle valve which acts upwards against a seating in the chamber cover and thus controls the fuel level. Fuel is drawn from the bottom of the float chamber by the supply pipe which delivers it to the body of the instrument (see fig. 1, Sketch III). The body is divided into two branches so as to form two distinct instruments from this point. At the root of each branch the passage is tapped to receive the orifice. This is a screwed plug provided with a flange seat (an intervening washer is fitted) and bored to form a venturi-shaped orifice. Each branch is divided at the front end into four passages leading in a downward direction to the special cock (B), inwards to the socket for the gauge glass, upwards to the air-release cock and forwards to receive a screwed plug

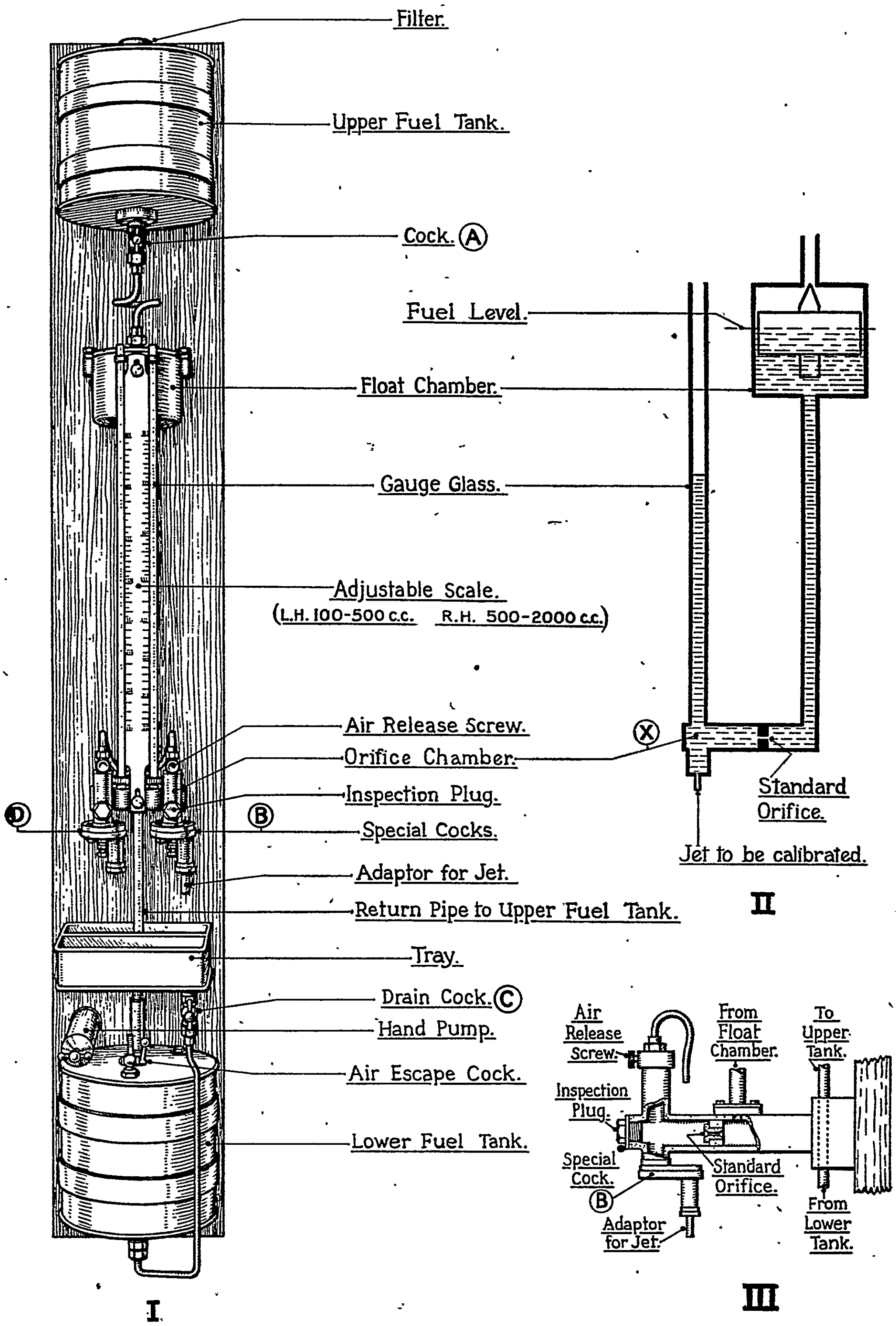

Fig. 1.—Jet calibrating machine, Mk. XB

which, when removed, provides access to the orifice to permit removal of the standard orifice by means of a hexagonal tube spanner. The downward branch terminates in an eccentric flange which is faced with cork to form the seat of the jet-adaptor cock. The jet-adaptor holder has a corresponding eccentric flange which pivots concentrically with that of the branch. Rotation of the jet-adaptor flange brings the adaptor holder in line with the downward branch of the orifice chamber and thus allows fuel to flow into the adaptor. The jet to be tested is mounted in its appropriate adaptor, which is then screwed upwards into the holder. The gauge glasses are open at their upper ends and are held in their sockets by a gland fitting. Two scales on the one scale plate are provided which are graduated during the manufacture of the instrument from the levels obtained when using the standard reference jets previously mentioned. Three reference jets are supplied with each instrument, their nominal sizes being 70 c.c., 300 c.c. and 1,250 c.c. respectively, whilst the actual individual rate of flow is marked on each jet. The left-hand portion of the instrument covers jets between 100 c.c. and 500 c.c. per minute, whilst the right-hand portion is intended for the calibration of jets between 500 c.c. and 2,000 c.c. per minute.

Principle of operation

4. In fig. 1, Sketch II, which illustrates the principle of operation, it will be seen that the fuel supply is maintained at a constant head by the float.chamber, whence it flows through the standard orifice to the chamber (X) from which the gauge tube leads upwards and the jet to be calibrated leads downwards. With the jet open and the instrument working for a sufficient length of time for the conditions to become stabilised, it will be found that the fuel in the gauge will remain at a certain height, depending upon the ratio between the sizes of the standard orifice and the jet to be calibrated. This is because the pressure provided by the head of fuel falls to zero in two steps, the first in proportion to the size of the standard orifice and the remaining drop to zero in proportion to the size of the jet. It will be evident that a scale, calibrated directly in c.c. per minute, can be placed on the gauge glass, but this scale, if fixed in one position, will not be correct for all conditions of temperature, specific gravity of fuel used, and so on. This difficulty is surmounted by making the scale plate adjustable as to its position relative to the level in the gauge glass, and its location for any given set of conditions is determined by first using a reference jet—which must be of the same type as the jet under test—the calibration of which is accurately know. The reference jets are calibrated on a master jet-calibrating instrument at the National Physical Laboratory and are marked with the actual rate of flow in c.c. per minute.

Operation

5. The instrument is operated as follows:—

(i) Fill the tray with fuel and open the air-escape cock and drain cock (C) on the lower tank Continue to replenish the tray until the lower tank is nearly full, then shut the air escape and drain cock (C).

(ii) Operate the hand pump to transfer fuel from the lower tank to the upper tank until the latter is at least half-full. The cock (A) on the upper fuel tank should remain open whenever the calibrator is in use.

(iii) Screw the 300 c.c. reference jet for the L.H. scale into the L.H. cock (D), making sure that a fuel-tight joint is obtained, otherwise it will not be possible to obtain a correct reading. For this purpose the adaptor must be fitted with a serviceable joint washer not greater than $\frac{1}{16}$ in. thick.

(iv) Open the cock by rotating from left to right, when fuel will flow into the tray.

(v) Release all air from the orifice chamber. The air above the jet is released by opening the air escape cock until fuel issues forth. Air in the vicinity of the jet is removed by placing a finger over the hole in the reference jet, when air bubbles will rise in the gauge glass. When the bubbles cease it can be accepted that there is no more air in the orifice chamber. Remove the finger from the reference jet and the fuel level in the glass will gradually fall until it remains constant. It is important that fuel shall flow for at least one minute to allow the level to become stabilised.

(vi) Adjust the scale plate so that the graduation on the L.H. scale which corresponds exactly with the marking on the 300 c.c. (nominal) reference jet is opposite the fuel level as indicated by the meniscus in the L.H. gauge glass. If, for example, the 300 c.c. reference jet is stamped 299, the graduation 299 will be placed opposite the fuel level.

(vii) Shut the L.H. cock (D) and remove the adaptor.

6. The instrument can now be used for calibrating any jets with a flow between 100 c.c. and 500 c.c. per minute. To use the R.H. portion of the calibrator, the same routine should be followed, the reference jet in this case being one of 1,250 c.c. flow per minute. It is essential that the setting of the scales is always checked against the marked figure on the proper reference jet before commencing work, if the instrument has been standing idle, and also after every hour if the instrument is in continuous use.

7. A complete set of jet adaptors is available, and when issued for use, the box contains an illustration of the adaptors and the method of inserting a jet in its appropriate adaptor (see fig. 2). Before making a calibration test, however, it is essential that reference is made to the particular aero-engine handbook, to verify that this method is in accordance with the latest modification to the carburettor. Adaptors should not be made up by Units locally.

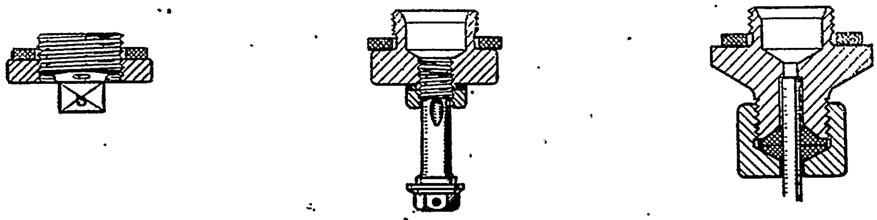

Fig. 2.—Types of adaptors used in calibrating machines

8. All carburettor jets are stamped with their nominal flow in c.c. per minute. If the actual flow recorded on test does not differ from the normal flow by more than ±2 per cent. (up to 200 c.c.) or ±1 per cent. (over 200 c.c.) the jets should be regarded as satisfactory. If the reading obtained is outside this tolerance, the jet should be rejected. On no account should any carburettor jet be altered or modified, and any jet rejected should be returned to Stores Depot as unserviceable.

9. After the completion of the tests, all fuel except that which is left in the orifice chamber should be allowed to run into the bottom tank; this prevents any possibility of inaccuracy due to difference in temperature between fuel in the top and bottom tanks.

Servicing

10. The following notes indicate the chief points in relation to the servicing of this calibrating machine:—

(i) It is advisable that the orifice chamber should only be emptied at the times of periodic cleaning and that a depth of 6 or 7 inches of fuel is always left in the gauge glasses. This will avoid the formation of air locks and will prevent the collection of deposit on the surface of the calibrated orifices.

(ii) The instrument should only require cleaning every 18 months or 2 years and on these occasions the calibrated orifices should be removed very carefully, and minutely cleaned in fuel, a piece of watchmaker's pegwood being perhaps the best material to remove any foreign matter in the orifice. Any such deposit would cause the instrument to indicate a higher reading, and would also show that the whole instrument required cleaning.

(iii) On no account should a metal instrument or tool of any description be put into the calibrated orifices or into any reference jet. Very slight mechanical damage to the hole of either the calibrated orifice or the reference jet will render them useless. Reference jets must, therefore, be handled with the greatest care and when not in use are to be kept in their wooden container.

(iv) Only clean, strained fuel of standard specification at a temperature in the neighbourhood of 15° C. (59° F.) should be used. The fuel should be changed periodically, as the density tends to increase.

(v) The packing around the gauge glass is made of cork and is held in position by a gland and nut. Leakage from the gland can generally be eliminated by tightening up the gland nut, but if this fails to remedy the defect, a new packing washer should be inserted. If occasion arises which necessitates fitting a new gauge glass, the orifice chamber and its adjacent connections should be thoroughly blown through to remove any trace of broken glass.

(vi) To prevent foreign matter collecting in the tray, a locally made cover should be improvised; the cover may be made in sheet metal with wired edges and should always be in position when the instrument is not in use.

JET CALIBRATING MACHINE, MK. XIII

11. The Mk. XIII jet-calibrating machine (see fig. 3) is the same in general principle as the Mk. XB already described. The Mk XIII machine is, however, mounted on its own base and is fitted with an electric motor driven fuel-circulating pump. It is intended for calibrating jets up to 15,000 c.c. which is three times the size of the maximum that can be checked on the Mk. XB machine.

Construction

12. The machine is an independent unit, 6 ft. 6 in. in height, mounted on a heavy cast-iron stand, the base of which can be bolted down to the floor. An electric motor and centrifugal fuel-circulating pump are mounted on the base whilst a fuel tank and the calibrating mechanism surmounted by the header tank are attached to the upright of the stand.

13. The machine is provided with a central scale plate on which there are two scales, viz.—Left-hand, 750 to 4,000 c.c. per minute, right-hand, 3,000 to 15,000 c.c. per minute. On each side of the scale plate there is a glass tube and a metal tube behind which there are three larger metal tubes. Of the latter the right-hand tube is the supply pipe for the header tank and the left-hand tube carries the overflow back to the fuel tank from the header tank, a sight glass being fitted to the L.H. tube in order that the overflow can be observed; both these tubes serve also as supports for the header tank. The larger tube, positioned between the support tubes, forms the main fuel feed to the jet adaptors and the four tubes at the sides of the scale plate.

14. At the base of each metal tube adjacent the glass tubes is an adjustable valve which can be closed when fitting a jet in the adaptor and opened when the jet is ready for calibration. The valves are cork-faced and close down on to a flat brass seat. Underneath the two valve operating knobs are two hexagonal caps, covering the entrances to the venturi chambers and these caps should be removed only when it is required to examine and clean the venturis. In between the caps are two milled-headed screws, the purpose of which is to permit the level of fuel in the glass tubes to be lowered quickly when calibrating a jet, the scale reading for which is in the lower range of the scale.

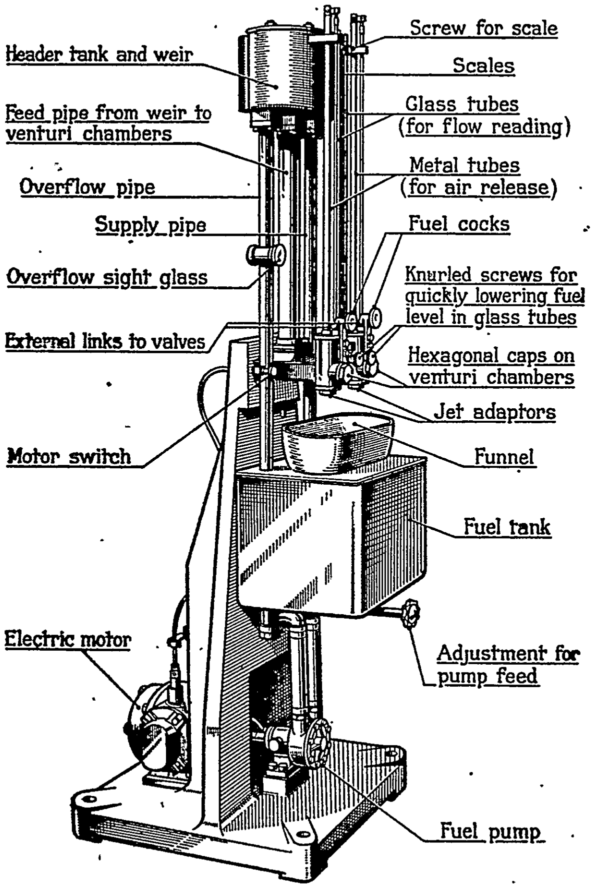

Fig. 3.—Jet calibrating machine, Mk. XIII

15. The fuel tank is provided with an integral funnel and anti-splash cups in which flame traps are incorporated. The tank has a working capacity of from four to five gallons and this latter amount must not be exceeded. A drain plug is fitted at the base of the tank for draining and cleaning purposes.

16. Below the tank is an adjustable valve for regulating the main flow of fuel from the pump, to suit the size of jet which is being calibrated. The pump-motor switch is attached to the left-hand support tube.

Operation

17. In order to operate the calibrating machine, from four to five gallons of clean, filtered fuel having a specific gravity of from 0·7 to 0·75 should first be poured into the tank.

18. The electric motor should then be switched on and the header tank allowed to fill and overflow, the two valves meanwhile remaining closed. When it is seen at the sight glass that the header tank weir is flooding, one of the two master jets provided should be fitted to the appropriate adaptor. The jet selected should be that which suits the scale to be used and which will give a reading approximately midway on the scale. The associated valve should then be opened and fuel allowed to pass through the master jet until all signs of air bubbles have disappeared from the fuel in the glass tube after which the pump fuel flow should be regulated by means of the valve until the weir just overflows.

19. When these conditions are stabilised the scale should be adjusted so that the level of the fuel in the glass tube in use is opposite the number of the scale which is equivalent to the size of the master jet. The valve should be closed and the master jet removed, the jet to be calibrated being screwed into the adaptor in its stead.

20. The valve should now be opened fully upon which the level of the fuel in the glass tube will begin to fall to a point where it remains steady. This point indicates on the appropriate scale the flow reading in c.c./min. of the jet under test.

21. Compensation should be made for slight variations in the temperature and specific gravity of the fuel feed by re-adjusting the scale to the master jet, hourly. After the fuel has been in use for some time evaporation of the lighter elements takes place and causes the specific gravity to become higher, therefore the fuel should be changed periodically.

Servicing

22. The calibrating machine should be kept clean and in a serviceable condition. Provided that clean fuel only is used, the machine should not require cleaning internally for at least two years. The pump gland should be lubricated periodically by means of the screw-cap lubricator provided; grease, petrol resisting, Stores Ref. 34A/62 should be used. The pump gland should be carefully tightened in the event of a leak at that point. The pump hose-connections should be kept tight and free from fuel leaks, new petrol-resisting hose being fitted when any signs of deterioration are seen in the old ones. If the gauge glass tubes leak at the ends, the gland nut should be gently tightened; if the leakage continues, a new cork gland packing should be fitted. In the event of a gauge glass being broken great care should be taken to remove all traces of broken glass and the new replacement tube should be cleaned, before it is fitted, by means of a pull-through.

23. Foreign matter should not be allowed to collect in the tank filler and a suitable lid made up locally from three-ply wood should be fitted. No metal instrument or wire should be used for cleaning the reference jets, which should be kept safely in the wooden container when not in use.

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Chapter 12 . . . DE-GREASING BY TRICHLOR-ETHYLENE PROCESS

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Introduction

1. Metal parts frequently require cleaning prior to inspection, assembly, heat-treatment, or the application of a protective coating. One approved method for this is by the use of a chemical solvent; trichlorethylene is frequently selected for the purpose.

2. Trichlorethylene is a colourless, spirituous liquid which boils at 87° C. The vapour given off is much heavier than air; the liquid may therefore be boiled in the lower part of a deep container and condensed in the upper part without serious loss of fluid by diffusion.

Articles may be cleaned by:—

(i) Suspending them in the vapour rising from boiling liquid; this is the method usually adopted for aircraft parts.

(ii) Immersing them in boiling liquid.

(iii) Immersing them in cold or boiling liquid, followed by suspension in the vapour.

General description of plant

3. A plant employing boiling liquid or trichlorethylene vapour consists of one or more deep vessels with means for heating the liquid in the lower part and provided with cooling pipes below the mouth of the vessel for condensing the vapour. Heating may be by means of:—

(i) Steam pipes.

(ii) High pressure hot water pipes.

(iii) A gas or oil burner.

(iv) Electric heaters.

4. Matter removed from the articles being cleaned passes into the sump, in solution or as solid sediment. The soluble materials raise the boiling point of the liquid and lower its specific gravity. The solid sediment may tend to insulate the source of heat and, in gas, oil or electrically-heated plants, may cause local overheating of the vessel if the sediment is not removed. Temperatures above 120° C. are to be avoided, as otherwise the trichlorethylene may decompose and produce a detrimental acid (see paragraph 15). Cold water is passed through the cooling pipes, and thermostatic and/or mechanical controls are provided to shut down the plant when the sump becomes unduly hot or when the cooling system fails.

Installation

5. The plant is to be installed in accordance with the maker's instructions and with regard to the type and volume of work handled. If any existing plant is called upon to handle a new class of material or part, the maker is to be consulted regarding the plant's suitability for use with the new part.

6. In view of the narcotic nature of trichlorethylene good ventilation is to be provided to remove any vapour which may be dissipated into the surrounding atmosphere. An efficient exhaust draught (natural or forced) from a convenient point a few feet above the plant rim to roof height is recommended. If the plant is near an outside wall a fan in the wall about 8 ft. above the plant, exhausting outside, is very efficient. Adequate fresh air inlets are to be provided near ground level, at the opposite side of the building if possible. If the plant is in a well more than 18 in. deep, suction ventilation is to be provided for use whenever the pit is to be entered.

Heating

Steam

7. This form of heating is very efficient. Superheated steam is not to be used and the gauge pressure must not exceed 30 lb. per sq. in. when pure trichlorethylene is in the plant. Higher pressures are permissible (with advantages in maintaining optimum performance) as the oil content, and consequently the boiling point of the sump contents, increases. If the supply is in excess of 30 lb. per sq. in. a reducing valve or an automatic control, which will regulate the pressure rise in accordance with the maker's recommendations, should be fitted.

High pressure hot water

8. This is also a very efficient method of heating. Control is effected by an orifice plate—supplied by the makers—in the supply line to the heating coils. The size of orifice required varies with the pressure and temperature of the supply, and should be determined by experiments so that the vapour generated is controlled by the condensing coils.

Gas or oil

9. Gas is the most usual form of heating: oil heating is only to be employed when other forms of heating are not available. In both instances it is desirable that the products of combustion be removed from the workshop as soon as possible. A flue pipe (fitted with a cowl to prevent down draught) is to be provided leading to open air by the shortest vertical route. If an outside delivery is not practical the flue should terminate high in the building near to a point where there is an efficient exhaust draught. The exit must be clear of any metal work and at no point is a flue pipe to pass over the tank. Precautions are to be taken to prevent the ingress of trichlorethylene vapour to the burners, otherwise decomposition and the production of hydrochloric acid will take place.

Electricity

10. There are no special points to stress in regard to electric heating.

Maker's instructions

11. The notices provided by the makers regarding the operation and precautions to be taken are to be exhibited prominently in close proximity to the plant.

Servicing

Introduction

12. Once the plant has been installed, successful operation depends upon:—

(i) Maintaining the trichlorethylene at the correct level in the sump of the plant.

(ii) The re-distillation of the liquid at sufficiently frequent intervals to prevent contamination increasing to such a degree that the trichlorethylene vaporised is not dense enough to de-grease the work satisfactorily.

(iii) The early removal of solid matter from the sump.

(iv) Keeping all internal surfaces, particularly those through which the liquid is heated, clean and free from deposit.

(v) The exclusion of water and water vapour from contact with trichlorethylene or its vapour.

Re-distillation

13. Re-distillation is to be done before the amount of oil and grease dissolved in the trichlorethylene becomes great enough to interfere with the efficient working of the plant. The necessity for re-distillation is usually indicated by:—

(i) The excessive time taken in de-greasing a normal batch of parts.

(ii) An excessive fall in the vapour line when new work is put in and delay in the line regaining its normal position (this should be between the second and third turns of the condensing coil, counting from the lowest).

14. The amount of oil present may be ascertained by:—

(i) Taking hydrometer readings of the liquor in the sump.

(ii) Analysing a sample of the liquor.

Note . . . The percentage of oil and grease present should not exceed 40 per cent.

Temperature control

15. Many plants are fitted with a thermostatically controlled fuel cut-off valve to prevent excessive temperature rise. If steam heating or high pressure hot water heating is employed, the temperature cannot rise excessively. The cut-off devices operate when the temperature of the mixture reaches 120° C., as trichlorethylene heated above this point decomposes, forming hydrochloric acid which can corrode the plant or parts treated. It is important that immersion cut-off thermostats, steam coils, etc., are never uncovered as the level of the sump mixture falls. If flame heating is employed and if no automatic cut-off valve is fitted, one of the methods described in paragraph 14 to determine the amount of oil present must be used at frequent intervals. When a plant is in regular use on work of a uniform character it is good practice to standardise the time between re-distillations, making the period short enough to preclude the possibility of excessive contamination.

16. If, after re-distillation and topping-up, the symptoms described in paragraph 13 (i) and (ii) persist, the heating equipment is probably defective.

Acidity

17. Aluminium and magnesium (and their alloys) in finely-divided form react with trichlorethylene and cause its decomposition. The consequent acidity corrodes the plant and work if the plant is not cleaned out regularly and thoroughly. Reaction may be indicated by unusual fumes, and by the formation of a black, sticky substance. To prevent such reaction it is essential that the following precautionary measures should be taken:—

(i) Pre-clean the parts by air blast or by washing in a light fuel oil. Paraffin or white spirit may be used where there is no fire risk, but if de-greasing plants are heated by gas, oil or electricity, these solvents are not to be used.

(ii) Clean the plant thoroughly at least every seven days, ensuring that all finely-divided metal is removed from the sump, heating coils, etc.

(iii) Ensure that the level of liquid in the sump never falls too low.

(iv) Add small quantities of anhydrous sodium carbonate (soda ash) twice daily, preferably when the solvent is not boiling. The soda ash is to be sprinkled evenly over the surface of the liquid. The amount added over a period of seven days should approximate to 1% of the trichlorethylene charge.

(v) The trichlorethylene is to be checked periodically to verify that it is not acid, as follows. Shake up 100 c.c. of trichlorethylene distillate with 50 c.c. of distilled water and add a few drops of bromophenol blue to act as indicator. A similar volume, i.e. 50 c.c., of distilled water is also to be treated with the indicator. Both solutions should be blue in colour. The alkalinity of each is then to be determined by titration with N/10 hydrochloric acid to a yellow end-point. The volume of acid required to neutralise the extract should exceed that required to neutralise the distilled water by at least 0·2 c.c.; otherwise the plant must be thoroughly cleaned and the solvent reconditioned.

(vi) Many of the larger de-greasing installations have small auxiliary plants which are used as stills for the sump liquor from the main plants. It is advisable to carry out distillation in these plants in the presence of sodium carbonate and water as this assists in reconditioning the solvent. To a gallon of water, ¼ lb. sodium carbonate should be added.

18. If, in spite of these precautions, acidity develops, the fact is to be reported to higher authority. The plant is not to be used until it has been rectified.

19. If a plant has been acidic it should, after cleaning out, be treated as follows:—

(i) Filled up to a point above the condensing coils with a solution of sodium carbonate in water, boiled for several hours and then emptied. A ¼ lb. of sodium carbonate should be added to each gallon of water.

(ii) Swilled with water.

(iii) Dried out.

(iv) Re-charged with fresh trichlorethylene.

20. In addition to the normal precautions for excluding water, care is to be taken to ensure that the plant is not installed near escaping steam. Excessive cooling may result in the condensation of atmospheric moisture which will fall into the sump. Water in a plant can cause rapid corrosion of the structure, particularly in the zone just below the cooling coils where it condenses and remains on the sides.

Prevention of corrosion

21. Corrosion of parts, particularly those made in light alloys, may occur if they are subjected to heat before all trichlorethylene has been removed. Care is therefore to be taken to ensure that parts of complicated form or containing blind holes are carefully turned about so as to remove all liquid. Bundles of parts intended for immediate heat treatment are to be shaken to ensure that liquid is not retained by capillary attraction between surfaces in contact. In any event, parts are not to be immersed in a salt bath until they have acquired atmospheric temperature after removal from the de-greaser; it is advisable to allow an interval before treatment. As, however, de-greasing produces a clean surface whose resistance to corrosive attack is at its lowest, a protective coating is to be applied, at the very earliest opportunity after de-greasing, to parts made of readily corrodible materials.

Note . . . Where the requirements of Specification D.T.D.901 apply, parts and materials, even if effectively de-greased, may need a further cleansing operation to remove insoluble solid matter.

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SECTION 4

MATERIALS AND HOW TO WORK THEM

LIST OF CHAPTERS

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

CHAPTER 1 Materials and how to work them—general (*to be issued later*)

CHAPTER 2 Timber

CHAPTER 3 Metals and alloys

CHAPTER 4 Marking of metals and alloys

CHAPTER 5 Working and repair of transparent plastics

CHAPTER 6 Glazing and sealing of aircraft components

CHAPTER 7 General adhesives and glazing and sealing compounds

AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—GENERAL ENGINEERING

This is A.L. No. 12 to A.P.1464B, Vol. I and concerns Part 2, Sect. 4
Insert this chapter

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CHAPTER 2

TIMBER

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General

1. Although timber is being replaced by metal for structural parts of aircraft, it is still an important constructional material and for certain purposes its use is likely to continue. Timber differs essentially from metals in that it is an organic material, and being the result of natural growth, it is influenced by changes in climate or weather which produce variations in both size and strength. It does not suffer appreciably from chemical corrosion, rusting, oxidation, etc., to which metals are liable, but it may deteriorate owing to attack by fungus, or may be injured by insects.

Structural characteristics

2. Wood is a structure rather than a homogeneous material and consists of tubes or cells firmly cemented together, the majority lying along the longitudinal direction of the grain. Viewed microscopically, a cross-section of the end grain resembles a honeycomb, and this resemblance is particularly marked in soft woods, e.g. spruces, firs, larches, pines, etc., in which the wood is composed chiefly of longitudinal cells or tubes laid side by side—see fig. 1. Hardwoods have longitudinal cells —side by side—to approximately the same extent. The thickness of the cell walls depends upon the season of the year at which their growth takes place. This seasonal variation may be seen on cross sections of the wood and gives rise to the concentric annual rings.

3. The hardwoods have a more complex structure. The longitudinal fibres are usually small and thick walled but relatively large tubes known as "vessels" are interspersed—see fig. 2. Rows of cells running radially from the centre to the edge of the tree are known as "medullary rays". These rays are indistinct and small in the conifers but in many of the hardwoods they are a prominent feature and influence the strength of the wood, although they are supposed to have a deleterious effect on some strength properties.

4. A log usually consists of heartwood, sapwood, and bark—see fig. 3. In a few species, e.g. spruce, there is little difference either in appearance or strength between the heartwood and sapwood.

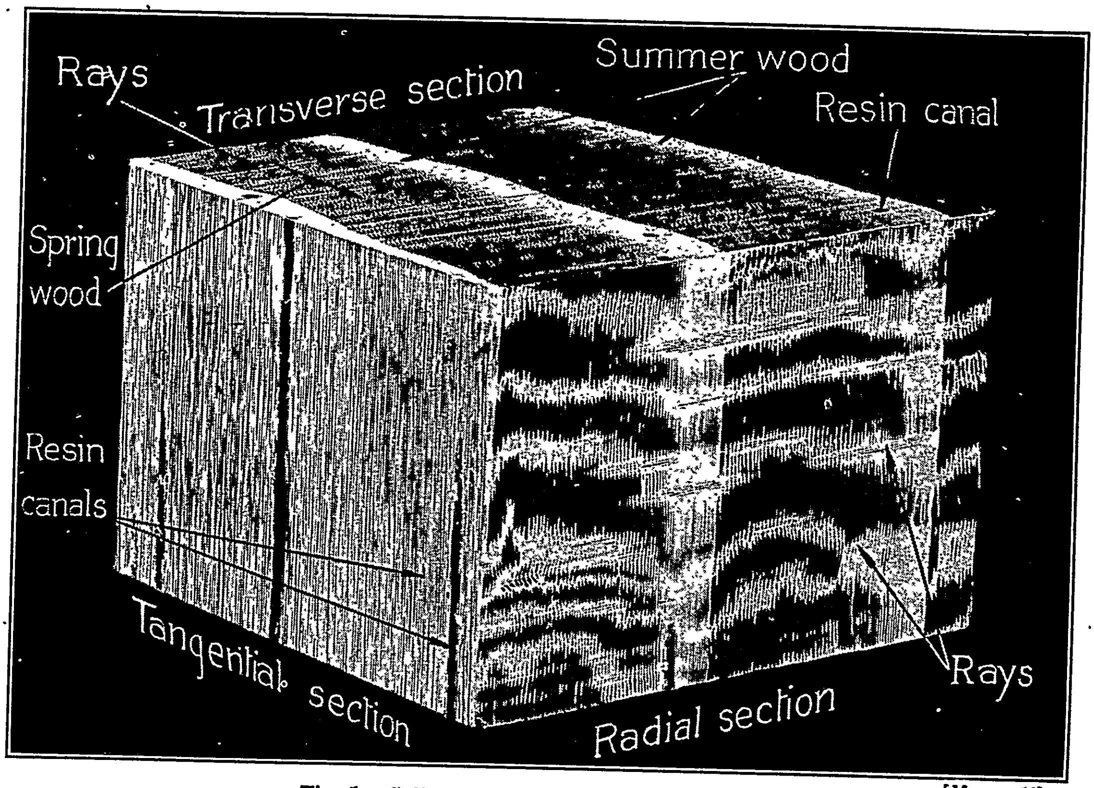

Fig. 1.—Softwood—Scots pine (*Pinus sylvestris*) [*Mag.* × 19]

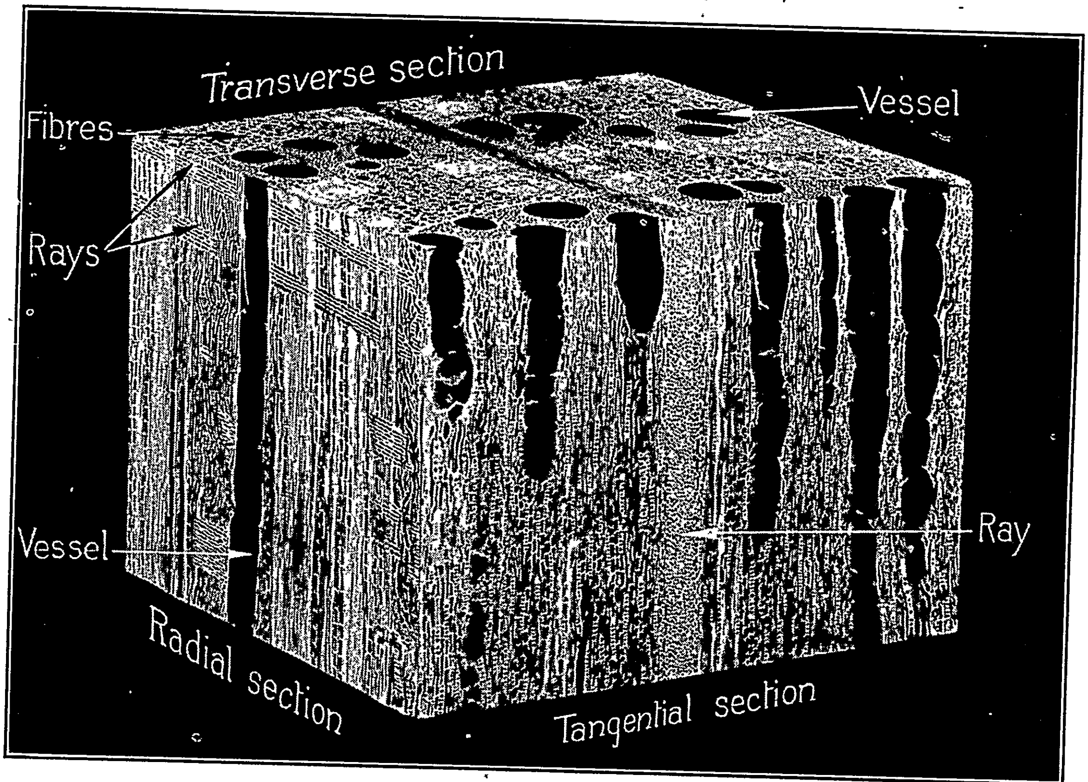

Fig. 2.—Hardwood—Oak (*Quercus robur*) [*Mag.* × 80]

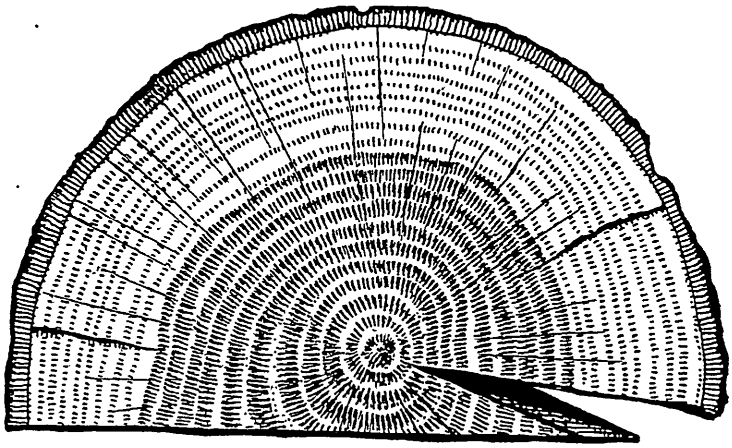

Fig. 3.—Cross-section of a log

In most species, however, the heartwood, which occurs towards the centre of the tree, is darker in colour and more durable than the sapwood and is found to yield the best timber for structural purposes.

The photographs for figs. 1, 2, 9, 10, 11, and 12 have been reproduced by courtesy of the Forest Products Research Laboratory.

The peripheral zone of sapwood is generally less durable than heartwood, and certain cells of the sapwood contain food materials which attract insects and support the growth of some fungi. The bark, although vital to the growing tree, has no utility as a structural material.

Seasoning

5. When a tree is felled, the wood is in a moist state. In this condition it is described as "green" and since removal of surplus moisture from the wood improves its strength, lightens its weight and makes it more immune to fungal attack, it causes shrinkage to occur before the timber is cut to size. A certain amount of drying is necessary before the wood is suitable for use. A log must be converted to planks before any drying will occur; this applies to air or kiln-drying referred to in para. 6.

6. The process of drying is called seasoning. So-called "natural" seasoning consists of exposure of the log to the atmosphere until a state of equilibrium between the moisture in the wood and the dampness of the atmosphere has been reached, when the wood is said to be "air dry". In some instances it is economical, or otherwise advisable, to accelerate or control the drying process by exposure of logs or planks in a heated chamber. This process is usually called "kiln-drying" and when carefully done, kiln-dried timber is superior to that which has been air-seasoned under poor conditions.

7. If artificial drying is not conducted under suitably controlled conditions it may cause temporary or permanent damage to the timber, but damage may also be caused during so-called natural seasoning if the conditions of stacking and storage have been unsuitable and if the atmospheric conditions are other than normal.

8. The success of kiln drying depends chiefly on control of the rate of removal of the moisture from the wood. As wood dries it shrinks. If the surface be rapidly dried while the centre is still moist, shrinkage will occur on the surface and at the ends while the central portions are still unchanged in size—see fig. 4. This will result in the formation of shrinkage cracks or "shakes". The stresses introduced by the uneven shrinkage may not be sufficient to drag the fibres of the wood apart and leave visible cracks, but may leave the wood with serious residual internal stresses so that the application of further stress by external forces will cause early failure. Wood in this condition is liable to warp after being cut.

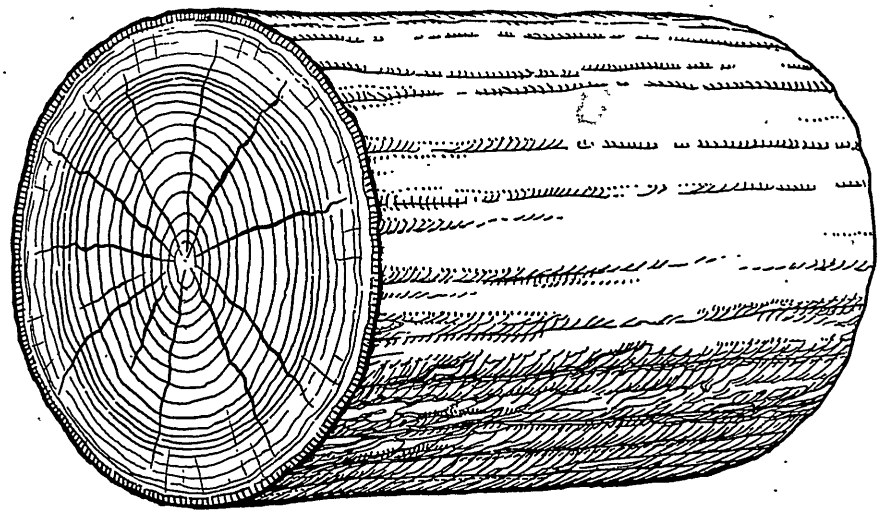

Fig. 4.—Typical surface cracks on the end of a log

Case-hardening

9. A common defect due to improper seasoning is that in which the surface layers of the wood are left in compression. This condition is known as "case-hardening" and the effect is not evident until the piece is cut. A simple test to detect the presence of case-hardening is illustrated in fig. 5.

Shrinkage

10. Wood retains its ability to shrink or expand with loss or gain of moisture throughout its lifetime. From an engineering point of view this constitutes a grave defect and is the cause of many of the troubles associated with the use of timber as a structural material. The rate of shrinkage is not equal in all directions but is greatest in the tangential (or circumferential) direction of the grain. In the radial direction of the grain, i.e. at right angles to the annual rings, the rate of shrinkage is about half as great and in the longitudinal direction of the grain the shrinkage is practically negligible. The extent of shrinkage will vary in the different species.

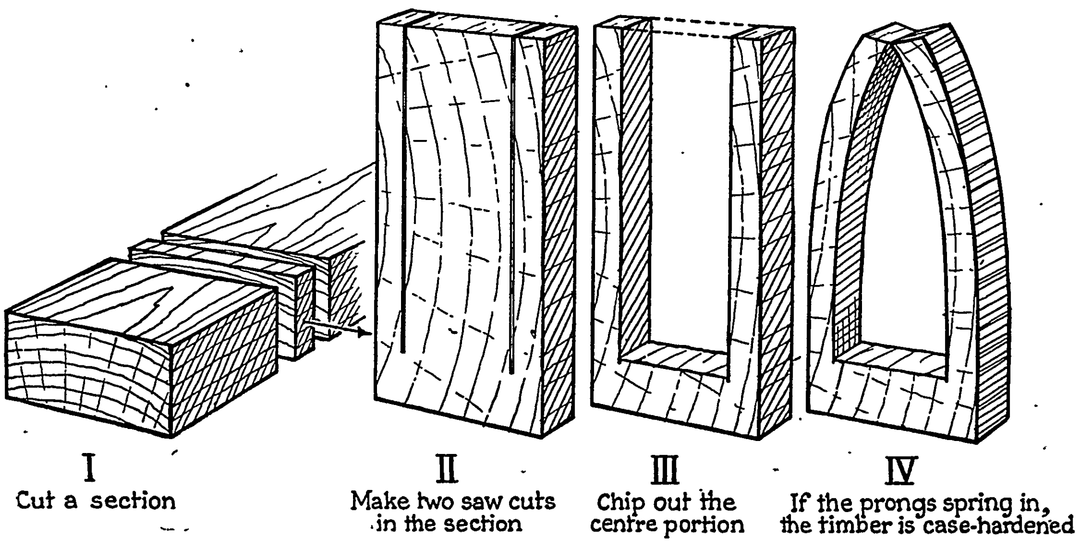

Fig. 5.—Shrinkage of timber

Defects

11. Timber is liable to various defects which may be the result of conditions of growth or injury during growth, felling, seasoning or transit. These defects should be eliminated, where possible, by rejection after careful inspection before the timber is used, but defects may develop or be disclosed during conversion of the timber or during its life as a structural member.

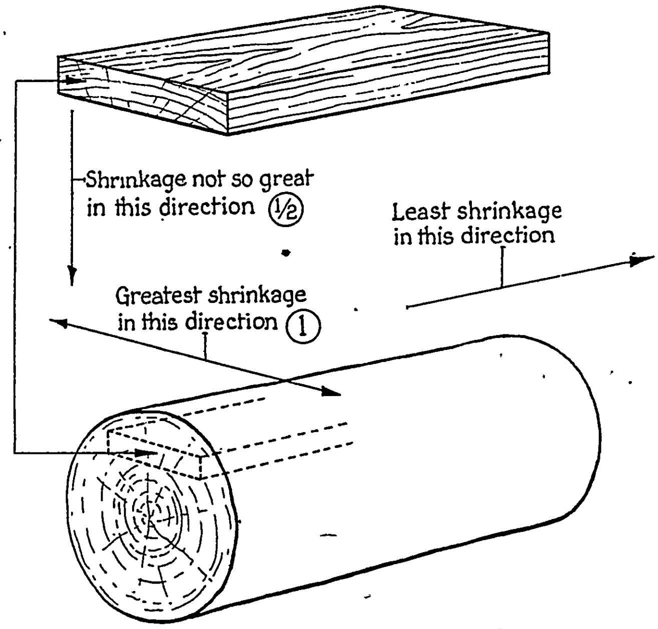

Fig. 6.—Direction of shrinkage

Structural defects

12. The general direction of the grain in timber may be disturbed by the presence of branches, or even buds, and also by accidental injuries to the bark or growing wood caused by various small accidents, such as abrasions, blows, bird pecks or insect attack. Branches cause a disturbance in the grain which may take the form of inconspicuous curls or swirls, or may take the form of knots—*see* fig. 7.

(i) *Knots.*—Knots are usually a source of structural weakness but their deleterious effect depends on their position and frequency, on their size and on whether or not the centre portion of the knot is loose.

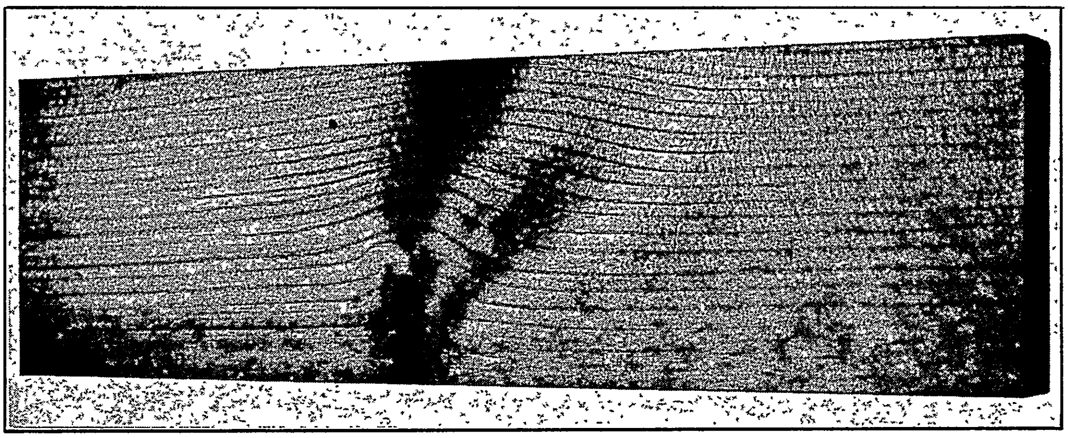

Fig. 7.—Disturbance of grain due to knots

(ii) *Interlock grain.*—Disturbance of the general direction of the grain is periodic in some species in which the grain of successive concentric layers may vary in inclination, giving rise to a condition known as interlock grain and producing on quartered surfaces alternating stripes of varying lustre, known as "roe" or "stripe"—see figs. 8 and 9. This is a feature of mahogany and many of the tropical hardwoods and though contributing to the strength in resistance shearing along the grain and splitting, it is detrimental to the strength in bending, particularly under suddenly applied loads.

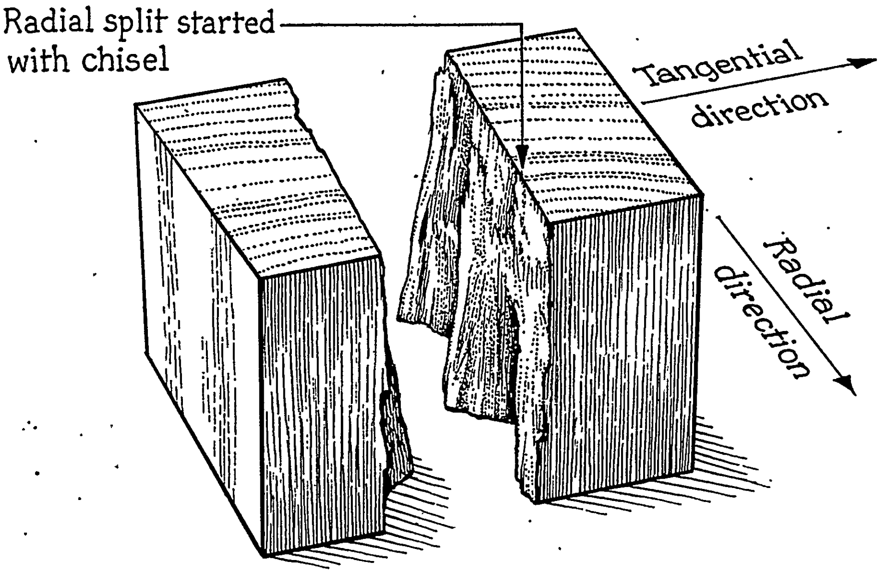

Fig. 8.—Change of direction of grain

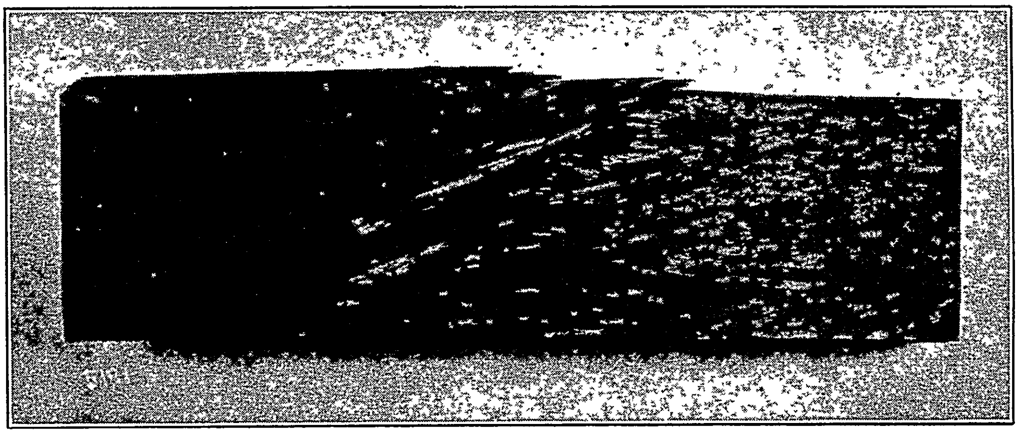

Fig. 9.—Fracture of a bending specimen showing interlock grain

Defects due to insect attack

13. Extensive damage to timber is caused by the larvae (or grubs) of certain insects. Although the larvae are usually soft bodied they possess jaws capable of breaking down the cell walls of the wood. Timber which has been injured by insect (e.g. pinhole borers) attack during growth or while in the log, is usually eliminated by inspection before it reaches a stores depot, or before it is converted into aircraft parts. Occasionally, however, bore holes are found in timber which is in store or in use.

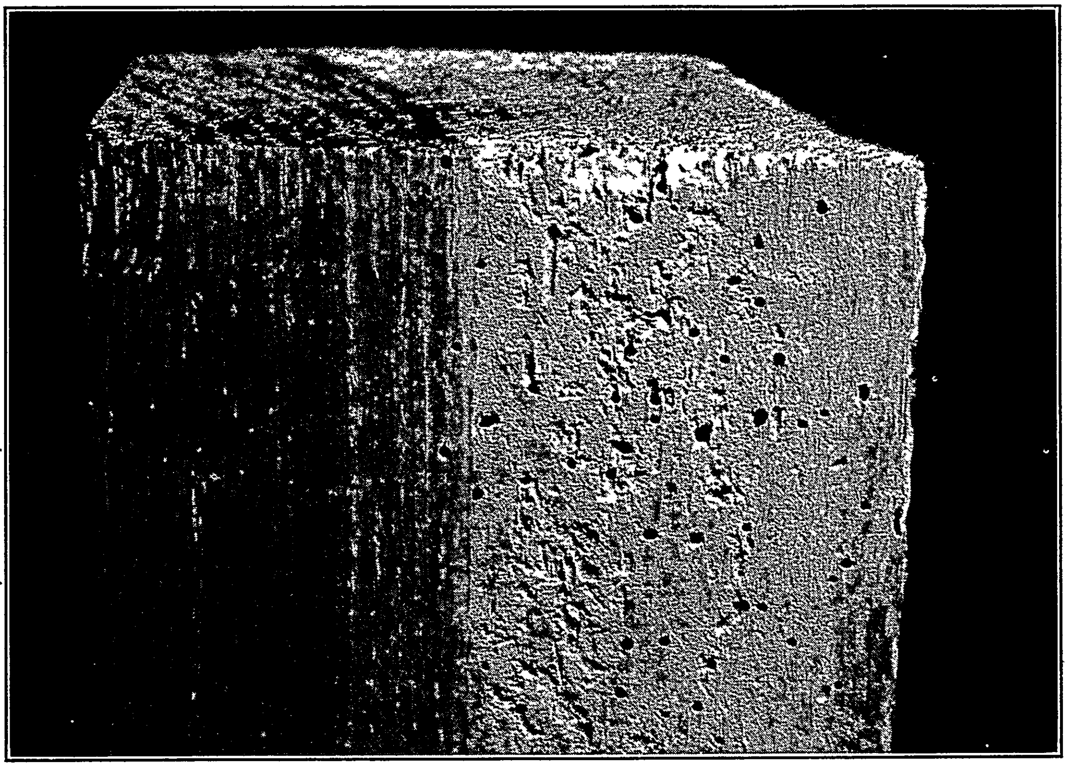

Fig. 10.—Oak plank attacked by powder-post beetles

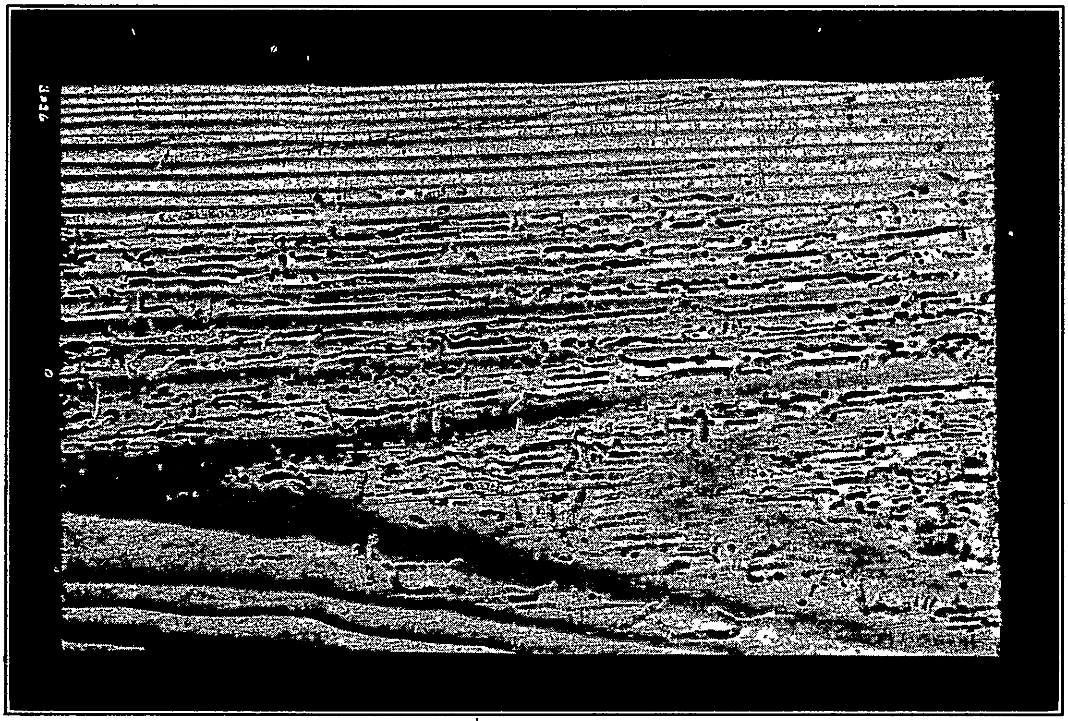

Fig. 11.—Damage done to Scots pine by common furniture beetles

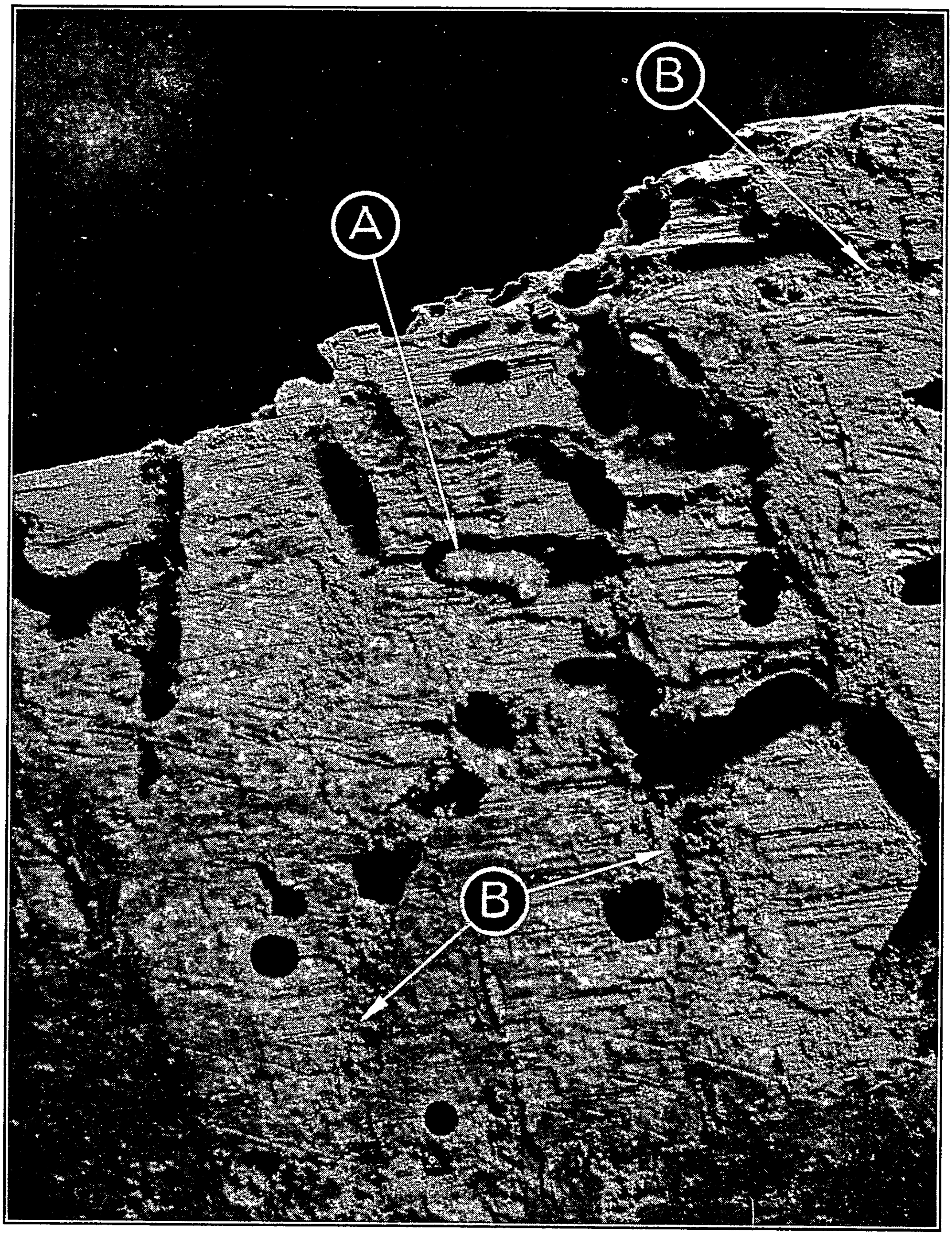

Fig. 12.—Oak beam attacked by death-watch beetles.

14. The reduction in strength due to the presence of bore holes will depend upon their size and number and also upon the location of the holes in relation to the stresses which the timber will have to support. Discovery of bore holes suggests the possibility of active attack and precautionary measures may be necessary to prevent spread of attack—see para. 18.

15. Injury to converted timber in this country is usually due to attack by powder-post (*Lyctus*) beetles, common furniture (*Anobium punctatum*) beetle, or the death-watch (*Xestobium rufo-villosum*) beetle. Fig. 10 shows a portion of oak plank attacked by the powder-post bettle, in which the dust-filled galleries follow the grain of the wood. Fig. 11 shows the damage done to Scots pine by the common furniture bettle. Fig. 12 shows a section of a portion of oak beam attacked by the death-watch beetle, in which A indicates the larva in tunnel (bore-dust or frass dislodged in cutting section) and B indicates bun-shaped pellets, characteristic of the bore-dust or frass of the death-watch beetle.

(i) *The powder-post beetle.*—Several species of this beetle which may be found in England appear to have been imported in considerable quantity since the war (1914–1918). The beetles cause much damage by attacking the recently, or partly seasoned sapwood of some hardwoods such as ash, walnut, etc. They select those woods which have pores of a size to suit their eggs. On this account birch is rarely attacked and softwoods (e.g. spruce, larch, etc.) are immune.

(ii) *The common furniture beetle.*—This beetle prefers the sapwood of well seasoned old wood, but may attack softwoods or hardwoods, including three-ply. As the beetle lays its eggs in cracks or crevices on the surface of the wood it is not limited by the pore size. This beetle never deposits eggs on a smooth or varnished surface.

(iii) *The death-watch bettle.*—This is the largest of the furniture beetles. It prefers old timber and usually confines its attack to oak, walnut, and similar hard woods. It is rarely found in timbers of small dimensions, but prefers large structural timbers in old buildings. This beetle is unlikely to be found in aircraft material.

16. All these beetles are small, elongated and cylindrical. They are only a few millimeters in length, the death-watch beetle, having a length of 6 to 8 mm., being the largest. The life cycle of the beetles is variable and depends on surrounding conditions. For the powder-post beetle it is usually one year, for the common furniture beetle one to two years and for the death-watch beetle two to three years. The eggs hatch out in about a fortnight and the grubs tunnel into the wood and remain for one or more seasons. It is at this stage that the damage to the timber chiefly occurs. Each grub eventually selects a position near the surface of the timber and turns into a chrysalis (or pupa). After two to four weeks the adult beetle emerges and, choosing suitable conditions of temperature, etc., bites its way to the surface and escapes leaving a small circular hole. Emergence may take place at any time in spring or early summer but is most likely during May or June for powder-post and furniture beetles and during April to June for the death-watch beetle.

17. The presence of these holes is usually the first indication that attack has taken place due to infection at least a year previously. Frequently the grubs betray their presence by throwing out small piles of wood dust or "frass". Examination of this "frass" may give a clue to the type of beetle concerned. The powder-post beetle leaves fine and powdery frass, the furniture beetle leaves granular frass in the form of small oval or cylindrical pellets and the death-watch beetle leaves comparatively large bun-shaped pellets. A further clue to the identity of the beetles is given by the size of the exit holes, i.e. about $\frac{1}{16}$ in. dia for the powder-post and furniture beetles and $\frac{1}{8}$ in. dia. for the death-watch beetle, and by the species and condition of the wood which is attacked.

18. Preventive treatment consists chiefly of preventing access of the beetle to the end grain of the wood by close fitting of joints, etc. Beetles are not likely to lay eggs on smooth surfaces especially if protected by varnish. Wood in store should be well ventilated and care should be taken that infected wood, or wood which is liable to be infected (such as fresh sapwood), should not be allowed to remain in the vicinity. The storage of timber is described in A.P. 830, Vol. II—see also para. 28.

19. Where attack is suspected, it is usually possible to prevent extension of the damage by treatment with an approved insecticide. Several applications should be made in spring or early summer at intervals of about a fortnight and the treatment should be repeated a year later—*see* para. 29. It is important to seal up joints, old bore holes, etc., where fresh egg laying might take place.

Decay

20. Injury to timber by decay is usually the result of attack by fungus. Fungi, which are low forms of plant life, can spread through the wood by means of fine strands or "hyphae" which are usually visible under the microscope only. Some fungi feed on the contents of the wood cells. Fungi

of this type cause most of the sap stains which discolour the wood but do not necessarily cause any reduction of strength. Other fungi have the power of digesting the material of the cell walls. These fungi may cause rapid deterioration of strength and under suitable conditions may eventually destroy the wood. Infection by fungus may occur by contact with wood which is already infected or by means of minute "spores" which are produced in large numbers under suitable conditions of growth and which may be conveyed by wind, in dust, etc.

21. Fungus will develop and spread only under suitable conditions of moisture and oxygen supply. Wood which has a moisture content of less than 20 per cent. in unlikely to suffer from fungus attack, but wood which is wet provides a suitable breeding ground. The presence of oxygen is, however, necessary as wood which is completely submerged in water may be preserved for hundreds of years.

22. The fungus which causes the greatest amount of injury to structural timbers is dry-rot or *Merulius lacrymans*. This fungus, in spite of its misleading name, not only requires moisture for its growth but can produce drops of moisture. Spruce is liable to attack by brown pocket rot or *Trametes serialis* fungus. In both instances the early stages of infection are very difficult to detect. As the infection spreads, discolouration may be observed and the timber may be found to be brittle. In advanced stages, the wood becomes brown with longitudinal and transverse cracks giving an appearance somewhat similar to that of charred wood.

23. Injury by fungus may be prevented by poisoning the food supply of the fungus with some preservative fluid such as creosote, by ensuring that the wood is kept in a dry and well ventilated condition and by reducing the risk of infection by removal of other wood which is infected or is likely to become infected.

Conversion

24. Since timber has greater strength along the grain than in any other direction it is important that the timber should be so sawn (or "converted") that the longer dimensions of the piece are parallel to the direction of the grain. The true direction of the grain can be found by splitting, but this is not always convenient.

25. Where the grain is inclined to the length of the piece on two opposite faces and parallel to the length on the two remaining faces, the degree of inclination can easily be estimated. An example is shown in fig. 13 of a piece of timber which has been so cut that the grain on all four faces is inclined

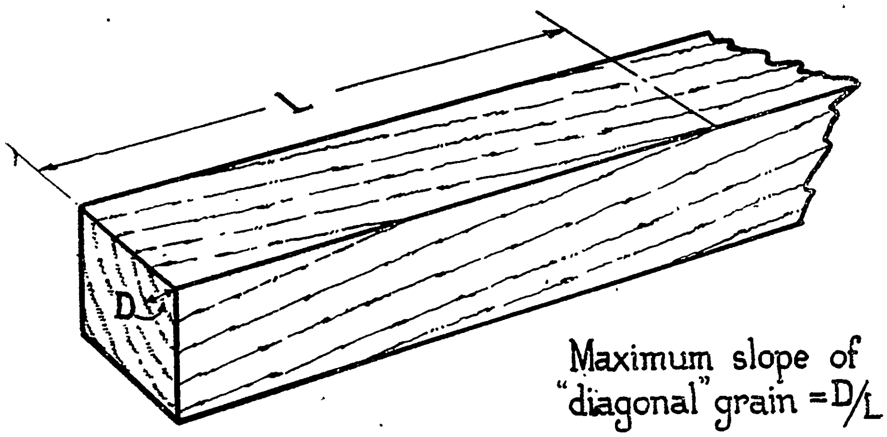

Fig. 13.—Slope of grain

to the length of the piece. The true inclination of the grain is greater than the apparent inclination and should be measured by the method shown. A piece of timber with the grain inclined in this manner is said to have "diagonal" grain.

26. If a split be made in a radial plane, the split may or may not travel in a direction parallel to the axis of the tree. In some trees the growth has a twisted or helical direction so that the grain in any annual ring may lie on a steep helix and therefore at an angle to the axis of growth. The true direction of grain in the annual ring cannot easily be determined by simple examination but may be found by making a small radial split (where possible) as at a–b, or by making an ink mark on a tangential surface as at c–c_1 and noting the direction in which the stain runs. Inclination of the grain with respect to the axis of the tree is known as "spiral" grain and is illustrated in fig. 14.

27. In some hard woods the direction of helical growth reverses at intervals of two or more years which leads to the banded appearance of a radial surface known as "roe"—see para. 12 (ii). In some timbers, such as spruce, the helical grown may be uniform over the whole piece. This condition is rather difficult of detection but the ink test (mentioned previously) will be found to operate well on tangential surfaces of these timbers.

Precautions during storage and use

28. Damage by beetle attack during storage may be limited by suitable precautions. The piling fillets or "stickers" which are used for separating the layers in a pile should either be of heartwood or of a coniferous wood rather than of sapwood of any timber which is liable to encourage attack. Any sapwood should be examined thoroughly in autumn and spring for signs of attack.

29. *Timber spraying fluid.*—Wood which has been attacked or which has been in the vicinity of infected pieces may be sprayed with a protective fluid, such as a mixture of orthodichlorbenzine 91 per cent., pure castile soap 7 per cent., and cedar wood oil 2 per cent. Good results for articles of furniture can also be obtained by brushing on paraffin or turpentine, with the usual precautions against fire. Several applications of the insecticide should be made at intervals of about 10 days.

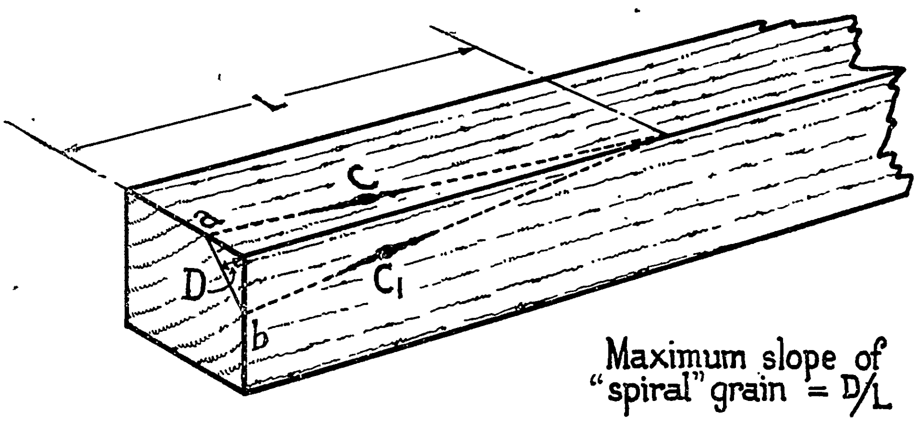

Fig. 14.—Test for determination of slope of grain

Where practicable it is advisable to segregate infected timber during treatment. This may be done by an enclosure of canvas screens which can be arranged to prevent the escape of any beetles which may emerge from the timber.

30. Attack by fungus can usually be prevented by ensuring that all timber in storage or in use is kept dry and well ventilated. Contact with infected timber should be prevented. All storage enclosures should be kept clean and free from sawdust, chips, bark, etc. Where dry conditions cannot be ensured the timber should be treated with some preservative. For exterior structural work creosote may be applied.

Mechanical characteristics

31. Owing to the peculiar structure of wood, the strength varies greatly in different directions. The tensile strength, for example, is about 25 times greater in the longitudinal direction of the grain than in the tangential, the compression strength is about six times greater in the strongest than in the weakest direction and the shear strength about three times greater. As all the properties of timber are affected by moisture content and by density, it is important that these factors be taken into account in all strength measurements and calculations.

32. The following table gives the minimum requirements in mechanical properties and density at the stated moisture content, stipulated in specifications for aircraft timbers.

Aircraft Timber	Bend Test				Compr. test Max. lb/sq. in.	Impact ft. lb. Izod	Specification
	Density lb/cub. ft.	Per cent. Moisture.	"E" lb/sq. in. × 10^6	Modulus of rupture lb/sq. in.			
Ash	40	15	1·5	10,500	5,800	8	B.S.I.3V4
Walnut ...	35	15	1·5	11,500	7,000	7	B.S.I. 3V5
Mahogany ...	32	15	1·5	10,000	6,250	4	B.S.I. 3V7
Spruce ...	24	15	1·5	8,000	5,000	6	D.T.D. 36a

33. *Tensile strength.*—Wood has relatively high tensile strength in the direction of the grain but it is seldom that this strength can be fully developed. Measurement of tensile strength is difficult and requires great care in the design and construction of the test piece so that premature failure shall not occur by crushing or shearing of the ends. Tensile strength is of importance in airscrews where the roots of the blades have to withstand large centrifugal forces and it also plays a part in resisting final rupture during bending.

34. *Compression strength.*—The strength of wood in compression is of major importance since this property usually limits the load which can be carried by any member. Failure occurs by collapse of the tubular structure. In most timbers this collapse is at first confined to narrow bands running transversely across the grain. These compression bands or creases are most easily visible in conifers such as spruce. It is important to be able to detect creases at an early stage. Experiments may easily be made by bending a strip of spruce (or other conifer) in the hands and observing the compression (or concave) face. If a strong light be arranged to fall at grazing incidence (skimming along the surface) the small creases will show up at an early stage of the bending.

35. Wood which has once formed a compression crease is permanently damaged. Although it is able to withstand compression it can no longer withstand tension and is, therefore, a potential danger in any position where it may be subject to reversals of load. This may be demonstrated in a simple manner by reversing the direction of bending on the small strip described in para. 34. If a compression crease has been formed, the reversed bending will apply tension across the crease and the strip will snap suddenly.

36. When compression acts across the grain, local creases do not usually form. The walls of the wood cells gradually collapse allowing the exposed surfaces to assume a ribbed or washboard appearance. A large amount of compression is possible without definite fracture and it has even been proposed to use wood compressed or "consolidated" in this manner, in place of other woods of greater density.

37. *Bending strength.*—A member which is in bending is subject to compressive strain along its concave face and tensile strain along its convex face. If the bending be continued, compression creases will form, but the adjacent parts will continue to support the compression stresses. As the bending strain increases, these compression failures will extend into the member until the tensile stress on the convex side becomes greater than the wood can stand, when the beam will collapse.

38. It is well known that the "modulus of rupture", or apparent stress which a rectangular bar will support when subject to bending, is considerably greater than the compression strength of the material. (About 60 per cent. greater in spruce.) This is not because any part of the wood can support more compressive stress in a beam than in a compression test piece but because the method of calculating the stress in bending takes no account of the power or ability of the wood to pass on any stress which it cannot support to surrounding portions which are less severely strained by the bending action. It is evident that in the case of a spar of 'box' or "I" section where the less strained material has been largely removed, the wood has little opportunity of escaping its punishment and the member fails soon after the surface stress reaches the compression strength of the timber.

39. It will be clear from this that the "Modulus of rupture" must be used with caution in the design of wood members. In America it has been customary to apply to the "Modulus of rupture" a correcting factor (called "form factor") to allow for the effect of the shape of the cross section. In the British Isles a rough working rule has been used by which the compression strength of spruce is taken as 500 lb/sq. in. greater in bending than in simple end compression.

40. Much may be learnt by careful examination of the fractures of light rods of spruce (or other timbers) broken in the hands. If a simple bending fracture be viewed from the end, in line with the grain (preferably using one eye only) the fractured area will be seen to consist of two parts, namely (i) The compression side, with comparatively flat areas where compression creases have formed—where this type of fracture extends across the entire section, the fracture is sometimes described as "short", "carrotty", or "block" fracture—and (ii) the tension side, with jagged, splintery surfaces. In timber which is weak for its species, the fracture on the tension side may also be very short; this is the characteristic of brittle timber. Experience in recognising these types of fracture is frequently of value in determining the nature of the forces which may have caused the accidental breaking of a wood member.

41. *Shear.*—One of the important characteristics of wood is the disparity between its tensile and shear strength. In most materials the shear strength is at least half the numerical value of the tensile strength. In woods it is less than one tenth of the tensile strength. It is largely for this reason that the full tensile strength of wood can seldom be utilised since attempts to apply tension to the wood are liable to cause shear failures.

42. *Elasticity.*—The most useful elastic property of wood is its extensibility under loads applied in the direction of the grain. The resistance to change in length is usually expressed as (Young's) "Modulus of elasticity" or "E". The value of "E" in the radial direction of the grain is about one tenth and in the tangential direction, one twentieth of the value for the longitudinal direction.

43. *Brittleness.*—Most of the mechanical properties of any species of wood vary in sympathy with the density of particular samples, the heavier pieces being correspondingly stronger and stiffer. This relation is much less marked in the case of brittleness and particularly "notch-brittleness" or liability to break off easily at any notch or sudden change of section, when subject to quickly applied bending forces. Many instances have been observed where samples of timber which are satisfactory in other respects are unusually brittle and although heavy samples are more likely to be tough, this is not always found to be the case.

Methods of test

44. The methods of test have now been standardised and are described in British Standard Specification No. 373. The tests usually made to determine the main physical properties of timber are as follows:—

Moisture content.
Density.
Compression. Parallel and perpendicular to the grain.
Shear.
Bending.
Impact.
Hardness.
Cleavage (liability to splitting).

Aircraft timbers

45. The species of timber most frequently used in aircraft are:—

Sitka spruce (*Picea sitchensis*).—The best known timber for spars, struts and structural parts generally. Chief source of supply—Canada.

Cuban mahogany (*Swietenia mahogani*)
Honduras mahogany (*Swietenia macrophylla*) } Used for airscrews.

Chief source of supply—Central America. There are many varieties of so-called mahoganies. Some of the better known come from West Africa. Although some samples are suitable substitutes for the Central American mahoganies the average quality is inferior.

Sweet birch (*Betula lenta*)
Yellow birch (*Betula lutea*) } Used for plywood and occasionally for the outer laminations of airscrews. Chief source of supply—Canada.

European ash (*Fraxinus excelsior*).—Occasionally used in structural parts where special hardness and strength are required. Source of supply—Europe.

American black walnut (*Juglans nigra*).—At one time extensively used for airscrews. The supply of suitable quality is now very limited.

46. The English names of timbers vary greatly and cause considerable confusion. As the Latin or botanical names are not always convenient or suitable for general use particular English names are being standardised in this country. A list of timbers which are, or have been, considered for use in aircraft is given in British Standard Specification No. 491.

Plywood

47. A characteristic of wood which is usually a disadvantage is the inequality of its strength properties in different directions with respect to the grain. This disadvantage can be overcome to some extent by gluing sheets of wood together with the grain of adjacent pieces running at right angles to one another. The resulting material is usually called "plywood".

48. The necessary thin sheets of wood are obtained from the log by slicing or by shaving circumferentially in a lathe. The sheets—which are called "veneers"—are then known as "slice" or "rotary" cut and can be obtained in almost any thickness from that of paper upwards.

49. The plywood most generally used consists of three of these veneers arranged with the grain of the middle ply running at right angles to the grain of the two outer plies. After being coated with cement in a special machine the plies are assembled and placed in a large press.

50. Plywood for use in structural parts is usually made of birch but for parts where great strength is not necessary other woods are sometimes used.

51. *Cements.*—The cements most common in aircraft plywood are (i) Blood albumen, (ii) Casein, and (iii) Synthetic resin.

(i) Blood albumen plywood is usually made in heated presses ("Hot press" process). It may be recognised by the dark colour of the adhesive when the plies are pulled apart.

(ii) Casein cement (which is a product derived from milk) can be applied without heat. Plywood which has been made with casein cement can usually be recognised by the presence of minute white flecks or spots in the adhesive layer.

Note.—Both these cements offer considerable resistance to the action of moisture but neither can claim to be waterproof.

(iii) *Synthetic resin.*—The recent introduction of synthetic resin cements has greatly increased the water resistance of plywood, especially in thin sizes. The synthetic resin is prepared by chemical processes and in its final form is similar to the material commonly known as "bakelite". It is usually applied in the form of thin sheets of impregnated tissue which are interleaved between the plies. The boards are then placed in hot presses which convert the resin into its final form and thus bind the plies of the wood together. This type of adhesive is also very resistant to fungus attack.

Demands for timber

52. To assist the issuing depot in the selection of suitable material, demands for timber should, wherever possible, state the finished sizes and particulars of the items to be manufactured, thus reducing the wastage of material in converting it to the required dimensions. It must be remembered that often the thicker sizes are inferior in general quality, owing to the irregularity of growth and seasoning, this being especially true of ash.

53. It is emphasised that the procedure of resawing timber down the centre of thick planks is wrong in principle, firstly because of the probability of the thicker plank having been cut from old trees of inferior quality and secondly because the exposure of the new surfaces, which may have a higher moisture content, is an inducement to warping and splitting; also, two thinner boards are cheaper than one of double thickness.

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AIR MINISTRY
May, 1944

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CHAPTER 3

METALS AND ALLOYS

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General

1. Metals and alloys are divided into two categories and classified as ferrous and non-ferrous, each with its own characteristics. Alloys of metals may be made with two or more elements included in the same group or with suitable elements from each group, so producing changes in the metals concerned. These changes may be in the form of improvements in grain structure to increase the strength or to give some entirely new property to a metal, *e.g.* resistance against corrosion. In aircraft design the primary consideration is the reduction of weight with increase in strength and with this objective in view, together with due consideration of other desirable qualities, alloys of various metals have been developed. In the production of metals and alloys the correct chemical composition and the control of temperatures during heating processes is very important. Metals and alloys used in the construction and repair of aircraft must conform to D.T.D. Specifications or British Standards Specifications. The metals available are easily identified by means of various colours as laid down in the Air Ministry Standard Colour Scheme (see Sect. 5 of this A.P.) A general description of ferrous and non-ferrous metals and alloys as used in the construction and repair of aircraft is given in the following paragraphs. Degrees of temperature are given throughout this chapter in Centigrade readings which may be converted if necessary to Fahrenheit readings by means of the following formula:—

$$\text{Fahrenheit} = (\tfrac{9}{5}\ \text{Centigrade}) + 32.$$

Specifications

2. Specifications of metals and alloys used in the Service consist of those issued by D.T.D. and the British Standards Institution. In these specifications all information is given regarding the composition, heat-treatment required and physical tests relevant to a particular metal or alloy; other particulars given concern the uses and the methods to be adopted for preparing test pieces. The compositions of metals and alloys are also given with the percentage of each element included, which may vary in some instances within the limits given in the specification. When any element has a deleterious effect upon a metal it is classed as an impurity and the total amount of impurities must be kept below a specified percentage. The effect of each element should be fully understood whether the element is regarded as an important constituent or as an impurity; for example, the percentage of carbon present in steel gives an indication of its suitability for hardening purposes, but consideration should also be given to other elements that will alter the effect of the carbon, as in the cases of manganese, nickel or chromium. A list of elements is given below with various values

relevant to each. The physical tests shown in D.T.D. and B.S. Specifications are those which are considered necessary for particular metals and are designed to prove that they are free from defects and have desirable qualities which render the metals suitable for the purpose for which they have been produced. Particulars of heat-treatment are given in detail where it is considered necessary, and maximum and minimum temperatures, quenching mediums and any important features peculiar to the metal concerned are also included in the specifications.

Characteristics

3. The characteristics of metals and alloys give each its own particular use for constructional purposes. Pure elements have their own characteristics, most of which may be utilised alone, as, for example the lightness and ductility of aluminium, the high conductivity of copper or the non-corrosibility of nickel. These characteristics, however, may in many instances be improved and other desirable qualities given to metals by alloying and heat-treatment. A typical example of the improvements and alterations that are possible in the characteristics of metals and alloys is shown by the large variety of steels now produced which have entirely new qualities not possessed by the original cast iron.

List of Elements

Element	*Symbol*	*Specific Gravity*	*Melting Point C°*	*Weight per cu. ft. in lb.*
Aluminium	Al	2·60	658	168
Antimony	Sb	6·62	630	412
Cadmium	Cd	8·65	321	540
Carbon	C	2·22	—	—
Chromium	Cr	7·14	1630	440
Cobalt	Co	8·9	1480	545
Copper	Cu	8·94	1083	550
Iridium	Ir	22·4	2405	1395
Iron	Fe	7·6	1530	470
Lead	Pb	11·35	325	707
Magnesium	Mg	1·74	652	109
Manganese	Mn	7·2	1230	450
Molybdenum	Mo	10·2	2620	—
Nickel	Ni	8·85	1452	540
Phosphorus	P	1·82	44	—
Platinum	Pl	21·45	1772	1344
Silicon	Si	2·4	1420	—
Silver	Ag	10·5	960	654
Sulphur	S	2·07	112	—
Tin	Sn	7·3	232	455
Titanium	Ti	4·5	1800	280
Tungsten	W	19·3	3370	1200
Uranium	U	18·7	1690	—
Vanadium	V	5·68	1710	—
Zinc	Zn	7·14	419	440

4. In aircraft construction, such light weight metals as aluminium and magnesium are used extensively, and various alloys containing these elements have been developed whereby with very slight increases in the specific gravity, a greater strength-weight ratio has been obtained, as for example in the cases of duralumin and copper-hardened aluminium. A metal may have all the desirable characteristics required in use except that machining may be found to be almost impossible, in which case the addition of some new element may give good machining qualities without affecting the other properties; the addition of nickel to some types of cast iron is an example of such a case. In other instances a metal may be increased in strength by hot or cold working or by heat-treatment. The specific gravity (see para. 3) of a metal gives its density compared with an equivalent volume of water having a unit weight of 1·00.

5. The grain structures of different metals vary widely in shape, size and density. The shape and size of the grain structure can be varied by alloying, heat-treatment and hot and cold working; these processes cause chemical changes, inter-granular changes, and changes in grain direction which give certain qualities to metals. Throughout the production of metals and alloys, close control of heat is necessary and this has been made possible by the use of suitable meters that give temperature readings, electrically from thermo-electric pyrometers, by relative light intensities, or by the use of cones made from materials which are known to melt at certain temperatures, one example of the latter type being the sentinel which is available to the Service and listed in A.P.1086.

6. In order to understand fully the effect of alloying metals one with another and the various changes which take place due to different heating and working processes, a brief reference to the

properties and chemical compositions of various metals is necessary. The properties are self-explanatory and include hardness, softness, toughness, brittleness, malleability, tenacity, elasticity, ductility, fusibility, conductivity of heat or electricity and non-corrosibility. Methods of testing and appliances for testing metals have been devised in order to decide the relative degree to which various characteristics are possessed by a metal. The relevant Specifications should always be referred to in instances where full particulars regarding the composition and general treatment of metals and alloys are required, and the descriptions of them given in this chapter should be regarded as a general indication of the nature, uses and limitations of the metals employed in aircraft construction.

Testing

7. Metals and alloys are developed and heat-treated in order to obtain or improve the properties required in the finished article for the particular purposes for which it is to be used. In order to ensure that the properties are obtained correctly to the degree required, and to ascertain whether undesirable properties have been eliminated or not, it is essential that tests are made during the course of production. In many instances, tests are necessary up to the final stage when the metal is put into use, especially so in the case of metals to be used in the construction and repair of aircraft; several such tests are dealt with in B.S. and D.T.D. Specifications with details of the manner in which the tests must be made. A brief survey of various tests will be found below.

Chemical analysis

8. Samples of metals are taken from the ingots or from the moulds, care being taken to ensure that the test pieces are representative of the whole. Test pieces may be taken after this stage by drilling out samples for test. The metal cuttings so obtained are then subjected to various applications of heat or acids that will determine the presence and percentage of the constituents, separate processes being used according to the nature of the element and the presence of other elements in the alloys under test; this is a highly specialised process and is only undertaken by skilled metallurgists. A further chemical process is chemical etching, used in testing prepared specimens by submitting a highly polished face which has been produced on the test piece, to the effect of various etching solutions containing nitric, picric or other acids; the nature of these solutions varies according to the elements included in the metal or alloy. Chemical etching may be used to show the depth of case hardening, the direction of grain and grain size, or it may be used to show the nature of welds. Photographs with magnification up to 5,000 diameters may be taken of polished, etched or fractured test pieces and used to show the general grain structure. Photomicrography is used extensively in connection with metals for the purpose of recording the effect of heat treatment upon the structure of the metal.

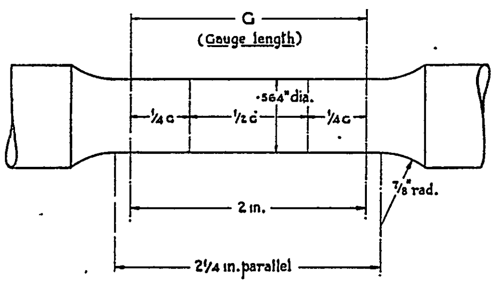

Fig. 1.—Example of tensile test piece

Tensile test

9. Tensile tests are made on standard test pieces (see fig. 1) suited to the material being tested, of a particular specified length and cross-sectional area. The ends of the specimens are usually larger than the area to be tested and the specimen is adapted to the type of machine in which it is to be tested. The testing machine stretches the specimen and at the same time gives a reading on a scale of values that are indicated throughout the test. The values to be noted are the yield point, the ultimate breaking strength, the amount of elongation and the reduction in cross-sectioned area; the resultant values of the first two being expressed in tons or pounds per square inch. Examples of such tests, specimen sizes and values to be obtained during the tests are contained in various B.S. Specifications.

Bending tests

10. Bending and flattening tests are made by approved methods on test pieces of tube, strip or sheet metal as described in D.T.D. and B.S. Specifications; descriptions of proof bend tests, hydraulic tests and tests for metal and tubes of various cross-sections are also given therein. These tests are made before the material is issued for use and they vary in the angle to which the test piece is to be bent, the radius of the bend, and the number of bends made; this test ensures that the metal is

suitable for the purpose for which it is to be used and indicates any liability to cold-shortness or the presence of seams and other defects that may be due to impurities in the metal or to errors in heat-treatment. A test for brittleness in wire is made by means of a wrapping test; for the purpose of this test the wire is wrapped eight times round its own diameter and then unwound, leaving the last turn, without showing signs of fracture. A torsion test may be given to wire by turning or twisting the wire a specified number of times for unit lengths equal to a standard number of diameters, as given in the relevant specification; the number of turns is usually 20 per length of wire having a length equal to 100 diameters.

Hardness tests

11. Hardness tests are made on metals by various methods most of which depend upon the application of a known pressure to an object so producing an indentation of varying width for different degrees of hardness. The measurements given are relative only and the tests referred to in the B.S. and D.T.D. Specifications are the Vickers Diamond Pyramid and the Brinell hardness tests; these are the generally accepted standard tests. Another type of hardness tester is known as the Scleroscope and the hardness values given on this machine depend upon the height of the rebound of a diamond tipped weight or hammer which is dropped from a certain fixed height upon the test specimen.

12. The Brinell test is made with a hard steel ball 10 mm. diameter which is placed on the test piece and a pressure of 3,000 kilograms is then applied to the ball for a period of not less than 15 seconds but for relatively hard metals this period is often extended to 30 seconds; a pressure of 500 kilograms is applied for a period of 60 seconds when testing softer metals. The tests are not reliable when dealing with material less than 0·50 in. thickness. The diameter of the ball impression is obtained by taking the average of two impressions from tests made at an angle of 90 degrees; from this average diameter the hardness number is derived by means of the following formula:—

$$H = \frac{P}{\frac{\pi D^2}{2}\left(D - \sqrt{(D^2 - d^2)}\right)}$$

when H = Brinell hardness number.
P = load in kilograms.
D = diameter of ball in millimetres.
d = average diameter of ball impressions in millimetres.

13. The Vickers test in which a square base pyramid diamond is used to make an indentation on the test piece, includes the application of a pressure which may be varied between 5 kilograms and 120 kilograms for a period of 30 seconds; measurement is made across the diagonals of the impression of the diamond on the test piece by means of a microscope. The following formula is applied to obtain the hardness number from the length of the diagonal:—

$$\text{Hardness number} = 1{\cdot}8544 \left(\frac{L}{d^2}\right)$$

d = length of diagonal in mm.
L = load in kilograms.

Impact tests

14. Impact tests are made to determine the brittleness of such metals as cast iron and heat-treated steel; this test is generally referred to as the Izod test. The test specimen (see fig. 2) of the required standard dimensions is prepared to the correct length and cross-section and a notch of known depth is cut. The specimen is then gripped in a vice in the testing machine in such a position that the hammer will strike the specimen when a pendulum of standard weight and length is released; the angle of the swing of the pendulum past the lowest point is measured along a graduated sector upon which the energy absorbed in breaking the specimen is directly indicated in ft. lb. The Izod value given in a test should be correct for the type of steel under test and its tensile strength, therefore the value will vary for different types of steel also for different tensile strengths of any one type, given by heat-treatment or working processes. If the steel has not been heat-treated correctly the Izod value will be lower than the specified value for that particular type of metal. The testing machine used is the Izod Impact Tester. In instances where the Izod notched bar test is considered impracticable or a fracture is required to be examined, a nicked bar test is substituted using a test piece nicked or sawn in such a manner that the area of the portion to be fractured is not less than one-half of the cross-sectional area of the bar.

General effects of heat

15. Metals and alloys are affected in various manners by heat applied during the course of production and subsequent heat-treatment. The control of heat, especially at certain critical temperatures, will have a decided influence on the characteristics and properties of metals, usually by changing the structure. Examples of such structural changes are noticeable particularly in the

cases of cast iron, tool steel and duralumin. Casting, cold working, uneven sections, and rapid or uneven cooling, will induce internal stresses in metals which can be removed by careful heat-treatment. The reduction of these stresses is dependent on plastic movements which take place when the correct amount of heat is applied for a requisite period of time, the cooling being arranged in order to ensure that other new stresses are not introduced. The rate of heating, the period of time over which heat is held and the rate of cooling, are all important factors in heat-treatment processes; steel, for example, should not be placed when cold in a highly heated furnace but the temperature of the furnace should be raised slowly and maintained for a period of time sufficient to allow for the heat to reach the centre of the metal, long pieces of steel being supported during the process to prevent sagging. The heating medium and gasses evolved within the furnace may affect heated metal by carburising or oxidising it and high temperatures and long periods of heating may cause excessive grain growth and oxidisation with consequent weakening of the metal. Liquid baths may be employed for heat-treatment for which purpose water, oil, lead, lead and tin, and salt baths cover a wide range of temperatures. Salt baths protect the metal from the harmful effect of furnace fumes and air, and provide rapid heating and ensure uniformity of temperature. Before any process is commenced involving the application of heat to metals it should be ensured that the character of the metal is known and that the process to be used is the correct one for the metal in question. Metal which has been exposed to excessive heat cannot be restored to its original state by heat-treatment, but must be re-smelted.

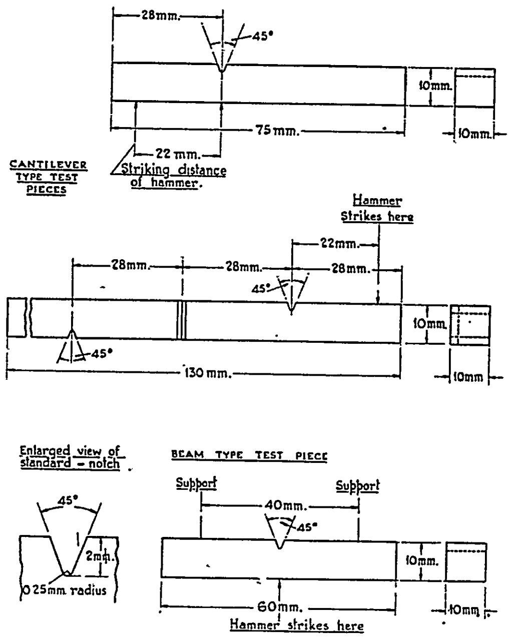

Fig. 2.—Standard notched bar dimensions

Pyrometers

16. In order that the high temperatures involved may be accurately gauged during the production and heat-treatment of metals and alloys, different types of pyrometers are used; those in general use are the thermo-electrical, the optical and the sentinel types. The thermo-electric pyrometer (see sketch I and II, fig. 3) embodies the application of the thermo-couple principle, i.e. if two wires of suitably different metals are joined together at one end and subjected to a sufficiently high temperature at the juncture, a small electric pressure is generated across the free ends. This pressure can be measured by means of a milli-voltmeter having a temperature scale, the resultant reading on the scale registering the changes in the temperature of the heated juncture when the free ends are maintained at a constant temperature that may be within the range of from 0 to 24 degrees Centigrade, allowance being made for slight fluctuations. The wires forming the thermo-couple must be capable of withstanding the effects of the heat applied and must have an electrical potential difference sufficient to give a reading on the milli-voltmeter. The combination of metals most frequently used in instruments registering temperatures up to 1650° C. is a platinum wire with an alloy wire of platinum and 10 to 15 per cent rhodium. For the protection of the platinum wires against the higher temperatures, the hot junction may be enclosed in a porcelain or ceramic tube; the thermo-couple in use should not come into contact with the flames otherwise the temperature reading shown on the scale will be higher than the true furnace heat.

17. In instances where a thermo-couple pyrometer cannot be used for the measurement of high temperatures some form of optical pyrometer should be used (see sketch III and IV, fig. 3). This type measures the intensity of the heat by the relative brightness of the heated object to that of a suitable standard light intensity. One type in use makes comparison with the heated object and the brilliancy of a lamp filament varied by a suitable resistance. In another type the lamp filament intensity of light is maintained at a constant standard value whilst the variation of the furnace brilliancy is measured, by means of alterations in the position of a wedge-shaped prism, which is moved until the intensity of light appears to be the same in both instances. The latter types of pyrometers are seldom used for gauging temperatures below 900° C. as the luminosity within the furnace below this point is difficult to match, also smoke and incandescent gases give errors in reading and readings taken may vary with individual observers.

18. Pyrometric cones are used for the measurement of heat temperatures; these are made in the form of triangular pyramids and are composed of various substances that are known to fuse at certain temperatures. The cones are graded and each grade is numbered in order to indicate small increases in the fusing points of the cones up to temperatures as high as 2,000°C., thus a cone can be selected to fuse at the temperature required for the work, and another cone of a slightly lower fusing point can be used as a warning to indicate that the critical temperature is almost reached, whilst a third cone can be used to indicate the safe maximum temperature for the work in hand and beyond which the work must not be heated.

Application of heat

19. The heat treatment of metals and alloys varies in accordance with the chemical compositions and with the purpose for which they are to be used. The heat at which temperature the desired constitutional changes take place should be applied in such a manner that it is carried to the core of the metal without burning or unduly scaling the exterior. Maximum temperatures should be held long enough to attain uniformity of temperature consistent with the area of the cross-section and the thermal conductivity of the metal. The rate of heating for non-ferrous metals is proportionally slower than for ferrous metals in accordance with the increase in the melting point. Direct impingement of the furnace flame on metals and alloys should be prevented and scale should be removed if present on the material or in the furnace, because this has a decarburising effect on ferrous metals which may form soft patches or spots on the material. Metals should be heat-treated as required at the temperatures given in the relevant B.S. and D.T.D. Specifications.

FERROUS GROUP OF METALS AND ALLOYS

20. The ferrous group of metals and alloys comprises those having iron as the base. The group may be sub-divided into two parts, i.e. (i) cast iron and its alloys, (ii) steel and its alloys. Brief descriptions of these metals most generally used for aircraft construction and repair are given in the paragraphs below.

Cast iron

21. Cast iron is produced from iron ore which is converted by smelting processes into various grades of pig-iron; these are not of use for constructional purposes until re-smelted, the chemical composition adjusted and the metal cast into the desired form. The following table gives the analyses of two grades of pig-iron available to the Service on demand and listed in Air Publication 1086; the table also gives an indication of the composition of a typical cast iron alloy:—

Elements	*Foundry No. 1*	*Foundry No. 3*	*Chromium Cast Iron*
	Percentages		
Carbon (graphite)	3·00 to 3·50	3·25	3·20
Carbon (combined)	—	0·24	—
Silicon	2·50 to 3	3·00 to 3·50	0·70
Sulphur	0·04 (max.)	0·03 (max.)	0·10 (max.)
Phosphorus	1·20 to 1·50 (max.)	1·10 to 1·40 (max.)	0·20 (max.)
Manganese	1·20 to 1·50	0·80 to 1·20	0·90
Chromium	—	—	0·35

Cast iron alloys

22. The desirable qualities in cast iron can be improved by means of alloying with other elements; particulars of all such alloys are to be found in the relevant B.S. and D.T.D. Specifications, but for convenience those in frequent use are dealt with in a general manner in the following sub-paragraphs:—

(i) *Nickel iron.*—The addition of 0·25 to 5 per cent nickel improves the texture of cast iron and gives better machining qualities and increased resistance to wear and corrosion, with a reduction in the coefficient of expansion. When the amount of nickel is increased from 10 to 18 per cent, the alloy changes in structure and becomes austenitic with high resistance to scaling at temperatures up to 815° C. the alloy is less liable to corrosion by the action of many acids, alkalies, etc.

(ii) *Chromium cast iron.*—Chromium cast iron has a reduced graphite-carbon content, effected by the addition of the chromium. Additions of 0·30 to 1 per cent chromium gives a uniform fine grain structure to the metal and when the amount of chromium is increased to 3 per cent the graphite content disappears, the alloy showing a very white fracture when broken. Chromium also gives an increase in the tensile strength at higher temperatures and reduces the tendency of castings to growth. If the basic cast iron is hard the resultant alloy may be too hard to machine although the amount of chromium may be as low as 0·25 per cent; the addition of nickel reduces this hardening effect.

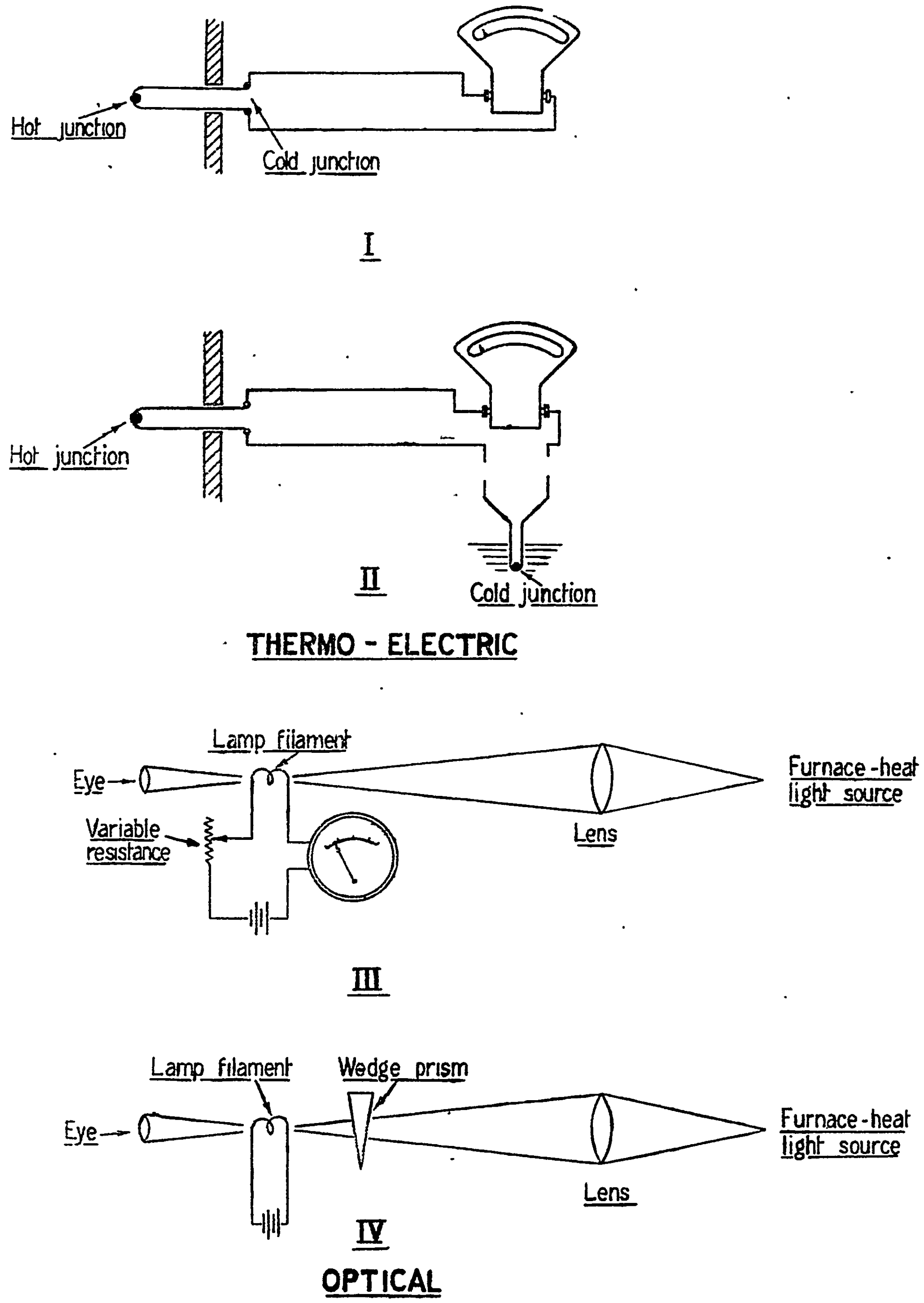

Fig. 3.—Metals and alloys—pyrometers

(iii) *Nickel-chromium cast iron.*—Nickel and chromium may be used together to produce cast iron alloy with a range of qualities suitable for particular classes of work. The addition of these elements is usually from 0·50 to 1 per cent. chromium and up to 3 per cent. nickel, giving a refined grain structure with increased hardness and strength without increasing machining difficulties. The use of chromium also obviates lowering the silicon content in the cupola mixture which would be necessary if nickel was used alone. The Brinell hardness number of this alloy is approximately double that of ordinary white cast iron. The alloy produced by mixing grey cast iron, 1·50 per cent nickel and 0·50 per cent chromium, is harder and tougher than the base cast iron, and is machined more easily. Nickel-chromium castings may be hardened by air cooling directly they are removed from the red hot moulds.

(iv) *Molybdenum cast iron.*—Molybdenum may be added to cast iron in quantities varying from 0·25 to 1·25 per cent and its action is to form carbide and increase the tensile strength and hardness. The influence on grey cast iron is greater than that of any other element for producing increase in the strength. The maximum increase in strength is obtained when the quantity of molybdenum added is about 2 per cent, but over this amount there is a decrease in the tensile strength of the alloy. Molybdenum retards the various changes that takes place in the alloy throughout the full range of temperatures, during heating processes. This alloy also has good wearing qualities, and has a uniform structure even in heavy sections.

(v) *Vanadium cast iron.*—Vanadium additions to cast iron are carbide forming in effect and the resultant alloy has a very fine grain and a more even distribution of fine graphite flakes than the base cast iron. The alloy is harder and tougher with increased effect of chill to a greater depth than is usual with the original cast iron due to stabilisation of the cementite caused by the presence of vanadium. The amount of vanadium usually added to cast iron varies from 0·10 to 0·50 per cent.

(vi) *Titanium cast iron.*—The alloy formed by the addition of titanium to cast iron is similar in character to a silicon iron and has a reduced reaction to chill. The size of the graphite particles in the alloy is reduced and this results in an increase in the tensile strength. Titanium is mostly used in more complex alloys containing other elements such as chromium, vanadium or molybdenum.

(vii) *Aluminium cast iron.*—Aluminium cast iron with an aluminium content of 1 to 1·75 per cent is used for the production of an alloy that may be hardened by the nitride process, by means of which an extremely hard wearing surface is formed. With this alloy the persistent formation of oxide during the pouring of the molten metal is a disadvantage, because the skin of oxide becomes thicker as pouring proceeds, resulting in the production of unsound castings.

Malleable iron

23. Malleable iron consists of cast iron which has been annealed for a period of about 10 days in close contact with a substance containing iron oxide such as red hematite. By this process a structural change is effected in the grain of the iron and a semi-steel skin is formed by the absorption of carbon which takes place during annealing; the core remains practically unchanged. Good malleable iron castings machine very freely, and will withstand shock loads much better than cast iron. Malleable iron cannot be welded by the same process as that used for cast iron or steel, but it can be bronze welded satisfactorily should an occasion arise where repair will suffice.

Wrought iron

24. Wrought iron is produced from refined pig iron by subjecting it to various processes during which carbon, silicon, phosphorus and sulphur are almost eliminated by oxidisation; these elements are considered to be impurities and should not be present in wrought iron in quantities above a limited amount. Wrought iron is a very ductile metal and has a very coarse fibrous grain structure in one direction caused by the rolling processes involved. It is easily forged and welded and can be case-hardened satisfactorily. When wrought iron is subjected to further treatment by heating over a period of several days in contact with charcoal, blister steel is produced which is used in the production of crucible cast steel.

Steel

25. Steel is produced from cast iron by several methods; these methods vary in the processes which reduce the amount of carbon and silicon and eliminate such undesirable elements as sulphur and phosphorus. The chief processes used are the crucible cast, open hearth, Bessemer and electrical smelting. These processes depend mainly upon the oxidising effects of an air blast on molten iron and they vary in the method of applying the heat and air, also in the type of fluxes employed for

different grades of iron used. Although strictly speaking all steel is an alloy it is usually classified under two groups, i.e. plain carbon steel and steel alloy. Carbon steels are divided into three classes, namely, low carbon, medium carbon, high carbon.

Steel alloys

26. A number of steel alloys have been developed for special purposes, several of the alloys having particular applications in aircraft construction. The new elements which are added to the metals in widely varying quantities may be used singly or in several combinations in order to produce alloy steels for some specific purpose. The effects of some elements may be to improve grain structure, to give increased hardness, toughness and ductility, or in the case of stainless steel to resist corrosion. The most frequently used alloy steels are dealt with in the following sub-paragraphs:—

(i) *Nickel steel.*—Nickel steel has several new properties in comparison with carbon steel. The addition of nickel increases the tensile strength and the yield point and gives increased hardness without loss of ductility when the steel is in either the annealed or heat-treated state; the alloy is invariably used after heat-treatment in order that full advantage may be taken of the properties given to the alloy by the nickel. Critical temperatures are spread over a wider range during heat-treatment and the alloy can also be subjected to relatively high temperatures for long periods without undue injury to the metal. Nickel steel is particularly suitable for case-hardening, a deep and uniform penetration of carbon combined with a very tough core, being obtained by this process. The quantity of nickel in one particular group of nickel steel alloys is usually between 0·50 per cent and 6 per cent; higher percentages of nickel are used in other groups in order to obtain special alloys. Electrical resistance wires may be made from a 25 to 30 per cent nickel alloy whilst a 35 per cent alloy is used for the production of invar which has a coefficient of expansion that is practically zero, and is non-magnetic; for these reasons invar is used in the manufacture of scientific instruments. Alloys with a 50 per cent nickel content are used for their magnetic properties as they have a high permeability at low field strengths. Nickel is also used in the more complex alloys in conjunction with chromium, silicon, tungsten, etc.

(ii) *Chromium steel.*—Chromium is alloyed with steel alone, or with nickel or other elements. The addition of chromium in producing chromium steels is 0·50 to 1·50 per cent, added in the form of ferro-chromium. Special air-hardening steels are made from chromium steel, the chromium content being from 12 to 17 per cent and carbon from 1 to 2·25 per cent; higher percentages of chromium are used in the manufacture of stainless steels of which there are many types each having a different composition and characteristics for some particular purpose. The high chromium content is common to all these steels but there are two groups. The first group consists of alloys with a low nickel content, and these can be hardened and tempered by heat-treatment, they are magnetic and are resistant against corrosion in the heat-treated condition only. Alloys in the second group have a high nickel content and they cannot be hardened by heat processes and are non-magnetic. Hardening is effected by working the material and softening or annealing is effected by heating it to a temperature of 1100° C. and then cooling rapidly. Forging temperatures are very high, being in the region of 980° C. and 1100° C. The chief properties of austenitic steels are resistance to corrosion and scaling and capacity for withstanding high temperatures. Stainless steel is manufactured in a variety of forms and may be cast, rolled, forged or drawn, and for each of these purposes it is possible to vary the composition of the alloy in order to give a particular property. Typical specifications of these alloys are given in the relevant B.S. and D.T.D. Specifications.

(iii) *Manganese steel.*—Manganese steel is very tough and has the property of work hardening slowly, and becomes hard and brittle if allowed to cool. Pearlitic manganese steels are frequently used, the manganese content of which is usually from 1 to 1·90 per cent, the carbon content being from 0·10 to 0·50 per cent. This alloy is usually quenched in oil during hardening processes and when the carbon content is high it is dangerous to quench it in water. Austenitic manganese steel contains from 11 to 15 per cent manganese and a carbon content of 1 to 1·40 per cent and is so tough and hard that the metal hardens as the tool is being forced into the work. During machining operations, the correct speeds and feeds should be used, special high-speed tools also are necessary. If the carbon content exceeds 1·40 per cent the alloy decreases in toughness and strength. The result of adding manganese to steel is for the manganese to (i) combine with some of the carbon and form carbide of manganese, (ii) act as a purifier by eliminating gases and oxides, (iii) combine with any sulphur, nullifying its harmful effect. The critical temperatures for manganese steel are increased in range so facilitating heat-treatment processes, the range from minimum to maximum being as high as 65° C. in some instances. Austenitic manganese steel has an electrical resistance seven times that of pure iron, is practically non-magnetic, and can be cast, forged and rolled.

(iv) *Cobalt steel.* Cobalt is very similar to nickel in appearance and in its properties, and it is usually alloyed with steel for use in the production of permanent magnets and high-speed tool steel. Tungsten vanadium steel alloys may be improved by the addition of cobalt which has the effect of making the alloy less sensitive to critical temperatures during heat-treatment processes. The amount of cobalt required for the different alloys varies considerably, e.g., from 1 per cent to 12 per cent is used for tool steels and 35 per cent for steel suitable for the production of permanent magnets. Special heat-treatment is necessary for all cobalt steels after forging otherwise cracking may result during cooling.

(v) *Tungsten steel.*—Tungsten is added to some steel or steel alloys in order to produce high-speed steels with special heat-resisting qualities. Tungsten is a carbide forming element and quantities of 0·50 per cent may be used for steels employed in the production of dies, etc., but the quantity added may be as high as 20 per cent in the case of special high-speed steel. Magnet steel may be produced containing from 5 to 7 per cent tungsten, but cobalt steel is more efficient for the purpose.

(vi) *Silicon steel.*—Silicon steel alloy usually contains silicon in combination with other elements such as chromium and manganese. Silicon acts as a deoxidiser and assists in producing steel which is practically free from blowholes, The percentage of silicon in the alloy varies in accordance with the qualities required in the finished product and with amounts of silicon up to 4·5 per cent the tensile strength and yield point are increased. Silicon-manganese steel is used commercially for the manufacture of flat leaf springs, and silicon-chromium alloys are used for making valves for internal combustion engines in which the high temperature conditions are destructive to ordinary steel.

(vii) *Vanadium steel.*—Vanadium steel is close-grained and uniform in structure and in use has great resistance to shock and fatigue. The usual quantity of vanadium added is from 0·18 to 0·20 per cent and the effect on the steel is to produce the quality of toughness and a high elastic limit, also an increase in tensile strength, without loss of ductility. Vanadium steel alloys respond well to heat-treatment and are used in the production of large forgings because of the low degree of distortion. Vanadium is also used in more complex steel alloys containing chromium, manganese and nickel; these alloys may be both forged and cast. Tool steels invariably contain a percentage of vanadium as this element gives increased cutting ability, especially when alloyed with tungsten steel. Chrome vanadium steel alloy is employed in the manufacture of valve springs for aero-engines.

(viii) *Molybdenum steel.*—Molybdenum steel alloys contain pure molybdenum which is a soft ductile metal similar in colour to platinum. The percentage of this metal in the alloy composition is between 0·25 to 0·40, but may be as high as 1 per cent if alloyed with manganese. The effect of molybdenum on steel is to slow down any structural change caused by heat-treatment and to give greater depth to hardening; it also gives toughness, structural stability, higher temperature strength and absence of temper brittleness. The alloy is not difficult to work and may be rolled, forged and welded, and in addition the tendency to cracking during heat-treatment is reduced. When the molybdenum content is low it does not affect the forging, rolling, machining or welding properties of the alloy. Molybdenum is mostly used in conjunction with other elements such as chromium and manganese to give increase in tensile strength or additional depth-hardening qualities.

NON-FERROUS GROUP OF METALS AND ALLOYS

General

27. The following paragraphs contain information regarding the most important of the non-ferrous metals and alloys, used in the construction and repair of aircraft and aero-engines. An indication is given in a general manner of the nature of the alloys by means of typical examples of the chemical compositions, etc., but in all instances when precise particulars are required regarding any metal and alloy reference should be made to B.S. and D.T.D. Specifications; it should be noted that different specification numbers may be given to one alloy in various states of hardness or of different formation as in sheet or tubular form, etc. In the non-ferrous group are included the light alloys, which are of special interest in connection with aircraft work. Brief descriptions are also given which are intended as a guide when gauging the relative properties and the behaviour of metals when they are subjected to heat, and which may be used for guidance in the processing and in the application of the metals and alloys in question.

Aluminium

28. Aluminium is a light-weight metal obtained chiefly from bauxite, four pounds of which is required to produce one pound of pure aluminium. In its pure state aluminium is very soft and ductile and has a specific gravity of 2·60. It is rarely used in the pure state owing to its low maximum strength but is often alloyed with copper, tin, nickel, manganese, zinc and silicon. An alloy may contain one of these metals only, added to the aluminium to form a simple alloy, or it may contain various combinations of several metals added in varying amounts to form complex alloys. Aluminium can be worked by most of the usual processes, e.g. rolling, spinning, drawing, extruding, forging, casting and welding. It has a high conductivity of heat and has a high coefficient of expansion although in some alloys the latter characteristic is reduced considerably. Aluminium is electro-positive to copper, iron, lead, tin, nickel and zinc, and contact with these metals, particularly when moisture or salt spray is present, will cause rapid deterioration of the aluminium caused by corrosion. Brief descriptions of the most important of the aluminium alloys are given in the following sub-paragraphs:—.

(i) *Duralumin.*—Duralumin is an aluminium-base alloy and has a specific gravity of 2·80; the usual composition is about 4 per cent copper, 0·50 per cent manganese, and 0·50 per cent magnesium. Special properties are given to the alloy by heat-treatment, mechanical working and by varying slightly the percentages of the alloying elements. Under certain conditions duralumin has the peculiar property of age-hardening and advantage is taken of this phenomenon in the preparation of the alloy for aircraft purposes. Duralumin can be annealed by heating to a temperature of 370° C. and then cooling in air or water; local annealing is permissible if the whole is subsequently normalised. The metal should not be left for long periods in its fully annealed condition because in this state it is very susceptible to corrosion. Normalising consists of heating the metal to a temperature within the range of 480° to 500° C. and then quenching in water. It is after this process that age-hardening occurs, maximum hardness being reached in a period of from 1 to 4 days. For convenience normalised parts can be stored in a cold-chamber with the temperature maintained at 0 degree Centigrade in order that the age-hardening process will be delayed for short periods. If this is done, the process is entirely suppressed for 24 hours only, after which the process commences at a reduced rate. If local melting takes place during the heating of duralumin caused by the application of excessive heat the alloy cannot be used unless re-cast and forged. Baths of molten salts are employed for the purpose of heat-treating duralumin and the salts used are a combination of potassium and sodium nitrates. In common with most other metals duralumin is subject to corrosion, particularly if exposed to sea water spray. A certain amount of protection can be given by anodic treatment consisting of the electrical deposition of a film of aluminium oxide on the surface of the duralumin. Sheet duralumin coated on both sides with aluminium is known as alclad, and is made by heating and rolling a sheet of duralumin between two sheets of pure aluminium at a sufficiently high temperature to ensure fusion of the surfaces in contact. The protection against corrosion is effected electrolytically, the aluminium coating being electro-negative to the inner duralumin.

(ii) *Aluminium-copper alloy.*—This alloy is relatively hard and is suitable for the production of die-cast pistons, carburettor bodies, etc. The composition is about 88 per cent aluminium and 12 per cent copper, the copper acting as a hardening element serves to maintain the original properties of the alloy at relatively high temperatures. The alloy is susceptible to corrosion, which is due to the effect of the copper content, therefore its uses are limited to parts which are not exposed to corrosive influences.

(iii) *Aluminium-magnesium alloy.*—Aluminium magnesium alloy has a high resistance to fatigue and surface corrosion and is suitable for casting. Aluminium is the basic constituent of the alloy which contains also between 3 and 6 per cent magnesium and 0·25 to 0·75 per cent manganese. A suitable alloy for the production of sheet metal has a magnesium content of 3 to 6 per cent and a maximum strength of 20 tons/sq. in., which is approximately twice that of pure aluminium sheet. There are several similar alloys in this class having slight variations in the chemical composition to which small additions of chromium, manganese or silicon, are made.

(iv) *"Y" alloy.*—"Y" alloy is an aluminium alloy containing 4 per cent copper, 2 per cent nickel, 1·50 per cent magnesium and the remainder aluminium. This alloy is highly resistant to corrosion and will withstand heat of relatively high temperatures without losing its original properties and is often used in the manufacture of drop-forged pistons and cylinder heads. "Y" alloy responds to heat-treatment in a similar manner to duralumin and is also subject to age-hardening. The alloy can be cast or wrought and although the maximum strength is lower for the cast alloy than for the wrought, an improvement in the cast alloy can be effected by suitable heat-treatment.

(v) *Aluminium-silicon alloy.*—Several different aluminium-silicon alloys are used to produce castings which are malleable and which have a low coefficient of expansion. The silicon content of such alloys is usually between 8 to 13 per cent with small additions of copper, manganese and other hardening and modifying agents. Included in this class of alloy are those known commercially as Alpax and Hiduminium. More complex alloys containing smaller amounts of silicon are used for the production of sheets, tubes and extruded bars. The addition of titanium to some of these silicon alloys gives a fine grain structure which is present in both the cast and wrought alloy.

Copper

29. Copper is commercially produced as a 99·95 per cent pure element and it can be employed in its pure state or alloyed with other metals. The important features of copper are that it is ductile, malleable, and tough while it has the property of good conductivity of heat and electricity. It is manufactured in a large variety of forms and can be obtained in sheets, bars, wire and as tube. Copper can be freely worked and can be work-hardened, annealed or electro-deposited; annealing consists of heating the metal evenly to a temperature of 650° C. and then quenching in water or allowing to cool in the air. A brief description of the chief alloys of copper are given in the following sub-paragraphs:—

(i) *Brass.*—Brass is the general term used for the copper-zinc alloys, other terms used to indicate different types of alloy are gun metal, phosphor-bronze, etc. There are two main groups of brass, which include those used when cold-working the brass into sheets, wire or tubes and those which are suitable for casting, hot-working or extruding; the first group has a copper content of about 65 per cent and a zinc content of 35 per cent, and the second group has approximately 60 per cent copper and 40 per cent zinc. Brass, when it is worked cold becomes harder, but it may be annealed by heating to a temperature of 600° C., the annealing period being the time taken by the metal to attain the correct temperature. If the required annealing period is not quite completed the grain of the metal is restored but is small in size whilst over-annealing causes an increase in the grain size with surface deterioration. To remove internal stresses in brass the heat required will be of a much lower temperature than that necessary for annealing; the temperature is 250° to 270°C., which should be applied for a period of half an hour to one hour. Brass has a good resistance to corrosion and corrosion fatigue, and this property is improved by adding 2 per cent of aluminium to the alloy. The addition of 2 to 3 per cent lead to brass gives greatly improved machining qualities but reduces the ductility, the lead breaking up into minute globules, so making the metal short. High tensile brass is the hot working type to which has been added from 0·5 to 3 per cent of each of such elements as iron, aluminium, tin, nickel and manganese, and is generally used for extruded work, etc. Brass can be worked by hand, and is easily machined; it can be joined by soft and hard soldering, or by brazing. It is particularly suitable as a basis metal for such processes as nickel and chromium plating. Brass foil may be obtained in thicknesses ranging from 0·002 in. to 0·012 in. Sheet brass, brass wire and the thickness of the walls of tube are usually measured and graded to S.W.G.

(ii) *Aluminium-nickel-silicon brass alloy.*—This alloy is known as Tungum, and is produced in sheet and tube form; it is very tough and has a high resistance to fatigue and corrosion. The copper content of a typical specification ranges from 81 to 84 per cent with zinc from 11 to 14 per cent and 1 per cent each of aluminium, nickel and silicon. Tungum tube is very strong and ductile, having a maximum stress of from 28 to 38 tons/sq. in.

(iii) *Bronze.*—Bronze is an alloy of copper and tin with a small amount of zinc, and may be obtained rolled, drawn or cast. It is used in the manufacture of small parts of aero-engines such as bushes, valve guides, etc. Cast bronze is not suitable for use in highly stressed parts because of its uncertain character. The addition of phosphorus in very small amounts forms phosphor-bronze, which is superior in mechanical strength to ordinary bronze; the phosphorus content varies from 0·10 to 0·50 per cent. Careful control of the critical heat temperatures and of the cooling rates is necessary in order to obtain the correct distribution of the phosphorus in the alloy. Hard-drawn phosphor-bronze bars are produced with a maximum strength of 30 to 40 tons/sq. in.

(iv) *Copper-lead alloy.*—Copper-lead alloys have been developed to produce a bearing metal that will withstand high loading stresses and which will have good mechanical strength and good adhesion to the metal of the bearing shell. The copper content of this alloy is usually 70 per cent and the remainder is lead with 1 per cent tin.

(v) *Copper-nickel alloy.*—Copper-nickel alloys are very ductile and are highly resistant to corrosion. They are produced mostly in sheet form and can also be rolled and extruded. The nickel content is high, being usually about 70 per cent, with the remainder copper and a small percentage of manganese. Copper-nickel alloy, or cupro-nickel, has been successfully employed in the construction of radiators of aircraft and in making inserts for aero-engine valve seats.

Lead

30. Lead is a very soft white metal and because of its low mechanical strength and high specific gravity its use on aircraft is very limited. Lead is resistant to atmosphere corrosion and to the corrosive effects of most acids, but it is attacked by both soft water and nitric acid. Combinations of lead alloy and lead oxides are used for the manufacture of the plates of accumulators of the lead-acid type. Lead is also included in the formation of solders of a low working temperature and in certain grades of white-metal bearing alloys. Lead pipes can be joined by means of a process known as "wiping", the metal being worked whilst it is in a plastic state during the operation. Sheet lead is usually welded by means of a process known as lead-burning.

Magnesium

31. Magnesium is the lightest of all the commercial metals, having a specific gravity of 1·74. It is used extensively in the manufacture of various aircraft components and forms an important constituent of a number of complex alloys, e.g. duralumin, "Y" alloy and the alloy commercially known as elektron. Magnesium is available in two forms, one being the familiar magnesium powder or strip which burns with a brilliant flash and the other being that used in the production of castings, forgings, extruded rod and sheet metal. Ordinary foundry practice cannot be used when casting magnesium as this metal reacts violently when in contact with moisture at, or above, melting point; green sand moulds cannot be used without the addition of an inhibitor such as sulphur, ethyl glycol or boric acid. To counteract the effect of the light weight of the metal during casting, "risers" of large cross section must be used. Magnesium alloy sheet can be worked cold for simple operations, but if heated to a temperature of 300° C. it becomes more amenable to bending, although in this condition it is only suitable for the formation of bends which are not acute. The principal metals used with magnesium for alloying purposes are aluminium and zinc, in addition, however, small quantities of copper, nickel and manganese are sometimes used. When magnesium is alloyed with aluminium, it combines with the silicon and forms a hard compound, the hardening effect being very marked although the quantity of silicon added may be relatively small. Magnesium can only be welded when the metal does not contain more than 3 per cent of other elements. Particulars of the chief magnesium alloys are given in the following sub-paragraphs:—

(i) *Magnesium-aluminium alloy.*—Magnesium-aluminium alloy is particularly suitable for the production of rolled, forged, extruded or drawn work. Heat-treatment is not necessary to produce the maximum strength unless the alloy has been specially annealed. It is lighter than duralumin, having a specific gravity of 2·63. In its hard condition it has a maximum strength of from 26 to 30 tons/sq. in. which is reduced to 20 tons/sq. in. when the alloy is in the annealed state; the alloy must not be heated during processes where it is not required to be annealed, to a temperature exceeding 100° C.

(ii) *Cast magnesium alloy.*—Particulars of magnesium alloys suitable for casting will be found in B.S. and D.T.D. Specifications. The specific gravity of these alloys is slightly greater than for magnesium alone, and is usually from 1·81 to 1·83. The compositions vary slightly in the percentages of the alloying elements and the properties are varied by heat-treatment. The percentage of aluminium in these alloys ranges from 8 to 11 per cent, that of zinc from 1 to 3·5 per cent, the manganese content being up to 1 per cent. These alloys are often used for the manufacture of die-cast pistons, crankcases, carburettor bodies, etc.

(iii) *Wrought magnesium alloy.*—Wrought magnesium alloys have a relatively high aluminium content with low percentages of zinc; 11 per cent aluminium, 1·5 per cent zinc and 1 per cent manganese, the remainder magnesium, is a typical example of the composition of an alloy suitable for forming extruded bars and forgings. It is a ductile alloy and has a good resistance to fatigue, the maximum strength ranging from 15 to 17 tons/sq. in.

Nickel

32. Nickel is a hard white metal which is very ductile, it can be welded and will withstand heat of very high temperatures. It is used chiefly in the formation of a very large range of alloys of the ferrous and non-ferrous groups. Nickel is highly resistant to corrosion and is used for nickel-plating which may be employed alone or as a base for chromium plating. Monel metal is a nickel alloy with a nickel content of about 70 per cent, the remainder being copper to which a 2·5 per cent addition is made of other hardening elements such as manganese and iron. This alloy is sometimes

used for the seats of aero-engine valves because of the capacity to retain its strength when subjected to heat at high temperatures and its resistance to the corrosive effects of the products of fuel containing lead. Nickel alloy sheet and strip is made from an alloy containing from 43 to 48 per cent nickel, 21 to 25 per cent zinc, small amounts of manganese and iron and the remainder copper. This alloy is practically non-corrosive and can be annealed, without causing any surface damage, by heating to a temperature of 780° C., followed by air or water cooling. This alloy in its soft state is used for making wire, tubes, rivets and pins.

Tin

33. Tin is a soft white metal which is very ductile but, whilst it is rarely used in the pure state, it forms an important constituent of several different alloys. It is obtainable mostly in ingot form of various grades, ordinary standard commercial grades being about 99·75 per cent pure. The property possessed by tin of amalgamating at relatively low temperatures with various other metals, is used to advantage in the formation of bearing metals and alloys used as solder. An indication of the nature of some of the more important alloys having a large tin content is given in the following sub-paragraphs:—

(i) *White-metal.*—White-metal, sometimes classified as copper-tin alloy, is used as a bearing metal because of its anti-friction properties, its toughness and its capacity for melting at a temperature low enough to prevent seizing in the event of a bearing overheating. A typical composition of one of these alloys is copper from 5·50 to 7·50 per cent, antimony 6 to 7 per cent, nickel not more than 0·60 per cent, and the remainder tin. There are various other grades which are included in B.S. and D.T.D. Specifications.

(ii) *Solders, Grades A and B.*—These solders listed in A.P.1086 are alloys of tin, lead and antimony, and are employed for different classes of work. Grade A solder contains 65 per cent tin, antimony up to 1 per cent and 34 per cent lead, and has a melting point of 180° C., whilst Grade B solder is composed of 50 per cent tin, antimony between 2·50 and 3 per cent and the remainder lead, and this solder has a melting point of about 225° C. The total impurities in both are limited to 0·25 per cent. Grade B solder is used for general work, radiator and tank repairs, etc., whilst Grade A solder is used only for specified work where lower working temperatures are necessary. Other grades of solder with special properties are included in B.S. and D.T.D. Specifications.

Zinc

34. Zinc in its pure state is a soft ductile metal having a low tensile strength. It is strongly electro-negative to other metals and is very resistant to atmosphere corrosion; it can be applied, as a protective coating, to sheet iron, wire ropes, etc., by means of hot-dipping and electro-depositing processes. Zinc is alloyed with several other metals, including copper, aluminium, magnesium and cadmium; an alloy of cadmium and zinc is used for the purpose of soldering zinc-coated metal parts and this solder contains 71 per cent cadmium and 29 per cent zinc, both metals being 99·95 per cent pure. When zinc is subjected to excessive heat it is very volatile and for this reason alloys containing zinc should be heated carefully; the fumes given off by volatilised zinc are injurious to health and should not be inhaled.

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AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—GENERAL ENGINEERING

This is A.L. No. 14 to A.P.1464B, Vol. I and concerns Part 2, Sect. 4
Insert this chapter.

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CHAPTER 4

MARKING OF METALS AND ALLOYS

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General

1. The marking of part numbers, etc. on components of aircraft and aero-engines is a matter that requires careful consideration and the operations entailed in the various processes must be undertaken with extreme care and under competent supervision; this applies in particular to highly stressed components constructed from metals and alloys. In many instances it has been found that the depressions made by engraving processes, metal stamps, centre punches, etc., and in the case of light alloys, etching reagent, have caused damage to the material which has formed the origin of fatigue cracks and consequent early failure of the component concerned. The damage usually takes the form of minute fractures which are seldom visible unless examined under a microscope or traced by a method of crack detection.

2. When aircraft and aero-engine components require marking the process employed and the actual position of the mark must be carefully selected to suit the material and the construction of the component. This chapter describes permissible processes suitable for service requirements, but the correct process to employ will depend upon the circumstances. A useful guide in this direction and an indication of the correct area to mark will be found by an examination of similar components that have been marked by the manufacturers. In instances where a specified area is called for, instructions and a sketch will be issued in Vol. II leaflets.

3. The fatigue resisting properties of light alloys may be dangerously impaired by the application of a chemical reagent during etching or pickling processes, and the use of metal stamps is undesirable for the reasons previously mentioned. When dealing with these materials the electric etching pencil described in this chapter should be employed. Light alloys must not in any circumstances be chemically etched, washed or pickled in solutions containing caustic potash, caustic soda, washing soda or acids. Etching or stamping must on no account be adopted for marking springs of any description. Springs which require marking should be marked with an approved paint or enamel, or labelled.

METAL STAMPS

4. The use of metal stamps for any marking purposes must be undertaken with due consideration and under competent supervision. The size and depth of the impression and the form of stamp is important. When impressions surrounded by a border are called for, the border should be of circular or oval formation; square or triangular borders with sharp angles or corners are undesirable. Prior to stamping an item a test should if possible be made on a piece of similar material which can afterwards be examined to ascertain that the correct impressions have been made and that the material has not been damaged. This test particularly applies at the commencement of repetition work where a number of articles may be ruined by incorrect stamping. After using metal stamps or making a mark of a similar nature by other means, a suitable authorised corrosion preventative should be applied to the affected area.

5. Chemical etching has a general application for marking purposes but, as previously mentioned is not permissible for service use when dealing with items constructed from light alloys. Briefly, this process consists of making the desired marks by dissolving the material locally with a chemical reagent which is applied by means of an acid-resisting stencil. The reagent is strongly corrosive and it is therefore of the greatest importance when employing this process to take precautions to prevent the reagent from coming into contact with the skin, clothing or any article with the exception of the actual work in hand (*see* para. 8). On completion of the chemical etching process immediate anti-corrosion action must be applied to the item concerned.

Chemical etching—general procedure

6. The general procedure for marking by the chemical etching process is given in the following sub-paragraphs, and the appropriate reagent to use in conjunction with a particular metal or alloy will be found in para. 7. The procedure is as follows:—

(i) Thoroughly clean the surface to be marked until it is perfectly free from oil or moisture. In instances where an anti-corrosive protective has been applied to the material only sufficient area should be carefully removed to allow the work to proceed.

(ii) Apply a thin coating of acid-resisting material over the surface to be marked, at the same time forming a lip round the edges to act as a container for any excess of the etching reagent. The material usually employed for this purpose is beeswax or paraffin wax which can be applied by first melting and then brushing it on the desired area; transfers are also employed by various manufacturers for this purpose. The correct application of the wax is of the greatest importance; it should be applied as thinly as possible to prevent the formation of air-locks. To facilitate an even flow when making the application there should only be a slight difference in temperature between the molten wax and the item to be etched.

(iii) Allow the acid-resisting material to set hard; this is important, as it is impossible to make clean cuts in the material if it is in a plastic state.

(iv) Cut the required letters, figures etc., in the acid-resisting material with a fine-pointed scriber, in such a manner that the metal or alloy is bared, but not scratched.

(v) Apply an appropriate etching reagent to the markings by means of a glass rod. The reagent should be allowed to fall in drops from the glass rod until the surface of the metal exposed has been completely covered; the glass rod should not touch the work during this operation and care must be taken not to apply an excess of the reagent.

(vi) Allow the etching reagent to remain on the work for a sufficient period to make the marks clear and permanent. The period will depend on the metal or alloy being worked on and also the depth of indentation required. If there is any doubt with regard to the period, the operator should experiment on a piece of similar material prior to applying the reagent to the work in hand.

(vii) Remove the reagent by thoroughly washing in hot water. A stiff brush will greatly assist in this operation and at the same time the acid resisting material will be removed. If necessary the last traces of the acid-resisting material may be removed by petrol.

(viii) The metal or alloy that has been etched should now be dried and examined. If certain areas necessitate re-etching, it is advisable to re-coat the surrounding area with acid-resisting material and repeat the process.

(ix) Treat the area that has been etched with a thin coating of oil or an approved corrosion preventative.

Chemical etching reagents

7. For all general purposes when chemically etching metal and alloys, but not light alloys, a suitable reagent can be made by adding concentrated nitric acid to an equal volume of water; the mixture must be well stirred before using, and it is important for several reasons when mixing acids and water invariably to add the acid to the water. Copper sulphate, commonly known as "bluestone" can be successfully employed for marking steel tools; the copper sulphate crystals should be crushed into powder form, a pinch of common salt added and then moistened with a small quantity of water so that a small amount of saturated solution is obtained. The appropriate acid or liquid to use in conjunction with a particular metal or alloy is given below (all parts are by volume except where otherwise stated). No attempt should be made to speed up the chemical etching process by using a concentrated reagent where a dilute reagent is stipulated.

Metal or Alloy	*Reagent*
Brass	Concentrated nitric acid.
Copper	Mixture of nitric acid (2 parts) and sulphuric acid (1 part)
Lead	Concentrated nitric acid.
Zinc	Mixture of equal parts of hydrochloric acid and water.
Carbon steel	Mixture of nitric acid (1 part) and water (3 parts).
Hard steel	Mixture of nitric acid (2 parts) and acetic acid (1 part).
Nickel steel	Mixture of nitric acid (1 part) and hydrochloric acid (4 parts)
High speed steel	
High chromium steel ...	Concentrated hydrochloric acid.
High speed steel	

Precautions—acids

8. The acids used as the medium for chemical etching are very powerful corrosives and it is of the utmost importance that extreme care is exercised during handling and storing. Precautions must be taken to protect personnel and equipment during the chemical etching procedure. The acids must always be stored in glass bottles or containers having ground glass stoppers. The bottles or containers must be suitably labelled to denote their content and reasonable precautions taken to prevent the acids from being used in error or ignorance. The stoppers should always be replaced after using the bottles. There should always be a plentiful supply of cold water available for immediate use in washing off any acid accidentally split on the skin. Oil or petroleum jelly should be to hand for immediate application, *after washing in water*, in the event of acid burns. Common washing soda, or ammonia if available, can be used for neutralising acid spilled on clothes, benches, floors, etc., but precautions should be taken to avoid splashing or spilling of any description.

ELECTRICAL ETCHING

General

9. The electrical etching process can be very widely applied for marking purpses, but can only be employed when dealing with material that is a conductor of electricity. An electric etching pencil (Stores Ref. 1B/4247) is available to all units for re-marking and re-numbering engine parts etc. This pencil can be operated by a 6-volt accumulator of similar capacity to that of the standard ground purpose accumulator (Stores Ref. 5A/1901) which is normally held by units. This process of marking may be employed on any grade of metal or alloy, but due consideration must be given when dealing with components of a highly stressed nature or material of thin section, as the marks produced by the etching pencil (if carelessly used) can have a similar damaging effect to those mentioned in para. 1.

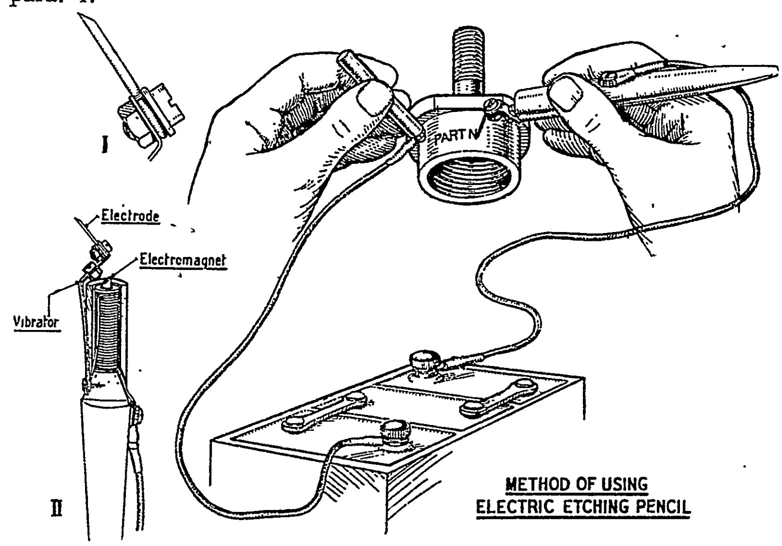

Fig. 1.—Electric etching pencil

10. The process is a very simple one consisting of placing the section of the item to be marked in a low voltage electrical circuit, in such a manner that the circuit is open until contact is made at the marking point by means of the etching pencil, when an arc is formed which fuses the metal and

so produces a mark. On gently pressing the point (electrode) of the pencil on to the work a vibrator is brought into operation which causes the point to make a succession of rapid contacts and so forming a, more or less, continuous arc which in turn produces corresponding fuse marks on the work. If the pencil is guided, as in normal wiring, these fuse marks will become an apparently continuous line which can be formed to make any desired mark.

Electrical etching—general procedure

11. Fig. 1 clearly illustrates the method of using the electric etching pencil. It will be seen that the pencil is connected by flexible wire to one pole of a 6-volt accumulator, and a hand-contact is connected to the other pole. The procedure for marking is in the first place to make a good electrical contact between the item to be marked and the hand-contact as shown in the illustration, and then to apply the etching pencil as desired. The pencil should be applied with a gentle pressure and guided at a rate to suit requirements. The depth of mark is dependent on the rate of movement and the grade of material being worked upon, and can readily be determined by experiment on a piece of similar material. It is important that the area to be marked is thoroughly cleaned and free from grease, rust, paint, etc. For the sake of neatness it is desirable to space out all lettering in pencil before using the etching pencil.

Electric etching pencil

12. Fig. 1, sketch II, gives a sectional view of the etching pencil which is of simple construction comprising a small electro-magnet and vibrator, embodied in the holder, with an electrode (point) consisting of a short length of hard drawn copper wire attached to the spring of the vibrator by a small brass screw and nut. Apart from sharpening and renewing the electrode the pencil requires no other attention. The electrode should be sharpened by filing the point to an angle approximately equal to that shown in sketch I of the illustration. To prevent overheating the winding of the electro-magnet, the pencil should not be used for long periods at a time, but when felt by the hand to be producing excessive heat it should be allowed to cool off before continuing with the work.

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CHAPTER 5

WORKING AND REPAIR OF TRANSPARENT PLASTICS

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Introduction

1. This chapter gives information on machining and working transparent plastics, and then describes the various methods by which bullet-holes, cracks, etc., in transparent panels may be repaired. The cleaning and polishing of transparent plastics is described in A.P.2656A, Vol. I, Sect. 13.

Note . . . The plastics are referred to by the names of the materials of which they are made rather than by their trade names. For instance, "Perspex" is methyl methacrylate and conforms to D.T.D.339, so that it is included under the heading "Methyl methacrylate (D.T.D.339)".

WORKING OF TRANSPARENT PLASTICS

Methyl methacrylate (D.T.D.339)

Protective covering

2. Methyl methacrylate (D.T.D.339) has a delicate surface susceptible to scratching,

and for this reason it is supplied with a protective covering of paper stuck on with a gelatine adhesive. Any working of the material, such as cutting and drilling, should be done with this protective paper in position, but the paper and all traces of adhesive must be removed before any shaping or moulding with accompanying heat is effected.

3. To remove the paper covering it should be raised at one corner and peeled off, after which any remnants of gelatine or paper should be washed off in warm soapy water (not warmer than 40°C.) and a final rinse given with clean water. The sheet should either be allowed to dry in air or should be rubbed dry with a soft leather—on no account should harsh fabrics be used. Washed sheets should not be placed in contact with one another. If it is necessary to pile or to stack washed sheets, wads of cotton wool should be used to separate the surfaces.

Cutting

4. Methyl methacrylate may be cut on any high-speed band or circular saw such as is used for cutting wood. The best results are obtained by the use of a fairly fine saw with about 14 teeth to the inch and very little "set". Dry cutting gives a good edge, but the finish is improved if water is used freely as a lubricant. The material should be slightly warmed if it shows a tendency to crack, but local overheating must be avoided.

5. Small pieces of the plastic may be cut with a fretsaw or a hacksaw, but the material tends to overheat and cause the saw to stick. Thin sheets, i.e. $\frac{3}{32}$ in. or less in thickness, may be scribed and broken along the scratch mark. Methyl methacrylate should not be guillotined or cut by shears.

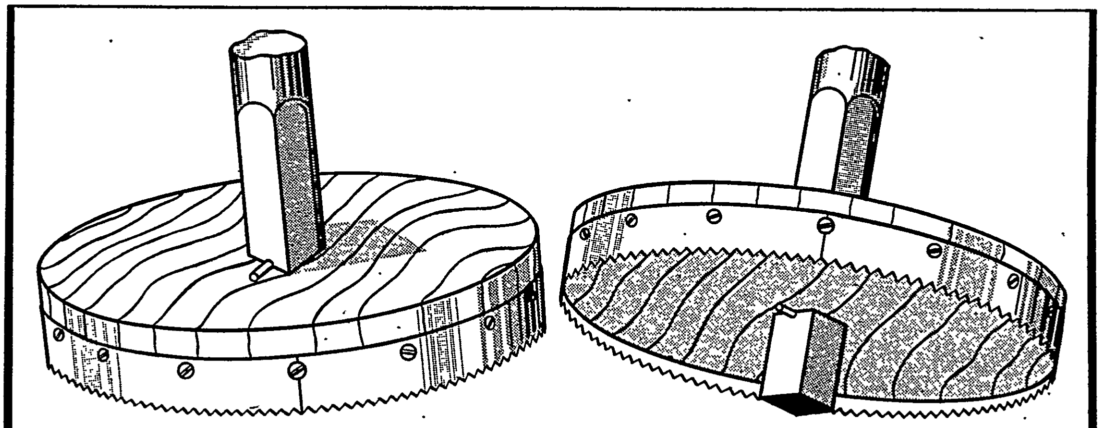

Fig. 1 – LOCALLY MADE DISC CUTTER

6. Thicker sheets should be cut by sawing. A hack-saw with a blade having from 18 to 24 teeth per inch, a jig-saw with a blade having about 10 teeth per inch and a cutting speed of 500 strokes per minute, a band-saw having 8 to 10 teeth per inch and running at about 2,500 ft. per min., and a carpenter's tenon saw, are all suitable tools for this purpose. When transparent panels are being sawn or drilled, the outline or position of the holes may easily be followed if a paper template is stuck to the under surface of the panel.

Preparing blanks

7. Blanks can be machined with a circular cutter revolving at 1,000 r.p.m. for blanks of about $1\frac{1}{2}$ in. diameter. In other words, the cutting speed should be about 400 ft. per min. The cutter should be cooled with compressed air, water, soluble oil or paraffin.

8. If a tubular cutter or other tool suitable for cutting circular blanks is not available, a useful substitute (*see fig. 1*) may be made up with materials which are easily available locally. A disc of hard wood about ¾ in. thick and carefully turned to the required diameter, a short length of ⅜ in. round scrap rod and a fine hack-saw blade are required.

9. The cutter should be made up as follows:—

(i) The saw blade must be carefully annealed and twisted round the periphery of the hardwood disc to measure the length of blade required.

(ii) Cut the blade at the correct point and drill holes suitable for ⅜ in. round-head wood screws at intervals of ½ in. along the length of the blade. In order that the butting ends of the blade may meet satisfactorily when the blade is screwed down around the periphery of the disc, file semi-circular recesses at each end of the blade, so that a wood-screw inserted into the disc between the blade ends will hold them down on to the disc.

(iii) Screw the blade down carefully, and tighten the screws.

(iv) File the length of scrap rod to square section for about 2 in. from the end, and drill a hole through the centre of the disc, filing it to a square suitable for the insertion of the rod.

(v) Insert the rod, and pin it above and below the disc, as shown in fig. 1. The tool should now be ready for use with either a carpenter's brace or a fitter's hand drill.

Note . . . Units may find it more satisfactory, where such a tool would be frequently used, to make up cutters with an alloy instead of a wooden disc and to fasten the saw blade with setscrews.

Drilling

10. Owing to its brittle nature, methyl methacrylate should only be drilled when the hole is to be plugged or filled with a cemented patch. In other instances, holes should be bored with a hot wire or needle. When a hole is drilled the sheet should be packed to prevent its splitting.

11. Methyl methacrylate may be drilled with ordinary twist drills. The following drilling speeds are recommended:—

$\frac{1}{16}$ in. dia.	7,000 r.p.m.
¼ in. dia.	1,800 r.p.m.
½ in. dia.	900 r.p.m.

12. To prevent the material from cracking when the drill emerges from the underside of the sheet, the twist drills should be ground rather flat. This reduces the cutting angle and the "corkscrew" effect of the drill drawing itself through the sheet. It is advisable to use a hand feed so that the feed can be instantly reduced if there is any sign of overheating.

13. If the drill is ground so that the point is slightly off centre, the resulting hole is larger than the nominal diameter of the drill, but there is less binding in the hole. This alteration to a standard drill is particularly useful when deep holes are being drilled.

14. When holes deeper than ½ in. are drilled, the drill should be lubricated with water, paraffin, or water containing soluble oil, and should be frequently removed from the hole. Fluted drills are best for small diameter deep holes.

Turning and milling

15. Methyl methacrylate may be readily turned by hand or slide-rest lathes. For hand turning, standard wood-working tools with flat tops and ground to an angle of 55° are suitable, and for slide-rest turning a similar type of tool should be used set at an angle of 60° with the spindle. A cutting speed of 65 ft. per min., and a feed of 0·010 in. per revolution is recommended.

16. Edge milling or bevelling can be done with standard tools such as are used for wood or metal working. Methyl methacrylate swarf should not be allowed to lie on the surface of the material as this may lead to crazing. It is usual to mill the material without a lubricant and the dry swarf can easily be blown away from the tool with compressed air.

Hand-planing

17. Methyl methacrylate may be hand-planed with very light cuts and filed if a coarse file is employed with fast light cuts. Rough edges should be finished by means of glass or emery paper, or a scraper. During all cutting operations where the material has to be gripped in a vice, thick paper packing should be used to protect the delicate surface of the material from injury by the jaws of the vice.

REPAIR OF TRANSPARENT PLASTICS

Introduction

18. Observation panels should be repaired only as an emergency measure if there are no new panels available. A repaired panel should be discarded as soon as possible and replaced by a new one. This is necessary because the repair may produce a blind spot and it is dangerous to use an imperfect panel.

19. It is, however, permissible to repair a damaged panel if the patch is so situated that it cannot impede the view—that is, if the panel is not used for anything but the admission of light.

Methyl methacrylate (D.T.D.339)

Identification markings

20. All methyl methacrylate (D.T.D.339) sheets and panels supplied to the Service bear an identification symbol, "D.T.D.339", stamped or inscribed near to one edge of the sheet or panel. This mark is in addition to any trade name such as "Perspex" which may appear on the material.

21. Where flat panels are made up by the Service from sheet material, this identification number must be inscribed in a position out of the range of vision and near to one corner, but so placed that it will not be obscured when mounted on the aircraft. The symbol is to be inscribed with a sharp pointed instrument, such as a scriber (Stores Ref. 1C/2187), in letters and figures not exceeding $\frac{1}{8}$ in. height and surrounded by a small circle. Care should be taken to ensure that, if the part of a stock sheet of material on which the specification number is inscribed is removed, the sheet is re-marked immediately.

Distortion of panels

22. No attempt should be made to remould distorted panels, since the application of heat, necessary for the process, causes shrinkage and is liable to result in the panel becoming partially opaque after the repair has been effected. Distorted panels should be replaced by new ones at the earliest opportunity.

Fitting panels to frames

23. Panels of methyl methacrylate (D.T.D.339) are subject to slight changes in area due to temperature variations. A permanent shrinkage of 0·1 per cent. in linear dimensions is usual after continued exposure to sunshine, and a further temporary shrinkage may occur during conditions of extreme cold. For this reason, holes drilled in methyl methacrylate (D.T.D.339) panels, for receiving fixing screws, bolts, or rivets, are given a clearance which may be from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. or more on the diameter according to the size and estimated linear contraction of the panel. Care should be taken, when transparent panels are renewed, to ensure that these clearances are retained.

Repairing damaged panels

24. The repair by patching of transparent panels made of methyl methacrylate (D.T.D.339) may be grouped into three categories:—

(i) Patches secured by screws or rivets.

(ii) Inlay patches secured at the edges by cement.

(iii) Overlay or lap joints secured by a cement.

Moulding repair patches

25. Methyl methacrylate is a thermo-plastic and may be satisfactorily remoulded, for making patches only, by the application of heat and light pressure. The plastic must be absolutely clean before it is remoulded. The temperature should be closely controlled. A temperature of 120–130°C. is suitable for remoulding material up to $\frac{1}{8}$ in. thick. The same temperature is suitable for material over $\frac{1}{8}$ in. thick, with oil or glycerin as the medium. The time required for heating depends on the thickness of the sheet—$\frac{1}{8}$ in. material needing 5 min., and material over $\frac{1}{4}$ in. thick needing about 30 min.

26. It is important that personnel handling the heated plastic should wear clean cotton gloves to avoid injuring the softened surface. When the patch is soft, it should be moulded by being pressed against the curved panel to which it is to be fitted, or else it should be placed in a mould made of wood or whitemetal. The surface of the mould should be covered with a stretchy fabric or with rubber latex. The pressure on the patch should be maintained until the material has cooled to room temperature, and the material should be quite cool before any attempt is made to polish it. Indeed, if it has been shaped properly, it should not need polishing.

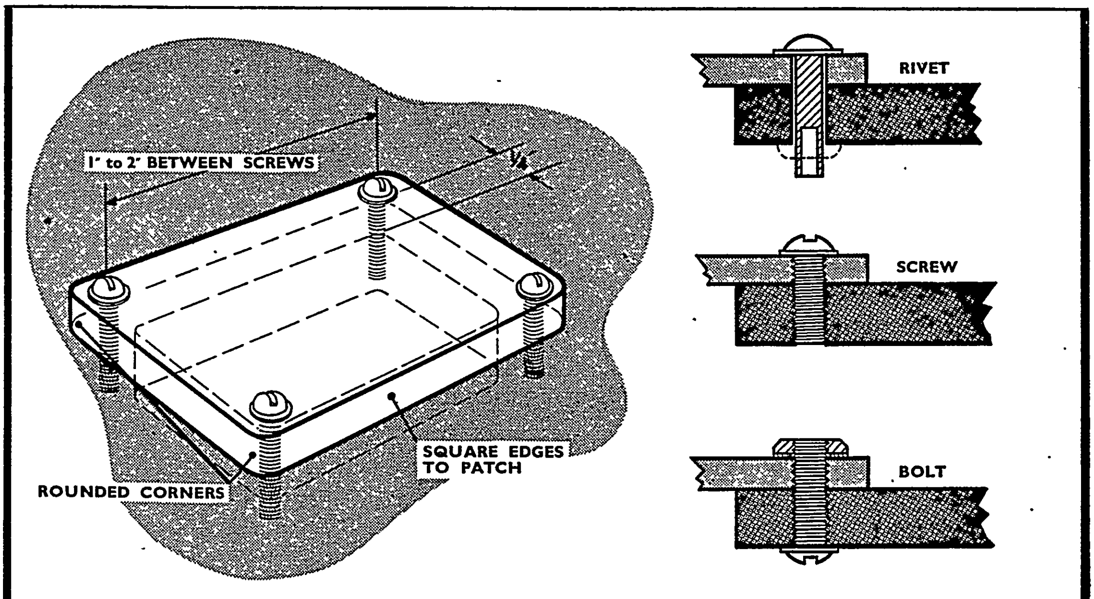

Fig. 2 – PATCHES SECURED BY SCREWS, RIVETS, OR BOLTS

Patches secured by rivets, bolts, or screws

27. Patches of transparent plastic may be secured to the panel by rivets, bolts, or screws. For panels up to $\frac{5}{32}$ in. in thickness, a patch of $\frac{3}{64}$ in. material should be used; for panels of

greater thickness the patch should be of $\frac{5}{64}$ in. material. In all instances patches should be applied to the inside surface of a panel to minimise air resistance and erosion.

28. The holes for screws or rivets should be drilled at intervals of 1 to 2 in., and should not be less than $\frac{1}{4}$ in. from the edge of the patch (*see fig. 2*). Rivets should be tubular or semi-tubular, and should be $\frac{3}{32}$ in. or $\frac{1}{8}$ in. dia. The rivet holes for $\frac{3}{32}$ in. dia. rivets should be drilled $\frac{7}{64}$ in. dia. (No. 35 drill) and those for $\frac{1}{8}$ in. dia. rivets should be drilled $\frac{9}{64}$ in. dia. (No. 28 drill).

29. Patches may be secured by bolts or by setscrews. When bolts are used, fine clearance holes should be drilled in both patch and panel. For instance, for 6 B.A. bolts and nuts, a No. 33 drill should be used throughout. Setscrews require a clearance hole in the patch and a tapping hole in the panel. A 2 B.A. setscrew should be used in conjunction with a No. 13 drilled hole in the patch and a No. 24 drilled hole in the panel. The setscrew is passed through the hole in the patch and screwed tightly into the panel, after which the projecting end should be cut off and filed flush.

30. Washers should always be used with the screws or bolts. Direct contact between the undersides of the screw heads and the patches during tightening-up may cause damage to the patches and it is essential that suitable washers be inserted.

31. Transparent patches secured by mechanical means to panels which are slightly curved in one direction only will not require moulding to shape. Where patches must be sharply curved, or curved in two directions, the instructions given for moulding patches in para. 25 should be followed.

Cements

32. The cement used for securing repair patches to methyl methacrylate is Cement, Perspex No. 6 (Stores Ref. 33C/888), which is supplied in pint cans. The cement is slow-hardening and a setting time should be allowed of about two hours. A piece of wood should not be used for stirring the cement as small bits break off and remain in it. A piece of metal, clean and free from rust, should be used instead. For the best results, only a second or two should elapse between the application of the cement and making the joint. When the cement is used in the open air, it becomes cloudy. The lid of the container should not be left off for any length of time.

33. When replacing the lid of the container, after the cement has been used, the operator should ensure that the lid is quite free of the adhesive, because the metal-to-metal bond is so strong that the lid cannot be removed.

> **WARNING.—Perspex No. 6 is inflammable and its fumes are poisonous, so that good ventilation is necessary. Smoking should not be allowed where the cement is being used owing to the risk of forming chlorine gas.**

34. Where Perspex No. 6 is not available, an adhesive can be prepared by dissolving a quantity of methyl methacrylate in a solvent of the material, as follows:—

> Prepare a solution of methyl methacrylate (D.T.D.339) filings in chloroform or benzine in the proportion of 4 per cent. of filings to 96 per cent. of chloroform or benzine. A higher concentration than 4 per cent. of the plastic in solution will cause the adhesive to become gelatinous. Even at the concentration recommended, a rapid increase in viscosity is liable to occur, and the adhesive should therefore be prepared immediately before it is required for use.

Masking tape

35. The cements used for securing repair patches are solvents of the plastic. If the cement is allowed to come in contact with any surfaces other than those being joined it destroys the smoothness. It is therefore necessary to protect the surfaces of the patch and the panel by the use of masking tape.

36. The tape should be applied round the edges of the repair in such a way that it covers all but the areas to be cemented and protects the rest of the panel from splashes and overflows of cement. The tape must be stripped off after one hour as otherwise it may cause crazing.

Inlay patches secured by cement

37. The use of inlay patches calls for a high degree of fitting skill. Surfaces to be cemented together must be in contact over their whole area, for the cement will not fill up cracks or gaps greater than 0·003 to 0·004. The material from which an inlay patch is made must always be the same as that of the panel. The method of repair by inlay patches may conveniently be divided into information for filling circular holes up to 1 in. or 2 in. diameter, and information for filling larger holes.

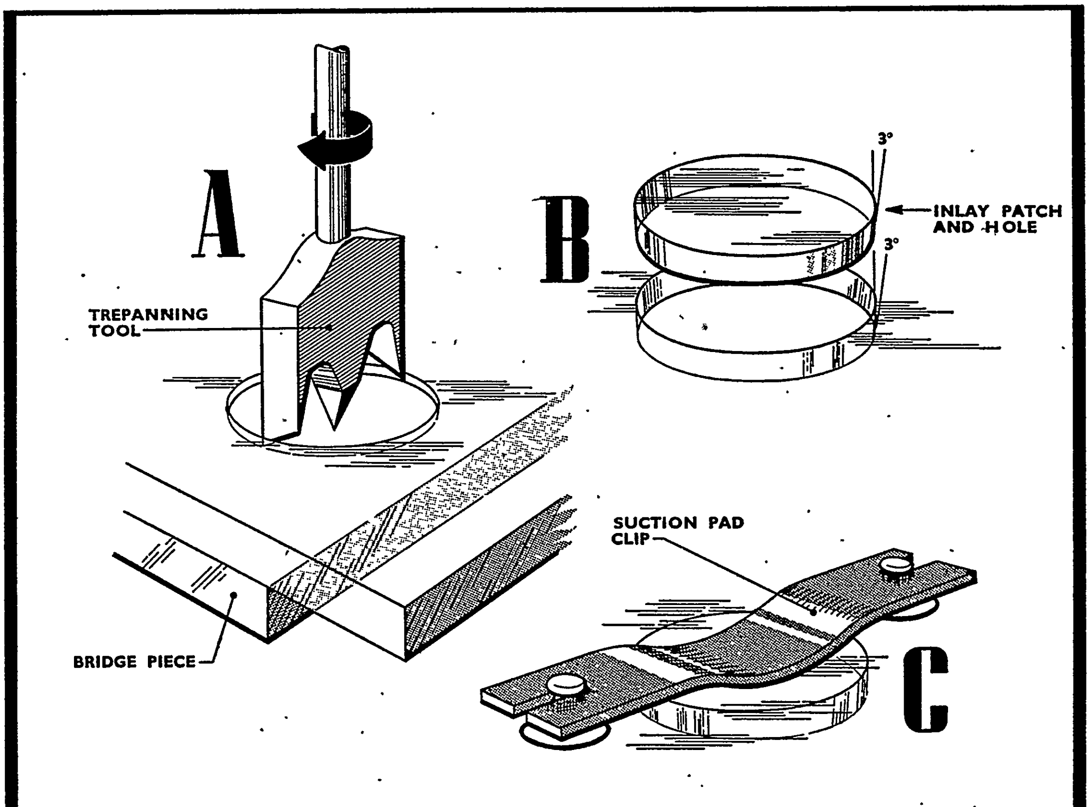

Fig. 3 – FITTING OF INLAY PATCHES

Preparing the hole—up to 2 in. diameter

38. Small holes, up to 1 in. or 2 in. diameter, should be made circular. Such holes may be cut with a drill (Stores Ref. 3B/1350 to 1601), a trepanning tool (*see A, fig. 3*), a centre bit (Stores Ref. 1A/122 to 132), or a washer cutting tool. Since the centre of the drill or bit will normally coincide with the centre of the original hole, a solid centre must be provided for the tool. For this purpose a short strip of the material of which the panel is made, i.e., methyl methacrylate (D.T.D.339), should be cemented across the hole (*see A, fig. 3*) as a bridge piece. If such material is not available a bridge piece may be made from a strip of any similar material, or of hardwood, and temporarily bolted to the panel. If the bridge piece is fixed on the reverse

side of the panel to that from which the drill is to be introduced it will act as a location until the boring operation is completed but, if this is not convenient, the bit may, with care, be made self-locating once the cutting is well started, and the severance of the bridge piece will not matter.

39. The edge of the hole should be bevelled to the full thickness of the panel at an angle of 3°. This enables the inlay patch to be fitted in the form of a wedge (*see B, fig. 3*) and prevents it from falling through the hole in the panel during the fitting and cementing processes. The bevel should be formed so that the inlay patch is inserted from the side of the panel which receives air pressure during flight—the tendency will then be for the patch to be forced more securely against the panel.

Preparing the blanks—up to 2 in. diameter

40. As the practicable size of circular inlay patches will not exceed 2 in. dia., the normal curvature of a transparent panel should not be such as to preclude their use, but where the curvature is complex the use of discs will be impracticable and repair will be only possible by means of moulded patches (*see para. 25*).

41. Circular blanks of methyl methacrylate (D.T.D.339) for inlay patches may be cut by means of a tubular cutter such as described in para. 7. The blank must be bevelled round the edge to its full thickness at an angle of 3° and carefully mated up to the hole it is required to fit. Smooth files and the blade of a penknife or some other sharp light cutting tool should be used to obtain smooth flat-fitting surfaces.

42. Before the patch is cemented in the panel, all traces of oil or grease should be removed with paraffin. The cleaned surfaces should then be left until they are thoroughly dry. The edges or surfaces to be joined should be rubbed with durex emery cloth to remove any roughness left by the cutter—there is no need to polish the surfaces. Masking tape should be applied on the upper and lower surfaces of both patch and panel to protect them from the surplus cement.

43. The cement should be applied with a camel-hair brush (Stores Ref. 1A/202). The cemented surfaces should not be fingered and the joint should be made immediately. When the patch has been pressed into position and all air excluded from the joint, it should be held in place with suction pad clips as shown at C, fig. 3.

44. The time taken for the joint to dry out will vary with the warmth and humidity of the atmosphere. A warm dry atmosphere hastens the drying process; a cool moist atmosphere prolongs it. Under normal conditions a joint should be ready for the removal of the clips after about an hour. After an hour, the masking tape should be removed, and after three hours any surplus adhesive still remaining should be cleaned off with Durex emery cloth. The surface of the plastic may tend to craze at first, but the effect should disappear, leaving a comparatively clean and clear union.

Repairs over 2 in. diameter

45. If an inlay patch is used for repairing a hole more than 2 in. diameter, the hole in the panel should be cut to a rectangular or square shape with rounded corners. A piece of the same material as the panel should be shaped to suit the hole. As with circular patches all the edges should be bevelled 3° and the mating surfaces finished with the utmost care. In cutting away the edges of the damaged material preparatory to fitting a patch it should be remembered that horizontal lines must be cut outside the line of sight. The procedure for fitting, cementing and cleaning rectangular and square patches is the same as that described for circular patches in para. 38 to 44.

Overlay patches secured by cement

46. Cemented overlay patches must not be used in positions where clear vision is essential. Overlay patches on flat transparent panels require little fitting skill (*see A, fig. 4*). The patches can also be moulded to suit panels of complex curvature, the nature and extent of such repairs depending largely on the skill of the fitter.

47. The damaged portion of the panel should first be cut by means of a hacksaw and filed to a regular shape—circular, rectangular, square, etc. A repair patch of the same material as the panel should be prepared; this should be the same shape as the hole in the panel, but $\frac{1}{4}$ in. larger on superficial dimensions. The sharp edges of the patch should be retained. If radii are filed on the edges, a distorted view may be obtained when the patch is fitted to the panel. Where the patch requires moulding to conform to the curvature of the panel, the procedure described in para. 25 should be adopted.

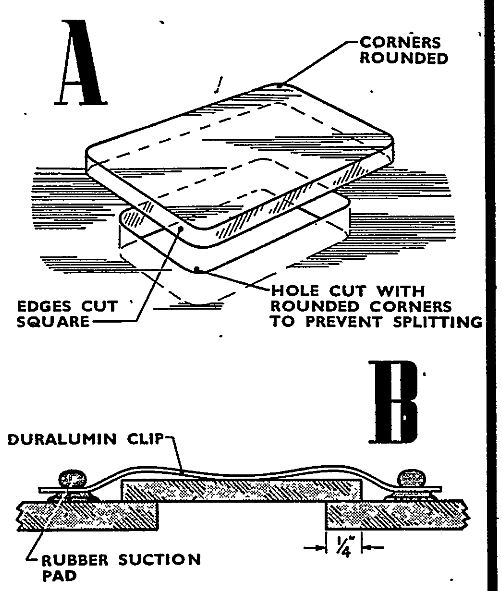

Fig. 4 — CEMENTED OVERLAY PATCH

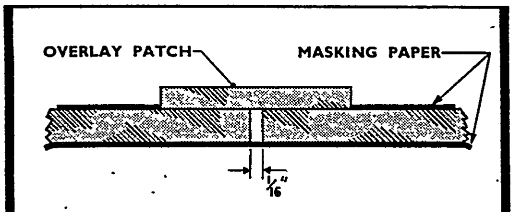

Fig. 5 — BUTT JOINT WITH OVERLAY

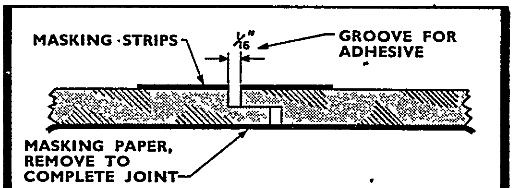

Fig. 6 — BUTT JOINT WITHOUT OVERLAY

48. The degree of accuracy required is such that when the patch is laid in position a 0·002 in. feeler will just enter, but not pass through, any part of the joint. If a larger feeler should enter, or the 0·002 in. feeler pass through at any point, the results will be poor and the joint should not be made until a better fit has been obtained. When the patch is ready for cementing, both this and the panel should be cleaned with paraffin.

49. Masking tape should be applied to any surfaces likely to be accidentally covered with the cement. The cement should then be spread on the mating surfaces with a camel-hair brush (Stores Ref. 1A/202). The patch should be carefully pressed into position by hand and secured by means of duralumin suction clips (*see B, fig. 4*). After one hour the masking tape should be removed, and the surfaces cleaned and polished if necessary.

Butt joints with overlay

50. The edges of the panels to be joined should be milled to ensure that the mating surfaces are parallel. The panels should be brought together until a gap of only $\frac{1}{16}$ in. remains between their edges (*see fig. 5*). This gap can be maintained by laying the panels on a strip or strips of masking tape. An overlay patch of similar composition and thickness to the panels (i.e. $\frac{1}{8}$ in. thick methyl methacrylate (D.T.D.339) panel) and $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. in width, should be cut and laid in position on the panels to be joined.

51. The surfaces of the panels immediately on either side of the patch should be covered with masking tape to protect them from the cement. The patch should now be removed and an excessive amount of the cement should be poured on the margins of the panels on which the

patch is to be placed, and in the $\frac{1}{16}$ in. groove, care being taken to prevent the formation of bubbles. The joint should now be made by placing one end of the patch in position and gently lowering the remainder until contact is made along its whole length. A light pressure should be applied with the fingers to remove air bubbles and excess cement. After a period of one hour has elapsed, the masking tape should be removed and the joint baked for 24 hours at 40 to 60°C.

Butt joints without overlay

52. Butt joints without overlay should only be used where no increase in thickness can be permitted. The panels to be joined should first be milled on their edges so as to leave a groove $\frac{1}{16}$ in. wide on each side of the assembly when the two panels are brought together (*see fig. 6*). Masking tape should be used as described in para. 50. The procedure is similar to that described for butt joints with an overlay patch.

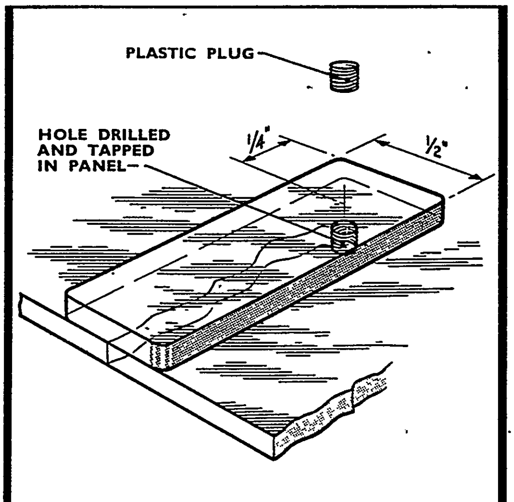

Fig. 7—CEMENTED PATCH ON CRACK RUNNING FROM PANEL EDGE

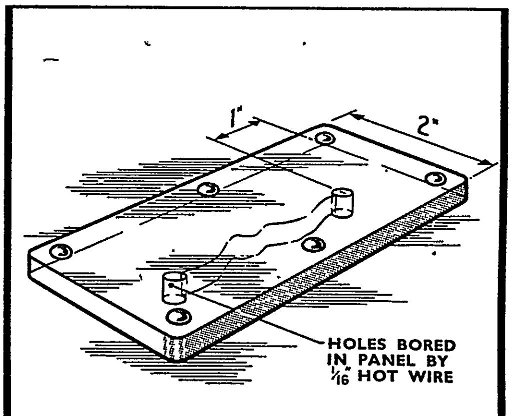

Fig. 8—BOLTED, SCREWED, OR RIVETED PATCH

Preventing cracks from spreading

53. Cracks in a transparent panel may be prevented from spreading if a hole is burnt at each end of the crack with a $\frac{1}{16}$ in. dia. hot wire or needle. The crack should be then covered by securing a covering strip of methyl methacrylate (D.T.D.339) or by one of the following methods:—

(i) Cut a strip of the transparent material $\frac{1}{2}$ in. wide and long enough to cover the crack plus $\frac{1}{4}$ in. overlap at each end of the crack. With the covering strip in position and using a No. 27 drill, drill a hole through one end of the crack and through the strip. Repeat for the other end of the crack and, if the length of the crack is more than 3 in., drill one or more intermediate holes of the same diameter through both the crack and the strip. Apply cement to the whole of one surface of the strip and to the area it covers surrounding the crack. Clamp the strip to the panel with two or three 4 B.A. bolts and washers through the holes. When the cement is set, remove the bolts and washers, tap the holes 2 B.A., and plug them with pieces of rod made of methyl methacrylate threaded 2 B.A. and dipped in the cement (*see fig. 7*). Clean and polish the surface.

(ii) Cut a strip of the transparent material 2 in. wide and long enough to cover the crack, plus about 1 in. overlap at each end of the crack. The strip should be bolted or riveted to the panel, the holes being drilled well clear of the crack in the panel (*see fig. 8*).

Cracks starting at the edge of the panel

54. If cracks appear at the edge of a panel when it is fitted into its frame, satisfactory repairs may be effected as follows:—

(i) Cover the crack with masking tape on both sides of the panel and slit the tape by inserting a razor blade into the crack, as near the edge of the panel as possible.

(ii) Using a fine camel-hair brush, paint the surface with cement, allowing it to run down into the crack. On no account attempt to flex the panel in order to separate the faces of the crack for the insertion of the brush, as this would extend the crack.

(iii) When the cement becomes tacky, withdraw the blade and allow the faces of the crack to come together. Leave the cement to dry for an hour, then remove the masking tape.

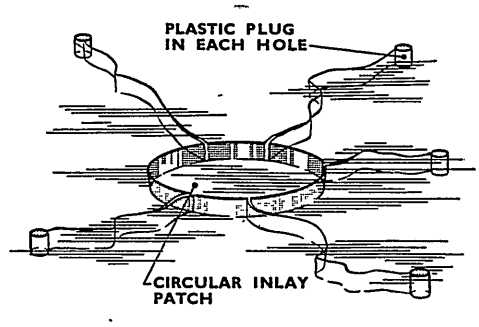

Fig. 9—REPAIR OF HOLE HAVING RADIATING CRACKS

Repair of hole with radiating cracks

55. The hole should be repaired with a circular inlay patch (*see fig. 9*) as described in para. 37. The extremity of each crack should be drilled and tapped 2 B.A. The holes should then be plugged with methyl methacrylate rod, threaded 2 B.A. and dipped in cement. The cracks should be painted with cement (*see para. 54*). When the cement is dry, the surface should be cleaned and polished.

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AIR MINISTRY
May, 1944

R.A.F. ENGINEERING—GENERAL ENGINEERING

This is A.L. No. 16 to A.P.1464B, Vol. I and concerns Part 2, Sect. 4
Insert this chapter.

CHAPTER 6

GLAZING AND SEALING OF AIRCRAFT COMPONENTS

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General

1. Various sealing compounds are provided in order that weatherproof joints may be made for such components as windscreens, bomb-aimer's windows, riveted joints, cupolas, etc. The essential feature of these materials is their capacity for filling a joint to prevent the ingress of air and/or water, and the retention of this property for a reasonable period, yet allowing a certain amount of flexing between adjoining parts without cracking.

2. The success or otherwise of approved compounds in use depends to a great extent on the method and condition of their application and for this purpose the following information covering typical examples of such work has been compiled.

Glazing materials

3. An approved material for glazing is Bostik-B glazing compound (Stores Ref. No. 33C/591), which is used alone in some classes of work, or, when it is essential that the compound should also be impervious to the action of oils or fuel, Boscolyn lacquer is also used in conjunction with the glazing compound. When, in addition, rubber, felt, or other similar material is employed in a joint for the purpose of absorbing excessive vibration, Bostik-C adhesive compound is used to stick these materials in position, the glazing proper still being effected by Bostik-B.

Bostik-B glazing compound

4. This compound is available in blue-labelled collapsible tubes each containing approximately 6 oz., and with each tube an extruder key and a nozzle are provided (see fig. 1). The key is intended to engage with the flattened end of the tube which is subsequently rolled up by the key, and the material is thus exuded through the nozzle which is screwed on to the other end of the tube, after the end-cap has been removed.

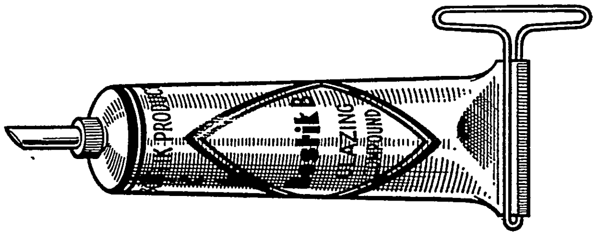

Fig. 1.—Collapsible tube of Bostik-B with nozzle and key

5. When using Bostik-B, the key should be threaded over the flattened end of the collapsible tube; it may be necessary to unroll the first layer of the clinched end in order to obtain a better grip with the key. With the nozzle in position and the work prepared, the key should be wound in a clockwise direction until the compound emerges from the nozzle. The nozzle should then be held near the joint where the compound is required and, turning the key, the tube should be moved at the same time steadily along the work at such speed that a continuous even strip of compound is exuded. Breaks or thickening of the bead of compound are caused by the feed being too slow or too fast, respectively, for the rate at which the tube nozzle is moved along the joint. A sound, weatherproof joint cannot be made by depositing dabs of compound at intervals along the joint.

Application of Bostik-B glazing compound

6. When applying the glazing compound all associated surfaces should be clean and the bead or beads of extruded compound should be so positioned that when the panel is fitted and pressed into position the compound will spread evenly and form a continuous seal along the edge of the mating components. Thus, for a glazed joint consisting of a simple rebate and fairing strip (see fig. 2) one continuous bead of compound laid along the corner will be sufficient, but for a channel section glazed joint two beads, one in each corner, should be applied (see fig. 3). Other examples of more complex joints are shown in figs. 5 and 6.

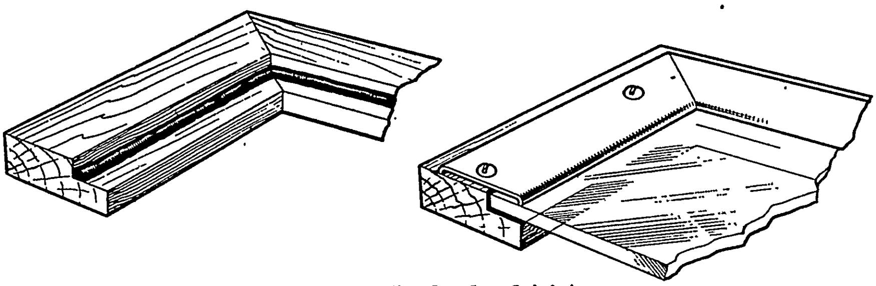

Fig. 2.—Simple glazed joint

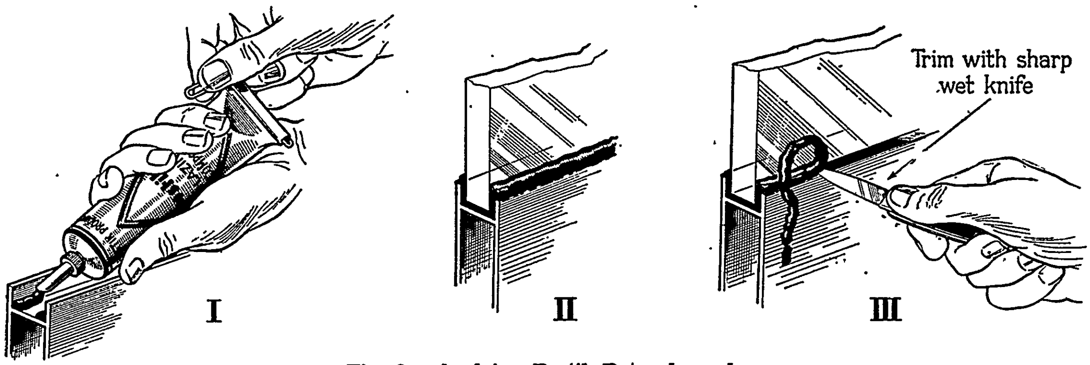

Fig. 3.—Applying Bostik-B to channel

7. The glazing compound can also be used for sealing the joints of electrical terminal and junction boxes and for weatherproofing electrical cable ferrules, etc. (see fig. 4). The compound can be pressed into the cavities, keeping the fingers wet with water while doing so. Surplus compound should be removed by means of a sharp knife wetted in water, but great care should be taken to avoid cutting or scratching the component during this operation.

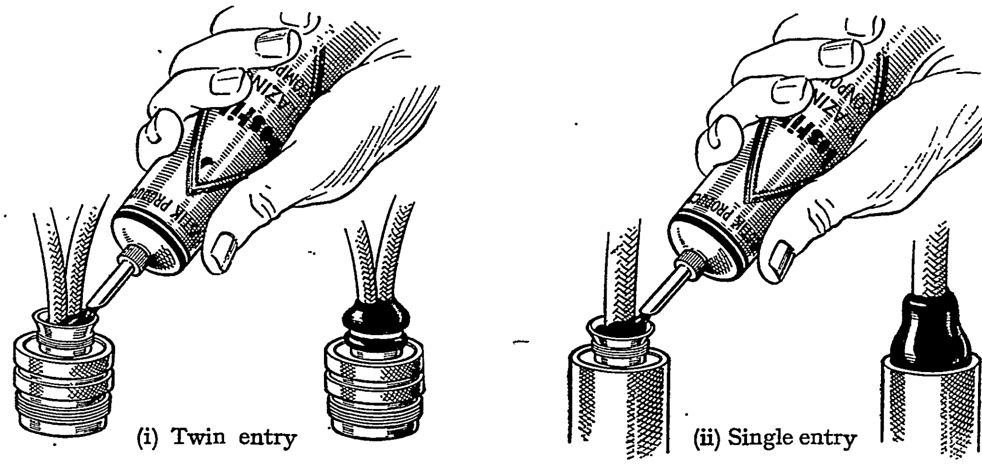

Fig. 4.—Sealing cable end-fittings

Protecting joint against oil and fuel

8. After a joint has been made using Bostik-B glazing compound, it may be necessary to proof the joint against the action of oil or fuel, in which case the joint should be allowed to stand for 24 hours and any surplus compound trimmed off by means of a sharp, wet knife. The exposed surface of the compound should then be coated with Boscolyn Lacquer (Stores Ref. No. 30C/590 or 668), applied by a fairly stiff bristle brush. The lacquer should be allowed to dry thoroughly before it is handled.

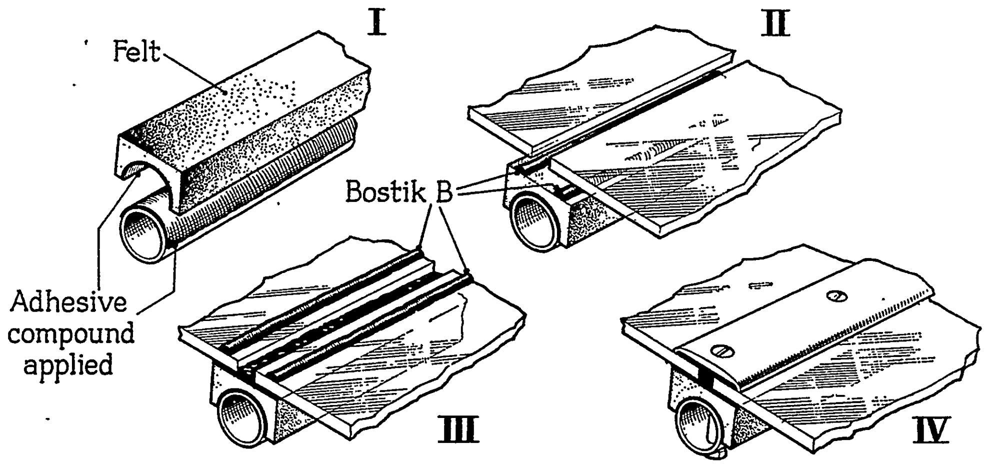

Fig. 5.—Attachment of felt to airframe for mounting Perspex and other panels

Bostik-C adhesive compound

9. This adhesive (Stores Ref. 33C/605) is supplied in yellow-labelled, gallon, quart and half-pint containers, and is used for the attachment of such materials as cork, rubber, felt, fabric and other similar materials to metal or wood, as for example, for interior and exterior walkways and for the attachment of moulded rubber beading to cabin doors, escape hatches, etc. (see figs. 5 and 6).

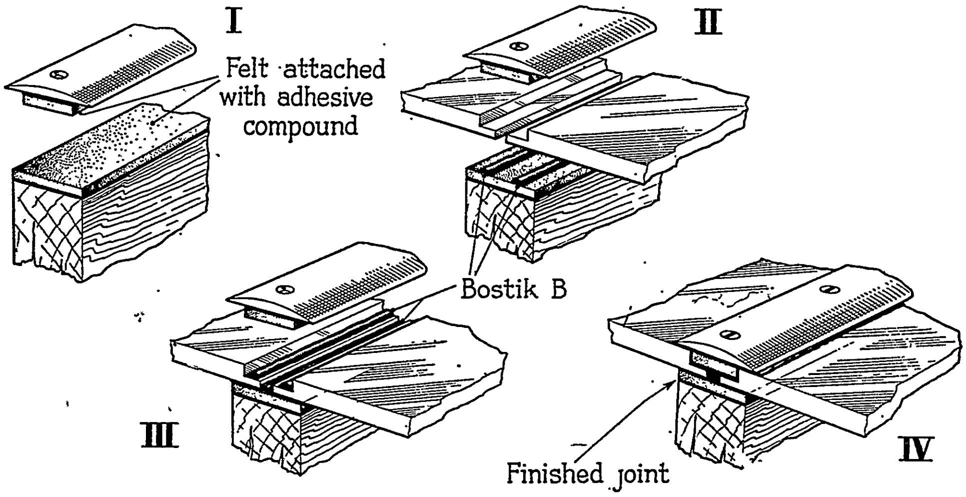

Fig. 6.—Attachment of felt strip to wooden frame and metal fairing strips

10. The mating surfaces should both be cleaned and coated with an even film of the Bostik-C adhesive compound, which should be allowed to dry until it can be touched without showing signs of tackiness, after which the two surfaces should be pressed together, applying the maximum pressure obtainable without damaging the components; a roller weighing about 7 lb. will be found suitable for the majority of jobs of this kind. If the material to be attached to a component is of plywood then it should be held in position additionally by means of sandbags for a period of from 4 to 5 hours (see fig. 7).

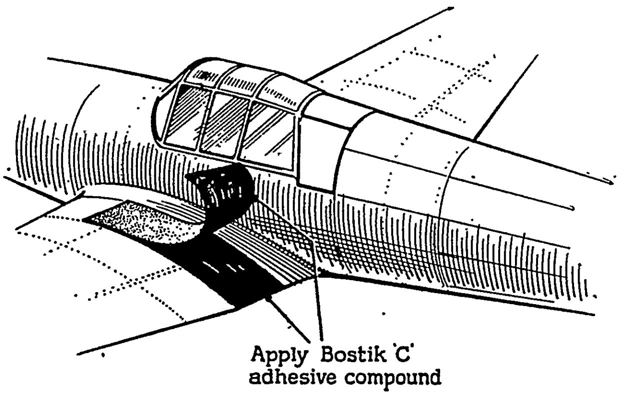

Fig. 7.—Attachment of walkway

11. The time taken by the solvent in the compound to dry out and so leave it in a non-tacky state will vary according to the surrounding temperature and humidity of the atmosphere, but a minimum period of 30 minutes should always be allowed between the application of the compound and the making of the joint; this period allows a margin sufficient to permit the bond to attain its maximum strength more rapidly than if a shorter drying period is allowed. Joints made by the use of this adhesive can be proofed against the action of oil or fuel by means of Boscolyn lacquer applied along the exposed edges of the joint.

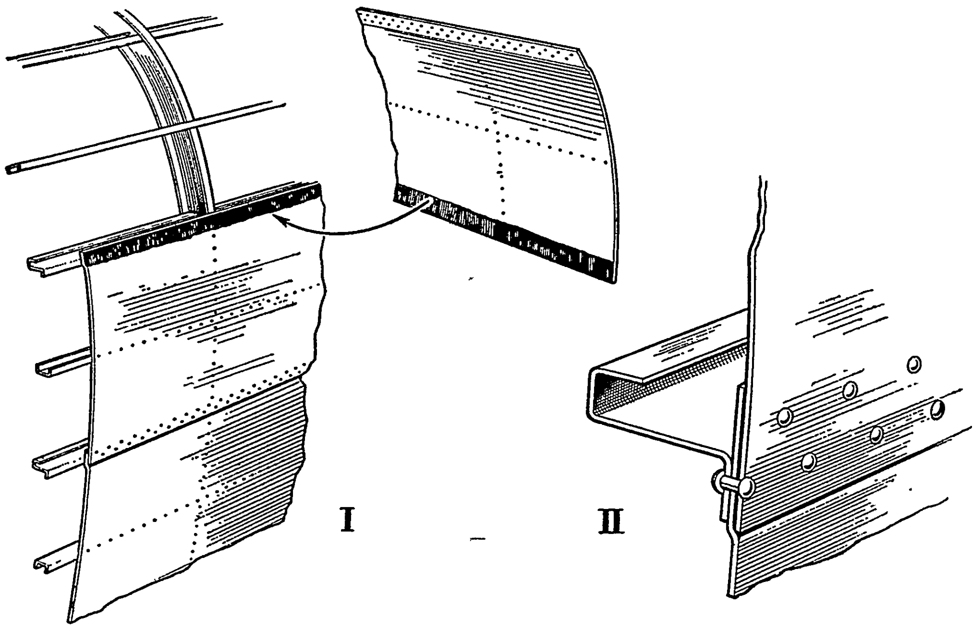

Fig. 8.—Weatherproofing riveted joints by Bostik cement No. 321

Bostik cement No. 321

12. This cement (Stores Ref. 33C/594) is used for overlap (see fig. 8) or butt-joints between similar metals on airframes, and is supplied in similar containers to the adhesive compound but the labels are in orange and white. In use the cement should be applied liberally to the borders forming the mating surfaces of the joint, which have been cleaned previously. The cement should be allowed to dry for a period of approximately 20 minutes, after which the parts to be joined can be riveted or bolted together in the normal manner.

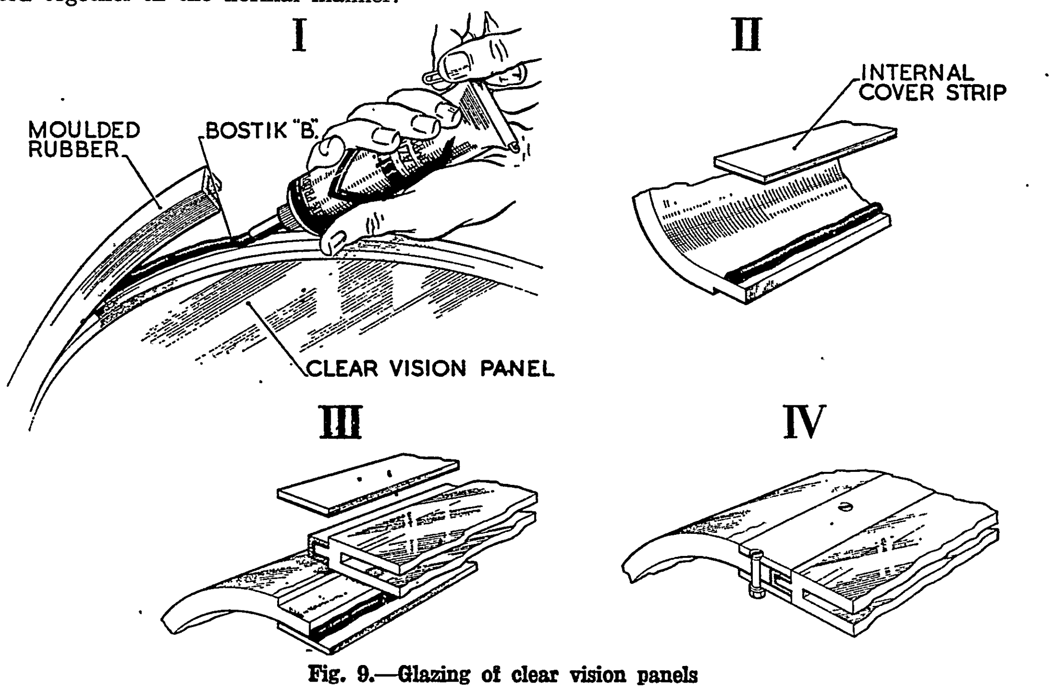

Fig. 9.—Glazing of clear vision panels

Glazing of clear vision panels

13. Clear vision panels should be fitted using Bostik–B glazing compound. The compound should be extruded around the edge of the clear vision panel, and the moulded rubber section carefully drawn into position (see fig. 9, sketch I). A liberal and continuous bead of glazing compound should then be extruded all around the internal edge of the curved glazed panels, after which the internal cover strip should be immediately attached with temporary bolts (see fig. 9, sketch II). The curved panel should then be reversed, and a liberal bead of glazing compound extruded into the angle formed by the cover strip and the edge of the curved glazed panel (see fig. 9, sketch III). The clear vision panel should now be pressed firmly into position, and two continuous beads of Bostik–B extruded into the channel for the reception of the external cover strip, which is secured by bolts (see fig. 9, sketch IV).

Glazing of flush fitting panels

14. Two examples of glazing flush fitting panels are illustrated in figs. 10 and 11. When glazing in accordance with the method shown in fig. 10, Bostik–C adhesive compound should be brushed thinly over the contacting surfaces of the relative anti-vibration materials, framing and cover strip (see fig. 10, sketch I). The adhesive compound should be allowed to dry for 30 minutes before placing the various parts together. The glazed panels should then be placed on the frame, and a continuous bead of Bostik–B glazing compound extruded into the rebate (see fig. 10, sketch II), after which the prepared cover strip should be bolted into position (see fig. 10, sketch III). After 24 hours the surplus compound can be trimmed off with a wet knife.

15. Another method of glazing flush fitting panels necessitates the use of Bostik–B glazing compound only. A liberal and continuous bead of compound should first be extruded on to the frame member (see fig. 11, sketch I), after which the glazing panel should be pressed into position so that a complete seal is obtained. The operation should be repeated for the second panel. Two further beads of Bostik–B must then be extruded on to the moulded recesses of the glazing panel (see fig. 11, sketch II), over which the masking or glazing strip should be placed in position and immediately secured with the bolts (see fig. 11, sketch III), leaving the bolts half a turn slack. After 24 hours the surplus compound can be trimmed off with a wet knife.

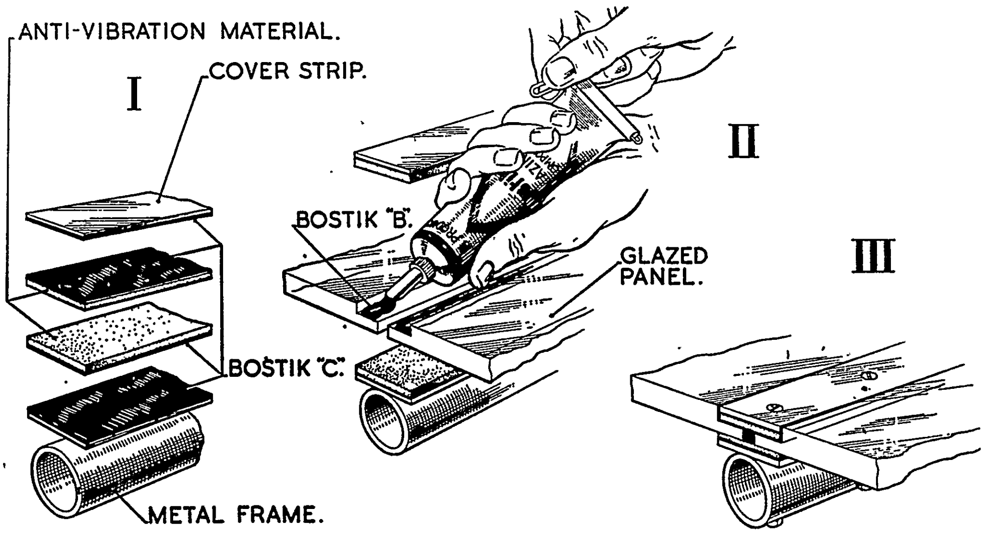

Fig. 10.—Glazing of flush fitting panels (A)

Sealing of butt joints

16. Butt joints should be sealed by applying a liberal and continuous bead of Bostik–B glazing compound to both face surfaces. The components should then be jointed immediately and bolted up in the usual manner (see fig. 12, sketches I, II, and III).

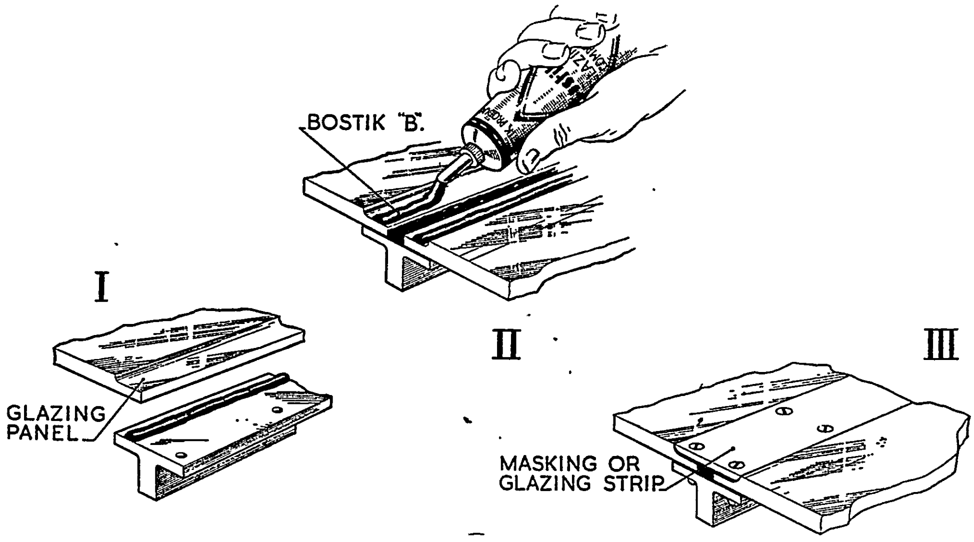

Fig. 11.—Glazing of flush fitting panels (B)

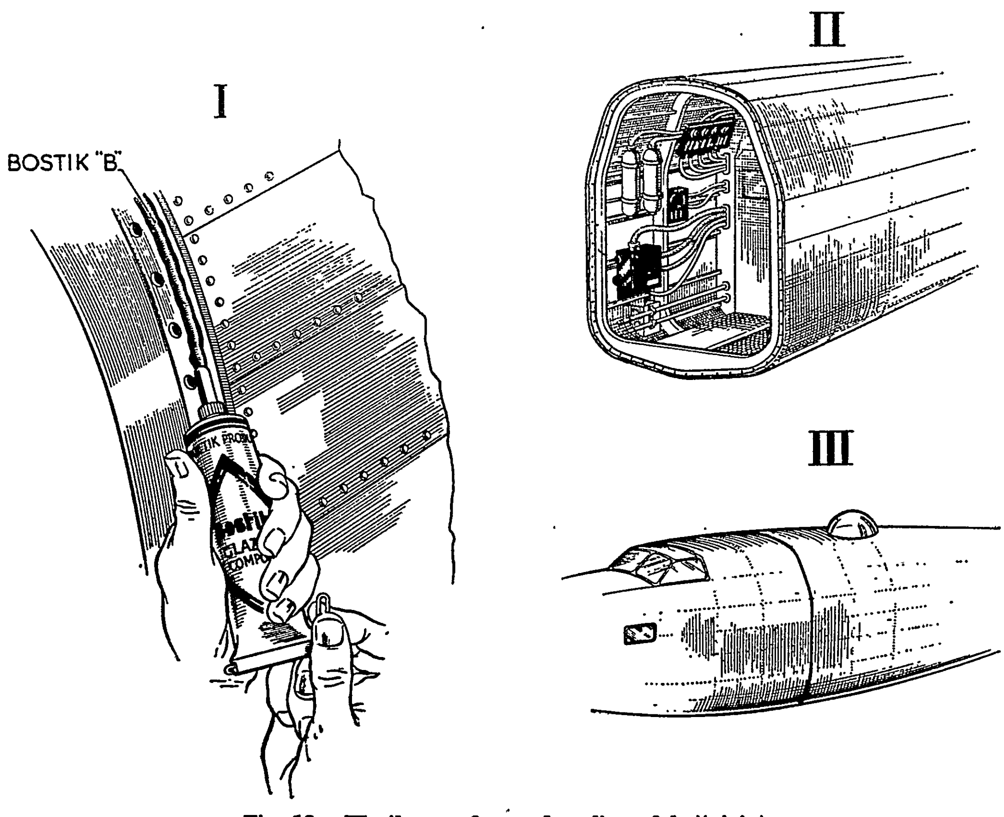

Fig. 12.—Weatherproofing and sealing of butt joints

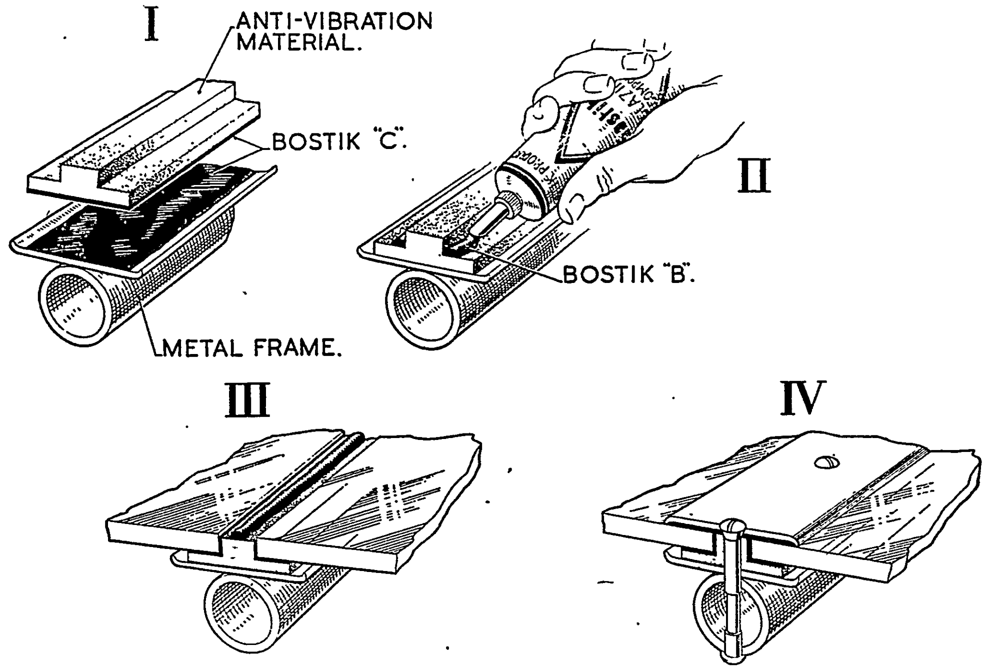

Fig. 13.—Glazing with anti-vibration material

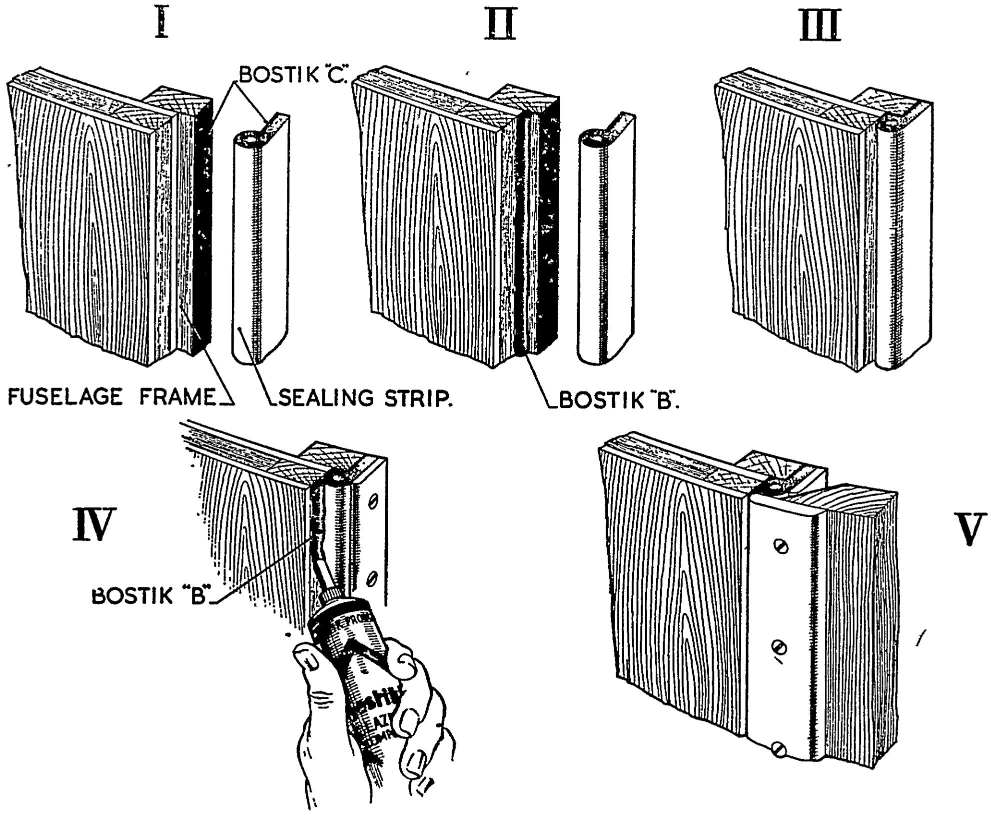

Fig. 14.—Attachment of sealing strips to entry doors, etc.

Glazing with anti-vibration material

17. Bostik–C adhesive should be brushed thinly over both contacting surfaces (see fig. 13 sketch I) and allowed to dry for 30 minutes before pressing together. A continuous bead of Bostik–B glazing compound should then be extruded into the angle of the anti-vibration material (see fig. 13, sketch II), following which the glazing panels should be pressed into position so that a complete seal is formed. A bead of glazing compound should then be extruded liberally on to the top centre of the anti-vibration material (see fig. 14, sketch III). The cover strip should then be placed in position and bolted immediately (see fig. 14, sketch IV), the surplus compound being trimmed off after 24 hours.

Attachment of sealing strips to entry doors, etc.

18. Sealing strips are attached to entry doors, hatches, etc., in order to prevent moisture from attacking the wood of fuselage frames, etc. Bostik–C adhesive should be brushed on to the contacting surfaces of the fuselage frame and sealing strip (see fig. 14, sketch I), allowing the adhesive to dry for 30 minutes. Before attaching the sealing strip, a fillet of Bostik–B should be applied to the frame angle (see fig. 14, sketch II). The sealing strip should then be placed in position (see fig. 14, sketch III), applying pressure by hand before attaching metal cover strip and screwing into position. An external fillet of Bostik–B should then be applied in the angle formed by the round section of sealing strip and fuselage frame (see fig. 14, sketch IV). After 24 hours this external seal should be painted with Boscolyn lacquer to provide protection against oil or petrol.

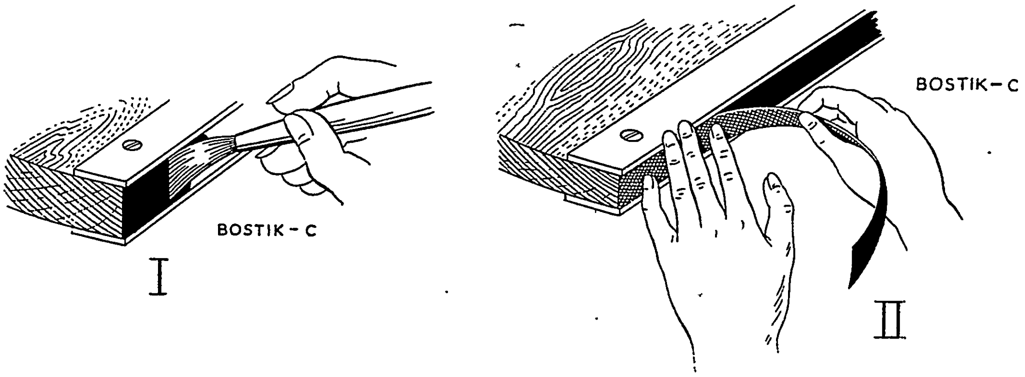

Fig. 15.—Attachment of sealing strips to bomb-bay doors, etc.

Attachment of sealing strips to bomb-bay doors, etc.

19. To attach rubber to metal, a procedure different from that detailed in para. 18 should be followed. The attachment of sealing strips to bomb-bay doors is a typical example. Prior to applying the adhesive, the contacting surfaces should be cleaned thoroughly with a cloth sprinkled with No. 1 Bostik Cleaner (Stores Ref. 33C/589) and then wiped with a piece of clean cloth. The surfaces should then be covered with an even film of Bostik-C applied with a stiff bristle brush (see fig. 15, sketch I). The adhesive should be allowed to dry for a minimum period of 30 minutes, after which the mating surfaces should be pressed together by hand, working gradually along the strip to make sure that no air is trapped (see fig. 15, sketch II). The process should be completed by carefully rolling the strip with a hand roller.

Method of sealing external components

20. When external components are attached to the fuselage, the joints should be sealed and the external edges protected by Bostik-B glazing compound. Bostik-C adhesive compound should also be used if anti-vibration material is fitted between the component and the fuselage.

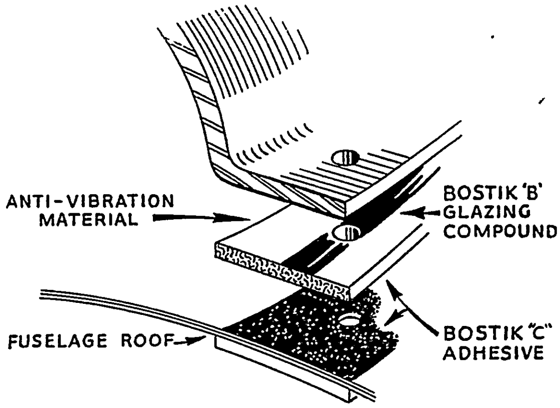

Fig. 16.—Method of affixing anti-vibration material

(i) *Method of affixing anti-vibration material.*—The metal surface should first be given a vigorous rubbing with a soft cloth moistened with the No. 1 Bostik cleaner, after which it should be dried with a piece of clean cloth. An even film of Bostik-C adhesive compound should then be applied to the mating surfaces (see fig. 16) and allowed to dry for 30 minutes. The surfaces should then be pressed together by the maximum pressure obtainable without damaging the components.

(ii) *Method of mounting Perspex moulding.*—A continuous bead of Bostik-B glazing compound should be extruded along the upper surface of the anti-vibration material (see fig. 16). The Perspex moulding should then be pressed down on this bead and secured by bolts.

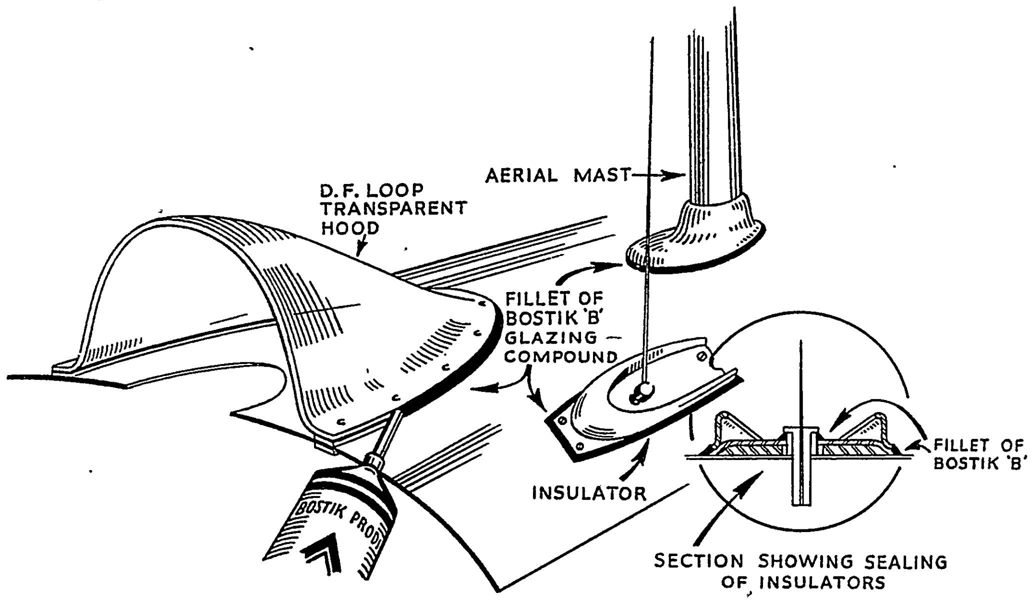

Fig. 17.—Sealing of external components

(iii) *Method of sealing exposed edges.*—A continuous fillet of Bostik-B should be extruded along the edge of the joint and should be thick enough to fill completely the junction of the component and the fuselage (see fig. 17). Where the moulding is of cellulose acetate this fillet should cover the exposed edge of the joint.

Other examples of sealing external components are shown in fig. 17.

Method of sealing buoyancy chambers

21. When buoyancy chambers are being sealed, Bostik-B glazing compound should be used. The metal surfaces should be thoroughly cleaned and a liberal fillet of the compound extruded along the angle joints (see fig. 18). A continuous bead should also be extruded on to the outer lip of the buoyancy compartment, thus sealing the edges of the cover plate. After 24 hours, the surplus compound may be trimmed off with a wet knife.

Boscoprene cement No. 551

22. Boscoprene cement No. 551 is employed for attaching oil resisting rubber to metal, and for sealing inspection panels, cover plates, etc., where resistance to oil is required. The cement consists of Part A (Stores Ref. 33C/740), which is provided in a half-pint tin, and Part B (Stores Ref. 33C/741), which is supplied in a small bottle. The cement is used on surfaces previously treated with Boscotex primer No. 5R (Stores Ref. 33C/739). Maximum adhesion is not obtained until 3–5 days after the joint is made and it should not, therefore, be allowed to come into contact with oil until this period has elapsed.

Method of mixing the cement

23. All the contents of the bottle, having been thoroughly shaken, should be poured into those of the tin, stirring thoroughly while pouring. Stirring should continue for 2 or 3 minutes to ensure a thorough mixing. The mixed cement becomes unfit for further use 12–18 hours after mixing and so must be used within that time.

Attachment of oil-resisting rubber to metal

24. When an oil-resisting rubber is to be attached to metal, the contacting surfaces should be cleaned with No. 4 Bostik cleaner applied on a cloth and should then be wiped with a clean cloth. A thin, even coating of Boscotex primer No. 5R should be applied to the metal surface and also to the contacting surface of the oil-resisting rubber. The primer should then be allowed to dry—a process requiring about one hour. An even film of the mixed cement should now be applied with a brush or a spreader knife to the primed surfaces of both the metal and the rubber and should be left to dry for 20 minutes.

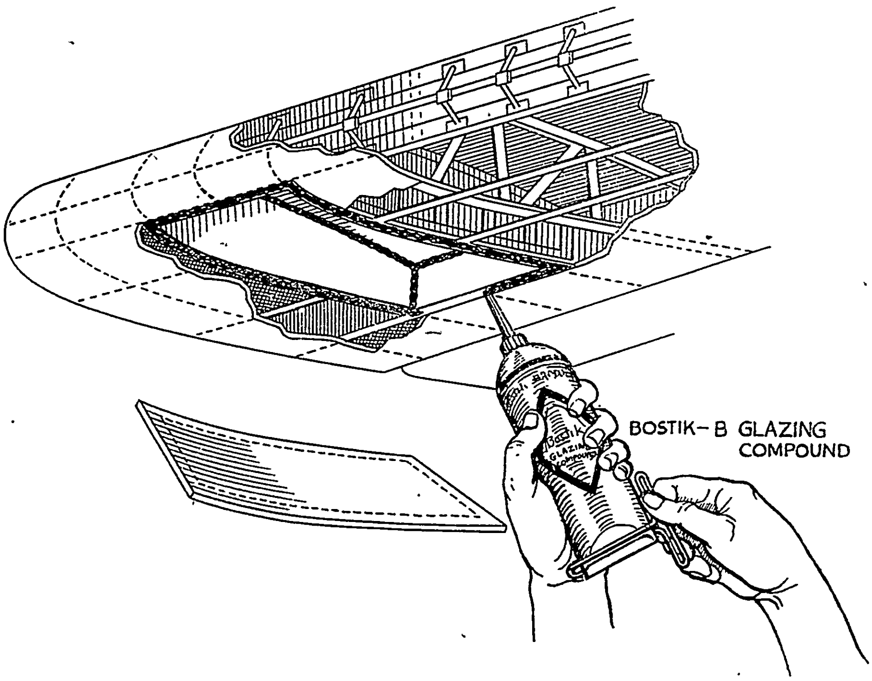

Fig. 18.—Method of sealing buoyancy chambers

25. The rubber should now be applied to the cement-covered metal and should be held in one hand and gradually pressed on the metal, care being taken to ensure that no air is trapped between the contacting surfaces. The rubber should finally be well handrolled where possible.

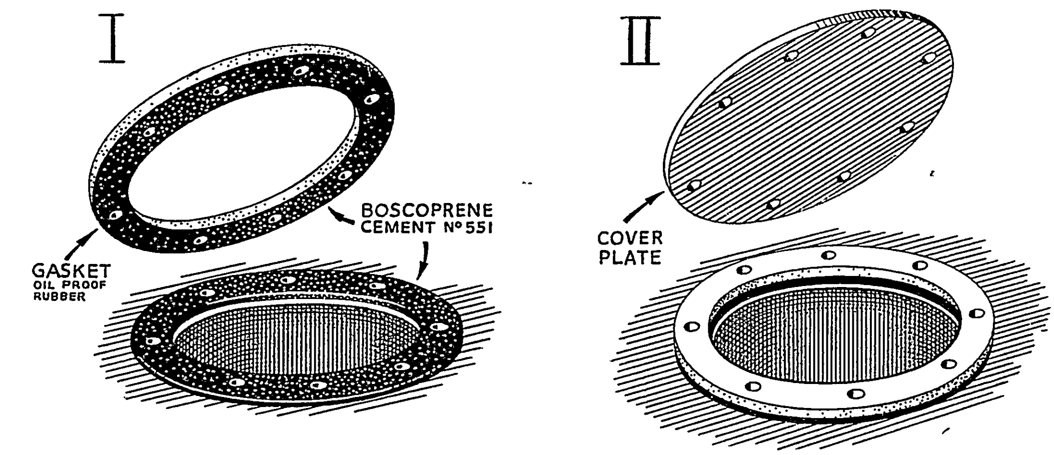

Fig. 19.—Method of sealing inspection holes

Method of sealing inspection holes

26. When inspection holes are sealed, the gasket is cemented to the seating of the inspection hole before the cover plate is attached. The metal seating should be cleaned with No. 4 Bostik cleaner and one side of the rubber gasket with No. 1 Bostik cleaner. After the cleaners have completely evaporated, an even coating of Boscotex primer No. 5R should be applied with a cloth, using a circular motion. The primer should then be allowed to dry, a process requiring from one to two hours. If the gasket is to be attached to wood, no primer is required. One coat of mixed Boscoprene 551 cement should be applied to one side of the rubber gasket and to the seating of the inspection hole (see fig. 19, sketch I). After being allowed to dry for 15 minutes, the cemented surfaces should be pressed together with the maximum pressure obtainable without causing damage to the components. Finally, the cover plate should be attached in the usual manner (see fig. 19, sketch II).

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AIR MINISTRY
October, 1944

R.A.F. ENGINEERING—GENERAL ENGINEERING
This is A.L. No. 29 to A.P.1464B, Vol. I, and concerns Part 2, Sect. 4
Remove and dispose of the existing Chapter 7, insert this chapter, and make an entry in the Amendment Record Sheet at the beginning of the Volume.

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Chapter 7 . . . . GENERAL ADHESIVES, AND GLAZING AND SEALING COMPOUNDS

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Introduction

1. This chapter contains information on various adhesives and glazing and sealing compounds, which are classified according to the purpose for which they are used. Some general notes concerning all the materials are followed by details of the method of application of each.

Adhesives

2. Adhesives are used for affixing rubber, fabric, and similar materials to themselves and to metal. The following are generally used:—

(i) Bostik–C adhesive compound (Stores Ref. 33C/605).

(ii) Holdtite general purpose adhesive (Stores Ref. 33C/685).

Compounds

3. Various forms of compounds are available and should be used only for those purposes for which they are intended, as follows:—

(i) GASKET SEALING COMPOUNDS.—These are used for coating gaskets to ensure that good joints are formed. The following compounds are available:—

(a) Grafix sealing compound (Stores Ref. 33C/682).

(b) Engine jointing compound (Stores Ref. 33C/525/524).

(ii) WINDSCREEN GLAZING COMPOUNDS.—The compounds used for glazing windscreens are as follows:—

(a) Bostik–B glazing compound (Stores Ref. 33C/591).

(b) Nobel 153–522 glazing compound (Stores Ref. 33C/686).

(c) BB pressure plastic No. 810 (Stores Ref. 33C/889).

(iii) SHELL PLATE SEALING COMPOUNDS.—These compounds are used on the overlapping surfaces of metal-to-metal joints such as on seaplane floats, etc., to make them watertight.

(a) Bostik Cement No. 321 (Stores Ref. 33C/594).

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(b) Pigmented varnish jointing compound (Stores Ref. 33C/885/886).

(iv) PRESSURE CABIN SEALING COMPOUNDS.—

These compounds are applied to the inner or pressure side of the cabin only, and are available as follows:—

(a) Pressure cabin compound (Medium) (Stores Ref. 33C/779/780).

(b) Pressure cabin compound (Thick) (Stores Ref. 33C/781/782).

(c) Pressure cabin compound (Thin). (Stores Ref. 33C/783/784).

General procedure

Cleanliness

4. The vital importance of absolute cleanliness in the application of these materials cannot be over-emphasized. An adhesive is no stronger than the surface to which it is applied. Thus, if it is applied on a film of dirt, the strength of the ensuing bond is no greater than the strength of the dirt on the material. It is essential, therefore, that before any work is commenced, the surfaces should be cleaned as follows:—

(i) Carefully remove every trace of dirt, oil, grease, paint, or old compound.

(ii) If a liquid such as petrol or a degreasing liquid is used for cleaning, dry the surfaces thoroughly with a soft clean cloth.

(iii) Do not touch or handle a cleaned surface. Even the slight trace of grease which is left by the finger tips would be sufficient to spoil the joint.

Application conditions

5. The application of these compounds and adhesives should be effected in a good light, and there should be sufficient room to enable every part of the job to be reached comfortably. They should preferably be applied at a workshop temperature of not less than 65°F. At temperatures much below this, difficulty may be experienced in application. *Proximity to a naked flame is extremely dangerous and must be avoided.*

Protection against fuel and oil

6. If protection is required against the action of fuel or oil, or both, the joint should be painted with Boscolyn lacquer No. 103 or 104 (Stores Ref. 33C/590 or 33C/668). Boscolyn lacquer No. 103 is intended for internal use, and the No. 104 for external use as it is aluminium pigmented. Two or three coats should be applied, each one being allowed to dry thoroughly before the next is added. These lacquers should on no account be used for adhesive purposes. They are intended solely for protecting joints against oil and fuel, and are useless for any other purpose.

Care of brushes

7. All brushes must be thoroughly cleaned and dried after use, otherwise they may be rendered useless for future work. Bostik cleaner (Stores Ref. 33C/589) is suitable for cleaning brushes.

Bostik materials

Method of application

8. Details of the methods of using the three Bostik materials are available in Chap. 6 of this Section and also on A.D.2487.

Holdtite general purpose adhesive

Method of application

9. This adhesive is used in the same way as Bostik–C, but requires only 15 minutes drying time, compared to the 30 minutes required for Bostik–C.

Gasket sealing compounds

Method of application

10. The liquids should be thoroughly stirred or shaken before use and should be kept well mixed during the period of application. A coat of the compound should be applied with a clean brush to each of the mating surfaces and to each side of the gasket and should be allowed to dry. A second liberal coat should then be applied to the underside of the gasket, which should immediately be placed in position. A second liberal application should then be made to the upper surface of the gasket. The bolts should be dipped into the compound or the studs coated and the joint immediately bolted up.

Nobel 153-522 glazing compound

Method of application

11. The compound should be applied with a palette or other suitable knife and the same precautions should be observed as for Bostik–B. Irregular dabs of the compound are useless, and a continuous bead must be applied.

BB pressure plastic No. 810

Description

12. The pressure plastic is a blue compound similar to putty in appearance. It can be moulded by hand and will stick to metal and other surfaces. The plastic is used for various

purposes—for instance, as a filler for glazing channels, especially where heavy bullet-proof windscreens are to be mounted. It forms a more or less resilient bead for the glass block and is used as a substitute for rubber channelling. It is also used as a filler for other similar deep or wide crevices, such as the transport joints found in certain wooden aircraft.

Preparation of surface

13. Any surface to which the plastic is to be applied should be clean and dry. Oil, grease, mud, and other dirt should be scraped away and the surface wiped and then well scoured with waste moistened in petrol. Any parts of the surface which cannot be reached with the waste should be cleaned with a small stiff brush dipped in petrol. Particles of grit may be removed from surfaces to be cleaned by a small pad moulded from the plastic. This pad, however, must not be used afterwards in the actual application.

Preparation of plastic

14. Before the plastic is used it should be well kneaded. This is simplified if the plastic is softened by being immersed in hot water for 15 to 20 minutes. After it is kneaded, the material should be rolled out into a strip of the required thickness. A small metal roller kept wet with water should be used for this purpose.

Method of application

15. To ensure good adhesion, a thin layer of the plastic should first be applied to the cleaned surfaces. This layer should be pressed on rather than spread over the surface. The remainder of the plastic should be built up on or around the component by progressive small additions, each addition being pressed and not spread on to the previous one. Any small gaps which may be left should be filled in with small pieces of the compound pressed into position with a spatch knife. Finally, any surplus or untidy compound should be trimmed away with a sharp wet knife.

Mounting glazing panels in cast frames

16. The plastic may be used for mounting glazing panels on cast frames where no rubber glazing channel is fitted. The plastic should be prepared as described in para. 15 and strips of suitable dimensions pressed on the frame as shown at A, fig. 1. The inner glazing frame, see sketch B, should then be placed in position and bedded well down into the plastic.

17. Further prepared strips of plastic should be pressed on the inner glazing frame and the glazing panels should be fitted as shown at C. The panels should be bedded well down into the plastic, strips of which should be pressed along the surfaces of the panels and into any cavities, as shown at D.

18. Finally, the outer glazing frame should be placed in position and the assembly bolted up, see sketches E and F. This will cause the plastic to extrude from the joints and the surplus should be neatly trimmed away with a sharp wet knife.

Mounting and sealing glazing panels

19. In the following examples of glazing, the pressure plastic is employed as the foundation, which is finally sealed by a layer of Bostik–B glazing compound.

20. The plastic should be prepared as described in para. 14 and a strip of suitable dimensions, see A, fig. 2, pressed lightly on the glazing frame. A bead of Bostik–B should be extruded liberally along the outer edge of the plastic as shown in sketch B and the glazing panel should be bedded down on the plastic. The panel should be so fitted that the Bostik–B forms a complete seal as at C. After 24 hours, any surplus Bostik–B may be trimmed off with a sharp wet knife.

21. Two similar examples of glazing and sealing are shown in fig. 3. Where the assembly is similar to that illustrated at A the fillet of Bostik–B is applied after the glazing panel has been pressed into the plastic. Where a cover plate is used as at B, the plate should be fitted before the strips of plastic are attached to the glazing panel. This is necessary so that the operator may judge the amount of plastic required. After the plastic has been attached to the panel, the bead of Bostik–B should be inserted and the cover plate mounted.

22. The method of mounting glazing panels on glazing strip is illustrated in fig. 4. A strip of plastic, prepared as described in para. 14, should be laid along the glazing strip, as at A, and pressed down lightly. The panels should be placed in position and bedded down into the plastic as shown at B. This causes the plastic to be forced up between the panels and it should if necessary be trimmed away with a sharp wet knife to about halfway up the edge of the panel. A gouge or drill should be passed through the bolt-holes to clear away the plastic so that the bolts can be inserted easily.

23. A continuous bead of Bostik–B should be extruded along the centre gap so that it overflows and covers the upper edge of the panels as shown at C. The cover strip should be

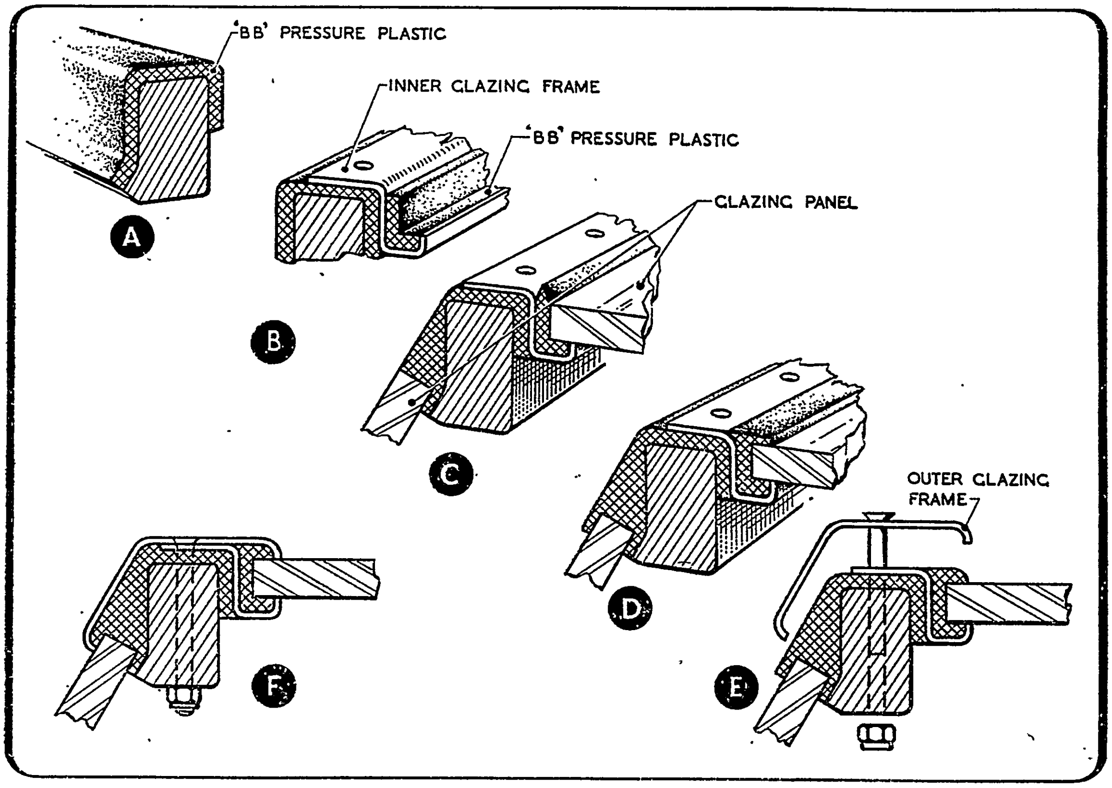

Fig. 1.—Mounting glazing panels in cast frames

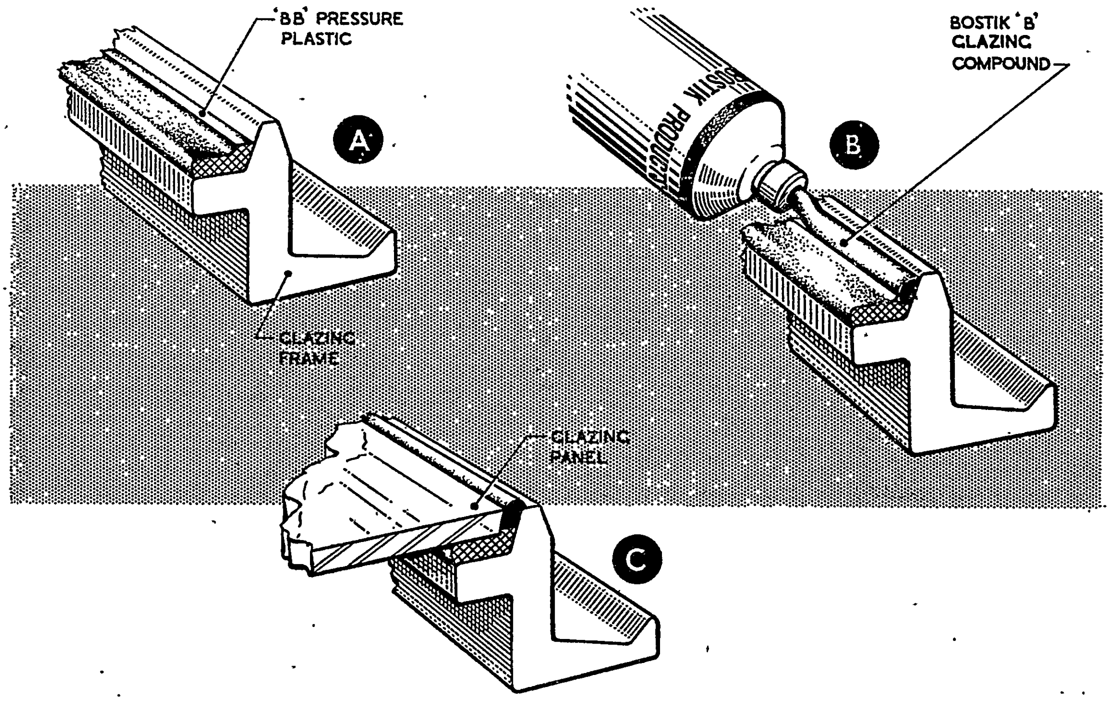

Fig. 2.—Mounting and sealing glazing panels

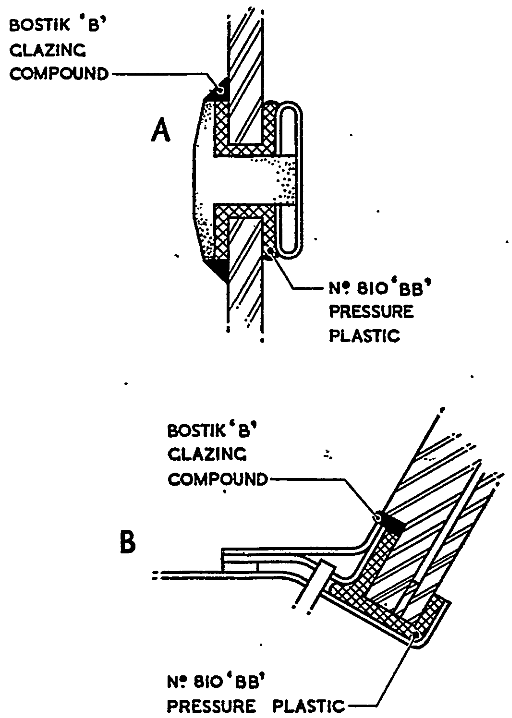

Fig. 3.—Further examples of mounting and sealing

placed in position and the bolts inserted and tightened so that the cover strip is pressed down on to the glazing compound, see sketch D. After 24 hours, the surplus compound should be trimmed off with a sharp wet knife.

Shell plate sealing compounds

Method of application

24. These compounds should be freely applied with a stiff bristle brush to each of the borders forming the mating surfaces of the joint to be made, and the parts should be immediately bolted together.

Pressure cabin sealing compounds

Method of application

25. Pressure cabin sealing compounds are applied to prevent the leakage of air under pressure through the joints of the pressure cabin to the rarefied external atmosphere. The compounds should only be used on the inner or pressure side of the cabin. They are useless if applied to the outside of the cabin because they will be blown off the joint as soon as air pressure is applied. The methods of application adopted for the various types of joints are shown in fig. 5.

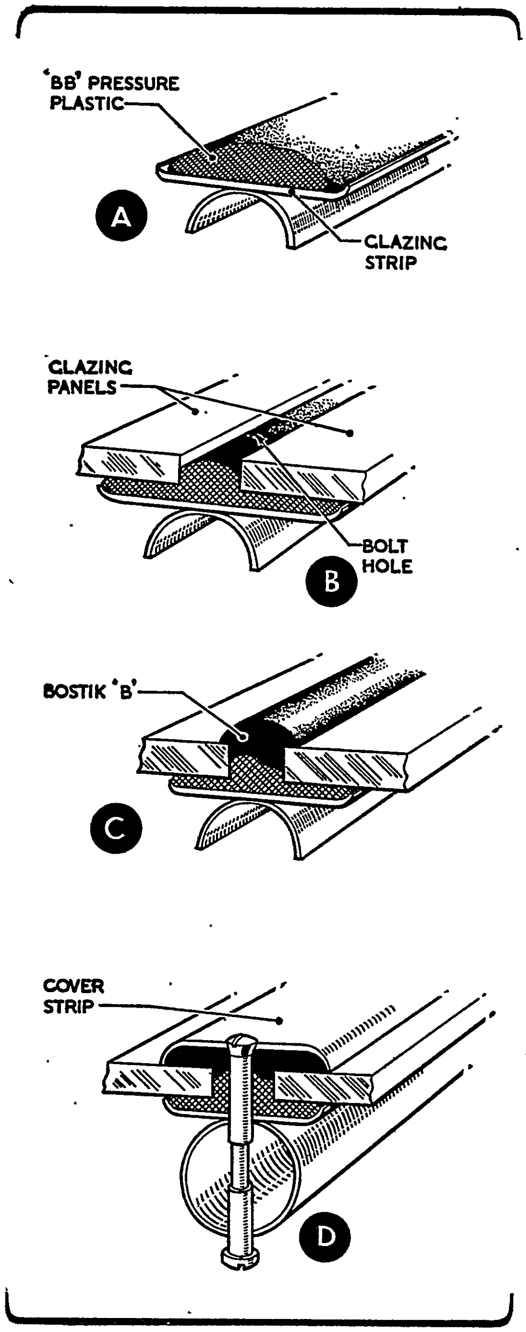

Fig. 4.—Mounting glazing panels on glazing strip

26. Leaks may occur at stringers, seams, rivets and other joints. When the leak has been located, the old compound should be cleared away and the metal surfaces round and near the leak thoroughly cleaned and dried. Containers

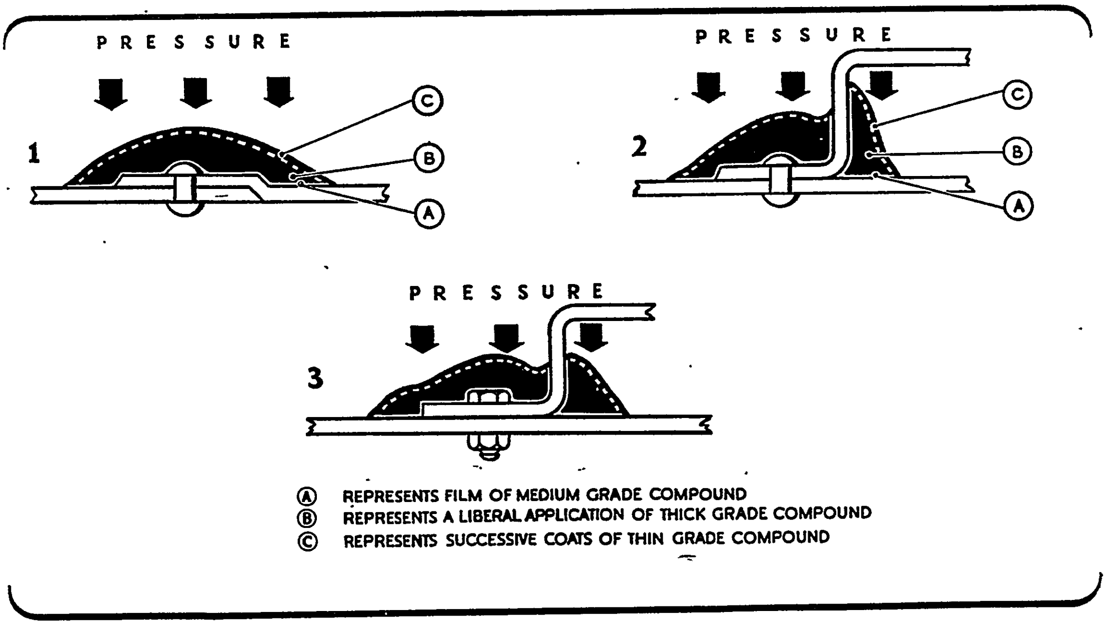

Fig. 5.—Typical applications of compounds to pressure cabin joints

of the three grades of compound should be ready to hand, with a clean stiff bristle brush for each. The compounds should be thoroughly stirred before application.

27. A uniform film of the medium grade compound should first be applied along the whole length of the seam, the coating being extended for an inch each side and at the ends. This film should be allowed to dry and a second coat applied on top of the first.

28. A liberal fillet of the thick grade compound should next be applied along and into the seam, and this in turn should be allowed to dry. The joint should be finished by successive coats of the thin grade compound over those already applied, each coat being allowed to dry before the next is added. In this way, the material is gradually built up on top of the joint and until all the interstices are completely filled and the original lines of the joint are completely hidden under a smooth surface of compound. For all three grades it will be found that the best results are obtained if the brush is used with a stippling instead of a painting motion.

P6496 M /G3710 2/45 5250 C&P Gp. 1

SECTION 5

R.A.F ENGINEERING STANDARDS AND SPECIFICATIONS

LIST OF CHAPTERS

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

CHAPTER 1 R.A.F. engineering standards and specifications—general (*To be issued later*)

CHAPTER 2 Standard colour scheme and index

CHAPTER 3 B.S. specifications (TO BE ISSUED LATER)

CHAPTER 4 D.T.D. specifications (TO BE ISSUED LATER)

CHAPTER 5 Newall standard system of fits and tolerances

Chapter 2 . . . STANDARD COLOUR SCHEME AND INDEX

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General

1. Before material is accepted into Material Stores at R.A.F. Units, main or sub-contractor's works, it is to be marked to indicate effectively the specification with which it complies. The method to be used is the standard scheme set out in the following paragraphs.

2. The standard colour scheme has been devised as the best practicable means of attaining effectual identification. The use of two or more methods of identification is obviously inadmissible; consequently, materials entering Unit's stores are to bear the standard colouring, whether or not they have previously borne some other mark of identification.

3. The colour scheme as a means of identification is additional to the identification requirements called for in the respective Specifications.

4. Direct purchases of metallic materials by or for the Air Ministry normally call for the standard marking and specify its details.

5. Particulars of the complete standard colour scheme are given below. For convenience a reverse index, in which the colour combinations are given in alphabetical sequence, is also listed.

Steels—"En" series

6. War Emergency British Standard Schedule 970 introduced a limited number of steels, known as the "En" Series, which are intended to serve a comparatively large number of purposes. In allocating identification colours to this series of steels, the following principles have been adopted:—

(i) An "En" steel delivered in the heat-treated condition which complies with the mechanical test requirements of a B.S. or D.T.D. specification, irrespective of its composition, is to bear the colour indetification of the B.S. or D.T.D. steel it represents. For example, En 16 or En 17 steels heat-treated to give S.11 mechanical properties are to bear the colours allocated to S.11 in the heat-treated condition, despite the fact that their compositions differ from that stipulated by S.11.

(ii) Where an "En" steel has the same composition as, and complies with, the mechanical test requirements of a B.S. or D.T.D. specification, it is to bear the appropriate identification colour allocated to the B.S. or D.T.D. steel, irrespective of whether it is in the heat-treated or un-heat-treated condition. Thus En 9 steel is virtually the same material as that covered by S.70, and is, therefore, to bear the colour identification allotted to S.70.

(iii) Where an "En" steel approximates so nearly to the composition of a B.S. or D.T.D. specification steel as to be acceptable within the normal discretionary allowance permissible for an aircraft steel, it is deemed the same as the B.S. or D.T.D. steel, within the meaning of sub-paragraph (ii) above, and so has the same colour identification.

(iv) "En" steels which cannot be placed in any of the above categories, have a new colour identification allocated to them. To render such steels easily distinguishable, an entirely new colour scheme, consisting of four bands of two colours disposed alternately, is used.

Colours

7. The colours used are Black, Blue, Brown, Green, Red, White, Yellow, and (for En steels, and for aluminium and aluminium alloys to American specifications only) Grey and Orange.

8. Difficulties in identification may be caused by colour markings being rendered indistinct or obliterated by the effect of handling or weather conditions; the fading of colours may cause confusion. In order that colour markings may be as permanent as possible, especially where material has to be stocked in the open, the use of paint to specification D.T.D.260 is recommended. The most distinct shades are as follows:—

Colour	B.S. Specification 381	
	Shade No.	Description
Blue ...	4	Blue Azure
Brown ...	10	Light Brown
Green ...	21	Brilliant Green
Grey ...	31	Light Battleship Grey
Orange ...	57	Orange
Red ...	37	Signal Red
Yellow ...	55	Lemon Yellow

Application

9. *Bars and tubes.*—Each bar and tube is to be painted at each end with the colour or colours indicated in the following manner:—

For one colour	1 band 12 in. wide
For two colours	2 bands each 6 in. wide
For three colours	3 bands each 4 in. wide
For four colours	4 bands each 3 in. wide

Note . . . As a war-time easement, marking of bars and tubes at one end only is acceptable.

10. *Sheets and strips.*—Each sheet and strip is identified by one of the following methods:—

(i) A band or bands of the required colours should be painted diagonally across the corner bearing the identification stamp marks. The width of the band or bands is to be in accordance with 9 (i) and the painting is to commence 6 inches from the corner, measured at right angles to the length of the band. Sheets or strips less than 1 foot wide should be painted at one end in a similar manner to bars and tubes.

(ii) Each sheet and strip is to be painted with a disc of colour. For a single colour the disc is to be 3 inches in diameter, additional colours when required being applied in concentric annular rings $1\frac{1}{2}$ inches wide.

(iii) Sheets and flat strips are to be painted in the following way, which is suitable for large scale markings. The sheets are to be stacked and then slid endwise, so that $1\frac{1}{2}$ inches of the end of each sheet is exposed in addition to the whole surface of the top sheet. Bands of paint of the width required are then to be painted on the whole of the sheets in one operation, resulting in an identification mark $1\frac{1}{2}$ inches by 12 inches in size on each sheet. The paint is to be applied to the face of the sheet which bears the identification marks, and preferably adjacent to them.

B.S. Specification

In order to avoid the necessity for amending this schedule when there are new issues of specifications, the issue prefix number has been omitted, e.g., 3 S.11 is given as S.11.

Table 1—Brass, bronze, and copper

Number and Description	Colour
B.8—Phosphor Bronze, Cast Bars	Yellow
B.11—Brass Bars suitable for brazing or silver soldering	Brown
B.21—White Metal (88/8/4) Ingots (suitable for bearings)	Blue, white
B.22—White Metal (92/4/4) Ingots (suitable for bearings)	Red, white
B.S.S. No. 24, Part 5 (Spec. 12a)—Copper Bars	Black, yellow
B.S.S. No. 218—Brass Bars and Sections (suitable for forging)	Red, white
B.S.S. No. 249—Brass Bars (high speed screwing and turning)	Black
B.S.S. No. 250—High Tensile Brass Bars and Sections:—	
Grade A	Black, brown, white
Grade B	Brown, yellow, green
B.S.S. No. 251—Naval Brass (Admiralty Mixture) Bars and Sections (suitable for forging)	Blue
B.S.S. No. 265—Cold Rolled Brass Sheets, Strip and Foil Copper Content of 61·5%:—	
Annealed	Green
Quarter-hard	Yellow, black, yellow
Half-hard	Red
Hard	Blue
Extra Hard	Brown, yellow, brown
B.S.S. No. 266—Cold Rolled Brass Sheets, Strip and Foil Copper Content of 64%:—	
Annealed	Green, red
Quarter-hard	Red, yellow, red
Half-hard	Blue, red, green
Hard	Blue, brown
Extra Hard	Blue, black, red
B.S.S. No. 267—Cold Rolled Brass Sheets and Strip, Copper Content 68/72%	White, green, yellow
B.S.S. No. 369—Phosphor Bronze Bars and Rods	Green, yellow, green
B.S.S. No. 384—Phosphor Bronze Wire, Hard-drawn	Blue, white
B.S.S. No. 407—Phosphor Bronze Sheet and Strip:—	
407/1 (Half Hard)	Brown, blue, yellow
407/2 (Half Hard)	Blue, yellow, brown
B.S.S. No. 518—Medium-Hard Copper Strip, Bars and Rods for Electrical Purposes	Black, red
B.S.S. No. 885—Hard Drawn Seamless Brass Tubes	Blue, red
B.S.S. No. 886—Annealed Seamless Brass Tubes	Blue
B.S.S. No. 899—Cold Rolled Copper Sheets and Strips:—	
Half Hard	Yellow
Annealed	Green, red, green

Table 2—Aluminium and aluminium alloys

Number and Description	Colour
L.1.A—Aluminium Alloy Bars and Billets for Forging	Green, yellow
L.1.B—Aluminium Alloy Bars for Machining (not exceeding 3 inches) and Extruded Sections	Yellow
L.3—Wrought Light Aluminium Alloy Sheets and Strips:—	
Fully heat-treated	Yellow
As rolled	Green, yellow
L.4—Aluminium Sheets (hard)	Green
L.16—Aluminium Sheets (half-hard)	Blue
L.17—Aluminium Sheets (soft)	Black
L.25.A—Aluminium Alloy Bars and Billets for Forging	Red, black, white
L.30—98% Aluminium Notched Bars and Ingots	Black, green
L.31—99% Aluminium Notched Bars and Ingots	Red
L.34—99% Aluminium Bars and Sections	Black, red
L.36—(Section I) Aluminium Rods and Wires for Rivets	Blue
L.37—Aluminium Alloy Rivets:—	
(Section II) Rods and Wires for Rivets	Black, yellow
(Section III) Tubes for Rivets	Black, yellow
L.38—Aluminium Coated Aluminium Alloy Sheets and Strips:—	
Fully heat-treated	Blue, yellow
As rolled	Blue, red
L.39.A—Aluminium Alloy Bars and Billets for Forging (over 3 inches) ...	Green, red
L.39.B—Aluminium Alloy Bars for Machining (3 to 6 inches)	Brown, yellow
L.39.D—Aluminium Alloy Bars for Machining (6 to 8 inches)	Red, white, red
A.L.40.A—Aluminium Alloy, type A, Bars and Billets for Forging (up to 3 inches)	Blue, red, blue
A.L.40.B—Aluminium Alloy, type A, Bars for Machining (up to 3 inches) and Extruded Sections	Blue, green, blue
A.L.40 (Softened)—Aluminium Alloy, type A, Bars (up to 3 inches) and Extruded Sections	Red, black, red
A.L.40—(Solution treated but not aged)—Aluminium Alloy, type A, Bars for Machining (up to 3 inches) and Extruded Sections	Blue, white, brown
B.L.40.A—Aluminium Alloy, type B, Bars and billets for Forging (up to 3 inches)	White, red, white
B.L.40.B—Aluminium Alloy, type B, Bars for Machining (up to 3 inches) and Extruded Sections	White, green, white
B.L.40 (Softened)—Aluminium Alloy, type B, Bars (up to 3 inches) and Extruded Sections	Red, blue, red
B.L.40—(Solution treated but not aged)—Aluminium Alloy, type B, Bars for Machining (up to 3 inches) and Extruded Sections	Blue, yellow, blue
L.44—Soft Aluminium Alloy Extruded Bars and Sections (up to 3 inches) ...	Green, white
A.L.45.A—Aluminium Alloy, type A, Bars and Billets for Forging (over 3 inches)	Yellow, blue, yellow
A.L.45.B—Aluminium Alloy, type A, Bars for Machining (3 to 6 inches) ...	Blue, black, blue
A.L.45.D—Aluminium Alloy, type A, Bars for Machining (6 to 8 inches) ...	Blue, brown, blue
B.L.45.A—Aluminium Alloy, type B, Bars and Billets for Forging (over 3 inches)	Yellow, white, yellow
B.L.45.B—Aluminium Alloy, type B, Bars for Machining (3 to 6 inches) ...	White, blue, white
B.L.45.D—Aluminium Alloy, type B, Bars for Machining (6 to 8 inches) ...	White, brown, white
L.46—Soft Aluminium Alloy Sheets and Coils	Blue, green
A.L.47.A—Aluminium Coated Aluminium Alloy, type A, Sheets and Coils (Softened)	Yellow, red, yellow
A.L.47.B—Aluminium Coated Aluminium Alloy, type A, Sheets and Coils (Quenched)	Yellow, blue, yellow
A.L.47.C—Aluminium Coated Aluminium Alloy, type A, Sheets and Coils (Quenched and Aged)	Yellow, green, yellow
A.L.47—Aluminium Coated Aluminium Alloy, type A, Sheets and Coils (as rolled)	Red, yellow, red
B.L.47.A—Aluminium Coated Aluminium Alloy, type B, Sheets and Coils (Softened)	Brown, red, brown
B.L.47.B—Aluminium Coated Aluminium Alloy, type B, Sheets and Coils (Quenched)	Brown, blue, brown
B.L.47.C—Aluminium Coated Aluminium Alloy, type B, Sheets and Coils (Quenched and Aged)	Brown, green, brown
B.L.47—Aluminium Coated Aluminium Alloy, type B, Sheets and Coils (as rolled)	Red, brown, red
B.S.S. No. 918—Aluminium Bars containing small proportions of Copper and Zinc	Green, yellow, red

Table 3—Steel

Number and Description	Colour
S.1—Bright Steel Bars	Yellow
S.1–N—High Sulphur Steel Bars for Nuts	Blue, white
S.1–N (Lead)—Lead-bearing High Sulphur Steel Bars for Nuts	White, blue, white
S.2—55-ton Alloy Steel Bars	Red
S.3—Hot Rolled Mild Steel Sheets (for welding)	Green
S.4—5% Nickel Steel Sheets (not suitable for welding)	Red
S.6.A—"40" Carbon Steel Bars for Forging	Brown, green
S.6.B—"40" Carbon Steel Bars for Machining	Green
S.11.A—Nickel Chrome Steel Bars for Forging	Red, yellow
S.11.B—55-ton Nickel Chrome Steel Bars for Machining	Red, blue, red
S.14.A—Carbon Case-hardening Steel Bars for Forging	Green, yellow
S.14.B—Carbon Case-hardening Steel Bars for Machining	Brown, yellow
S.15.A—3% Nickel Case-hardening Steel Bars for Forging	Brown, yellow, brown
S.15.B—3% Nickel Case-hardening Steel Bars for Machining	Yellow, brown, yellow
S.20—Tinned Steel Sheets	Black, green
S.21—"20" Carbon Steel	Blue, yellow
S.24—Bright Steel Bars for Keys	Green, red
S.28.A—Air-hardening Nickel Chrome Steel Bars for Forging	Blue, red
S.28.B—Air-hardening Nickel Chrome Steel Bars for Machining	Blue, red, yellow
S.61.A—High Chromium Steel (non-corroding) 35 tons Bars for Forging ...	Black, yellow, red
S.61.B—High Chromium Steel (non-corroding) 35 tons Bars for Machining ...	Brown, yellow, red
S.62.A—High Chromium Steel (non-corroding) 46 tons Bars for Forging ...	Yellow, red, yellow
S.62.B—High Chromium Steel (non-corroding) 46 tons Bars for Machining ...	Yellow, black, yellow
S.65.A—Nickel Chrome Steel Bars for Forging	Blue, black, red
S.65.B—65-ton Nickel Chrome Steel Bars for Machining	Brown, red
S.67.A—5% Nickel Case-hardening Steel Bars for Forging	Blue, yellow, brown
S.67.B—5% Nickel Case-hardening Steel Bars for Machining	Blue, red, brown
S.68.A—16% Tungsten Steel Bars for Forging	Black, yellow
S.69.A—3½% Nickel Steel Bars for Forging	Blue, green, blue
S.69.B—3½% Nickel Steel Bars for Machining	Blue
S.70.A—"55" Carbon Steel Bars for Forging	Blue, green
S.71.A—"30" Carbon Steel Bars for Forging	Brown, green, brown
S.71.B—"30" Carbon Steel Bars for Machining	Yellow, green, yellow
S.76.A—"40" Carbon Steel Bars for Forging	Green, red, green
S.76.B—"40" Carbon Steel Bars for Machining	Green, blue, green
S.77.A—"30" Carbon Steel Bars for Forging	Yellow, blue, yellow
S.77.B—"30" Carbon Steel Bars for Machining	Brown, blue, brown
S.79.A—"55" Carbon Steel Bars for Forging	Blue, red, green
S.80.A—High Chromium Steel (non-corroding) Bars for Forging	Black, yellow, brown
S.80.B—High Chromium Steel (non-corroding) Bars for Machining	Brown, black, red
S.81.A—65/75 ton Nickel Chromium Steel Bars and Billets for Forging and Drop Forging	Black, blue
S.81.B—65/75 ton Nickel Chromium Steel Bars for Machining	Black, brown
S.82.A—Nickel Chromium Case-hardening Steel Bars and Billets for Forging and Drop Forging	Red, brown, yellow
S.82.B—Nickel Chromium Case-hardening Steel Bars for Machining	Green, red, yellow
S.84—Low Carbon Steel Sheets and Strips	Black green, blue
S.85—Non-corrodible Steel Sheets	Black, green, brown
S.86.A and B—Nickel Chromium Steel Sheets and Strips (40/50 Tons 0·1 per cent. Proof Stress) (Softened Sheets and Strips)	Blue, brown, blue
S.86.C—Nickel Chromium Steel Sheets and Strips (40/50 tons 0·1 per cent. Proof Stress) (Strips Hardened and Tempered, Cold Rolled, and Cold Rolled and afterwards Tempered)	Brown, green, white
S.87.B—Nickel Chromium Steel Strips (55/65 Tons 0·1 per cent. Proof Stress) (Softened Strips)	Blue, yellow, blue
S.87.C—Nickel Chromium Steel Strips (55/65 Tons 0·1 per cent. Proof Stress) (Hardened and Tempered Strips)	Brown, red, brown
S.88.B—High Tensile Nickel Chromium Steel Strips (65/75 Tons 0·1 per cent. Proof Stress) (Softened Strips)	Green, black, white
S.88.C—High tensile Nickel Chromium Steel Strips (65/75 Tons 0·1 per cent. Proof Stress) (Hardened and Tempered Strips)	Brown, yellow, green
S.90—High tensile 5 per cent. Nickel Case-Hardening Steel	Blue, white, yellow
B.S.S. No. 15—Mild Steel for Building Construction and General Purposes	Green, brown, yellow
B.S.S. No. 32—Steel Bars—	
Grade 1	Brown, black, brown
Grade 2	Green, white, green
Grade 4	Red, brown, white

Table 3—Steel—continued

Number and Description	Colour
B.S.S. No. 51—Wrought Iron Grade "B"	Green, black, green
B.S.S. No. 5005/101—"15" Carbon Case-hardening Steel	White, brown, yellow
B.S.S. No. 5007/214—Cold Rolled Mild Steel Sheet	Green, brown, green
B.S.S. No. 5007/215—Hot-rolled Mild Steel Sheets	Yellow
B.S.S. No. 847—Cold Rolled Mild Steel Strip—	
Temper (*a*) Hard	Green, black, green
Temper (*b*) Medium Soft	Green, blue, green
Temper (*c*) Soft	Green, yellow, green
Temper (*d*) Deep Drawing	Green, red, green

Table 4—Tubes

Number and Description	Colour
T.1—35-ton Steel Tubes	Green
T.2—85-ton Nickel Chromium Steel Tubes (primarily for use as axle tubes)...	Red
T.4—Wrought Light Aluminium Alloy Tubes	Yellow
T.4X—Aluminium Alloy Tubes in D.T.D.364A type material verified as complying with the mechanical test requirements of B.S. Specification T.4	Black, yellow, black
T.7—Seamless Copper Tubes, for Oil, Petrol, Gas Starters and general purposes	White
T.9—Aluminium Tubes...	Black
T.26—Mild Steel Tubes—	
(Section II) Half-hard	Blue, yellow
(Section III) Softened	Red, yellow
T.35—35-ton Steel Tubes (suitable for welding)	Black, brown, black
T.45—45-ton Steel Tubes (suitable for welding)	Black, brown, blue
T.47—Brass Tubes for Honeycomb Type Radiators	Yellow
T.50—50-ton Steel Tubes	Brown, yellow
T.51—High Pressure Seamless Copper Tubes	Black
T.52—Hard Drawn Phosphor-bronze and Phosphorous Deoxidised Bronze Tubes	Red, yellow

Table 5—Solders

Number and Description	Colour
B.S.S. No. 219—Solder, Grade "A"	Blue
B.S.S. No. 219—Solder, Grade "B"	Yellow
B.S.S. No. 219—Solder, Grade "C"	Black
B.S.S. No. 219—Solder, Grade "D" (Plumbers')	Brown
B.S.S. No. 219—Solder, Grade "G"	Green
B.S.S. No. 219—Solder, Grade "M"	Red

Table 6—Steel (En Series)

Number and Description	Colour
B.S.S.970—	
En 1	Colours as for B.S.S.32, grade 4
En 2	Orange, green, orange, green

Table 6—Steel (En series)—continued

Number and Description	Colour
En 3	Colours as for S.21
En 4	Colours as for S.71
En 5	Colours as for S.77
En 6	Colours as for S.1
En 7	Colours as for S.1—N
En 8	Colours as for S.6
En 9	Colours as for S.70
En 10	Colours as for S.79
En 11—Not yet used for aircraft purposes	
En 12	Colours as for S.76
En 13	Colours as for D.T.D.510
En 14	Colours as for D.T.D.126
En 15—Heat-treated Bars	White, black, white
En 15—Un-heat-treated Bars	Grey, blue, grey, blue
En 16—Heat-treated Bars	Appropriate colours as for S.11, S.69, etc.
En 16—Un-heat-treated Bars	Orange, grey, orange, grey
En 17—Heat-treated Bars	Appropriate colours as for S.2, S.11, etc.
En 17—Un-heat-treated Bars	Orange, blue, orange, blue
En 18	Colours as for D.T.D.461
En 19	Colours as for D.T.D.470
En 20—Not yet used for aircraft purposes	
En 21—Not yet used for aircraft purposes	
En 22	Colours as for S.69
En 23	Colours as for S.11
En 24—Heat-treated Bars	Appropriate colours as for S.2, S.11, S.28, etc.
En 24—Un-heat-treated Bars	Orange, black, orange, black
En 25—Heat-treated Bars	Appropriate colours as for S.65, S.81, etc.
En 25—Un-heat-treated Bars	Orange, brown, orange, brown
En 26—Heat-treated Bars	Appropriate colours as for S.28, D.T.D.331, etc.
En 26—Un-heat-treated Bars	Orange, white, orange, white
En 27	Colours as for S.81
En 28	Colours as for D.T.D.331
En 29—Steel to En 40 will normally be used in place of this steel	
En 30	Colours as for S.28
En 31—Un-heat-treated Bars	Grey, black, grey, black
En 32	Colours as for S.14
En 33	Colours as for S.15
En 34—Un-heat-treated Bars	Grey, brown, grey, brown
En 35—Not yet used for aircraft purposes	
En 36—Un-heat-treated Bars	Grey, green, grey, green
En 37	Colours as for S.67
En 38	Colours as for S.90
En 39	Colours as for S.82
En 40—Heat-treated Bars	Colours as for D.T.D.306 or 317
En 40—Un-heat-treated Bars	Colours as for D.T.D.306
En 41	Colours as for D.T.D.87
En 42—Not yet used for aircraft purposes	
En 43—Not yet used for aircraft purposes	
En 44—Not yet used for aircraft purposes	
En 45	Colours as for D.T.D.115
En 46—Not yet used for aircraft purposes	
En 47—Not yet used for aircraft purposes	

Table 6—Steel (En series)—continued

Number and Description	Colour
En 48—Not yet used for aircraft purposes	
En 49 ...	Colours as for D.T.D.5
En 50 ...	Colours as for D.T.D.4
En 51—Not yet used for aircraft purposes	
En 52 ...	Colours as for D.T.D.13
En 53 ...	Colours as for D.T.D.311
En 54 ...	Colours as for D.T.D.49
En 55 ...	Colours as for D.T.D.282
En 56 ...	Colours as for S.62
En 57 ...	Colours as for S.80
En 58 ...	Colours as for D.T.D.176
En 100—Un-heat-treated Bars ...	Blue, brown, blue, brown
Heat-treated Bars ...	Appropriate colours as for S.2, S.11, etc.
En 101—Un-heat-treated Bars ...	Blue, green, blue, green
En 102—Un-heat-treated Bars ...	Blue, white, blue, white
En 110—Un-heat-treated Bars ...	Blue, red, blue, red
Heat-treated Bars ...	Appropriate colours as for S.2, S.11, etc.

American Specifications for Aluminium and Aluminium Alloys

Table 7

For each American specification the colours allocated may be used irrespective of form, *i.e.*, Bar Sheet, Tube, etc., as appropriate.

Number and Description	Colour
2SO—Aluminium (Softened) ...	Orange, black
2S½H—Aluminium (Half-hard) ...	Orange, black, green
2SH—Aluminium (Hard) ...	Orange, black, brown
3SO—Aluminium Alloy (Softened) ...	Orange, green, red
3S½H—Aluminium Alloy (Half-hard) ...	Orange, green, blue
3S¾H—Aluminium Alloy (Three-quarters hard) ...	Orange, green, brown
17ST—Aluminium Alloy (Solution-treated and aged) ...	Orange, yellow
24ST—Aluminium Alloy (Solution-treated and aged) ...	Red
Alclad 24ST—Aluminium Alloy (Solution-treated and aged) ...	Orange, red, black
52SO—Aluminium Alloy (Softened) ...	Orange, white, blue
52S½H—Aluminium Alloy (Half-hard) ...	Orange, white, green
53SO—Aluminium Alloy (Softened) ...	Orange, blue, red
53ST—Aluminium Alloy (Solution-treated and aged) ...	Orange, blue
57SO—Aluminium Alloy (Softened) ...	Orange, brown, red
57SH—Aluminium Alloy (Hard) ...	Orange, brown, green

Table 8

In certain instances material of a composition stipulated by an American specification has been proved to comply with the mechanical properties required by a British specification and a special colour identification has been allocated as under:—

Number and Description	Colour
17S—Aluminium Alloy Bars for Forging:—	
Up to 3 inches diameter (verified as complying with the mechanical test requirements of B.S. Specification L1A)	Green, yellow
Over 3 inches diameter (verified as complying with the mechanical test requirements of B.S. Specification L39A)	White, yellow
17ST—Aluminium Alloy Tubes (verified as complying with the mechanical test requirements of B.S. Specification T4)	Yellow

D.T.D. Specifications

In order to avoid the necessity for amending this schedule when there are new issues of specifications, the issue suffix number has been omitted, e.g., D.T.D.130A is given as D.T.D.130.

Table 9

Number and Description	Colour
D.T.D.4—Chromium-Vanadium Steel for Valve Springs	Red, green, red
D.T.D.5—Hard-drawn Carbon Steel for Valve Springs	Black, green
D.T.D.6—Cobalt-Chromium Valve Steel	Red, brown, red
D.T.D.10—High Nickel-Copper Alloy Sheets	Blue, red
D.T.D.13—Silicon-Chromium Valve Steel	Green, brown, green
D.T.D.30—Bronze Bars for Carburettor Needle Seatings	Brown, white
D.T.D.39—Non-corrosive Low Tensile Steel Sheets	Blue
D.T.D.41—Mild Steel Tubes suitable for Welding...	Yellow
D.T.D.46—Non-corrosive Steel Strip of 65 tons Proof Stress	Brown
D.T.D.49—High Nickel High Chromium Steel for Valves	Red, yellow, red
D.T.D.53—Non-corrosive Low Tensile Steel Bar	Black, yellow, black
D.T.D.59—Magnesium Alloy Ingots	Green
D.T.D.60—High Chromium Non-corrodible Sheets and Strips:—	
(Sections II and III) Softened	Blue, black, blue
(Section IV) Hardened and Tempered	Black, blue, yellow
D.T.D.61—Chromium-Nickel Non-corrosive Welding Rod	Yellow
D.T.D.82—Iron or Mild Steel Wire for Welding purposes	Blue, green, yellow
D.T.D.87—55/65-ton Chromium Aluminium-Molybdenum Steel (suitable for nitrogen hardening):—	
(Section II) Bars and Billets for Forging	Red, black, red
(Section III) Bars for Machining	Blue, black, white
D.T.D.97—Low Tensile Non-corrosive Steel Tubes	Black, yellow, red
D.T.D.102—35-ton Non-corrosive Steel Tubes	Blue, green
D.T.D.115—Silico-Manganese Steel Bars	Green, black, red
D.T.D.118—Magnesium Alloy Sheets (suitable for welding)	Black, blue, red
D.T.D.120—Magnesium Alloy Sheets (suitable for welding)	Black, brown, red
D.T.D.124—Hot Rolled or Cold Rolled Carbon Steel Sheets and Strips:—	
(Sections II and IV) Softened	Green, red, white
(Sections III and V) Hardened and Tempered or Cold Rolled and Tempered	Green, blue, red
D.T.D.126—Carbon Steel Bars (suitable for welding):—	
(Section II) Bars and Billets for Forging	Brown, green, yellow
(Section III) Bars for Machining	Black, white
D.T.D.130—(Solution treated but not aged)—Aluminium Alloy Bars for Machining (up to 3 inches) and Extruded Sections	Red, blue, yellow
D.T.D.130—Aluminium Alloy Bars, Extruded Sections and Forgings:—	
(Section II) Bars and Billets for Forging (up to 3 inches)	Green, red, yellow
(Section III) Bars for Machining (up to 3 inches) and Extruded Sections	Red, black, yellow
D.T.D.136—Magnesium Alloy Ingots	Red
D.T.D.137—Hot Rolled or Cold Rolled Carbon Steel Sheets and Strips of 50/65 tons 0·1 per cent. Proof Stress:—	
(Section II and III) Softened Sheet and Strips	Green, blue, white
(Section IV) Strips Hardened and Tempered, Cold Rolled, and Cold Rolled and afterwards Tempered	Brown, blue, red
D.T.D.138—Hot Rolled or Cold Rolled Carbon Steel Sheets and Strips:—	
(Sections II and III) Softened	White, black, white
(Section IV) Hardened and Tempered	Blue, green, red
D.T.D.140—Magnesium Alloy Ingots	Black
D.T.D.142—Magnesium Alloy Bars (15 tons tensile strength)	Black, blue, red
D.T.D.146—High Chromium Non-corrodible Steel Sheet and Strip of 30 tons Proof Stress	Brown, green, red
D.T.D.153—Bright Steel Bars for Pins and High Tensile Bolts	Black, red, yellow
D.T.D.155—Hard Rolled Bronze (Gun Metal) Bars	Black, white
D.T.D.158—Non-corrodible Steel Strips of 35 tons Proof Stress	Black, yellow, green
D.T.D.160—Aluminium Bronze for Valve Seats	White, yellow
D.T.D.161—Non-corrodible Steel Rods, Wire, Rivets and Split Pins ...	Brown, yellow, white
D.T.D.164—Aluminium-Nickel-Iron Bronze Bars	Black, blue, white
D.T.D.166—Chromium-Nickel Non-corrodible Steel Sheet and Strip of 40/50 tons 0·1 per cent. Proof Stress	Black, blue
D.T.D.167—45-Ton Steel Tubes	Blue, yellow, red

Table 9—continued

Number and Description	Colour
D.T.D.168—High Chromium Non-corrodible Steel Sheets and Strips of 60 tons 0·1 per cent. Proof Stress:—	
(Sections II and IV) Softened Sheets and Strips	Green, black, yellow
(Sections III and V) Hardened and Tempered Sheets and Strips	Black, blue, brown
D.T.D.171—Chromium-Nickel Non-corrodible Steel Sheet and Strip of 15 tons 0·1 per cent. Proof Stress	Black, red
D.T.D.176—Chromium-Nickel Non-corrodible Steel of 15 tons 0·1 per cent Proof Stress:—	
(Section II) Bars and Billets for Forging	Green, yellow, white
(Section III) Bars for Machining (not exceeding 2½ inches)	Black, red
D.T.D.178—Chrome-Molybdenum Steel Tubes (suitable for welding) ...	Black, green, yellow
D.T.D.182—7% Magnesium-Aluminium Alloy Sheets and Strips (annealed) ...	Brown, white, yellow
D.T.D.185—High Chromium Non-corrodible Steel Rods and Tubes	Black, white, blue
D.T.D.186—7% Magnesium-Aluminium Alloy Tubes (hard)	Brown, black, yellow
D.T.D.187—Spring Steel Strips:—	
(Section II) Softened Strips	Black, green, red
(Section III) Hardened and Tempered Strips	Blue, black, yellow
D.T.D.188—55/65 Ton Carbon Steel:—	
(Section II) Bars and Billets for Forging	Blue, brown, green
(Section III) Bars for Machining	Blue, brown, white
D.T.D.189—Chromium-Nickel Non-corrodible Steel Rods	Black, white, brown
D.T.D.190—7% Magnesium-Aluminium Alloy Tubes (annealed)	Brown, white, yellow
D.T.D.192—High Nickel-Copper Alloy Hot Rolled or Forged Bars Stampings and Forgings	Black, red, blue
D.T.D.195—Non-corrodible Steel Strip of 55 tons 0·1 per cent. Proof Stress:—	
(Section II) Softened Strips	Brown, red, white
(Section III) Hardened and Tempered Strips	Blue, brown
D.T.D.196—Cold Rolled or Cold Drawn and Annealed High Nickel-Copper Alloy Bars (suitable for cold bendings)	Blue, red, white
D.T.D.197—Aluminium-Nickel-Iron Bronze Bars, Forgings and Stampings ...	Black, yellow, white
D.T.D.198—(Section I) Magnesium-Aluminium Alloy Rods and Wires for Rivets	Brown, green, brown
D.T.D.199—50-ton High Chromium Non-corrodible Steel Tubes	Brown, black, red
D.T.D.200—Hard-drawn High Nickel-Copper Alloy Bars and Strips	Black, red, white
D.T.D.203—50-ton Non-Corrodible Steel Tubes	Black, brown, white
D.T.D.204—High Nickel-Copper Alloy Rods, Wire and Tubes:—	
(Section II) Rods and Wires for Rivets	Black, white, green
(Section III) Tubes for Rivets	Black, white, green
D.T.D.207—35-ton Chromium-Nickel Non-corrodible Steel Tubes	Black, red
D.T.D.208—Cadmium-Copper Alloy Strips	Yellow, white, yellow
D.T.D.211—50-ton Chromium-Nickel Non-corrodible Steel Tubes	Black, blue, green
D.T.D.213—Aluminium-Manganese Alloy Sheets and Coils	Black, red, blue
D.T.D.214—White Metal Ingots	Green, white
D.T.D.215—High Tensile Steel Wire	Green
D.T.D.217—Cadmium Alloy Ingots	Brown, red
D.T.D.220—Wrought Light Aluminium Alloy Tubes	Blue, white
D.T.D.221—Cadmium Zinc Solder	White
D.T.D.225—High Chromium Non-corrodible Steel Sheets and Strips of 20 tons 0·1 per cent. Proof Stress	Red, brown, white
D.T.D.228—55/65-ton Nickel-Chromium-Molybdenum Steel:—	
(Section II) Bars and Billets for Forging	Blue, black, brown
(Section III) Bars for Machining	Blue, black, green
D.T.D.229—Lead Bronze Ingots and Bars	Black, white, yellow
D.T.D.232—45% Nickel Alloy Sheets and Strips of 40/50 tons 0·1 per cent. Proof Stress	Red, white, red
D.T.D.237—45% Nickel Alloy Sheets and Strips of 15 tons 0·1 per cent. Proof Stress	Red, white, yellow
D.T.D.239—Steel Wire for Springs (not suitable for engine valve springs) ...	Green, brown, white
D.T.D.241—High Carbon Steel Strips	Red, blue, white
D.T.D.247—High Thermal Expansion Steel (suitable for valve seats):—	
(Section II) Bars and Billets for Forging	Blue, green, white
(Section III) Bars for Machining	Blue, red, blue
D.T.D.253—Aluminium-Nickel-Silicon Brass Tubes	Red, green, white
D.T.D.254—75-ton Nickel-Chromium Steel Tubes	Black, brown, yellow
D.T.D.259—Magnesium Alloy Bars	Black, red, yellow
D.T.D.261—Alloy Steel Bars	Blue, yellow, white
D.T.D.263—Silicon-Brass Sheets (annealed)	Brown, black, green
D.T.D.265—Hard Drawn Phosphor-Bronze Bars and Tubes (suitable for bushes)	Blue, black, white

Table 9—continued

Number and Description	Colour
D.T.D.267—Silicon-Brass Sheets (half hard)	Brown, black, white
D.T.D.268—45% Nickel Alloy Rods and Tubes	Black, white, red
D.T.D.271—Non-corrodible Steel Strips (suitable for Magneto Contact Breaker Springs)	White, black, yellow
D.T.D.273—Aluminium Alloy Tubes	White, green, yellow
D.T.D.274—Lead Bronze Ingots and Bars	Brown, blue, white
D.T.D.282—High Chromium Steel (Bars or Billets for) Valve Forgings ...	White, green, white
D.T.D.283—Aluminium-Nickel-Silicon Brass Sheets (annealed)	White, blue, white
D.T.D.286—55/65-ton Chromium-Aluminium-Molybdenum Steel (suitable for nitrogen hardening):—	
(Section II) Bars and Billets for Forging	Brown, white, brown
(Section III) Bars for Machining	Brown, white, red
D.T.D.297—7 per cent. Magnesium-Aluminium Alloy Bars, Extruded Sections and Forgings (Softened):—	
(Section II) Bars and Billets for Forging	Black, blue, black
(Section III) Bars for Machining and Extruded Sections ...	Black, brown, green
D.T.D.299—Mild Steel Bars, Forgings and Tubes (suitable for Bearing Shells)	Black, green, white
D.T.D.301—High Chromium Non-corrodible Steel Tie Rods (Swaged):—	
(Section I) Steel Rod for Tie Rods	Black, brown, red
D.T.D.303—5 per cent. Magnesium-Aluminium Alloy wire and Rivets ...	Black, yellow, blue
D.T.D.305—30-ton Carbon Steel Tubes	White, brown, white
D.T.D.306—60/70-ton Chromium-Molybdenum Steel (suitable for nitrogen hardening):—	
(Section II) Bars and Billets for Forging	Blue, brown, red
(Section III) Bars for Machining	Brown, red, green
D.T.D.307—Silicon-Brass Tubes (annealed)	Green, brown, red
D.T.D.310—Soft Aluminium Alloy Tubes (suitable for Oil, Petrol, Gas Starters and general purposes)	White, brown, yellow
D.T.D.311—Silicon-Chromium Steel (Bars or Billets for) Valve Forgings or Stampings	Green, brown, red
D.T.D.312—Hard Drawn Silicon-Brass Tubes	Green, white, green
D.T.D.316—Chromium-Nickel Alloy Sheets and Strips of 10 tons 0·1 per cent. Proof Stress	Green, white, red
D.T.D.317—45/55-ton Chromium-Molybdenum Steel (suitable for nitrogen hardening)	Green, white, yellow
D.T.D.318—Tin-Iron Brass Tubes	White, green, white
D.T.D.319—Aluminium-Nickel-Silicon Brass Bars	Black, green
D.T.D.323—Aluminium-Nickel-Silicon Brass Tubes (medium pressure) ...	White, red, white
D.T.D.325—Magnesium Alloy Ingots	White
D.T.D.327—Aluminium Alloy Wire and Rivets	White, red, yellow
D.T.D.328—Nickel-Chromium-Iron Alloy Sheets and Strips	White, yellow, white
D.T.D.330—Soft Iron Sheets and Strips (suitable for electrical purposes) ...	Black, blue, green
D.T.D.331—80/90-ton Nickel-Chromium Steel:—	
(Section II) Bars and Billets for Forging	Black, green, black
(Section III) Bars for Machining (not exceeding 2½ inches diameter)	Black, green, yellow
D.T.D.341—Nickel-Copper Alloy Tubes for honeycomb type Radiators ...	Red, black, red
D.T.D.346—Soft Aluminium Alloy Sheets and Strips	Brown, white, green
D.T.D.347—50-ton Manganese-Molybdenum or Chrome-Molybdenum Steel Tubes (suitable for welding)	Blue, brown
D.T.D.348—Magnesium Alloy Tubes for Lightly Stressed Parts (suitable for Welding)	Black, blue, white
D.T.D.354—Chromium-Bronze Bars, Extruded Sections and Tubes	Blue, green, red
D.T.D.356—Wrought Light Aluminium Alloy Sheets and Strips:—	
(Section II) Softened Sheets and Strips	Black, brown, black
(Section III) Quenched Sheets and Strips	Black, brown, blue
(Section IV) Quenched and Aged Sheets and Strips ...	Black, brown, green
As rolled	Green, red
D.T.D.359—45-ton Manganese-Molybdenum or Chrome-Molybdenum Steel Tubes (suitable for welding):—	
(Section II) Annealed	Brown, red
(Sections III and IV) Normalised or Cold Drawn and Blued	White, yellow
D.T.D.363—Aluminium Alloy Bars (Extruded or Rolled) and Extruded Sections	Brown, blue, brown
D.T.D.363—**(Solution treated but not aged)**—Aluminium Alloy Bars (Extruded or Rolled) and Extruded Sections	Brown, green, brown
D.T.D.364—**(Solution treated but not aged)**—Aluminium Alloy Bars for Machining and Extruded Sections	Green, brown, red

Table 9—continued

Number and Description	Colour
D.T.D.364—Aluminium Alloy Bars and Forgings:—	
(Section II) Bars and Billets for Forging	Black, brown, black
(Section III) Bars for Machining and Extruded Sections ...	Green, brown, green
D.T.D.367—Aluminium-Nickel-Silicon Brass Wire and Rivets:—	
(Section I) Rods	White, blue, white
D.T.D.390—Aluminium Coated Aluminium Alloy Sheets and Strips:—	
Annealed	Red, green, red
Heat-treated and Aged	Red, blue, red
As rolled	Black, red
D.T.D.404—(Section I) Hard Drawn High Tensile 7% Magnesium-Aluminium Alloy Rods and Wires for Rivets	Yellow, red, yellow
D.T.D.408—75-ton Manganese-Molybdenum or Chrome-Molybdenum Steel Tubes (suitable for welding):—	
(Section II) Annealed	Black, green
(Sections III and IV) Hardened and Tempered	Red, white
D.T.D.410—Aluminium Alloy Bars and Forgings:—	
(Section II) Bars and Billets for Forging (over 3 inches)	Blue, white, yellow
(Section III) Bars for Machining (3 to 6 inches)	Brown, black, white
(Section V) Bars for Machining (6 to 8 inches)	Green, white, red
D.T.D.422—Lead Bronze Ingots and Bars (suitable for bearings)	Brown, yellow, red
D.T.D.423—(Solution treated but not aged)—Aluminium Alloy Bars for Machining and Extruded Sections	Red, yellow, red
D.T.D.423—Aluminium Alloy Extruded Sections and Bars for Machining:—	
(Section II) Bars and Billets for Forging	Green, black, red
(Section III) Bars for Machining and Extruded Sections ...	Red, yellow
D.T.D.432—Commercial Quality 20-ton Steel Tubes:—	
(Section II) Coils for Manufacture of Tubes	Brown, red, yellow
(Section III) Half Hard Tubes	Red, black, white
(Section IV) Softened Tubes	Red, blue, yellow
D.T.D.440—11/15 Aluminium Alloy Tubes	Red, white, yellow
D.T.D.443—Aluminium Alloy Bars, Extruded Sections and Forgings:—	
(Section II) Bars and Billets for Forging	White, blue, yellow
(Section III) Bars for Machining and Extruded Sections ...	Red, brown, red
D.T.D.450—10/17 Aluminium Alloy Tubes	Red, blue, white
D.T.D.460—18/22 Aluminium Alloy Tubes	Blue, yellow, blue
D.T.D.461—55/65-ton 1 per cent. Chromium Steel:—	
(Section II) Bars for Forging	Black, blue, white
(Section III) Bars for Machining	Black, brown, blue
D.T.D.463—55/70-ton Non-Corrodible Steel:—	
(Section II) Bars and Billets for Forging	Brown, blue, red
(Section III) Bars for Machining	Black, blue, red
D.T.D.464—Aluminium Alloy Tubes:—	
Solution-treated	Black, green, white
Solution-treated and Aged	Black, blue, yellow
D.T.D.470—55/65-ton Chromium-Molybdenum Steel:—	
(Section II) Bars for Forging	Black, brown, yellow
(Section III) Bars for Machining	Brown, blue, white
D.T.D.473—75/85-ton Nickel-Chromium-Molybdenum Steel:—	
(Section II) Bars and Billets for Forgings	Blue, green, yellow
(Section III) Bars for Machining	Blue, brown, blue
D.T.D.477—High Nickel-Copper Alloy Tubes	Blue, green
D.T.D.478—99 per cent. Secondary Aluminium Notched Bars and Ingots for Re-melting	Blue
D.T.D.479—Secondary Aluminium Alloy Notched Bars and Ingots for Re-melting	Yellow
D.T.D.480—55/65-ton $1\frac{1}{2}$ per cent. Nickel-Chromium-Molybdenum Steel:—	
(Section II) Bars for Forging	Black, yellow, green
(Section III) Bars for Machining	Black, red, green
D.T.D.487—Aluminium-Copper-Nickel Alloy Cold Headed Bolts:—	
(Section II) Rod and Wire	Red, green, red
D.T.D.489—Chrome-Nickel Heat Resisting Steel Rods and Wire (suitable for welding and for Split Pins)	Brown, black, green
D.T.D.490—55/65-ton $2\frac{1}{2}$ per cent. Nickel-Chromium-Molybdenum Steel (Medium Carbon):—	
(Section II) Bars for Forging	Black, yellow, white
(Section III) Bars for Machining	Brown, white, green
D.T.D.491—Chromium-Nickel Heat Resisting Steel Tubes (suitable for welding)	Brown, black, white
D.T.D.493—Chromium-Nickel Heat Resisting Steel Sheets and Coils (suitable for welding)	Black, white, yellow

Table 9—continued

Number and Description	Colour
D.T.D.498—Silicon-Nickel-Copper Alloy Bars and Forgings:—	
Bars and Billets for Forging	Black, yellow, red
Bars for Machining	Blue, red, green
D.T.D.500—80/90-ton 2½ per cent. Nickel-Chromium-Molybdenum Steel (High Carbon):—	
(Section II) Bars for Forging	Blue, green, brown
(Section III) Bars for Machining	Blue, brown, yellow
D.T.D.501—Commercial Quality 35-ton Steel Tubes	Brown, green, white
D.T.D.503—Steel Tubes (suitable for high-pressure hydraulic systems) ...	Yellow, white, yellow
D.T.D.504—Silicon-Nickel-Copper Alloy Bars	Green, red, green
D.T.D.507—Commercial Quality 40-ton Non-corrodible Steel Tubes (suitable for welding):—	
(Section II) Coils for Manufacture of Seam Welded Tubes	Red, green, white
(Section III) Seam Welded or Solid Drawn Tubes	Black, red, white
D.T.D.510—40/50-ton Manganese-Nickel Molybdenum Steel:—	
(Section II) Bars for Forging	Brown, blue, green
(Section III) Bars for Machining	Black, red, brown
D.T.D.519—3 per cent. Nickel Chromium Case-Hardening Steel	Green, white
D.T.D.520—23/27 Aluminium Alloy Tubes	Brown, red, brown
D.T.D.525—45/55-ton Non-corrodible Steel, free machining:—	
(Section II) Bars and Billets for Forging	Blue, white, brown
(Section III) Bars for Machining	Blue, white, green
D.T.D.529—Chromium-Nickel, Heat-resisting Steel Bars and Forgings:—	
(Section II) Bars and Billets for Forgings	Brown, green, red
(Section III) Bars for Machining	Brown, red, brown
D.T.D.535—Commercial Quality 35-ton Steel Tubes (suitable for welding)...	Blue, red, brown
D.T.D.545—Commercial Quality 45-ton Steel Tubes (suitable for welding)...	Blue, green, yellow
D.T.D.546—Aluminium-coated High Tensile Aluminium Alloy Sheets and Coils:—	
Solution-treated and artificially aged	Blue, red, blue
D.T.D.549—Chromium-Nickel Non-corrodible Steel Welding Rods and Wires	Red, white, red
D.T.D.551—3 per cent. Chromium-Molybdenum Steel Thrust Rings (Nitrogen hardened):—	
Bars for manufacture	Brown, black, white
D.T.D.563—Commercial Quality 35-ton Steel Tubes (suitable for welding)...	Red, blue, red
D.T.D.569—55/65-ton Manganese Molybdenum Steel Pressings (Section II):—	
Plates for Pressing	Green, white, green
D.T.D.571—Chromium-Nickel Non-corrodible Steel Sheets, Coils, Tubes and Wire (suitable for welding)	Blue, white, red
D.T.D.578—35-ton Chrome Molybdenum Steel Tube (suitable for welding)	Red, green, yellow
D.T.D.600—55/65-ton Low Alloy Steel Bars for Machining (not exceeding 2½ inches diameter)	Green, white, red
D.T.D.603—Aluminium Alloy Sheets and Coils:—	
Solution-treated and naturally aged	Black, yellow, black
Annealed	Red, white, red
As rolled	Green, yellow, green
D.T.D.604—Brass Tube suitable for Low Pressure Hydraulic and similar systems	Black, red, black
D.T.D.609—85-ton 4¼ per cent. Nickel-Chromium Steel Bars (softened condition)	Blue, white, blue
D.T.D.610—Aluminium-coated Aluminium Alloy Sheets and Coils:—	
Solution-treated and naturally aged	Black, green
Annealed	Red, black, red
As Rolled	Green, red, green
D.T.D.628—Magnesium Alloy Ingots	Red, white
D.T.D.646—High Tensile Aluminium Alloy Sheets and Coils:—	
Solution-treated and artificially aged	Brown, white, brown

Table 10—Tool steels

Number and Description	Colour
A.M.71—Temper 1. Carbon Tool Steel	Red, blue, yellow
A.M.71—Temper 2. Carbon Tool Steel	Blue, yellow, red
A.M.71—Temper 3. Carbon Tool Steel	Green, yellow, red
A.M.71—Temper 4. Carbon Tool Steel	Red, green, yellow
A.M.71—Temper 5. Carbon Tool Steel	Red, black, yellow
A.M.71—Tungsten Tool Steel, Grade "A"	Green, blue, yellow
A.M.71—Tungsten Tool Steel, Grade "B"	Blue, yellow, green
A.M.71—Silver Steel	Green, yellow, green

Table 11—Colour Index

Colours	Specifications
Black	**B.13, L.17, T.9, T.51, B.S.S.219** (Grade C), **B.S.S.249, D.T.D.140**
Black, blue	**S.81A, D.T.D.166, D.T.D.275** (Annealed)
Black, blue, black	**D.T.D.297** (Section II)
Black, blue, brown	**D.T.D.168** (Sections III and V)
Black, blue, green	**D.T.D.211, D.T.D.330**
Black, blue, red	**D.T.D.118, D.T.D.142, D.T.D.463** (Section III)
Black, blue, white	**D.T.D.164, D.T.D.348, D.T.D.461** (Section II)
Black, blue, yellow	**D.T.D.60** (Section IV), **464** (Solution treated and aged)
Black, brown...	**S.81.B, D.T.D.351** (Section II)
Black, brown, black	**T.35, D.T.D.356** (Section II), **D.T.D.364** (Section II)
Black, brown, blue	**T.45, D.T.D.356** (Section III), **D.T.D.461** (Section III)
Black, brown, green	**D.T.D.297** (Section III), **D.T.D.356** (Section IV)
Black, brown, red	**D.T.D.120, D.T.D.301** (Section I)
Black, brown, white	**D.T.D.203, B.S.S.250** (Grade A)
Black, brown, yellow	**D.T.D.254, D.T.D.470** (Section II)
Black, green	**L.30, S.20, D.T.D.5, D.T.D.408** (Section II), **D.T.D.610** (Solution treated and naturally aged), **D.T.D.319**
Black, green, black	**D.T.D.180, D.T.D.331** (Section II)
Black, green, blue	**S.84, D.T.D.293** (Section II)
Black, green, brown	**S.85, D.T.D.293** (Section III)
Black, green, red	**D.T.D.187** (Section II)
Black, green, white	**D.T.D.299, D.T.D.464** (Solution treated)
Black, green, yellow	**D.T.D.178, D.T.D.331** (Section III)
Black, red	**L.34, B.S.S.518, D.T.D.171, D.T.D.176** (Section III), **D.T.D.207, D.T.D.390** (as rolled)
Black, red, black	**L.45.D, D.T.D.175, D.T.D.604**
Black, red, blue	**D.T.D.192, D.T.D.213**
Black, red, brown	**D.T.D.270** (Heat-treated and aged), **D.T.D.280, D.T.D.510** (Section III)
Black, red, green	**D.T.D.275** (Heat-treated and aged), **D.T.D.290, D.T.D.480** (Section III)
Black, red, white	**D.T.D.200, D.T.D.507** (Section III)
Black, red, yellow	**D.T.D.153, D.T.D.259**
Black, white	**D.T.D.126** (Section III), **D.T.D.155**
Black, white, black	**D.T.D.170**
Black, white, blue	**D.T.D.185** (Section I)
Black, white, brown	**D.T.D.189** (Rods)
Black, white, green	**D.T.D.204** (Sections II and III)
Black, white, red	**D.T.D.268** (Section II)
Black, white, yellow	**D.T.D.229, D.T.D.493**
Black, yellow...	**L.37** (Sections II and III), **S.68.A, B.S.S. No. 24** (Spec. 12a)
Black, yellow, black	**D.T.D.53, D.T.D.342** (Section II), **D.T.D.603** (Solution treated and naturally aged), **T4X**
Black, yellow, blue	**D.T.D.303** (Rods), **D.T.D.342** (Section III)
Black, yellow, brown	**S.80.A, D.T.D.342** (Section IV)
Black, yellow, green	**D.T.D.158, D.T.D.480** (Section II)
Black, yellow, red	**L.47A, S.61.A, D.T.D.97, D.T.D.498** (Section II)
Black, yellow, white	**D.T.D.197, D.T.D.490** (Section II)
Blue	**B.6, L.16, L.36** (Section I), **S.69.B, T.8, D.T.D.39, B.S.S.219** (Grade A), **B.S.S.251, B.S.S.265** (Hard), **B.S.S.886, D.T.D.478**
Blue, black, blue	**D.T.D.60** (Sections II and III), **A.L.45B**
Blue, black, brown	**D.T.D.228** (Section II)
Blue, black, green	**D.T.D.228** (Section III)
Blue, black, red	**S.65.A, B.S.S.266** (Extra hard)
Blue, black, white	**D.T.D.87** (Section III), **D.T.D.265**
Blue, black, yellow	**D.T.D.187** (Section III)

Table 11—Colour Index—continued

Colours	Specifications
Blue, brown	**D.T.D.195** (Section III), **D.T.D.347, B.S.S.266** (Hard)
Blue, brown, blue	**S.86A** and **B, A.L.45D, D.T.D.473** (Section III)
Blue, brown, blue, brown... ...	**En 100.** Untreated bars
Blue, brown, green	**D.T.D.188** (Section II)
Blue, brown, red	**D.T.D.306** (Section II)
Blue, brown, white	**D.T.D.188** (Section III)
Blue, brown, yellow	**L.47.B, D.T.D.500** (Section III)
Blue, green	**L.46, S.70.A, D.T.D.102, D.T.D.477**
Blue, green, blue	**S.69.A, A.L.40.B**
Blue, green, blue, green	**En 101.** Untreated bars
Blue, green, brown	**D.T.D.213, D.T.D.500** (Section II)
Blue, green, red	**D.T.D.138** (Section IV), **D.T.D.354**
Blue, green, white	**D.T.D.247** (Section II)
Blue, green, yellow	**D.T.D.82, D.T.D.545, D.T.D.473** (Section II)
Blue, red	**S.28.A, T.18, D.T.D.10, B.S.S.885, L.38** (as rolled)
Blue, red, blue	**D.T.D.247** (Section III), **A.L.40.A, D.T.D.546**
Blue, red, blue, red	**En 110.** Untreated bars
Blue, red, brown	**S.67.B, D.T.D.535**
Blue, red, green	**S.79.A, B.S.S.266** (Half-hard), **D.T.D.498** (Section III)
Blue, red, white	**D.T.D.196**
Blue, red, yellow	**S.28.B**
Blue, white	**B.21, S.1–N, B.S.S.384, D.T.D.220**
Blue, white, blue	**L.40.A, D.T.D.206** (Section II), **D.T.D.609** (Softened condition)
Blue, white, blue, white	**En 102.** Untreated bars
Blue, white, brown	**D.T.D.206** (Section III), **A.L.40, D.T.D.525** (Section II)
Blue, white, green	**L.40.B, D.T.D.206** (Section IV), **D.T.D.525** (Section III)
Blue, white, red	**D.T.D.252** (Section II), **D.T.D.571**
Blue, white, yellow	**S.90, D.T.D.410** (Section II)
Blue, yellow	**L.38** (fully heat-treated), **S.21, T.26** (Section II)
Blue, yellow, blue	**S.87.B, D.T.D.460**
Blue, yellow, brown	**S.67.A, B.S.S.407/2** (Half hard)
Blue, yellow, green	**A.M.71** (Grade B)
Blue, yellow, red	**D.T.D.167, A.M.71** (Temper 2)
Blue, yellow, white	**D.T.D.261**
Brown	**B.11, D.T.D.46, B.S.S.219** (Grade D)
Brown, black, brown	**D.T.D.249, B.S.S.32** (Grade I)
Brown, black, green	**D.T.D.263, D.T.D.489**
Brown, black, red	**S.80.B, D.T.D.199**
Brown, black, white	**D.T.D.267, D.T.D.410** (Section III), **D.T.D.491, D.T.D.551** (Bars for manufacture)
Brown, black, yellow	**D.T.D.177, D.T.D.186**
Brown, blue, brown	**S.77.B, D.T.D.363, B.L.47.B**
Brown, blue, green	**D.T.D.266, D.T.D.510** (Section II)
Brown, blue, red	**D.T.D.137** (Section IV), **D.T.D.463** (Section II)
Brown, blue, white	**D.T.D.274, D.T.D.470** (Section III)
Brown, blue, yellow	**B.S.S.407/1** (Half-hard), **D.T.D.278**
Brown, green	**S.6.A, D.T.D.351** (Section III)
Brown, green, brown	**S.71.A, D.T.D.198** (Section I), **B.L.47.C, D.T.D.363**
Brown, green, red	**D.T.D.146, D.T.D.354, D.T.D.529** (Section II)
Brown, green, white	**S.86.C, D.T.D.501**
Brown, green, yellow	**D.T.D.126** (Section II)
Brown, red	**S.65B, D.T.D.217, D.T.D.359** (Section II)
Brown, red, brown	**S.87.C, D.T.D.520, B.L.47.A, D.T.D.529** (Section III)
Brown, red, green	**D.T.D.306** (Section III)
Brown, red, white	**D.T.D.195** (Section II)
Brown, red, yellow	**D.T.D.194, D.T.D.432** (Section II)

Table 11—Colour Index—continued

Colours	Specifications
Brown, white	**D.T.D.30**, **D.T.D.209**
Brown, white, brown	**D.T.D.286** (Section II), **D.T.D.646**
Brown, white, green	**D.T.D.346**, **D.T.D.490** (Section III)
Brown, white, red	**D.T.D.286** (Section III)
Brown, white, yellow	**D.T.D.182**, **D.T.D.190**
Brown, yellow	**L.39.B**, **S.14.B**, **T.50**
Brown, yellow, brown	**S.15.A**, **B.S.S.265** (Extra hard)
Brown, yellow, green	**S.88.C**, **B.S.S.250** (Grade B)
Brown, yellow, red	**S.61.B**, **D.T.D.422**
Brown, yellow, white	**D.T.D.161** (Rods)
Green	**L.4**, **S.3**, **S.6.B**, **T.1**, **B.S.S.265** (Annealed), **D.T.D.59**, **B.S.S.219** (Grade G), **D.T.D.215**
Green, black, green	**B.S.S. No. 51**, **B.S.S. No. 847** (Hard)
Green, black, red	**D.T.D.115**, **D.T.D.423** (Section II)
Green, black, white	**S.88.B**, **D.T.D.270** (Annealed)
Green, black, yellow	**D.T.D.168** (Sections II and IV)
Green, blue, green	**S.76.B**, **D.T.D.351** (Section IV), **B.S.S. No. 847** (Medium soft)
Green, blue, red	**D.T.D.124** (Sections III and V)
Green, blue, white	**D.T.D.137** (Sections II and III)
Green, blue, yellow	**A.M.71** (Grade A)
Green, brown, green	**D.T.D.13**, **D.T.D.364** (Section III), **B.S.S.5007/214**
Green, brown, red	**D.T.D.307**, **D.T.D.311**, **D.T.D.364**
Green, brown, white	**L.47.C**, **D.T.D.239**
Green, brown, yellow	**B.S.S. No. 15**
Green, red	**L.39.A**, **S.24**, **B.S.S.266** (Annealed), **D.T.D.356** (as rolled)
Green, red, green	**S.76.A**, **B.S.S.899** (Annealed), **D.T.D.504**, **D.T.D.610** (as rolled), **B.S.S. No. 847** (Deep-drawing)
Green, red, white	**D.T.D.296**, **D.T.D.124** (Sections II and IV)
Green, red, yellow	**S.82.B**, **D.T.D.130** (Section II)
Green, white	**L.44**, **D.T.D.214**, **D.T.D.519**
Green, white, green	**D.T.D.312**, **B.S.S.32** (Grade 2), **D.T.D.569**
Green, white, red	**D.T.D.316**, **D.T.D.410** (Section V), **D.T.D.600**
Green, white, yellow	**D.T.D.317** (Section II)
Green, yellow	**L.1.A**, **L.3** (as rolled), **S.14.A**, **17.S** Bars (Equivalent to **L.1.A**)
Green, yellow, green	**B.S.S.369**, **A.M.71** (Silver Steel), **D.T.D.603** (as rolled), **B.S.S. No. 847** (Soft)
Green, yellow, red	**B.S.S.918**, **A.M.71** (Temper 3)
Green, yellow, white	**D.T.D.176** (Section II)
Grey, black, grey, black	**En 31.** Untreated bars
Grey, blue, grey, blue	**Dn 15.** Untreated bars
Grey, brown, grey, brown ...	**En 34.** Untreated bars
Grey, green, grey, green	**En 36.** Untreated bars
Orange, black	**2SO**
Orange, black, orange, black ...	**En 24.** Untreated bars
Orange, black, brown	**2SH**
Orange, black, green	**2S½H**
Orange, blue	**53ST**
Orange, blue, orange, blue ...	**En 17.** Untreated bars
Orange, blue, red	**53SO**
Orange, brown, green	**57SH**
Orange, brown, orange, brown ...	**En 25.** Untreated bars
Orange, brown, red	**57SO**

Table 11—Colour Index—continued

Colours	Specifications
Orange, green, blue	3S½H
Orange, green, brown	3S¾H
Orange, green, orange, green ...	En 2
Orange, green, red	3SO
Orange, grey, orange, grey ...	En 16. Untreated bars
Orange, red, black	Alclad 24ST
Orange, white, blue	52SO
Orange, white, green	52S½H
Orange, white, orange, white ...	En 26. Untreated bars
Orange, yellow	17ST
Red	B.1, L.31, S.2, S.4, T.2, B.S.S.265 (Half-hard), 24 S.T., D.T.D.136, D.T.D.563, B.S.S.219 (Grade M), 24ST
Red, black, red	D.T.D.87 (Section II), D.T.D.341, A.L.40 (Softened), D.T.D.610 (Annealed)
Red, black, white	L.25A, D.T.D.432 (Section III)
Red, black, yellow	D.T.D.130 (Section III), A.M.71 (Temper 5)
Red, blue, red	S.11.B, D.T.D.390 (Heat-treated and aged), D.T.D.563, B.L.40 (Softened)
Red, blue, white	D.T.D.241, D.T.D.450
Red, blue, yellow	D.T.D.432 (Section IV), A.M.71 (Temper 1), D.T.D.130
Red, brown, red	D.T.D.6, D.T.D.443 (Section III), B.L.47 (as rolled)
Red, brown, white	D.T.D.225, B.S.S.32 (Grade 4)
Red, brown, yellow	L.45.A, S.82.A
Red, green, red	D.T.D.4, D.T.D.390 (Annealed), D.T.D.487 (Section II)
Red, green, white	D.T.D.253, D.T.D.507 (Section II)
Red, green, yellow	A.M.71 (Temper 4), D.T.D.578
Red, white	B.20, B.22, D.T.D.408 (Sections III and IV), B.S.S.218, D.T.D.628
Red, white, red	L.39D, D.T.D.232, D.T.D.549, D.T.D.603 (Annealed)
Red, white, yellow	D.T.D.237, D.T.D.440
Red, yellow	S.11.A, T.26 (Section III), T.52, D.T.D.78, D.T.D.423 (Section III)
Red, yellow, red	D.T.D.49, B.S.S.266 (Quarter-hard), A.L.47 (as rolled), D.T.D.423
Red, yellow, white	D.T.D.252 (Section III)
White	T.7, D.T.D.221, D.T.D.325
White, black, white	D.T.D.138 (Sections II and III), En 15 (Heat-treated)
White, black, yellow	L.45.B, D.T.D.271
White, blue, white	D.T.D.283, D.T.D.367 (Section I), B.L.45.B, S.1–N (Lead)
White, blue, yellow	D.T.D.292, D.T.D.443 (Section II)
White, brown, white	D.T.D.305, B.L.45.D
White, brown, yellow	D.T.D.310, B.S.S.5005/101
White, green, white	D.T.D.318, B.L.40.B, D.T.D.282
White, green, yellow	D.T.D.273, B.S.S. No. 267
White, red, white	D.T.D.323, B.L.40.A
White, red, yellow	D.T.D.327 (Rods)
White, yellow	D.T.D.160, D.T.D.359 (Sections III and IV), 17S. Bars (equivalent to L.39A)
White, yellow, white	D.T.D.328
Yellow	B.8, B.15, L.1.B., L.3 (fully heat-treated), S.1, T.4, T.47, D.T.D.41, D.T.D.61, B.S.S.219 (Grade B), B.S.S.899 (Half-hard), B.S.S. 5007/215, D.T.D.479, 17ST (Equivalent to T.4).
Yellow, black, yellow	S.62.B, B.S.S.265 (Quarter-hard)
Yellow, blue, yellow	S.77A, A.L.45.A, A.L.47.B
Yellow, brown, yellow	S.15.B
Yellow, green, yellow	S.71B, A.L.47.C
Yellow, red, yellow...	S.62A, D.T.D.404 (Section I), L.47A
Yellow, white, yellow	D.T.D.208, B.L.45.A, D.T.D.503

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AIR MINISTRY
May, 1944

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CHAPTER 5

NEWALL STANDARD SYSTEM OF FITS AND TOLERANCES

General

1. The Newall standard system of fits and tolerances is based on the production of holes which are as near to standard as is commercially possible. In this system two grades of holes are accepted as commercial standards and these are classified as Classes A and B.

2. The allowances for the fit required is made on the shaft in accordance with the classification indicated in the tables below, for the particular diameter and class of fit.

TOLERANCES OF STANDARD HOLES—CLASSES A AND B

Nominal Diameters			Up to $\frac{1}{2}$ in.	$\frac{9}{16}$ to 1 in.	$1\frac{1}{16}$ to 2 in.	$2\frac{1}{16}$ to 3 in.	$3\frac{1}{16}$ to 4 in.	$4\frac{1}{16}$ to 5 in.	$5\frac{1}{16}$ to 6 in.
A	High Limit	+	0·00025	0·00050	0·00075	0·00100	0·00100	0·00100	0·00150
	Low Limit	−	0·00025	0·00025	0·00025	0·00050	0·00050	0·00050	0·00050
	Tolerance		0·00050	0·00075	0·00100	0·00150	0·00150	0·00150	0·00200
B	High Limit	+	0·00050	0·00075	0·00100	0·00125	0·00150	0·00175	0·00200
	Low Limit	−	0·00050	0·00050	0·00050	0·00075	0·00075	0·00075	0·00100
	Tolerance		0·00100	0·00125	0·00150	0·00200	0·00225	0·00250	0·00300

ALLOWANCES ON SHAFTS FOR VARIOUS FITS

:—

Force fit, requiring hydraulic pressure or heat applied.—

Nominal Diameters			Up to $\frac{1}{2}$ in.	$\frac{9}{16}$ to 1 in.	$1\frac{1}{16}$ to 2 in.	$2\frac{1}{16}$ to 3 in.	$3\frac{1}{16}$ to 4 in.	$4\frac{1}{16}$ to 5 in.	$5\frac{1}{16}$ to 6 in.
F	High Limit	+	0·00100	0·00200	0·00400	0·00600	0·00800	0·01000	0·01200
	Low Limit	+	0·00050	0·00150	0·00300	0·00450	0·00600	0·00800	0·01000
	Tolerance		0·00050	0·00050	0·00100	0·00150	0·00200	0·00200	0·00200

CLASS D :—

Driving fit, requiring arbor press or hammer to drive in.—

Nominal Diameters			Up to $\frac{1}{2}$ in.	$\frac{9}{16}$ to 1 in.	$1\frac{1}{16}$ to 2 in.	$2\frac{1}{16}$ to 3 in.	$3\frac{1}{16}$ to 4 in.	$4\frac{1}{16}$ to 5 in.	$5\frac{1}{16}$ to 6 in.
D	High Limit	+	0·00050	0·00100	0·00150	0·00250	0·00300	0·00350	0·00400
	Low Limit	+	0·00025	0·00075	0·00100	0·00150	0·00200	0·00250	0·00300
	Tolerance		0·00025	0·00025	0·00050	0·00100	0·00100	0·00100	0·00100

CLASS P:—

Push fit, requires to be pushed or tapped into position but is not free to rotate.—

Nominal Diameters		Up to ½ in.	9/16 to 1 in.	1 1/16 to 2 in.	2 1/16 to 3 in.	3 1/16 to 4 in.	4 1/16 to 5 in.	5 1/16 to 6 in.
P	High Limit —	0·00025	0·00025	0·00025	0·00050	0·00050	0·00050	0·00050
	Low Limit —	0·00075	0·00075	0·00075	0·00100	0·00100	0·00100	0·00100
	Tolerance	0·00050	0·00050	0·00050	0·00050	0·00050	0·00050	0·00050

CLASSES X, Y, Z:—

Running fits, three grades. Class X is suitable for engine bearing and other work where any easy fit is required with clearance allowed for a liberal oil film. Class Y is suitable for high speed work and for good machine work, whilst Class Z is suitable for fine tool work.

Nominal Diameters		Up to ½ in.	9/16 to 1 in.	1 1/16 to 2 in.	2 1/16 to 3 in.	3 1/16 to 4 in.	4 1/16 to 5 in.	5 1/16 to 6 in.
X	High Limit —	0·00100	0·00125	0·00175	0·00200	0·00250	0·00300	0·00350
	Low Limit —	0·00200	0·00275	0·00350	0·00425	0·00500	0·00575	0·00650
	Tolerance	0·00100	0·00150	0·00175	0·00225	0·00250	0·00275	0·00300
Y	High Limit —	0·00075	0·00100	0·00125	0·00150	0·00200	0·00225	0·00250
	Low Limit —	0·00125	0·00200	0·00250	0·00300	0·00350	0·00400	0·00450
	Tolerance	0·00050	0·00100	0·00125	0·00150	0·00150	0·00175	0·00200
Z	High Limit —	0·00050	0·00075	0·00075	0·00100	0·00100	0·00125	0·00125
	Low Limit —	0·00075	0·00125	0·00150	0·00200	0·00225	0·00250	0·00275
	Tolerance	0·00025	0·00050	0·00075	0·00100	0·00125	0·00125	0·00150

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AIR MINISTRY
May, 1944

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CHAPTER 2

RIVNUTS AND TOOLS

LIST OF CONTENTS

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Clinching tool	2		

General

1. Rivnuts are essentially hollow internally-threaded rivets, which are used on aircraft for the attachment of such components as de-icing overshoes to aerofoils, or carpets and treadways to sheet metal floors. They can be inserted and riveted from one side of a structure by the use of two hand-tools, one being used for the purpose of cutting a notch or keyway in the side of the hole in which the rivet is to be inserted and the other for the purpose of upsetting the sleeve portion of the rivnut after it has been inserted. A projection or key which engages with the keyway is formed beneath the head of the rivnut during manufacture whereby it is prevented from rotating when a setscrew is being screwed into, or out of, the rivnut. Rivnuts are threaded to various British and American standards as adopted on different types of aircraft and it is essential that only screws having threads of the same denomination as the selected rivnuts should be used. The tools required when fitting rivnuts are described below, followed by the method of using the tools.

Keyway cutting tool

2. The keyway cutting tool (see fig. 1) consists of a tube in which is housed a detachable spring-loaded plunger, which carries a steel cutter and is operated by means of a handle. The handle is

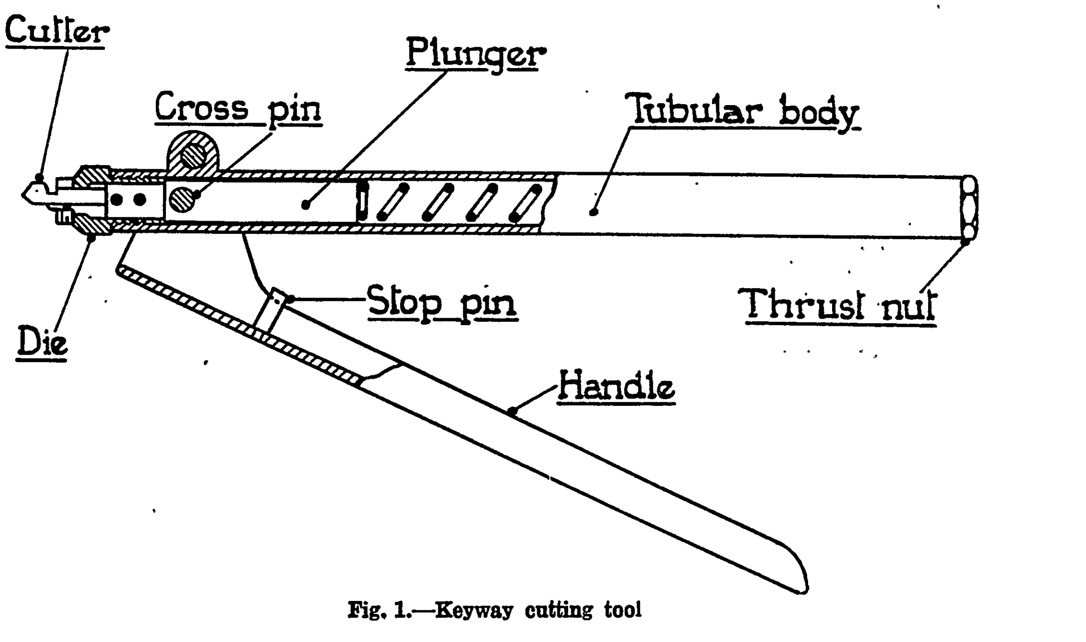

Fig. 1.—Keyway cutting tool

hinged at one end of the tube and is pivoted at the same end to the plunger. The steel cutter protrudes from one end of the plunger and when the handle is operated the cutter is drawn into the tube end or die, against the pressure of an internal return spring. A stop pin is fitted to the handle for the purpose of limiting the length of the working stroke of the cutter and preventing injury to the hands of the operator when the tube and the handle are forced together. The cutter is attached to the end of the plunger by means of two steel pins which can be removed when it is required to replace the cutter by a new one. In order to remove the plunger, the thrust nut should be removed from the opposite end of the tube to the cutter, the coil spring can then be extracted, after which the plunger cross-pin should be removed, thus allowing the plunger to slide out of the tube.

Rivnut clinching tool

3. The rivnut clinching tool (see fig. 2) is comprised of a tubular housing, a retractable spring-loaded plunger and a handle which is hinged to the tube and pivoted on the plunger. A spindle, in two sections mounted axially thro ugh the tube and the plunger, projects from each end of the tube and is threaded at one end to fit the rivnut threads, the other end being fitted with a small handwheel by means of which the threaded end can be screwed into a rivnut. The spindle is free to rotate in both the tube and the plunger, while axial movement, constituting the working stroke, is limited by the plunger and its handle. The detachable screwed end of the spindle is held in the plunger by means of a small setscrew; alternative ends, threaded either to U.S. or B.A. standards, are available, to suit the rivnuts.

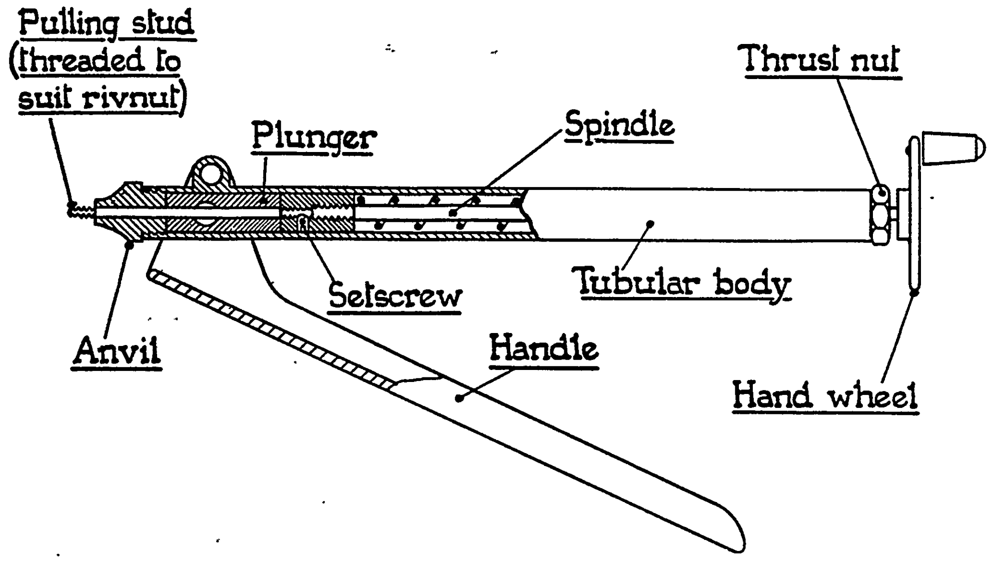

Fig. 2.—Clinching tool

Fitting rivnuts

4. Rivnuts should be fitted as follows:—

(i) A hole $\frac{3}{16}$ in. dia. should be drilled in the sheet-metal member and the edges of the hole chamfered slightly to remove burrs and sharp edges. A small hooked cutter may be used to remove burrs on the underside when this is not accessible from below.

(ii) The cutter of the keyway-cutting tool should now be inserted in the hole which has been drilled and, holding the tool square with the sheet-metal, the handle should be gripped and the cutter operated (see fig. 3, sketch I).

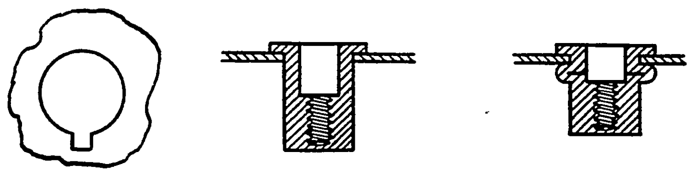

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Fig. 3.—Sequence of operations

(iii) The rivnut should be screwed on to the threaded end of the clinching tool spindle until all the threads are engaged and the head of the rivnut is against the anvil on the tube end. The rivnut should then be inserted in the hole which has been drilled and the key engaged with the keyway and, holding the tool squarely, the handle should be gripped and drawn to the tubular body of the tool until a solid resistance is felt. The small handwheel should then be used to screw the tool spindle out of the rivnut, meanwhile keeping the tool in line with the axis of the rivnut.

Removing rivnuts

5. A rivnut which has worked loose, or one in which the screwthreads are damaged, should be removed and replaced by a new one. In order to remove a rivnut it should be drilled out by means of a suitable hand-drilling machine. A $\frac{5}{16}$ in. drill should be used and care should be taken to keep the drill central and in line with the axis of the rivnut in order to ensure that the sheet metal does not sustain any damage during the operation. If the drill has been centred correctly it should only be necessary to drill through the head of the rivnut to separate the head from the body, but in the event of the drill wandering, the head of the rivnut should be carefully filed off, the surface of the surrounding sheet metal being protected meanwhile by means of a suitable mask cut from shim steel 0·002 in. thick, having a hole in the centre, through which the rivnut head may protrude.

Blanking-off rivnuts

6. Rivnuts, which have been installed and are not in use because of the removal of some component, should be blanked off by means of the special screws provided. These screws have thin countersunk head, slotted cross-wise, and a special cruciform screwdriver bit is required for inserting and removing them.

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AIR MINISTRY
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CHAPTER 3

DZUS FASTENERS

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General

1. DZUS fasteners (see fig. 1) are used on aircraft for the purpose of securely holding detachable sheet-metal components in their respective positions, at the same time providing a means for repeated rapid attachment and detachment of the components without causing wear or localised fatigue of the sheet metal. The fastener consists of a bayonet-fitting type catch provided with a slotted head, and a wire spring. The catch is retained in the outer sheet-metal member and the spring is secured to the inner member; a helix slot is machined in the catch sleeve which engages with the centre portion of the spring, drawing it up when

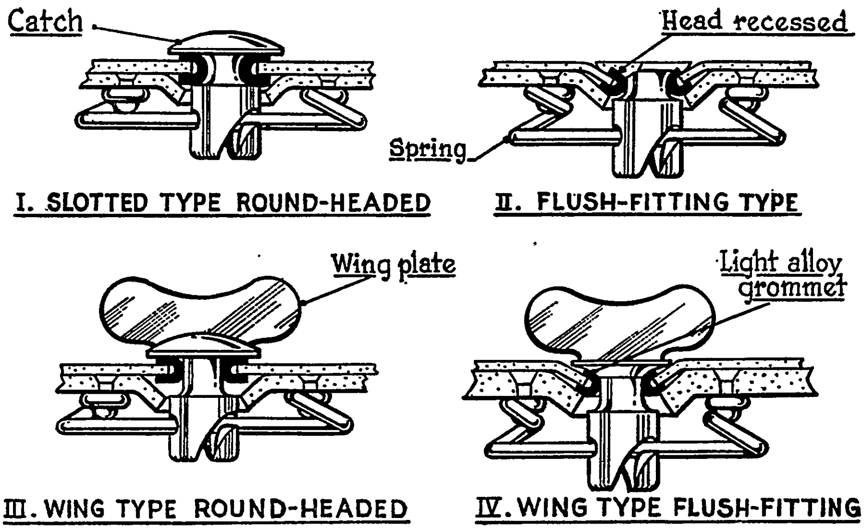

Fig. 1.—Types of DZUS fastener

the catch is given a quarter turn in a clockwise direction. The catch is retained in position in the outer member by means of a light alloy ferrule or grommet and the spring is riveted at each looped end to the underside of the inner member, the fastener catch engaging with the spring through a hole drilled in the inner member. Various types of catch and spring are used for different applications and a description of the types generally used is given in this chapter, together with information on the methods adopted for fitting the components of the various types of fastener.

Description

2. All types of DZUS fasteners consist of a catch and a spring, typical examples of the parts being described in the following sub-paras. and illustrated in fig. 1:—

(i) *Catch*—The catch (see fig. 1) is made in the shape of a sleeve-type nut with a screw head, a helix slot being machined at the end remote from the head, to form a bayonet-type fitting. The catch may be round-headed (see sketch I), or in instances where the fastener is required to be flush-fitting, the underside of the head is recessed (see sketch II), or bevelled (see sketch IV). The sleeve portion under the head is made in different lengths (see sketches I and III) according to the application of the fastener and to the thickness of the plate in which the catch is fitted. The hole in the outer member is fitted with a light-alloy grommet which prevents the catch from falling out when the fastener is unlocked (see fig. 1). The head of the catch is usually slotted to provide for the engagement of a locking key. In addition to the slotted types of catch, similar types are available fitted with a fixed wing plate to facilitate the locking and unlocking operations in positions where drag does not prohibit their use (see sketch III).

(ii) *Spring*—The fastener spring (see fig. 2) is a short length of spring-steel wire, the ends of which are coiled in opposite directions to form spirals, through the eyes of which the spring is riveted to the inner member. The centre portion of the spring engages with the helix slot in the end of the catch. The pitch of the rivet-centres of the springs and the height of the spring vary with different types, according to the position of the fasteners on the aircraft; fig. 2 shows a typical arrangement of small-type springs at a joint in an engine cowling. When the fastener is in its locked position the spring is deflected by the helix slot, and

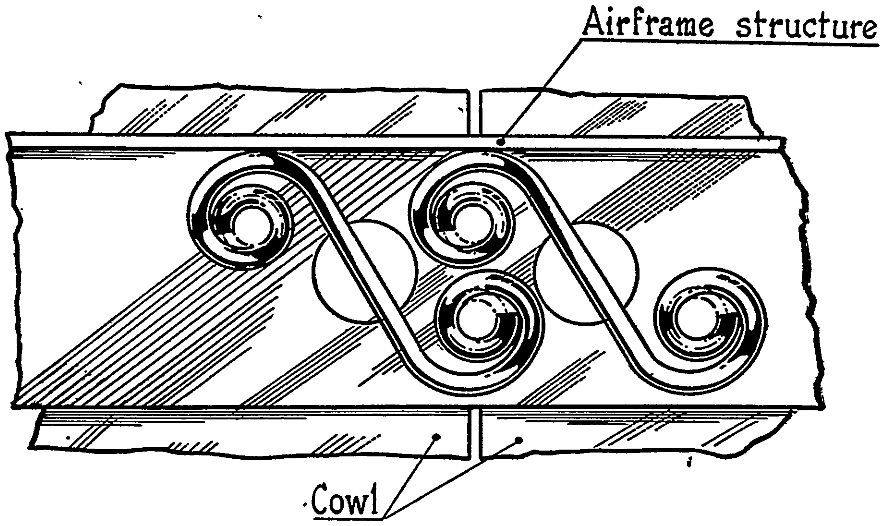

Fig. 2.—Typical installation of small type springs

the outer member is thereby firmly held in position under compression. The recommended deflection for all springs where the pitch of the rivet-centres is over 1 in. is 0·062 in. ± 0·010 in., whilst the deflection for most other types is is 0·047 in. ± 0·010 in., exception being made in the case of the small-type spring already referred to; the latter can be identified by the diameter of the wire, which is 0·09 in. and the rivet-centre pitch which is 1 in. The deflection of the small-type spring is 0·062 in. ± 0·010 in.

INSTALLATION

General

3. Care must be taken during the installation of DZUS-type fasteners to ensure that the correct type of spring is used in conjunction with the required types of catch, and that the information given in this paragraph for the determination of the correct length of fastener is followed closely. In instances where a defective fastener is to be replaced by a new one, the defective parts should be used as a guide to the size and shape of the replacement parts required. The length of the catch is measured from the lower edge of the locking slot to the upper surface of the head, for all flush-type fasteners, but to the underside of the head for round-headed fasteners (see fig. 3). The length of the catch for any particular application may be determined, in the majority of cases, by subtracting the deflection of the spring (para. 2, sub-para. (ii)) from the combined thicknesses of the plates and packing (where fitted) through which the catch passes, plus the thickness of the grommet, plus the height of the spring (see fig. 3); in the types of head which are bevelled or recessed on the underside, however, the thickness of the grommet should be omitted. If the calculated length of catch differs from the lengths of the nearest size available, the next larger size should be used, and shim-washers to the required thickness should then be inserted under the spring seats to bring the spring deflection to the recommended figure. The procedure adopted for fitting the various types of fasteners is described in paragraphs 4 to 7.

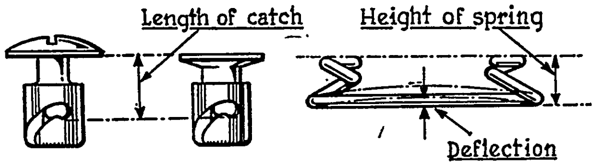

Fig. 3.—Primary dimensions of catch and spring

Equipment

4. For the purpose of installing DZUS-type fasteners special equipment is required for each particular type and the drifts and blocks used are illustrated in figs. 4 to 7. The drifts and blocks are of case-hardened steel and they should be struck when in use, with a wooden mallet or a lead hammer; under no circumstances should a steel hammer be used for this purpose or the drifts and blocks will be damaged. Round-headed aluminium rivets, $\frac{1}{8}$ in. diameter, together with drills of the sizes indicated in the following paragraphs, will also be required.

Fitting round-headed fasteners and springs

5. Two sizes of drifts and blocks are provided for use when fitting round-headed type fasteners of different diameters, four drifts and one block being used for each. Each block is machined on five of its sides to suit the various purposes for which it is used (see figs. 4 and 5). To fit round-headed fasteners and springs proceed as follows:—

(i) Drill a hole of the same outside diameter as the grommet, in the outer member, and then insert the grommet from the underside (see fig. 4, sketch I).

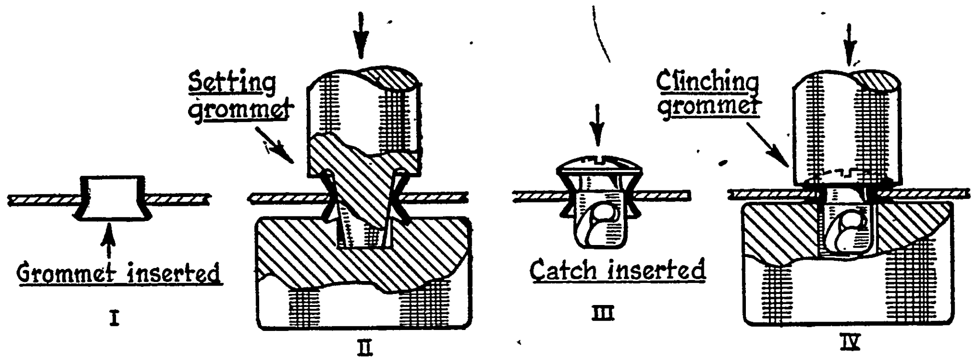

Fig. 4.—Operations for fitting round-headed catch

(ii) The grommet should then be partially set by means of a drift and block, as illustrated in sketch II, the set of the grommet being controlled by the depth of the hole in the block.

(iii) The catch should then be inserted in the grommet (see sketch III) and clinched by completing the set of the grommet by means of the drift and block illustrated in sketch IV.

(iv) The inner member, to which the spring is riveted, should then be drilled, due precautions being taken to ensure that the hole will register correctly with the catch; the diameter of the drill used should be of the same diameter as the sleeve of the catch.

(v) The inner member should then be countersunk by means of the drift and block, as illustrated in fig. 5.

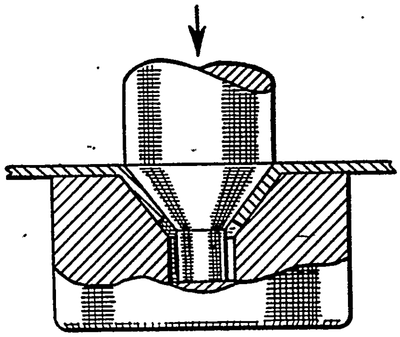

Fig. 5.—Forming countersink in inner member

(vi) The rivet holes for the spring should then be marked out and drilled $\frac{1}{8}$ in. diameter, ensuring during the operation that they are symmetrically placed with regard to the hole in the inner member which accommodates the fastener. Each rivet hole should then be countersunk on the upper side of the inner member by means of a $\frac{1}{4}$ in. diameter countersink.

(vii) The spring should then be riveted in position using two round-headed aluminium rivets, $\frac{1}{8}$ in. diameter, of sufficient lengths to enable the countersink to be completely filled when the rivet end is riveted over. The rivet ends remote from the head should then be filed flush with the surface.

Fitting flush-type fasteners and springs

6. The information given in this paragraph applies to both types of flush-fitting fastener. Three drifts and blocks are used, the essential difference between the separate drifts or blocks being in the included angle of the countersunk end. The particular type of drift and block required for the various operations are illustrated in figs. 6 and 7. It is intended that flush-type

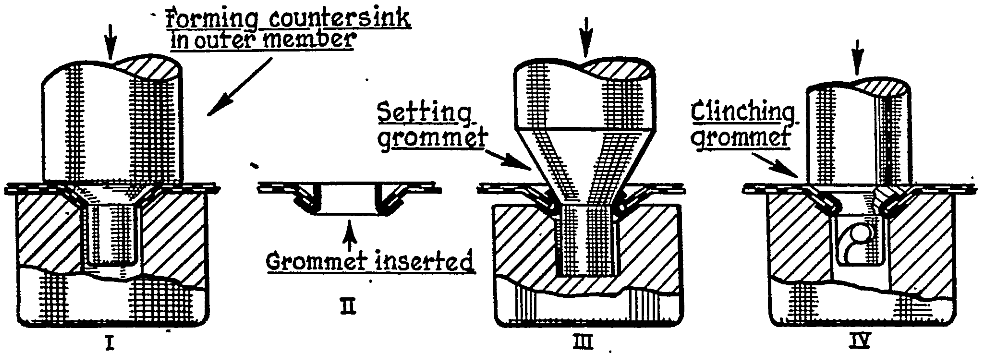

Fig. 6.—Operations for fitting flush-type catch

fasteners should be installed with the slot cut in the head of the fastener parallel with the direction of the slip-stream, and the slot is cut at various angles for this purpose. In order to fit flush-type fasteners and springs the following procedure should be adopted:—

(i) Drill a hole, $\frac{7}{16}$ in. diameter, in the outer member, which should then be countersunk by means of the type of drift and block illustrated in fig. 6, sketch I.

(ii) The grommet, which is of the type illustrated in sketch II, should then be inserted from the underside of the outer member and partly set, as indicated in sketch III. The set of the grommet is limited to the correct amount by the depth of the hole in the block, which is machined to give the required amount of set to the grommet.

(iii) The catch should then be inserted and clinched by the application of a few light blows with a mallet on a flat-nosed punch of the same diameter as the head of the catch, the outer member and grommet being supported in a block, as illustrated in sketch IV.

(iv) The procedure adopted for fitting the spring of flush-type fasteners is similar to that described for round-headed fasteners in para. 5, sub-paras. (iv) to (vii), except that the hole in the inner member should be drilled $\frac{7}{16}$ in. diameter and that the drift and block illustrated in fig. 7 should be used.

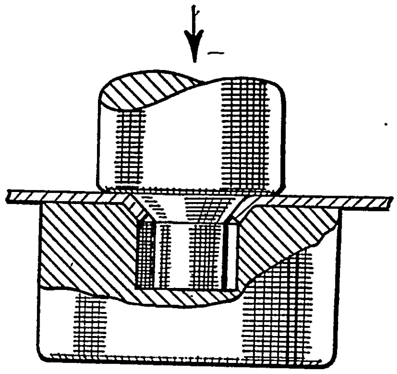

Fig. 7.—Forming countersink in inner member

Fitting wing-type fasteners and springs

7. The procedure adopted for fitting fasteners provided with wing-plates is the same as that described in paragraphs 5 and 6 for the same type of fastener without the wing-plate except that a block provided with a groove around its periphery is used during the clinching operations instead of the drift or punch illustrated in figs. 4 and 6 respectively. The sides of the block are hollowed out to suit the various types of fastener-head and the groove is provided to accommodate the wing-plate.

Removal of fasteners

8. If the catch is defective it should be replaced by a new one. To remove a defective catch the aluminium grommet should be cut away by means of a trepanning tool, which is kept centred during the cutting operations by means of the sleeve end of the catch. When the grommet has been completely cut through, the catch may easily be removed from the outer members; a new fastener should then be fitted in accordance with the information given in paras. 5 to 7. If a spring is distorted or broken it should be replaced by a new one of the same type. To remove a broken spring the rivets should be drilled out by means of an $\frac{1}{8}$ in. diameter drill and then the new spring should be riveted in position, as described in paras. 5 to 7. If a catch or spring shows signs of wear or is badly corroded it should be replaced by a new part of the same type, whilst loose spring rivets should be drilled out and new ones fitted. If a grommet is loose or free to rotate in the outer member, it should be reset, using the appropriate drift and block for the type of fastener held in the grommet or if there is any signs of wear, it should be replaced with a new one.

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AIR MINISTRY
May, 1944

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CHAPTER 4

ODDIE FASTENERS

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General

1. Oddie fasteners (see fig. 1) have been introduced to secure engine cowlings, fairing panels, and similar sheet metal components requiring repeated and rapid attachment and removal, without being subjected to undue wear or localised fatigue of the surrounding metal.

2. Each fastener comprises essentially, a central pin, a coil spring or rubber washer and a two-legged spring clip (see fig. 1).

3. The spring clip is riveted to the underside of the structure at the point where the fastening is to be made.

Description

4. The central stud is made of mild steel with a rustproof coating, and is available in standard and midget sizes, each in several lengths and with different types of head.

5. In all instances, the stud is undercut below the head to accommodate the rubber washer which retains the stud in its panel and absorbs vibration; the bullet-shaped end of the stud is recessed at each side to co-act with the spring legs, when in the locked position.

6. The heads may be of the following types:—

(i) *Slotted head,* generally used for panels from the engine cowling back to the tail plane fairing.

(ii) *Flush fitting head* can be used when in the airstream and a flush surface is required, namely the upper surface of a main plane, gun access doors on the upper wing surface, and various positions on other parts of the aircraft.

(iii) *Wing type* heads can be used for a large variety of applications, such as internal stowages on the aircraft, locker lids, etc.

7. Washers may be of two types:—

(i) Rubber, (ii) coiled spring.

The resilient watertight rubber washer is spaced between the panel and the mounting and is essential to reduce vibration and chattering to a minimum; the application of the coiled spring is similarly intended for positions where excessive heat is encountered.

8. Spring clips are held in position by two light alloy rivets, and are made from spring steel and are rustproofed. The spring clip legs engage with the flats on the stud, the leading ends of the spring acting as a guide on the bullet end of the stud.

Installation

9. It is important and essential that all installation data and dimensions are adhered to strictly in order that the correct functioning of the fasteners is ensured, and that the fasteners are used to the best advantage. It is essential to ensure that the correct alignment is obtained between the stud and spring clip.

10. The maximum dimensions given on the various assemblies (see subjoined Table) between the top face of the clips and the top or outer face of the panel, must not be exceeded on any account, and it is always advisable to keep on the minus side of these dimensions to obtain secure engagement of the studs in the spring clips.

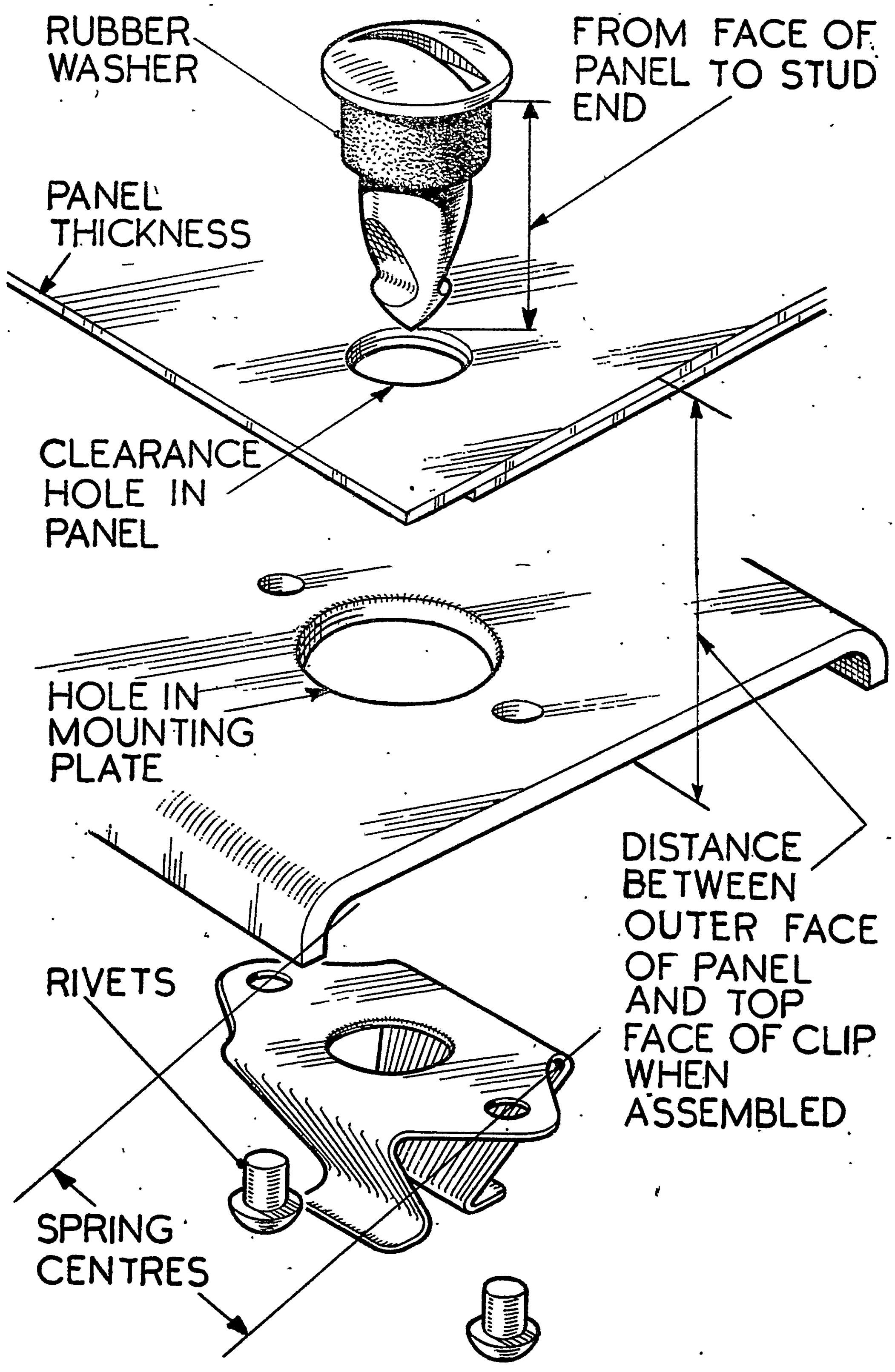

Fig. 1.—Exploded view of Oddie fastener

11. It should always be possible to engage the fasteners by finger-pressure only, and there must be a definite and audible "click" as the fastener engages, indicating that it is locked. If the "click" is not heard, then the installation is incorrect and the condition should be rectified.

12. The edge of a washer or similar device may be used to unlock the fastener by turning the head through 90°. When unlocked, it is advisable to turn the head 90° back again to its original position, ready for reassembly.

13. The essential dimensions for installation of various types of these fasteners are given in the Table.

Removal of fasteners

14. To remove the stud from its mounting, the rubber washer at the inner side of the panel should be removed, the stud will then be easily slipped out. In order to remove the spring clip, the rivets in the structure should be drilled out and new rivets and spring clips fitted, using the same rivet holes.

TABLE OF DIMENSIONS
(Oddie fasteners)

DESCRIPTION (see Fig. 1)	MIDGET		STANDARD	
	DOME HEAD	FLUSH HEAD	DOME HEAD	FLUSH HEAD
Panel thickness	0·065 in.	0·065 in. dimpled 0·10 in. max.	0·10 in.	0·10 in. dimpled 0·15 in. max.
Clearance hole in panel	$\frac{1}{4}$ in. dia.	$\frac{1}{4}$ in. dia.	$\frac{3}{8}$ in. dia.	$\frac{3}{8}$ in. dia.
Hole in mounting plate	$\frac{15}{32}$ in. dia.	$\frac{15}{32}$ in. dia.	None	None
Radiused hole in mounting plate ...	None	None	$\frac{5}{8}$ in. dia.	$\frac{5}{8}$ in. dia.
Distance between outer face of panel and top face of spring clip when assembled	0·17 in. max.	0·24 in. max.	0·26 in. max.	0·34 in. max.
Dia. of light alloy rivets for spring clip	$\frac{3}{32}$ in.	$\frac{3}{32}$ in.	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.
Recommended pitch of fasteners per inch run	2 in. to 4 in.	2 in. to 4 in.	6 in. to 10 in.	6 in. to 10 in.
Distance from top face of panel to end of stud	0·70 in.	0·77 in.	0·95 in.	1·04 in.
Distance of rivet hole centres ...	0·69 in.	0·69 in.	1·000 in. min. 1·062 in. max.	1·000 in. min. 1·062 in. max.

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Chapter 5 . . . ALL-METAL STIFFNUTS

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Introduction

1. This chapter gives information on the various metal stiffnuts used on aircraft. It includes an account of their function and a description of the nuts and their anchorages, followed by some general notes on usage.

2. A stiffnut is a nut provided with means whereby the friction between the thread of the nut and that of the standard bolt on which it is mounted is so increased that the nut may be considered self-retaining. There is necessarily a certain amount of play between the threads of an ordinary nut and a bolt owing to the manufacturing tolerances. A stiffnut, however, is so constructed that on the body of an ordinary nut is superimposed a locking device of some sort which grips the thread of the bolt and holds it firmly. As the name implies, the nut is stiff and hard to turn once the thread of the bolt engages with the locking device.

3. There are, broadly speaking, two types of stiffnut—the fibre insert nut, and the newer, all-metal nut. Stiffnuts may be simple hexagon nuts or they may be provided with anchor plates which are held by rivets to the component. The nuts may be either fixed or floating in the anchor plates and are more commonly used with screws than with bolts.

4. Stiffnuts are largely used on aircraft for attaching panels which have to be removed frequently for inspection or other purposes. For instance, access to the fuel tanks is obtained by the removal of wing panels which are held in place by rows of stiffnuts anchored behind the panel mounting. The all-metal nuts can be used at any temperature up to +500° C. and are unaffected by oil or by any fluid employed in the aircraft.

5. Stiffnuts are made in brass, mild steel, and light alloy. The brass nuts are mostly used for electrical work.

General description

6. The nuts have an addition on the top constituting the locking device, which usually consists of one or more threads which are de-pitched by about 50 per cent. As the bolt is inserted, therefore, the locking part is forced away from the main part of the nut and so grips the bolt threads tightly.

7. The all-metal stiffnuts, (Stores Ref. 28M/–) which are interchangeable among themselves, are as follows:—

(i) SIMMONDS' PINNACLE NUT.—The nut, (*see fig. 1*), has a cap of spring steel which engages with the thread on the bolt and is forced upwards by it.

(ii) ODDIE STIFFNUT.—The nut, (*see fig. 2*), is similar in action to the Pinnacle nut, but instead of having a spring steel cap fitted at the top, each side of the hexagon is extended and bent inwards to form a claw. The six claws form a circle of slightly smaller diameter than the thread of the bolt, against which they jam themselves.

(iii) PHILIDAS NUT.—The nut, (*see fig. 3*), is made with a circular crown in which two slots are milled one above the other with an arc of about 270°. The wings thus formed are de-pitched to provide the locking tension.

(iv) G.K.N. AEROTIGHT NUT.—The nut, (*see fig. 4*), is made with a circular crown which is slit across its diameter, slotted each side through about 150° and then de-pitched. In addition

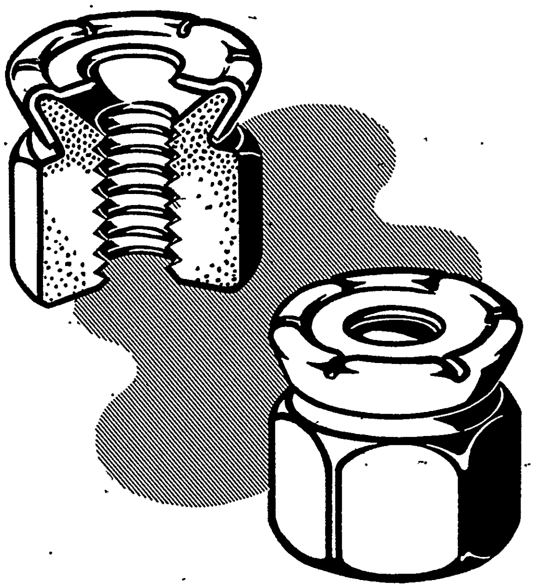

Fig. 1.—Simmonds pinnacle nut

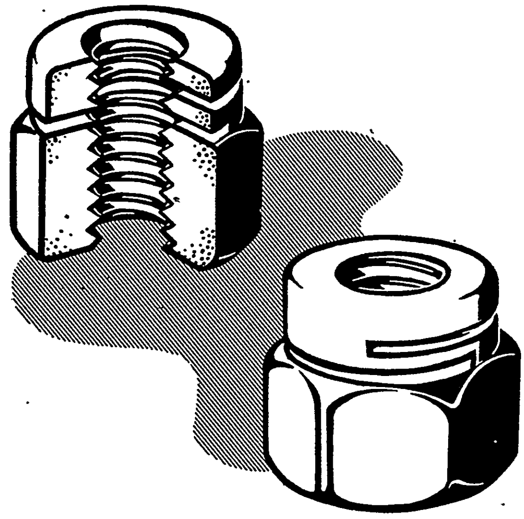

Fig. 3.—Philidas nut

to being de-pitched, the wings are forced inwards radially, so that there is a sideways as well as a downwards tension on the bolt.

Protective coating

8. The steel nuts are all zinc or cadmium plated except for the Philidas nut, which is Walterized, and dyed black; Walterization is a treatment based on a phosphate dip. For purposes of identification, some G.K.N. Aerotight nuts are tinted blue, indicating that they are light alloy nuts. Brass nuts have no protective coating.

Clinch nuts

9. Clinch nuts, see fig. 5, are normal stiffnuts which are mounted on their support by a flange at the bottom of the nut. The flange passes through a countersunk hole and is expanded by clinching tools as shown in fig. 6.

Anchor nuts

10. Some typical anchor plates and anchor cages are shown in fig. 7. The anchor plates are riveted on the back of the component and hold the nut so that the bolt or screw can be inserted from the front. The nut may be either fixed or floating in the anchor cage. A double anchor plate is one which is secured on

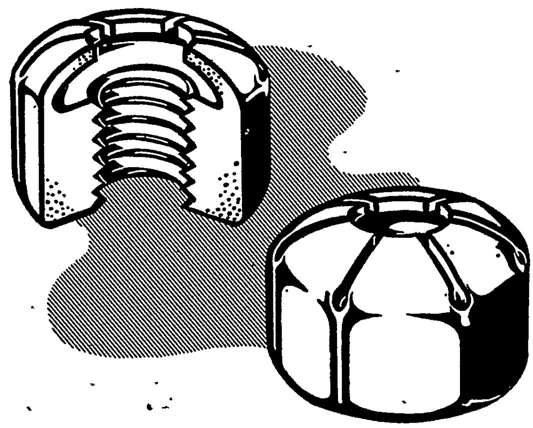

Fig. 2.—Oddie stiffnut

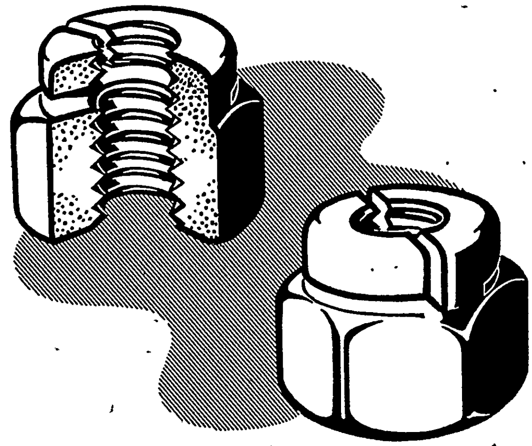

Fig. 4.—G.K.N. Aerotight nut

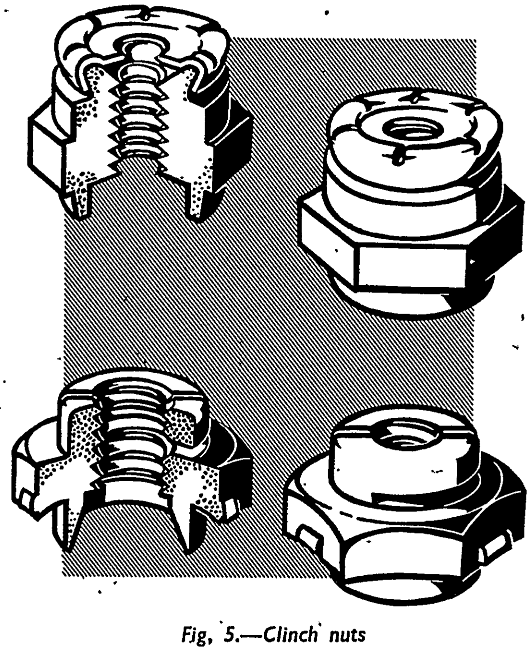

Fig. 5.—Clinch nuts

its support by two rivets while a single anchor plate is held by only one rivet. Anchor plates are made for both standard and thin hexagon nuts and consist of a metal plate to which the nut is fitted before the plate is riveted to its support.

Floating strip

11. Instead of attaching single nuts to the component, it is sometimes more convenient to use strip, on which the nuts are mounted in a row at a fixed distance apart. As shown in fig. 8, the nuts are fitted to plates which are assembled in a strip of sheet metal. The nuts have a slight amount of free movement to allow for a small margin of error.

Thin nuts

12. The range of anchor plates and cages for the thin hexagon nuts are similar to those for the standard nuts. The thin nuts are used for shear bolts only.

Notes on usage

13. The nuts can be used almost indefinitely, but as soon as the operator does not feel a reasonable torque when the bolt or screw is inserted, the nut should be renewed. On any size above 2 B.A., the nut should be more than fingertight if it is to be used again. The light alloy nuts and bolts are the quickest to wear and require most frequent renewal.

14. When a nut is discarded it should be replaced by one of the same material and having the same type of anchorage. The all-metal stiffnuts are interchangeable except for the clinch nuts. The thin hexagon nuts should only be used for shear bolts.

15. The bolt or screw which is inserted in the nut should not have a damaged thread, and there should be 1½ clear threads showing above the top of the nut.

16. Under no circumstances should the nut be tapped out before use.

17. If the wings of a Philidas or Aerotight nut snap owing to faulty material, the nut must be discarded and a new one used. The wings are liable to snap as the bolt is screwed in or even after assembly owing to vibration.

18. No attempt should be made to restore the locking properties of the nut by hammering the wings down or squeezing them together.

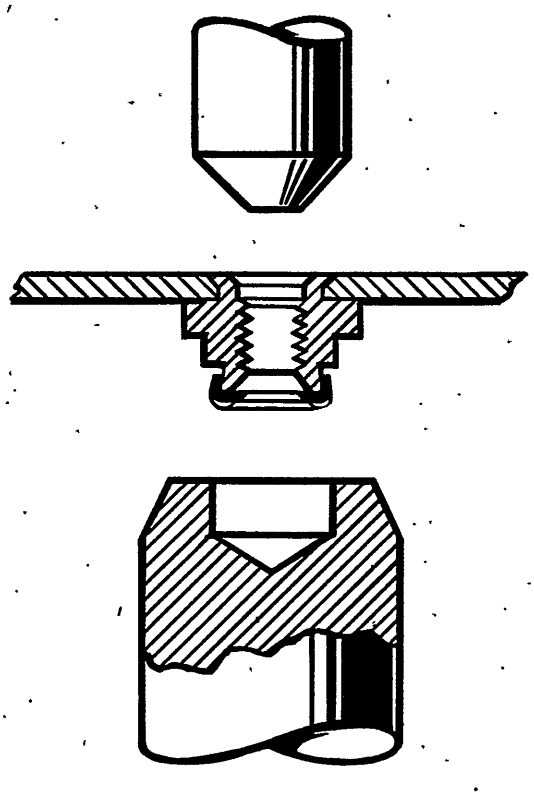

Fig. 6.—Clinching tools

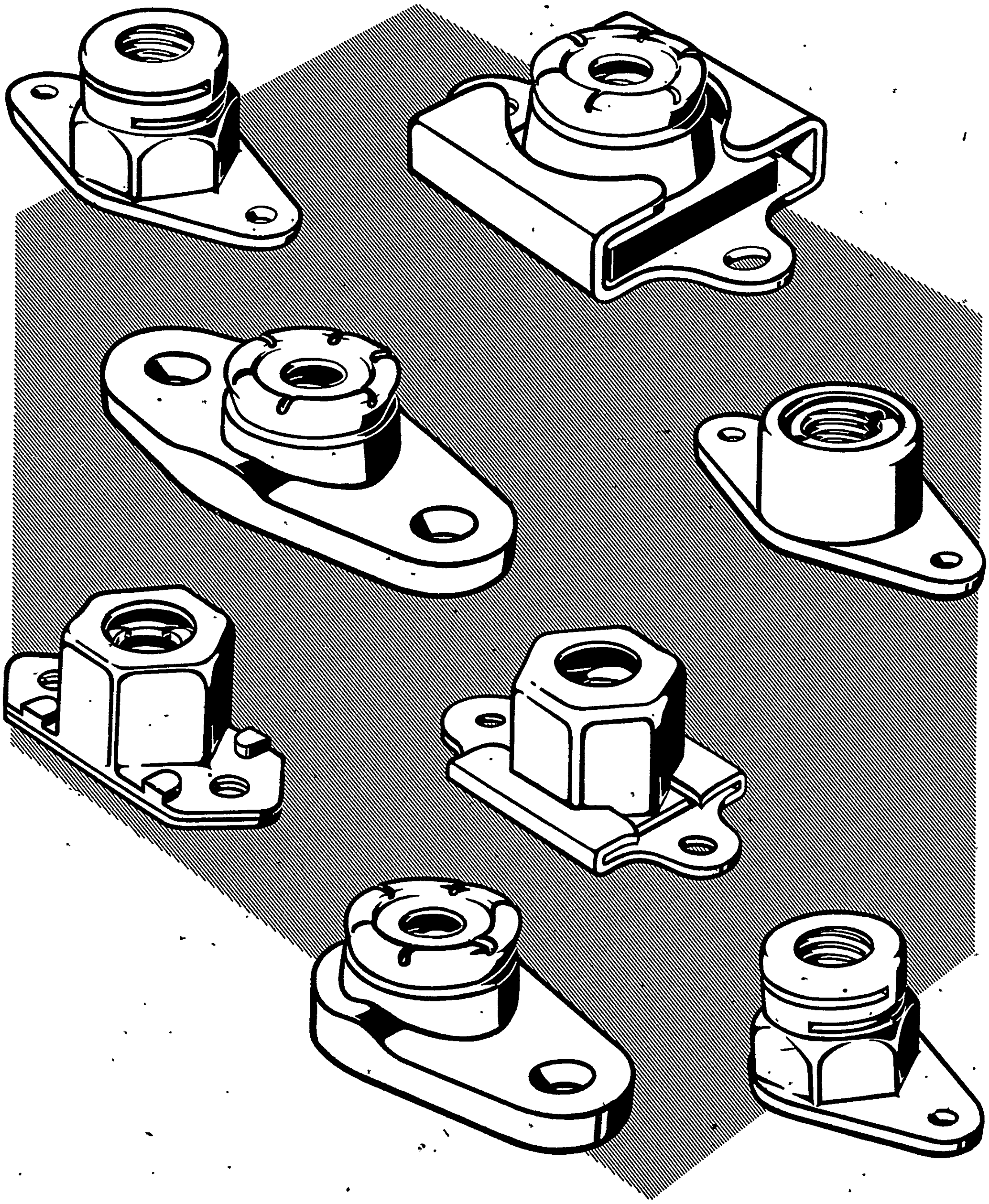

Fig. 7.—Some typical anchorages

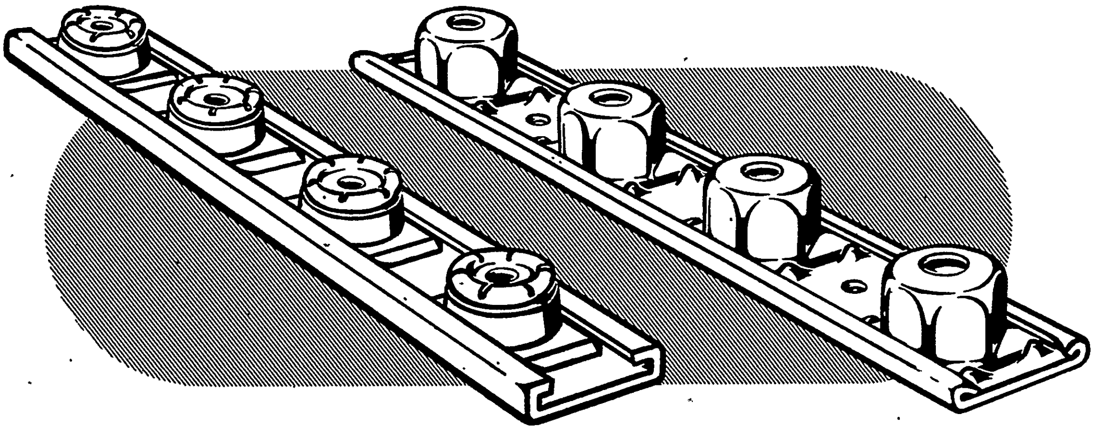

Fig. 8.—Floating strip

Clinch nuts

19. If a clinch nut turns as the bolt or screw is inserted, the nut should be removed and replaced by a new one of the same type. This is necessary because for any given size of nut the diameter of the hole required in the component varies with the type of nut.

Anchor nuts

20. Before an anchor nut is scrapped as having lost its gripping power, it should be tried with a new bolt or screw, because, often when there is no appreciable torque, it is due to the bolt's being undersize or worn and not to the inefficiency of the nut.

Floating strip

21. Owing to the fact that in the past some strip was made of metal of too light a gauge metal, the nut was pushed right through the strip, when the screws were put back. Care should be taken, therefore, not to press too hard on the screwdriver. If one nut of a strip is pushed out the whole strip should be renewed.

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