Birla Central Library
PILANI (Jaipur State)
Class No :- 744.06213
Book No :- G292I V.1
Accession No :- 29229

AN INTRODUCTION TO
ELECTRICAL DRAWING

IN TWO PARTS

BY

E. H. H. GIBBINS
B.Sc.(Hons.) (Lond.)

PART I

BLACKIE & SON LIMITED
LONDON AND GLASGOW

BLACKIE & SON LIMITED
66 Chandos Place, London
17 Stanhope Street, Glasgow
BLACKIE & SON (INDIA) LIMITED
Warwick House, Fort Street, Bombay
BLACKIE & SON (CANADA) LIMITED
Toronto

First published 1928
Reprinted 1929, 1932
New edition 1937
Reprinted 1942, 1945

Printed in Great Britain by Blackie & Son, Ltd., Glasgow

PREFACE

A large number of Electrical Engineering students receive the same instruction in engineering drawing as those who are to become Mechanical Engineers. This is often a matter of convenience, especially as there are only a few authorities who set examinations in Electrical Drawing. Moreover, there are, no doubt, good reasons for Electrical Engineering students becoming familiar with mechanical details and using them as drawing exercises. At the same time there are teachers and students who, for various reasons, may desire to have a set of drawing exercises based upon modern Electrical Engineering practice, and it is for such that the drawings in this book have been collected.

It is assumed that the student has already received some instruction in plane and solid geometry, and is able to proceed at once to the representation of solids by their projections. Both the first quadrant and the third quadrant methods of projection are described, but the former is used throughout, with the exception of figs. 5 and 6, page 47.

As most students have difficulty in visualizing an object from its orthographic projections, many of the details are shown by isometric views. Notes are added to assist in obtaining a correct idea of the form and function of the parts and to give some account of factors which influence the design.

The drawings represent fittings which are manufactured by various firms of Electrical Engineers, and specific reference is made to these firms in the text.

In conclusion, the author wishes to thank all those firms which have been good enough to furnish information for the preparation of the drawings, and the names of which are included in the letterpress. Thanks are also due to Mr. B. J. Chubb, F.C.P., and Mr. W. Abbott, B.Sc., A.M.I.Mech.E., for their assistance in reading the proofs.

E. H. H. G.

H.M. DOCKYARD SCHOOL,
DEVONPORT,

CONTENTS OF PART I

PROJECTION

Instruments and Materials.—In order to work the given exercises the following instruments and materials will be required. A drawing board to take paper of half imperial size (22″ by 15″), T-square, with 24″ blade, 45° and 60° set squares, protractor, compasses, dividers, and pencils. For small circles spring bows will be found useful. An ordinary 12″ boxwood scale with inches divided into sixteenths and tenths, and with millimetres, may be used for measurements, but it is much better to provide suitable fully divided scales for the scales most generally employed.

Projections.—Objects are represented by their projections on planes mutually at right angles. Fig. 1 represents a cable-end provided with a 1″ diameter hole for sweating-in the end of a cable, and with a ¾″ diameter hole for bolting to a terminal. In the pictorial view the cable-end is represented as being partly cut away at the bottom, so that the hole can be seen. Fine lines, called projection lines, show how the object is projected on to the three planes. The projection on to one vertical plane is called the **Front Elevation** or **Side Elevation;** the projection on to the other vertical plane is called the **End Elevation** or **End View,** and the projection on to the horizontal plane is called the **Plan.** When the planes containing the end elevation and the plan are turned about until they are in the same plane as the side elevation, the projections will be in the positions shown in fig. 2. The positions are such that a point in one view can be projected into either of the others. Such representation is called **Orthographic Projection.** An object cannot be completely represented by one view; at least two, and sometimes three or more, are necessary. Widths in one direction and heights can be obtained from the side elevation, but the circular shape of the part to take the bolt cannot be seen without the end view. As far as can be seen from these two views, the part into which the cable is sweated might be square, but the plan shows it to be circular.

Procedure.—If there is symmetry about any part a centre line is drawn; centre lines and base lines are the first to be made in a drawing. Wherever possible, circles are drawn before straight lines, but the centres of all circles must be marked before the circles are attempted. It is not desirable to complete one view before commencing another, but all views are advanced together. Beyond this no definite rules can be laid down.

Lines.—The types of line to be used are shown on the opposite page. The outline is lined-in so that it shows in contrast to construction and other lines. Continuous thin lines are used for centre lines, and projection lines. Dotted lines are reserved for parts hidden from view. Where it is necessary to make offsets for dimension lines, broken (not dotted) lines may be used. Dimension lines are continuous, except where they are broken for the dimension, and their ends are clearly shown by arrow heads.

Dimensions.—Wherever possible dimensions are taken clear of the drawing. Sometimes all dimensions are placed vertically, but many draughtsmen place the numeral at right angles to the dimension. It is usual to give all the dimensions on a drawing in the same units: if one dimension is given as 2′ 3″, another should not appear as 22″, and, except in a few cases, inches and centimetres should not appear on the same drawing.

Many of the drawings shown in the following pages are isometric or picture views; they are to serve as models, and to assist in visualizing the object. They should not be copied.

EXERCISE

Copy the views shown and project another end view, looking from the right; this view should be placed on the left of the side elevation. Scale: full size

The British Standards Institution have issued "Recommendations for British Standard Engineering Drawing Office Practice (B.S.S. 308)" in which there is some slight difference in the type of line.

PROJECTION

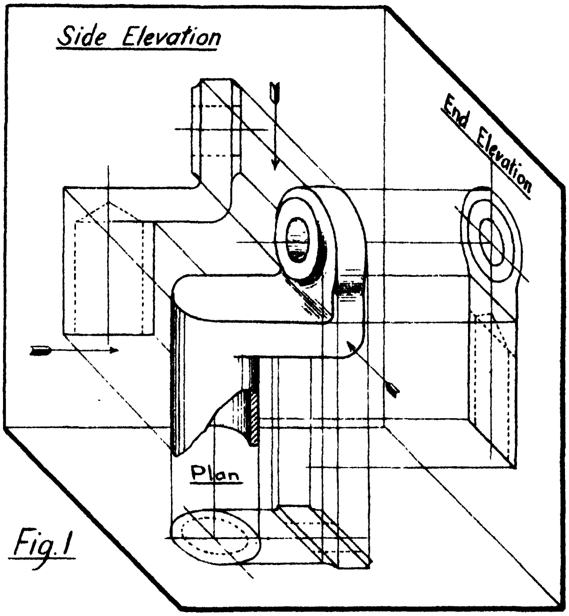


Fig. 1

Lines to be used

Outline
Hidden line
Projection line
Offset for dimension
Dimension line
Centre line

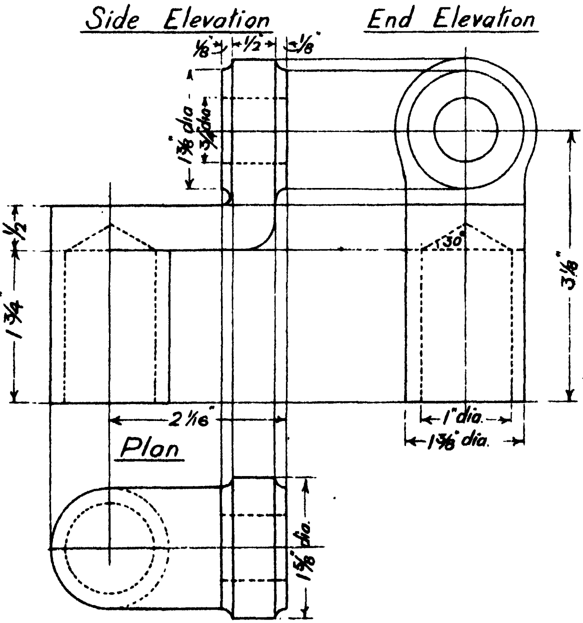


Fig. 2

Fig. 3

Fig. 4

Other Methods of Projection.—The planes of reference may be extended in every direction so as to form four quadrants. In the previous case the object was placed in front of the vertical plane and above the horizontal plane; that is in the first quadrant. Suppose now the object is placed behind the vertical plane and below the horizontal plane, that is in the third quadrant. Fig. 1 shows a soft-iron armature placed in such a position. Suppose the planes are transparent and that the object is traced on the planes as it would appear if viewed through them normally. We thus obtain a plan and an elevation, and if a third plane is taken at right angles to the others, we get an end view. But when these planes are turned into a single plane as before, the plan comes above the elevation (figs. 2 and 3), and the end view, looking towards the left, is on the right of the elevation (fig. 4). This is known as **Third quadrant projection,** and is the method adopted by a number of firms. In many drawing offices modifications of these methods are used; for instance, many put the plan beneath the elevation, and the end view looking towards the left is placed on the right. It is sometimes convenient to place the end views in this way when the object is very long, as this avoids the necessity of looking right across the elevation to see the shape of the end. Although perhaps the first method is most commonly used in Britain, it does not matter what method is adopted, as long as the drawings are perfectly clear and cannot cause confusion to those who may have to use them.

Sections. — The example of the lever is another illustration of third quadrant projection. This also shows the use of sections. There are cases when the plan, elevation, and end views do not show sufficiently the exact form of the part represented, and sectional views are used to give the additional information. There are two ways of showing these sections: the section may be drawn about the line of section produced (fig. 8), or a projection may be made imagining part of the solid to be cut away at the line of section (fig. 9). The latter is really a sectional elevation, and shows not only the actual section, but also all that can be seen of the solid beyond the section. Whereever a sectional view is shown, the section is indicated by drawing section lines over the area. Section lines are inclined at 45°; fine lines should be used and they should be drawn close together, but in drawing-office practice time forbids the latter. No actual distance between the lines can be given, as this depends upon the area to be sectioned. Cylindrical parts, such as bolts, rods, rivets, &c., are not sectioned if the section is taken through the axis; the bolt or rod is then shown in elevation (see fig. 4, p. 29). Sometimes all the information can be given in one view; for example, Fig. 10 is an elevation of a porcelain reel insulator, with the left-hand half in elevation and right-hand half in section. This method is very often used when the part to be represented is symmetrical about a centre line, as it avoids drawing separate elevation and section. When an object is long and of uniform section or uniformly changing section, it is sometimes cut and the middle part removed. This method is used in order to save space. The lever (figs. 5 and 6) is shown in this way.

EXERCISES

(1) Draw the views shown of the soft-iron armature. Use third quadrant projection. Scale: twice full size.

(2) Draw the views shown of the lever. Place the plan beneath the elevation, but project the end views as shown. The section (fig. 8) should be drawn between the elevation and plan. Scale: twice full size.

(3) Draw an elevation of the reel insulator, showing the left-hand half in section, and the right-hand half in elevation. Project a plan of the insulator. Scale: twice full size.

PROJECTION

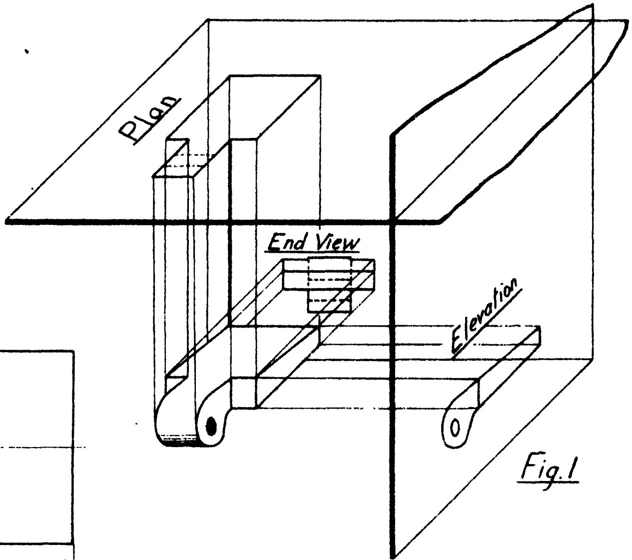


Fig. 1

Soft Iron Armature

Scale,- full size

Plan

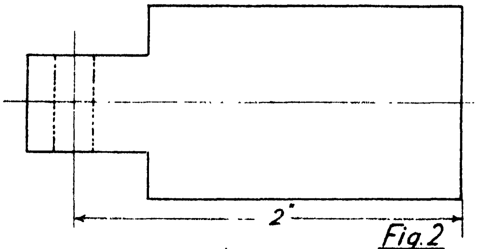


Fig. 2

Elevation

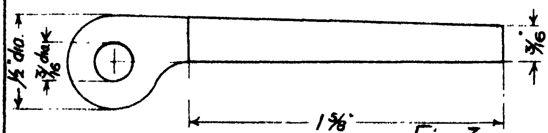


Fig. 3

End View

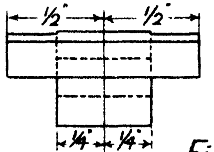


Fig. 4

Lever

Scale,- half full size

Plan

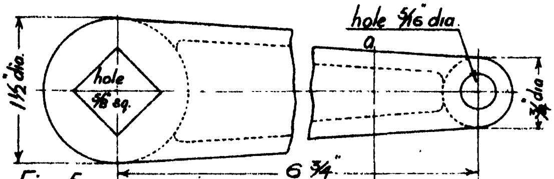


Fig. 5

Section at a.a.

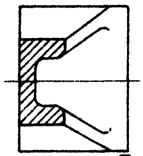


Fig. 9

Elevation

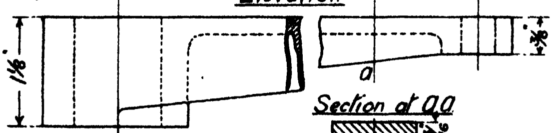


Fig. 6

Section at a.a

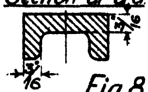


Fig. 8

End View

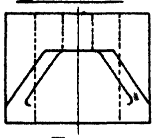


Fig. 7

Reel Insulator

Elevation (part section)

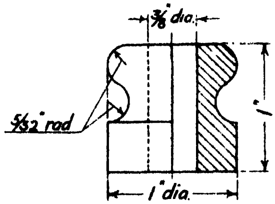


Fig. 10

Spirals.—If a smooth cylinder rotate about its axis and a pencil is held against it and moved uniformly parallel to the axis, a spiral is traced on the cylinder. If, instead of the pencil, a tool is used which removes some of the material, a screw thread is formed. Screw threads may be represented by a number of spirals.

The True Elevation of a Spiral.—If the axis is vertical the plan of a spiral is a circle and the elevation is obtained as follows. Draw the plan of the circle (a semicircle, as shown, is sufficient) and the elevation of the axis (fig. 1). Draw a horizontal line to mark the base of the spiral and set off along the axis a length equal to the distance from any point on the spiral to the corresponding point on the next turn; this distance is called the *pitch*. Divide this distance into a number of equal parts by horizontal lines. Divide the circumference of the circle into the same number of equal parts (eight in the fig.). Suppose the spiral commences at (0). If a point on the spiral makes ⅛ revolution it will have travelled parallel to the axis a distance equal to ⅛ the pitch and will therefore be on the line (1). Project the point (1) in the plan into the line (1) in elevation; this gives the elevation of a point on the curve. In the same way if (2) in plan is projected into line (2) in elevation, the elevation of another point is obtained. Proceeding in this way a series of points is obtained and the elevation of the spiral is a fair curve through these points. By setting off equal distances along the axis the process may be repeated and any number of turns may be drawn. If the spiral is on the surface of a cylinder only the portion in front will be shown by a full line, the remainder will be dotted. Spirals may be either right-handed or left-handed according to the direction of rotation. Fig. 1 also shows a second spiral of equal pitch but of smaller diameter.

True Elevation of Springs and Screws.—A spring of square section may be represented by four spirals, one for each corner of the square. The spirals are drawn as already described. Thus, fig. 2 is obtained from fig. 1 by drawing two more spirals above those already shown. The spirals should be drawn in fine lines and then the parts required carefully lined-in. Special care must be taken to select the right lines to line-in.

The true elevation of a screw thread is shown in fig. 3; this is obtained from four spirals as for the spring, but the lining-in is different. It can be seen that the spiral spring in fig. 2 could be made to fill the groove on the cylinder in fig. 3. The depth of thread is in most cases equal to half the pitch, so that fig. 3 represents a very coarse thread; such a thread is used when a second thread is to be cut in between the parts of the first so as to form a double-threaded screw. Fig. 4 shows a vee thread; this is represented by the spirals at the top and bottom of the vee.

Conventional Methods of Representing Springs and Screws.—Figs. 5 and 6 show right-hand and left-hand spiral springs in which the curves are replaced by straight lines. Figs. 7 and 8 show right- and left-hand vee threads with straight lines replacing the spirals. Fig. 9 represents a spiral spring of circular cross-section; the circles should be drawn first and the straight lines drawn tangentially. A square-threaded screw is shown in fig. 10. Figs. 11 and 12 represent the method most frequently used to represent vee thread screws. In drawing this care must be taken that the alternate thin and thick lines are given at the correct inclination. It should be noted that one end of a thin line is exactly opposite the mid point between the ends of two adjacent thin lines on the other side. Figs. 13 and 14 show sections through nuts with right-handed threads; it should be observed that the threads behind the section will be visible and inclined in the opposite direction to those in the front.

EXERCISES

(1) Draw a spiral spring made of material ½″ square having external diameter of 2½″, and pitch 1½″. Show two complete turns. Scale: full size.

(2) Draw a square thread ½″ deep and 1½″ pitch on a cylinder of diameter 2½″. Show two turns. Scale: full size.

(3) Copy fig. 9 for a spring made of ½″ diameter rod, having a pitch of 1″ and external diameter 2½″.

(4) Use the conventional methods to draw the examples 1 and 2.

(5) Draw vee threads by the methods illustrated in figs, 7, 8, 11, and 12 for screws ⅜″ diameter and $\frac{1}{10}$″ pitch.

SPRINGS & SCREW THREADS

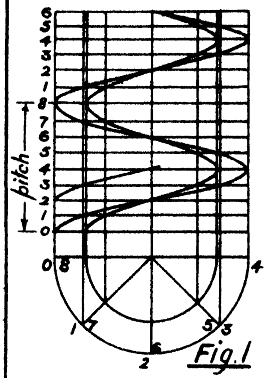


Fig. 1

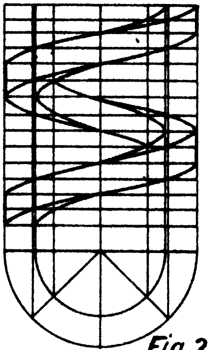


Fig. 2

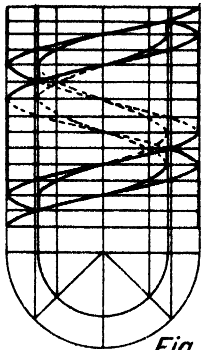


Fig. 3

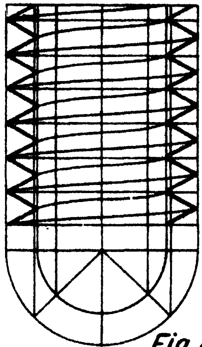


Fig. 4

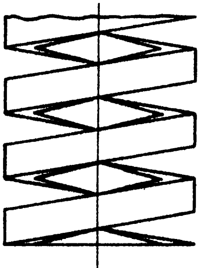


Fig. 5

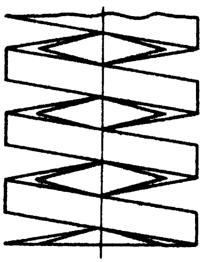


Fig. 6

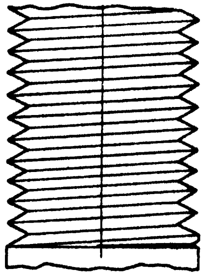


Fig. 7

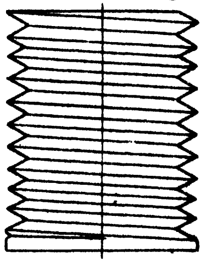


Fig. 8

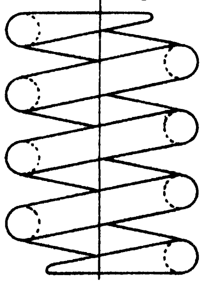


Fig. 9

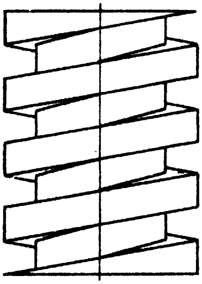


Fig. 10

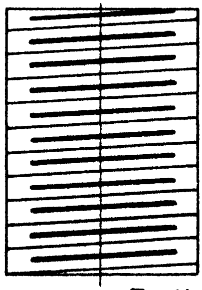


Fig. 11

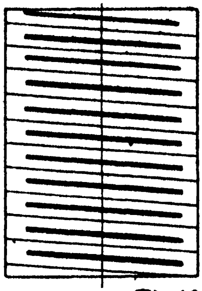
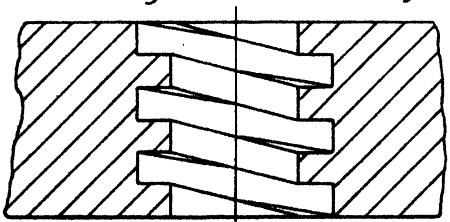


Fig. 12



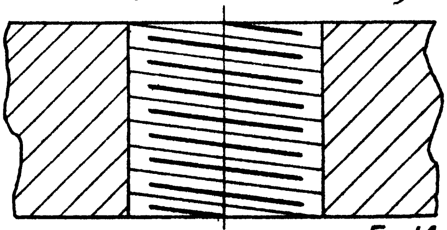


Fig. 13 Sections of nuts for right handed screws Fig. 14

Forms of Screw Threads.—Screw threads vary in form and pitch. In addition to the square and vee threads there are, for instance, buttress threads which are used for pressure in one direction only, and Sellers threads.

Vee threads are those most commonly used in electrical engineering. These may be of the form and pitch suggested by Sir Joseph Whitworth and known as **Whitworth threads**, or the **British Association threads.** Sometimes none of the standard types are suitable and a special screw is made; usually the Whitworth form is used but the pitch is altered. The diagrams, figs. 1 and 2, on the opposite page show the standard forms of Whitworth and British Association (B.A.) threads. The form of thread is constant for all diameter screws, but the pitch varies with the diameter. The tables show the values of the pitch and the core diameter for screws of various external diameters. In Specifications Nos. 92 & 93 of the British Standards Institution, values of pitch, &c., are given for Whitworth threads from ¼" to 6" diameter, and for B.A. threads from ·25 mm. to 6 mm. diameter.

The specification also contains details of the Whitworth fine screw threads; these threads have the Whitworth form but the pitch is in every case smaller than that for standard Whitworth threads of corresponding diameter.

Bolts and Nuts.—Figs. 3, 4, 5, and 6 show the standard form of hexagonal-headed Whitworth nuts and bolts, recommended by the British Standards Institution. For the bolt head the width across the corners of the hexagon is equal to twice the diameter of the bolt and the depth of the head is ⅞ the diameter of bolt. The edge is chamfered at an angle of 30°, so that the tops of the flat faces appear as curves. The nut has a depth equal to the diameter of bolt, otherwise the dimensions are the same as for the bolt head. It should be noted that in one elevation of the nut or bolt three faces are seen, but in the other elevation only two appear. The actual width of each face is equal to the diameter of the bolt. The dimensions are shown in the orthographic views.

Sometimes bolts are made with square heads; in this case the edge of the square is the same as the width over the flats for a hexagonal nut, and the depth of the head is equal to the diameter of bolt. If the head of the bolt cannot be held whilst the nut is being tightened a part of the shank is sometimes made square in section to fit a square hole. The length of the square part is approximately equal to the diameter of the bolt. Examples of such bolts are seen in the cable box (fig. 4, p. 23). In some cases it is not convenient to use a bolt with a square neck; but it is sometimes possible to prevent the bolt turning by driving a short pin into the bolt close up to the head and making a slot to fit the pin in the part through which the bolt passes.

EXERCISES

(1) Draw three views of a Whitworth bolt with hexagonal head. Diameter of bolt, 1¼"; length of bolt, 3¼". Represent the thread in the conventional way shown in figs. 4 and 5. Scale: full size.

(2) Draw elevation and end views of a Whitworth bolt and nut. The bolt is 1½" diameter and 4" long, and has a square neck to prevent it turning. Scale: full size.

Information on pages 12 to 15, taken from the British Standard Specifications, has been extracted by permission of the British Standards Institution from its Specifications, No. 57–1920, Heads for British Association Screws; and No. 190–1924, British Standard Whitworth Bright Hexagon Bolts, Set-screws and Nuts, Split-pins, Washers and Studs, Official Copies of which can be obtained from the Offices of the Institution, 28 Victoria Street, Westminster, S.W.1. Price *2s. 2d.* each, post free.

SCREW THREADS, NUTS & BOLTS

Whitworth

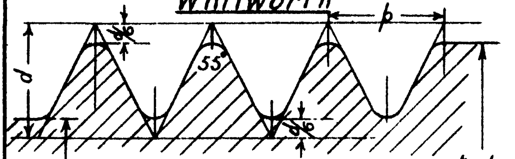


Fig. 1

British Association

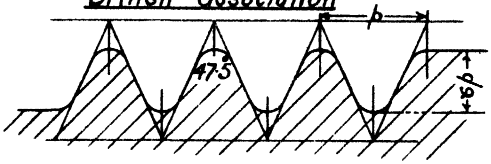


Fig. 2

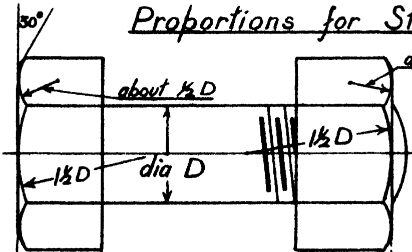
Table for Whitworth screw threads

Outside or full diameter in inches	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2
Number of threads per inch	20	16	12	11	10	9	8	7	7	6	6	5	4 1/2	4	4
Pitch decimals of an inch	·05	·06	·08	·09	·10	·11	·13	·14	·14	·17	·17	·20	·22	·25	·25
Minimum or core diameter at bottom of thread	·19	·30	·39	·51	·62	·73	·84	·94	1·07	1·16	1·29	1·49	1·72	1·93	2·18

Table for British Association screw threads

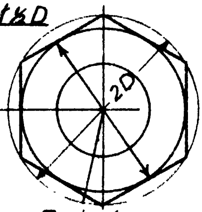
Designation	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Outside or full diameter in millimetres	6·0	5·3	4·7	4·1	3·6	3·2	2·8	2·5	2·2	1·9	1·7	1·5	1·3	1·2	1·0
Pitch m.m.	1·0	·9	·81	·73	·66	·59	·53	·48	·43	·39	·35	·31	·28	·25	·23
Minimum or core diameter at bottom of thread. m.m.	4·8	4·2	3·7	3·2	2·8	2·5	2·2	1·9	1·7	1·4	1·3	1·1	·96	·9	·72

Proportions for Standard Whitworth nut & bolt



Side View

Fig. 4



End View

Fig. 6

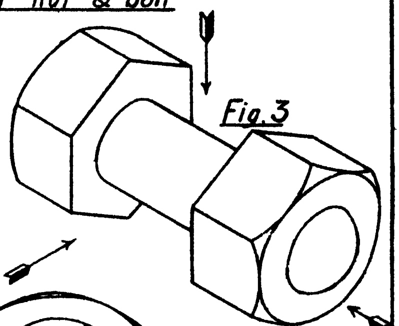
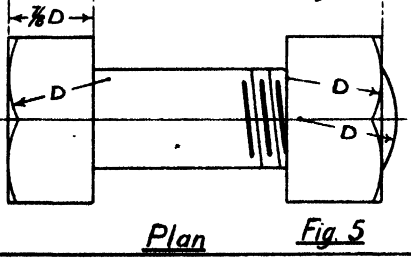


Fig. 3



Plan

Fig. 5

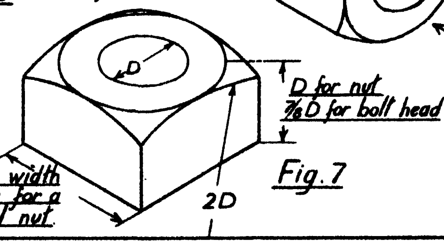


Fig. 7

Figs. 1, 2, 3, 6, and 7 on p. 15 show the standard proportions for the heads of some of the most commonly used screws. These proportions are extracted by permission from the report of the British Standards Institution.

Fig. 1 is a cheese-head screw. Diameter of head, W = 1·75D; depth of head, A = ·75D; width of saw cut, S = ·2D + ·1 mm.; depth of saw cut, N = ·375D.

Fig. 2 is a countersunk head screw. W = 1·75D; T = ·375D; Q = ·05D + ·1D; K = ·22D approximately; S = ·2D + ·1 mm.

Fig. 3.—Round head. W = 1·75D; B = ·8D; U = ·8D; M = ·4D; S = ·2D + ·1 mm. V = (1·75D − 1·6D) = ·15D.

Fig. 6.—Filister. W = 1·75D; A = ·75D; C = ·2D; R = ·2D; O = ·475D; S = ·2D + ·1 mm.

Fig. 7.—Instrument. W = 1·75D; T = ·375D; C = ·2D; Q = ·05D + ·1 mm.; R = 2D; L = ·31D approximately; S = ·2D + ·1 mm.

Fig. 4 is an elevation of a set screw. The point is cut at an angle of 60° to the axis. The length of the screw is such that its top is flush with the material through which it passes.

Fig. 5 represents the type of screw which is fitted as a plug to filling holes. Such screws are seen in the cable box illustrated on p. 23 (figs. 4 and 5). It is provided with a square portion at the top so that the screw can be turned with a spanner. In cases where it is not desirable to have a projecting head a square recess or slot is formed so that the plug can be turned with a wrench.

Fig. 8 represents a round nut with a portion of its surface milled or knurled so that it can be rapidly turned by hand. The slot at the top is to enable the nut to be made tight by a key.

A butterfly nut is shown in figs. 9 and 10. These nuts are used where they have to be frequently removed by hand without the aid of a spanner.

Methods of Locking Nuts.—It is often necessary to prevent a nut slacking back due to vibration, and there are several methods of doing this. Three common methods are shown on the opposite page. In fig. 11 there are two nuts which are tightened up together so that one acts as a check nut to the other. Sometimes these nuts are of different thicknesses, one being half that of the other, but they are often made of equal thickness; in this case the thickness of each is about two-thirds that of the usual nut. There is some considerable variation in the use of lock nuts both as regards thickness of nuts and methods of fastening them.

A castle nut is shown in figs. 12 and 13. This is a hexagonal nut in which the top part has been turned cylindrical and provided with six slots at right angles to the axis. A pin is driven through a hole in the bolt and two opposite slots, and this prevents the nut from slacking back. Dimensions for Whitworth nuts are given in the British Standard Specification No. 190. The following approximate proportions may be used for drawings: C = 1½D + ⅛″; T = 1·25D; H = ·8D; S = ·4D. The width of the slot varies from ·084″ for a ¼″ bolt to ·5″ for a 2″ bolt.

Figs. 14 and 15 represent a method which is often used. A hole is drilled through the bolt just above the nut, and a split pin is driven through the hole. This method, however, does not admit of any adjustment unless a washer is placed under the split pin.

Eye Bolt.—Figs. 16 and 17 show a typical eye-bolt. Such bolts are fitted to heavy machines, &c., for convenience in lifting.

EXERCISES

(1) Draw the screws shown in figs. 1, 2, 3, 6, and 7. Size of screws 0 B.A Scale: twice full size.

(2) Draw the screw plug (fig. 5) and the nuts shown in figs. 8, 9, and 10. Scale: full size.

(3) Draw an elevation, plan, and end view of the eye bolt shown.

(4) Taking the diameter of the bolt in each case to be ⅝″, show the three methods of locking nuts illustrated on p. 15.

SCREWS & NUTS

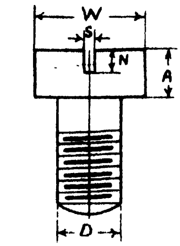


Fig. 1

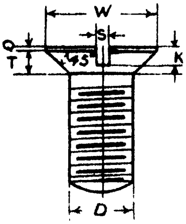


Fig. 2

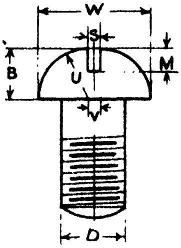


Fig. 3

Fig. 4

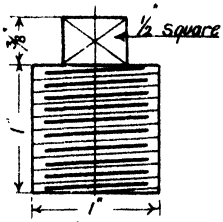


Fig. 5

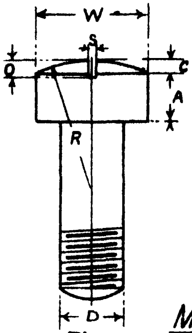


Fig. 6

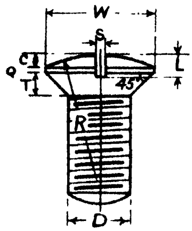


Fig. 7

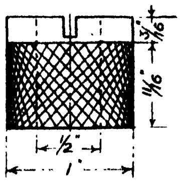


Fig. 8

Side Elevation

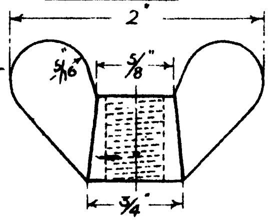


Fig. 9

End View

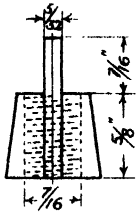


Fig. 10

Methods of locking nuts

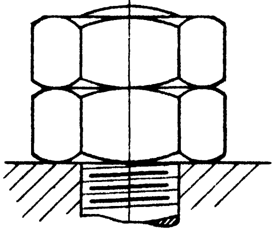


Fig. 11

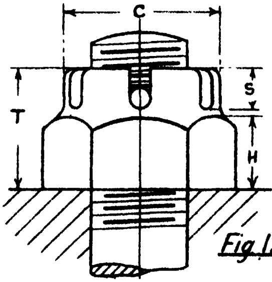


Fig. 12

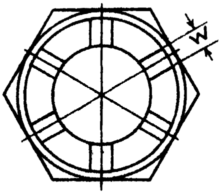
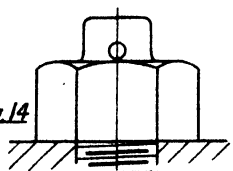


Fig. 13

Fig. 14



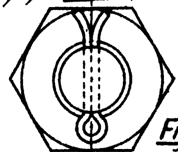


Fig. 15

Eye Bolt

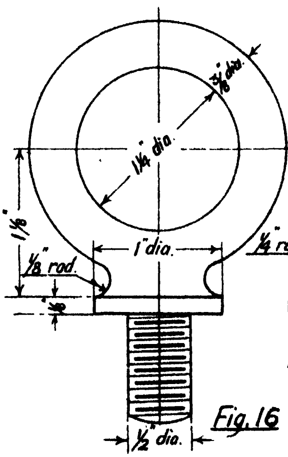


Fig. 16

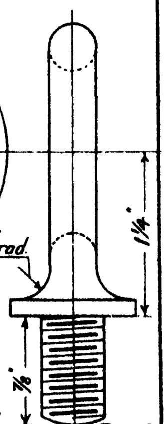


Fig. 17

WIRING DIAGRAM CONVENTIONS

The drawing of wiring diagrams is often an important part of a draughtsman's work. These diagrams show the way in which the various parts are connected, but are not intended to give information about the shape and dimensions of these parts. A number of items are therefore represented in a conventional way, and several of these are illustrated on the opposite page, and described in the following table.

Letter.	Part Represented.	Letter.	Part Represented
a or a_1	conductors crossing but not touching.	*o*	battery of cells.
b	non-inductive resistance.	*p*	condenser.
b_1	inductive resistance.	*q* or q_1	earth connexion.
c or c_1	fuse.	*r*	lamps in parallel.
d	single-pole, single-throw knife switch.	*s*	variable resistance.
e	double-pole, single-throw knife switch.	*t*	shunt-wound dynamo or motor.
f	single-pole, double-throw knife switch.	*u*	series-wound machine.
g	double-pole, double-throw knife switch.	*v*	voltmeter.
h	single-pole oil switch.	*w*	ammeter.
k	three-pole oil switch.	*x*	three slip rings of generator or motor.
l	field switch.	*y*	power transformer.
m	circuit breaker with overload coil.	*z*	potential transformer.
n	single cell.		

Thick lines represent conductors of large cross section for heavy currents, finer lines represent wires for connecting up instruments, &c. The work involved by using convention *a* or a_1 is often avoided by simply crossing the lines when conductors are not connected, and placing a solid dot when connexion is made (as in fig. 3). A number of other symbols are suggested by the British Electrical and Allied Manufacturers Association in their Standardization Rules.

Whatever convention is used, the main thing is to be certain that the drawing is quite clear to those who may use it, and that the use of any such representation will not cause difficulty or misunderstanding. Wherever there is any possibility of doubt the name of the part should be printed against the outline which represents it; in fact, on many wiring diagrams the exact type of each fitting is noted.

EXERCISES

(1) Draw each of the representations *a* to *z*, making each about twice the size shown.

(2) Fig. 1 represents a shunt dynamo *t* connected to bus bars through a D.P. knife switch *e*, ammeter *a* and breaker *m*. The volmeters *v* show the pressures across the mains and dynamo terminals respectively. In addition a field breaking switch *l* is shown together with the necessary non-inductive resistance *b* and a field regulating resistance *s*. Copy the diagram.

(3) Fig. 2 represents a series motor in parallel with a bank of lamps, connected to mains through a D.P. knife switch and fuses. A method of showing a tumbler switch in the lamp circuit is shown.

(4) Fig. 3 is an outline of connexions for a motor. By means of a double-pole double-throw switch the motor can be run from the mains or from a battery. Separate fuses are shown protecting battery and mains. A switch is shown which enables the last five cells of the battery to be inserted one at a time as the pressure falls, and the motor is connected through the usual type of starter. Complete the diagram.

(5) Fig. 4 is an outline of connexions between a three-phase A.C. generator and the mains through an oil switch and knife switches. Current transformers are shown for the ammeter and reverse power relays with their mid-point earthed. Draw the diagram, inserting the items indicated by the letters.

Note.—Make each of the diagrams for exercises 2, 3, 4, 5 about 6″ deep.

WIRING DIAGRAM CONVENTIONS

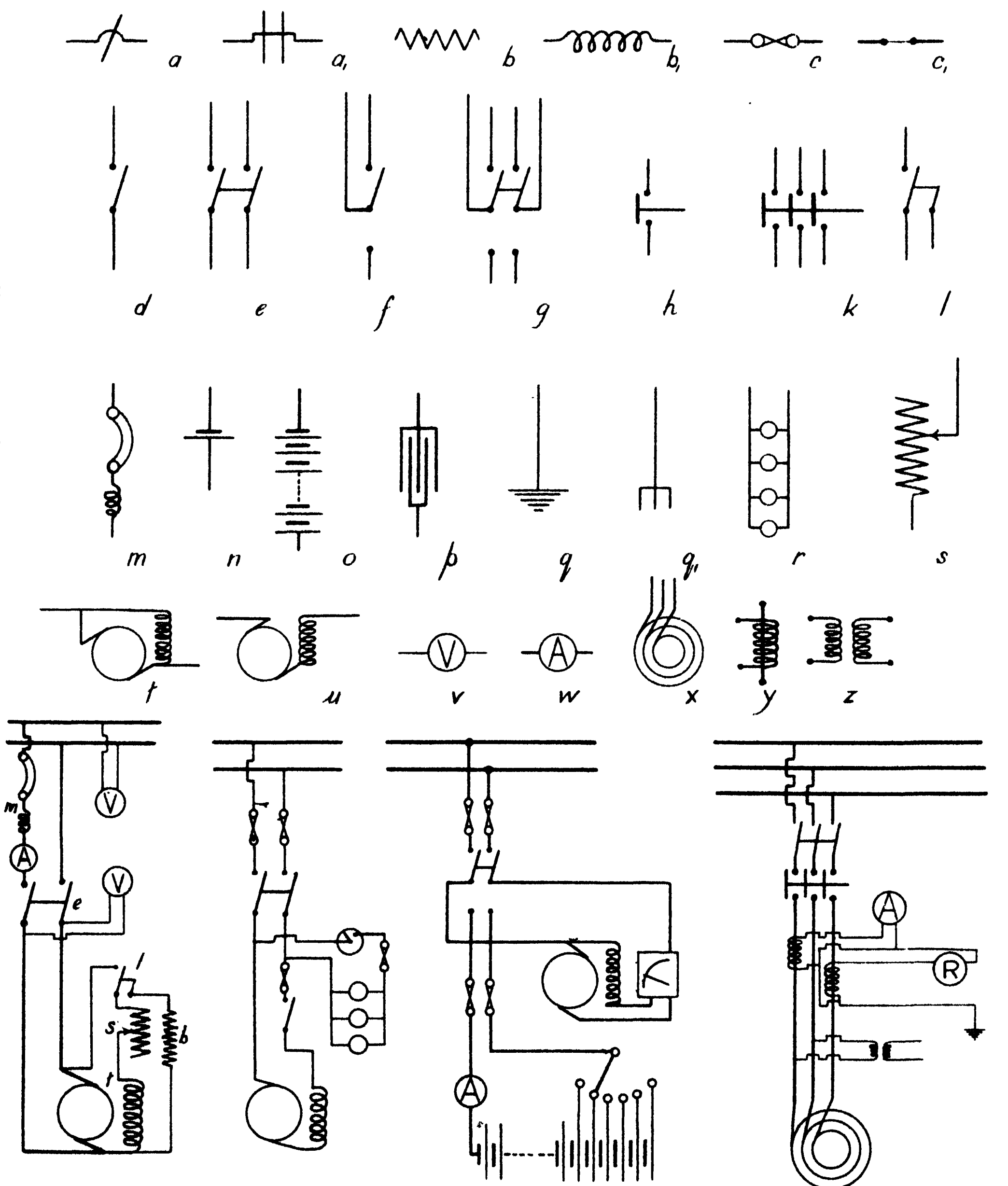


Fig. 1 Fig. 2 Fig. 3 Fig. 4

CONDUITS AND CABLE SUPPORTS

Earthenware Conduit. — Unarmoured cables which are laid underground are usually placed in earthenware conduits. These are of two kinds: those which are tubular, and through which the cable is drawn after the conduit has been laid, and those which are of open channel section so that the cable can be put in place as the conduit is laid. The former may be square, rectangular, or circular in section, and may contain one or more separate channels, arranged in various ways; the latter may be square, rectangular, or half-round in section. The conduit or **troughing** is laid in lengths of about two to three feet.

Fig. 1 shows a length of rectangular troughing. The bottom corners are rounded both inside and out, and the end of each section fits into an enlarged part formed on the neighbouring section. Red lead may be used to make a good joint, and to assist the jointing material in holding, four ridges are cast on the parts where the joint is made. The cable is not laid directly on the troughing, but rests on earthenware supports, one of which is shown in fig. 3. This support is designed to take two cables side by side. To protect the cables from moisture and corrosion, bitumen is run in until they are completely covered. The cable supports should not be placed over the joints, as they may permit moisture to creep in. Tiles such as that shown in fig. 2 are placed on the troughing. These systems of laying cables are known as the "draw-in" system and the "solid" system respectively.

Steel Conduits. — Cables used for wiring buildings are placed in steel conduits or are lead covered. Various types of conduit are used; the lightest type is butt jointed, but the best conduit is welded or solid drawn. Boxes are used where branches occur and at other suitable positions. The various lengths are connected by sockets, and the joints are made either by pushing the conduit into the socket or by screwing both conduit and socket. A variety of forms of boxes are used with the conduit, and connexions to the boxes are made in the same way. It is essential that the whole of the conduit should be in good electrical contact, and efficiently earthed. Fig. 7 shows a rectangular joint box, used to assist in pulling through and in jointing cables. It has been drilled at the ends so that the ends of the conduits can be pushed into the end projections. A much better connexion is made by screwing the conduit into the box. The projections are not in the centre of the ends, but near the bottom of the box, so that the conduit may be kept close to the wall. Fig. 6 is a view of a circular tee box screwed for conduit. In this box two lugs are provided for the screws which hold the cover plate, the same as those in fig. 5. The box shown in fig. 5 is sometimes used to provide a place for pulling through wires, in which case it is fitted with a cover plate, or it may be used for mounting a switch or ceiling rose. The boxes shown illustrate those manufactured by Messrs. Electrical Conduits, Ltd., of Walsall.

Where a number of cables run together, such as often occurs behind a switchboard, they may be supported in **cable racks.** Fig. 4 shows a portion of a cable rack. It consists of an iron base plate from which studs project for holding the porcelain insulating blocks. These blocks, which have grooves at the ends to fit the studs, are shaped to fit the cables, and allow a certain amount of adjustment for cables of different sizes. The upper blocks are held in place by a steel strip. In practice, this strip is often omitted, otherwise when a cable has to be removed, all the nuts have to be taken off and the other cables become loose.

EXERCISES

(1) Draw a side elevation and plan of a length of troughing such as that shown. Then draw a section through the trough perpendicular to its length, showing a cable support in place. Show one tile on the troughing and cut the drawings by broken lines as shown in the figure to save space. Scale: half full size.

(2) Draw an elevation and plan for each of the boxes shown in figs. 5, 6, and 7. In each case show the left-hand half of the plan with the cover, and the right-hand half with the cover removed. Scale: full size.

(3) Draw three views of the cable rack (fig. 4) for supporting four cables. There are two lugs at the farther end similar to those shown. Scale: half size.

CONDUITS AND CABLE SUPPORTS

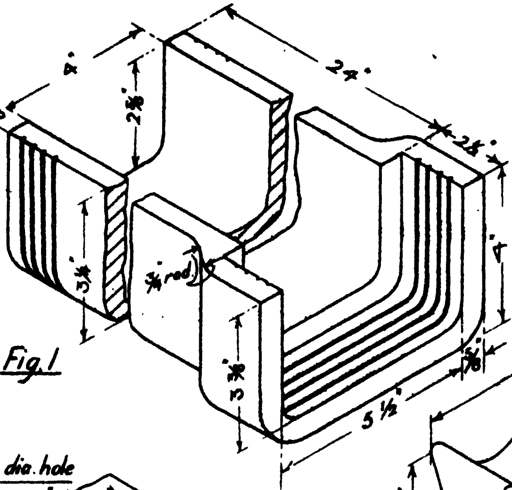


Fig. 1

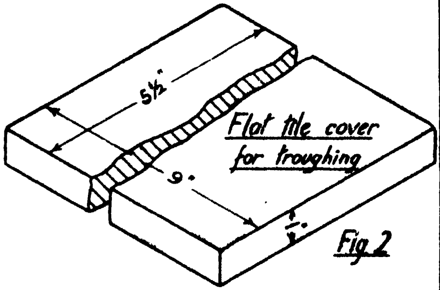


Fig. 2

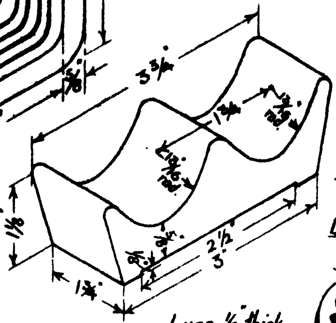


Fig. 3

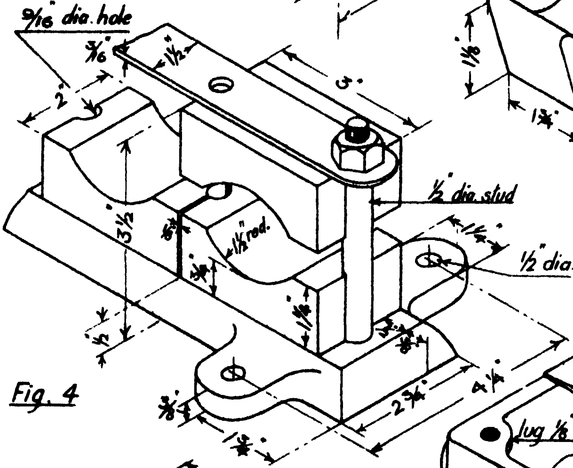


Fig. 4

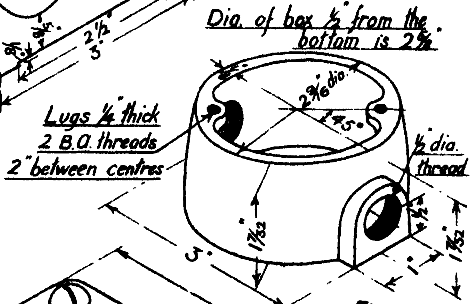


Fig. 5

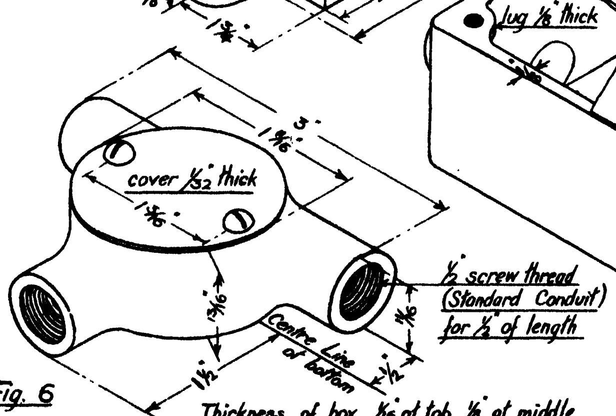


Fig. 6

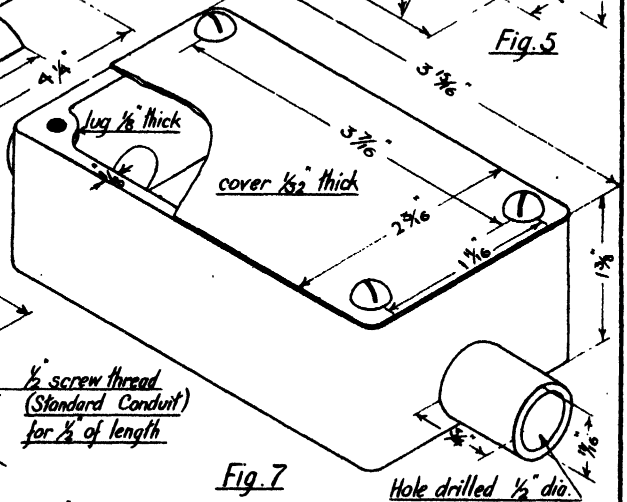


Fig. 7

CABLES AND CABLE SOCKETS

There are at least two essential parts to an electric cable: the conductor, or core, which consists of a single wire or a number of wires twisted together; and the insulating material, or dielectric, which surrounds the core. Many cables have, in addition, a protective covering or armouring, sometimes called a sheathing.

The cores are made as nearly circular as possible by arranging the conductors in a suitable way, and for this reason cores contain only certain numbers of conductors. Thus a small core may consist of a single central conductor with six equal conductors arranged round it, seven wires in all. Twelve conductors can be arranged round this core to form a nineteen-wire core. Such a core is shown in section in fig. 1. By adding successive layers to this core we get cables containing 37, 61, 91, and 127 strands of wire. All the wires in a cable of this sort are of the same diameter. In drawing a section of a cable it is convenient to draw a set of conductors in line and then draw concentric circles for the centres of the circles in each layer.

Fig. 1 shows a **single-core** cable, but **double-core,** or **twin** cables and **triple-core** cables are often used. Fig. 2 shows a triple-core cable; there are three equal cylindrical conductors. In some double- and triple-core cables the cores are not circular in section but are shaped so that when they are put together they form a cylindrical outer surface. There is another class of cable in which the cores are arranged concentrically. Fig. 3 shows a double-core concentric cable. In these cables the wires in the outer layers are smaller than those in the inner core, but they are arranged so that the total cross-sectional area of each core is approximately the same.

A number of different materials are used for insulation: some of the most common are paper, jute, bitumen, and india-rubber. The proper insulation of a cable is most essential; not only should the insulation have a high specific resistance, thus reducing the leakage current to a minimum, but, for high-tension currents, the *dielectric strength* should be sufficient to resist puncture, and, for alternating currents, the *dielectric constant* should be such as to produce only a small capacity current.

An outer covering is often provided which protects the cable against mechanical injury or, where a hygroscopic material is used for insulation, renders the cable watertight. This may take the form of a lead covering which is forced on under hydraulic pressure; an impregnated braiding; a steel-wire armouring, or even a combination of these.

The reference in the drawings to the copper conductors gives the number of wires and the diameter of each; thus 19/·083 copper indicates that there are 19 strands of wire, each of which has a diameter of ·083″.

Where a cable ends and is connected to a terminal some suitable form of **cable end** or **cable socket** is fitted. Figs. 4, 5, 6, and 7 show various forms of cable sockets suitable for single-core cables. In the type shown in fig. 6 the cable is gripped by two $\frac{5}{16}$″ bolts. But in the other types the cable is sweated into the socket; grub screws (not shown) are usually fitted in addition. Cable ends may be provided with a bolt and nut as in fig. 4, or a flattened part with a hole for bolting to the terminal face, as in figs. 5, 6, and 7.

EXERCISES

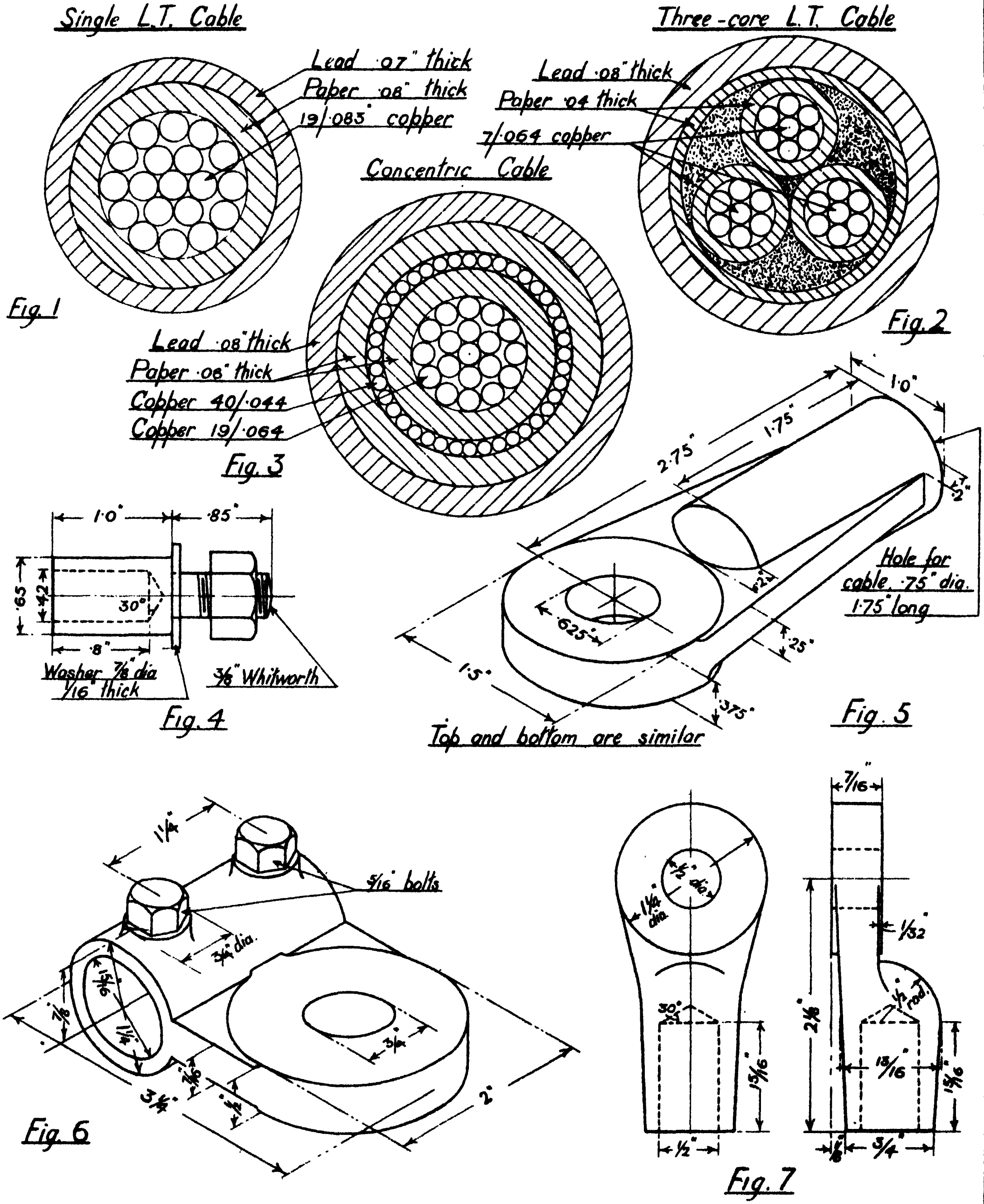
(1) Draw the cable sections shown. Scale: three times full size. The outer conductor in fig. 3 will present most difficulty and should be commenced by dividing it into eight equal parts with the 45° set square.

(2) Make an elevation of the cable end (fig. 4) clamped to a terminal $\frac{3}{8}$″ thick and showing a short length of cable in the socket. Scale: twice full size.

(3) Draw a plan, elevation, and end view for each of the isometric views (figs. 5 and 6). Scale: full size.

(4) Draw the view shown on the right in fig. 7 and project a plan. Scale: full size.

CABLES & CABLE SOCKETS



BIRLA C

CABLE BOXES

Large cables terminate in cable boxes, and there are different forms of boxes for use with single, double, triple, and concentric cables. They are designed to clamp the cable and its covering securely and to seal the end of the cable and prevent leakage. Such boxes are provided where cables are connected to a machine or to switchgear and where cables are connected together or branched.

Fig. 1 illustrates a type of sealing end made by Messrs. Siemens Bros., and is an isometric view in which the right-hand side of the porcelain box is partly cut away to expose the interior. A brass gland is securely fastened to the lead covering of the cable by making a plumbed joint, and a cable end is attached to the exposed end of the core. A screw is cut on the cable end and a brass nut serves to hold the porcelain cylinder tightly against the brass gland. The cable end is bent considerably to one side so that the cable can be secured to a flat surface or bolted to a terminal behind a switchboard.

Figs. 2 and 3 represent a type of high-tension sealing end made by Messrs. Johnson & Phillips, Ltd., and is for fastening to a wall or other support. For this purpose two brackets are provided. As in the last case the lead covering is fastened to a sweating gland by a plumbed joint, but the gland in this case is screwed to the bottom of the box. The box itself is a casting and on the front is a filling pipe through which the filling compound is introduced for sealing the end. The core of the cable passes through a long porcelain insulator to the terminal. The top cover plate is in two parts to enable the insulator to be put in place. If the cable is to carry heavy alternating currents, the box is made of a non-magnetic metal to avoid eddy current losses, and if the cable is armoured a special clamp is provided to secure the end of the armouring instead of the plumbing gland. In some cases, however, it is desirable to use both armouring clamp and wiped joint.

A joint box for connecting the ends of two twin cables is shown in figs. 4, 5, and 6. The cables to be joined are circular in section and are brought into the box through circular wooden bushes—two for each cable. A metal **bonding strip** is passed tightly round the end of the cable and screwed to the box in the space between the bushes; these strips serve to connect electrically the lead coverings of the two cables. The box is in two parts, the top and bottom being connected by bolts. The joint is made by connecting the ends of the conductors with tinned sleeves, and after the cover has been fixed in place the box is filled with sealing compound through the screw plugs. The shanks of the bolts are made square for a short length under the heads; so that the heads need not be held with a spanner whilst the nuts are being screwed up. The tops of the screw plugs are also square, and attention is called to the method of representing this by drawing *diagonal* lines over the square parts. A groove is cut round the edge of the lower part to hold locomotive or other packing to make the box watertight.

EXERCISES

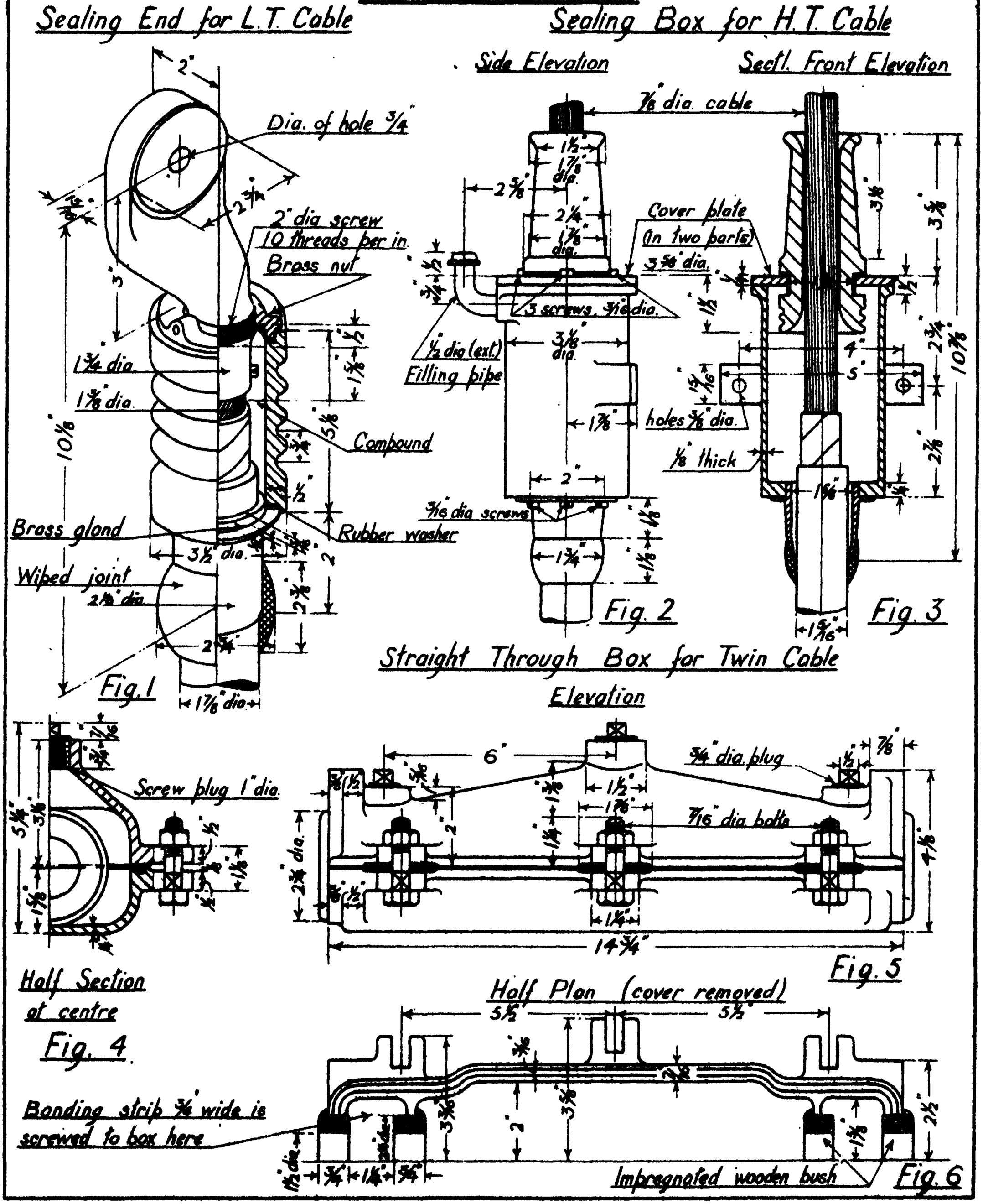
(1) Draw an elevation and plan of the sealing end shown in fig. 1, showing the right-hand half of the elevation in section. Scale: half full size.

(2) Copy the sectional elevation of the sealing-box shown in fig. 3 and project a plan. Scale: half full size.

(3) Draw an elevation of the box shown in fig. 5, but with the right-hand half in section. Project a plan of the box with the cover in place. Scale: half full size.

(4) Draw a plan of the joint box without the cover and project an end view. Scale: half full size.

CABLE BOXES


Sealing End for L.T. Cable
Sealing Box for H.T. Cable
Side Elevation
Sectl. Front Elevation
Dia. of hole 3/4"
2" dia screw
10 threads per in.
Brass nut
1¾ dia.
1⅞ dia.
Compound
Brass gland
Rubber washer
Wiped joint
2⅛" dia.
3½" dia.
1⅞" dia.
Fig. 1
⅞ dia. cable
Cover plate
(in two parts)
3⅝" dia.
3 screws, 3/16 dia.
½ dia (ext)
Filling pipe
holes ⅜" dia.
⅛" thick
3/16 dia screws
Fig. 2
Fig. 3
Straight Through Box for Twin Cable
Elevation
Screw plug 1" dia.
¾" dia. plug
7/16" dia. bolts
14¾"
Fig. 5
Half Section
at centre
Fig. 4
Half Plan (cover removed)
Bonding strip ¾" wide is
screwed to box here
Impregnated wooden bush
Fig. 6

FUSES

In order to protect circuits from injury due to excess current, automatic cut-outs are provided which break the circuit when the current exceeds a certain predetermined value. These may be mechanical cut-outs called **circuit breakers**, or thermal cut-outs called **fuses.**

In the latter the current passes through a length of wire which melts when the current reaches a certain value. These fuse wires are held in some sort of special form of holder so that they may be easily replaced, and the holder should be so designed that the molten metal cannot fly out and do damage when fusion occurs.

In circuits where the current is small and which can be easily made " dead " by switches, the fuse wire may be connected to fixed terminals and protected by a removable cover; but in the majority of circuits it is desirable that the holder be removed from the circuit in order to replace the fuse wire.

Figs. 1, 2 and 3 show a 100-ampere cut-out of Messrs. The General Electric Co. Ltd.'s manufacture, which is suitable for use in Ironclad Fuseboards and complies with the Home Office regulations.

Both the base and holder are made of vitreous porcelain; the fuse wire is housed in an asbestos tube which is carried by the two lugs on the holder; the ends of the wire terminate under screw heads on the brass blocks (fig. 3). These blocks are self aligning and the feature is obtained by a spring washer, which is inserted between each contact block and the holder, so that any slight variation in alignment of the blocks and the spring contacts is taken up by a slight movement which the spring washer allows.

The heads of the screws holding the contact blocks to the holder are covered with leather washers, porcelain or plaster; fig. 2 shows leather washers fitted.

The spring contacts (fig. 4) are mounted in the base and are made of high conductivity copper; a brass terminal block is riveted and brazed on.

In cut-outs of large capacity, steel springs are inserted behind the contact springs to give an additional pressure (see fig. 4).

This type of cut-out can be arranged for front or rear connexion.

When closed the fuse wire and contacts are completely enclosed in a porcelain box.

Figs. 5, 6 and 7 show an example of a 5-ampere cut-out, which is one of a number of different types used to protect local circuits, such as will be found on test benches where it is desirable that each local testing equipment shall carry its own fusing arrangements, so that in the event of a fault developing, only that particular section will be isolated and the rest of the bench unaffected.

Both the holder (fig. 5) and the base (fig. 6) are made of vitreous porcelain; the fuse wire is carried in the holder which forms the cover and is so constructed that the wire passes between two walls. These walls are plaster lined and open out in the centre to form an expansion chamber as shown in fig. 5, in which the pressure set up by fusion is dissipated.

The method of assembly is simple. The holder is inserted into the base, and with a slight right-hand turn locks itself on to the base contacts which have a slight indent as shown in fig. 8. These are engaged by the contacts of the holder with similar indents (see fig. 9), and in this way the holder is held firm.

This locking arrangement also closes the circuit. The deep wall of the base protects the operator in case the fuse is replaced on a faulty circuit.

The contacts are made of phosphor bronze.

EXERCISES

(1) Draw in section a side elevation of the base (fig. 1), showing the spring contacts (fig. 4) in position and from this view project a front elevation. Scale: full size.

(2) Draw a side elevation of the fuse holder, the top half to be in section to show the assembly of the details of the contact block (fig. 3), fuse wire, and asbestos tube. From this project an elevation showing the contact face. Scale: full size.

(3) Make a side elevation of the complete cut-out, the top half to be in section. From this view project an end elevation with the porcelain removed from the front to reveal the contact assembly. Scale: full size.

(4) Draw a plan view of fig. 6 and an under plan of fig. 5. Scale: twice full size.

(5) Draw in half section an elevation similar to that shown in fig. 7 and project from it a plan view. Scale: twice full size.

FUSES

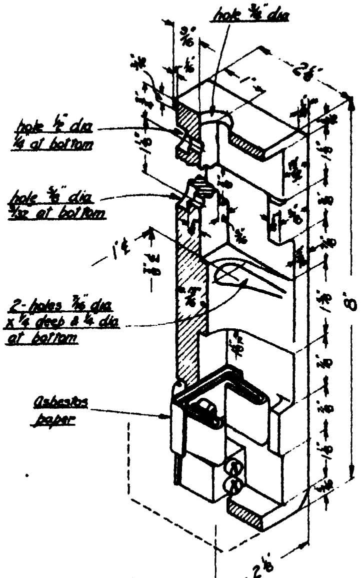


Fig.1

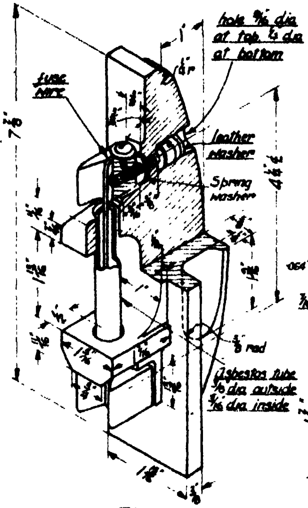


Fig.2

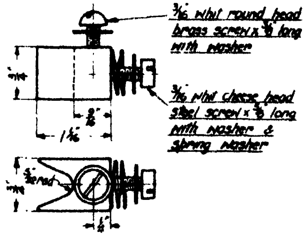


Fig. 3

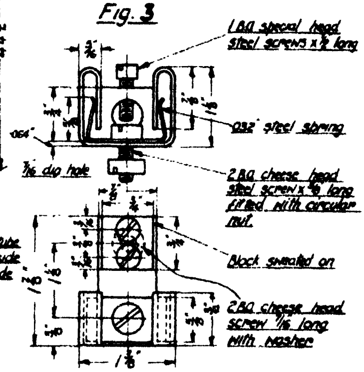


Fig. 4

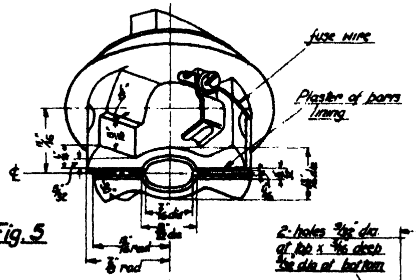


Fig. 5

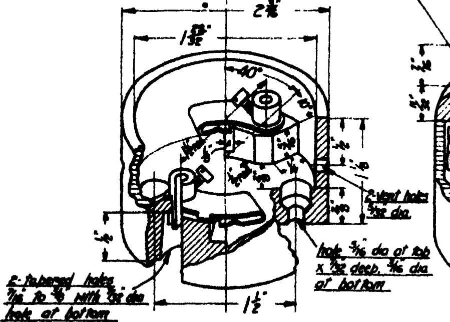


Fig. 6

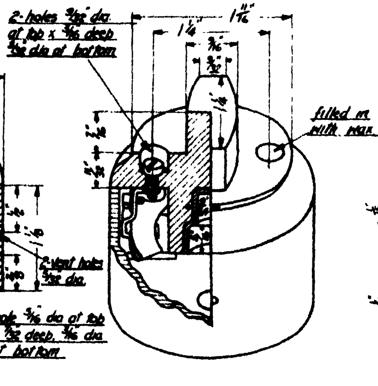


Fig. 7

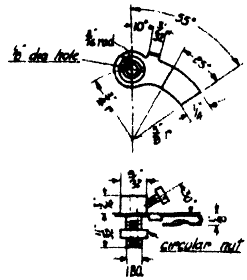


Fig. 8

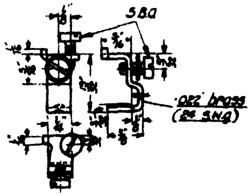


Fig. 9

The function of insulators is to support conductors in such a way that they shall not be in contact with, or too near, other conductors at different electrical pressures. The type and size of insulator for any particular position is determined by the voltage of the conductor and by such other conditions as whether it is to be under cover or exposed and the mechanical stress it will have to bear. Insulators may break down by the current flashing over the surface or by piercing the material; the former is the more usual. There is a very large variety of shapes of insulators and their peculiar form is due to the endeavour to make the path of the current *over the surface* as long as possible. Porcelain, owing mainly to its high resistance, to the fact that it does not absorb water and to the ease with which it is moulded, is almost invariably used for insulators. Insulating bushes, &c., however, are not made of porcelain.

Fig. 1 is a **shackle-type insulator** which is usually used at the end of a run of aerial wire, where there is some considerable mechanical stress. The wire passes round the insulator, and as the bolt passes right through the centre of the insulator the material is under a compressive force.

Fig. 2 is a very common type of porcelain insulator which is used for supporting telephone wires and overhead electric light wires. These insulators have to be supported on a stalk and a central hole which does not extend right through is moulded in them. The hole has a coarse thread formed in it, and with regard to this it should be noted that the right-hand half of the figure is in section, and that therefore the back of the hole and thread will be seen. As the thread is right handed the back of it will appear to be left handed; see figs. 13 and 14, p. 11.

Two forms of **stalks** are shown in figs. 3 and 4. The former is for a single insulator, but the latter is branched to take two insulators. They are usually made of steel, forged to shape and galvanized. Screws are provided on those shown, for the insulators, but many stalks have the top parts notched and the insulators are then put on the stalks over hemp and white lead.

The other figures illustrate supports for the stalks. Fig. 5 is a bracket for fastening to a wall; the two arms are shown at 120°, but they may, of course, be at any desired angle. It is made of a single strip, bent to shape, the two parts being bolted where they come together. The bracket shown in fig. 6 is a casting. The back plate portion is shown flat, but it is frequently curved when, for example, it is fitted to a wooden post. The angles at the webs of the bracket are shown by straight lines for convenience in illustration by an isometric view, but in practice they are slightly rounded, and they should be shown rounded where they occur in orthographic views. A very large number of insulators are supported on wooden poles. Fig. 7 shows the top of a pole with a cross-piece recessed into it and bolted to it. Holes are drilled at the ends for two stalks. The edges of the cross-piece are slightly chamfered at the outer ends. The poles are creosoted; the top of each pole is cut at an angle on both sides and fitted with a metal roof to protect it from the weather.

EXERCISES

(1) Copy the drawing shown in fig. 1 and project a plan. Scale: full size.

(2) Draw a side elevation and front elevation of the wall bracket shown in fig. 6, and show on it the stalk (fig. 3) and the insulator (fig. 2). In one of your views show one half of the insulator in section. Scale: half full size.

(3) Draw a plan and elevation, looking from the left, of the bracket (fig. 5) fitted with the stalk (fig. 4). Scale: half full size.

Note.—The three vertical parts in fig. 4 are all in one plane.

(4) Draw three views of the top of the pole (fig. 7) fitted with two shackle insulators (fig. 1). In this case the bolt will be 3″ long between the strips, and the strips bent to suit. Do not show the insulators but only the centre lines. Scale: one-sixth full size.

INSULATORS AND SUPPORTS

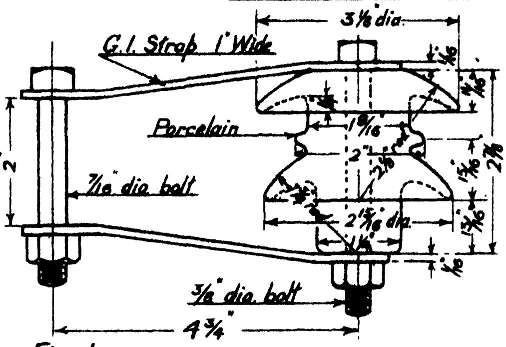


Fig. 1

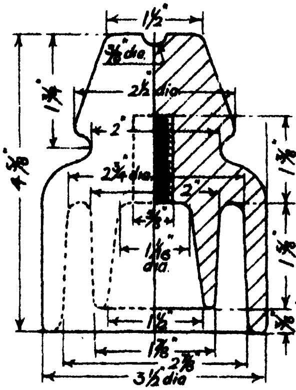


Fig. 2

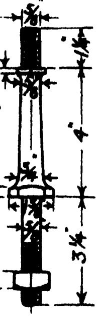


Fig. 3

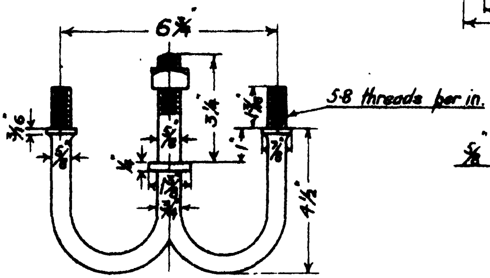


Fig. 4

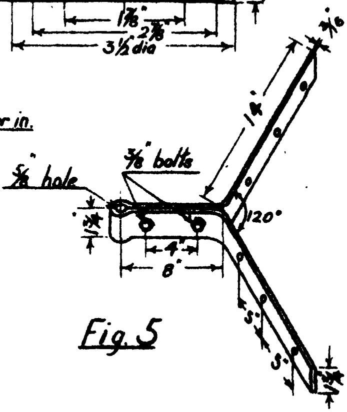


Fig. 5

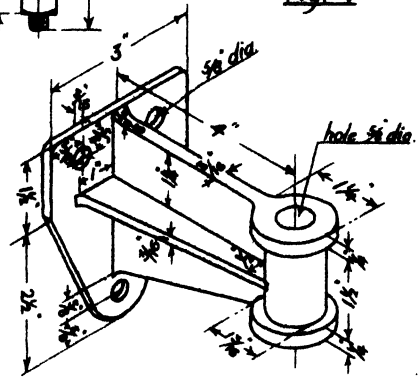


Fig. 6

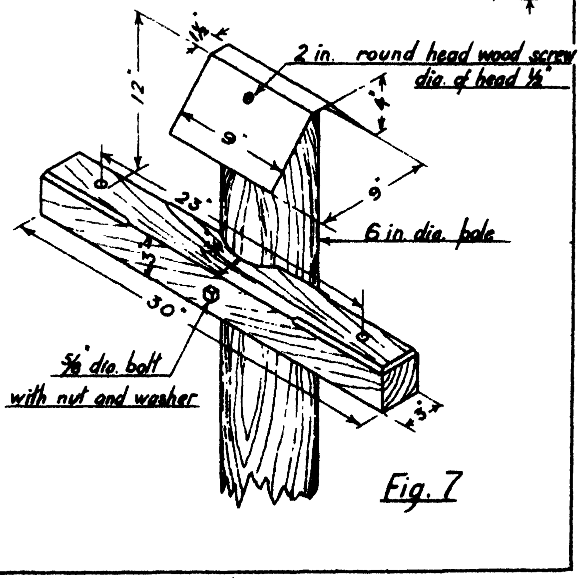


Fig. 7

Some further types of insulators are shown on the opposite page. The first is an **oil insulator;** in this there is an annular space for holding oil. The oil must be highly insulating and must not evaporate. Any leakage current must cross the surface of the oil, which is in a protected position and therefore always fairly clean. A groove is provided in the top of this insulator for the conductor. The insulator may be screwed on to a stalk similar to that shown in fig. 3, p. 27.

Figs. 2 and 4 represent types of **extra high-tension insulators** made by Messrs. Bullers, Ltd. The first is a standard line insulator made in three parts, which are cemented together. The lowest section has a tapering hole at the bottom and the hole is roughened or screwed to hold a lead lining. A taper screw on the spindle or stalk is screwed into this lining. This insulator has a *spark-over voltage* of 125,000 volts when dry, and 84,000 volts when under rain: 22,000 volts are required to *puncture* the porcelain. The actual length of the path over which leakage occurs is about 19½″.

Fig. 4 shows one section of a **metal cap insulator.** In this type the conductor hangs beneath the insulator, which is suspended by the cap. The section is made in three parts: the insulating part is of porcelain, and is cemented into a malleable cast-iron cap, and a mild-steel spindle is cemented into the hole in the porcelain. A number of these sections may be joined together to form a complete insulator, and each spindle is made so that it will fit into the cap of the section next below. In the type shown the top of the cap is formed into a clevis and the bottom of the spindle is formed into a tongue, which will fit into a similar clevis on the next unit. Bolts are used to connect the sections together. The actual length of arc from cap to spindle is 6¾″, but the leakage length over the disc is 11″. The spark-over voltage for one of these units is 80,000 volts when dry, but this may be reduced to about half this value when in horizontal rain. The voltage required to puncture a disc is about 130 k.v When more sections are used the spark-over voltage is increased, thus it becomes 195 k.v. for three units, and 340 k.v. for six units. The line voltages should be always much below these values; for a line voltage of 44 k.v. an insulator with three units is recommended.

The porcelain insulator shown in **fig. 3** is the type used in one of Messrs. Johnson & Phillips' oil switches. A rod passes through the insulator and a fixed switch contact is attached to the bottom of the rod. The top of the rod is screwed, and three nuts are screwed down on the top of the insulator and hold the rod in position besides forming a terminal for the switch (see figs. 2 and 3, p. 59). The porcelain cap at the top of the insulator is put on after the cable has been connected, and encloses the otherwise exposed metal parts. A strip of manilla paper is used to make the cap fit tightly.

In these drawings the centres of the circles should be determined geometrically from the dimensions given, and as they are for the most part symmetrical about a centre line the outlines for both sides should be advanced together.

EXERCISES

(1) Copy the part sectional elevation of the insulator shown in fig. 3 and project sectional plans through the cap at 2″ and 3½″ from the top. Scale: half full size.

(2) Draw the part sectional elevation of the oil insulator (fig. 1) and project a plan. Scale: full size.

(3) Copy fig. 2 and project a view looking from underneath. Scale: half size.

(4) Draw a part sectional elevation of the insulator unit shown in fig. 4 in a direction at right angles to the view shown. Scale: half full size.

(5) Draw an elevation of a complete insulator, without supports, formed of four units such as that shown in fig. 4. Scale: one quarter full size. Measure the spark-over distance from the cap of the top section to the spindle of the lowest section.

INSULATORS

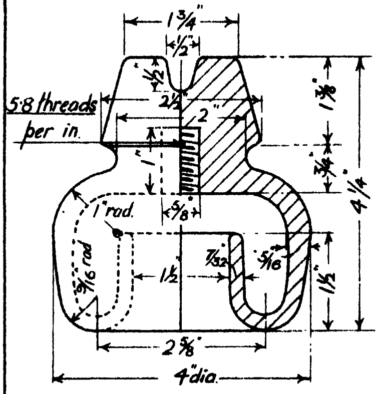


Fig. 1

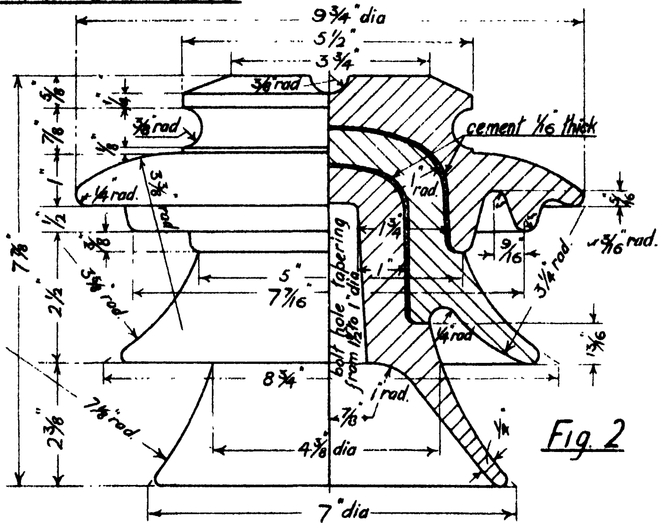


Fig. 2

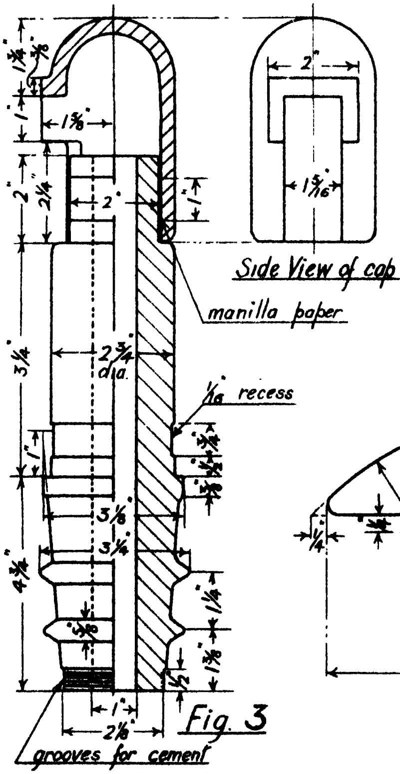


Fig. 3

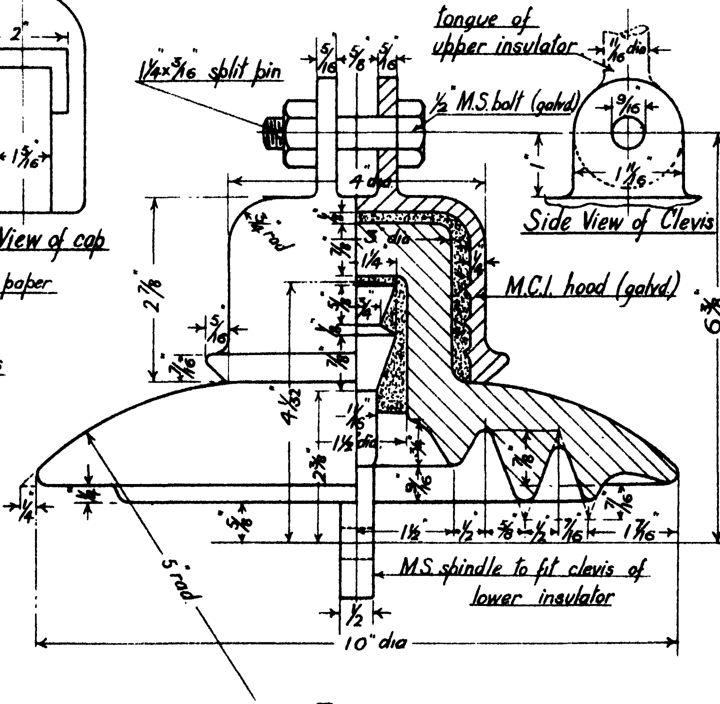


Fig. 4

OVERHEAD WIRE FOR RAILWAY

There are various methods of supporting overhead wires for railways and tramways, and the design is influenced by the speed of the trains or cars and the voltage of supply. The aerial wire is carried on tubular steel poles or lattice-work masts (unless the system is temporary, when wooden poles are used) either in pairs, one on each side of the track, or singly, when they are fitted with cantilever arms.

Figs. 2 and 3 show a **lattice-work mast** supporting an **aerial wire** for a railway; the cantilever arm in this case consists of two 6″ by 3″ channel bars. A number of different designs are used in connexion with the supports for overhead wires for railways and tramways. For tramways, the conductor is usually supported directly from insulators fastened to the cantilever arm or to wires stretched between the poles. For railways the overhead wire is supported on the *Catenary Principle*; the high speeds of the trains necessitate the conductor being kept as nearly level as possible. The method usually consists of stretching a steel messenger wire between the supports, and "droppers" attached to this at regular intervals support a secondary messenger wire; shorter droppers from the latter support the actual conductor. Fig. 1 shows a messenger wire hanging over a 240′ span, with a sag of 29¾″; from this the secondary wire is supported by droppers the lengths of which are given, and the droppers from the secondary wire are such that the conductor is everywhere 6″ below it. In this diagram, owing to the smallness of the vertical distances compared with the horizontal ones, different scales are used for vertical and horizontal distances.

Figs. 4 and 5 show how the overhead conductor is suspended from the secondary messenger. The forked part at the top consists of a double hook, the hooks being turned in opposite directions, which can be readily hung on the wire. The bottom part, which is at right angles to the length of the dropper, is square in section, and has a bolt hole through it. The bolt clamps together the plate clips, which are bent at the bottom to fit into the grooves on the conductors. Two similar conductors are suspended from this dropper, and the section of each is circular, with a groove cut out on each side for the suspension.

The method of supporting the messenger wire from the cantilever arm is shown in **figs. 6, 7, and 8.** The support can be placed on the arm in any position, and can be moved by slacking the nuts which hold the hanger. Two steel bands are bolted to the bottom of the hanger and grip the special cup-shaped porcelain insulators. A steel spindle which is covered with a $\frac{3}{16}$″ layer of lead has its ends fixed into these insulators, and carries in the centre another insulator, cupped at each end. This central insulator is prevented from sliding along the spindle by copper distance pieces. A saddle is clamped to this insulator, and a groove at the top carries the steel messenger wire, whilst a short anchor wire passes through a similar groove underneath and prevents the messenger wire from slipping (see figs. 3 and 6). Leather washers are fitted over all the insulators to prevent them from being damaged by the clamps. The fittings illustrated are made by Messrs. Bricknell, Munro & Rogers, Ltd.

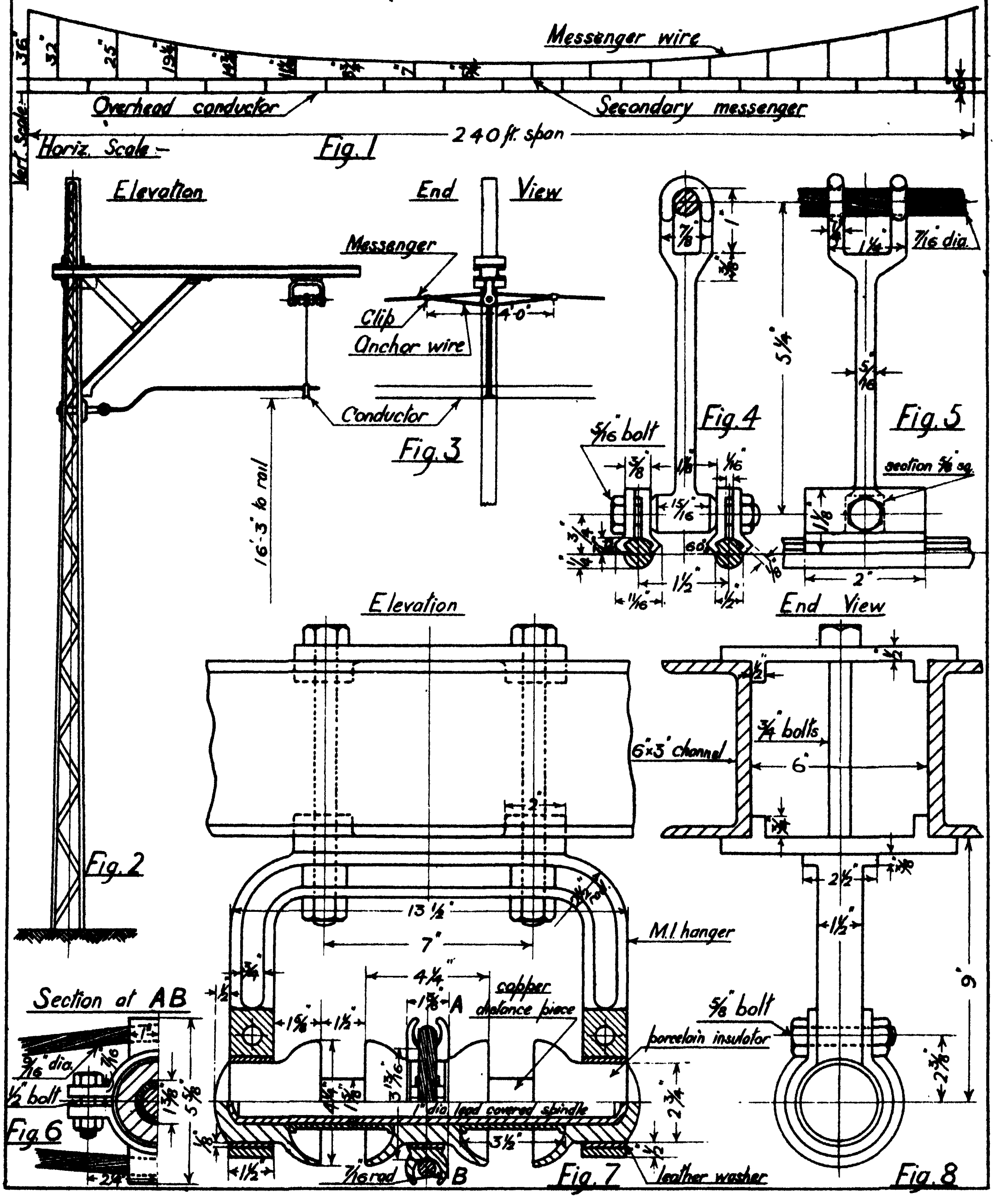
EXERCISES

(1) Draw the wires shown in fig. 1, assuming the secondary messenger wire and the overhead conductor to be straight and horizontal. Set out the lengths of the droppers and draw the messenger wire. Choose your own scales so that the figure can be put on your paper.

(2) Draw the views of the dropper shown in figs. 4 and 5 and add a plan. Scale: full size.

(3) Copy fig. 7 and project a vertical section through the centre at right angles to the figure. Scale: one-quarter full size.

OVERHEAD WIRE FOR RAILWAY



COLLECTOR SHOE GEAR

In tramway systems and in many railways the current is fed through overhead conductors, the return being either through the rails and earth or through a separate rail. Instead of the overhead conductor some railways are fed through a separate rail. These rails are placed alongside or in the centre of the track, and the contact is made by suitable shoes which slide on them. There are, in general, two types of shoe gear: in one case the shoe slides on the top of the rail; in the other case the shoe makes contact with the under side of a flange on the rail, the shoe being kept in contact by springs. The latter type is used for high-speed railways. In all designs of collector shoe gear it is necessary to allow the shoe to have a considerable amount of free vertical movement, because, although the position of the rail may vary slightly with reference to the track, the carriage swings in its motion and its position depends upon the loading.

The figures shown on the opposite page illustrate collector shoe gear supplied by Messrs. Metropolitan Vickers, Ltd., for contact with the top of the rail. The shoe is connected to two brackets by two slotted links; the bracket and link on the right have been omitted for clearness, and the shoe is shown in its lowest position with reference to the brackets. Teeth are cut horizontally across the back of the brackets and engage with corresponding teeth which are cut on the raised parts at the ends of the upper casting. A single bolt at each end connecting the two parts makes a rigid joint, and the slot in the bracket allows for a considerable amount of adjustment in a vertical direction. The bolt has been omitted in the drawings. The flat face at the back of the top casting is screwed to the woodwork of the carriage; four countersunk screw holes $\frac{1}{4}''$ in diameter are drilled in the thinnest part for the wood screws; these are not shown.

The shoe is not in good electrical contact with the top part of the fitting, and therefore a short length of cable is clamped to the two parts. The cable clamps are in the centre and are similar, but the head of the bolt for the clamp on the shoe is accessible whereas that for the upper clamp is not. A slot is therefore provided, so that the bolt head can be placed through the large hole on the right, and then slipped along into position.

Attention is called to the shape of the brackets, which are provided with webs for stiffening and which are forked at the bottom to take the slotted links. Similar forked parts are cast on the shoe, and the parts at the rear are joined by a web to which the cable clamp is bolted.

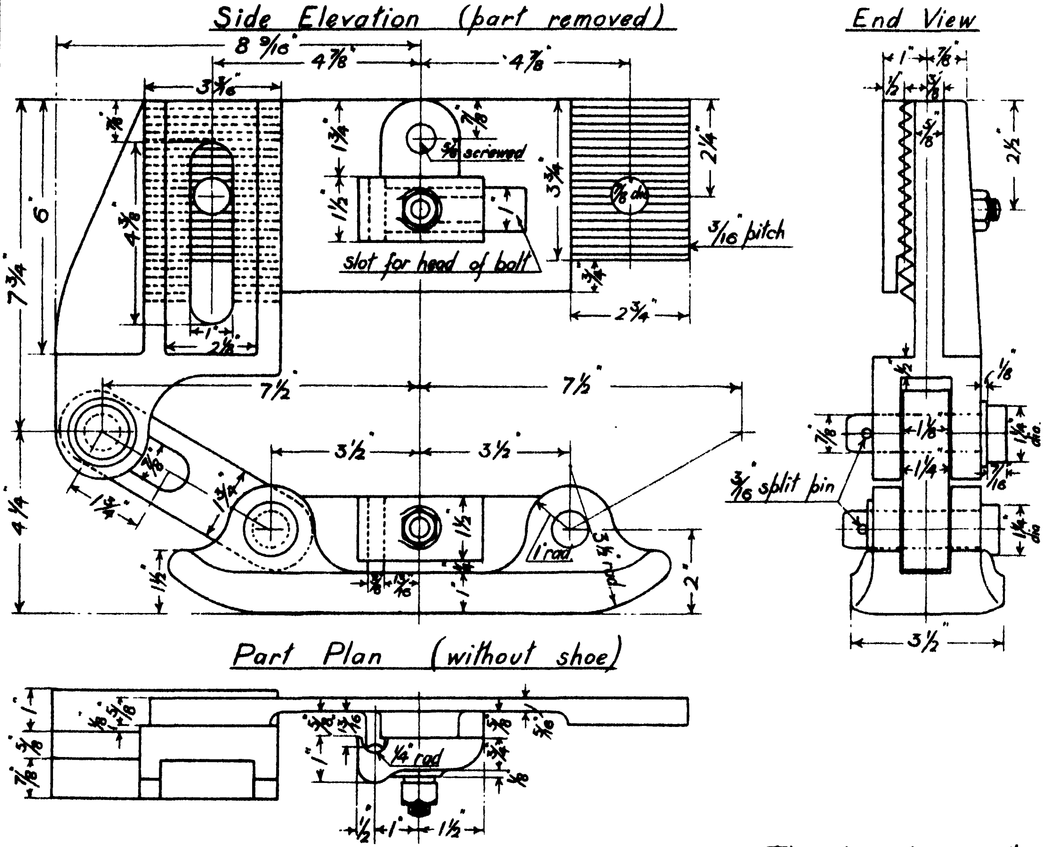
EXERCISES

(1) Draw the elevation of the collector shoe gear and project a vertical section through the centre line. Omit the bracket and link in your section, and take the shoe in its lowest position. Scale: half full size.

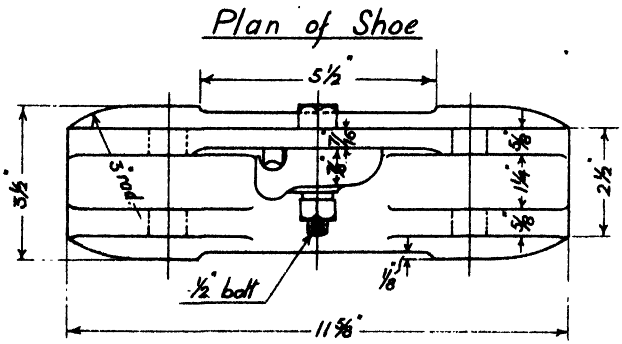
(2) Draw the end view of the left-hand bracket, looking towards the right, and project a horizontal section at $4\frac{1}{2}''$ from the top. Scale: half full size.

(3) Draw a complete plan of the fitting, showing only parts which can be seen. Scale: half full size.

COLLECTOR SHOE GEAR



The shoe shown is the Positive, the Negative is similar but 4½" wide.



When an overhead conductor is used the current is collected either by a **trolley arm** which holds a grooved wheel against the conductor, or by a **bow collector** in which a metal framework is held against the conductor; the latter form is used for high-speed vehicles. In railway work the collector is usually of the **pantagraph** form; the collector shoe is supported by a system of rods hinged together, and attached to the roof of the vehicle in such a way that the collector shoe may be moved vertically. Compressed air cylinders control the mechanism and give the shoe a certain freedom of motion, so that it can always keep in contact with the overhead wire. The shoes are for the most part flat, but the ends slope down at an angle; the elevation (fig. 1) is in the direction of the conductor, so that it is seen that this allows a lateral motion of the conductor of about four feet. This is not necessary on a straight track, but is needed where there are curves. The shoe is a bent plate with copper pans screwed to the flat portion. It is bent at the ends in order that it may run easily under an overhead wire, and the copper plates at the end of the flat parts are bevelled to enable the wire to slip on to the top with ease. In the type illustrated, which is made by Messrs. Metropolitan Vickers, Ltd., there are two similar shoes supported on the same pantagraph frame, and the shoes are hinged to arms which are controlled by springs; each shoe can swing down into the position shown by the dotted lines.

Third-rail Insulator.—Figs. 4, 5, and 6 show a third-rail insulator of a type made by Messrs. Bricknell, Munro & Rogers, Ltd. The fitting is composed of nine component parts, the size of clamp varying with the size of rails to be supported. The elevation is in part section, and the three views fully illustrate the construction of the insulator. This drawing is typical of the usual works practice when articles such as this are to be manufactured. The table at the bottom right-hand corner shows the items which are to be used in the assembly, the number of each required, and the material of which it is made. The smaller table above shows how the dimension "A" varies with the size of rail. It is usual to give a **table of quantities**, or **schedule of material**, in this way on all works drawings; in many cases there are more columns, the last of which is used for remarks, where special particulars concerning any of the items are inserted. A space is left beneath the schedule where other items may be added from time to time if necessary. The various items are referred to by numbers, and in the drawing these numbers are placed in small circles. Where a large number of such details have to be manufactured it is not usual to dimension the drawing as shown, but to prepare separate drawings of each item and fully dimension these. This is shown later on p. 39. Only the overall dimensions are given on the drawing of the complete assembly when this method is adopted.

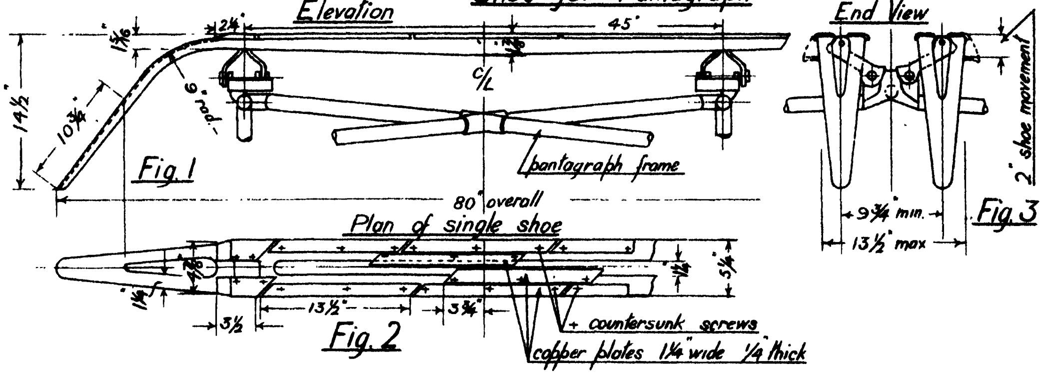
EXERCISES

(1) Draw an end view of the third-rail insulator (fig. 5), but with the right-hand side in section. Project a plan with cap and clamps removed. Scale: full size. Number the items.

(2) Draw a plan and elevation of the top cap. Scale: twice full size. Make a table of quantities similar to the one shown but about twice the size.

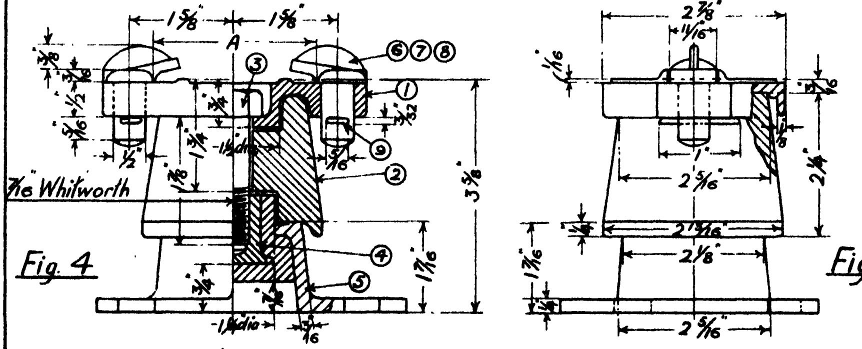
PANTAGRAPH SHOE AND RAIL INSULATOR

Shoe for Pantagraph



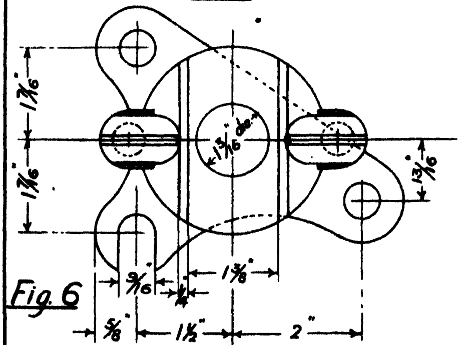
Third Rail Insulator

Scale ⅓ full size



Size of Rail	A
12 lbs.	2⅛"
16 lbs.	2⅜"
20 lbs.	2⅝"

Plan



Item	Part	Material	No. Reqd.
1	Top cap	M.I.	1
2	Insulator	Insulating compound	1
3	Insulator tension bolt	Steel	1
4	Insulated bushing	M.I	1
5	Base for 12, 16, 20 lbs. rail	M.I.	1
6	Clamp for 12 lbs. rail	M.I.	2
7	" " 16 " "	M.I.	2
8	" " 20 " "	M.I.	2
9	Cotter pin	Steel	2

MAGNET COILS

The magnetic effect of the electric current is so widely used that magnet coils, in one form or another, are found in a large proportion of electrical apparatus and machinery. The coils vary considerably in size: from the small coils used on measuring instruments and other apparatus, in which the wire is exceedingly fine, to the large coils used on generators, in which the coil is made of thick copper bars.

The representation of a coil on a drawing does not present much difficulty; the method depends to some extent upon the size of the coil and the size of the drawing. Usually the elevation and section of a coil is represented by fine lines as shown in the exposed parts of the coil in fig. 1. Sometimes the sectional lines are inclined at 45° in both directions instead of being horizontal and vertical. Where two coils come together or are wound one over the other, it is useful to use horizontal and vertical lines for one coil, and inclined lines for the other coil. The figures opposite illustrate three different coils.

Telephone Coil.—This is a coil of very fine wire wound on an ebonite spool. The length of wire is not stated, but this is determined by specifying its resistance. The coil is covered by a layer of bookbinders' cloth and the wire is not seen, but in drawings of coils such as this it is usual to draw lines close together to represent the wire, although it may not actually be seen.

Overload Coil.—This is a coil consisting of three turns of thick copper strip, and is used in connexion with the trip gear of a circuit breaker. A metal tube is fixed in the centre of this coil, and inside this is a soft-iron bar which rests on an adjustable screw near the bottom of the tube. The main current flows through the coil, and when it reaches a certain value the magnetic field produced in the coil is sufficient to cause the iron bar to rise and strike the trip gear mechanism which opens the breaker. The coil is of copper and its ends are sweated into copper blocks on the front of the terminal stems.

Lifting Magnet.—Figs. 4 and 5 illustrate the construction and show the position and size of the coils in a standard circular pattern lifting-magnet made by Messrs. Witton-Kramer. The body or shell of the magnet is a casting of high permeability steel, and the coil is held in its place in the shell by clamping bars of non-magnetic metal. There is one coil made of a number of sections, each in the form of a disc; these coils are shown in the sectional view (fig. 5). Rectangular section copper strip is used for the coils and the turns are insulated by specially prepared asbestos tape. Discs of asbestos which have been treated with heat-resisting materials are placed between the sections and the parts of the coil are assembled on a mica former. The rectangular opening on the right is a terminal box, the cover of which has been omitted.

EXERCISES

(1) Draw an elevation of the telephone coil looking towards the right and project a sectional end view. Scale: three times full size.

(2) Draw the elevation of the overload coil and project an end view. Do not use an accurate construction for the spirals, but draw straight lines instead of curves. Scale: full size.

(3) Copy the section of the lifting magnet and project a plan, showing the position of the coils in the plan by dotted lines. Scale: one-sixth full size.

MAGNET COILS

Telephone Coil

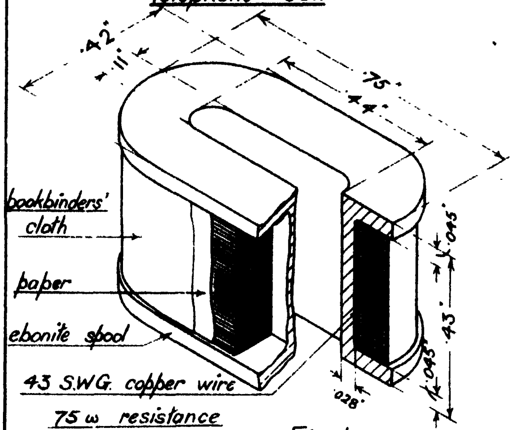


Fig. 1

Overload Coil

Elevation

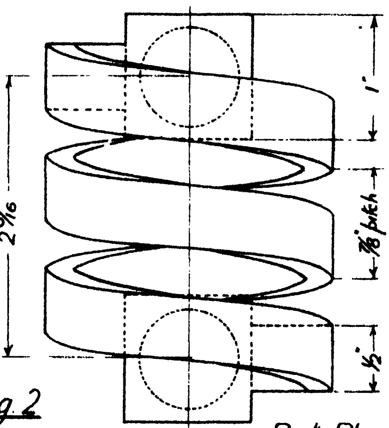


Fig. 2

Part Plan

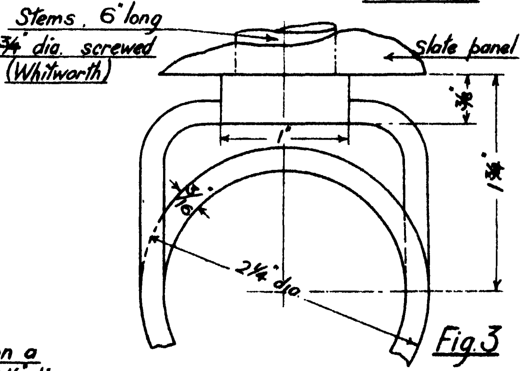


Fig. 3

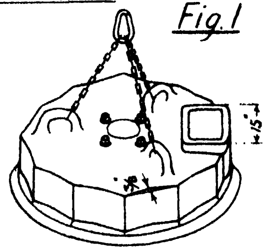


Fig. 4

Lifting Magnet

Sectional Elevation

Scale, 1/12 full size

Bolt and nut at AA
bolt 7/8" dia.
nut 2 1/4" across flats

3 Eye bolts on a
pitch circle 26 1/4" dia.

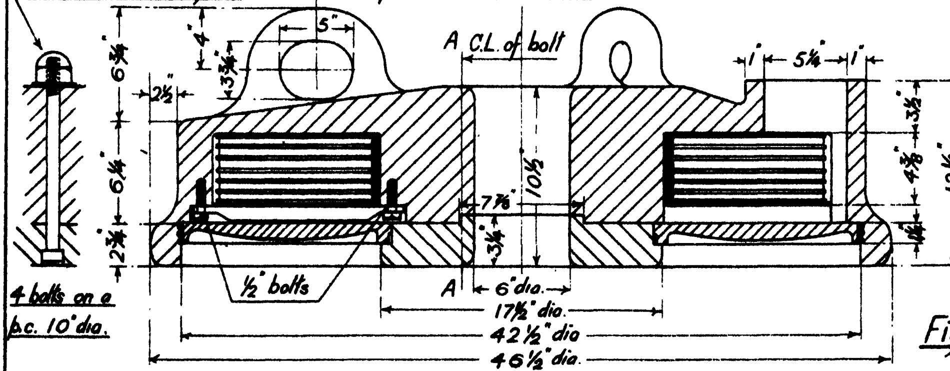


Fig. 5

Telephone Jack

The usual practice in a works where a number of articles of one kind are to be manufactured is to make separate drawings of each part as shown on the opposite page.

An **assembly drawing** shows the finished article with all the items in their proper position; this drawing gives the overall dimensions and each separate part is shown by a number. The numbers are surrounded by circles which may be from $\frac{3}{8}''$ to $\frac{5}{8}''$ diameter according to the size of the drawing. Each part is then shown by a separate drawing, the number of the part being placed alongside. Separate drawings or prints can then be made and issued to the work-people who are to manufacture the parts. These drawings must be fully dimensioned and must have any necessary notes so that the parts can be produced exactly as required. On most assembly drawings a list or schedule of parts is shown. Lack of space prevents this being placed on the opposite page, but such a schedule is given for the Third Rail Insulator on p. 35.

The method of making a working drawing is illustrated by the drawings of the telephone jack. There are various types of jacks; the one shown is one of the simplest. A fixed metal frame, (1), holds insulated spring contacts, (2) and (3), which end in soldering tags. A suitable plug on a flexible lead is used with the jack. When the plug is inserted through the hole at the top of the frame it presses out against the spring contacts and completes the electrical circuit through a telephone connected to the flexible lead. The jack and plug together form a switch for closing a circuit through a telephone. The drawings on the opposite page represent a type of jack made by Messrs. Siemens Bros.

The assembly drawings are figs. 1, 2, and 3; figs. 1 and 2 are elevations and fig. 3 is a sectional elevation. The method of numbering the various parts should be noted. The other drawings show the various parts and are fully dimensioned. In this set of drawings all the dimensions are given in decimals of an inch and in most cases to the third decimal place. The drawings cannot, of course, be made to this degree of accuracy, nor is it necessary that they should be, but the dimensions must be given in this way so that the part can be manufactured correct to the nearest thousandth of an inch. In making such working drawings what is required, therefore, is a drawing which shows the form of the part and giving sufficient dimensions and other information for accurate manufacture. Only reasonable care is necessary with regard to the accuracy of the measurements provided all dimensions are given in figures, because the drawing is usually traced and blue prints are made. The latter frequently shrink considerably, and the following note is often added: "*Print—not to be scaled.*"

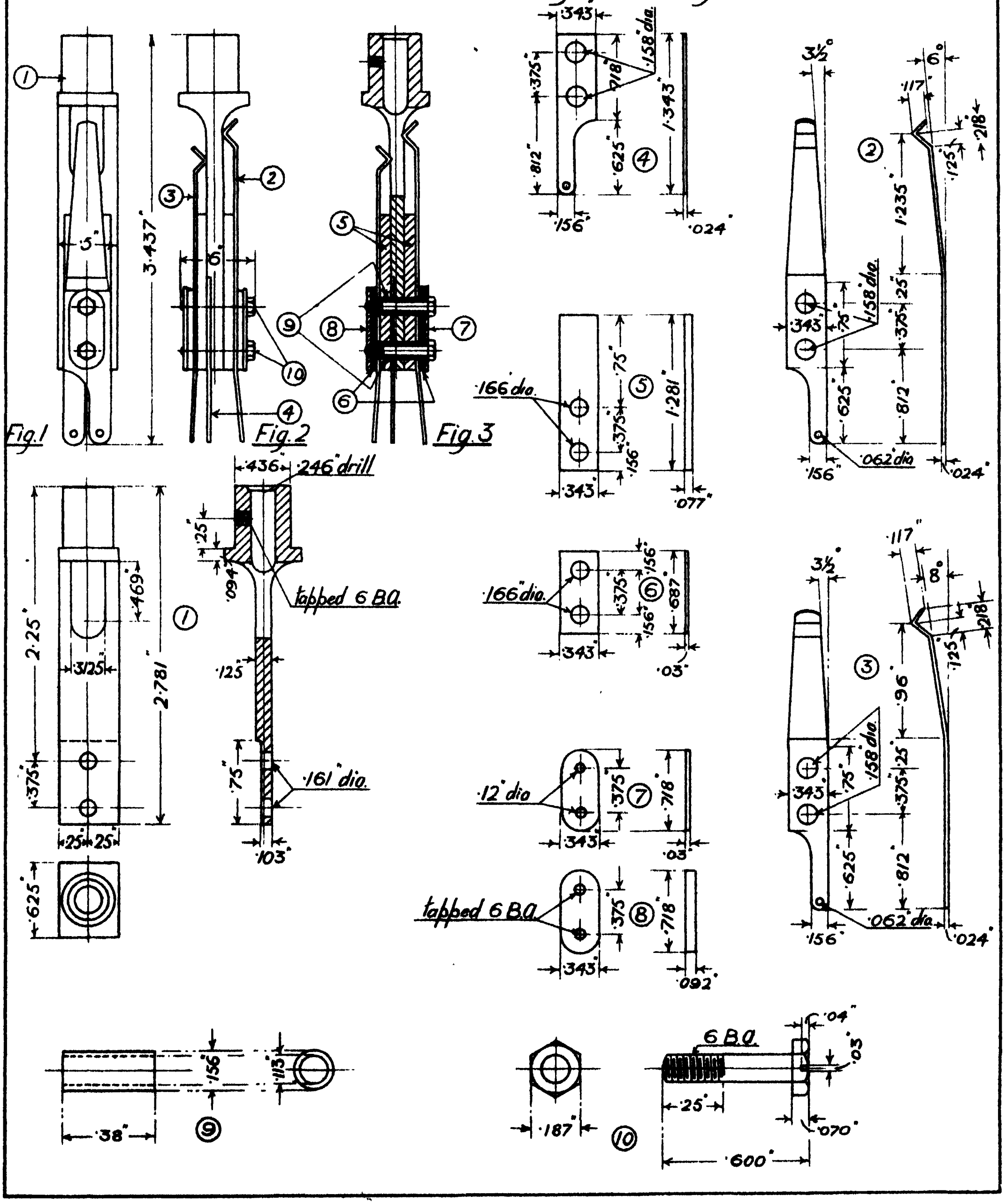
Many working drawings indicate the degree of accuracy required in the manufacture of the parts by adding *tolerances* to the important dimensions. No tolerances are shown in the drawings opposite but they are represented thus:—$1{\cdot}125''^{+{\cdot}001}_{-{\cdot}0005}$; this indicates that the dimension may not be more than ·001″ greater or ·0005″ less than 1·125″.

EXERCISE

Draw the assembly drawings and the detail drawings of the telephone jack. Make the assembly drawing full size and choose suitable scales for the parts. Fully dimension the drawings. Make a schedule of the items as completely as you can.

TELEPHONE JACK

Working Drawing



SWITCHBOARD SUPPORTS

Switchboards may be made of (1) slate or marble, or (2) steel plates in which insulating bushes are fitted for the stems of instruments, switches, &c. Complete switchboards are built up of separate panels which are placed side by side and usually adjacent to each other. Separate panels are used for special purposes; for example generator panels—one panel for each machine — feeder panels, battery panels, &c. The way in which the panels are arranged depends upon the scope and purpose for which the switchboard is to be designed. The pressure and amount of the current to be controlled will considerably influence the design of the switchboard, on account of the room which must be allowed for the switches, meters, transformers, &c., and the space which must be provided between " live " parts.

For a large number of low-tension, and for some high-tension switchboards, the panels are of slate or marble; the latter is usually employed when appearance is an important consideration, but it is more costly than slate. For many high-tension switchboards and most extra high-tension switchboards the panels are of steel. There are three methods of operating switchboards. (1) **Direct control** in which the switchgear is on the front or back of the board and is operated by hand directly. (2) **Remote control** in which the switchgear is contained in a separate space at some distance from the board —either above or behind—and is operated by a system of levers and rods. (3) **Electrically operated remote control** in which the switches on the board are small and operate relays connected to the main switches. This is the usual method of control for extra high-tension current. The current on the switch-board and relays is at a low pressure of about 200–300 volts, and all high-tension parts are protected and out of reach. In (2) and (3) the main switchgear is enclosed in **cubicles** built of steel plates and angle sections. These may be of the " fixed " type or the " draw-out " type.

Fig. 1 shows an angle structure, fastened to floor and wall, for supporting a single small panel. The framework is arranged to carry motor starter and regulating resistance, &c., at a short distance behind the board.

Fig. 2 shows a method of supporting **bus bars**. The latter consist of strips of copper placed side by side. They are fed by bars of similar type from the generator panels, and the bars are not bolted but held together by clamps. The number and size of strips depends upon the current to be carried· 1 sq. in. cross section of copper is allowed per 1000 amp.

Figs. 4 and 5 show a **draw-out cubicle.** A set of such cubicles is formed by arranging them side by side, and each is separated from its neighbour by a fixed steel plate. The bus bars, &c., are supported on fixed supports at the rear of the fixed structure and are automatically screened when the cubicle is withdrawn.

The draw-out part consists of an angle bar frame with steel plate front and rollers at the bottom corners. The rollers are made with a part of smaller diameter on the outside which rests on the upper edge of angle guides bolted to the floor. The front part of these fixed angles is cut at an inclination to the horizontal so that the weight is transferred to them as the cubicle is pushed into place.

The figure shows portions of the fixed structure cut away and the front plate of the cubicle removed.

Contacts at the back of the draw-out portion engage with corresponding contacts on the fixed portion, and until the cubicle is quite in place and the contact made properly the switch cannot be closed. Neither can the cubicle be withdrawn until the switch is opened. This is effected by the slotted bar through which the switch lever passes being fastened to a projecting horizontal bar. For the cubicle to be moved the bar must be opposite the slot in the framework, and this means that the switch lever must be in the open position.

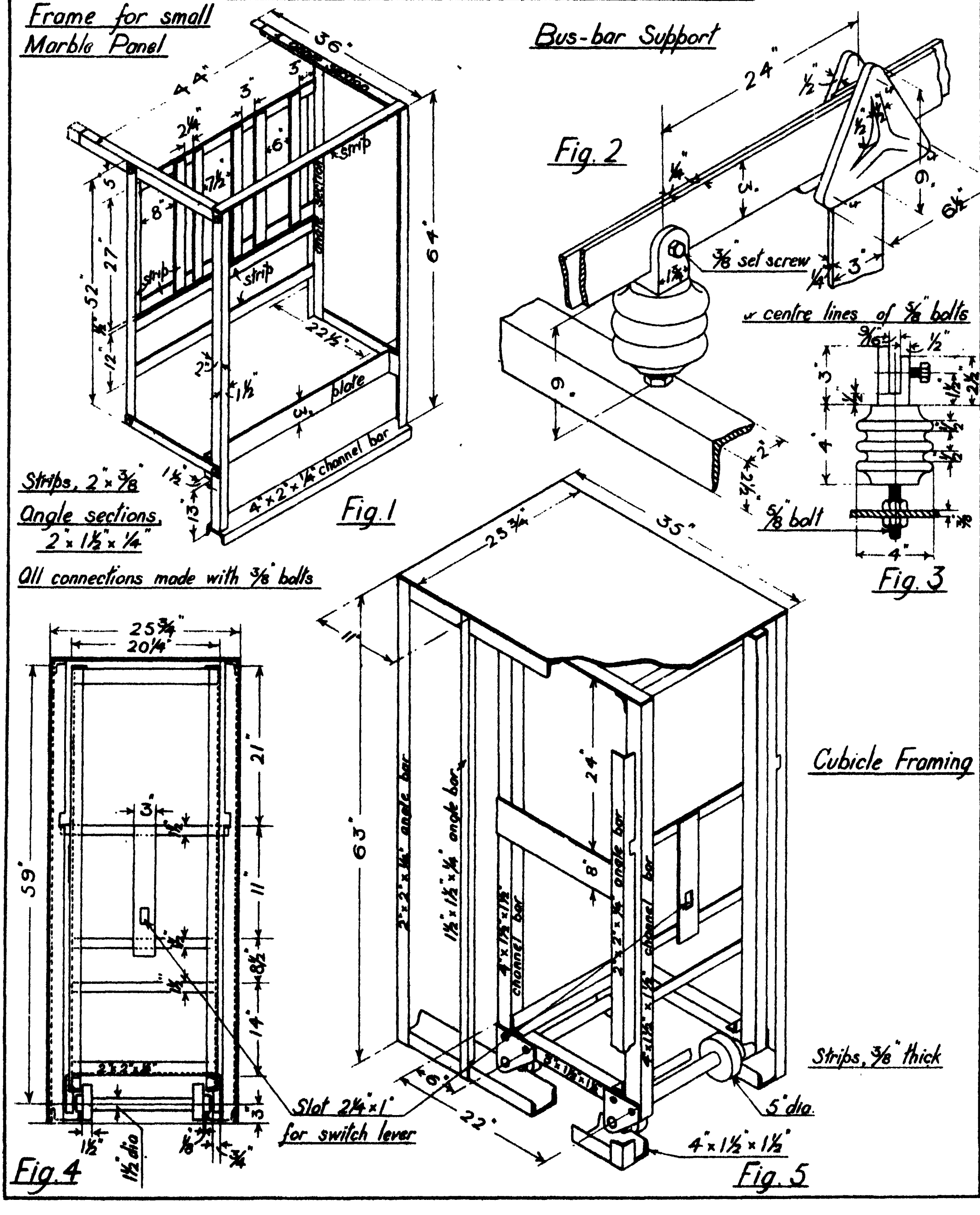
EXERCISES

(1) Draw elevation and end view of the framework shown in fig. 1. Scale: 1″ = 1 foot.

(2) Draw a side elevation and plan of two bus bars, side by side, 2′ apart, showing a clamping plate on each. Scale: quarter full size. Use the dimensions given in figs. 2 and 3.

(3) Draw an elevation and end view of the complete draw-out cubicle with front plate removed. Scale: 1″ = 1 foot.

FRAMING FOR SWITCHBOARDS



ISOLATING LINKS AND KNIFE SWITCHES

Isolating Links. — These are slow-break knife switches which are not intended to be opened when a current is passing. They are used in order that instruments, switchgear, or certain portions of a circuit may be entirely disconnected from the supply so that they may be safely handled and adjusted. They are of the simplest design, and, as they do not have to break the circuit when current is flowing, there is no need to provide a quick-break device, but they must be large enough to carry the full load current continuously.

Fig. 1 represents an isolating link for a medium pressure circuit. The link consists of a strip of hard-drawn copper, hinged in one of the clips which hold it. To open the link it is merely pulled out of the spring clip at the top and allowed to swing down. No insulating handles are fitted to these links, but a hole is drilled at one end into which a hook on a long insulating handle is inserted.

Fig. 3 represents an isolating link for a high-tension circuit. On account of the higher pressure much better insulation must be provided for this link. The bolts do not pass through the insulators but are cemented to the ends. The conductors are bolted to the flat parts which are cast with the clips for this purpose.

Knife switches of various forms are very commonly used in electrical engineering. They are fitted with insulated handles of a suitable type for convenience in operating. They may be single pole, in which there is one blade or knife; double pole, in which two blades are fitted side by side in suitable clips and are operated simultaneously; or triple pole, in which there are three blades. There are **single-throw switches,** where there is only one position in which the switch can close the circuit, and **double-throw switches,** where another set of contacts is fitted beneath the hinge; this provides another means for closing the circuit by swinging the switch into its lowest position. In the latter case an alternative circuit is connected to the lower contacts, and this type of switch is sometimes known as a change-over switch.

In designing knife switches it is essential to provide sufficient cross section of copper at all points to allow adequate contact surfaces and to ensure that the electrical contact over these surfaces will be as good as possible, otherwise the current density at certain points may become so high as to produce an undesirable rise in temperature. The current density allowable is approximately 1000 amp. per square inch for the blade and 120 amp. per square inch for the contact surfaces. The clips are made with a certain amount of spring so that there shall be considerable pressure on the blades, and in the larger switches the clips have slots which divide them into two or three parts and so ensure a satisfactory contact surface.

Figs. 4 and 5 show a three-pole, double-throw switch. The end of each blade is fastened to a rectangular ebonite bar so that when the switch is opened the blades move together and the circuit is broken at each contact simultaneously. The switch shown is of the quick-break type, having auxiliary blades or snap blades in front of and behind the main blades. The snap blades are hinged to the main blades, and are held in place by springs. When the switch is opened the snap blades remain in the clips after the main blades have been withdrawn, and are not pulled out until the tension in the spring reaches a certain value or the lower bevelled edge comes in contact with the main blade. This ensures that the final rupture of the circuit shall occur rapidly. The corner of the clip where the blade leaves it is often cut away to prevent the arc concentrating on the point. Fig. 6 is an isometric view of one of the clips.

EXERCISES

(1) Copy the views given of the isolating switch (figs. 1 and 2), and add a plan. Scale: half full size.

(2) Draw the side elevation of the high-tension isolating link shown in fig. 3, and project a front elevation. Scale: half full size.

(3) Draw three views of a double-pole, single-throw switch, using the same dimensions as for the triple-pole switch shown. Scale: half full size. The bottom of each blade should be as shown by dotted lines in fig. 4 to form a stop.

ISOLATING LINKS AND KNIFE SWITCHES

Side Elevation

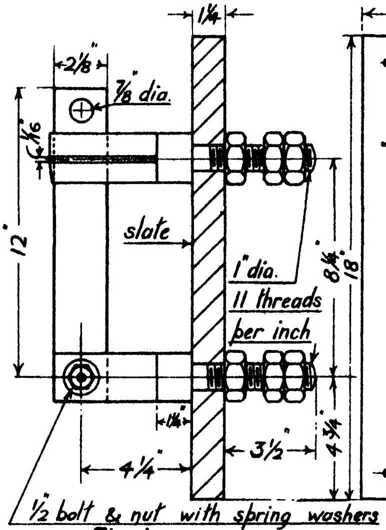


Fig. 1

Front Elevation

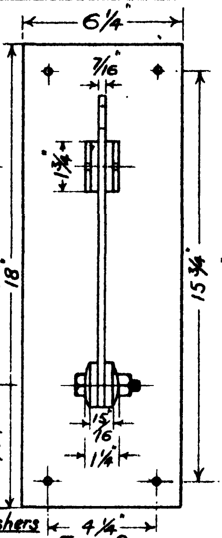


Fig. 2

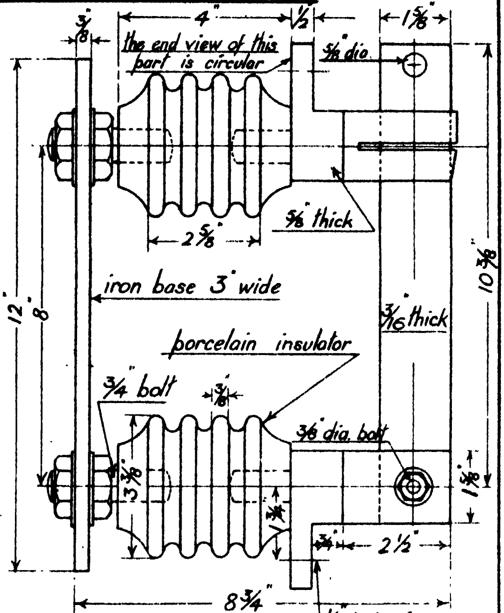


Fig. 3

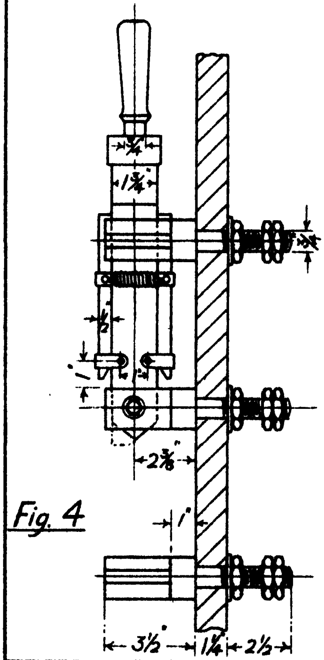


Fig. 4

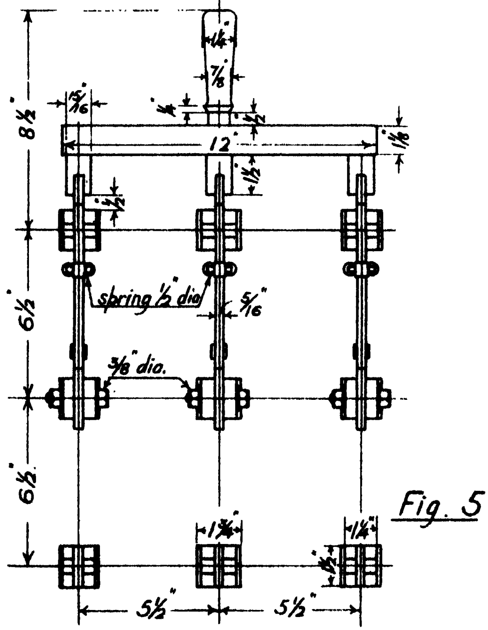


Fig. 5

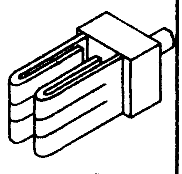


Fig. 6

Laminated Main Switch.—This is a knife switch which is designed for heavy currents. Instead of a single link there are copper plates, the number of which depends upon the current-carrying capacity of the switch. The fixed contacts are also formed of plates, arranged so that they fit between the moving contacts; there is one less plate in the fixed contact than in the moving contact. Clamps are provided for pressing the contact surfaces closely together when the switch is closed. By using a number of blades instead of a solid bar, a much greater heat radiating surface is obtained, and there is better bedding of the contact surfaces. The switch illustrated is of the slow-break type, and is not intended to be opened when carrying current. These switches can be arranged for single or double throw, but, as the moving parts are heavy, stops are usually provided in double-throw switches to prevent them falling down into the lower contacts; these consist of pins which can be inserted by hand into holes in the middle contact. In the figures the fixed contacts pass through rectangular holes in the panel, and are held in place by flanges. Bolts pass through both flanges and the panel, and some of these bolts are shown only by their centre lines. This method of showing bolts is sometimes adopted to avoid repetition and save time when there is no possibility of misunderstanding.

Field Magnet Switch.—This type of switch is used to break highly inductive circuits such as field magnets of dynamos and lifting magnet coils. Before the circuit is opened a non-inductive resistance of suitable value is placed in parallel with the magnet coils, so that on opening the circuit the energy in the coils is dissipated in the non-inductive resistance, and sparking is reduced to a minimum. The switch is similar to a single-throw, double-pole knife switch, with the addition of fixed contacts in front of the hinges. The ends of the non-inductive resistance are connected to the contacts so that the first part of the movement on opening the switch brings the knife contacts into these fixed contacts, and so puts the non-inductive resistance in parallel with the coils. A quick-break action is fitted to field breaking switches.

The switch shown in figs. 4 and 5 is made by the General Electric Company and it will be noticed that the snap or flicker blades are broad and carry the current; they fit loosely into slots $\frac{1}{8}''$ wide through the knives. Copper plates are fitted into the bottom of the slots and held by rivets so that when the switch is opened these plates fit into the contacts in front of the hinges and connect the non-inductive resistance to the field coils. The hinges are not designed to carry the main current and many ordinary knife-switches are fitted with additional fixed contacts in this way. The method of representing the screw threads in fig. 4 should be noted; this is a much quicker method than those previously shown.

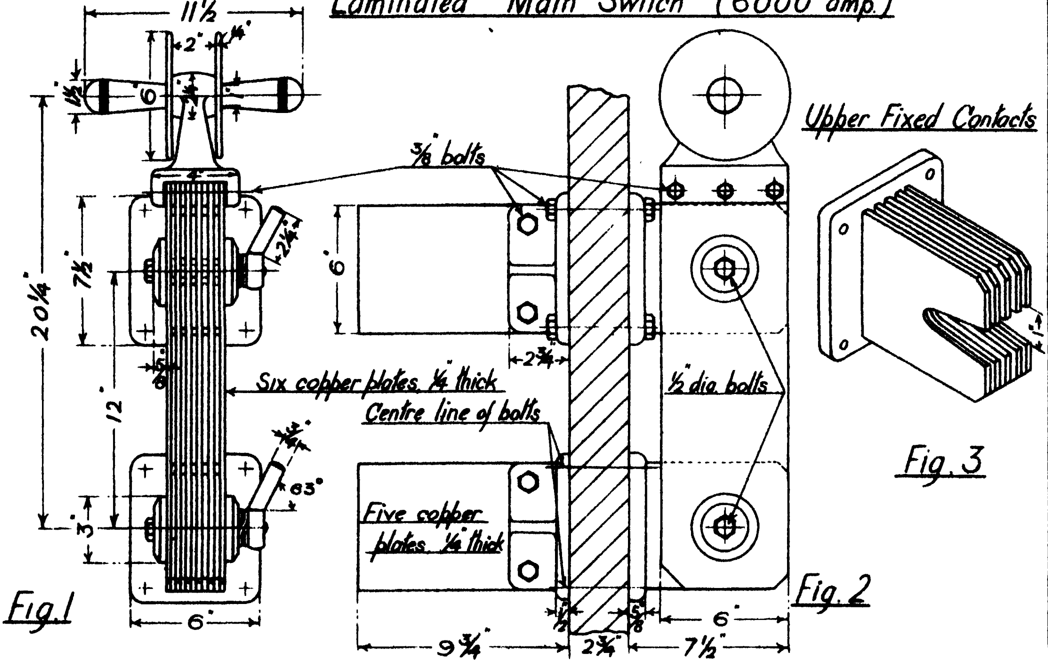
EXERCISES

(1) Draw the front elevation, side elevation, and plan of the laminated main switch, showing the switch closed. Scale: quarter full size. Spring washers are shown under the clamping levers; the double bends at the centre may be taken as 45°.

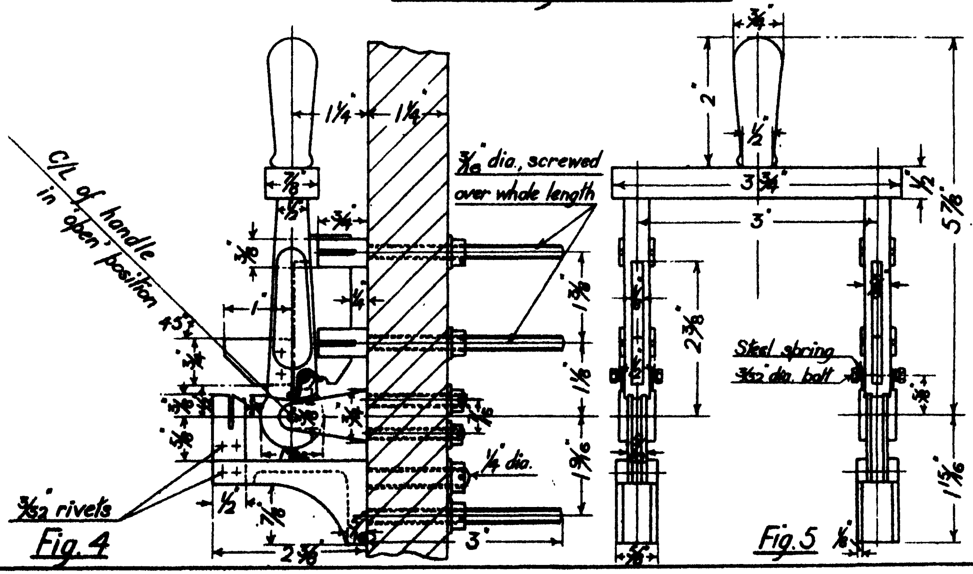
(2) Copy the views given of the field magnet switch and add a plan. Scale: half full size.

KNIFE SWITCHES

Laminated Main Switch (6000 amp.)



Field Magnet Switch



MULTIPLE WAY SWITCHES

Resistance Regulating Switch. — This switch is used to vary the current in a circuit, within limits, by including a variable resistance. Fig. 1 shows a switch of the faceplate type; a lever can be rotated so as to make contact with a series of fixed studs. A suitable brass bush is screwed to the faceplate to provide a bearing for the lever, and the motion of the lever is limited by stops. The screws holding the bush are inserted from the back, the points showing in the figure. The lever is fitted with an insulated handle, and the contact is *laminated*. The lever and bush are shown separately, but without the laminated contact, in fig. 4. Some of the contact studs are omitted in fig. 1, but the holes in the panel for fixing them have been shown, and they are arranged symmetrically about a centre line. The stops are placed so that full contact can be made on the outer studs. Separate diagrams show the form and dimensions of the contact studs and the stops. The resistances are wound on a framework, and are fixed behind the switch, and the ends of the resistance coils are secured to the screws which hold the studs.

Voltmeter Switch. — This is a selector switch by means of which a single voltmeter may be used to indicate the pressure across any pair of mains. A number of contact studs are arranged in circular arcs and inside these arcs are two brass quadrants which are connected to the voltmeter. There is one pair of studs for each pair of mains. Laminated contacts carried in porcelain blocks are fitted at each end of a lever which can be rotated so that the contacts will bridge across from a pair of contact studs to the quadrants. The top of each porcelain block fits into a slot near each end of the lever, and a steel spring under the lever presses the blocks down and ensures good contact. The end elevation shows the upper block and contact in section. Insulated studs of smaller diameter are placed between the contact studs, and stops are provided as in the regulator switch to limit the movement of the lever. The switch is mounted on a slate base, which can be fastened to the front of a switchboard panel, the contact stud screws being long enough to extend right through. Both switches are made by the General Electric Company.

EXERCISES

(1) Draw a front elevation and side elevation of the regulator lever with laminated contact, together with bush and one contact stud. Scale: three-quarter full size.

(2) Draw an elevation of the resistance regulator with lever removed, but with bush in position. Project an end view. Scale: half full size.

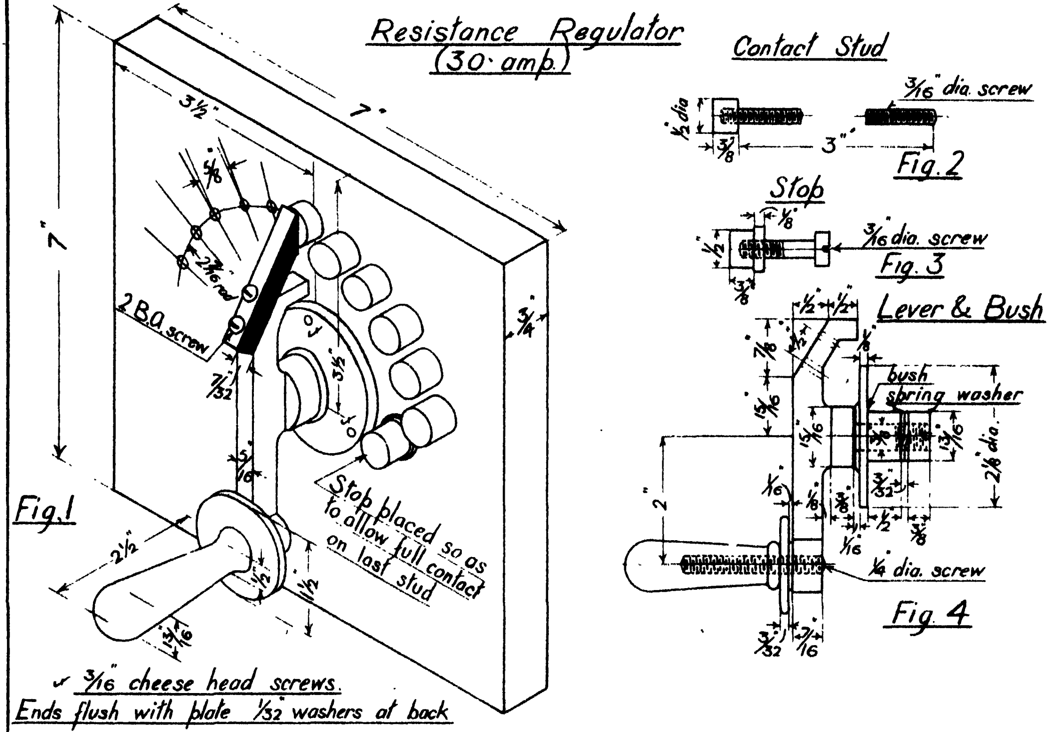
(3) Draw a front elevation of a resistance regulator similar to that shown but with one more contact. The contacts are to be the same size and the same distance apart but must have their centres on a larger radius so that the angle through which the lever turns shall be the same as before.

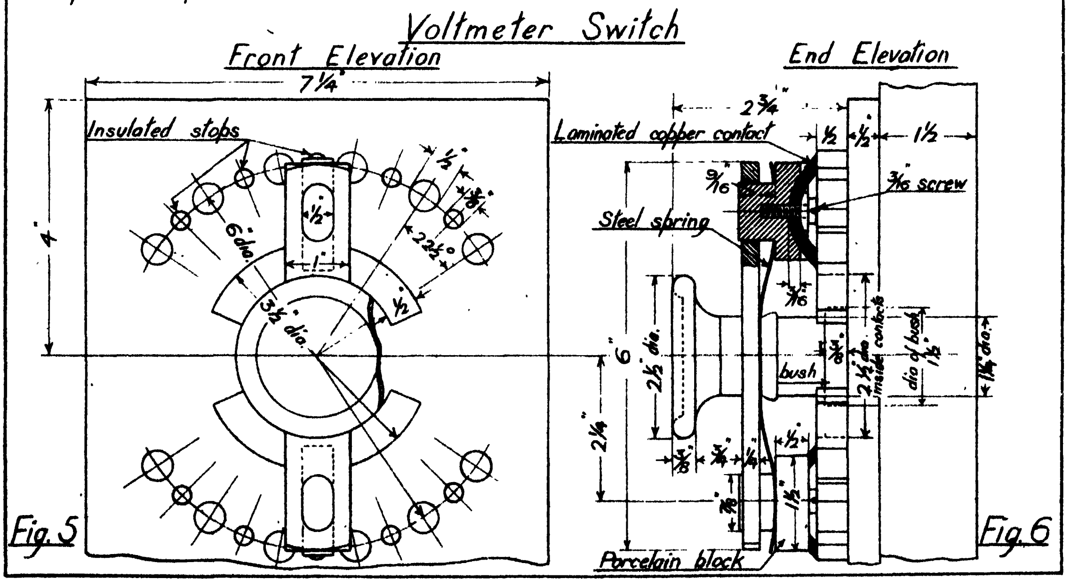
(4) Draw an elevation of the voltmeter switch with lever removed, and project a vertical section at the centre. Scale: half full size.

(5) Draw an elevation of the lever for the voltmeter switch, and project an end view, showing the top half in section. Scale: half full size.

(6) Arrange the studs on a voltmeter switch similar to fig. 5 but having five pairs of voltmeter studs instead of six. Keep the distance between the studs the same but reduce the radius of the arc to 5½″. Draw the front elevation and measure the angle through which the lever may be turned.

MULTIPLE WAY SWITCHES





MOTOR STARTERS

Only the very smallest motors can be connected directly to the mains; with all others some sort of starting device is necessary. The starter usually consists of a resistance which can be gradually reduced by the movement of a lever over contact studs. For series motors this resistance is put in series with the motor; for shunt motors it is put in series with the armature, the field coils being of high resistance can be connected directly to the mains. For A.C. induction motors the resistance may be placed in series with the stator windings or, if a large starting torque is required, and the minimum line disturbance, the resistance is put in series with the rotor coils. For a three-phase induction motor there will be three sets of resistances, one for each rotor winding, and the switch is usually in three parts, so that all the resistances are cut out at the same time.

D.C. Starter.—Fig 1 shows the plate panel of a shunt motor starter with the starting lever and overload coil removed. The details of the starting lever are shown separately in figs. 2, 3, and 4. The spring tends to pull the lever to the "off" position, but when the motor is running the lever is held in the "on" position by the attraction of the "no-volt" coil. Should the current fail the coil will cease to hold the lever, which will fly to the "off" position. The position of the studs which hold the "overload coil" are shown in fig. 1, but the coil is not shown. This coil carries the full load current, and if the latter exceeds a certain value an armature is attracted which short-circuits the no-volt coil and stops the motor. It should be noted that the contact stud which carries the current when the motor is running at full speed is larger than the others. The resistance coils are not shown; they are carried on a frame which is fastened to the back of the panel.

Both types of starter shown are made by the General Electric Company.

A.C. Starter.—Fig. 8 shows the starter panel with the fixed contacts in position. There are three similar sets; one for each phase. The edge of each fixed contact is placed so that it will coincide with the edge of the moving contact when the contacts just touch. Details of the starting handle and lever are shown in figs. 6 and 7. If an overload coil and no-volt coil are fitted to this switch it is necessary to use a spring to pull the lever to the "off" position.

EXERCISES

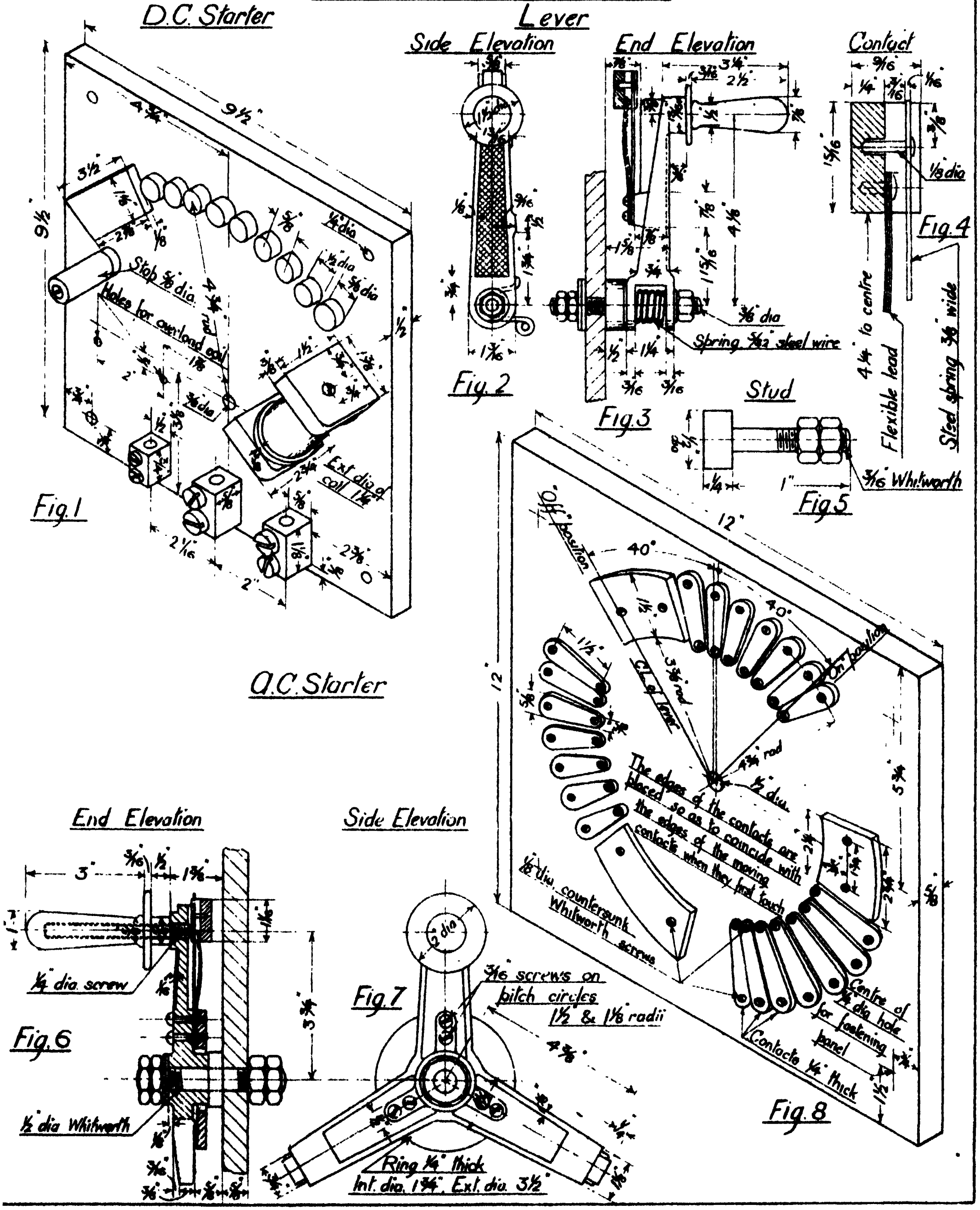
(1) Draw a front elevation of the D.C. starter panel, omitting the starting lever and overload coil, and project a plan. Scale: half full size.

(2) Copy the views of the lever shown in figs. 2 and 3 and add a plan. Scale: full size.

(3) Draw an elevation of the A.C. starter panel shown in fig. 8. Scale: half full size.

(4) Draw the front elevation of the lever for the A.C. starter, but place it in the "off" position. Project a plan. Scale: half full size. The contact for this lever is similar to that on the D.C. starter.

MOTOR STARTERS



A circuit breaker is a switch for carrying a heavy current which is closed by hand but which opens automatically when the current reaches a certain value. In generator leads, feeders, &c., where the currents are very heavy, it is undesirable to fit fuses, and it is in such positions that circuit breakers are used. They not only protect the circuit from overload, but can be used as switches and they can be arranged to open if the current is reversed. The automatic action may be immediate or may be delayed to any extent by using a time-lag device, and in some cases the length of time during which the delay action occurs is made to depend on the amount of the overload. There are two sets of moving contacts, the main contacts and the sparking or auxiliary contacts. The sparking contacts may have carbon tips or renewable metal tips, and the spark is extinguished by creating a magnetic field across it.

Fig. 1 is a view of a circuit breaker made by Messrs. Statter & Co. It is fitted with an overload device and a magnetic blow-out, and is suitable for use with either direct or alternating currents. The essential parts of the breaker are the fixed contacts (*a*) and (*b*); the moving contacts (*f*), which hinge about pillars on the lower contact; the lever and handle (*g*); the crank and lever (*d*) and the links (*e*) which connect the moving contact with the crank.

The breaker is shown closed in fig. 1; when it opens the moving contacts hinge outwards about the pillars on the lower contact. The breaker is closed by a double motion of the handle and lever; first upwards into the horizontal position, then downwards into the original position. When the handle is raised the insulated cross bar behind it presses against the back of the moving contact frame and pushes it inwards; this causes the crank and the lever (*d*) to rotate downwards. The pin on the end of this lever engages with the notched spring catch on the lever (*g*). Now when the handle is depressed the lever (*d*) continues to turn downwards and pull the moving contacts against the fixed ones. When the switch is closed the lever is held down by the pawl on the bracket (*c*). Thus most of the downward movement of the handle is employed in obtaining a high contact pressure. The breaker is opened by pushing the button, which knocks up the spring catch and releases the lever (*d*); this, as it swings up, lifts the pawl on the bracket (*c*) and releases the handle. The upward motion of the lever is limited by the part of the bracket which forms the bearing for the pawl and is covered with a rubber strip.

In fig. 1 part of the iron plate and asbestos screen have been cut away to show the **magnetic blow-out coil** and the sparking contacts. The magnetic field produced between the iron plates when the breaker is opened causes the spark which forms between the contacts to be blown out.

Figs. 2 and 3 show the upper main fixed contact. It is of copper and is held in position by the stalk at its rear which clamps it firmly on to the cast-iron distance piece. This distance piece is cylindrical but has been cut away on one side. When the stalk is carrying alternating currents it is impossible for eddy currents to be produced in the distance piece.

The **lower main contact** (figs. 4 and 5) is held in place in a similar way, but the distance piece is a cast-iron rectangular box, the right-hand side being continued downwards to form a hinge for the soft-iron armature which forms the lower side of the box. This forms the essential part of the overload release. The box becomes magnetized by the current in the stalk, and, if the current is sufficiently strong, the field produced in the iron will cause the armature to be lifted. By placing the armature in a suitable position it can be arranged that it will lift for any specified current. When the armature is attracted it opens the breaker by the bolt knocking up the notched lever on (*g*). The contact plate is of copper, and at the bottom corners are the pillars to which the moving contacts are attached.

Figs. 6 and 7 are two views of the bracket plate and bearing for holding the spindle and pawl. This is cast in one piece, and there is a hole recessed in the plate to provide room for the crank when the breaker is closed.

CIRCUIT BREAKER

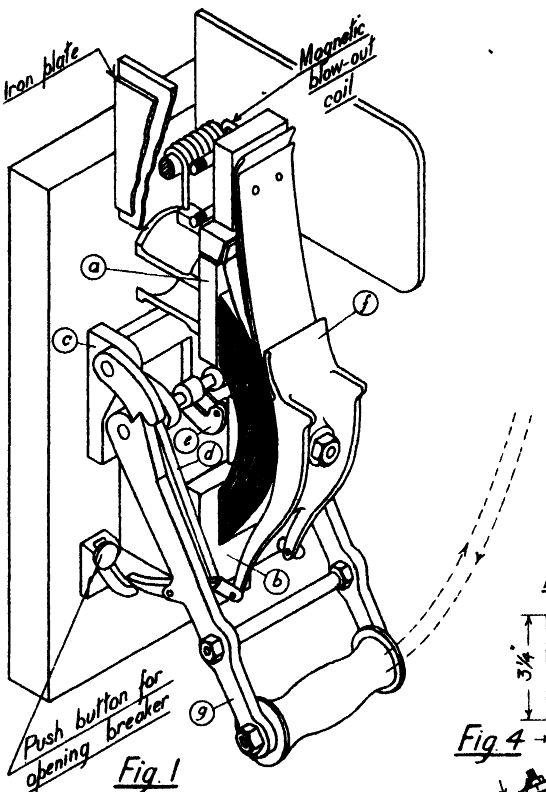


Fig. 1

Upper Main Contact

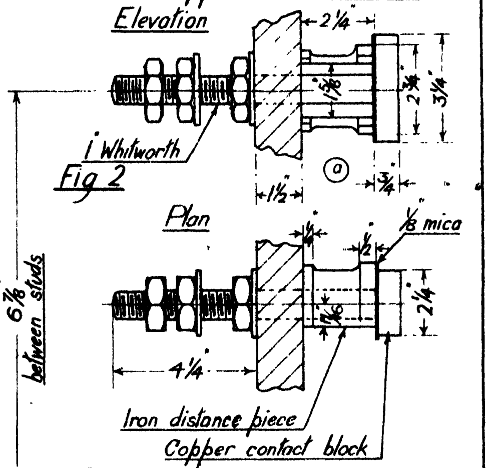


Fig 2

Fig 3

Lower Contact

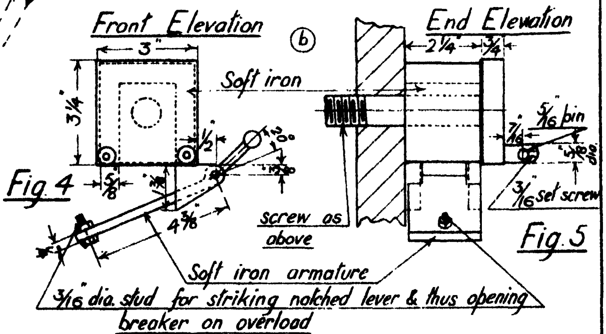


Fig 4

Fig 5

Bracket

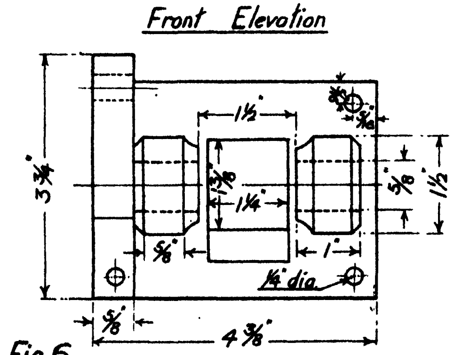


Fig. 6

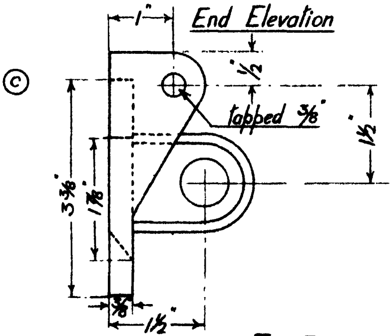


Fig. 7

Some further details of the circuit breaker are shown on p. 53. **Figs. 1 and 2** show the crank and lever, rigidly keyed to the spindle. For the position in which they are drawn the breaker is closed. The spindle fits the bearings on the bracket plate and is long enough to project beyond the ends; the holes in the levers (*g*) fit over these projections.

The moving contacts are shown in figs. 5, 6, and 7. The contacts are of copper laminations and they are clamped into a steel frame by a bolt which passes through the centre and holds a steel block against the inner curved surface. The sparking contacts are held in the same frame; each consists of two metal strips, one much thicker and stiffer than the other, riveted at the top to a sparking tip of copper. The outer edges of tie frame are curved so as to slip easily along the bar behind the operating handle as it is raised. The clamping bolt is in contact with the operating mechanism and is therefore insulated from the contact laminations and frame by a fibre or composition sleeve and washers. Some of the smaller radii have been omitted from this drawing, and it is left for the student to supply them.

The laminations in the figures are thicker than they actually measure. There are 68 copper plates, and to show this number the lines would have to be drawn very closely together. Apart from the difficulty of drawing lines accurately to a small scale, it is waste of time, and not at all necessary, and if the lines are fairly close together they can represent laminations of any specified thickness. In a working drawing the thickness of the laminations and the number would be stated in a note or in the schedule. Most of the laminations are of the same thickness, but those nearest the frame, in both the main contact and the sparking contacts are considerably thicker.

The contacts are shown in the closed position. There is a considerable amount of "spring" in the laminations, which causes the plates to spread out with a sliding action on the fixed contacts when the breaker is being closed, but there is much more "spring" in the sparking contacts, so that when the breaker is opened they will not break the circuit until the main contact has moved some distance.

The operating handle and lever are shown in figs. 8, 9, and 10. As seen from the general view on previous page there are two levers with the handle bolted between them. In addition, there is a steel bolt behind the handle, and this is covered with an insulating sleeve because it comes in contact with the back of the moving contact frame when the handle is raised. The two levers are almost similar; the only difference is that one has a projection for the notched spring catch which engages with the pin on the end of the lever in figs. 1 and 2.

EXERCISES

(1) Draw the front elevation and end elevation of the fixed contacts for the circuit breaker in their proper relative positions, showing the overload device. Scale: three-quarter full size.

(2) Make an isometric view of the bracket and bearing shown on previous page (figs. 6 and 7). Scale: full size.

Or, copy the views shown of the bracket and bearing, and project a section through the centre line of the bearing, looking vertically upwards. Scale: full size.

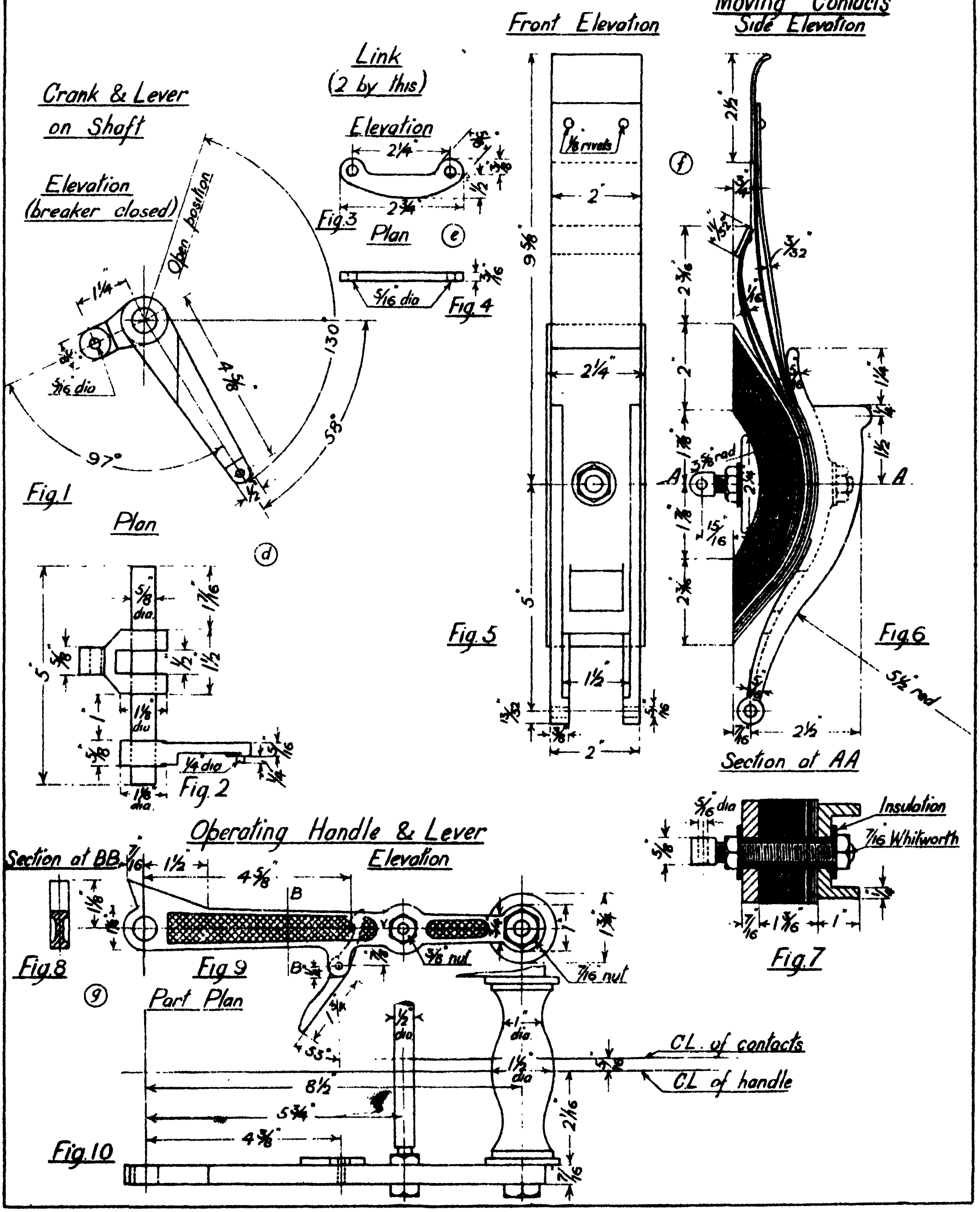
(3) Draw an end elevation of the bracket (fig. 7, p. 51). Then show the lever and crank in position when the breaker is closed. Scale: full size.

(4) Draw the side elevation of the moving contacts (fig. 6) and project an elevation looking towards the right. Scale: half full size.

(5) From the dimensions given in the drawings, construct a line diagram and determine the angle through which the moving contacts can turn in passing from the open to the closed position.

(6) Draw an elevation of the operating handle and lever inclined at 45° to the vertical and project an end view. Scale: three-quarter full size.

CIRCUIT BREAKER



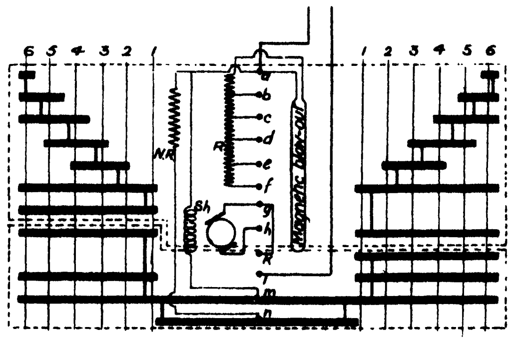
Motors which have to be started frequently, and which have to be run at different speeds, are regulated by **motor controllers.** Examples of fittings from drum type controllers are given on pp. 55 and 57. There is some variation in the construction of controllers for various purposes; for instance, a controller for a crane motor is somewhat different from a controller for traction work. The general construction of a motor controller is shown in figs. 1 and 2. A vertical **power cylinder** carries a number of copper **segments** which, as the cylinder is rotated, come into contact, one after another, with a series of fixed spring contacts. Rotation of the cylinder changes the resistance in the motor circuit or changes the way in which the motor is connected and hence alters the speed or direction of rotation. In the crane type controllers the motor may be reversed by reversing the direction of rotation of the cylinder from the " off " position, but in the traction type there is a separate reversing cylinder. When the contact segments leave the fingers, arcs are formed, and a **magnetic blow-out** coil is fitted to extinguish them. Partitions of asbestos or fireproof insulation are placed between adjacent contacts to prevent arcs forming between them, and these are attached to the blow-out coil. The latter consists of a coil of wire wound on a soft-iron core, so that when the contacts are separated a current flowing in the coil causes a strong magnetic field to be formed across the arc. The controller is enclosed in an asbestos-lined steel casing. The front of the casing can be removed and the blow-out coil hinged out to give access to the contacts. Two forms of power cylinder contacts are shown.

Figs. 3, 4, 5, and 6 illustrate the top contacts for the power cylinder of a crane controller made by the General Electric Company. Two castings are bolted together on a square bar covered with micanite. Horizontal webs project on either side, and the copper contact segments are fastened to them by countersunk screws as seen in fig. 4.

Figs. 7 and 8 show a small set of contacts from the power cylinder of a traction type controller made by The English Electric Co., Ltd. At the end of each segment there is a short **sparking tip.** It is on these pieces that arcs are formed when contact is broken and the tips can be easily renewed when damaged, without replacing the whole segment.

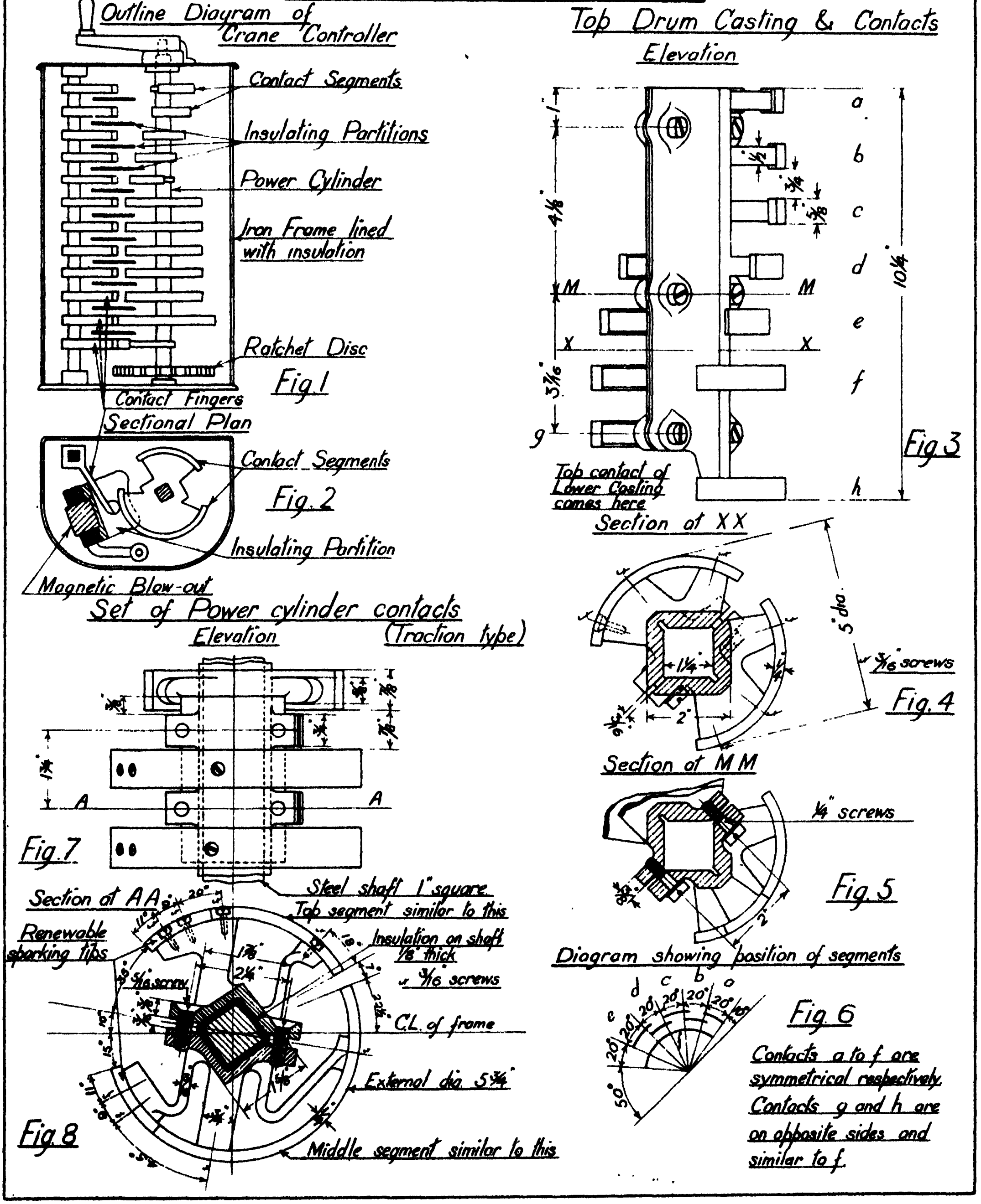
The contacts are of equal depth and are equally spaced.

A typical **wiring diagram** for a drum controller for a reversing shunt-wound motor is shown below. The dotted lines represent the drum castings. The thin vertical lines represent the position of the fixed contacts with reference to the moving ones for various positions of the power cylinder.



Sh – Shunt winding   NR – Non-inductive resistance
R – Resistance coils   a.b.c.d. · contact fingers

MOTOR CONTROLLERS



Two types of **contact fingers** are shown in figs. 1 to 4. Figs. 1 and 2 illustrate the registered design of the General Electric Co. All the other diagrams show details of parts from traction controllers of the English Electric Co., Ltd.

The contact finger in figs. 1 and 2 is mounted on a micanite covered steel bar. The contact tip is of hard-drawn copper, half-round in section, and the current passes from it to the clamping block through a number of copper laminations which provide a certain amount of spring. The position of the contact tip can be adjusted by means of the milled nut. This nut has a square portion at one end which fits into a slot in a forked brass strip, and is therefore prevented from turning accidentally.

The contact finger shown in figs. 3 and 4 is connected by a flexible copper strip to a casting which is screwed to an impregnated wooden bar. Adjustments are made by the square-headed set screw which is locked by the spring.

The **contacts** on the **reversing cylinder** are much smaller than those on the power cylinder, and they are mounted on a square-section, mica-covered steel shaft. One set of contacts is shown in figs. 7 and 8. A mechanical interlocking device prevents this cylinder from being rotated when current is passing into the motor, and therefore renewable contact tips are not necessary.

The **magnetic blow-out coil** is wound on a vertical iron rod so that the magnetic field produced is vertical. The coil is surrounded by a copper cylinder, and the arcs which form between the contacts spread out to the copper cylinder and travel round it, increasing in length until they are extinguished. The coil is carried on two brackets which are attached to a vertical rod so that the coil can be swung out clear of the contacts. The insulating partitions, which prevent arcs forming between adjacent contacts, are all the same size and are equally spaced along the coil.

EXERCISES

(1) Draw the elevation of the top drum contact (fig. 3, p. 55) and project a section through the contact (*g*). Scale: half full size.

(2) Draw an elevation of the power cylinder contacts (figs. 7 and 8 on previous page) in a direction at right angles to that shown in fig. 7. Also draw a plan. Scale: full size.

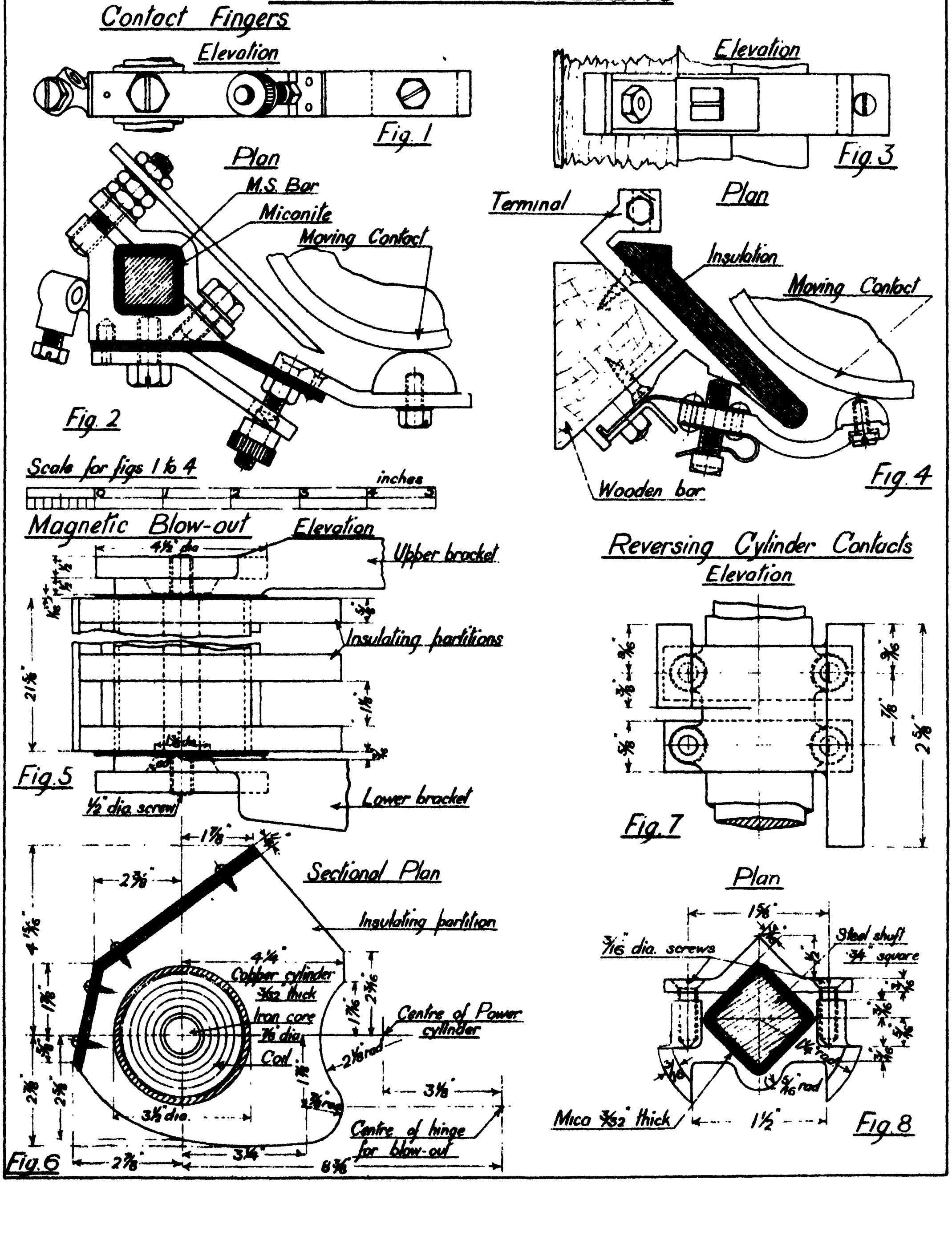
(3) By means of the scale given, copy the plan of the contact finger shown in figs. 3 and 4. Scale: full size.

(4) Use the scale to draw an end view of the contact finger (figs. 1 and 2) looking to the right. Scale: full size.

(5) Copy the plan of the reversing cylinder contact (fig. 8), but turn it through 45°. Project an elevation. Scale: full size.

(6) Copy the sectional plan of the blow-out coil and draw a sectional elevation through the centre, omitting the brackets. Show four partitions. Scale: half full size.

MOTOR CONTROLLERS



The contacts of switches which break high-tension circuits are immersed in oil to ensure the rapid and effective rupture of the circuit. It should be realized that a smooth contact surface is essential and that any roughness caused by excessive arcing at the contacts is detrimental to the satisfactory functioning of the switch.

Oil switches are employed for the control and protection of circuits associated with electrical generation and distribution systems.

It is the usual practice to provide two breaks in each phase.

The efficient rupturing of a circuit is more involved than may be at first appreciated, since under short-circuit conditions the switch will be called upon to rupture a kVA considerably in excess of the normal carrying capacity. This short-circuit kVA is only limited by the impedance of the alternators and transformers feeding the current.

It is important to secure a sufficient quantity of oil and adequate insulation of the "live" parts. Ample clearance must also be allowed between the breaking contacts and the case of the switch, since the hot gases developed in the oil during a heavy rupture rapidly expand over an area considerably larger than the contacts, and thus may provide a conducting path to the case if sufficient clearance were not allowed, causing a short circuit to earth over which the switch would have no control.

Fig. 1 shows the general arrangement of the fixed and moving contacts of an oil switch made by The General Electric Co. Ltd. Both sets are mounted on a steel top plate which forms a cover to the oil container into which the contacts are immersed.

The **fixed contact** assemblies are arranged in three sets of two each, and each assembly consists of a connecting rod which passes through a high-quality porcelain insulator; the upper end of the rod carries an isolating plug, while the lower end carries the contact "fingers" (see fig. 7).

The contact "fingers" consist of three pairs bolted to a mounting head; the outer pair of each set, known as the arcing contacts, are slightly longer than the rest, as shown in fig. 8.

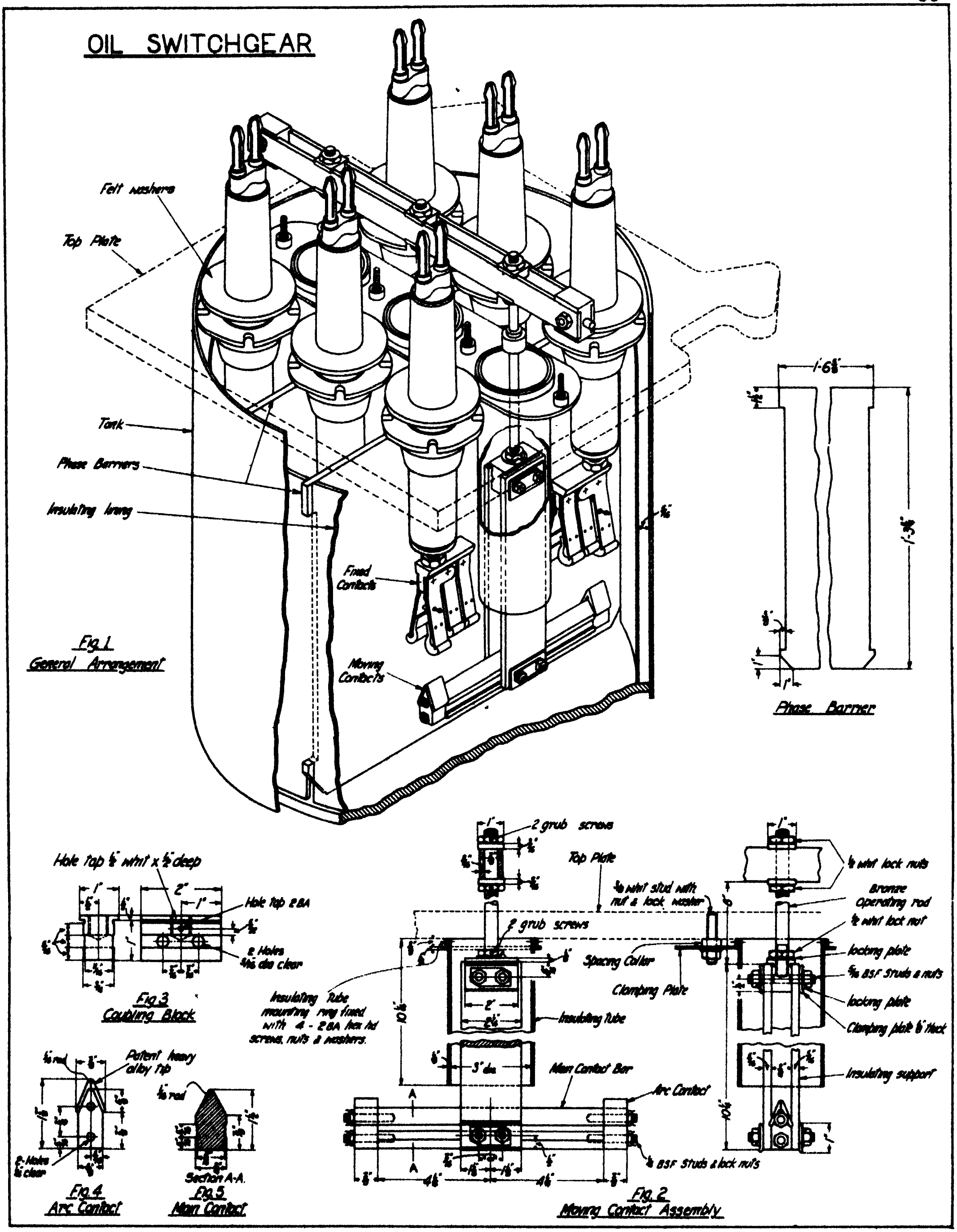
These arcing contacts are made of a special heavy alloy and are for the purpose of carrying the current at the time of rupture so as to localize burning, thus leaving the main contacts smooth. It is for this reason that they are made detachable so that they can be easily replaced.

The main contacts (fig. 9) are of high-conductivity, hard-drawn copper. The contacts are riveted to copper laminations and are designed to have sufficient spring to ensure good contact when the switch is closed. This is obtained by a steel backing spring to the laminations (see figs. 8 and 9).

The **moving contacts** are made of high-conductivity, hard-drawn copper bars of wedge section as shown in fig. 5. At each end renewable arcing contacts (fig. 4) are fitted; these are made of a special heavy alloy and are the companion contacts to the fixed arcing contacts (fig. 8).

There are three sets of contacts and these are always in pairs. Fig. 2 shows one pair of moving contacts.

All nuts must be locked to prevent them working loose. These switches are suitable for a maximum voltage of 11,000 volts, and at 6000 volts and upwards have maximum breaking capacities ranging from 75,000 to 250,000 kVA.


OIL SWITCHGEAR
Felt washers
Top Plate
Tank
Phase Barriers
Insulating lining
Fixed Contacts
Moving Contacts
Fig. 1
General Arrangement
Phase Barrier
Hole tap ½" whit x ½" deep
Hole tap 2BA
2 Holes clear
Fig. 3
Coupling Block
Insulating Tube mounting ring fixed with 4 - 2BA hex hd screws, nuts & washers.
Patent heavy alloy tip
Fig. 4
Arc Contact
Section A-A
Fig. 5
Main Contact
2 grub screws
Top Plate
whit stud with nut & lock washer
2 grub screws
Spacing Collar
Clamping Plate
Insulating Tube
Main Contact Bar
Arc Contact
BSF Studs & lock nuts
whit lock nuts
Bronze Operating rod
whit lock nut
locking plate
BSF Studs & nuts
locking plate
Clamping plate thick
Insulating support
Fig. 2
Moving Contact Assembly

The top plate (fig. 6) carries the **lifting mechanism** which operates the moving contacts; this is mounted as shown in fig. 10.

The moving contacts are coupled to the lifting mechanism by insulating plates, which are bolted to coupling blocks (fig. 3). These blocks carry $\frac{1}{2}''$ diameter bronze rods that pass through the top plate and are in turn bolted to cross bars as shown in fig. 10, which couple the lifting mechanisms situated at each side of the top plate. Accelerating springs are provided to give the correct speed of operation when the circuit breaker is opened.

The bronze rods to which the moving contacts are connected are shrouded by insulating tubes, so that there is no exposed earthed metal in close proximity to the arc (see fig. 1).

A baffled vent is fitted in the top plate to allow escape of gases formed during the rupture of the circuit.

The links are designed to give a vertical straight line motion to the cross bar, and the toggle joint mechanism embodied causes a considerable pressure to be exerted between the contacts when the switch is closed.

Details of the link mechanism are as follows: Link A is $\frac{1}{4}''$ mild steel, $\frac{7}{8}''$ wide at each end, and $1\frac{1}{8}''$ wide in the middle.

Link B is $\frac{3}{32}''$ mild steel, channel shaped, $1\frac{1}{8}''$ inside width, and each of the sides has an outside width of $1''$. The base of the channel is cut away for a distance of $1\frac{5}{8}''$ at the top end, and $\frac{3}{4}''$ at the bottom to clear the couplings.

Link C and the double link D are $\frac{3}{4}''$ wide and $\frac{3}{16}''$ thick mild steel.

The link which holds the spring to the centre pin is $\frac{3}{16}''$ thick by $1\frac{1}{2}''$ long overall, rounded off at each end

The moving mechanism has a travel of $5\frac{1}{4}''$ measured from the top of the arc contacts.

The actual break is approximately $4''$. When closed the moving arc contacts fit $1\frac{1}{4}''$ inside the fixed arc contacts.

The tank that houses the switch shown in fig. 1 is $1'\ 7\frac{1}{2}''$ diameter by $1'\ 6''$ inside depth. The wall is $\frac{3}{16}''$ thick and the bottom $\frac{1}{2}''$ thick. It is provided with a lining of insulating material. A small space of $\frac{1}{4}''$ to $\frac{3}{8}''$ is allowed between this lining and the inside of the tank, in order that there shall be a layer of quiescent oil; this prevents an arc coming in contact with the earthed metal.

Each set of contacts is separated by a wooden partition, called a "phase barrier" (see fig. 1).

EXERCISES

(1) Draw a front and side elevation of the fixed contact shown in fig. 7. Scale: half full size.

(2) Draw a front and side elevation of the moving contact and project a plan view. Scale: half full size.

(3) Draw a side elevation of the complete assembly of the top plate, showing in position the fixed contacts, link mechanism, and the moving contacts in the open position. Scale: three-eighths full size.

(4) From exercise 3, project a front elevation, showing the outline of the tank, phase barriers, and moving contact insulating shrouds in position; show also the oil level.

For details of the construction and link dimensions read text. Scale: three-eighths full size.

OIL SWITCHGEAR

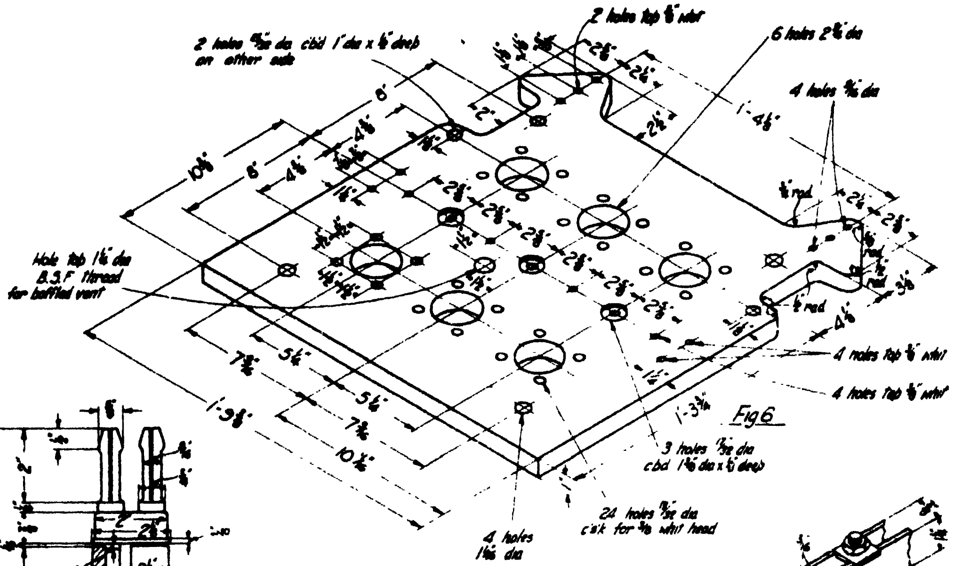


Fig 6

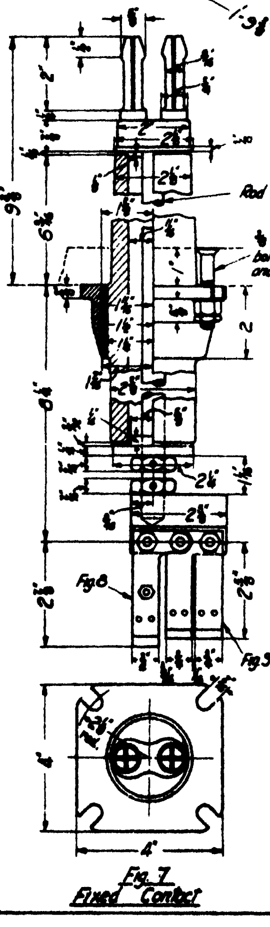


Fig. 7
Fixed Contact

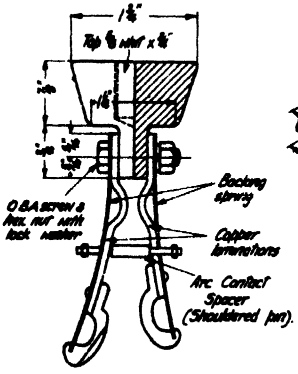


Fig.8
Arc Contact

Fig.9
Main Contact

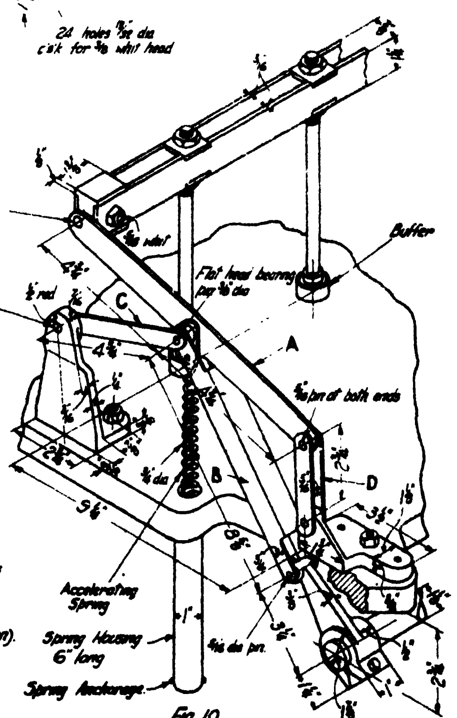


Fig 10
Switch Operating Mechanism
Left Hand Side (Switch Closed)

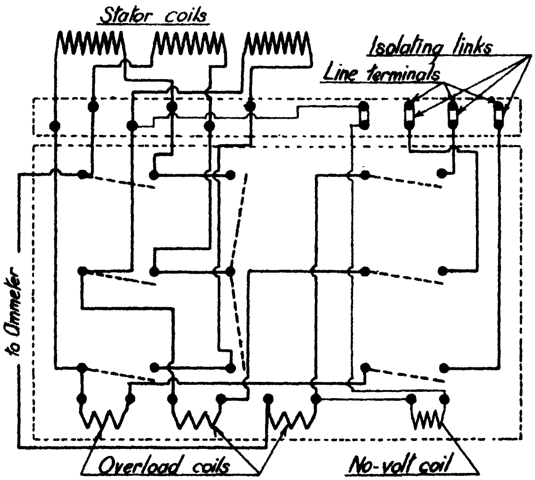
IRONCLAD STAR-DELTA STARTER

A switch for starting an A.C. motor by putting resistance in the rotor or stator coils has been shown on p. 49. Other devices which are frequently used for starting A.C. motors are auto-transformers and star-delta starters. A **star-delta starter** is a switch which is arranged so that the first movement connects the stator windings to the mains in " star "; after a short interval, during which the motor gains speed, a further movement connects the windings to the mains in " mesh " or " delta ". Much industrial switchgear is of the ironclad type, that is, wholly enclosed in an iron case. It has the advantage of being fireproof and free from dust and dirt.

The starter shown opposite is made by Messrs. Brookhirst Switchgear, Ltd. The ammeter and the cable connecting box which form part of the equipment are not shown. It is of the iron-clad type, the switch and connexions being totally enclosed in cast-iron boxes. The switch contacts are oil immersed, and the oil tank is held in place by long vertical bolts which pass through lugs on the end of the tank. The tank may be lowered for inspection of the contacts by removing the thumb screws; the tank can then be let down until the upper lugs rest on the nuts. Overload coils for each phase and a no-volt coil are fitted, and there is a push-button release in the front of the case for stopping the motor.

All the fixed contacts are bolted to a slate panel and the moving contacts are raised by vertical rods whose upper ends are connected to levers. There are three sets of contacts; one set forms a circuit breaker, another set connects the stator coils in " star ", the third set connects them in " delta " or " mesh ". The switch is operated by the handle shown in the extreme right in fig. 2. It is raised into the dotted position and then worked backwards and forwards; this, by a ratchet inside the casing, causes the cam shaft to rotate. The cams are arranged so that the levers and switch contacts will be raised in the proper sequence—circuit breaker closed, star contacts closed; star contacts opened and delta contacts closed. The circuit breaker remains closed not by the action of the cam, but by the pin on the end of the lever engaging with the trip gear on the overload coils.

A wiring diagram for the switch is shown below. Three isolating links are fitted so that the whole switch may be disconnected. The fourth link is removed if a remote control is required.



EXERCISES

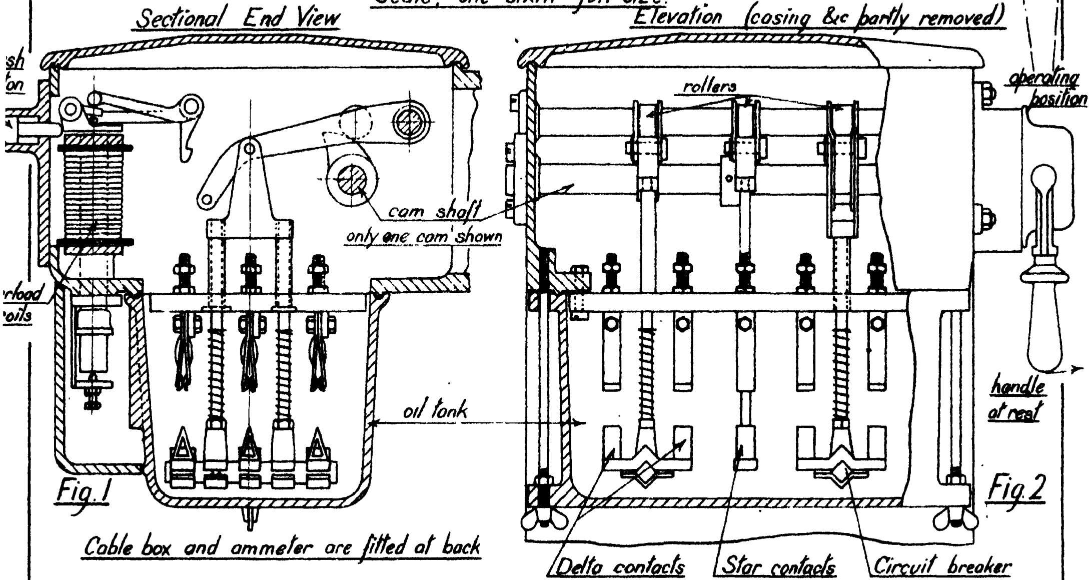
(1) Draw an elevation and end view of the fixed contacts (fig. 4) and project a view looking from below. Scale: full size.

(2) Draw an elevation and end view of the moving contacts (fig. 3). Scale: full size.

(3) Draw the wiring diagram for the star-delta starter, omitting the third overload coil—that is, showing overload coils on two phases only—and show a switch connected for remote control.

IRONCLAD STAR-DELTA STARTER

Scale, one-sixth full size.



Cable box and ammeter are fitted at back

Details of Contacts

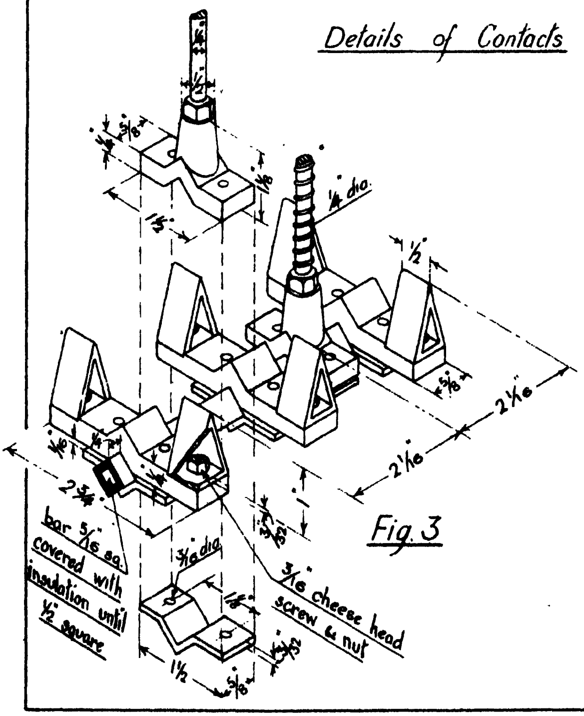


Fig. 3

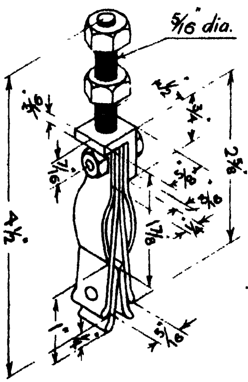


Fig. 4

29229

DATE OF ISSUE

This book must be returned within 3, 7, 14 days of its issue. A fine of ONE ANNA per day will be charged if the book is overdue.