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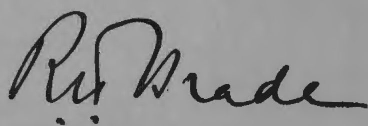

WAR OFFICE,

9*th March*, 1915.

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MILITARY ELECTRIC LIGHTING.

VOLUME II.

CHAPTER I.

THEORY OF ELECTRIC ARC.

CONTENTS.

The source of light used in the military service for electric lights in attack or defence is the electric arc. Electric arc.

If two points of conducting material have a potential difference, whether alternating or continuous, of not more than 100 volts maintained between them, it will be found that they may be brought extremely close together before any discharge takes place between them, and the 100 volts will not produce a spark across any distance visible to the naked eye.

Should, however, the discharge once start in consequence of their touching, then, if the potential difference be maintained, a brilliant luminous mass will form between the points, and a current will pass between them even if they be considerably separated. This mass is the arc, and, as stated, it is established whether the current is alternating or continuous. In the service, however, arc lights are invariably produced by continuous currents, and in this chapter this case only will be considered. How formed.

Conductors.

The arc appears to be a flow of the particles of which the conductors are made taking place from the conductor attached to the positive pole of the source of power towards that attached to the negative. The heat is, however, so great that portions of the conducting particles are volatilized and pass away, and the conductors consequently waste, the positive considerably faster than the negative.

In practice, the conductors are invariably formed of carbon, the relative sizes of positive and negative being arranged so that the rate of burning away is equal.

Shape and Appearance of Arc.

The main object when manipulating an arc light is to obtain as much light as possible while maintaining the steady burning of the carbons.

To obtain this, it is necessary to understand something of the action and appearance of the arc under conditions approximating to those in use for military purposes, viz., a potential difference between the carbons of 60 volts and a current of 120 amperes.

In the first place the arc is extremely bright if looked at with the naked eye, but, by projecting its image on a screen, or observing it through a dark glass, the following points may be noticed when the arc is burning steadily :—

(1) The end of the positive carbon is somewhat tapered, with a depression at the tip called the crater, which is brilliantly luminous.

(2) The end of the negative carbon is burnt to a blunt point, in which there is a small bright spot like a minute crater.

(3) The tips of both carbons are white hot, diminishing further from the point through yellow to red.

(4) Round the base of the points of both carbons is an irregular ring of bubbles of burning carbon.

(5) Between the points is the "arc," which for a given distance between the carbons assumes a fairly regular shape. The centre of the arc has a violet hue, the outer portion is green, and there is a definite shadow-like portion lying between these two.

(6) Round the arc and points there is a bright flame.

(7) The arc does not remain steady, but tends to move about over the crater of the positive carbon.

Source of light.

By obscuring parts of the arc it will be seen that the greatest source of light is the white hot tip and crater of the positive carbon, that the tip of the negative carbon gives an appreciable but much smaller amount of light and that the arc itself contributes a still smaller amount.

Further observation shows that while both carbons are consumed away, there is a continuous flow of particles of carbon from the positive to the negative. The latter is thus partially renewed by the action of the arc and wastes much more slowly than the positive.

Flow of carbon particles from positive to negative carbon.

This also tends to keep the crater on the negative carbon very small as it is filled up, as fast as it forms, by these carbon particles.

Electrical Properties of the Arc.

The exact method in which the arc is produced by the electric current is still not definitely known, or at least expert opinion is not yet unanimous, but the following explanation, based on the theory propounded by Mrs. Ayrton, is probably accurate, and explains the facts as far as we know them.

It is well known that a bad contact in an electrical circuit is a source of heat, and this is due to the fact that the current finds itself restricted to a few points of contact, the resistance of which is high and the heating effects consequently large.

If two conductors with a considerable difference of potential are brought tight together the current is at first comparatively large, but as the conductors are slowly separated the contact becomes bad, and the heating effect increases, until at last the whole current is passing through some very small portion of the conductor. The heating effect then becomes so great that the conductors are melted and formed into vapour, which acts as a conductor of high resistance, providing a passage for the current after actual separation of the conductors has taken place. This arc of hot vapour increases as the conductors are separated.

Heating effect commences with bad contact.

A further analysis of the arc seems to show that the vapour goes through three stages :—

Analysis of vapour in the arc.

(1) It is formed mainly at the surface of the positive carbon.
(2) As the arc increases in size, the vapour is cooled by contact with the air to form a mist, which forms the central purple portion of the arc.
(3) The outside of this mist combines with the air and burns in a flame enveloping not only the arc, but the tips of the carbons as well. This is the outer green flame which is readily noticed round the arc.

There is also some definite action at the point where the arc strikes the negative carbon. It seems possible that there may be here a thin film of vapour acting in the same way as that at the positive carbon, but on a smaller scale, or there may be here a true back E.M.F.

The resistances of these three elements of the arc probably vary considerably. Vapours as a rule have a high resistance, therefore it is supposed that the thin films of vapour have a comparatively high resistance. The mist is, however, composed largely of minute particles of carbon, and thus has a resistance

Resistance of parts of the arc.

approximating to that of a thin carbon conductor, while the flame has such a high resistance that it is practically an insulator.

If, then, the fall of potential is traced through the arc, we find first in the positive carbon a very small fall, then in the vapour on the positive carbon a comparatively large fall, in the mist a smaller fall, at the surface of the negative carbon a larger fall, and in the negative carbon a very small fall again.

The heating effect is proportional to the fall of potential, and is thus large in the vapour, small in the mist, and very small in the conductors.

Apparent counter E.M.F.

This theory explains a difficulty which has been met in practical working, that is, the apparent existence of a counter E.M.F. in the arc. There never seemed any reason why such an E.M.F. should exist, and yet there was no doubt that some 35 to 40 volts were apparently swallowed up in forming the arc. The presence of layers of vapour with high resistance requiring 35 to 40 volts to force the current through them explains the known facts in a way which is in accordance with known electrical phenomena.

The fact that an arc cannot be started with less than a certain difference of potential is also explained by the theory that the arc depends on the formation of an intensely hot vapour, which vapour offers considerable resistance. If the potential is unable to overcome this resistance the arc cannot be formed.

The loss of potential in the arc is approximately constant for a given length of arc, and this implies the condition that the resistance of the vapour film decreases as the current increases. This also coincides with facts, as the area of the crater or luminous portion of the positive carbon increases proportionally to the current, while, assuming the vapour film is very thin, its resistance will be inversely as the size of the area of the carbon in contact with it. The product of current into resistance will thus be constant.

Careful measurements by Mrs. Ayrton showed that one-fifth of the loss in the vapour occurs at the negative carbon and four-fifths at the positive, or in actual figures about 7·5 volts are used at the negative and 30 volts at the positive.

When a current is flowing the greatest production of heat takes place at the points of high resistance, in this case the vapour films, the carbon in contact with these films thus becomes highly heated so as to be luminous and also generates more carbon vapour and thus maintains the arc.

Resistance depends on length of arc and cross section of mist.

The resistance of the mist depends on the length of the arc and the average area of cross section, the latter depends on the amount of the mist, and this amount is found to increase faster than the current. This is to be expected from the fact that the heating effect varies as the square of the current.

Potential falls as current rises.

For a given length of arc an increase of current therefore reduces the resistance faster than the current increases, so that as the current *increases*, the potential difference required to send the current through the arc *decreases*.

We can now summarize the effects produced by changes in the various factors affecting the arc. Summary of effects produced.

Length of Arc.

Length of arc.

1. The longer the arc the higher the resistance, and the greater the potential difference required.

2. The shorter the arc, the greater the current, and consequently the larger the crater and the greater the evolution of heat.

3. The transference of carbon from the positive to the negative will thus be greater with a short arc than with a long one.

4. With a long arc the positive carbon will burn with a blunter tip and the crater will be nearly flat.

With a short arc the tip is hotter and consequently wastes more and the crater is deeper.

5. With a long arc the tip of the negative carbon becomes rounded and blunt. With a short arc the tip is being constantly renewed by the deposit of carbon from the mist and therefore remains more pointed.

Potential Difference.

Potential difference.

1. The amount required must be sufficient to form the vapour films and to overcome the resistance of the mist.

2. An increase of potential difference enables a longer arc to be used, with a decrease a shorter arc is necessary.

Current.

Current.

1. The greater the current the greater the size of the crater and the larger the volume of mist.

2. An increase of current thus increases the size of the source of light, but for reasons which are given in the next chapter, this increase cannot be usefully employed beyond a certain limit.

Variations in electrical conditions

All the above is based on the assumption that the arc has been properly formed, that the carbons are of suitable size and that burning has been regular.

There are, however, two sets of conditions which may arise which must be studied to ensure good burning. These are:—(1) The conditions when first starting; (2) the hissing arc.

When first starting.

When the arc is first started, and for some time afterwards, the principal change to notice is that the difference of potential required to maintain the arc will be very much less than normal, and as the arc is formed the potential will rise to a *higher* value than that required for steady running and then fall slowly to the normal. The original low value for the difference of potential is probably caused by the fact that the positive carbon in not sufficiently heated to thoroughly volatilize the carbon, the latter is thus transferred across the arc in the form of dust with consequently a lower resistance in the arc itself. The thin film of vapour is also probably not properly formed. The rise of potential above the normal is due to the fact that additional power is required at first to heat the tips of the carbons.

The hissing arc.

Under normal conditions the noise from the arc is small, but under certain circumstances the burning of the arc will entirely change, and be accompanied by a loud hissing noise or roar. Such an arc is called a "hissing arc," and, as it is accompanied by a marked decrease of light, the conditions under which it is formed must be studied to ensure good burning.

Take an ordinary service lamp burning a normal silent arc and gradually bring the carbons closer together so as to shorten the arc, until the latter begins to hiss. The following can then be observed:—

(1) There is a sudden rise of current through the arc.
(2) There is a sudden fall of potential of about 10 volts.
(3) The burning becomes unsteady, the arc flickers violently and dark patches appear on the crater of the positive carbon.
(4) If the hissing arc is allowed to continue, the negative carbon becomes more pointed until a protuberance shaped like a mushroom appears on the tip.

The illumination from such an arc is very much less than from a silent arc, while the fact that the arc is not steady makes it very difficult to usefully employ the light.

If instead of closing the carbons we could gradually increase the current through the arc without changing other details, we should find that the crater would gradually increase in size till it nearly fills the end of the positive carbon, and then a hissing arc would form with the same effects as above.

In fact it will be found that a hissing arc is formed whenever there is an excess of current in the arc, and further that hissing commences whenever the mist ceases to cover the whole of the crater. Following this further it can be shown that the hissing is the result of allowing the oxygen in the air access to any part of the crater.

Use of hissing arc.

A hissing arc, though unsuitable for illumination, may often be used to advantage to bring carbons when first started or when burning irregularly to a "normal" shape, as the shortening of the arc tends to centralize the crater on the positive carbon and the increased deposit on the negative tends to point the latter and make the running more steady.

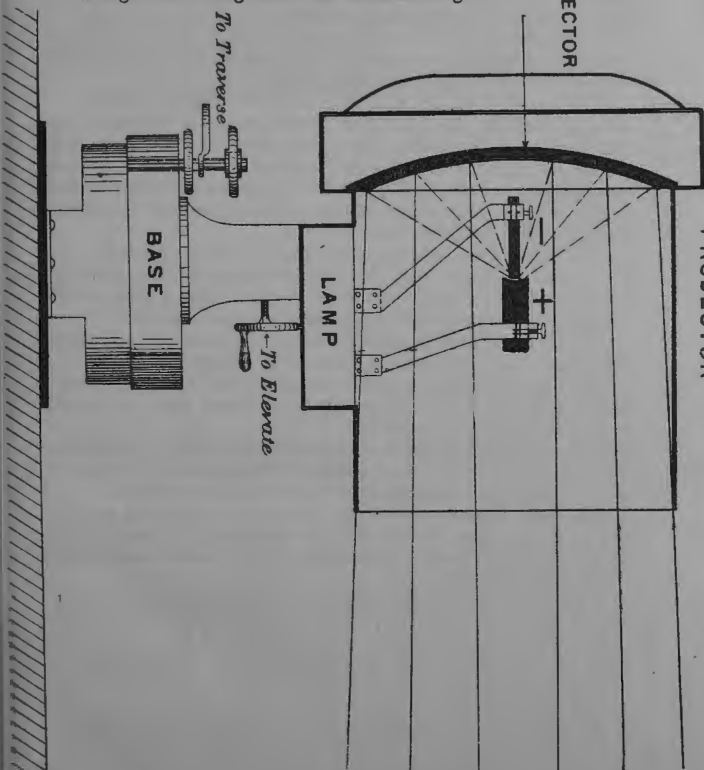
Size of Carbons and Conditions of Arc adopted for Military Purposes.

To fully appreciate all the factors which have to be considered in selecting the conditions to govern the size of carbons and arc adopted for military service, it will be necessary to study the next chapter on the "Optics of Projection," but in order to complete our consideration of the detailed working of the arc, the following may be noted :—

Practical considerations.

(1) The source of light used for military purposes is the crater of the positive carbon.
(2) The arc is formed in a lamp with the carbons horizontal.
(3) The crater is placed as nearly as possible in the focus of a curved reflector which projects the lights.
(4) When the maximum illumination of a distant object is required the reflector is shaped as a paraboloid, and the projected light is shaped as a cone with a small conical angle.

The general arrangement will be seen in Fig. 1.



GENERAL ARRANGEMENT OF PROJECTOR, SHOWING LAMP, ETC.

Fig. 1.

From this it will be seen that as only one point of the crater can be in exact focus, an increase of the size of the crater, for a given form of reflector, does not increase the illumination of any small object but only increases the angle of the cone of light. In fact it lights a larger area.

Limitation of size of crater and positive carbon.

The size of crater required is thus limited by the size and range of the target required to be lit, and in practice it is found that the necessary conditions are complied with when the angle of the cone of light is about 2½ to 3 degrees.

This is obtained when the diameter of the crater is about one-twentieth of the focal distance, or for the service reflectors of 90 cm. diameter and 42 to 45 cm. focal distance, a crater of a diameter of 2·25 cm. or about 0·9 inch is required.

It is essential that the carbon shall be larger than this, so as to leave a margin of carbon round the crater and to prevent the tip from getting too hot and wasting unduly.

Limitation of length of arc and size of negative.

The length of the arc and the size of the negative carbon are both affected by the important consideration of reducing the "obscuration" or shadow from the negative carbon. In the service arrangement of lamp and reflector this carbon does not contribute in any material degree to the amount of light collected by the reflector, while it does intervene between parts of the crater and some portions of the reflector.

It is obvious that the bigger the carbon and the closer it is to the crater the greater this interference becomes. The negative carbon should therefore be as thin as possible. Also a thin carbon burns to a better point and thus keeps the arc more steady.

On the other hand, a carbon which is too thin will not carry the current, though this can be remedied by a coating of copper.

The ideal negative should thus be a thin rod of carbon heavily coated with copper, but in practice it is found that the heavy coating of copper is objectionable.

The next point to consider is whether the carbons should be "solid," that is of the same substance throughout, or "cored," that is, should have down the centre a core of softer material.

Cored carbons.

This core burns more readily than the surrounding carbon, and tends to deepen the crater in the centre and to concentrate the principal heating effect at this point, the arc burns more steadily and flickering is reduced.

When cored carbons are used the potential difference required is lower for a given length of arc and the hissing point is also lower.

The potential difference on first starting is lowered by using cored positive carbons, and the time required to reach normal running is also greater.

Care of carbons at starting.

The time required for both these operations can, however, be reduced by shaping the tips of the carbons before placing them in the lamp as nearly as possible to the form obtained with normal running. Tools for this purpose are provided in the accessories of each lamp (see Chapter III.).

SUMMARY.

As a result of the above considerations the following figures have now been adopted for the service defence arcs used with the normal 90 cm. reflector :—

Summary of details.

Diameter of reflector, 90 cm.
Focal distance of reflector, 42 to 45 cm.
Carbons { Positive, 38 mm. cored.
Negative, 26·5 mm. uncored.*
Current, 120 amperes.
Potential difference between carbons, 60 volts.

With the above figures the crater should be about 1 inch ($2\frac{1}{2}$ cm.) in diameter and 1 inch long.

The fall of potential in the mist will be about 22 volts, or the resistance of this part of the arc will be 0·18 ohm.

---

* This size is not entirely satisfactory, and experiments are in progress with a cored negative carbon of smaller diameter with a view to obtaining a steadier arc and eliminating flickering as far as possible.

CHAPTER II.

OPTICS OF ELECTRIC LIGHT PROJECTION.

CONTENTS.

Arrangement of projector.

In the last chapter a reference has been made to the general arrangement of lamp and reflector to provide a concentrated light from the point of view of the production of the most useful form of light.

In this chapter the question is considered of the most useful form of reflector and of the changes which can be made in the form of the light by changes in the pattern of reflector or of the relative arrangement of reflector and lamp.

Details and definitions.

The following details may be added to those already stated on page 9 :—

(1) The lamp and reflector are mounted for use in a metal frame, called a "projector," the details of which are given in a subsequent chapter.

(2) The projector is mounted on bearings in such a way that the reflected light can be directed as required.

(3) The reflectors now in the service are made either of silvered glass or of metal, generally copper, with a highly polished

surface of some special metal—such as palladium, nickel or gold.

(4) Reflectors are identified by their shape, diameter and focal distance. The diameter is measured on a vertical plane through the centre of the reflector, and is the distance from edge to edge.

(5) The crater may be considered as a flat disc with its edge corresponding to the outer edges of the crater. The "diameter" of the crater is the diameter of such an imaginary disc, and the "centre" of the crater is the centre of the disc.

(6) A lamp is said to be in focus when the "centre" of the crater is in the central axis of the reflector at a distance from the reflecting surface equal to the focal distance of the reflector.

(7) The source of light may be assumed to be uniformly bright, though this is not, of course, obtained in practice.

(8) The intrinsic brilliancy of the crater surface, *i.e.*, the amount of light per square cm. of crater surface given off in a direction normal to that surface, is constant. This assumes that the best conditions for running are adopted.

Patterns of Reflectors.

The first attempts to concentrate the light from an electric arc were made with glass lenses similar to those in use in lighthouses. An apparatus on this principle, called a "Holophote," was in use in the military service for some years. Early patterns.

The next step was to use a curved glass reflector placed behind the arc and reflecting the rays forward. It was recognised that the correct form for such a reflector was a paraboloid, but at the time it was not found possible to manufacture glass or metal reflectors of this type with sufficient accuracy. Spherical reflector.

But it was found that for a small angle of collection, a mirror shaped as a segment of a sphere using a focal distance equal to half the radius of the sphere, was nearly as good as a paraboloid. If the mirror is increased in size the light reflected from the outer portion will diverge considerably from the true parallel form. This is called spherical aberration, and is illustrated in Fig. 2; where C is the centre of curvature of the spherical reflection, F, the focus of the parabola, of nearly identical shape, and A and B, centres of reflection, showing the errors introduced by a small error of focus.

A great step in advance was made by Colonel Mangin, of the French Engineers, who pointed out that a silvered glass reflector with the inner and outer surfaces ground to spherical curves of different radii produced almost identical results with that obtainable from paraboloids. Mangin reflector.

SPHERICAL REFLECTOR SHOWING ABERRATION.

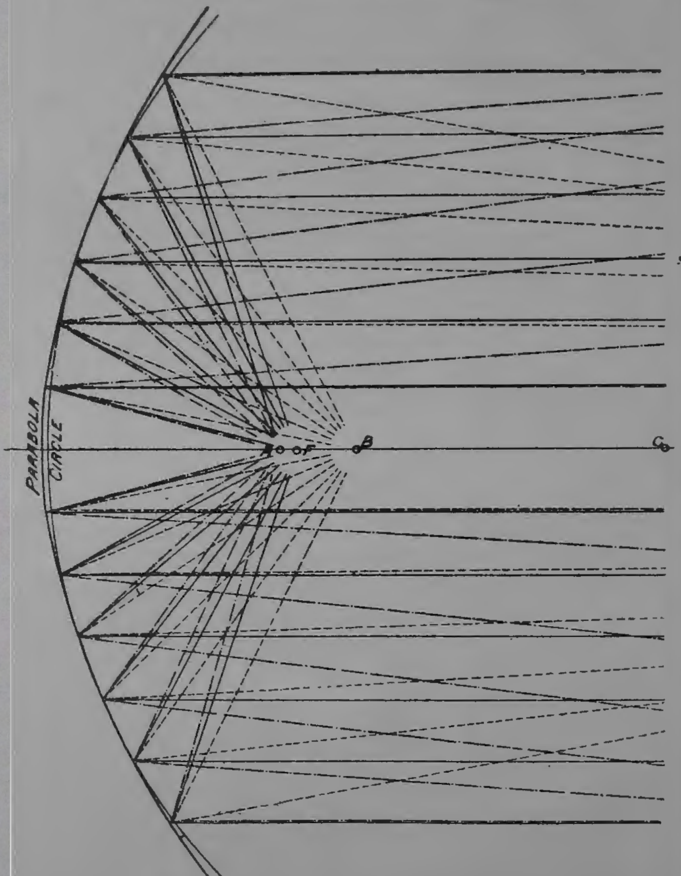


Fig. 2.

Fig. 3 shows a section of such a reflector, from which it will be seen that the rays from the focus are successively refracted, reflected and refracted again. The spherical aberration is almost perfectly compensated by the double refraction.

MANGIN REFLECTOR.

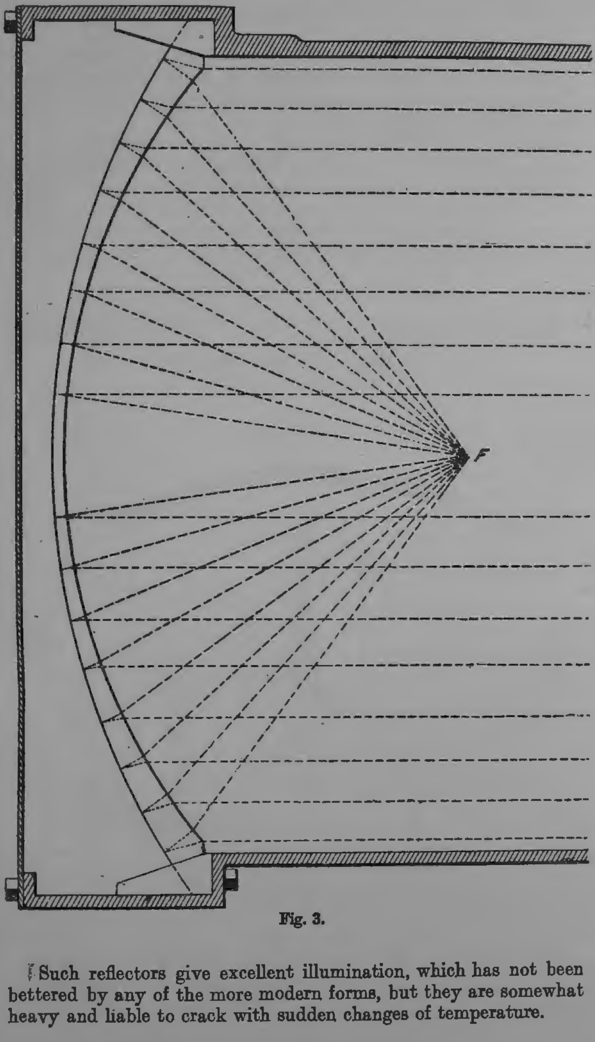


Fig. 3.

Such reflectors give excellent illumination, which has not been bettered by any of the more modern forms, but they are somewhat heavy and liable to crack with sudden changes of temperature.

Paraboloid reflector.

The first practical reflectors of the shape of a paraboloid were made by Messrs. Chance, who pressed the glass into shape without grinding the surface. These reflectors answered well, but were inferior to the Mangin type.

Finally a method of grinding a parabolic surface was developed by Messrs. Schuckert, and since then all glass reflectors for concentrated lights are true paraboloids, the glass being of equal thickness throughout.

Dispersing lens.

But for certain uses of the light, such as the illumination of a definite area at short ranges, the concentrated form produced by the paraboloid reflector is not the most effective.

For these cases the best form of projection would be such that the vertical section of the reflected light should remain concentrated while the light is spread out horizontally over any required area.

PLAN OF PROJECTOR, SHOWING THE METHOD OF USING A DISPERSING LENS.

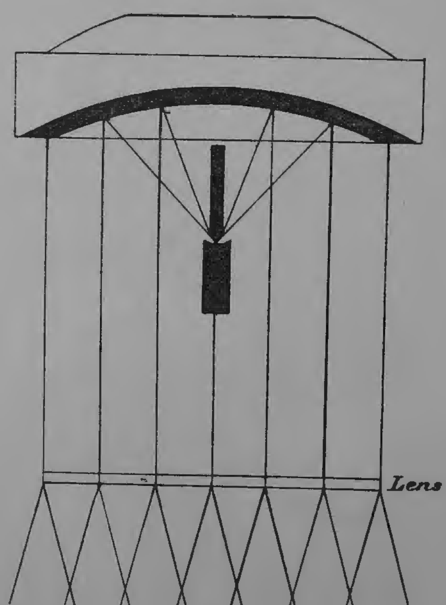


Fig. 4.

This effect was first obtained by placing on the front of the projector a lens composed of vertical glass prisms, which divided up the reflected light into vertical sections and spread the light from each section into a fan, as in Fig. 4.

A modification of this arrangement was made by using converging lenses, by which the rays from each side of the reflected light were refracted inwards, aiming at a point a little distance in front of the projector, where the width of the reflected light was narrowed to a comparatively small strip. This lens was specially designed for use behind portholes. Beyond the porthole the rays of light diverged to an angle which depended on the degree of refraction. Converging lens.

The next step was to effect the same result by a variation in the shape of the reflector, thus making the additional lens unnecessary. Parabola-hyperbola reflector.

The first trials were made with a reflector so shaped that all vertical sections were parabolas, all horizontal sections hyperbolas.

The effect is that the rays are spread outwards horizontally over an angle depending on the shape of the hyperbola. This form is in use for ship lighting on the Suez Canal, but was not adopted for military purposes.

It is obvious that this shape does not lend itself to the porthole arrangement, and the next step was to shape the reflector so that while vertical sections remained parabolic, the horizontal sections took the form of an ellipse. The properties of this latter curve are such that if the source of light is placed at the nearer focus of the ellipse, the reflected rays will all pass through the further focus. Parabola-ellipse reflector.

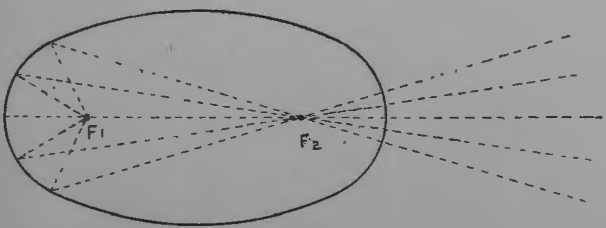


Fig. 5.

This will be made more clear by Fig. 5, where F_1 is the focus at which the source of light is placed, F_2 the focus where the reflected beams cross.

Figs. 6, 7, 8, 9 show horizontal sections of a paraboloid reflection, and of the three classes of parabola-ellipse reflections in the service.

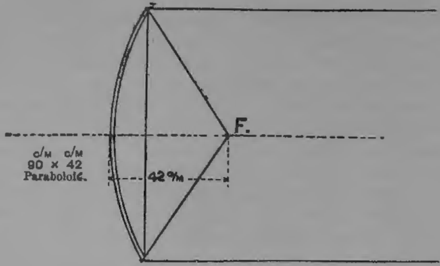


Fig. 6.

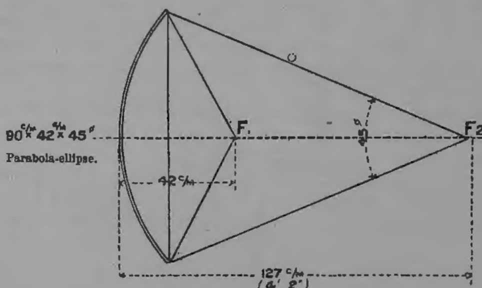


Fig. 7.

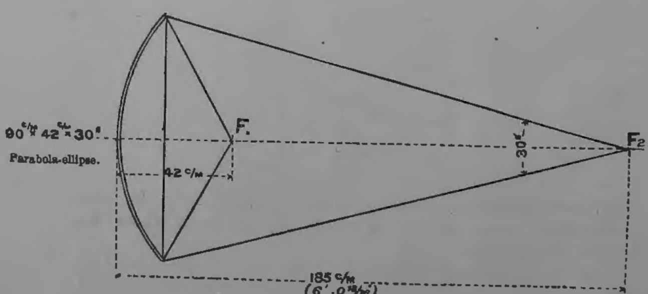
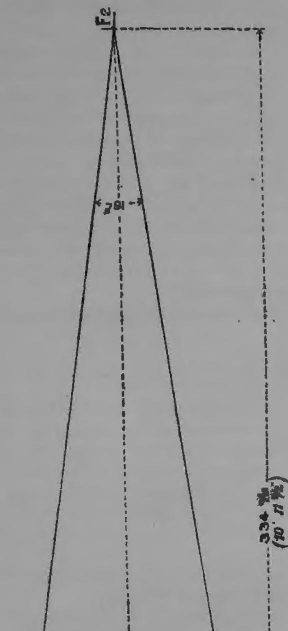


Fig. 8.



Parabola-ellipse.

Fig. 9.

It will be seen that the shape of the reflected light from such a reflector is exactly what is required to give a dispersed light combined with the protection of the porthole arrangement.

There are still practical difficulties in manufacturing to this shape, which makes this pattern of reflector less perfect optically than the paraboloids, but in practice the results are sufficiently good, and this pattern of reflector is extensively used in the service.

Metallic reflectors.

All the above have been discussed as if they were of glass silvered, and this pattern still gives the best results. But the advantages of a metal reflector are so great for military purposes that many efforts have been made to find a suitable material for the reflecting surface, and some metal reflectors have been introduced into the service. The optical principles involved are practically the same whether glass or metal is used.

The details of the actual service reflectors are given in Chapter IV.

Light-Projection by the Heliograph.

Introductory remarks.

Before considering in detail the optics of Electric Light Projectors, it will be convenient to consider a rather simple case of light-projection, namely one which occurs with the heliograph.

The Service heliograph consists of a plane circular silvered glass mirror, 5 inches in diameter, but in order to simplify the problem the mirror will be considered as a plain metallic reflector without any glass; this assumption will not materially affect the accuracy of the conclusions arrived at.

It is proposed to consider the simplest case of the use of the heliograph, not that of duplex working.

Sun is the source of light.

The sun may be considered as a spherical source of light sending out light in a precisely similar manner from every part of its surface.

It is clear that every part of the sun's surface facing the heliograph mirror, however obliquely, sends rays of light to every part of that mirror.

By far the larger number of the rays emitted from the sun's surface, of course, do not fall on the heliograph mirror; all such rays are lost as far as heliographing is concerned. We are only concerned with those falling on the mirror.

We know from actual observation that all parts of the sun's visible surface as seen from any point on the heliograph mirror appear equally brilliant. Therefore, for any given relative positions of the sun and that mirror the effect produced is just the same as if the spherical sun were replaced by a plane disc at right angles to the straight line joining the centre of the sun and the centre of the heliograph mirror.

Influence of shape of heliograph mirror.

Consider the central part of the heliograph mirror. A cone of rays of light falls on it as shown in the diagram below, Fig. 10, and will be reflected as there shown; for the diameter of the sun and its distance from the earth are relatively such that its diameter subtends an angle of 32 minutes at the earth's surface.

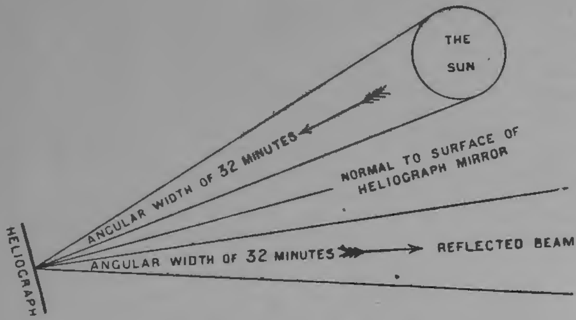


Fig. 10.

It is evident from what has been said above regarding the sun's disc, that all parts of the base of this cone of reflected rays will be equally illuminated.

Now, since the dimensions of the heliograph mirror are very small—infinitesimal, in fact—as compared with the sun's diameter and distance from the earth, every part of the surface of the mirror may be regarded as in exactly the same case as the central part of the mirror. Each part of the mirror receives and reflects, then, such a cone of rays of light.

At a considerable distance from the mirror, such as 1,000 yards, all these cones of light will be practically exactly superposed; for the greatest dimension of the mirror (2½ inches radius) disappears entirely in comparison with the radius of the base of each of these cones of reflected rays (roughly 160 inches at 1,000 yards), being only about 1/64th part, or about 1½ per cent., of it.

Therefore at any working distance (for signalling purposes) the beam thrown from the heliograph mirror may be regarded as a right cone with its apex at the centre of that mirror and its base a circle *whatever the shape of the heliograph mirror*, whether circular, elliptical, square, or triangular, &c., &c., provided, of course, that it is a *plane* mirror.

It is very important to grasp this fact.

It is not always clearly recognised, because at short distances from the heliograph mirror the cross section of the reflected beam resembles the shape of the projection, on a plane at right angles to the direction of the reflected rays, of the outline of the heliograph mirror; and consequently with service mirrors would not generally be circular, but elliptical. And it so happens that it is at short distances from the heliograph mirror that the shape of the reflected beam is most often observed.

The smaller the heliograph mirror, or the larger the angle subtended at its centre by the distant source of light, the less the distance from the mirror at which the reflected beam assumes this simple conical form. This suggests a simple method of verifying the statement. Cover the heliograph mirror with a sheet of paper with a square of ½ inch side, an equilateral triangle of ½ inch side, and a circle of the same diameter, cut in different parts of it: thus in effect making from the one mirror three heliograph mirrors each very small indeed, in the same plane and pretty close together. Take the reflected beams from the parts of the mirror left exposed, where these holes are cut, on a surface normal to the reflected rays and about 12 feet distant from the mirror: all the luminous areas on that surface will appear as circles. Now move the surface up towards the mirror till it is only about 12 inches from it: the luminous areas on it will now be oblong, triangular, and elliptical respectively. At a distance of about 12 yards from the mirror these three beams will be all merged in one cone with a circular base.

Influence of size of heliograph mirror.

Moreover, we note that since at working distances each part of the mirror contributes its cone of rays, and all these cones are alike and are superposed, the intensity of the illumination produced at the far station (*i.e.* the amount of light thrown on each element of area on which it falls) is proportional to the size, irrespective of the shape, of the mirror. Hence a 5-inch diameter mirror at any given considerable distance produces 25/9, or nearly three times as great an intensity of illumination as a 3-inch diameter mirror.

The area illuminated at any distance, commonly called the width of the beam, is, however, the same for all diameters and shapes of heliograph mirror, being that due to the angular width of the sun as seen from the earth.

Influence of obliquity of plane of heliograph mirror to line joining its centre to centre of sun.

Consider next how the reflected beam from a given heliograph mirror is affected by variations in the angle between the straight line joining the centres of the sun and the heliograph mirror, and the straight line joining the centre of the heliograph mirror and the point on which the heliograph is laid.

Fig. 11 shows two cases where the same sized and same shaped heliograph is set up to reflect the sun's rays in two different directions.

It is quite clear from this figure that in the lower of the two positions indicated in the diagram, a larger number of the rays from every point on the sun's surface fall on, and are reflected by, the heliograph mirror than in the upper of the two positions in the diagram.

Yet in either case each part of the mirror receives and reflects a cone of rays of precisely the same dimensions, viz., a cone with the sun's face for its base and the distance of the sun from the earth for its height.

Consequently the width of the reflected beam at any considerable distance from the mirror is the same in both cases; but, as more rays are reflected in the lower case than in the upper case, *the intensity of illumination produced at a given considerable distance from the mirror is greater in the lower case than in the upper case.* In fact the intensity of illumination produced by reflection from a plane mirror of any given area, at a considerable distance from the mirror, is that due to the area representing the projection of the mirror's surface on to a plane at right angles to

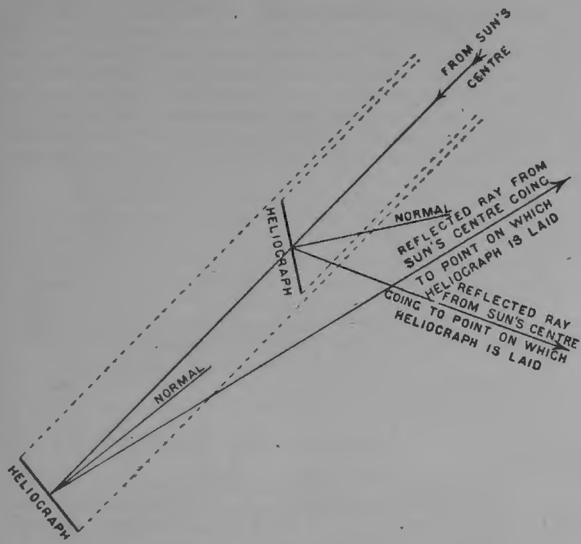


Fig. 11.

the straight line joining the centres of the sun and the mirror, $a_1\, b_1$ in Fig. 12; or, since these two areas are equal, is the same as that due to the area represented by the projection of the mirror's surface on to a plane at right angles to the line joining the centre of the mirror and the point the heliograph is laid on, $a_2\, b_2$, Fig. 12.

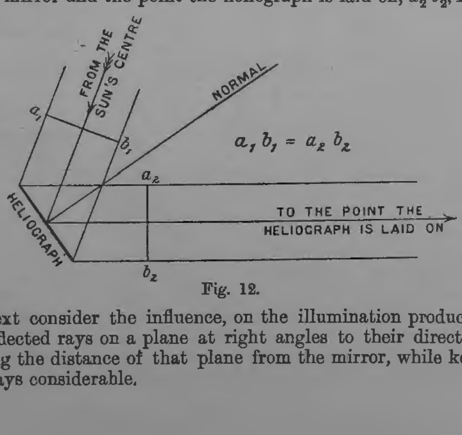


Fig. 12.

Next consider the influence, on the illumination produced by the reflected rays on a plane at right angles to their direction, of varying the distance of that plane from the mirror, while keeping it always considerable.

Influence of range of point heliograph is laid on.

Assuming, which is not actually the case, that the reflected light passes through the intervening air without any absorption of light, it is clear that the illumination produced on a plane at right angles to the axis of the cone of reflected rays from any part of the heliograph mirror falls off as the square of the distance between that plane and the heliograph mirror: for the area of the base of the cone increases as the square of that distance, while the whole number of rays of light included in the cone remains the same.

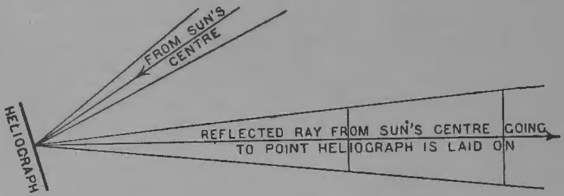


Fig. 13.

And this is true of every cone of rays reflected from any part of the mirror.

Hence, subject to the condition (which, as said before, is not quite correct) that the air absorbs no light, the intensity of the illumination produced by the beam reflected from the heliograph mirror on a plane at right angles to the direction of the reflected beam falls off as the square of the distance from the mirror of that plane.

The width of the beam obviously increases in exact proportion to the increase in the range.

Influence of distance of source of light from the mirror.

To enable us to take full advantage of the consideration of the case of light projection with the heliograph as an introduction to the optics of electric light projection, it is desirable to consider what would happen in certain cases which do not actually arise with the heliograph.

Thus suppose the sun, *i.e.* the source of light, was further off from the earth than it is.

Each part of the heliograph mirror would receive and reflect a cone of rays with the same base as when the sun was nearer, but with a greater height than in that case. Hence at any given considerable distance from the mirror the width of the beam of light would be reduced as the distance of the sun from the mirror was increased. The intensity of illumination produced at the given distance from the mirror would not be affected by the change in the distance of the sun from the mirror.

Another way of looking at the matter is as follows:—

As the sun's distance from the heliograph mirror is increased, fewer of the rays sent out from any part of the sun's face fall on the heliograph mirror. But on the other hand the area illuminated at any given considerable distance by the reflected beam of light is reduced in the same proportion. Consequently the intensity of illumination produced by the reflected beam at any considerable distance is unaltered.

Influence of variation of the brightness of the source of light.

If the brightness, sometimes called the "intrinsic brilliancy," of the sun, the source of light, is varied, while all other things remain the same, then the intensity of illumination produced by the reflected rays at a given considerable distance will vary in a precisely similar manner. The width of the beam will not be in any way affected.

If one part of the source of light, say the top, is less bright than the rest, then, if a cross section of the reflected beam be taken at a considerable distance from the mirror, the lower part of the cross section of the beam will be less illuminated than the rest; the shape of the less illuminated portions of the source and of the less illuminated portions of the cross section of the reflected beam will exactly resemble one another; and the reduction in the brightness of the source and the intensity of the illumination of the affected part of the cross section will also correspond exactly.

Influence of shape of source of light.

Suppose the sun, the source of light, were not spherical.

All parts of the heliograph mirror see exactly the same view of it whatever its shape, since the mirror is small compared with the distance of the sun, the source of light, from the earth. This view will not, of course, correspond to the truc shape of the source of light, but to the shape of the source of light as seen from the part of the mirror under consideration.

Hence each part of the mirror receives and reflects a pyramid of rays whose base depends for its shape on the shape of the source of light as seen from the centre of the mirror, and whose height is the distance of the sun's centre from the earth.

At a considerable distance from the mirror all the pyramids of light are practically exactly superposed, the mirror being a small one. Consequently at any considerable distance from the mirror, the beam thrown from the heliograph would be a pyramid with its apex at the mirror and its base an exact (but inverted) reproduction of the form of the source of light as seen from the centre of the mirror.

Summary results.

Summing up the conclusions we have arrived at so far, we find that—given a plane mirror, small in size in comparison with its distance from the source of light—we get the following rules for the results produced by the reflected rays of light on a plane at right angles to the straight line joining the centre of the mirror and the point towards which the reflected rays are directed, if that plane be at any considerable distance from the mirror:—

1. The intensity of illumination depends on—

(*a*) *The intrinsic brilliancy of the source of light.*

It varies directly as the intrinsic brilliancy of the source of light.

(*b*) *Size* (*not the shape*) *of the plane mirror.*

It varies directly as the area of the plane mirror.

(*c*) *The obliquity of the plane mirror to the direction of the central* (*incident or*) *reflected ray.*

It varies directly as the cosine of the angle of the mirror's departure from direct opposition. Or in other words, in reckoning the size of the plane mirror account must only be taken of the area of its projection on to a plane at right angles to the central (incident or) reflected ray.

(*d*) *The distance from the plane mirror to the illuminated plane.*
It varies inversely as the square of this distance.

The intensity of illumination does not depend on—

(*a*) The size or shape of the source of light.
(*b*) The obliquity of the principal face of the source of light to the direction of the central incident ray.
(*c*) The distance of the source of light from the mirror.
(*d*) The shape (not the size) of the plane mirror.

2. The area illuminated depends on—

(*a*) *The size (not the shape) of the source of light.*
It varies directly as the area of the source of light.

(*b*) *The obliquity of the principal face of the source of light to the direction of the central incident ray.*
It varies according to a law which states that in reckoning the size of the source of light, account must only be taken of the foreshortened view of it seen from the centre of the mirror.

(*c*) *The distance of the source of light from the mirror.*
It varies inversely as the square of this distance.

(*d*) *The distance from the plane mirror to the illuminated plane.*
It varies directly as the square of this distance.

The area illuminated does not depend on—

(*a*) The intrinsic brilliancy of the source of light.
(*b*) The size of the plane mirror.
(*c*) The shape of the plane mirror.
(*d*) The obliquity of the plane mirror to the direction of the central (incident or) reflected ray.
(*e*) The shape of the source of light.

3. The shape of the area illuminated depends on—

(*a*) *The shape of the source of light.*
It resembles the foreshortened view of the shape of the source of light seen from the centre of the mirror, but inverted.

(*b*) *The obliquity of the principal face of the source of light to the direction of the central incident ray.*
It resembles the foreshortened view of the shape of the source of light as seen from the centre of the mirror, but inverted.

The shape of the area illuminated does not depend on—

(*a*) Anything else except 3 (*a*) and 3 (*b*) above.

LIGHT PROJECTION OF ELECTRIC LIGHT.

Introductory remarks.

Turning now to the subject of Electric Light Projectors, the source of practically all the light from continuous current arc lamps is the crater of the positive carbon. This crater is generally speaking somewhat irregular in its shape in consequence of miperfections in the burning of the arc; nor does it present exactly the same shaped view to all parts of the reflector of an electric light projector. As seen from any part of the reflector, except the actual centre, the view presented is equivalent to a direct view of an elliptical source of light. Also from certain parts of the reflector the tip of the negative carbon may cut off the view of part of the crater. More will be said of such a state of things further on.

Case of a paraboloid reflector.

Now commence the consideration of an actual service electric light projector, whose reflector is metallic (without any glass), and paraboloid in shape.

It may be assumed that a horizontal arc lamp is being used with this projector, and that everything is so arranged as to produce proper burning of the arc.

That diameter of the crater which is not foreshortened will, as seen from any part of the reflector, subtend an angle of about 3 degrees when a 120-ampere arc is being used. This angle depends, of course, on the nature of the carbons used, and on the amperage of the arc employed, and is somewhat less for parts near the edge of the reflector than for parts near the centre.

The form of the reflector, a paraboloid, is such that all rays of light starting from the focus will after reflection be projected in a direction parallel to the axis of the paraboloid.

Reflector formed of small plane mirrors.

Now, consider the paraboloid as being made up of an infinite number of equal infinitesimally small plane mirrors, and that these elemental mirrors are arranged in a series of concentric circles or zones round the axis of the reflector. The plane of each of these small mirrors will be at right-angles to the normal to the surface of the paraboloid at the centre of the infinitesimally small plane.

Each of these small plane mirrors will be under circumstances exactly similar to the case already considered of the plane heliograph mirror.

In the case of the heliograph mirror, the source of light from the mirror is, relatively, infinitely far away; the size of the source of light is, relatively, infinitely great; the size of the mirror is finite. In the case of the element of the paraboloid, the distance of the source of light from the mirror is finite; the size of the source of light is finite; the size of the mirror is infinitesimally small. Relatively, then, in the two cases the various dimensions involved are of the same order of magnitude.

Action of elemental plane mirror.

Consequently, at any great distance from the little mirror forming the element of the paraboloid, we shall get a cone of rays projected from the surface of the small elemental mirror with its axis parallel to the axis of the paraboloid, and with its base an ellipse. And the dimensions of the major axis of the ellipse will depend partly on the diameter of the crater and partly on the distance the small elemental mirror is from the centre of the source of light, while the dimensions of the minor axis of the ellipse will depend partly on the foreshortened view of the diameter of the crater as seen from the small elemental mirror, and partly on the distance of that mirror from the centre of the source of light, Fig. 14. The intensity of illumination over the

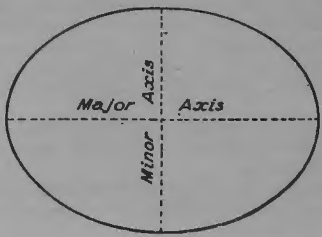


Fig. 14.—Base of cone of rays reflected from a part of the reflector near its edge.

base of this cone of rays will be everywhere the same, and will be mainly that due to the intrinsic brilliancy of the crater, and to the size of the small elemental mirror; the latter must, however, be considered as reduced in proportion to the obliquity of the small elemental plane mirror to the central reflected ray.

In other words, the intensity of illumination over the base of the cone of rays will be such as would arise from the intrinsic brilliancy of the source multiplied by the projection of the area of the small elemental mirror on to a plane at right-angles to the axis of the paraboloid.

Every cone of rays may be considered as originating at apex of reflector.

At great distances from the reflector, such as 1,000 yards, the diameter of the reflector, 90 cm., or about 3 feet, vanishes in comparison with the dimensions of the base of the cone of rays from any part. Consequently at such great distances we may consider that we get the apex of every cone of rays sent from every part of the reflector as originating from the centre of the paraboloid.

Now, every part of the paraboloid all round the circumference of a circle or zone is in exactly the same case, and sends out exactly the same sort of cone of rays.

Every zone reflects a cone of rays with *circular* base.

Hence, every zone of the paraboloid of elemental width, such as we have described above, produces at a great distance from the reflector a cone of rays which may be regarded as emanating from the apex of the paraboloid.

The base of such a cone will be *circular* (see Fig. 15), and consists of a central circle of uniform illumination, surrounded by a ring of less uniform illumination. The diameter of the central circle is determined by the foreshortened view of the crater seen from any part of the zone. The diameter of the outer circumference of the illuminated ring is determined by the unforeshortened view of the crater as seen from any part of the zone. The illumination in this ring is not uniform, but falls off gradually and regularly from the outer circumference of the central

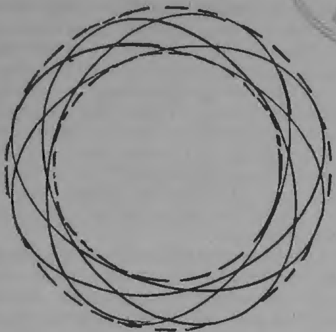


Fig. 15.—Base of cone of rays due to corresponding zone of the reflector.

uniformly illuminated circle, to nothing at the outer circumference of the base.

And the value of the illumination of the central (most illuminated) part of the base of the cone is that due to the product of the intrinsic brilliancy of the crater multiplied by the area of the projection of the zone on to a plane at right-angles to the axis of the paraboloid.

Now, supposing for the present that there was no obscuration at any part of the paraboloid of part of the crater by the negative carbon, we can clearly, then, regard the paraboloid as made up of a series of such zones as that already described.

Each such zone will produce a cone of rays such as already described, but neither the angular width of the central circle, nor the angular width of the outer rings of the bases of these cones will be identical for all zones.

These angular widths, and consequently the corresponding diameters of cone bases, will be least for the parts of the paraboloid nearest its edge, and greatest for the parts of the paraboloid at its centre.

All such cones due to zones of the paraboloid may then be regarded as superposed, and as emanating from the apex of the paraboloid when considering the effect of the illumination at a great distance from the reflector.

Resultant illumination of all zones superposed.

There will, therefore, result from the whole paraboloid a cone of rays emanating from its centre, with the centre of the cone of rays coincident with the axis of the paraboloid, with a base consisting of a central part uniformly illuminated, and a ring outside this central part not uniformly illuminated, but gradually falling in illumination from a value equal to the illumination of the central uniform illumination to nothing at its outer circumference.*

* Sometimes called the "central spot" of the beam.

The diameter of the central portion of this base will be that due to the most foreshortened view of the crater's diameter seen from a part of the reflector at the edge of the paraboloid, and the width of the circle constituting the outer boundary of the cone of rays, where the value of the illumination just vanishes, will be that due to the unforeshortened view of the diameter of the crater seen (or supposed to be seen) from the apex of the paraboloid.

Moreover, it is evident from what has gone before that the value of the illumination of the central part of the cone-base will be that due to the intrinsic brilliancy of the crater multiplied by the projection of the whole reflector on to a plane at right angles to the axis of the paraboloid.

It will also be evident that the value of the illumination produced with this paraboloid reflector on a plane at right angles to the axis of the paraboloid, at considerable distances from the reflector, will vary inversely as the square of that distance.

Or, in symbols—

If D be the diameter of the paraboloid reflector,
R be the considerable distance from the paraboloid reflector to the plane at right angles to its axis, the illumination on which is being considered,
i be the intrinsic brilliancy of the source of light,
I be the intensity of illumination produced on the plane mentioned above at places where this illumination is a maximum (*i.e.*, in the central part of the beam),

we have

$$I \propto \frac{i D^2}{R^2} .$$

It will be observed that neither the focal length nor the value of the current employed appear in this expression for I. They affect the width of the cone of light. The focal length affects not only the total width, and the width of the central uniformly illuminated part where the illumination is greatest, but also the relative widths of these two. The value of the current employed affects not only the total width of the cone of light, but also the width of the central part where the illumination is greatest; but it does not affect the relative values of these two widths.

Now, it is the central uniformly illuminated part of the light that is regarded as the really useful portion.

The outer non-uniformly illuminated portion is regarded as rather a drawback than otherwise, forming, as it does, a sort of luminous haze between the observer and an object in the best part of the light.

Proportion of focal length to diameter.

Consequently, such a value is given to the focal length, relative to the diameter, that the width of the central uniformly illuminated part may be about a maximum. But the *exact* value of this ratio to produce a maximum is not actually employed, because, where there is no obscuration at any part of the paraboloid* of part of the crater by the negative carbon, it is considered better to use a slightly longer focal length in order to reduce the width of the ring of non-uniform illumination. And when there is obscuration at parts of the paraboloid of part of the crater by the negative carbon, it is considered necessary to use a shorter focal length in order to reduce the influence of this obscuration, as will be explained presently when considering the effect it produces.

These conditions are fulfilled in the case of paraboloids of 90 cm. diameter, by a focal length of about 65 cm. when there is no obscuration by the negative carbon, and by a focal length of about 42 cm. to about 45 cm. where such obscuration exists.

Heating effect with short focus.

It would not, of course, be practically possible, even if it were optically desirable, to reduce the focal length much below the lower figures given above, as the heating effect produced on the paraboloid reflector would be so great as to damage it, unless, of course, the strength of the current used were considerably reduced. But since reducing the current reduces the width of the beam, we should soon find, if we reduced the current much, that to illuminate a given width at a given range required too many projectors to be practicable, either from the point of view of the first cost of projectors, or of the staff required for their manipulation. These considerations of cost also prohibit the use of very long focal lengths.

Obscuration by negative carbon.

We have still to consider the influence, such as it is, of the obscuration by the negative carbon of part of the crater in the positive carbon as seen from certain portions of the paraboloid reflector.

It is clear that with horizontal arc lamps any part of the reflector near the apex of the paraboloid will only see a lune-shaped view of the crater.

Let us first consider a zone of the reflector which, while it sees a lune-shaped view of the crater, can see the centre of the crater.

Any such part of the reflector reflects a pyramidal beam of light with the base of the pyramid exactly resembling this lune-shaped view, but inverted, Fig. 16; moreover, the ray in this pyramid

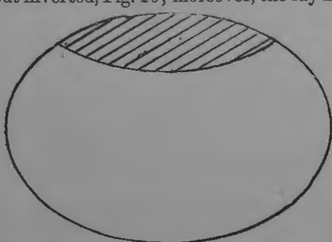


Fig. 16.—Base of pyramid of rays reflected from a part of the reflector where there is slight obscuration.

* This, of course, can never be the case with horizontal arc lamps, but may with inclined arc lamps.

joining the centre of the part of the reflector to the focus of the paraboloid is reflected in a direction parallel to, and practically coincident with the axis of the paraboloid.

Considering the effect produced by all such exactly similar pyramids of rays reflected from all parts of the zone, we see that we shall get from them a circular-based cone of light. The apex of this cone will be at the apex of the paraboloid, and its axis will be coincident with that of the paraboloid. The illumination over its base will be uniform and of a maximum value in the central circular part of the base, and there will be an outer ring with the illumination dying away from the value of the illumination in the central portion to nothing at the outer circumference, Fig. 17.

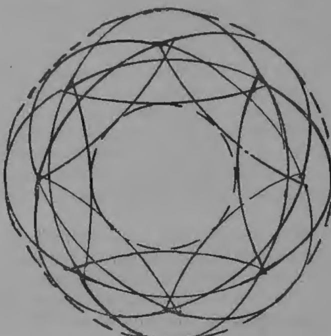


Fig. 17.—Base of pyramid of rays due to corresponding zone of the reflector.

Moreover, all such zones as that just described will together produce as their resultant a circular-based cone of light with its apex at the apex of the paraboloid, with its axis coincident with the axis of the paraboloid, and the illumination over its base a maximum at the centre of the base, and falling away gradually to nothing at the circumference of the base.

Next let us consider a zone of the reflector which sees a lune-shaped view of the crater but cannot see the centre of the crater. Any such part of the reflector reflects a pyramidal beam of light with the base of the pyramid exactly resembling the lune-shaped view of the crater seen by that part of the reflector, but inverted, Fig. 18.

Considering the effect produced by all such exactly similar pyramids of rays reflected from all parts of the zone, we see that we shall get from them a funnel-shaped beam of light. The apex of the funnel will be at the apex of the paraboloid; its axis will be coincident with the axis of the paraboloid; its base will be a circular ring, and the illumination over its base will be nothing

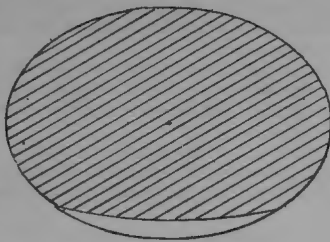


Fig. 18.—Base of pyramid of rays reflected from a part of the reflector where there is much obscuration.

at the inner and outer circumferences of the ring, and will rise to a maximum for a circle lying between these diameters.

Moreover, all such zones as that just described will together produce as their resultant a circular based cone of light, with its apex at the apex of the paraboloid, its axis coincident with the axis of the paraboloid, and the illumination over its base of the value nothing at the centre and at the circumference of the base, and rising to a maximum for a circle lying between the centre and the circumference, Fig. 19.

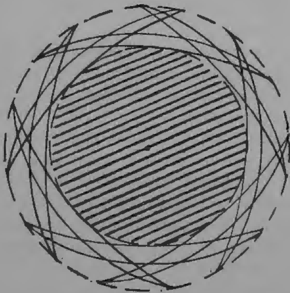


Fig. 19.—Base of funnel-shaped light due to corresponding zone of the reflector.

Summary of illumination produced.

Any paraboloid reflector, then, when used with a horizontal arc lamp, will produce a conical beam of light which may be regarded as being made up of three parts, viz. :—

1. A conical beam from the parts of the reflector where there is no obscuration.

2. A conical beam from the parts of the reflector where there is some obscuration, but the centre of the crater is not obscured.

3. A conical beam from the parts of the reflector where there is so much obscuration, that the centre of the crater is included in the obscured portion of the crater.

These cones all have the same axis and the same apex, and the resultant illumination produced on a plane normal to their axes at a considerable distance will be the sum of the illumination due to each of the three parts.

Now the effect of the obscuration is clearly altogether bad; not only does it decrease the resultant illumination as a whole, but it tends to upset the uniformity of the illumination produced.

In order then to reduce the evils produced, the focal length of the paraboloid is made as small as is consistent with other considerations already mentioned, as under these circumstances the area of the reflector affected by obscuration, and consequently the effect of the obscuration on the resultant beam, is reduced. The obscuration is also reduced by lengthening the arc.

In practice the focal length and the length of arc adopted are such that the influence of obscuration may be almost neglected.

Shape of light from Mangin reflector.

The shape of the light reflected from a Mangin reflector is governed by the same principles and is practically identical with that from a paraboloid.

Shape from a parabola-ellipse reflector.

But with a parabola-ellipse reflector several of the conditions are altered, and it is necessary to analyse the action in such cases.

A reflector of this type may be considered as made up of a system of elemental plane mirrors, each infinitesimally small, arranged in vertical parallel rows.

Illumination from central strip.

Neglecting the obscuration from the negative carbon, the centre row of these small mirrors will act exactly as the centre row of a paraboloid, that is, it will project a cone of light of which the base will be as shown at A in Fig. 20.

It will be seen that the elemental mirrors near the centre of the reflector send out a cone with a circular base, those nearer the edge a cone with an elliptical base, of which the longer diameter is practically identical with the diameter of the circular base, and the shorter diameter is less than this by an amount which depends on the foreshortened view of the crater, seen from a point near the outer circumference of the reflector. The resultant effect of these superposed cones is to produce a central uniformly illuminated part of elliptical shape with above and below it a lune-shaped portion in which the illumination gradually falls away to nothing.

Illumination from a strip nearer the edge.

Now take a vertical strip about half-way between the centre and the edge. In this case the cones of light are all more or less elliptical, and the general effect will be to produce an illuminated cone with a base as at B in Fig. 20.

It will be seen that the result is to produce a central uniformly illuminated part of a generally elliptical shape, rather smaller than that from the centre strip, with a top and bottom portion of decreasing illumination of rather larger area than that from the central strip.

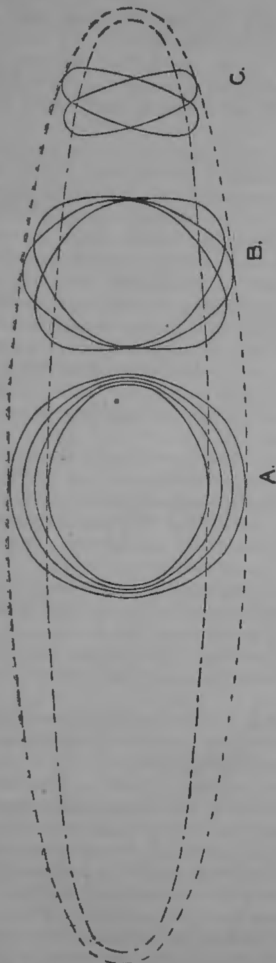


FIG: 20

BASES OF RESULTANT CONES FROM PARABOLA-ELLIPSE REFLECTOR.

Further, it must be noted that as the length of the vertical strip under consideration will be less than that at the centre, the illumination of the central part at B will not be quite as great as the centre part of the cone produced by the central vertical strip at A.

There is, however, a limit to the focal length, for, with the horizontal lamp the obscuration due to the negative carbon increases in proportion to the length of the focus.

Changes with a parabola-ellipse. Change in crater.

With a parabola-ellipse reflector, an increase in the crater increases the size of each series of cones of light, so that the height of the illuminated area is increased proportionally, but the width is only increased by a small amount at each end, the increase in the size of the intermediate cones tending to *increase the illumination*.

Change in focal distance.

Similarly, with an increased focal distance the height of the illuminated area is decreased, and the decrease in the size of the intermediate cones *decreases the illumination*.

Change in diameter.

An increase in the vertical diameter will increase the number of reflected cones and so *increase the illumination*. An increase in the horizontal diameter will increase the opening out of the light in the horizontal plane.

Change in more than one factor.

A proportional increase of the diameter and focal distance will thus have no effect on the illumination, but will *reduce* the area illuminated.

A proportional increase of all three factors will *increase the illumination*, leaving the area constant, if the effect of obscuration is neglected. Obscuration is, however, in this case a very considerable factor, and in practice it is generally better in parabola-ellipse reflectors to keep the focal distance small with the diameter of reflector in proportion.

CHAPTER III.

Carbons and Lamps.

Contents.

Carbons.

The carbon rods used with arc lamps are made out of gas coke, lamp black, soot, or other material composed of almost pure carbon, ground fine and mixed with a tarry or syrupy substance rich in hydro-carbon, such as pitch or molasses. The mixture is tested, cooled and again ground into a flour, after which the carbons are formed into the required shape either by moulding in steel moulds or by being forced through suitable dies. How made.

After this the rods are baked at a high temperature to consolidate them and to drive off volatile impurities. The resulting product should have great homogeneity, very high fusing point, and be of fair electrical conductivity.

Different supplies of carbons, made by different makers, vary considerably in characteristics, and it is desirable to keep the various makes separate, as each may require somewhat different treatment when used in the lamp. Variation in supply.

Supplies which may be found less efficient may be used up for peace training, but a regular turnover of the whole stock should be arranged.

To reduce the diameter of the negative carbon, while retaining the necessary current carrying capacity, it is sometimes externally copper-coated, or has a hard core coated with copper. Cored carbons.

To keep the crater as central as possible the positive carbon has a core of nearly pure graphite or plumbago, in diameter about one-fourth or one-fifth the diameter of the carbon.

Sizes of carbons.

The following are the sizes and nomenclature of service carbons :—

Designation.	Detail.	Remarks.
CARBONS.	For electric arc lamps.	
Horizontal lamps.	10 inches long.	
Negative 26·5 mm. *cored* ...	*For* 150 *amperes*	For fortress or field lights.
Negative 26·5 mm. uncored	For 120 amperes	For fortress or field lights.
Negative 23 *mm.*	*For* 120 *amperes*	For fortress or field lights.
Negative 18 mm.	For 60 to 90 amperes	For field lights.
Positive 38 mm. ...	For 120 amperes	For fortress or field lights.
Positive 33 *mm.* ...	*For* 120 *amperes*	For fortress or field lights.
Positive 25 mm. ...	For 60 to 90 amperes	For field light.
Inclined lamps.	12 inches long.	For fortress lights.
Negative 17 *mm.*–19 *mm.*	*For* 150 *amperes* coppered	
Negative 16 *mm.*–17 *mm.*	*For* 120 *amperes* coppered	
Positive 30 *mm.* ...	*For* 150 *amperes*	
Positive 25 *mm.*	*For* 120 *amperes*	
Vertical lamps.		For general lighting.
Negative 11 *mm.*	For 10 amperes.	
Negative 12 mm.	For 10 amperes.	
Positive 13 *mm.*	For 10 amperes.	
Positive 18 mm.	For 10 amperes.	

Ferrules.

In order to facilitate a good connection between the carbon holders and the carbons, brass ferrules are supplied to be slipped over the end of the carbon before insertion in the holder. It is necessary to see that these ferrules fit the carbons tightly and are clean both inside and out, and that the carbon holders should also be clean inside. If this precaution is neglected contact will be bad and heat will be set up, causing the metal to expand and making the holders hard to adjust.

The above details sufficiently indicate the uses to which the various patterns of carbons can be put.

Carbons for vertical lamps.

The vertical lamps referred to are used for the general lighting of parades, sheds, drill halls, &c., and not for defence purposes.

There are many patterns of this class on the market, and commercial patterns are often obtained, and in such case special sizes of carbons may have to be used. In demanding carbons for vertical lamps not of service type full details of the class of lamp should be given.

Carbons to be shaped before use.

Carbons before being used in a lamp should be shaped approximately in the form in which they burn. Thus, negative carbons should be filed to a blunt point, and positive carbons formed with

To face

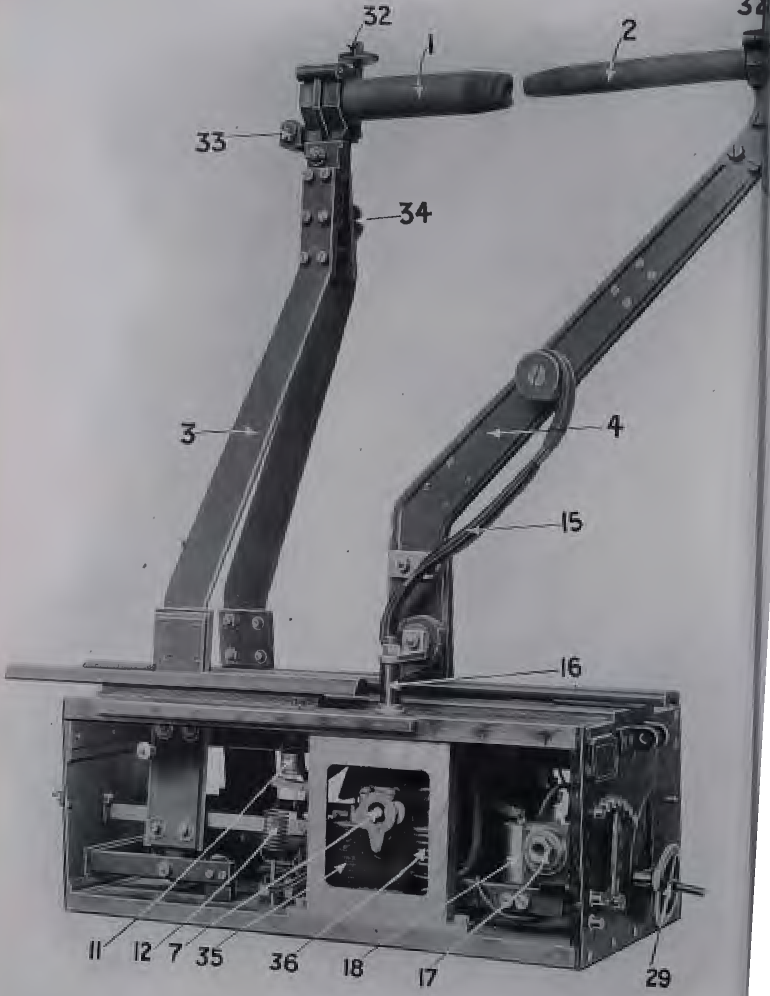


Fig. 21.—Horizontal arc lamp.

To face page 39.

Fig. 22.—Horizontal arc lamp.

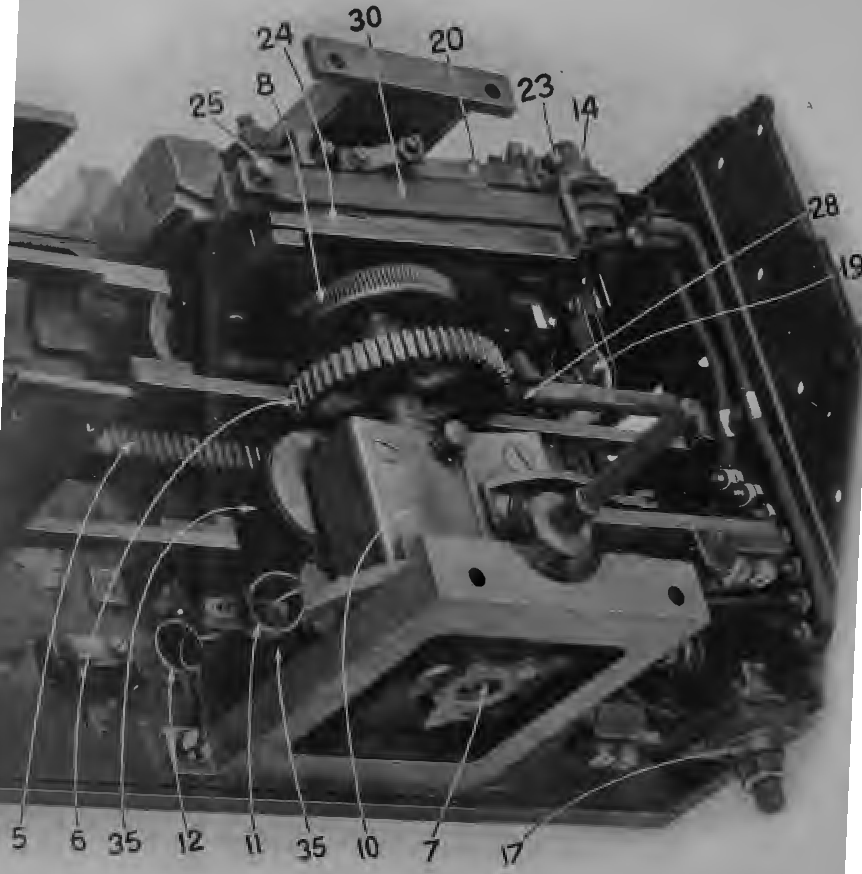


Fig. 23.—Horizontal arc lamp.

a small hollow or crater. Tools for this purpose are included in the list of accessories on page 47.

Lamps.

Types in use.

The lamps used for defence electric lights are of two kinds—"horizontal" and "inclined," these names indicating the position of the carbons.

The horizontal type is the present service pattern, and can be used with any type of reflector or projector in the service. It is arranged for either hand or automatic working.

The inclined lamp is an old pattern and can only be used with an adapter, and with reflectors of not less than 45 cm. focal distance. It is worked by hand, and is retained mainly for practice in manipulating the arc.

In addition to the above there are various types of vertical lamps in use for general lighting. The service type, which is fairly representative of the remainder, is described on page 50.

Description of the Horizontal Arc Lamp.

Nomenclature.

The *vocabulary* nomenclature for the lamp is as follows:—

Designation.	Detail.
LAMPS, ELECTRIC, Arc, Horizontal, 90 cm. projector	Automatic and hand. For use with short focus reflectors 120 amperes Without accessories

The accessories are described on page 47.

The lamp referred to is constructed for either hand or automatic working for currents of 120 to 150 amperes, with a potential difference at its terminals of 60 volts.

Lamps designed for currents of from 90 to 120 and for from 60 to 90 amperes have been supplied for service requirements. These lamps are similar generally to that described here.

The details of the lamp are shown in Figs. 21, 22 and 23, in which the various points are identified by figures as under:—

1. Positive carbon.
2. Negative carbon.
3. Positive carrier.
4. Negative carrier.
5. Positive carrier rack.
6. Spur wheel.
7. Shaft carrying armatures and feeding magnet.
8. Worm wheel.
9. Feeding rod.
10. Armatures.
11. } Steadying springs.
12. }
13. Shunt coil resistance switch.
14. Positive terminal of lamp.
15. Flexible connection.
16. Insulated terminal.
17. Negative terminal of lamp.
18. Dashpot.
19. Shunt and feeding coil switch.

20. Contact tongue of feeding coil.
21. Switch lever.
22. Feeding magnet.
23. Contact screw B.
24. Feeding coil armature.
25. Screw D for adjusting spring.
26. Pawl.
27. Pawl spring.
28. Cone.
29. Feeding wheel.
30. Spring for working feeding coil.
31. Bone button on negative carrier.
32. Screws for fastening carbon holders.
33. Screw for moving carbon sideways.
34. Screw for elevating or depressing carbon.
35. Shunt coils.
36. Series coils.
37. Terminals of adjustable resistance in feeding coil circuit.

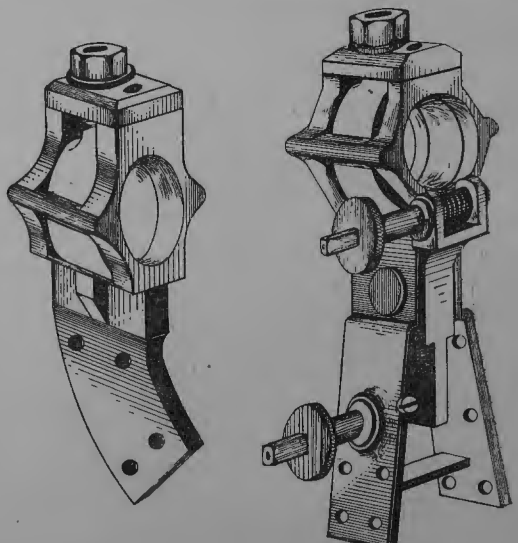
Body of lamp.

The lamp has a brass body 19¾ inches long, 10¼ inches wide, and 7¾ inches deep, and weighs about 104 lbs.

The body is provided with projecting guides along the upper edges for about half its length. These guide fit into corresponding grooves in the projector body, the lengths of the guides and grooves being so arranged that it is not necessary to remove the "front door" to insert the lamp in the projector.

Carbon-holders and carbon-carriers.

The carbons are supported in a horizontal position by the carbon-holders, secured to the tops of the carbon-carriers (3) and (4) (figs. 21, 22, 23). Each carbon-carrier is supported upon wheels, so that it can move easily in a horizontal direction. Electrical connection is maintained between the carbon-carriers and the fixed



Negative. Positive.

Fig. 24.—Carbon-holders of Mark II lamp.

conductors in the lamp by means of flexible leads. In the case of the positive carbon-carrier these leads are three in number, contained inside the body of the lamp. In the case of the negative carbon-carrier the connection is external, and consists of an insulated terminal on the top of the lamp box and a number of strips* of copper foil between it and the carbon-carrier (15).

A new pattern of carbon holder (fig. 24) has been introduced into Mark II lamps and will be fitted to Mark I lamps as soon as the present stock of carbon holders is used up.

Arc-striking magnets.

The lamp is provided with a pair of horseshoe magnets wound in the usual way, one with shunt (35), and the other with series coils (36). These magnets act on a rocking shaft (7) by means of an armature (10), rigidly attached thereto; the shunt-wound horseshoe magnet acting in opposition to the series-wound horseshoe magnet. They serve the purpose of striking the arc, and of *quickly* altering the length of the arc to suit any *sudden* variations of current due to bad or irregular carbons, &c. This they effect as follows:—

The rocking armature (10) is keyed to the shaft (7), and can cause it to rock; the feeding rod (9) is carried on a framework attached to the automatic feeding magnet (22), which is also keyed to the shaft (7), and consequently rocks with the armature of the arc-striking magnets; the feeding rod has a worm thread cut on it which engages with the wheel (8), which is keyed on the same sleeve as the wheel (6), which sleeve rides loose on the rocking shaft (7). Consequently when (10) rocks, (6) partially revolves, and moves the carbon-holders in doing so, through the agency of the racks which are fitted to the carbon-carriers and which engage with wheel (6).

A "damping" arrangement is fitted to the rocking armature to prevent these alterations being too suddenly effected, and to check the effect of the inertia of the moving parts. To the rocking armature are rigidly fixed two short arms. To the end of one of these is jointed the cylinder of an air "dash-pot," (18) the piston rod of which is fixed to the bottom of the lamp box. To the end of the other arm two opposing helical springs (11) and (12) are secured, the other extremities of the springs being attached to the top and bottom of the lamp box respectively. The springs are so arranged that neither exerts any pull on the arm when the ends of the rocking armature are equidistant from the poles of the arc-striking magnets. It may be necessary to regulate the tension on the springs in order to get the correct length of arc, *i.e.*, to compensate for any small error in the relative windings of the series and shunt coils. In the lamps of earlier manufacture the dash-pot was not fitted, and its functions were indifferently performed by means of a friction brake acting on the opposite end of the rocking shaft.

* These strips should be bound over with "primed tape" or other suitable insulating material, in order to prevent electrical contact between them and the positive carbon-carrier when the carbons are nearly burnt out

Feeding magnet. To feed the carbons together as they burn away, a second electro magnet (22) is employed. The body of this magnet is keyed to the rocking shaft, and carries with it its own armature and a steel spindle (9), to which is attached a ratchet wheel and a hand feeding wheel (29) (for hand working) The feeding magnet is shunt-wound, and its armature (24) is provided with a make and break device regulated by an adjustable tension spring, as in a "trembling" bell, by means of which it is caused to vibrate as soon as the "voltage" on the terminals of the coil reaches a definite value, depending on the adjustment of the lamp. The armature carries a pawl, the reciprocating movement of which causes the ratchet wheel and rod (9) to revolve. A sleeve rides loosely on the rocking shaft and carries a spur wheel (6), and worm wheel (8), both rigidly attached to the loose sleeve. The spur wheel engages in two racks (5), the upper rack being attached to the negative carbon-carrier, and the lower rack to the positive carbon-carrier. The worm wheel engages in a worm cut upon the feeding rod (9), so that any rotation of the feeding rod is thereby communicated to the carbon-carriers independently of the motions of the rocking armature, while at the same time, as was shown when speaking of the arc-striking magnets, any rocking of the armature of the arc-striking magnets about its own axis, moves the carbon-carriers independently of rotation of the feeding rod.

Switches and adjustable resistances. The shunt wound coils of the arc-striking magnets and the coil of the feeding magnet can be disconnected by a switch when the lamp is to be worked by hand. This switch (19) is controlled by a metal arm or switch lever (21), on the back of the lamp, which in addition to manipulating the switch, secures the feeding rod when the lever is down and the lamp arranged for hand working.

To assist in the regulation of the lamp, adjustable resistances are also provided in circuit with the above coils. These resistances are contained in the base of the lamp box, and are controlled by two finger switches (13) and (37) on the end of the lamp close to the hand feeding wheel (29).

The leads and connections are all entirely insulated from the body of the lamp.

Details of Circuits through the Lamp.

When the switch lever is placed "up," *i.e.*, in its vertical position, the circuits through the lamp are three in number, arranged as follows (see fig. 25) :—

1.—*Main Circuit.*

(*a*) From positive terminal by a copper strap and flexible connections to the positive carbon-carrier.

(*b*) Thence by positive carbon across the arc to negative carbon and negative carbon-carrier.

HORIZONTAL ARC LAMP.

DIAGRAM OF CIRCUITS THROUGH THE LAMP.

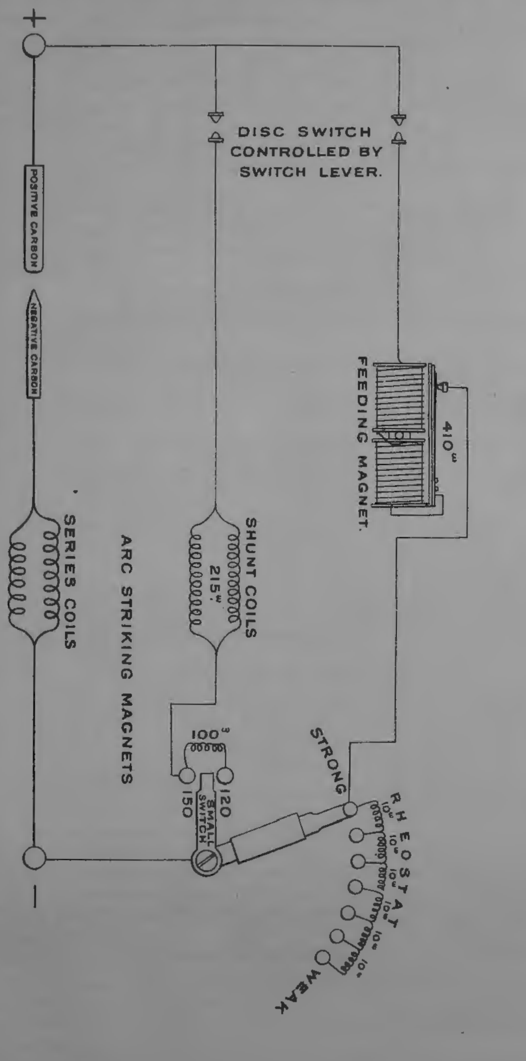


Figure 25.

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(*c*) Thence by a flexible connection and an insulated pillar on the top of the lamp body to the series coils of the arc-striking magnet. These coils are two in number, wound in parallel.

(*d*) Through these coils to the negative terminal.

2.—*Circuit of Shunt Coils of Arc-striking Magnets.*

(*a*) From the positive terminal to the disc switch (the switch lever being up).

(*b*) Disc switch to one end of the shunt coils of the arc striking magnets. These coils are two in number, wound in parallel.

(*c*) Through these coils to stud on back of lamp marked 150.

(*d*) Thence through a resistance of about 100 ohms to stud marked 120; thence along finger of small switch to negative terminal.

3.—*Circuit of Coil of Feeding Magnet.*

(*a*) From the positive terminal to the disc switch (the switch lever being up).

(*b*) Disc switch by flexible connection to one end of feeding coil.

(*c*) Through coil of feeding magnet to contact spring on armature.

(*d*) Thence to contact stud; thence by a flexible connection to left-hand stud of seven-point rheostat. Six coils, each of 10 ohms resistance, are connected in series, and one or more of these can be placed in circuit by means of the rheostat switch.

(*e*) Through finger of this switch to negative terminal.

When the switch lever is placed "down," *i.e.* in its horizontal position, all the coils and resistances with the exception of the "series coils" of the arc-striking magnets are cut out.

RESISTANCES OF COILS, ETC.

The resistances of the various coils are approximately as follows:—

Arc-striking magnets { Series coils, two in parallel, very low practically negligible. Shunt coils, about 215 ohms; *i.e.* two coils in parallel about 430 ohms each.

Feeding magnet coil, about 410 ohms.

Resistances in base of lamp:—

Between each pair of studs of rheostat, 10 ohms, making a total of	60 ohms.
Between studs marked 150 and 120	100 ohms.

ADJUSTMENTS.

Caution.—Before turning the hand feeding wheel by hand, always press it in. There is a coned surface on the feeding rod which throws the pawl and ratchet out of gear and prevents injury to them.

To Adjust the Lamp.

1.—*For Hand Working:—*

(*a*) Press in the feeding wheel. This should throw pawl and ratchet out of gear.

(*b*) Clamp down the feeding rod with the switch lever. This should disconnect the shunt coils of the arc-striking magnets and the feeding magnet coil from the positive terminal. In the most recent pattern lamps, a collar is fixed on the feeding rod close to the hand feeding wheel, to prevent the withdrawal of that wheel after the switch lever has been clamped down, and it should be noted that this collar is between the switch lever and lamp body before the hand feeding wheel is turned by hand.

2.—*For Automatic Working:—*

(*a*) Release the feeding rod by raising the switch lever. This should connect the shunt coils of the arc-striking magnets and the feeding magnet coil to the positive terminal.

(*b*) Pull out the hand feeding wheel. This should throw the pawl and ratchet into gear.

(*c*) See that the hand feeding wheel turns when the armature of the feeding magnet is worked by hand.

If it does not turn either—

(i.) The clamping collars are loose, and the pawl has in consequence fallen on one side or other of the ratchet wheel; or

(ii.) The pawl is damaged or out of adjustment; or

(iii.) The teeth on the ratchet wheel are damaged.

(*d*) Adjust the distancing screw so as to allow the armature a play of about $\frac{3}{16}$ths of an inch.

(*e*) Adjust the contact point by the screw so to have a clearance of about $\frac{1}{4}$th of an inch when the armature and contact spring are pressed hard down.

(*f*) Adjust contact spring so that the circuit through the feeding magnet coil is *just* broken when armature is pressed right down. This adjustment is made by means of a screw, which is got at through a hole, covered with a screw cap, in the top plate of the lamp box. To make it, place a cell and "detector" in simple circuit with the lamp terminals. Temporarily break the circuit through the shunt coils of the arc-striking magnets. (This can usually be done by setting the switch of this coil's circuit at an intermediate position between the studs marked 150 and 120. If this cannot be done, place a piece of paper between the arm of the switch and the studs). No carbons should be in the lamp, or if there are they must be separated. Press armature down, and screw down adjusting screw until deflection just goes off.

Clamp the adjusting screw, and replace the screw cap after making the adjustment. Restore the circuit of the shunt coil of the arc-striking magnet.

(*g*) By means of the capstan-headed screw, which regulates the tension of the spring, adjust the armature to work when the volts at the terminals of lamp are 60, and the switch of the rheostat is on the central stud. This adjustment may very well be made while the lamp is burning.

HORIZONTAL ARC LAMP.

CIRCUIT FOR ADJUSTING LAMP WHEN NOT WORKING.

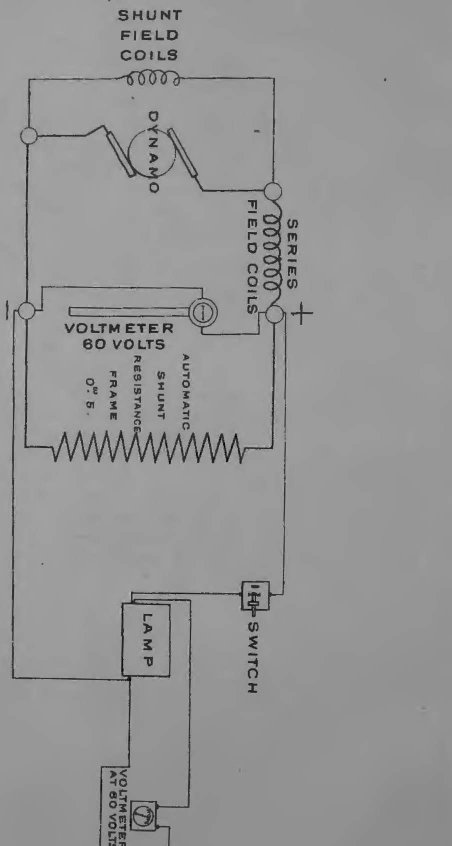


Figure 26.

Malby & Sons, Lith.

If it be desired to make the adjustment when the lamp is not burning, the volts may be obtained from a dynamo by connecting up as shown in Fig. 26, and take the following steps:—

A resistance of 0·5 ohms, capable of carrying 120 amperes, should be connected to the terminals of the generator so as to put a fair load on the engine, and the generator should be run to give 60 volts at its terminals. The shunt resistance which is used in conjunction with the automatic switch is suitable for this purpose.

Press in the hand feeding wheel in order to throw the pawl and ratchet wheel out of gear.

Separate the carbon-holders.

Raise the switch lever, to bring the coil of the feeding magnet into circuit.

Connect the terminals of the lamp to the terminals of the dynamo by two small leads and a switch.

Adjust the armature as above.*

There will be practically no loss of volts in the leads, because the current will be so small.

(*h*) See that the brake or dash pot is in working order.

To Commence Working.

Always commence by Hand Working as follows:—

1. Place the lamp, adjusted for hand working in the manner described above, in the projector and fix the carbons in their holders, leaving the points separated about half an inch.

2. Switch on the current and bring the carbon points together by hand, immediately separating them by hand until a proper length of arc is arrived at. The volts just after first striking will be low, about 45 volts, but as the carbons heat the arc can be gradually lengthened until the volts reach 60. The current should then be 120 ampères.

3. When the lamp is burning steadily change to automatic working.

While the Lamp is Burning.

1.—*To Change from Hand to Automatic Working.*

(*a*) Gradually raise the switch lever and at the same time turn the hand feeding wheel (without pulling it out) so as to open the carbon points sufficiently to compensate for the movement of the feeding rod.

(*b*) Pull out the hand feeding wheel to throw the pawl and ratchet into gear.

Adjust the rheostat switch so that the feeding magnet coil causes its armature to vibrate when the volts on lamp terminals reach 60. Should the armature vibrate when the P.D. at terminals of lamp is less than 60 volts, the switch must be moved towards

* All adjusting screws of the feeding magnet coil are provided with lock nuts. These should invariably be tightly screwed up as soon as the adjustments have been made.

the right hand side, and conversely. Each step will make a difference of about one volt in the P.D. required at lamp terminals to cause "feeding."

(*c*) Place the small switch on the stop marked 120.

2.—*To Change from Automatic to Hand Working.*

(*a*) Move the switch of rheostat on to the left hand stud and wait if necessary until the armature of the feeding magnet ceases to vibrate, then move the switch hard over to the right. The object of this is to prevent the armature of the feeding magnet from working, and thereby giving slight shocks to the operator, while the following adjustments are being made.

(*b*) Press in the hand feeding wheel to throw pawl and ratchet out of gear.

(*c*) By means of the switch lever gradually clamp down the feeding rod, and at the same time turn the hand feeding wheel so as to close the carbon points sufficiently to compensate for the distance they would have been opened by the movement conveyed to the rocking shaft.

It may be useful to remember that when clamping down or releasing the feeding rod, the feeding wheel should be turned in the direction that the switch lever is moved.

ACTION OF THE LAMP.

The action of the lamp when set for hand working requires no further explanation.

The action of the lamp when set for automatic working is briefly as follows:—

When the main switch is closed, a difference of potential is established at the lamp terminals, a current therefore flows through the shunt coils of the arc-striking magnets and one end of the rocking armature is pulled down. This armature being geared through the feeding rod to the spur wheel which gears into the racks fixed to the carbon-carriers, the above movement of the armature causes the carbons to move towards each other, and possibly to touch, so completing the main circuit. Should, however, the movement of the rocking armature be insufficient to cause contact between the carbons, the feeding magnet will operate its armature and gradually close the carbons, through the agency of the pawl and ratchet wheel, until they touch and complete the main circuit.

As soon as the main circuit is completed, a large current flows through the series coils of the arc-striking magnets, and that end of the rocking armature is then pulled down, the carbon points separated, and the arc struck.

The construction of the lamp is such that when the arc has reached its proper length, the pulls of the shunt and series coils of the arc-striking magnets are equal.

As the carbons burn away the volts across the arc gradually rise; and as soon as they reach 60 the current through the coil of the feeding magnet is sufficiently strong to attract its armature, causing it to vibrate and so feed the carbons gradually together until the volts fall below 60.

When the carbons have been so fed together that the distance between the carbon-holders is reduced to about 6 inches, an insulated stop (31) Fig. 22 on the inner end of the lower rack comes in contact with one of the springs of the disc switch and breaks the circuit through the coil of the feeding magnet. Further effort to close the carbons by means of the hand wheel presses the spring against the back of the lamp body and the travel of the rack is prevented.

Caution.—When the total length of a carbon is reduced to 4 inches a fresh carbon should be fitted to the lamp.

The lamp was originally designed for a normal current of 150 amperes. The resistance between the studs marked 120 and 150 is inserted in the circuit of the shunt coils of the arc-striking magnets so as to diminish the pull of those coils in the same proportion as the pull of the series coils.

Arc Deflector.

With horizontal arc lamps an "arc deflector" is used to counteract the tendency of the electric arc between the carbons to burn principally at the upper edges of the carbons.

The arc deflector consists of a piece of soft iron, $\frac{9}{32}'' \times \frac{31}{32}''$ in section, bent into the arc of a circle such that the partial ring so formed has an inside diameter of $4\frac{13}{16}$ inch. It is fixed to the projector body by means of two corrugated brass supports.

Although arranged to be concentric with the positive carbon, the arc deflector is not placed directly below the electric arc, but is fixed so that when the lamp is correctly focussed the edge of the arc deflector nearest to the electric arc is 30 mm. ($= 1\frac{3}{16}$ inch about), further from the reflector than the tapered end of the positive carbon.

The object of this is to keep the arc deflector from being damaged by the heat given out by the electric arc.

Accessories.

The following accessories are required for use with the lamp. They are described below in accordance with their *Vocabulary* nomenclature, those marked * are ordinary service stores.

Designation.	Detail.	Remarks.
Bits, rose, Mark II ...	For positive carbons ...	
Bottles—		
Glass	*Oil, in tin case*	
**Tin* oil, ¼ pint ...	... ...	
Box, wood	... ...	To be made locally required.
Brushes—		
Camel-hair, 1½" ...	Flat	
*Paint, sash tool, No. 2	... ...	
*Watchmakers' ...	Telegraph equipment ...	

Designation.	Detail.	Remarks.
Cleaners, contact ...	... ...	
Conductors, flexible—		
Negative	Copper strip	Spare.
Positive	Silk covered	"
*Drivers, screw—		
13 mm.	Steel, handled	Obsolescent, when used up "R.E. 6 inch" will be used in lieu.
9 mm.	... ...	
7 mm.	... ...	
R.E. 6 inch	... ...	
Ferrules—		
Brass—		
38 mm.	For positive carbon ...	
26·5 mm.	For negative carbon ...	
Gunmetal—		
33 *mm.*	*For positive carbon* ...	
23 *mm.*	*For negative carbon* ...	
*Files, bastard, safe edge, 10″	Handled	
*Leather, chamois ...	... ...	
Nuts	Brass, for repair (No. per set)	For Mark I only.
*Pin, adjusting, 4 inch ...	... ...	
Screws	Brass and steel, for repair (No. per set, 49)	For Mark I only.
Spanners—		
Box, hexagonal ...	Steel handled, for main terminals	
Box, square, 8 mm. ...	Handled, for carbon holder	
Double ended, 12 and 14 mm.	Steel, for nuts	
Double ended, 10 mm.	Steel for nuts	
Forked, small ...	Gunmetal, for nuts of switch	
Forked, large... ...	Gunmetal, for screw collars of main terminals	
Springs, pawl	Steel, for ratchet wheel ...	
*Tips, oil	... ...	
Tongs, small	For carbons ... pairs	
Washers, insulating ...	Various, for repair of lamp (No. per set, 42)	
Wheels, ratchet... ...	Brass	

The ferrules included above are fitted to each carbon before use, so as to facilitate changing carbons and ensure a good contact in the holders. The remaining articles are for small repairs or for adjusting and cleaning the lamps.

Inclined Lamp.

The present service inclined lamp is known as "Lamp, Electric Arc, Inclined. Mark III."

Mark I of this lamp is obsolete, but a number of Mark II lamps may be found at stations. Mark III only differs from Mark II in some small points, the general principle being identically the same, but the design better in the details.

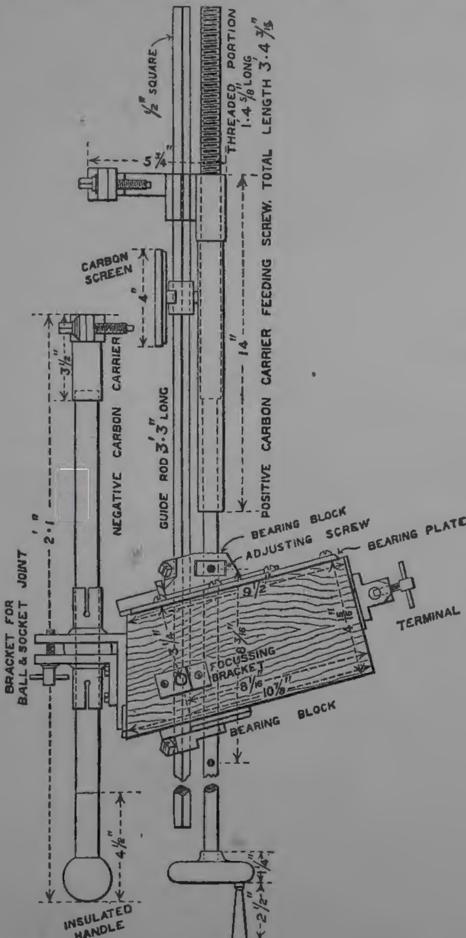


Fig. 27.

The details of the lamp are shown in Fig. 27.

The terminals are constructed to take conductors $\frac{7}{16}$-inch in diameter.

The positive carbon holder is constructed to take carbons from 15 to 36 mm. diameter, and the negative carbon holder from 15 to 21 mm. diameter.

A brass spanner is supplied with each lamp for fixing the carbons.

The lamp was intended for use with the Mark I 90 cm. projector only, but can be used in later marks of projector by means of an adapter It is suitable for currents up to 150 amperes.

The lamp weighs about 30 lbs.

Adapters.

An *Adapter, lamp* is required with each inclined lamp to enable these to be used with Mark II, III or IV projectors. The outside shape of the adapter is similar to that of the body of a horizontal lamp, and inside it has grooves to fit the bearing plate of the inclined lamp.

Vertical Lamps.

The arc lamp used in the service for general illuminating purposes is known as "Lamp, Vertical, Arc, 10 Amp." Most of these lamps are of the "Brockie Pell" pattern.

They have an illuminating power of 1,000 candles. The lamp depends for its action on the differential working of two coils, one in series with the arc, the other in shunt across it. The carbons are fed together by means of a brake wheel.

The lamp is a focussing one, with a dash-pot damping arrangement.

The lamp is constructed to burn on a 50-volt circuit, with 42 volts at the terminals of the lamp, the current being 10 amperes, *i.e.* when burning on a 50-volt circuit 8 volts should be lost in the leads.

When these lamps are run off a service generator a series resistance to lose 38 volts will be necessary.

Length of arc from $\frac{1}{8}$ inch to $\frac{3}{16}$ inch.

The details are shown in Fig. 28.

Circuit through the lamp.

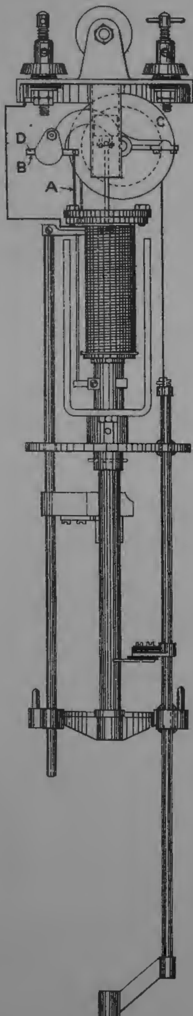
From positive terminal through the series coil to an insulated flexible connection to the positive carbon holder (which is insulated from the body of the lamp), across the carbons to negative carbon holder to body of lamp, the negative terminal being connected to body of lamp.

The shunt coil is connected across the carbons. If the shunt were connected across the lamp terminals an increase of volts would increase the pull of both series and shunt solenoids, therefore length of arc would remain the same and the current across it would increase.

As the shunt coil in this lamp is connected across the arc a rise of volts will cause an increase of current through the series coil which will tend to separate carbons and maintain a constant current through the circuit.

BROCKIE-PELL ARC LAMP.

Figure 28.



3731. Malby & Sons. Lith.

When no current is passing the carbons fall together owing to the prevailing weight of the metal block attached to the positive carbon holder, the brake chain allowing brake wheel to rotate freely when the rocking bar to which the cores are attached is in its normal position, *i.e.*, the core of shunt being inside the shunt solenoid owing to its prevailing weight.

Action of the lamp.

When the current is switched on, the core of the series solenoid is drawn inside the coil, and the rocking bar lifts the rod attached to the counterpoise lever. The movement of this lever causes the brake chain to grip the brake wheel and turns it slightly in a right-handed direction, this movement opening the carbons about ⅛ inch and striking the arc.

As the carbons separate the current through the series coil decreases, and the volts rise at the ends of the shunt coil, the core of which is gradually sucked down into the solenoid, this movement tending to close carbons, and maintain the arc at the proper length.

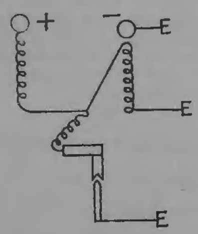


Fig. 29.—Circuit diagram.

When the arc becomes too long the magnetic pull of the shunt coil will preponderate and the rocking bar will assume a horizontal position, as this occurs the brake chain will be loosened sufficiently for the brake wheel to slip round and allow the carbons to feed together by gravity, after which it will be gripped tightly once more as the pull of the series coil reasserts itself.

Resistance of series coil, 15 amperes ; resistance of shunt 123·4 ohms.

The current used should not exceed 11 amperes, nor be less than 9 amperes. To work with minimum current, fill hollow of piston with small shot.

To work at maximum current, take off lead weights on shunt side of rocking bar.

The following patterns of arc lamps are also likely to be met with in the service :—

Other patterns.

Multiple carbon lamps, flame arc lamps and mercury lamps.

CHAPTER IV.

Projectors, Projector Gear, and Reflectors.

Contents.

Description of Projectors.

The present service projectors are:—

Projector, 90 cm. (Marks III and IV)—

	Parts.	No. to a Projector.
Body	with arc deflector and six ½-inch bolts for securing reflector frame	1
Bed plate	cast-iron, rectangular	1
Door glazed	with trunnions	1
Frame reflector ...	with 36 ½-inch nuts and 9 washers for studs	1
Focus observer ...	metal, with bolts and nuts	2
Pedestal	upper and lower raceway with U arms, and two lengths of D.20 cable with terminal lugs	1
Plate graduated ...	brass, circular, with pillar, wing nut, 2 screw studs and index. For horizontal training	1

The details of the above are shown on Figs. 30 and 31.

Body. The *body* of the projector is a short cylinder of steel plate of 3 feet diameter, strengthened with iron angle rings at the front and back and fitted with trunnions mounted on slides, by which the balance can be adjusted. On the top is a ventilating hood, and at the sides are doors through which the carbons can be manipulated. Small observing windows are provided in each door and on each side of the body. They are glazed with emerald and ruby glass, superposed. Adjustable hooks are provided at the front end to carry the glazed door or diverging lens, as may be required. The lower part of the body is fitted with a pair of cast-iron guide-plates about 10 inches apart, which carry the lamps, and an adjusting screw for regulating the focal distance of the arc.

Frame reflector.

The *frame reflector* is fixed on the back of the body by means of

Side elevation.

Scale $\frac{1}{16}$.

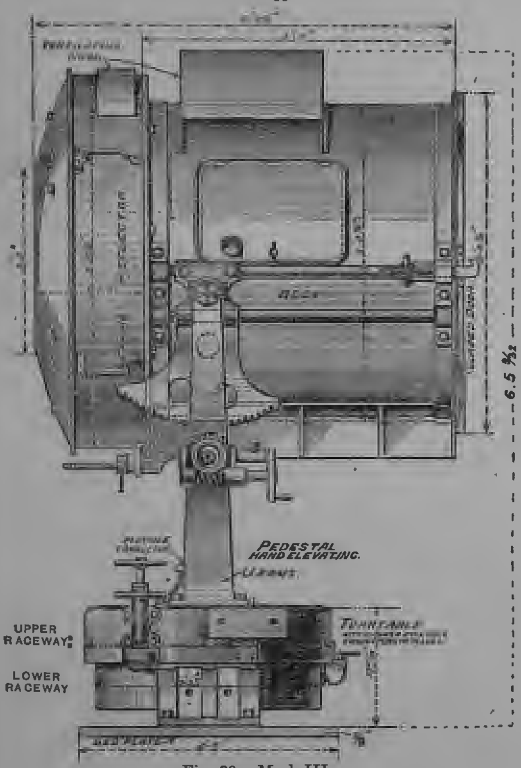


Fig. 30.—Mark III.

six ½-inch bolts, and is fitted outside with lifting handles, a ventilating hood on top, and on the back a system of baffle plates. Inside the frame is fitted with nine bolts for securing the reflector ring.

An asbestos washer is provided between the body and reflector frame.

The baffle plates are to prevent the direct access of a draught of air to the back of the reflector. The outer opening in the back of the reflector frame should be closed by a tampion, made locally of wood, covered with felt, which is only removed during running.

Pedestal. The *pedestal* consists of a base in two parts, called the upper and

Sectional elevation (back view)

Scale $\frac{1}{16}$.

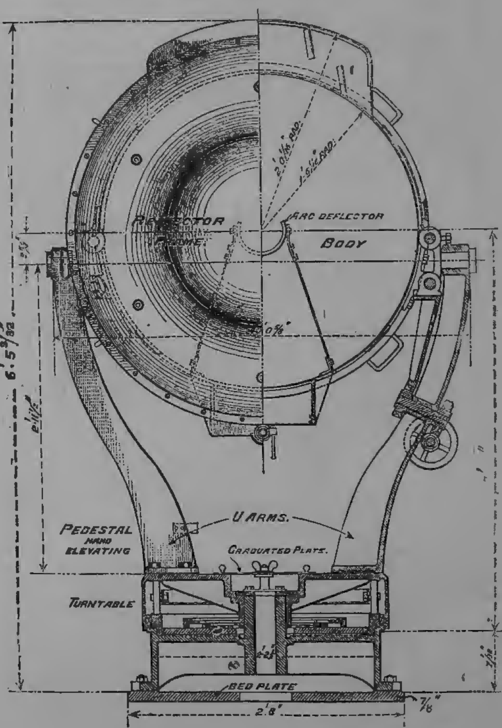


Fig. 31.—Mark III.

lower raceways, and a pair of U arms, with bearings to support the trunnions of the body. One side of the U arms carries a hand gearing for controlling the elevation of the body, consisting of a hand wheel, worm and toothed wheel engaging with a toothed segment on the body. A clamping handle to lock the gear is provided. This hand gear is issued with all projectors, but can be replaced by the motor gear described on page 59.

Raceways.

The upper raceway runs on a system of roller bearings in the lower raceway.

The connections from the switchboard come to terminals on the lower raceway, which are connected to insulated contact rings inside the base. The upper raceway carries a series of rubbing contacts, which bear on the contact rings, and are connected with the lamp by flexible leads of D 20 wire, fitted with terminal lugs.

The lower raceway of Mark III projectors has 4 contact rings, two for use with lamp leads and 2 for elevating motor when used.

When used with traversing motor an additional pair of contact rings will be issued and fitted locally.

The lower raceway of Mark IV projector has 6 contact rings, 2 for lamp, 2 for elevating motor and 2 for traversing motor.

Locking brackets are provided on both upper and lower raceway, so that the projector can be pinned in one position.

Hand traversing gear.

A hand traversing gear is provided as part of each projector. It consists of a hand wheel, with pinion gearing into a rack formed round the lower raceway. A clamping handle to lock the gear is provided. This gear can be replaced by the motor gear described on page 61.

Well for dial.

A well is formed in the centre of the base to take a directing dial (now obsolescent). It is covered by a graduated brass plate when the dial is not in use.

In Mark III projectors there is a machined projection on the lower part of the base, which was intended for use with a "see-saw" apparatus now obsolete. This projection is omitted in Mark IV projectors.

Mark IV projector is fitted with an improved form of rubbing contact and improved terminals, and also with fitting for motor traversing gear.

Bed plate.

The lower raceway is secured to a cast-iron bedplate, which should be fixed into the floor of the emplacement by bolts and nuts.

Focus observers.

All Mark IV projectors, and certain Mark III, are fitted with focus observers on each side. These are short telescopes, with ground-glass eye-pieces, on which an image of the arc appears. They can be clamped in any position. To use them, ascertain by actual trials the best position for the arc, and then set the focus observer so that the image is in the centre of the object glass. If the lamp is then moved or the carbons burn irregularly it is easy to restore it to the correct focus by moving the lamp or carbons till the image appears in the same position as before.

Glazed door.

The glazed door is provided to keep draught and spray from the lamp and reflector. It should always be used when running. The glass is arranged in strips to facilitate repair. When the projector is used with 30-degree or 45-degree parabola-ellipse reflectors, the side strips can be replaced by sheets of metal.

Projector Gear.

Projector gear is provided to enable the movements of the projector to be controlled from the directing station. There are two motions to provide for :—

(1) A horizontal or "traversing" motion.
(2) A vertical or "elevating" motion.

Dial gear for traversing.

There are two patterns of traversing gear, "dial" and "motor."

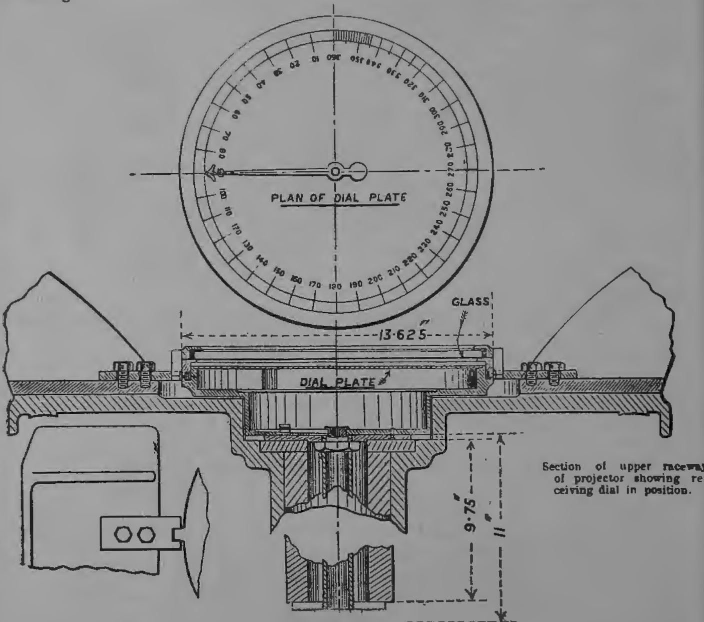


Fig. 32.

The first consists of a pair of dials, one for "transmitting" at the directing station, one for "receiving" on the projector.

The transmitting dial (Fig. 32) has a metal case, fitted with a crank handle by which the pointer is operated—one revolution of the handle advances the pointer 1 degree; the movement of the handle also transmits currents, by means of a commutator, for working the receiving dial.

The receiving dial has a metal case, with a brass tubular stem and securing nut. It is fitted in the well of the projector, and should be correctly oriented. The bevel ring is free to revolve on the case, and is provided with two lugs to fit brackets on the projector. Tapped holes are provided in the projector, inside the U arms, to take brackets which should be made and fitted to engage in these lugs. A mark, or point, is provided inside the bevel ring to enable an operator at the projector to follow the movements of the pointer of the receiving dial.

Power required.

Each pair of dials must be connected by 4 wires, viz., 3 line wires and 1 common return. A battery of 10 Leclanché cells (cells, electric, Leclanché G) is supplied to work the dials, and must be connected in the return wire.

Use of power from main generator.

It is generally better to utilise power from the main generator than from a Leclanché battery, which is liable to become polarised when the dial is working continuously through a winter night's run. Power leads from the engine room are generally available in the directing station, but care must be taken that the necessary resistances are included in the circuit so that the current through the dial does not exceed ·25 ampere.

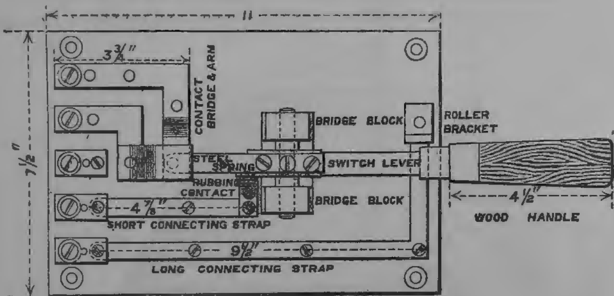


Fig. 33.—Switch motor directing, Mark I.

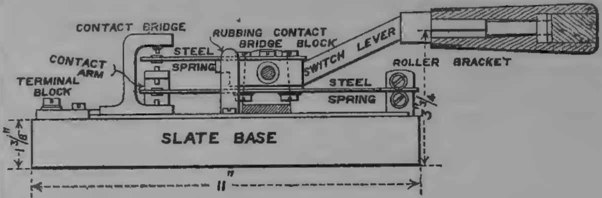
Motor Gear for Elevating.

The motor gear for elevating consists of an elevating motor on the projector, controlled by a switch, with a resistance at the directing station.

The official nomenclature of the parts is :—

Frame resistance 2·5 ampères 23 ohms	German silver, with six-point switch and cut out, for use with switch motor directing.
Projector gear, motor elevating, Mark I	Comprising motor in case ; supporting bracket, with 4⅜-inch bolts ; spindle collar ; worm, with 2 pins ; worm wheel, with key ; bevel wheel, with handle ; supporting stud, with split pin, and washer ; four insulated conductors and I.R. tubing for projectors ; 90 cm., Marks III and IV.

Switch E.L., motor directing, Mark I .. .. — For directing elevating motor of projector, on slate base, with fuze wire terminals.



Elevation.—Front of bridge block removed.
Fig. 34.—Switch motor directing, Mark I.

Power. The power for working the motor is obtained from the generator which provides the power for the light, two wires for this purpose being led from the engine room to the switch in the directing station, whence two wires are led to the emplacement, and connected through

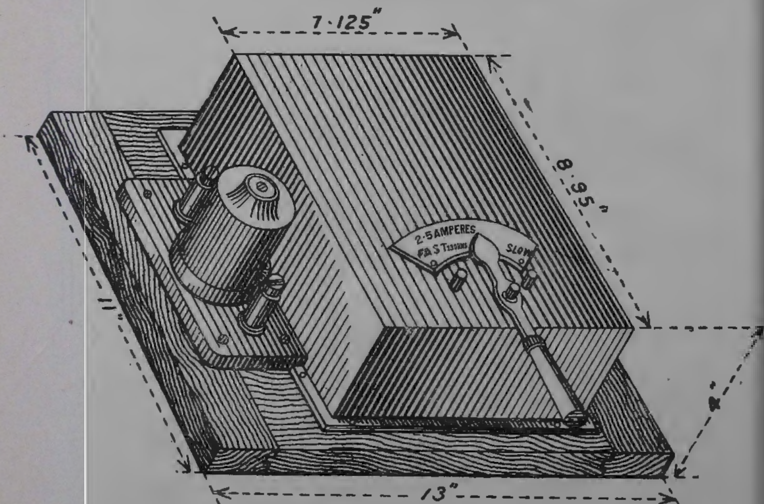


Fig. 35.—Frame resistance 23 ohms.

the contact rings in the raceway of the projector to the armature of the motor.

Details of the circuit are given in Chapter VIII.

The directing switch has three positions: the centre being that of rest, with the circuit disconnected; the upper and lower actuating the motor in opposite directions by a simple reversal of the direction of the current through the armature. They should be so connected Switch motor directing

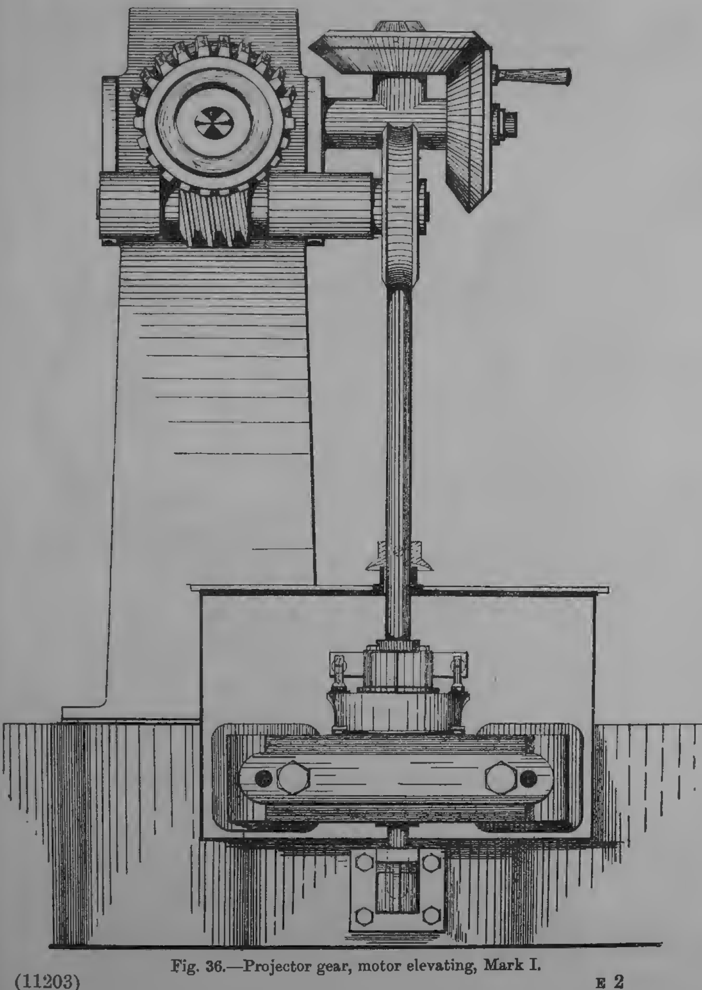


Fig. 36.—Projector gear, motor elevating, Mark I.

that an upward movement of the switch handle will elevate the light, while a downward movement will depress it. Five terminals are provided, 2 for wires to armature of motor, 2 for power and 1 to enable a fuze to be inserted in the negative power wire. (Figs. 33 and 34.)

Frame resistance.

The resistance frame has a maximum resistance of 23 ohms, and will carry a current of 2·5 amperes.

It is provided with a six-point switch to give varying amounts of resistance, and is connected in the circuit between the switch and

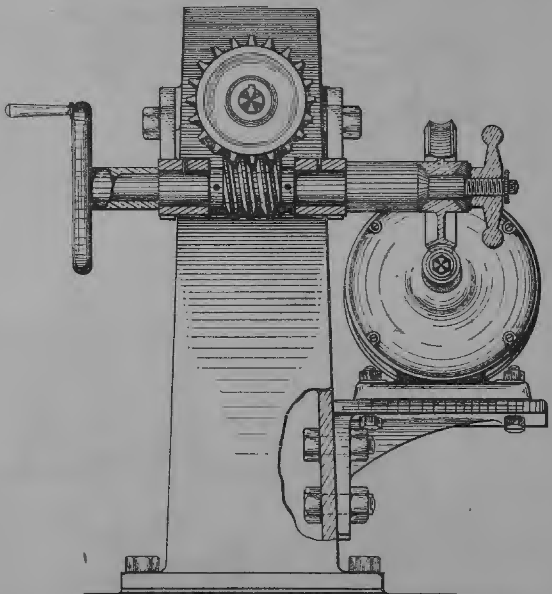


Fig. 37.—Projector gear, motor elevating, Mark II.

motor. The resistance will normally be at "slow," but by moving the pointer in the direction of "fast" a more rapid elevating or depressing movement of the light can be obtained. (Fig. 35.)

Motor elevating.

There are two patterns of elevating motor, Marks I and II (Figures 36 and 37). In both the field magnet coils are permanently connected across the lamp terminals by means of flexible conductors attached to the rubbing contacts of the main circuit in the raceway, the excitation of the field magnets being thus entirely independent of the circuit through the armature.

The armature is connected to the wires from the directing station through the contact rings in the raceway and the lugs terminal small. The current through the armature should not exceed 2 amperes.

The details of Mark I gear are shown in Fig. 36, those of Mark II in Fig. 37. The latter will be used for new supplies.

The wires must be so connected at the switch that the movements of the projector may correspond to that of the switch. The connections of the circuit are shown in Fig. 38.

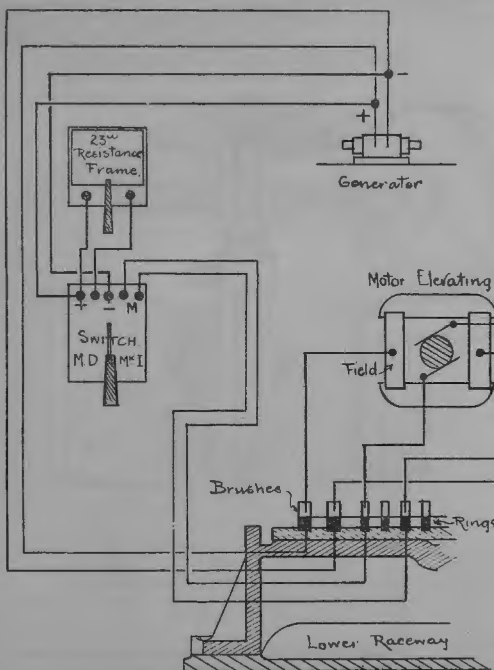


Fig. 38.—Circuit of motor elevating gear, Mark I.

Motor Gear for Traversing.

The motor gear for traversing consists of a traversing motor on the projector, controlled by a switch in the directing station.

There are two patterns of motor :—

The Mark I traversing motor is intended to be fitted to Mark III 90 cm. projectors. Motor traversing.

The Mark II traversing motor is similar to Mark I, except that fewer parts are issued, as some are embodied in the Mark IV 90 cm. projector, to which it is fitted.

The official nomenclature of the parts is :—

Projector gear. Motor traversing, Mark I.	Also with hand and clamping wheels and sleeve for hand traversing, two small terminals, contact brushes in wood block, two connecting straps, and four contact rings on ebonite base; for Mark III 90 cm. projectors.
Mark II.	For Mark IV 90 cm. projectors.

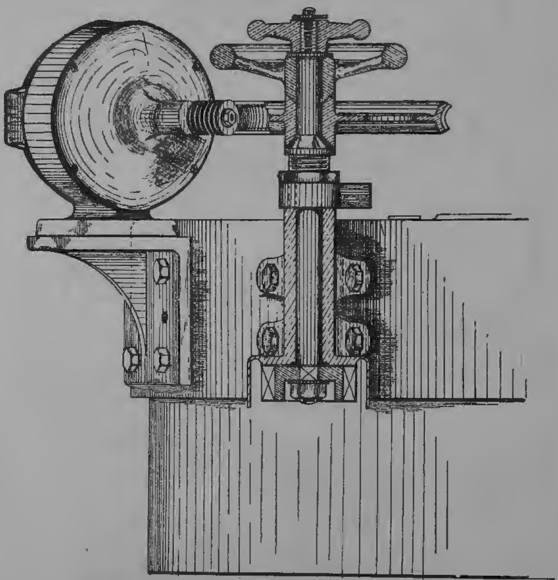


Fig. 39.—Projector gear, motor traversing. Mark I.

The motor is of Siemens standard G.M.3 type, wound for 65 volts, and provided with a special end casting for taking lengthened armature spindle and steel threaded worm.

The motor brushes are self-adjusting, and lubrication is by wick lubricators from underneath.

The motor is mounted on a cast-iron supporting bracket, which is secured to the outside of the upper raceway by four ½-inch screws and two steady pins. A second bracket is secured to the upper raceway and supports the traversing spindle, which drives the projector by means of a worm wheel gearing into the worm of armature spindle and a pinion gearing into a rack on the outside of lower raceway; the motor and fittings thus travel round with the projector. A hand wheel and clamping arrangement are fitted to the traversing spindle and a double-coned sleeve is also provided to take the place of the worm wheel for traversing the projector by hand should the motor be dismantled.

As in the case of the elevating motor, the field magnet coils are permanently connected across the lamp terminals by flexible con-

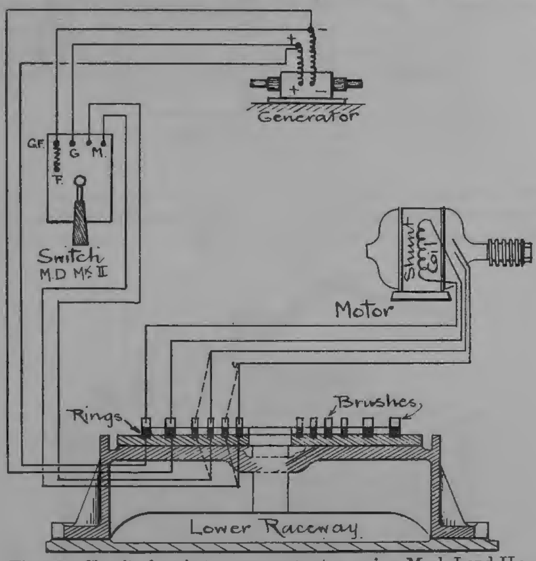


Fig. 40.—Circuit of projector gear, motor traversing, Mark I and II; or motor elevating, Mark II.

ductors to the rubbing contacts of main circuit, and the armature is connected by two wires to the switch in directing station through contact rings in the lower raceway of projector.

The circuit is shown in Fig. 40.

A section of the motor used in projector gear, traversing, Mark II, and elevating, Mark II, is given in Fig. 41.

The motor will be found to traverse the projector satisfactorily with a difference of potential across the field of 55 to 60 volts, and a current in the armature of from ·5 to 2 ampères, according to whether the maximum or minimum speed is required. The current in the armature should not exceed 2 ampères.

The switch motor directing, and frame resistance 2·5 ampères 23 ohms, as described on page 58, can be fixed in the directing station to control the traversing motor, and the connections are the

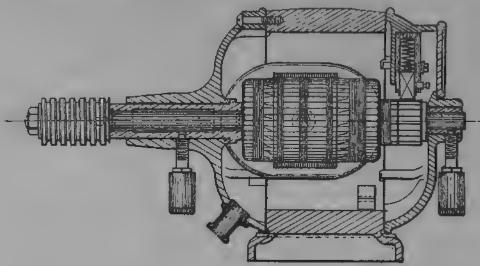


Fig. 41.—Section of motor traversing, Marks I and II, or motor elevating, Mark II.

same as those to elevating motor. With the resistance at "fast," the projector should traverse one complete revolution in 45 seconds; with the resistance at "slow," one revolution should take 70 seconds.

Fig. 42.—Switch, E.L., motor directing, Mark II.

Switch E. L. motor directing Mark II.

A new pattern of directing switch, including an adjustable resistance, has been recently introduced, which can be used with either the motor elevating or motor traversing gear. (Fig. 42.)

It consists of a four-point change-over rheostat switch, mounted on a box containing the resistance bobbins of rheostat. With the switch handle in a central position the circuit is disconnected, and a movement right and left over the central points of rheostat will actuate the motor in opposite directions, the speed increasing as the switch handle is pushed over. The switch handle is controlled by a spring, which ensures a quick break at the last contact point, and enables a series of make-and-break contacts to be made on either side when a very slow motion of the projector is required. There are four contact points on each side, which give an equal number of different speeds, varying from one complete revolution of the projector in about 45 seconds to one complete revolution in about three minutes. These figures are to a great extent dependent on the pressure of the brushes on the contact rings in raceway of

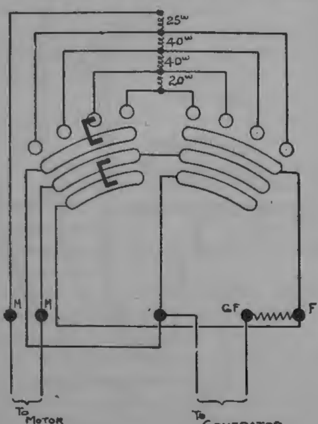


Fig. 43.—Diagram of circuit of switch E.L., motor directing, Mark II

projector, and care should be taken in the adjustment of these brushes.

Five terminals are provided—two for power leads, two for the wires to armature of motor, and one to enable a fuze to be inserted in the circuit to generator.

Fig. 43 shows the internal connections and the resistances in circuit at each contact point.

Older Patterns of Projector.

There were prior to Mark III numerous types of projector in use, many of them of an experimental nature. They are usually known as Marks I and II.

The essential feature of these is that the Mark I was constructed with the guide plates only 6 inches apart to take an inclined lamp, and could not therefore be used with the horizontal lamp. This pattern is now obselete, though a few may still be found at stations.

In the Mark II pattern the guide plates will take the horizontal lamp, but the details of the pedestal and body are as in Fig. 44. This pattern is retained in the service till worn out. It cannot be used with projector gear.

Other sizes. Experiments are in progress with a projector to take 120 cm. reflectors for fortress use, and with smaller and lighter projectors to take 90-cm., 60-cm. and 35-cm. reflectors for field use.

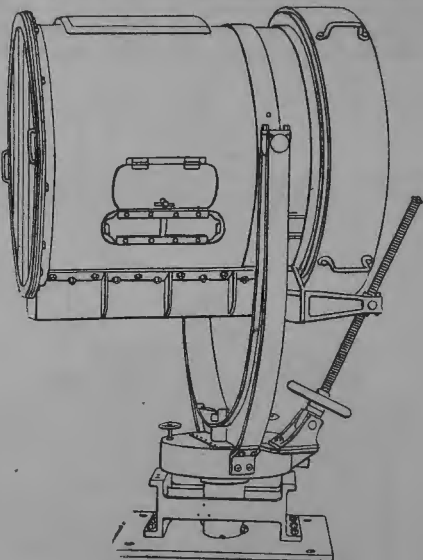


Fig. 44.—Mark II.

REFLECTORS.

Glass. The reflectors in the service fall into two main classes, "glass" and "metallic."

The glass reflectors in the service are known as :—

Reflectors, glass, silvered—

Mangin	*90/65 cm.* *90/45 cm.*
Parabola-ellipse, 90/42 cm	16 degrees. 30 degrees. 45 degrees.

Paraboloid .. .. { *90/45.* 90/42

The optical properties of the above varieties have already been discussed in Chapter II. The principal dimensions are shown on Figs. 6, 7, 8 and 9, Chapter II.

The figures in the nomenclature are (1) the diameter of the reflector in centimetres, (2) the focal distance in centimetres, (3) the degree of divergence (if any) in degrees. These figures are marked on each reflector thus, 90/42/16.

The only metal reflector at present in the service is :— Metallic.

Reflector, metallic, Paraboloid 90/45 cm. } Palladium faced, with special aluminium mounting ring.

The above has not proved entirely satisfactory, and no more of this pattern are being obtained at present.

There is no doubt that the silvered glass reflectors give at present the most effective illumination, and where this property is important, as for fighting or searchlights, glass reflectors should be used. Comparison of glass and metallic reflectors.

On the other hand this class of reflector is liable to damage by careless handling or sudden changes of temperature, and would probably be rendered unserviceable by a single bullet.

The metallic reflectors are much safer to handle, and a bullet striking them passes right through, leaving a dent a few inches across. This class are thus especially suitable for fixed illuminated areas where range is less important and where the lights may be exposed to hostile fire at short range.

The main practical difficulty with metallic reflectors has been to get a reflecting surface which will stand the heat of the arc and changes of weather without tarnishing.

In addition to the palladium surface adopted to some extent in the service, experiments have been made with many varieties of surface, of which the best have been nickel (on an iron backing) and gold. The latter so far promises the best results.

So far the metallic surface has not been applied to the parabola-ellipse 90/42 reflectors, but experiments with this shape, but of smaller diameter, are in progress for field use.

In all classes of reflectors the greatest care is necessary in cleaning the reflecting surface, and the special instructions given in detail at the end of this chapter must be carefully followed under the supervision of an experienced man. Care in cleaning.

Mounting Reflectors.

The various patterns of reflectors are secured in the reflector frame of the projector by mounting blocks or rings.

For reflectors, glass, mangin 90/65, the arrangement consists of nine wooden blocks secured to the bolts of the reflector frame in such a way that the edges of the reflector are gripped by the blocks. Mangin 90/65.

To secure this pattern to the Mark III or IV projectors a special form of reflector frame is necessary, differing from the ordinary pattern in being 3 inches deeper. The reflector is fixed in the frame as in Fig. 45. One such frame will be supplied for each 90/65 reflector in use at the station, and the latter should be kept permanently fixed in the frame.

Mangin, 90/45.

The reflector, glass, mangin, 90/45, is mounted in a wooden ring,

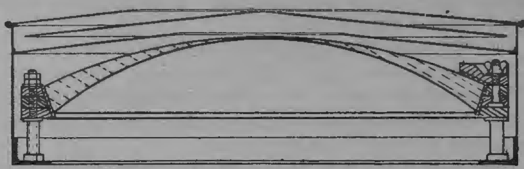
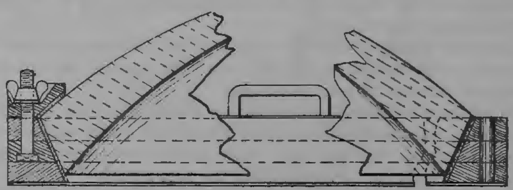


Fig. 45.—Mangin reflector 90/65 in special frame.

which is issued with each reflector. This ring is bored with holes, which fit on the bolts of the frame reflector, and the ring is secured in the same way as the metal rings described below.

The early pattern of wood mounting ring did not provide sufficient ventilation round the reflector; it has, therefore, been reduced in diameter. The method of fixing is shown in Fig. 46.



Section through securing bolt.

Section through hole for stud in reflector frame.

Fig. 46.—Method of mounting 90/45 mangin reflector in wood mounting ring.

All wooden mountings must be protected from the heat of the arc by washers or sheets of asbestos cloth.

Metallic.

Special mounting rings are for the present issued with all metallic reflectors.

Paraboloid or parabola ellipse.

All other forms of glass reflector are issued in the—

Ring mounting .. .. { Iron, with 36 brass springs, with 4 iron screws and nuts.

The details of this mounting are shown in Fig. 47.

In fitting reflectors the following instructions should be carefully followed.

Instructions for Fitting Reflectors in Iron Mounting Rings.

Take the front portion of four clips and place them, one at the point marked top, one at bottom of iron mounting ring, and the other two at the sides at right angles to the top and bottom pair.

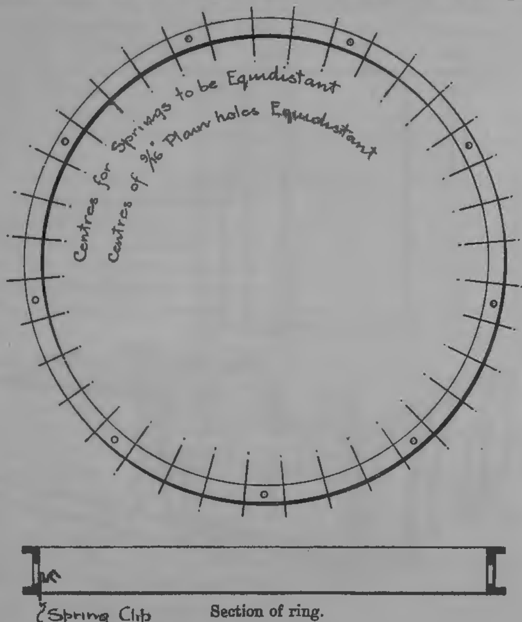


Fig. 47.—Mounting ring for glass reflectors.

Place the reflector on the front clips, taking care that top of reflector is exactly opposite top of ring, and clamp up with back clips.

Adjust the top and bottom clips until the top and bottom edges of reflector are at exactly the same distance from the front edge of iron mounting ring; having got this, proceed to do the same with the side springs.

Put on the remainder of spring clips.

Transport Cases.

As a general rule all reflectors should be kept fitted in their mounting rings, and, when not actually fitted in reflector frames they should be kept for safe custody in transport cases.

These are called :—

Cases, transport—

A..	With padlock, key, and tubular spanners for reflector, glass, silvered, paraboloid, 90/42.
B..	For reflector, mangin, 90/45.
Spanners, tubular, 11 inch by $1\frac{1}{4}$ inch ..	Steel, for nut.

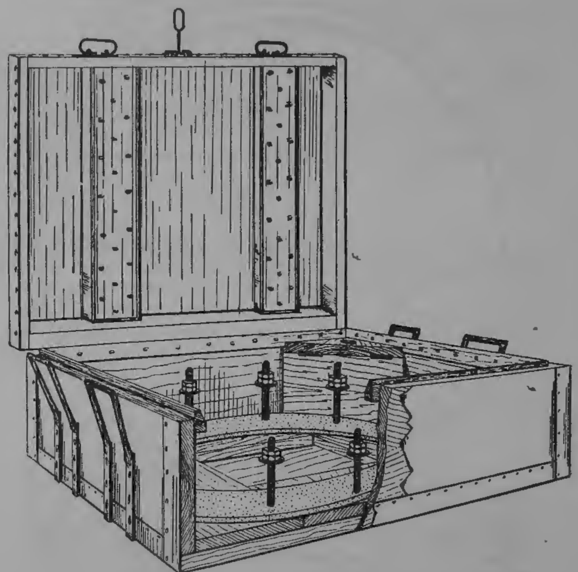


Fig. 48.—Case, transport C.

C	For reflector, glass, silvered, paraboloid and parabola-ellipse, also metallic paraboloid.
Spanners, tubular, $\frac{3}{4}$ inch across flats ..	Steel.

The details of C are shown on Fig. 48.

For additional safety when travelling, the transport cases are packed in packing cases.

Instructions for the Care of Reflectors.

General.

All reflectors should be kept in their mounting rings, and, when not actually mounted in projectors, they should be stored in the special transport cases described on page 70. Reflectors should always be placed in transport cases when it is necessary to move them, and for journeys by rail or sea the transport cases should be packed in packing cases as an additional security.

Reflectors should never be rested on their centres, especially those of the Mangin type.

To prevent damage by shocks from gun fire and to admit of expansion when hot, they should not be screwed up too tight in their mounting rings. Carbon dust, &c. must not be allowed to accumulate on the reflector or in the projector; the back of the reflector frame must be removed frequently and all dust, insects, &c., cleared out.

The securing bolts and nuts should also be kept slightly oiled to insure that they work freely and readily admit of the reflector being changed.

Instructions for cleaning.

Reflectors should be lightly cleaned before every run. The materials used for cleaning must be kept scrupulously clean in boxes supplied for that purpose. Every precaution must be taken to avoid scratching the surface of the reflector, particularly the metallic types. On no account must the surface be rubbed with anything until the carbon dust has been removed.

The following procedure will be followed in cleaning the various types:—

Silvered Glass. Glass.

(*a*) All dust and dirt should first be removed from the projector and emplacement.

(*b*) With a clean dusting brush lightly used, remove all traces of carbon dust from the surface.

(*c*) With the "powder puff" lightly cover the surface with a small quantity of powder by gentle taps.

(*d*) With a clean, soft, chamois leather, polish the surface with a light circular motion from the centre outwards.

Lens and glass door should be treated in a similar manner, polishing the strips of glass length-ways.

Metallic Reflectors (palladium type). Palladium.

(*a*) Clean fresh water, cotton wool, and a solution of liquid ammonia (10 of water to 1 of ammonia liquid by measure) are the requisite materials. On no account must they be cleaned with rouge, chamois leather, or any other material.

(*b*) Remove the reflector from its frame, and in a suitable position, free from dirt and grit, flood the surface with clean water to remove all traces of carbon dust, turning the reflector around to prevent the dust lodging in the ring.

(*c*) Thoroughly dry with cotton wool with a circular motion from its centre outwards.

If an extensive cleaning is required, or the reflector is tarnished, or splashed with salt water, it must be cleaned at the earliest opportunity as follows:—

(*d*) Proceed as in (*a*) above, then rapidly bathe the surface with a 10 per cent. solution of ammonia, using a small pad of cotton wool, with a circular motion from the centre outwards, and remove all tarnish if possible.

(*e*) Again thoroughly flood the surface with clean water, then dry and polish with cotton wool, as before.

Gold. **Metallic Reflector (gold-plated type).**

(*a*) Remove the reflector from its frame, and thoroughly wash the surface with clean water to remove all traces of carbon dust as above.

(*b*) Then with a small pad of clean cotton wool and a little ordinary white soap and water remove all stains and tarnish.

(*c*) Again thoroughly bathe the surface with water, using a pad of clean cotton wool to remove all traces of soap.

(*d*) Thoroughly dry with cotton wool, and polish with a very soft chamois leather.

This, and the operations in (*b*) and (*c*) above, should be done with a circular motion from the centre outwards.

Precautions to Prevent Cracking of Glass Reflectors when in Use.*

1. The breakage of a reflector usually occurs during a run or just after a run, and may be attributed to—

(1) The reflector being burnt by flame from the arc, or by portions of hot carbon dropped from the lamp.

(2) The reflector being exposed, while running, to a sudden draught.

(3) Unequal or too rapid heating or cooling of the reflector on starting or just after a run.

2. The main precaution against (1) is care in working the lamp. Any carbon which shows a tendency to splinter or burn irregularly should be discarded.

3. The precautions against (2) depend on the state of the weather. If hot and calm, it is best to leave door and openings open, so as to keep the temperature as low as possible. But if it is windy, especially when the wind is accompanied by rain, extra care should be taken; doors and windows should not be opened simultaneously, the front glass should be kept in position, and the side doors of the projector opened as little as possible.

During peace practice before changing carbons the shutters of the emplacement should be closed, and the door closed and locked, The lamp should be started and burning steadily before the shutters are again opened.

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* In the event of a reflector being broken while running, the facts should be investigated by a Board, as laid down in the King's Regulations; a copy of these instructions should be laid before the Board, and evidence tendered as to how far the instructions were complied with.

4 (*a*). To guard against (3) (too rapid heating) the lamp should be started in a position well out to the front of the projector, and remain there for five minutes before being put in focus.

(*b*). To guard against (3) (too rapid cooling) the shutters and door of the emplacement should be closed, the lamp should be run out well to the front of the projector, and the ventilators of the back of the projector choked by filling the circular opening at the back by a "tampeon," or by placing a wadmiltilt over the whole back of the projector, or closing the ventilator of the 120 c.m. projector.

The lamp should be kept burning in the forward position for at least 5 minutes, during which the emplacement should remain closed and the detachment at their posts.

5. It follows from the above that the engines must not be stopped on conclusion of a run till after all lamps are extinguished The orders for stopping should be given by the E.L. director.

If the engines are accidentally stopped, or if a lamp for any reason is extinguished and cannot be restarted, the emplacement should be at once closed and the projector covered as in 4 (*b*).

Copies of these precautions, together with the above instructions for cleaning reflectors, should be hung up in a prominent position in all electric light emplacements.

The best form of protection for the back of the projector not provided with louvred ventilators," at the conclusion of a run is a "tampeon" made of wood and covered with felt. It should be provided with a handle so that it can be readily placed in position in the circular opening at the back of projector frame. Care should be taken that it is not in position during the run, or the back of the reflector may become overheated and the backing peel off, taking the silvering with it. Use of tampeon.

It should be noted that while carbons may have sometimes to be changed rapidly, care of the reflectors is necessary both in war and peace. Therefore, in wet or windy weather, the above precautions should always be taken, and some care must be taken in arranging the times for changing carbons, so that too many lights shall not be out of action simultaneously. Of course in an emergency, such as the breakage of a carbon during an attack, carbons must be changed as quickly as possible.

Diverging Lens.

There are three sizes of diverging lens for use with paraboloid or mangin reflectors for producing diverging lights. They are known as :—

Lenses, 90 cm.	In gunmetal frames, with steel trunnions.
Diverging—	
16 degrees	With 15 glass prisms.
30 degrees	With 15 glass prisms.
45 degrees	With 11 glass prisms.

The details are given in Fig. 49.

Diverging lenses.

The diverging lens opens out the light direct from the front of the projector. The opening of the emplacement has thus to be much larger than with a porthole arrangement. This pattern is, however, suitable for the few cases where a diverged light is made capable of traverse.

For convenience of repair the glass strips or prisms are identified

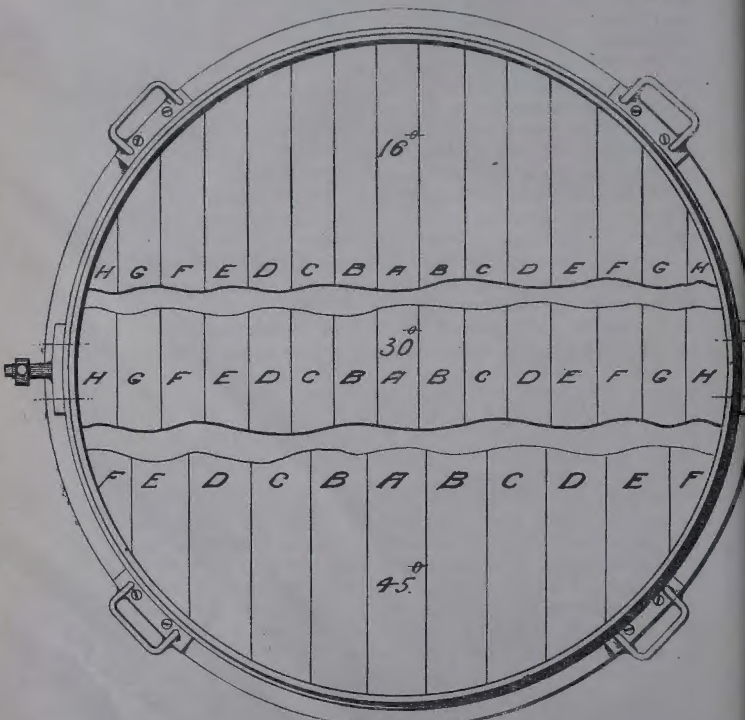

Fig. 49.—Diverging lens.

by letters, as shown on Fig. 49; spare strips of each size are supplied to stations.

In cases where it is sometimes necessary to remove the lens and use a concentrated beam, it is advisable in order to save time to weight the glass door which replaces the lens to equal the weight of the lens, as otherwise the balance of the projector on the trunnions is disturbed, and it will be necessary to shift the projector along the slides.

Obscurating Shutters.

To enable a light to be temporarily obscured, louvred shutters are provided as shown in Fig. 50. They are placed on the projector in front of the glass door.

Accessories.

In addition to the tools described in the last chapter as being required for use with the lamps, the following are required by the operators in each emplacement.

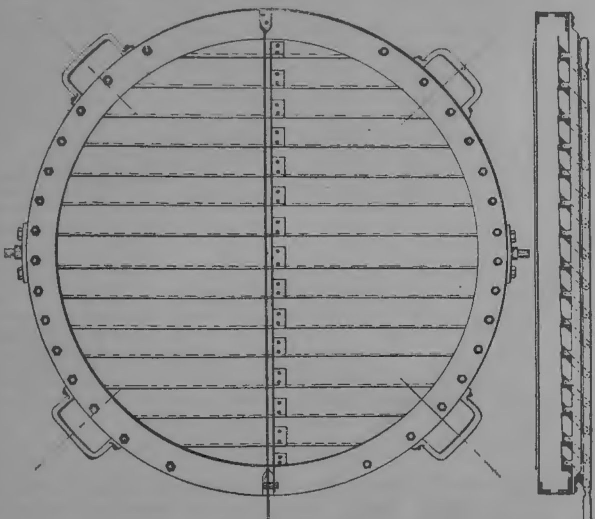

Fig. 50.

Tray, lamp	Iron, with four handles for lifting lamp into projector.
Glasses, framed, coloured, ruby and green ..	In wood frame, with handle and red and green glass.

The first is for carrying the horizontal lamp and lifting it into place in the projector.

The second is to enable the operator to observe the arc through the doors of the projector.

The glass is in two layers, ruby and emerald. Spare glasses are issued in pairs, carefully selected according to their optical properties. The pairs should thus be always stored and used as issued. These glasses can also be used to glaze the inspection holes in the projectors.

CHAPTER V.

ENGINES AND GENERATORS (FORTRESS PATTERNS).

CONTENTS.

NATURE OF ELECTRICAL POWER PLANT.

Single unit system.

The electrical plant required to produce the power for defence lights is usually arranged on the single unit system. That is, for each light there is provided a separate engine and electric generator.

This system has been adopted after careful consideration instead of the system of a central supply, which is that usually adopted for civil work, as giving greater elasticity for military conditions of work and limiting the effect of casualities of all kinds to the actual light or engine affected.

Two or more units grouped in one engine room.

It is, however, not desirable to place each engine in a separate building, and in practice two to four engines are usually grouped together. This simplifies supervision and oil supply, and also allows of all the electrical connections being brought to a common switchboard, where arrangements can be made to connect any generator at will to any light. Such arrangements should always be provided, and are, of course, essential when a spare engine and generator are provided in a group.

Type of power plant. Steam.

In the early days of electric lighting all power was derived from a steam-driven plant, but such plant had the disadvantage of requiring a long time to raise steam and was also extravagant in *personnel*. The development of the internal combustion engine using heavy oil gave a power plant which combines most of the good points required for a military light, viz., simplicity, rapidity of starting, economy of *personnel*, and a fuel which can be readily obtained, and this type has now superseded the steam plant in most of our defences.

Oil.

Type of generator.

In a similar way the types of electric generators formerly in use have now been reduced to one simple type—a two-pole, compound-wound machine, capable of giving a current of 200 amperes, with a voltage which depends to some extent on local conditions.

Size of generator required.

From Chapter I it will be seen that the conditions adopted for the lamp are a current of 120 amperes and a voltage at the terminals of the lamp of 60 volts. But these figures only apply for the best conditions of running and are thus not constant; for instance, with a hissing arc, the current may reach 200 amperes or more for a short period. The generator is, therefore, made of a size to give 200 amperes, thus providing a factor of safety against overheating.

Current.

Again, although the machine is compounded, the amount of excitation does vary to some extent with the changes in the conditions of the arc, and these variations affect the load on the engine and tend to make the whole working irregular. It is, therefore, found necessary to have between the generator and the lamp a steadying resistance of such a nature that with the current of 120 amperes it will absorb at least 20 volts. The normal voltage at the generator is therefore fixed at 80 volts.

Voltage.

Special cases of variation of voltage.

With the pattern of lead usually employed 1,000 yards is required to produce the resistance necessary to absorb 20 volts, and thus, as a return lead is always used, the maximum distance between engines and lamps with the normal 80 volts generator should not exceed 500 yards.

When this distance must be exceeded, the electrical conditions can be satisfied by :—

(1) Overrunning the generator up to a voltage of 85 volts.
(2) Reducing the current to 100 amperes.
(3) Using thicker leads.

The first two expedients combined will suffice for a distance of 700 to 800 yards, but the third expedient is seldom used on account of the cost.

If the distance is much over 500 yards it is better to raise the power of the plant and use a generator with a higher voltage. Thus a voltage of 100 volts will run a light 1,000 yards away, and a voltage of 120 will run up to 1,500 yards. This latter size has been adopted at several stations.

Sizes of service generators.

Generators are referred to by their output in kilowatts, thus a generator giving 200 amperes at 80 volts is called a 16-unit machine; one giving 200 amperes at 120 volts a 24-unit machine.

These may be regarded as the two normal types in the service, though other sizes may be met with.

Horse-power of engine.

As each kilowatt is the equivalent of 1⅓ horse-power, a 16-unit machine requires 21⅓ horse-power and a 24-unit machine 32 horse-power. Allowing for internal losses in engine and generator and slip in belt, the normal sizes of oil engine to work with the service generators are fixed at 25 horse-power and 40 horse-power respectively.

Nature of fuel.

The pattern of engine adopted is the Hornsby Akroyd internal combustion engine, using as fuel petroleum conforming to the following specification :—

Specification for oil fuel.

1. The oil supplied must be equal in quality to the Standard Pattern deposited in the Chemical Department, Royal Arsenal, Woolwich.

Should any discrepancy be found to exist between the Standard Pattern and Specification, reference is to be made to the War Department Chemist, Chemical Department, Royal Arsenal, Woolwich.

2. The oil to be refined petroleum, free from acid, or solid matter in suspension.

3. Its specific gravity (at 60° F.) to be from 0·820 to 0·830.

4. Its flashing temperature to be not lower than 78° F. (close test).

5. On distillation it must yield not less than 90 volumes per cent. of constituents boiling between 302° and 572° F. (150° and 300° C.).

6. A portion of each order or delivery will be subjected to the tests necessary to determine whether the article supplied fulfils the conditions required by this Specification. Any that may be destroyed thereby shall, if found defective, be replaced by the contractor at his own expense.

If the oil so tested be found inferior or contrary to the terms of the Specification, the whole delivery may be rejected.

General Principles of Internal Combustion Engines.

Definition.

An Oil Engine is called an "Internal Combustion" Engine because it is one in which the heat is generated by combustion of the fuel with air inside the cylinder where it is turned into mechanical energy. This mechanical energy is transmitted by the piston through the connecting rod to a crank shaft, and on this latter is mounted a flywheel, which, by its momentum, keeps the engine moving smoothly during the "idle" strokes of the piston.

In general an oil engine consists essentially of :—

Method of working.

(1) A Vaporiser, in which the liquid fuel is converted into vapour and mixed with the proper proportion of air to produce an explosive mixture.

(2) The Cylinder, in which the heat energy is produced and converted into work.

To face page 79.

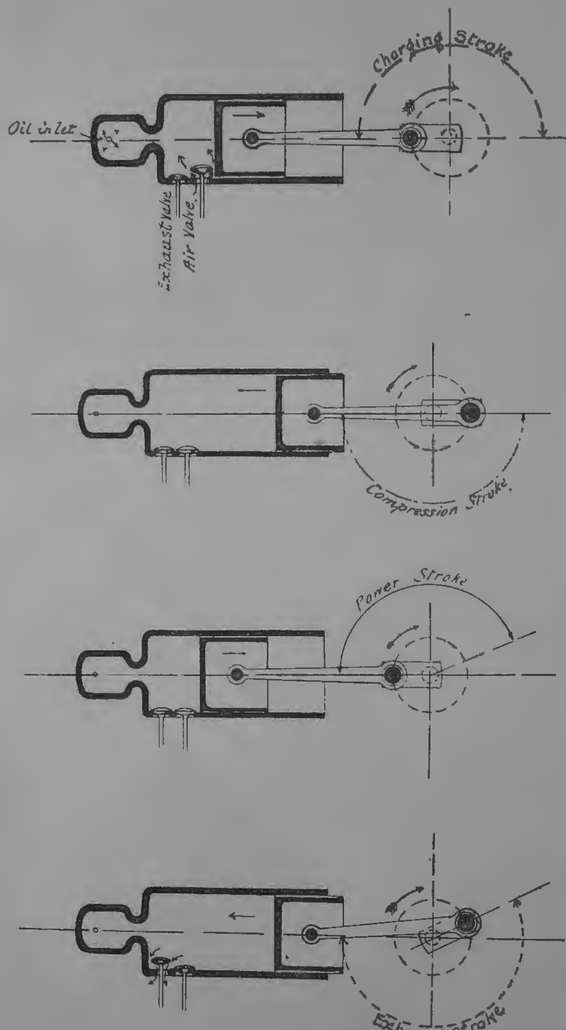

Fig. 51.

The principle governing the action is as follows :—

An explosive mixture of oil-vapour and air is drawn into the cylinder by the moving piston, then compressed and ignited, the increased pressure caused thereby forcing out the piston, after which the burnt gases are driven out on the return stroke. Thus only one stroke of the piston out of every four transmits energy to the crank-shaft, the remaining three strokes performing operations which are indispensable adjuncts to the working stroke.

Cycle of operations. First stroke.

Taking the beginning of a complete " cycle " of operations to get a clear idea of the system (Fig. 51), we have first the admission stroke, in which the piston moves out and the " inlet " valve opens simultaneously, and a charge of explosive " mixture " is sucked into the cylinder ; when the piston has reached the end of its stroke the admission of gas is completed and the " inlet " valve closes.

Second stroke.

The second stroke then begins, the piston moves inwards and compresses the charge, reducing the original volume of gas to one-fourth, or rather less.

This stroke is termed the compression stroke, and is a vitally important factor in the efficient working of the engine, as if there is any loss or leakage of the gas under the compressing influence of the piston, there will be a loss of power. The effect of compressing the gas into a much smaller volume is to make it capable of exploding with much greater energy than it otherwise would. In the compression of the charge a very considerable amount of heat is given to it, which represents so much of the energy stored up in the flywheel. The average amount of compression used is about 60 lb. per square inch ; some engines go a good deal higher, but there is a limit to the compression which can safely be used, as if it exceeds that figure it is quite possible for the charge to explode prematurely, causing a backfire. The amount of compression depends upon the size of the " clearance " volume or space behind the piston when at the inner end of its stroke.

Third stroke.

The compression stroke being completed, the charge of gas is ignited, and the pressure due to the heat energy developed by the combustion rises so rapidly that the maximum pressure is reached before the piston has moved appreciably on its out stroke. This is the only working stroke, and the piston is pushed forward with great force by the pressure of the burning and expanding gases.

Fourth stroke.

The working stroke having been accomplished, there, of course, remains in the cylinder a considerable volume of burnt gases under pressure, which must be got rid of as quickly as possible. Just before the piston reaches the end of its stroke the exhaust valve opens, and remains open the whole time the piston is completing the inward stroke. The burnt gases are thus swept out through a silencer into the air, the ejection being also aided by the fact of the gases still being at considerable pressure. It is usual to open the exhaust valve just before the working stroke is complete to facilitate the clearance of the gases. This is termed giving the exhaust valve a " lead."

It might be thought that this would reduce the effectiveness of the power stroke, but a little consideration will show that by the time the valve begins to open the crank is at a position where it has very little leverage, and the exploded gases are doing no effective work; therefore, they can with advantage be released, and this is always done.

Working of valves.

Thus the four operations, viz., inlet of gas, compression of same, explosion, and exhausting are completed and one "cycle" performed, this being commonly known as the "Otto Cycle." The working of the valves, as will have been noted, is of vital importance in the "cycle" of operations. The principle of the valves will be easily followed by studying the diagram (Fig. 51).

The opening of the valves at the correct time is performed by means of cams, which are rotating pieces, operated by a simple piece of mechanism from the crankshaft, so arranged that this cam-shaft rotates at half the rate of the crankshaft.

Method of distinguishing the various strokes.

The four strokes of the Otto Cycle may be distinguished as follows:—

An in stroke must be either a compression stroke or an exhaust stroke.

If a compression stoke, the exhaust valve must be shut.

If an exhaust stroke, the exhaust valve must be open.

An out stroke must be either a suction stroke or a working stroke.

If a suction stroke, the air valve must be open; if a working stroke, the air valve must be shut.

Description of 25-Horse-Power Hornsby-Akroyd Oil Engine.

This engine works on the Otto cycle.

Ordinary petroleum is used for fuel.

The vaporiser is heated by a lamp externally to start with, and it is afterwards kept hot by the explosion inside it, or the lamp may be kept burning.

The compressed charge is fired by the heated walls of the vaporiser.

The charge is compressed to about 50 lbs. per square inch, and the maximum pressure after the charge is fired is about 150 lbs. per square inch.

The following particulars will enable the two patterns of the 25 horse-power service engine to be identified:—

Mark I.—

Diameter of cylinder, 16 inches.
Stroke, 20 inches.
Vaporiser, not water-jacketed.

Mark II.—

Diameter of cylinder, 14½ inches.
Length of stroke, 19 inches.

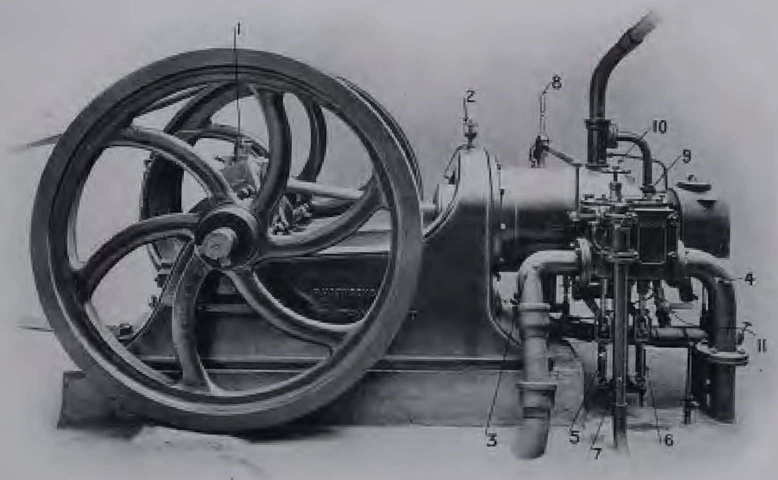

Fig. 53.—Side view of engine showing valves.

1. Crank pin lubricator.
2. Piston lubricator.
3. Air pipe.
4. Exhaust pipe.
5. Admission valve springs.
6. Exhaust valve springs.
7. Supply pipe from compressed air tank.
8. Self-starting handle.
9. Self-starting valve case.
10. Locking wheel.
11. Cock for vaporiser water jacket.

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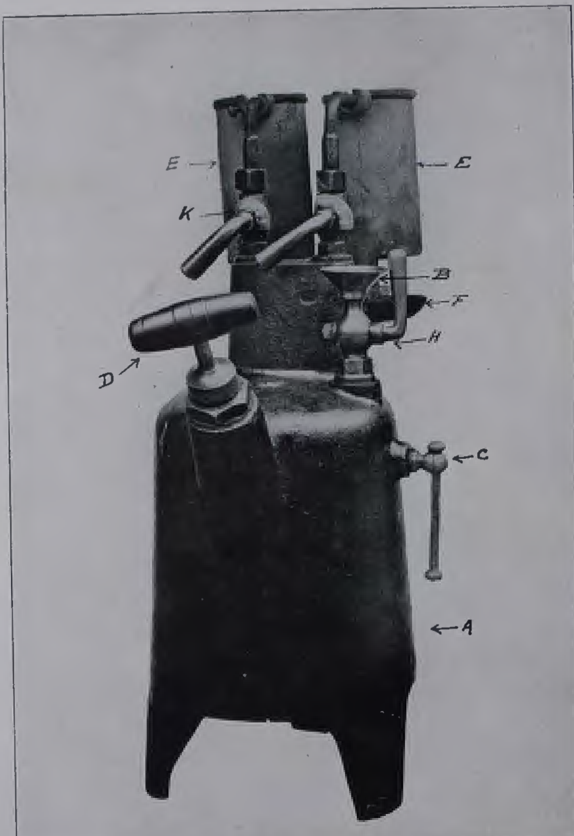

Fig. 54

A. Tank.
B. Funnel.
C. Plug and hole.
D. Pump handle.
E. Burner hood.
F. Cup.
H. Cock.
K. Adjusting cock

Vaporiser, water-jacketed.
Revolutions per minute, 190.
Brake horse-power, 25.

The details of the engine are shown on Figs. 52 and 53.

Blow lamp for heating vaporiser.

A few engines are heated by a gas burner, but the majority use a blow lamp.

The blow lamp (Fig. 54) consists of a tank A, which is nearly filled with petroleum, a vaporiser and burner inside each of the hoods E and an air-pump (D being the handle of same) for pumping air into the tank. The tank is fitted with a funnel B and a cock H for filling, and a plug C to allow air to escape while filling and for ascertaining when the tank is full enough. A cup F is fitted for heating the vaporiser when starting.

A cock K is fitted, which can be put in three positions, marked "work," "stop," and "start." When at "work" petroleum can get from the tank, up an internal pipe, to the burner. When at "stop," communication between the tank and burner is closed. When at "start," air can get from the top of tank to burner.

Blow lamps must never be put out by shutting off the oil to the burner, but will invariably be put out by letting the air out of the tank. If this is not done, the oil in the burner will deposit carbon and choke up the burner.

Blow lamps will be worked as follows :—

Open the cock H.
Take out the plug C.
Fill the tank A with petroleum, through the funnel B until it runs out at the hole C.
Replace the plug C.
Close the cock H.
Fill the cup F with petroleum.
Set the cock K to "start."
Set the petroleum in the cup on fire, using a ring of cotton waste round the centre as a wick, this will heat the coil in E. Increase the heat by pumping air through the flame.
When the coil is hot, turn cock K to "work," and pump up the air in the tank.
Take the wick out of the cup F and let the petroleum burn itself out.
When the lamp begins to give a steady roar, the pressure in the tank may be increased.
To put out the lamp open the cock H.
If the hole in the burner from which jet issues gets choked, nothing but the prickers provided for the purpose must be used to clean it.

When sufficiently heated, the vaporiser water jacket (in engines so fitted) should feel uncomfortably warm to the back of the hand, but in any case the vaporiser should be hot enough if the blow lamp is allowed to heat it for twenty minutes.

The indicator cock should not be used for testing whether the engine is hot enough or not.

When the engine has started and the hood has been put on, the lamp can be put out.

A very frequent cause of engines not starting is that the vaporiser is not hot enough.

If the vaporiser gets too cold the engine will not work, as the charge will not fire. If it gets too hot the charge will fire too early, and the engine will slow down.

When a water jacket is fitted to the varporiser the latter can be kept at the right temperature by adjusting the flow of water. It is a good plan to mark the position of the cock for future guidance when the right opening has been found for the usual load. The vaporiser must never be allowed to get red hot.

Unjacketed vaporisers get red hot after a short run; nothing can be done except to remove the iron cover and open any doors and windows in the vicinity.

Air supply and exhaust.

Air is allowed to enter the cylinder on the suction stroke by the admission valve F (Fig. 55). The air is usually taken from under the base of the engine to lessen the noise made when it is drawn in, but in some cases it may be necessary to take it from outside the engine room.

The burnt charge when done with is allowed to escape from the cylinder by the exhaust valve H (Fig. 55) into a silencing box, and thence to the open air.

Oil supply and adjustment.

Petroleum is forced into the vaporiser through the vaporiser valve box by a pump 17 (Fig. 52), worked by the admission valve lever. A charge of oil is therefore pumped up every suction stroke.

The amount of petroleum pumped up can be varied by raising or lowering the plunger by the disc G (Fig. 56), thus altering the length of stroke. The plunger is locked in position by the nut K (Fig. 56), which must be jammed tight against the bracket above it, or it will shake loose and the plunger will work down until the engine stops for the want of oil. The plunger is forced down by the admission valve lever and withdrawn by a spring. Care must be taken that the gland D (Fig. 56) is not set up too tight or the spring will not be able to withdraw the plunger.

The oil pump must be adjusted so that the speed of the engine will give the full volts, usually 80 volts on the voltmeter in the engine room. The gauge provided for setting the pump is only an approximate guide, and the best adjustment for each engine must be obtained by practice.

Full stroke of the pump is usually required at starting.

The object of the vaporiser valve box (Fig. 57) is to cause the paraffin to enter the vaporiser in a very fine spray so as to be easily vaporised. The pump forces oil up through E and past the valve A through four small holes in the disc L into the vaporiser. A water jacket H is fitted round the box, and a bye-pass valve B is provided. When the bye-pass valve is open, all the oil forced up by the pump

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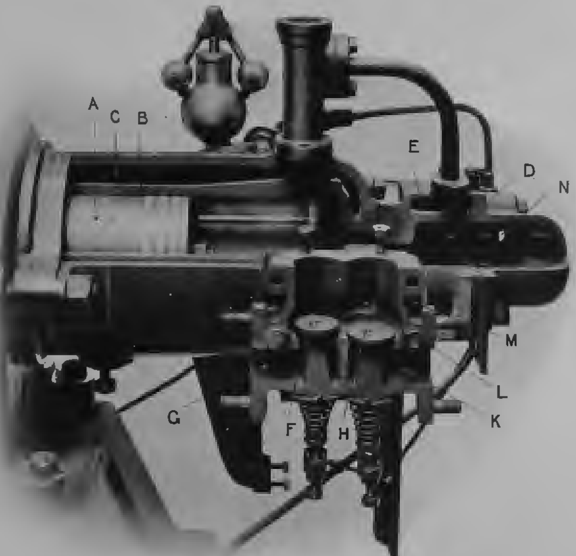

Fig. 55.—Sectional view of engine.

A. Piston.
B. Cylinder liner.
C. Cylinder water jacket.
D. Vaporiser.
E. Vaporiser water jacket.
F. Admission valve.
G. Admission passage.
H. Exhaust valve.
K. Exhaust passage.
L. Passage to cylinder from valves.
M. Water jacket round exhaust valve.
N. Paraffin inlet to vaporiser.

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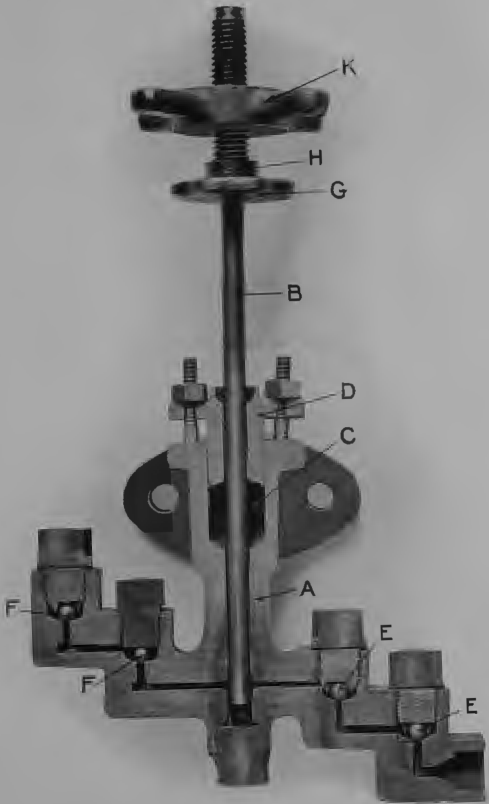

Fig. 56.—Section of oil admission valve.

A. Barrel.
B. Plunger.
C. Packing.
D. Gland.
E. Suction valves.
F. Delivery valves.
G. Hand disc.
H. Ferrule.
K. Locking nut.

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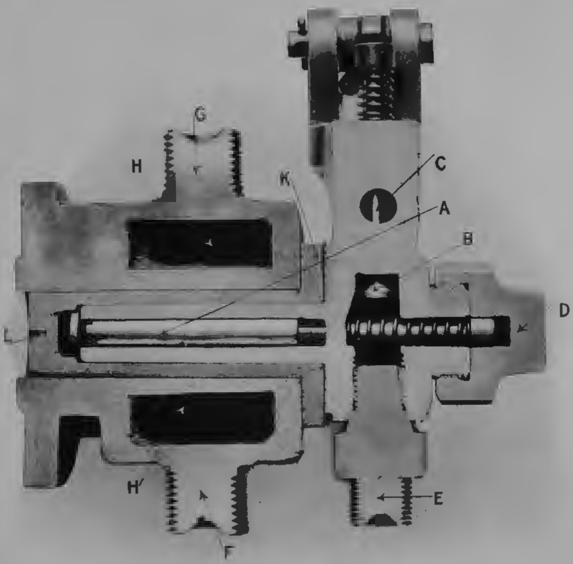

Fig. 57.—Vaporiser valve box.

A. Inlet valve.
B. Bye-pass valve.
C. Overflow.
D. Cap.
E. Pump delivery.
F. } Water circulating pipes.
G. }
H. Water jacket.
K. Sleeve.
L. Disc.

runs out at the overflow C, but when it is shut all the oil has to go into the vaporiser.

The bye-pass valve is operated by a handle on the governor casting, and must be closed before starting the engine, otherwise no oil will go into the vaporiser. The engine is stopped by opening the bye-pass valve and letting the oil run back into the supply tank.

The bye-pass valve is also opened and shut by the governor (see below).

The holes in the disc occasionally get choked with carbon deposit, and must be cleaned with a special reamer provided for the purpose, great care being taken that they are not enlarged.

The petroleum is kept in a tank 20 (Fig. 52) under the engine.

Camshaft and valve adjustments.

The admission and exhaust valves are operated by levers 10 and 11 (Fig. 52), by cams 12 and 14, on a shaft 8 at the side of the engine. This shaft is worked by gearing from the crankshaft, so that it runs at half the speed of the latter, as it is only required to turn once in a complete cycle, *i.e.*, in two revolutions of the crankshaft.

The cams are loose on the shaft and are driven by a bolt which clamps them to a disc placed between them. On each cam is a line marked F and a line marked B, on the central disc is a line marked FB. If the engine is required to run "over" (that is, the top of flywheel moves away from cylinder), the cams must be fixed so that the three lines marked F are in a line, but if the engine is required to run "under" (*i.e.*, top of flywheel towards cylinder) then the three lines marked B must be set in a line.

In order that the valves may open and close at the right time, care must be taken to adjust their driving gear properly. The gear wheels on crank and camshafts are marked and they must be seen to engage as marked. Next, the wheel on camshaft (which is not keyed on but only fits on a conical seat) must be set with its mark to the mark on the camshaft.

The nuts on the end of the camshaft must be slacked back to see these marks, and when properly set the nuts must be set up tight to prevent the wheel from slipping.

An auxiliary exhaust cam is provided at the opposite side of the camshaft to the main exhaust cam. It can be put in and out of action by a handle 15 (Fig. 52). This auxiliary cam opens the exhaust valve during the first half of the compression stroke and makes the engine easier to turn round.

The auxiliary exhaust cam will invariably be used when starting by hand, and may be required when starting with compressed air if the pressure of the latter is low. It will be put out of action when the engine has attained sufficient speed to make a normal compression stroke. This cam will be kept out of action when running.

Lubrication.

Syphon lubricators are provided for the bearings of crank and camshafts.

A sight feed lubricator is provided to oil the piston and small end of connecting rod.

All engines are fitted with a syphon lubricator for the crank pin, and a sight-feed lubricator it usually fitted in addition.

Moving parts of the engine not provided with lubricators have small oil holes, and must be oiled occasionally.

The general principle of a sight-feed lubricator is that a small hole in the bottom of the oil cup is fitted with a conical plug. The higher the plug is raised the faster the oil will run through. They should be set to feed about six drops a minute, and require watching, as they are somewhat unreliable. When not required to feed, the plug can be dropped so as to close the hole and thus stop the flow of oil.

In a syphon lubricator a trimming, consisting of a few strands of cotton or, still better, worsted, syphons the oil out of the cup, the end of the trimming in the tube must be well below the level of the oil in the cup. A bit of wire is twisted up in the trimming to form a handle and to regulate the distance the trimming goes down the tube. Care should be observed that the trimmings are never so tight in the tube as to form a plug rather than a syphon.

When not required to feed, the trimming is taken out of the tube and placed in the cup, the wire being kept out of the oil so that the trimming can be handled without groping in the oil for it. Experience will show how the trimmings must fit the holes for efficient lubrication.

The rate at which trimmings feed is regulated by varying the number of threads they are made of.

Syphon lubricators are absolutely reliable when properly made and adjusted.

Owing to the high temperature, a special lubricating oil is required for the piston. This oil is called in the service "oil, lubricating, for cylinders of oil engines." This oil can be used all over the engine and for the dynamo, and no other oil should be allowed in the engine room, as their presence introduces the risk of being used on the piston. Animal or vegetable oils rapidly carbonise if used on the piston.

Cooling water.

In order to prevent the engine from getting too hot, a water jacket C (Fig. 55) is fitted round the cylinder and one H (Fig. 57) round the vaporiser valve box. In addition, engines of recent make have a jacket E (Fig. 55) round part of the vaporiser.

The water is cooled in two or three tanks, each holding about 750 gallons. As these tanks have to be sheltered from the fire of the enemy, they may have to be fitted in places where there is no circulation of air, and to get over this difficulty a multitubular tank is sometimes supplied through which air is forced by a fan driven by the engine.

The heated water flows from the jackets to the top of each tank; cooling, it sinks to the bottom of the tanks and thence to the bottom of the jackets.

To get the best effect the tanks should be connected "in parallel" with connecting pipes at top and bottom.

If the circulation is too rapid it can always be checked by the main circulating valves.

A valve is fitted between the tanks and the engine. This controls the flow through the cylinder jacket.

A plug cock II (Fig. 53) is fitted under the engine to control the circulation through the vaporiser jacket. The above valves may be partially closed when heating up for starting, but only under the direct supervision of the mechanist or engine driver in charge.

On certain engines valves are fitted to shut off the water from the vaporiser valve box jacket, these must always be kept open when running.

Care must be taken that the water in the tanks is above the top of the pipe from top of cylinder.

If it can be avoided, the water passing from the top of the cylinder jacket must not be allowed to get so hot that the hand cannot be kept on the top of the cylinder, *i.e.*, about 160 degrees Fah.

The flow through the vaporiser jacket must be so adjusted that the vaporiser does not get red hot. After about 15 minutes' run on full load, the plug cock can usually be turned full on.

The circulation through the vaporiser valve box jacket requires no attention except to see that the valves, if fitted, are kept open while heating up and running.

At stations where the water used in the jackets contains much lime in solution it will be found to form a coating on the internal surfaces, which in course of time will become thick enough to affect the efficiency of the cooling and will require removal. In the case of the vaporiser this can be done by opening the inspection doors on the same, but with the cylinder it will be necessary to withdraw the liner; in the latter case, however, the deposit is much slower than in the former and would not require attention so often.

Governing.

The governor acts on the bye-pass valve B (Fig. 57) and allows the oil to run back into the tank when the engine runs too fast, thus missing one or more explosions.

In some engines it is possible to set the governor so as to reduce the paraffin supply when the engine runs too fast.

In most cases, however, it will be found that the governor cuts out all the paraffin or none, and the speed must therefore be adjusted by the pump.

Starting and Stopping.

Compressed air starting gear.

To facilitate starting the engine, compressed air starting gear is fitted. This consists of :—

1. A tank into which air can be compressed on the compression stroke, or burnt gases when the charge fires. This tank is fitted with a pressure gauge and a stop valve, the latter must always be kept shut, except when starting the engine, or charging the tank, as the pipes between the tank and engine are usually somewhat leaky, it being very difficult to keep them absolutely tight.
2. A starting valve box.
3. Gear for working the valves in the starting valve box.

In the starting valve box (Fig. 58) are two valves, A and B, which close the passages C and D. The passage C communicates directly with the cylinder and D is connected by pipes to the tank.

A lever E, pivoted at F, and worked by the starting handle passes through a slot H in each of the valves. *The slots are so made that the lever can only lift the valves off their seats and cannot prevent them from rising, if from any reason they should try to do so.*

The locking wheel and screw K is to prevent the valve A from chattering when the starting gear is not in use.

Care must be taken when starting that the locking wheel is unscrewed sufficiently to allow of the starting handle being pushed right to the end of the quadrant. Cases have occurred when this has not been done, with the result that the gear has been bent and the valve B prevented from closing when the starting handle is pinned in the working position.

When the starting handle (Fig. 59) is in the mid position ("work" on the quadrant), both valves are free to sit on their seats. When the handle is pulled over towards the operator ("to charge" on quadrant), the valve B is lifted off its seat.

When the handle is pushed as far as it will go from the operator, the valve A is lifted off its seat.

If the handle is put in the charging position, as soon as the pressure in the cylinder is greater than the pressure in the tank, air will flow from the cylinder along C and, lifting the valve A, will go past the valve B (which is off its seat) down D into the tank. As soon as the pressure in the cylinder is less than in the tank, valve A will automatically shut and prevent air from escaping from the tank.

To start the engine, a supply of compressed air is required in the cylinder during a portion of the working stroke. When this air is required, the starting handle is pushed to the end of the quadrant furthest from the operator. This lifts the Valve A, and the air then comes up D and, lifting the valve B, goes past valve A (which is off its seat) along C into the cylinder, and forces the piston out. The air must be shut off from the cylinder before the exhaust valve opens or it will escape from the tank. To shut the air off, the starting handle is put in its mid position, thus freeing the valve A and allowing it to close.

Care must be taken that a charge of air is only given on a working stroke, and that the crank is over its centre before the valve A is opened.

To Start by Hand.

1. Heat the vaporiser, taking care that all circulating valves are open. It is best to keep the cock which regulates the flow of water to the vaporiser jacket closed while heating the vaporiser for starting, opening it slowly to the mark afterwards as some engines will only stand it very slightly opened even when running with the full load.

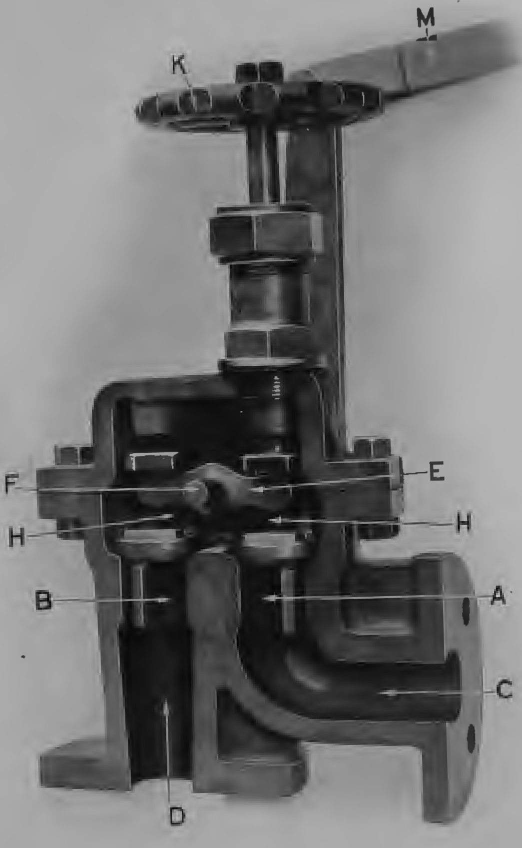

Fig. 58.—Starting valve box.

A. } Valves.
B. }
C. Passage to cylinder.
D. Passage to tank.
E. Lever.
F. Lever spindle.
H. Slot in valve.
K. Locking wheel.
M. Rod to starting handle.

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Fig. 59.—Starting handle.

M. Rod to valve box.
N. Starting handle.
P. V. Quadrant.
Q. Hole for pin ("work").
R. Hole for pin ("start").
S. Ditto ("charge").
T. Pin.

2. See that there is enough water in the tanks.
3. See that there is enough paraffin in tank in base of engine, and that the three-way cock is set so that the pump can draw from the tank.
4. Put all lubricators in action and oil up.
5. Adjust pump to full stroke.
6. See that pump is working properly.
7. Make sure that the vaporiser is hot enough by allowing it to have a full 15 minutes' heating by the lamp while burning with a strong hot flame.
8. Fasten the admission valve open.
9. Put the engine half-way along the compression stroke.
10. Release the admission valve.
11. Put the auxiliary exhaust cam into action.
12. Close the bye-pass valve.
13. Pump a charge of oil into the vaporiser.
14. Turn the engine quickly backwards. (On the working stroke the engine should reverse and run in the right direction.)
15. When the engine gains sufficient speed, put the auxiliary exhaust cam out of action.

To stop.

1. Open the bye-pass valve.
2. Pin down the admission valve.
3. The engine having stopped, put it on the working stroke with the end of the piston just flush with the end of the trunk.
4. Release the admission valve.
5. Put the lubricators out of action.
6. Close circulating valves (except those for vaporiser valve box jacket).

To Start with Compressed Air.

Having carried out the operations 1 to 8, as directed for starting by hand—

9. Put the engine on the working stroke, just off the dead centre.
10. Release the admission valve.
11. Close the bye-pass valve.
12. Put the pin in the second hole from you in the quadrant.
13. Unscrew the locking wheel.
14. Open the valve on the tank about two turns.
15. Push the starting handle from you smartly as far as it will go.

    Caution.—Be careful before moving the starting lever to see that the sleeve will not touch the top of the governor, as cases have occurred where the ends of split pins have caught the clothing, twisting it up.
16. When the piston has moved about three-fourths of its stroke bring the starting handle smartly back to the pin.

(If necessary repeat 15 and 16 on successive "working" strokes. The auxiliary exhaust cam should not be required if the pressure in the tank is 40 lbs. or more.)

To charge air tank.

The recharging of the air tank is best deferred until the engine has been running some little time with the full load on and so become well heated up; it can then be done without appreciably affecting the output of the engine if the locking wheel is released not more than one revolution.

To charge air tank proceed as follows :—

1. Pull the starting handle towards you as far as it will go and pin it there.

   When the tank is pumped up sufficiently (about 80 lbs.).
2. Pin the starting handle in the third hole from you.
3. Close the valve on the tank.
4. Screw down the locking wheel.

Putting load on.

A good load should always be got on the engine as soon as possible after it has started, as by so doing a continuous succession of ignitions can be maintained, which soon brings the vaporiser to the proper working heat; whereas, if the engine is allowed to run light a few minutes with the governor cutting out the oil supply over several cycles, the vaporiser, which has only been made just hot enough in one place to cause ignition, soon cools down to a temperature too low to ignite the charge. The oil pump should also be adjusted as soon as the load is on so as to give as few idle cycles as possible.

The water circulation must then be adjusted and the lamp under vaporiser put out.

When stopping, the dynamo brushes should be lifted as the engine stops, as in freely-running engines the weight of the crank, &c., may turn the engine backwards. Before stopping, see that there is enough air in the tanks, and, if not, pump up.

General instructions.

When it is necessary to turn the engine round, the admission valve should always be fastened open with the catch provided for that purpose. If this is not done it will be very difficult, if not impossible, to move the engine over the compression or working strokes. The indicator cock is fitted solely for taking indicator diagrams, and is not to be used for decreasing the compression.

Ample time should be taken to heat the vaporiser. With a blow lamp working properly it is possible to get the engine away in eight minutes, but it is not advisable to do this except in a great emergency and under the definite orders of a responsible officer.

No precise rules can be given for the adjustment of the cooling water; much depends on local conditions.

The pipe, where the water leaves the top of the cylinder, should be so hot that the hand can be only just borne on it, but no harm will be done if the water in the cylinder jacket gets hotter than this so long as *circulation is going on and no steam is formed.*

The circulation through the vaporiser jacket must be regulated to suit the working of the engine. Its object is to prevent the vaporiser from getting too hot and firing the charge too early. The engine should work well with the vaporiser black hot, or at all events not more than a dull red.

Thumping in the engine is caused by the charge firing too early. It is doubtful if an excessively hot vaporiser affects this to any extent, it being more probable that it is caused by too rich a charge. When thumping occurs the oil supply should always be reduced, and the vaporiser should, if possible, be cooled, but care must be taken not to get it too cool.

Some engines will start with less than the full amount of oil, but, unless a man is familiar with the engine he is starting, the pump should be set to full stroke.

The engine should be set so as to have 80 volts on the engine room voltmeter with 120 amperes, but no attempt should be made to adjust the oil supply to keep the voltage constant as the load varies, except that if in consequence of a temporary heavy load, such as a man striking the arc slowly, it is likely the engine will stop, a little more oil may be given to keep it going.

It is the duty of the engine driver to have the engine room volts right when the current is right, and it is the duty of the lamp man to keep the current right. The governor fitted to the Hornsby-Akroyd engine allows a large fluctuation in speed with alteration in the load, and consequently the speed, and therefore the voltage, of the dynamo varies. It is impossible to keep the speed of the engine constant with varying load, and the only thing to do is to arrange matters so that the engine runs at the correct speed when the load is right, the correct adjustment of the load being, as above pointed out, the duty of the lamp man.

Both Russian and American petroleum are used as fuel, the choice depending principally on the price of each. Liners are fitted in the big end to regulate the compression according to the best condition for each engine. No particular brand of oil is required.

Cleaning.

Deposit on the piston and valves is caused chiefly by the lubricating oil. An engine in constant use ought to run 400 hours without requiring cleaning. The spindles of the exhaust and admission valves should be cleaned with paraffin and then with knife powder and lubricating oil. The valves themselves should be ground on their seats with very fine emery powder—ordinary knife powder is excellent for this purpose.

If a dirty or gummy deposit appears on the piston it should be washed off with petroleum or a mixture of petroleum and lubricating oil. If the piston is drawn the rings will probably be covered with a black deposit. This can be washed off with petroleum. *The rings should not be sprung out of their grooves unless absolutely necessary.* There is no need for the piston rings and their grooves to be clean; all that is necessary is that there is no hard deposit to prevent the piston rings from expanding and contracting as required.

A hard carbon deposit is usually formed in the hole in the side of the vaporiser where the oil enters. If the engine works badly, the vaporiser valve box should be taken off and this hole cleaned out. The vaporiser itself should run for years without cleaning.

Precautions against frost.

If the water in the cylinder jacket is allowed to freeze, the jacket or the liner is almost certain to be cracked. In frosty weather care must be taken to prevent this. If the engine is often wanted, a lamp or stove can be kept burning under the vaporiser, but if the engine is not wanted for some time the jackets and pipes may be emptied. The tanks may also be emptied, although they will take no harm through frost, except that if they are frozen up they will have to be thawed out if the engine is wanted. *Emptying the tanks and not the jackets is of no use.*

Other types of engine.

At a few stations other types of oil engine have been supplied. In such cases special instructions as to running will be issued.

Service Generators.

The latest types of machines in the service are known as—

Generators, electric, continuous current, with pulleys	For search and incandescent lighting.
16·0 units	80-volt, compound wound, 600 to 650 revolutions.
24·0 "	Compound wound, 610 revolutions.
36·0 "	Compound wound, 600 to 650 revolutions.

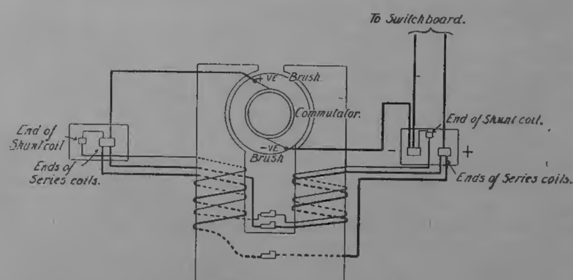

Fig. 61.—Circuit diagram of 16-unit service generator.

They have a level characteristic, and are practically sparkless at all loads.

The general form of the machine will be seen from Fig. 60. The diagram of connections is given in Fig. 61.

Extracts from the specification for this machine are given below :—

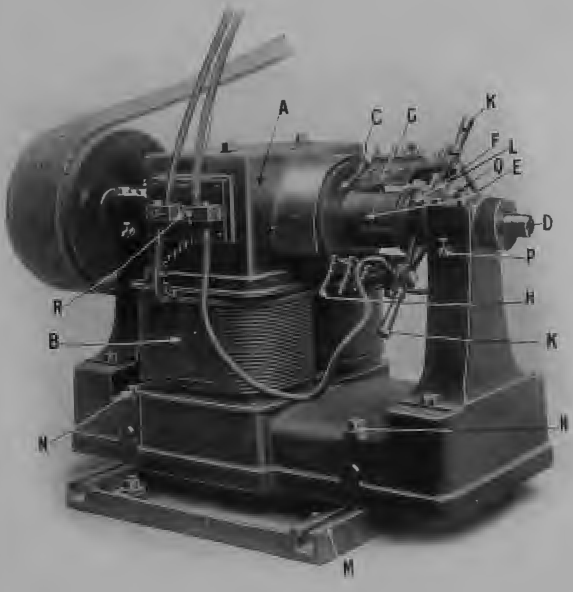

Fig. 60.—16 unit generator.

A. Field Magnets.
B. Field magnet coils.
C. Armature.
D. Armature spindle.
E. Commutator.
F. Rocker.
G. Brushes.
H. Handles for lifting brushes.
K. Rocker handles.
L. Locking screw on Rocker.
M. Slide rails.
N. Holding down bolts.
P. Overflow cock on oil reservoirs.
Q. Filling hole for oil reservoir.
R. Terminals.

Extracts from Specification.

1. The dynamo to conform in all particulars to this specification, and to be of the best material and workmanship throughout.

2. The dynamo to be of the two-pole type (poles uppermost), mounted on a substantial cast-iron bed, and constructed to give a continuous current of 200 amperes, and a difference of potential of 80 volts, at a speed not greater than 650 revolutions per minute. Each machine to be fitted with an over-hung pulley 11-inch face, and of such diameter as may be specified. Type, output, &c.

3. Two eye-bolts screwing into the pole-pieces to be provided for lifting the machine.

4. Suitable plugs to be provided to replace the eye-bolts when not in use. The machine to be constructed to revolve in a clockwise direction, when viewed from the pulley end.

5. A suitable under-frame, with all necessary holding down bolts and belt-tightening screws, to be provided. The belt-tightening screws to work in dogs, made to slide on the under-frame, and capable of being secured thereto by a clamping screw.

6. The frame to allow a movement of the machine of not less than 12 inches. The under side of the bed and the upper surface of the under-frame to be machined to a true surface. The distance apart of centres of holes in bed for holding down bolts to be 30 inches, measured parallel to axle.

7. The field magnet cores to be compound wound, with short shunt. Field magnets.

8. The characteristic of the machine is to be level, *i.e.*, the potential difference at the main terminals under all conditions of load, within the capacity of the machine, is to be between 79 and 81 volts for constant speed, the speed maintained being that required to give a difference of potential of 80 volts at the terminals at full load. The machine to be self-exciting on open circuit.

9. The inside end of the shunt coil on each bobbin to be connected inside the coil to a heavy insulated flexible conductor of substantial section, so as to preclude any chance of failure to this portion of the machine.

Armature.

10. The armature is to be well secured to a forged steel shaft. The end of the shaft nearest the commutator to project beyond the bearing sufficiently to take a small pulley for driving a tachometer if required. The armature to be of the bar pattern. The winding to be of the drum type. The number of conductors to be 104. The conductors to be supported by means of driving studs, so that no movement of the conductors can take place irrespective of the direct rotation of the machine.

11. The cylindrical surface of the completed armature to be true, and as regular as possible. The diameter over windings to be 12½ inches.

12. The deviation from perfect form not to exceed $\frac{1}{16}$ inch at any point. The armature conductors to be tightly bound with tinned steel wire binders, of ample strength to resist the centrifugal force due to rotation.

13. The bindings to be arranged, as regards strength and position, so that a speed of a thousand revolutions per minute shall not injure them, or disturb any part of the armature winding.

14. The armature to be protected by suitable guards from injury while rotating, and to be correctly balanced, so that no appreciable vibration shall exist at normal speed.

Commutator and brushes.

15. The commutator sections to be of phosphor bronze, or other suitable alloy, not less than $1\frac{1}{2}$ inches deep. The number of sections to be 52.

16. The commutator to be mounted on a gun-metal sleeve fitted on to the armature shaft.

17. The commutator sections to be held in place by collars on the sleeve, a closely-fitted recessed joint being formed between the collars and the ends of the commutator segments. The sections to be formed with radial lugs of segmental section, forming a solid end to the commutator, and slotted to receive the armature connections.

18. The contact surface of the commutator to be not less than $6\frac{3}{4}$ inches long, and to be perfectly smooth and concentric with the axle.

19. The armature connections to be led to the commutator in such a manner that the diameter of commutation, when the machine is working on open circuit, shall be vertical.

20. Three brushes, in independent holders, to be fitted at each point of commutation. The brushes to be supplied with each machine. The width to accord with that of a standard gauge which will be issued on application.

21. Each brush to be of the following dimensions: 7 inches × $1\frac{3}{4}$ inches × $\frac{1}{4}$ inch, and to be constructed in accordance with specification R.E./254, which can be obtained on application to the Inspecting Officer, R.E. Stores, Royal Dockyard, Woolwich.

22. The brush holders to be of approved pattern, and to be provided with pointers, to facilitate the adjustment of their length, and also with pressure plates and hold-off catches. The amount of pressure of the brushes on the commutator to be effected by means of adjustable springs, the tension of which can be varied so that the pressure on the toe of the brush, measured normally to the commutator, is capable of variation between 0 lb. and $2\frac{1}{2}$ lbs. for each separate brush. The width of the holders measured internally to accord with a standard gauge which will be issued on application.

23. The whole of the brush holders must be mounted on a rocker, and must be arranged so that they can be reversed should it be desired to revolve the dynamo in the opposite direction.

24. The rocker and the flexible connections must allow of sufficient angular movement for this purpose, and also for the adjustment of the brushes under all conditions of load.

25. For any output the volts and amperes being varied independently between 40 and 80 volts, and 0 and 200 amperes respectively, it shall be possible to find a position for the brushes such that *no* sparking *at all* occurs.

Also when the brushes are set in the proper position for an output of 80 volts and 150 amperes, it shall be possible to vary the amperes between 75 and 200 *without causing any* sparking *at all*, the brushes remaining in the same position while the current is varied.

Also when the brushes are set in the proper position for 80 volts and any number of amperes up to 200, it shall be possible to reduce the amperes gradually to zero, without producing appreciable sparking, the position of the brushes remaining fixed.

Terminals.

26. The main terminals of the machine are to be of the dimensions given in the drawing.* A similar terminal is to be provided at the junction of the brush connection with the series coil.

27. The ends of the shunt coil are to be connected up by means of separate terminals, in such a way that they may be easily disconnected if required.

28. The clamping screws of the main terminals to be ½ inch in diameter, rounded at the point, and of such length as to reach to the bottom of the hole in the terminal.

29. The head of each screw to be square, and to be provided with a stout pin, so that it may be used as a thumb-screw. The arrangement of the terminals is to be as shown in the drawing.

Bearings.

30. The bearings to be of gun-metal of ample substance, and lined with white metal. Each gun-metal block to be properly fitted to the bed, or bearing caps.

31. Suitable lubricating channels to be cut in the inner surfaces of the bearings. The pulley bearing to be so mounted that the armature can be withdrawn without difficulty.

32. Suitable receptacles to be arranged, either in the bed or attached thereto, to catch all oil draining from the bearings, and to permit the same to be drawn off at will. Oil channels, drips, &c., to be arranged in such a manner that all oil running out of the bearings shall pass into the receptacles provided, and not find its way on to any other portion of the machine.

33. Lubricators of approved size and pattern to be provided. One or more for each bearing.

34. The lubricators to be Bailey's patent sight drop dial lubricator, of the dimensions detailed in Specification R.E./284, unless special sanction is obtained for the employment of another pattern of lubricator.

Insulation.

35. The insulation used throughout the machine to be of the highest quality, and to the entire satisfaction of the Inspecting Officer.

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* Not reproduced.

36. Mica insulation to be used in all cases between conductors which lie alongside or cross each other, and between which the full potential difference of the machine may exist.

37. Mica insulation to be used between the armature conductors and binding wires.

38. The insulation between the commutator and sleeve, together with its collars, and also between the several sections and lugs of the commutator, to be of mica, and to be not less than 20 mils in thickness. The mica washers at the ends of the commutator segments to project ⅛ inch above the surface of the commutator, and to be suitably supported with vulcanised fibre discs. The connections between the armature conductor and the commutator to be insulated by varnished tape or braiding throughout their length.

39. The armature core to be carefully insulated by means of layers of prepared tape coated with insulating varnish. The field magnet bobbins to be thoroughly insulated with varnished paper or other suitable material before the coils are wound upon them.

40. The inside ends of the field magnet coils to be carefully insulated where they are brought out from the bobbin. The whole surface of the armature conductors and the exterior surface of the field magnet coils to be thoroughly coated with a protective varnish, insoluble in water and oil, and of such a nature as not to become soft or brittle from the rise of temperature in the machine while under test.

41. The brush pillars to be insulated from the rocker by washers and bushes of vulcanised fibre, varnished with shellac. The size and shape of the washers to be such as to preclude any chance of leakage or short circuit across them from the deposition of copper dust. The insulation throughout to be capable of withstanding, without injury, a difference of potential of 400 volts continuous or 300 volts alternating between the dynamo frame and conducting wires, and also between the series and shunt coils.

42. The total insulation of the machine after the conclusion of the trial specified in paragraph 43 to be not less than 200,000 ohms.

Tests of dynamo.

43. The machine will be tested by being run for six hours at full load (80 volts and 200 amperes).

44. The machine, either during the run or after the conclusion of it, must not attain in any part a temperature more than 60 degrees Fahr. in excess of that of the surrounding atmosphere. The measurement of rise of temperature will be taken either by thermometer or by increase of resistance of the conducting wires, at the option of the Inspecting Officer.

45. The electrical efficiency must not be less than 90 per cent., and the efficiency of conversion not less than 85 per cent.

Engraving.

46. The following information is to be given on each machine in a conspicuous manner either cast thereon, or cast or engraved on a metal plate or plates attached thereto :—

Name of manufacturer.
Year of supply.
Weight of machine, exclusive of under-frame.
Maximum current (200 amperes).
Volts at terminals (80).
Revolutions required per minute to maintain 80 volts at full load.
Position of axis of commutation.
Maker's number for future reference.

Workmanship and materials.

47. All workmanship and materials to be of the very best.

48. All cast iron employed in any part of the machine or underframe to be of tough grey cast-iron, sound and free from flaws.

49. The field magnet cores to be of the best wrought iron, or magnetic steel, except yoke, which may be of cast iron, if desired.

50. All joints in magnet cores to be carefully faced, and securely bolted together.

51. The armature core to be of the finest magnetic iron, properly annealed, laminated, and insulated. The thickness of the sheets used for the armature core not to exceed No. 24 S.W.G. The forged steel armature shaft to be free from flaws of every description.

52. All gun-metal and brass castings to be perfectly sound.

53. The gun-metal to contain not less than 12 per cent. of tin in its composition.

54. The metal of the commutator to be dense and tough, of uniform hardness throughout, and free from all imperfections. All brass screws to be of hard rolled or drawn metal. The copper used for the conductors and connections to have a conductivity not less than 98 per cent. of that of pure copper, to be of the finest quality, and perfectly annealed.

55. The armature conductors to be stranded and constructed in such a way as to avoid eddy currents.

56. Each separate wire of the stranded conductors or shunt coil winding to be capable of bearing an extension of 10 per cent. without breaking.

57. No flux for soldering except resin, is to be used in any part of the machine.

58. All screws are to be full threaded, and to fit without shake. Ordinary threads are to be Whitworth standard.

59. Similar parts of all machines made to this specification by any one contractor are to be constructed to gauge, so as to be interchangeable. Spare parts, whether ordered with the machines or subsequently, are to be similarly constructed. The dimensions of the armature, commutator, and shaft are to agree with the drawing, so that armatures made by different makers to this specification shall be interchangeable.

Management of Generators.

Faults in generators are referred to below in the order in which they are likely to occur under service conditions, other than failure to excite, which is dealt with later.

Electrical faults.

I.—*Electrical faults.*

(i) *Sparking at brushes;* the causes and prevention of which are dealt with in Vol. I.

Whenever sparking takes place the generator is not working under its best conditions, and the brushes and commutator are liable to injury.

(ii) *Failure to excite* from loss of magnetism is dealt with later, but may also be caused by—

(*a*) Disconnection or short circuit in shunt coil;

(*b*) Disconnection in armature coils, or short circuit in armature; or no contact between brush and commutator.

(iii) *Dynamo not giving its full volts* on open circuit at proper speed, owing to—

(*a*) Partial short circuits, perhaps due to contact between series and shunt coils, or high resistance in shunt coil;

(*b*) Short circuit in armature coils.

(iv) *Volts at terminals* of a properly compounded generator *decreasing* with increase of load, due to a short circuit in series coil; or to the series coil being connected the wrong way round.

(v) *Bad insulation* between field magnet coils and body of machine, owing to careless workmanship or to the insulation being rubbed off. This fault is generally to be found where the ends of the coils or sections are brought out. The result would be a loss of volts if the fault be in more than one part or coil of the generator, or if there be a leak in the external circuit. Injury to the machine may easily result.

Mechanical faults.

II.—*Mechanical faults.*

(i) *Heating of bearings* due to want of proper lubrication or to the generator not being properly set up.

(ii) *Belt slipping* or jumping off. See that the generator pulley is carefully lined up with the driving wheel.

(iii) *Armature coils rubbing against pole-piece,* owing to the wearing away of the bearings, perhaps due to the generator being badly set up; these must be refitted.

(iv) *Heating of coils.* The normal output should never be exceeded.

Localisation of Faults.

I.—*By rough tests of conductivity and insulation* with a three-coil galvanometer and two or three Leclanché cells. Rough tests.

Disconnect the brushes from the field magnet coils, the ends of the shunt and series coils from each other, and raise the brushes off the commutator.

Then for continuity tests of— Continuity.

(*a*) *The armature.*—Plug the low resistance coil of the galvanometer, connect it up to the battery and note deflection obtained on short circuit; then hold the ends of the leads on the segments of the commutator approximately where the brushes would rest, and turn the armature slowly by hand until all the segments have passed under the leads. The deflection obtained should be practically equal to that obtained on short circuit. If one of the radial connecting strips were disconnected from its segment or from the armature winding, the deflection would go off while the disconnected segment remained under either of the testing leads. A disconnection in one of the coils cannot be localised in this manner when the armature is of very low resistance; under such circumstances, more elaborate instruments must be used.

(*b*) *Brush connections.*—Hold one lead on to the end of the brush lead and the other to the tip of the brush or parts of the brush. The deflection obtained should be as at (*a*). The fault likely to occur is dirty contact owing chiefly to the proximity of the bearing lubricator.

(*c*) *Series coils.*—Hold the leads on to the two ends of the coil, the deflection obtained should be as in (*a*).

(*d*) *Shunt coil.*—Plug 10-ohm coil of galvanometer.

A good deflection should be obtained.

If a rough idea of its resistance be required, it may be found by substitution, that is, by using the same leads, galvanometer and battery connected up to a box of coils; adjust the resistance in the box until the deflection obtained through the shunt coil is reproduced, the resistance unplugged will be the approximate resistance of the shunt coil.

For insulation tests— Insulation.

Plug the high resistance coil of the galvanometer.

If the insulation is perfect, no deflection will be obtained.

Should any appreciable deflection be obtained, the resistance of the fault may be approximately determined as in (*d*) above.

For insulation tests of :—

(*a*) *Armature.*—Hold one lead on to any part of the commutator and the other on the spindle (*b*) *Brush holders and body of dynamo.*—One lead on to a clean spot on the body of the machine, and the other to each of the brush holders in turn.

(*c*) *Brush holders with each other.*—One lead on each brush holder.

(*d*) *Series coil and body of dynamo.*—One lead on to one end of the series coil, the other on to a clean spot scraped on either pole-piece.

(*e*) *Series and shunt coil.*—The leads on to one end of each coil.

(*f*) *Shunt coil and body of dynamo.*—One lead on end of shunt coil, the other to pole-piece.

The faults (*b*) and (*c*) usually occur through a want of cleanliness. The metallic dust from the commutator is apt to bridge over the insulation between the brush holders and the body of the machine. The insulation should be kept quite clean and free from oil.

Accurate tests.

II.—*By accurate tests*, using Wheatstone's bridge and reflecting or horizontal galvanometer for conductivity and a megger for insulation.

For testing and localising faults with Wheatstone's bridge and sensitive reflecting galvanometer, always use leads of a low resistance compared with the part to be tested or the result will be of only approximate accuracy. In any case the resistance of the leads should be accurately determined and allowed for.

When testing very low resistances, care must be taken not to heat the resistances in the box of coils; to prevent this a resistance of 100 or 200 ohms should be placed in the battery circuit.

The tests should be taken in the order detailed in I, clean, tight, and well insulated connections being a most important feature.

Tests while running.

III.—The following tests can be taken while the generator is running:—

To test the insulation of the field magnet coils.—Use the high resistance coil of a three-coil or similar galvanometer. Connect leads to its terminals of sufficient length to allow of its being placed outside the range of the magnetism of the generator.

Hold one lead on to the pole-piece, and momentarily touch the other on to each of the generator terminals in succession. If any appreciable deflection be obtained the fault must be localised.

The generator must, of course, be run either on open circuit or with a well-insulated external circuit when the test is made.

To test the conductivity resistance of the series coil.—With a voltmeter, measure the volts at the brushes and the volts at the terminals, and note the current in the external circuit; then

$$\text{R of series coil} = \frac{\text{volts at brushes} - \text{volts at terminals.}}{C}$$

To localise short circuits in—

(*a*) *The armature.*—Run the generator on open circuit at full volts for five minutes, then stop the engine and turn the armature by hand, feeling each coil as it passes.
The *warm* coils will be the short circuited ones.

(*b*) *Series coil.*—Run the generator at 10 per cent. in excess of its normal current for about 15 minutes. The short circuited coils would be *cool*, while the others would be rather warm.

(*c*) *Shunt coil.*—Run generator on open circuit at full volts for about 15 minutes and localise as in (*b*).

To Excite a Generator.

A generator may fail to excite from such faults in the coils as have been previously mentioned, but it may sometimes happen that a generator has lost its residual magnetism to such an extent as to render it unable to excite without assistance.

This occurs, as a rule, in cases in which—

(*a*) The field magnets are constructed wholly of wrought iron and the machine is seldom used.

(*b*) The direction of rotation has been reversed without reversing the brush connections.

(*c*) The position of the brushes or brush connections have been reversed, thus establishing a small current through the field magnet coils, tending to demagnetise instead of "building up."

*To Excite a Short Shunt Compound Generator.**—1. Place the brushes on what are considered to be the neutral points, but in all the tests the brushes must be moved by means of the rocker to different positions on the commutator, allowing them to rest for 2 or 3 minutes at each point (because in some generators the ends of the coils are not brought straight out to the commutator, but twisted in such a manner as to bring the brushes into a convenient position). Run the generator at its normal speed on open circuit for about 5 minutes. Should this fàil, reverse the shunt coil, connect it to the brushes and try again. Should this fail, restore the original condition and join the terminals with a piece of copper wire, which will fuse at a current not exceeding the normal output of the generator.

Should this fail—

2. Reverse the brush connections, leaving the terminals connected by the fine wire as before, and, if necessary, move the brushes as before.

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* In a long-shunt machine the procedure will differ a little from that given. A short consideration should suffice to show in what particulars.

Should this fail—

3. Disconnect the shunt coil from the brushes and on to it connect another generator, or some secondary cells or other source of E.M.F. with an adjustable resistance, the positive terminal of which must be connected to that end of the shunt coil which it is intended to connect to the positive brush.

Pass a current in this manner through the shunt coil for 2 or 3 minutes (being careful to break it gradually), then re-establish the generator connections, when the machine should excite. If it fails the operations described must be gone through again.

In the above tests the possibility of the series and shunt coils opposing each other has not been considered, as it is a contingency unlikely to occur.

Reversing the Polarity or Direction of Rotation of a Generator.

When a generator is to be run by itself it does not matter in the least what its polarity is as far as the dynamo itself is concerned, but when two or more compound dynamos are to be run in parallel, it is necessary that the brushes which are connected to the series coils should be of the same polarity; also, when a generator has a polarity permanently marked on it, it is desirable to adhere to this to prevent mistakes.

Generators sometimes have their polarity reversed during the process of charging accumulators or when two or more are run carelessly in parallel.

To Reverse the Polarity of a Compound Generator.—Disconnect its shunt coil and apply a source of power to the ends of the shunt so that the current is in the reverse direction to that in which it originally went. Keep the current on for 3 or 4 minutes, then on re-establishing the connections the machine will be found to be reversed in polarity.

To Reverse the Direction of Rotation of a Generator.—1. Reverse the position of the brush holders on their spindles and by means of the rocker shift them back so as to allow the brushes to rest in their proper positions on the commutator.

2. Reverse the brush connections.

[N.B.—In a four-pole machine, with the brushes at 90 degrees, it will generally be found unnecessary to reverse the connections, as when the brush holders have been reversed, the rocker can generally be rocked *forward* sufficiently to allow the brushes to change their neutral points.]

Instructions for N.C.O. or Man in Charge of Generator.

1. Before starting the generator, see that all connections are clean, bright, and properly insulated from each other.

2. See that the commutator is clean, that there is no dirt between the radial and connecting strips, and that there is nothing likely to foul the armature.

3. See that the lubricating arrangements work satisfactorily.

4. See that the brushes are properly set. Before fixing the brushes in their holders they must be carefully trimmed and bevelled to the proper angle (see below).

The greatest wear and tear on the machine takes place at the brushes and co mutator, and it is of the greatest importance that they receive careful attention. The machine will not give any better results by pressing the brushes hard on the commutator, and the effect will be additional wear. With proper care the commutator should soon acquire a dark burnished surface which shows that it is properly attended to, but which is not easy to obtain with a varying load such as large arc lights.

When the work comes on the brushes must be carefully adjusted by means of the rocker to the position of least sparking.

5. Care should be taken that the brushes are fed forward occasionally to make up for wear.

If there are two or more brushes side by side they may be raised or removed one at a time for purposes of adjustment, but the greatest care must bo taken never to break the circuit by lifting a complete brush off the commutator while the machine is running.

6. The commutator should be cleaned before each run, and may while running be occasionally wiped over with a piece of clean rag (not waste) on which is a very small quantity of vaseline.

Repairs to Generators.

If for any reason it be found necessary to take the field magnets apart, great care should be used in putting them together again, to wipe all iron faces perfectly clean, and to screw them firmly into contact, all electrical connections being made exactly as they were before dismantling.

The even wearing of the commutator is much promoted in broad ring or drum armatures by lining up the machine so carefully that the armature spindle can travel backwards and forwards in its bearing as it runs. End play is often allowed for this purpose.

Should the commutator become at all rough, it should be smoothed with a smooth file well chalked, followed by emery cloth well oiled, and finished with very fine emery cloth used dry. This must only be done with the brushes removed and the machine revolving slowly, preferably turned by hand.

When through wear or damage it becomes necessary to true the commutator up in a lathe, the following precautions should be observed :—

(*a*) Before starting make sure that no part of the armature will come in contact with any part of the lathe, saddle, or slide rest in any part of its travel.

(*b*) Use a fairly fine pointed tool, with considerable top rake (such as is used for turning steel), and take a light cut with slow feed. If too wide a tool be used the copper will be dragged over the insulation.

In any case, when the turning and polishing is complete the separate strips should be carefully examined and any copper bridging the insulation must be scraped off.

(*c*) When the armature has been replaced, test it for short circuits by running on open circuit as described previously.

When moving an armature, if it be necessary to put it down, be careful that it does not rest on its winding. Wooden blocks should be used and the armature supported on them by its spindle.

Spare armatures.

Spare armatures are provided at all stations to replace any which may become unserviceable. They are carried hermetically sealed in a special case, and should be kept stored in these cases till required.

Trimming brushes.

For trimming brushes a clamp is provided (Fig. 62) consisting of a trough and pressure plate of wrought iron with a bridge clamp and screw for tightening.

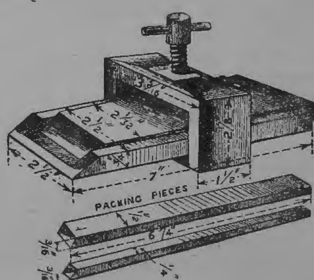

Fig. 62.

The bevelled facets of the trough and clamp are case hardened. The brushes are clamped between these pieces and the ends filed off smooth.

Coupling Two or More Service Generators in One Circuit.

It may often be necessary to connect two or more service generators together in one circuit.

(*a*) In series, to obtain an increased voltage to charge an accumulator battery or in special cases for an arc light circuit.

(*b*) In parallel, to enable an extra light to be run off the available plant, or to provide that no light shall be out of action in the event of a breakdown to one set.

To couple two or more compound wound generators in series it is only necessary to connect the positive terminal of one machine to the negative terminal of the other, and to connect the shunt coils of the field magnets together in series so as to form one shunt across the pair as in Fig. 63. If the machines are dissimilar, the output should not exceed that of the weaker machine. In series.

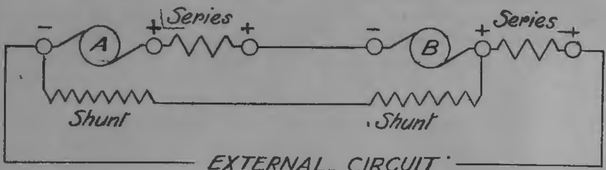

Fig. 63.

To connect two or more compound wound generators in parallel it is necessary to connect together the positive terminals, the negative terminals, and also the brush terminals which are connected to the series coils (in the case of service machines these are the positive brush terminals), as in Fig. 64. In parallel.

A little consideration of Fig. 64 will show the reason for this latter connection. Suppose that the two generators A and B are connected in parallel by closing switches *b* and *c*, and that switch (*a*) is left open. If now the speed of B increases so that the E.M.F. at its terminals rises a little above the E.M.F. at the terminals of

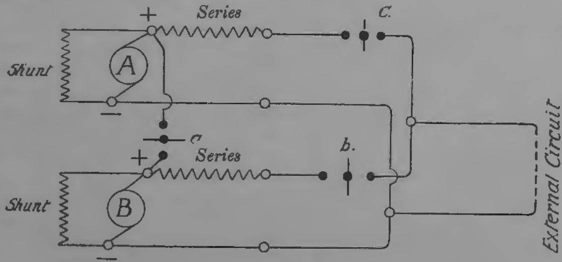

Fig. 64.

machine A, a reverse current will flow through the series coil of A, tending to demagnetise the field magnets and causing a further fall of the E.M.F. of this machine; which will then be driven as a motor. Its engine will tend to race, while machine B will be overloaded. In the case of series-wound machines the reverse current in the series coils would reverse the polarity of A, and the two machines would then be working in series round their own field magnet coils, resulting probably in both their armature coils being burnt out.

If, however, the positive brush terminals be first connected by closing switch (*a*) before switches *b* and *c* are closed, there will be no difficulty provided that the resistance of the conductor between the brush terminals is negligible as compared with the resistance of the series coils of the field magnets.

A slight rise in the E.M.F. of machine B above that of A will now produce a current in the connecting lead between the brushes, which will flow through the series coil of A in the right direction and maintain the excitation of the field magnets. This current will produce an additional load on B, which will tend to decrease the speed of the armature and consequently the E.M.F. at the terminals, while the E.M.F. of A will tend to rise on account of the increased speed of its armature due to a lighter load, until finally the E.M.F. of both machines is the same.

Similarly, if the E.M.F. of A should rise above that of B a current will flow through the conductor connecting the brushes from A to B until the difference is adjusted.

It will thus be seen that the machines will exercise a considerable power of mutual adjustment, which will extend also to the engines, resulting in an equal speed and an equal division of the load between them. Of course this power of mutual adjustment cannot be relied on to remedy inequalities of a serious nature, and with service plant it is advisable to load each engine separately for a few minutes before paralleling the generators, so that at the moment of paralleling the engines may be running steadily and under approximately the same conditions of load.

Generators having the same constants should be selected for parallel working, and the term "service generator" in what has gone before refers to the 16-unit generator, a specification of which is given in this chapter. It is, however, quite possible for generators of different power to be run in parallel provided that the respective resistances of the series coils are inversely proportional to the current intended to be generated by each machine.

In practice this can be arranged by adjusting the resistances of the leads connecting the generators to the bus bars common to all the machines, so that the fall of potential between the brushes (not the generator terminals) and the bus bars is the same.

A diagram and description of the switch board used for connecting service generators in parallel will be found at the end of Chapter VI.

To face page 105.

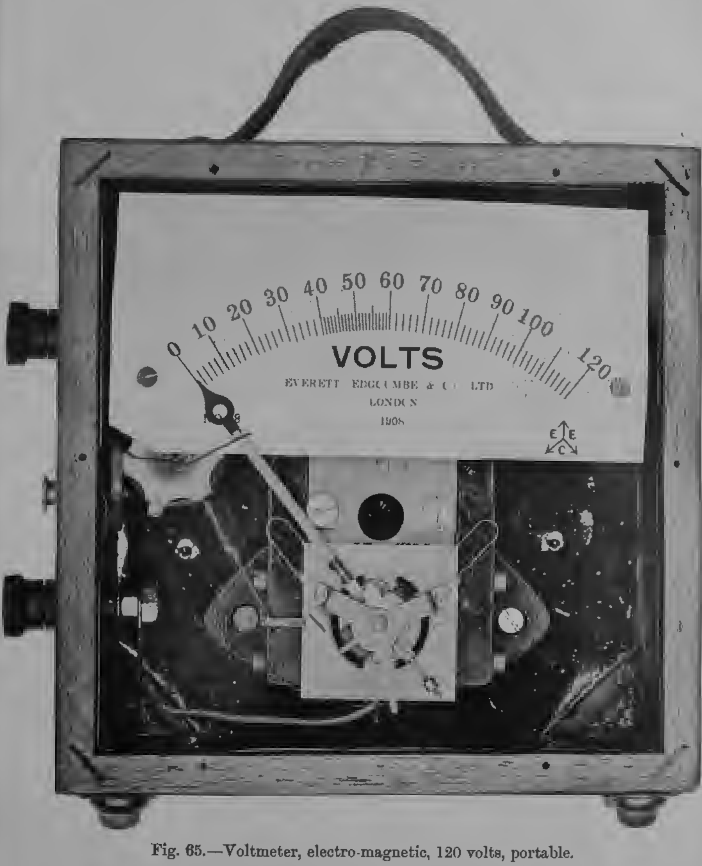

Fig. 65.—Voltmeter, electro-magnetic, 120 volts, portable.

To face page 105.

Fig. 66.—Voltmeter, electro-magnetic, 100 volts, station.

To face page 105.

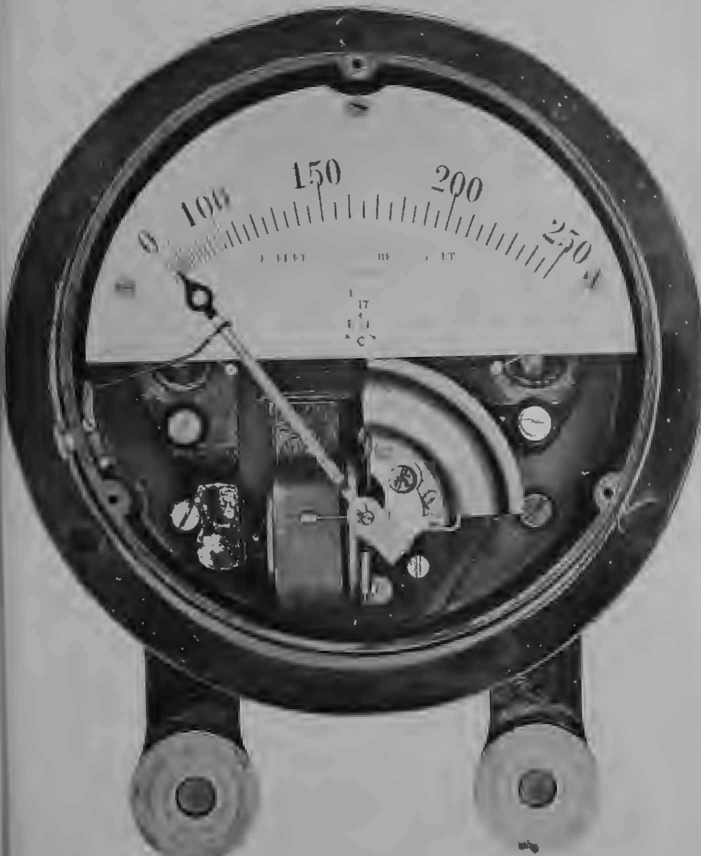

Fig. 67.—Ammeter, electro-magnetic, 250 amperes.

To face page 105.

Fig. 69.—Voltmeter, electro-magnetic, 80 volts.

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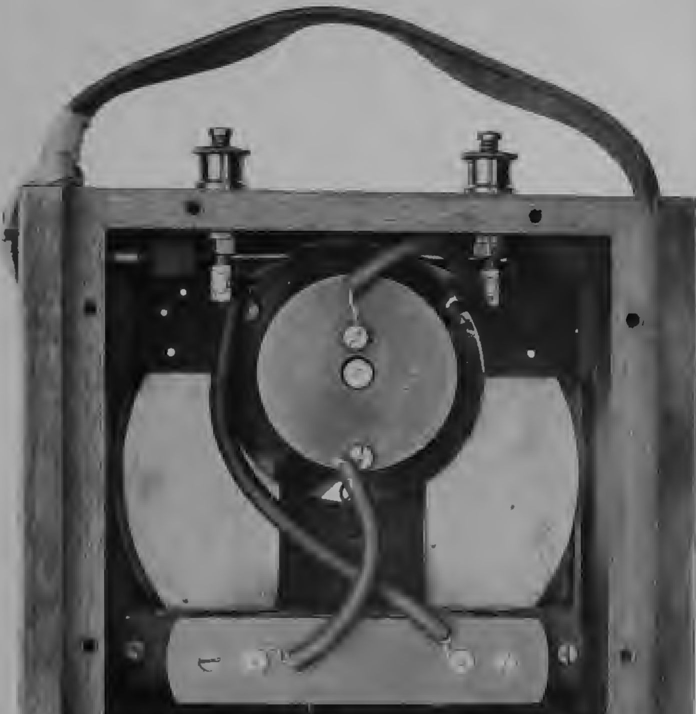


Fig. 70.—Voltmeter, electro-magnetic, 80 volts. (Back view.)

CHAPTER VI.

Accessories, Switchboards and Arrangement of Circuits.

Contents.

Accessories.

The accessories in the service are :—

Ammeters	for direct currents.
Electro-magnetic—	
250 amperes	portable or station.
200 amperes	vertical, direct reading, Schückert type, with two terminal lugs.
Frames, resistance—	
200 amperes, ·25 ohm, Mark II	iron, with 11-point switch.
Switches, E.L.—	
Automatic	60 to 150 amperes.
Single pole.	
200 amperes—	
Mark I	on slate base, with two terminals.
Mark II	also with two lugs with set screws.
Voltmeters—	
Electro-magnetic—	
100 volts, station	with connections and two terminals.
120 volts, portable	with two terminals.
80 volts	in teak case with leather handle.
Hot-wire, 120 *volt, Mark II* ...	*Cardew type, horizontal tube, in wood case.*

Ammeters and voltmeters, electro-magnetic, are now obtained to an open specification which lays down only certain essential qualifications. The details may vary slightly in different supplies. Ammeters and voltmeters, electro-magnetic.

The "station" instruments have a gravity or spring control, with dead-beat action, and are suitable for reading with the face vertical. The moving parts are covered by a soft iron band or shield or are enclosed in an iron case.

Fixing holes are provided to enable the instrument to be fixed on any vertical surface.

The portable instruments are similar, except that spring control is always used and that they are enclosed in a wooden case with leather handle.

All spring-control instruments have a zero adjustment which is not accessible from the outside.

The maximum permissible error in first supplies is :—

In *ammeters*, the maximum error "high" added to the maximum error "low" must not exceed 2 per cent. of the range of the instrument.

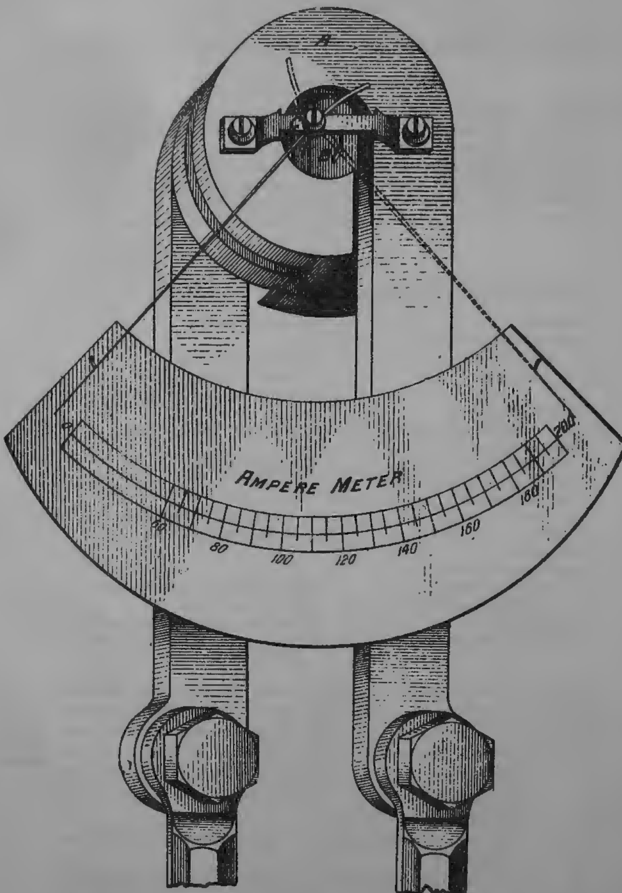


Fig. 68.—Ammeter (200 amperes).

In *voltmeters* portable, the maximum error of any reading must not exceed 2 volts, and the readings "face horizontal" must be within 2 volts of the readings "face vertical."

In *voltmeters* station the maximum error of any reading must not exceed 1½ volts.

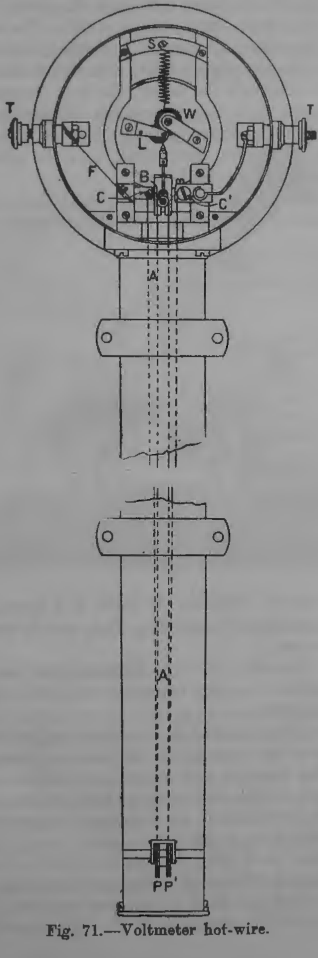


Fig. 71.—Voltmeter hot-wire.

Typical instruments are shown in Figs. 65, 66 and 67.

Ammeter, 200 amperes.

Ammeter, 200 amperes, is shown in Fig. 68; it is only used as a station instrument. Its principle is as follows:—

A is a helix of three turns of copper bar; B is a small curved piece of very thin sheet iron, moving at the end of an arm about a pivot C, placed eccentrically as regards the helix. A long pointer moves with the sheet iron over a scale. The arrangement is weighted, so that when no current is passing, the sheet iron is at some distance from the copper helix, although within it; and when a current passes through the latter, the iron moves so as to place itself in a stronger field (*i.e.*, nearer the copper conductor); as it does so, the opposing force (gravity) has its moment increased. The forces are, of course, very weak, and the chief drawback is that the instrument is not dead beat.

It is not affected by any uniform field, however strong, but is strongly affected if put near the pole of a powerful magnet.

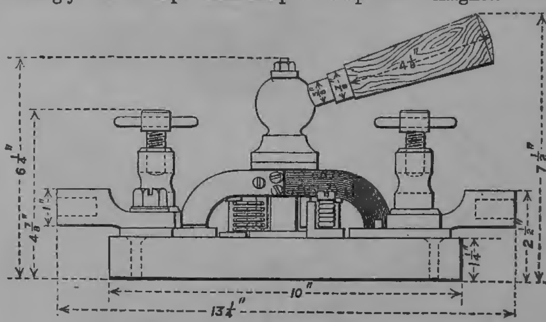


Fig. 72.

Voltmeter, 80 volts.

Voltmeter, electro magnetic 80 volts, is a portable instrument (and is shown in Figs. 69 and 70). It is usually fixed on a small shelf for station use.

Voltmeter, hot-wire.

"*Voltmeter*, hot-wire, 120 volts, Cardew type," depends on quite a different principle, viz., the expansion of a wire when heated by the passage of a current.

It is made to read either in a vertical or horizontal position, and the wire is either mounted in the tube, as shown, or on a rod which slips inside the tube; in either case the tube or rod is made of brass and iron in the proportion of two lengths of brass to one of iron, as this combination has the same temperature expansion co-efficient as the platinum silver wire used.

The conductor A A (Fig. 71) passes twice up and down the tube; it consists of 12 feet of platinum silver wire, ·0025-inch in diameter. The ends are fixed to the two supports C C′, which are in connection with the terminals T T′. The wire is then passed over the two insulated pulleys P P′, and the centre is passed round the bone block B, which is held in place by the spring S attached to the frame of the instrument. The wire connecting this block to the spring passes round a grooved wheel, the shaft of which also carries a toothed wheel W, geared into a small pinion. On the end of the pinion shaft is fixed a pointer, moving over a dial graduated in volts. The terminal T′ is connected direct to C′, but between T and C is inserted a fine fuze wire, F, ·0014-inch diameter, so that should the current get dangerously large by an accidental increase of volts, the fuze wire may melt, and so save the instrument.

Advantages.—Suitable either for direct or alternate currents,

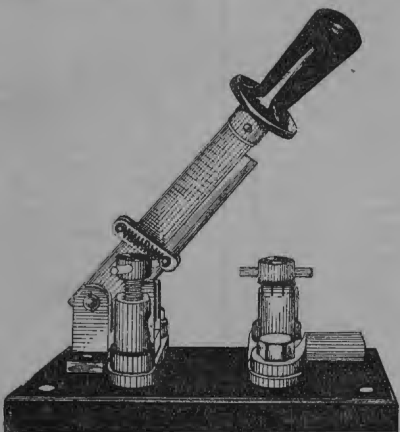


Fig. 73.—Switch, E.L. Mark II.

dead beat, fairly even and open scale, unaffected by magnetic fields.

Disadvantage.—Not portable.

Switch, single pole, 200 ampères, Mark I, is shown in Fig. 72. It is used in any circuit where a large current may pass. Switch, single pole.

The switch bridge is of laminated brass plates, pivoted in the centre and making contact at either end. It is operated by a wooden handle with a loose head, and is fitted with a powerful quick-break action. The terminals and cable lugs are suitable for conductors up to ½-inch diameter.

The Mark II switch is shown in Fig. 73. It is of the modern chopper type.

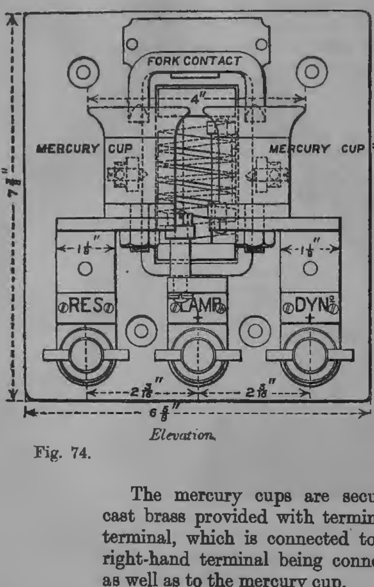
Switch, electric light, automatic (Mark I) is shown in Figs. 74 and 75. Switch, automatic.

It consists of an electro-magnet, mounted on a slate slab.

The coil of the electro-magnet is formed of a spiral of bare copper.

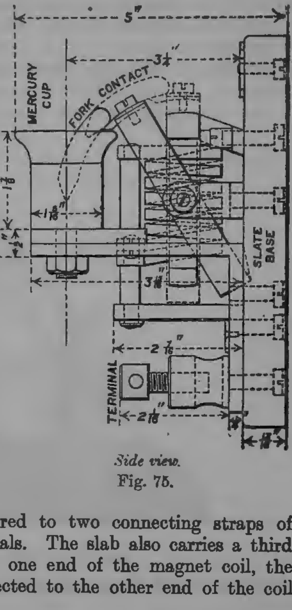
The electro-magnet actuates an oblong armature pivoted at its centre to a brass bracket fixed to the slate slab.

The upper end of the armature is fitted with a forked contact of copper rod, which rests in two iron mercury cups when the armature is not attracted by the magnet.



Elevation.

Fig. 74.



Side view.

Fig. 75.

The mercury cups are secured to two connecting straps of cast brass provided with terminals. The slab also carries a third terminal, which is connected to one end of the magnet coil, the right-hand terminal being connected to the other end of the coil as well as to the mercury cup.

Three buffer blocks fitted with indiarubber are provided for the armature.

The switch works with a minimum current of 60 amperes, and is intended for use with currents not exceeding 150 amperes in conjunction with "Frames, resistance ·25 ohms," or the locally-made resistance described below.

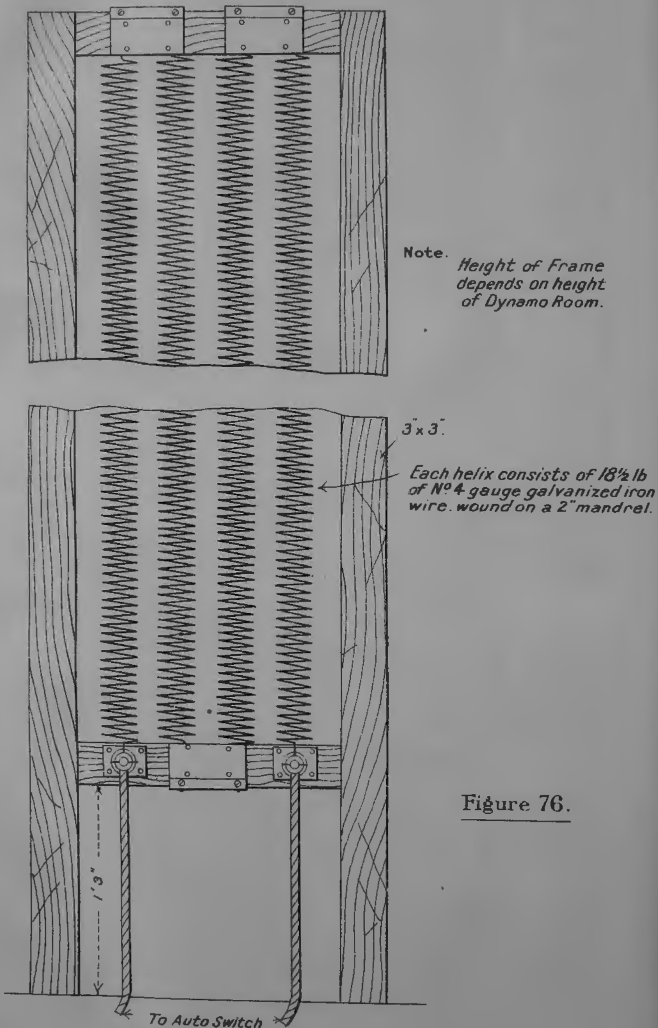
The approximate weight of the switch is 9 lb. 11 oz.

Frame, resistance, 200 amperes.

Frame, resistance, 200 amperes, ·25 ohm, is used as a steadying resistance in the circuit of any light, or in connection with an automatic switch, as described above.

Or it can be used either separately or in conjunction with other resistances for electric lighting purposes generally.

RESISTANCE FRAME FOR AUTOMATIC SWITCH.



ELEVATION.

Figure 76.

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It consists of an iron frame, the ends being formed of cast-iron, the sides of 1 inch gas piping.

The resistance coils are of galvanised iron wire, ·171 inch in diameter (No. 7½, S.W.G.), formed into helices and arranged four in parallel. The helices are supported on porcelain insulators at the ends of the frame, intermediate connections being made by brass connecting bars.

The coils at the front and back of the frame are prevented from coming in contact with each other by porcelain insulators fixed to iron crossbars.

To the centre of the frame is fixed an 11-point switch, mounted on a cast-iron frame, the various points of the switch being connected to the resistance coils by bare copper wire, ·232 inch in diameter (No. 4, S.W.G.).

The total resistance of the frame when a current of 150 ampères is passing is equal to ·25 ohm, divided by means of the switch into 10 steps of ·025 ohm each.

Its weight is 228 lbs.

Local pattern of resistance frame.

In lieu of the frame, resistance, a resistance similar to that in Fig. 76 is made locally of helices of No. 4 gauge, G.I. wire.

The resistance cold is about ·7 ohm, allowing with a generator at 80 volts for a current of 114 amperes, which will fall as the wire heats to a current of about 70 amperes. If used in the emplacement the resistance should be reduced to ·5 ohms cold.

The frame supporting the helices can be of wood or iron gas piping, or they can be fixed direct on to the walls or ceilings of the engine room on suitable porcelain insulators.

Miscellaneous Stores.

Patterns of the following stores have been sealed for the purpose indicated in the table.

Designation.	Detail.	Use.
Clamps, trimming brushes	Iron, with collar, screw and two packing pieces	For all sizes of brushes
Counters, revolution, Mark II	In case, with watch...	For revolutions of engines or generators
Cut-outs, fusible, single pole	Porcelain, with cover, with two sweating thimbles and binding screws	For incandescent light circuits, maximum working current, and class of wire must be stated on demands
Fuze wire, E.L.	Tin	(as above)
Graphite, lubricating ...	Circular stick in wood box	For commutator
Mercury	In bottles	For Mark I automatic switches
Powder puffs	In box	For cleaning glass reflectors

Designation.	Detail.	Use.
Switches	Incandescent lighting	State amperage in demands
Single pole, 25 to 150 amperes	... ...	
Double pole, 25 to 150 amperes	... ...	
Single pole—		
20 amperes	Porcelain base, with cover	
10 ,, ...		
5 ,, ...		

Arrangement of Circuits.

The principles governing the general arrangement of circuits have been discussed in Chapter V.

It was there stated that is, as a matter of policy, the "single unit" system had been adopted.

Single circuit.

The best arrangement for running one arc light from one generator is shown in diagram form in Fig. 77.

In the engine room all that is required is a switch, ammeter and voltmeter. The switch should be connected between the positive terminal of the generator and the positive main lead, the ammeter in the negative lead and the voltmeter directly across the terminals of the machine, so that the rise of volts can be seen before the main switch is closed. All connections should, however, be made on the switchboard. The two mains should be the only leads between the generator terminals and the switchboard.

In the emplacement, a switch and frame resistance should be placed at the end of the positive main, and an ammeter at the end of the negative main. The voltmeter should be connected across the mains at points on the switchboard as near as possible to the lamp terminals, but on the generator side of the lamp switch, so that the voltage can be read before the switch is closed.

Shunt resistance.

An automatic switch and shunt resistance should always be fitted and can be placed either in the emplacement or engine room, as shown at A and B in Fig. 77.

The latter is the more usual, and has the advantage of allowing the engine to be run without any connection with the emplacement, but the disadvantage, that when the lamp carbons are first closed, the voltage at the lamp will be practically that of the generator, and there will be at first a very high current through the lamp. With 80-volt generators this is not harmful, but with 120-volt generators the large current will damage the lamp.

When the shunt resistance is placed in the emplacement, the electrical difficulties are overcome, as, whether the current is running through the lamp or through the resistance there is a steady fall of potential through the leads and the voltage at the lamp terminals remains nearly constant at 60 volts. There is, however, the practical

ARC LIGHT CIRCUIT, ONE GENERATOR SUPPLYING ONE ARC.

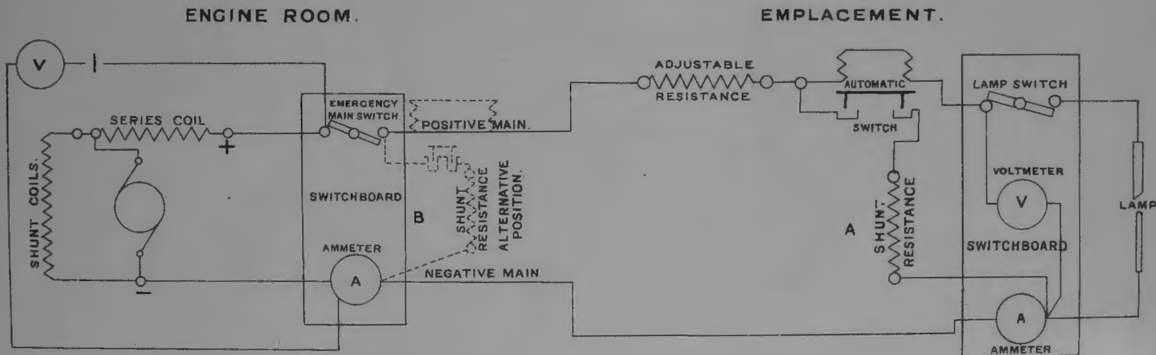

Figure 77.

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ENGINE ROOM SWITCH-BOARD FOR 3 GENERATORS.

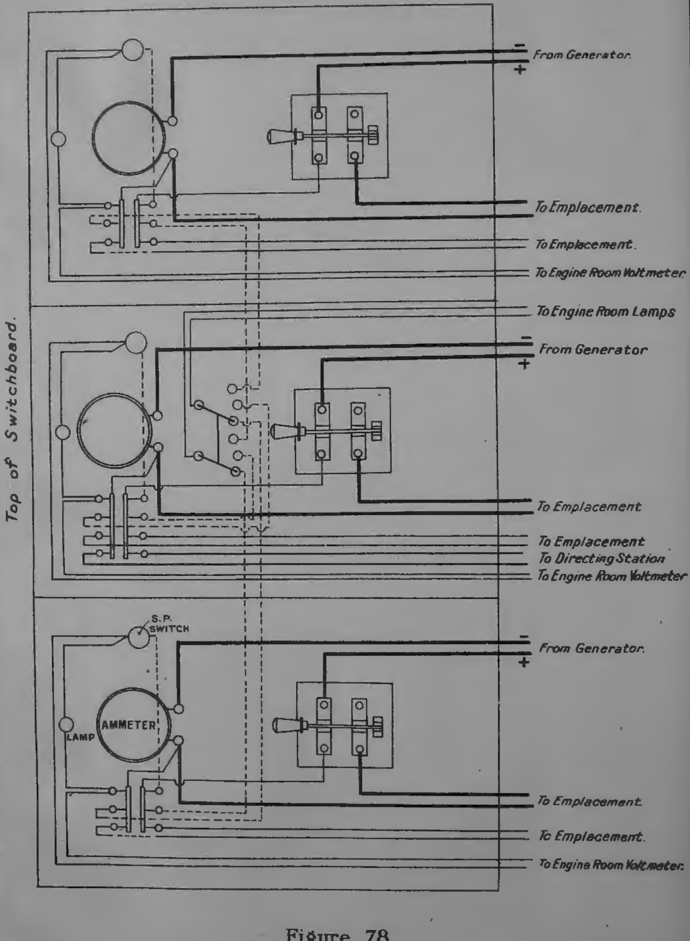

Figure 78.

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difficulty of finding room in the emplacement for the necessary resistance.

While, therefore, it is desirable in erecting new installations to place the shunt and resistance in the emplacement, these latter may be retained in the engine room when they are not harmful.

Lighting engine-room and emplacement.

It is usual, unless separate secondary batteries are provided, as in Chapter X, to provide incandescent lamps in engine room and emplacements connected direct to the service generators.

Such lamps should be for 60 volts, suitable resistance being added as required.

The connection of the lighting circuit in the engine room should be to the terminals of the generator clear of the main switch, so that the lighting will be effective even if the switch is not closed, the necessary connections being made on the engine room switchboard.

Separate leads for incandescent circuits in emplacements should be run from the engine room switchboard. If connected across the main leads, the lamps will be subjected to all of the variations of voltage of the arc, and this is more especially noticeable in those installations where the automatic shunt resistance is in the engine room.

In the directing station the lamps may be connected across the power leads for motor, as in this case the variation of voltage is small.*

The lighting circuits should have their own switch, which may be any of those on page 112 or of any suitable commercial type.

Several plants in one room.

Although each plant is electrically independent, it is usual to group several in one engine room to economise personnel. This also enables various combinations of engines and lights to be arranged.

Switchboards.

In such cases the instruments for all the generators in one engine room should be placed on a common switchboard of hardwood or slate and arrangements added so that any generator can be connected to any lamp. This can be effected by using "terminals E.L." and movable connections of either copper rod or flexible conductors. A suitable switch should be arranged so that the incandescent lighting can be run from any generator.

A typical switchboard for three generators and three lights is shown in Fig. 78.

Wiring switchboard.

The wiring on switchboards may be either on the front or back. Front wiring has the advantage that all the connections can be readily seen and traced, but all the leads must be securely fastened, so that the operator will have easy access to the switches and instruments. Colouring may be used to identify leads, and all terminals and connecting points should be very clearly marked.

---

* Any system of lighting direct from the main generators does not provide for illumination when the engines are not running, and therefore it is always necessary with such a system to provide an alternative means of lighting by lamps, candles, &c.

Back wiring has the advantage of leaving only the instruments visible and of making it easier to dispose of "slack" cable or wires. It is essential that all connections shall be readily accessible for purposes of inspection, and therefore the switchboard should be fixed at some distance from the wall, thus requiring a certain amount of floor space.

When back wiring is employed, the connections from point to point should be clearly indicated by coloured lines painted on the front of the board.

As a general rule front wiring should be adopted in all emplacements and in small engine rooms, and back wiring in larger rooms where floor space permits.

Running two lights off one generator.

There is no practical difficulty in running two arc lights off one generator, provided that the latter will carry the current and that the two circuits are separate and independent throughout from generator to lamp.

Running from bus bars.

When two or more engines are placed in one engine room there are certain advantages in cross-connecting them so that any number of machines can be connected to a pair of bus bars, to which are also attached any number of lights, thus two machines might be used to run three lights, or in installations where defence plant is used to charge an accumulator battery the surplus power may be utilised in charging the battery during the night and thus effect a saving of personnel, *i.e.*, the extra relief required if the cells have to be charged during the day.

The advantage would be a ready means of meeting a breakdown of one engine or generator; the disadvantage, greater complication of the switchboard and consequently a higher standard of training required from the attendant.

Multiple switchboard.

A diagram of the Service pattern engine-room switch-board for use when it is required to connect two or more generators in parallel is given in Fig. 79. The board is made up of a number of polished slate panels, one such panel being provided for each generator.

The panels are supplied fitted but without instruments, which should be demanded separately.

Frame.

The board should be supported in an iron frame and fixed not less than 3 feet from the wall by means of stay rods.

Top.

The top is of teak and can be used for a board of any size.

Voltmeters.

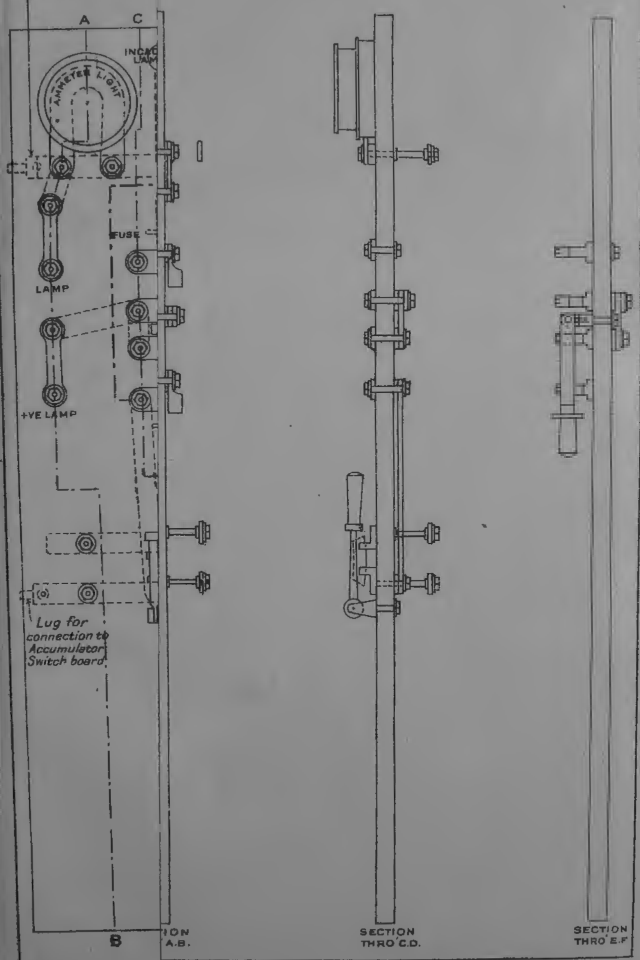
It carries two voltmeters of the "moving coil" type, one of which is connected across the positive and negative bus bars through a 5-ampere switch, while the other is connected between the negative bar and a change-over switch. The contact points of this switch correspond to the number of generators and are connected to the positive terminals of the machines.

Incandescent lamps.

An incandescent lamp with switch is provided for each panel. The connections are shown to the generator terminals, so that each panel is only illuminated when its generator is running. The lamps may, however, be connected to the bus bars if desired.

...ITCH-BOARD FOR ... IN PARALLEL.

...79.



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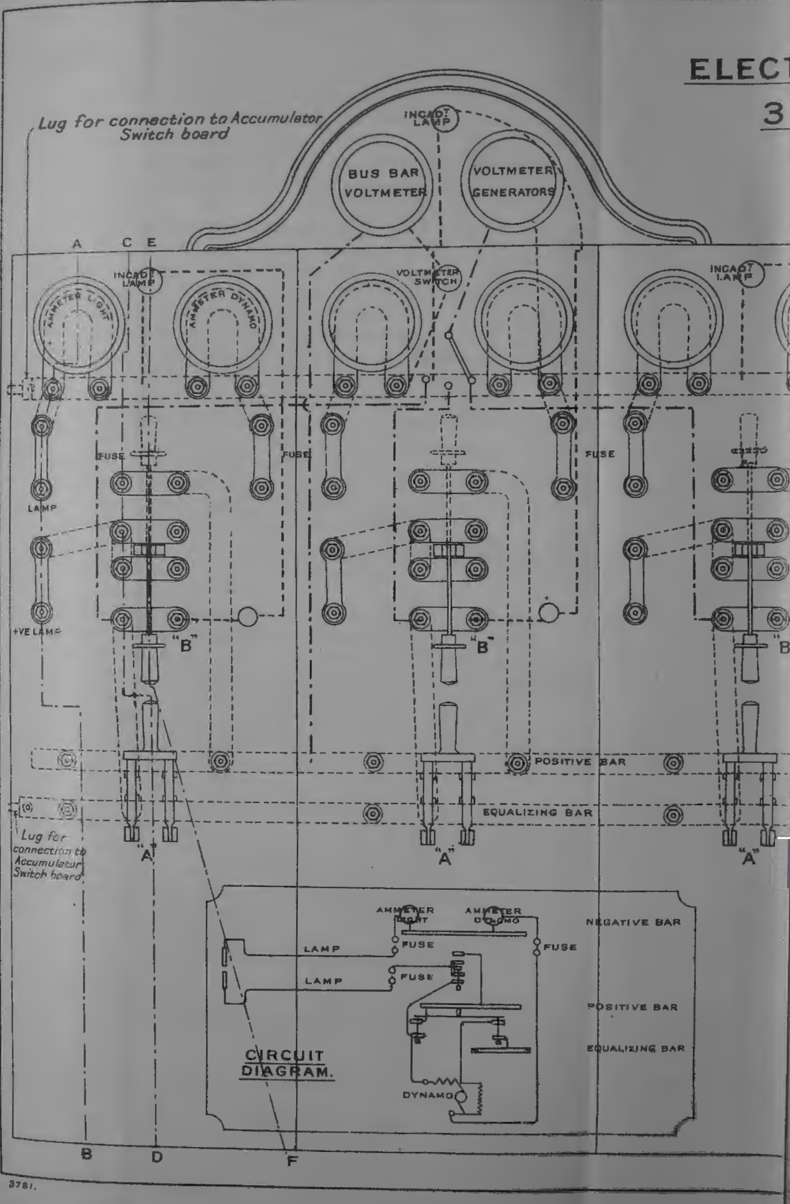

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The bus bars are composed of 1½ by ½-inch copper bar and are supported 2½ inches clear of the back of the board by ½-inch bolts. Bus bars.

The ammeters and D.P. switches "A" are connected direct to the bus bars by ½-inch bolts.

Back connections are employed throughout, 1½ by ⅜-inch copper straps being used for the main circuit whenever direct bolts cannot be used. Connections.

Each panel is similarly arranged. On the top are the ammeters side by side; that on the left is in the negative main to the emplacement and the other is between the negative bar and the generator. Arrangements of instruments.

In the centre of the panel is the single pole change-over switch "B" and below this the double pole switch "A." The 300-ampere fuses on the left are in the mains to emplacement and that on the right is in the negative main between the generator and negative bar.

The method of connecting two or more compound-wound generators in parallel has been explained in Chapter V, and an examination of the circuit diagram shown at the bottom of the centre panel in Fig. 79 will show how the necessary connections are made on the board. The positive terminal of each generator is brought to the positive bus bar through the left-hand side of the D.P. switch "A." The negative terminal of each generator is connected to the negative bus bar through the fuse on the right of the panel, while the positive brush terminal is brought through the right-hand side of the D.P. switch "A" to the bottom bar, which is known as the "Equalising Bar." Circuits.

It will be seen that when the D.P. switches "A" are closed, the machines are connected together, as explained in Chapter V.

All the positive terminals are connected together through the positive bar, the negative terminals through the negative bar, and the positive brush terminals through the equalising bar.

The knife on the right-hand side of switch "A" is made ¼-inch broader than the knife on the left-hand side, so that when the switch is closed the connection between the brushes is made first, and similarly, broken last when the switch is opened.

Switch "B" is to enable the light to be run direct from its own generator independently, or from the bus bars if this generator is out of action. The bottom point of this switch is permanently connected to the positive terminal of the generator, the top point is connected to the positive bar, and the two centre points to the positive main to emplacement.

Instructions for using the Board.

Each light should be run independently for a few minutes at starting to give the engines a load and allow them to become steady. For direct running it is only necessary to close switch "B" in its lower position.

When the engines have become steady, one generator should be connected to the bus bars by closing switch "A." The bus bar voltmeter on the top of the board will now indicate the E.M.F.

of this machine. The remaining generators may now be connected to the bars as follows :—By means of the 4-way voltmeter switch in the centre panel, measure the E.M.F. of each in-coming machine on the right-hand voltmeter, and, if necessary, adjust the speed of the engine until the reading is one or two volts above that of the bus bar voltmeter, then close switch " A."

Great care should be taken that the in-coming machine is of correct polarity and switch A must not on any account be closed if there is no deflection of the needle of the generator voltmeter. If moving coil voltmeters are not available, the low resistance coil of a Q and 1 galvanometer must be inserted in the voltmeter circuit (in series) to indicate the polarity of the in-coming machine.

When all the generators have been connected to the bars the readings of the right-hand ammeters should be compared, and, if necessary, the speed of the engines should be adjusted, so that the load is equally divided. A considerable amount of hunting will be noticeable in the dynamo ammeters and this cannot be altogether avoided.

In the event of a breakdown the machine concerned should be disconnected altogether from the bus bars by opening switch " A " and removing the fuse on the right-hand side of the panel. The circuit to emplacement is completed by changing switch " B " over to the upper position.

It may possibly happen that, owing to the failure of the oil supply or some other cause, one of the engines ceases to work, and the generator, being driven as a motor by the other machines, will keep the flywheel in motion. This can be detected by the excessive sparking at the brushes of the generator concerned, and the top of the belt will become the working part. Switch " A " should be opened and the machine disconnected from the bars.

Instructions for fitting up the board.

It is very necessary that the resistance of the connections between the positive brush terminals and the equalising bar should be low as compared with the resistance of the series coils of the field magnets. For this reason the switchboard should be centrally placed, so as to be as near as possible to all the generators, and the cable used for the connections should not be smaller in sectional area than that used for the main connections.

Reversals of current in the series coils will be prevented, provided that the resistance of the leads between the brush terminals and the switchboard is not greater than the resistance of the leads to the dynamos terminals, but the nearer the machines are to the switchboard the greater will be their power of mutual adjustment.

It is very important that the connecting leads from the switchboard to all the machines (having the same constants) should be of the same resistance. A little consideration will show that it will otherwise be impossible to divide the load equally. The cables should be selected and cut to length accordingly. If any of the generators is more than 45 feet away from the switchboard it is advisable to duplicate the leads, if 37/15 cable is the largest lead available.

CHAPTER VII.

Electric Cables and Wires, Laying and Jointing.

Contents.

The term "electric cable" for vocabulary purposes is used for all conductors carrying a current of 10 amperes or over, for all conductors containing more than one core (except small flexible leads) and for insulated conductors, which are also lead-covered or armoured. *Definitions.*

The term "electric wire" is used for all single conductors, whether covered or uncovered, which do not come under one of the above categories.

When an electric cable has more than one core or conductor, it is called a multiple cable.

Electric cables and wires are demanded, held on charge, and accounted for as follows :— *Provision.*

(1) All uncovered wires. (2) Silk and cotton-covered wires used for coil winding.	by weight.
(3) Covered wires other than those mentioned at 2. (4) Cables, electric.	by measurement in yards.

On account of the weight of many of these cables, it is not practicable to supply them in longer lengths than those mentioned, and to avoid unnecessary cutting of, or joints in, multiple cable, demands should state the exact lengths required (see below).

Laying Cables.

Cables for electric light can be laid either in trenches or in pipes. The patterns to be used in either case will be seen from the table above.

Laying in trenches.

All cables following the same route should be laid in the same trench.

As a general rule, the depth of trench in ordinary soil would be not less than 3 feet, except on rifle ranges or where there is no risk of injury by vehicles or shell fire, when the depth may be reduced to 2 feet.

The bottom of the trench should be as level as possible and the cables should be laid neatly along it, crossing being avoided as far as possible.

In filling in the trench the cables should first be covered with 3 or 4 inches of fine soil and care should be taken that no sharp stones are in contact with them.

In some cases it may be desirable to place above the cables, before completing the filling in of the trench, a layer of flat stones, slates, tiles, or tarred planking, to give further protection from accidental injury.

Inside forts and batteries it is often necessary to mark the line of the trench on the surface in some way, as it not infrequently happens that cables are injured by the pickets used by the Royal Artillery as anchors and holdfasts.

When opening trenches containing cables, the use of picks should be prohibited, except where absolutely unavoidable.

Position of joints.

The A and B-type cables are made in lengths of 4 yards over a fraction of a mile, with the intention that the distance apart of the joint boxes should be multiples of a quarter of a mile, consequently, there will then be 4 yards spare cable at each joint. It is very desirable that these joints should be arranged, as far as possible, at uniform intervals, and that, when several cables are laid together, the whole of the joints on each section should be grouped at one point.

Protection of joints.

The joints must be protected by one of the following methods :—

(a) By means of the "box, joint, lead-covered cables," which has been specially designed for this purpose.

(b) By means of brick or masonry joint boxes built in the ground, when the special boxes are not available.

(c) When no other means is practicable, by splicing.

When an extended system of lead-covered cables is to be laid, two wheels and an axle, suitable for transporting the drum, should be provided. Transport of cables.

The diameter of the wheels should be about 18 inches greater than that of the largest drum, and the axle should be arranged so that it can be passed through the centre of the drum, and secured to the cheeks. The axle should be 2½ to 3 inches diameter, and provided with linch pins, washers, and drag ropes, and with shafts for animal draughts, if the nature of the ground is such as to make this system of transport suitable. Where the ground is difficult, it is generally more convenient to move the drum by manual labour, but shafts of some description will still be required for steering.

In order to mount the drums, a wooden ramp should be made, upon which they can be run up. The axle should be passed through and the wheels attached. The drums can then be transported to the trench in which the cable is to be laid. For handling the drums, four hand-spikes and two large scotches should also be provided.

If the trench is in open ground, the cables can be laid by wheeling the drum parallel to it, and unwinding at the same time. In wooded country, or where obstacles prevent the passage of the drum close to the trench, it will be necessary to leave it at one end of the section and carry out the cable by hand. Laying cables in trenches.

For this purpose fair-leads are useless with these heavy cables. The quickest and most satisfactory method is to carry it bodily on men's shoulders, loop by loop.

If the ground should not be suitable for this method of transporting the drums, it will generally be possible to roll them into position, where they can be jacked up, so as to revolve on a spindle, and allow the cable to be paid out. The drum should be so turned that the cable is paid out from the top of the drum. Care must be taken not to bruise the cable when rolling the drum. On no account whatever should the drum be taken to pieces and the cable paid out in coils, nor should any attempt be made to pay out the cable by rolling the drum along the ground.

When necessary to pass obstacles such as water mains, drain pipes, &c., the cables should, if possible, be laid above them, and, where necessary, specially protected by pipes, iron troughing, or in other ways. When necessary to pass below such obstacles, the cables must be threaded through. In many cases it will be advantageous to pass them through pipes at this point. A separate pipe should be provided for each cable. Obstacles.

Trenches when first made are liable to damage by heavy rain, as the subsidence of the newly filled soil turns them into watercourses. This can often be avoided by careful selection of routes, but where necessary, the surface must be protected by rough concrete or flat stones. Trenches should be carefully perambulated periodically.

When two or more lines of cables are laid in the same trench, care should be taken to preserve their relative positions, so long as they continue in the same trench, *i.e.*, they should not be laid across one another. Position of cables in trenches.

Changes of direction, by crossing of cables, should, if possible, only take place immediately outside a joint box, or where the joint giving rise to the change of direction occurs.

Much subsequent trouble will be saved if this is strictly adhered to, and the relative position of various cables accurately recorded in the route diagram kept at the station.

The cables having been laid, and the position of the boxes having been decided upon, the latter should then be placed in position, and the cables inserted.

Joint boxes. The joint boxes should be so placed that there are 2 yards spare of each cable at the box.

The method of inserting the cables into these boxes is described below.

In very wet ground the boxes may be placed in a brick pit suitably drained.

In the case of boxes being grouped together where the trench contains many cables, each box should have an identification letter legibly marked inside it.

Testing before filling in. A rough test should be taken and recorded of each cable before filling in the trench.

As soon as two consecutive sections of a line of cable have been tested and covered in, the electrical jointing may be commenced, For details of *testing* and *jointing*, see below.

Terminating. At the termination of each line, the cables will be led to a switchboard in the engine room, emplacement, or a directing station.

Casing. All unarmoured wires inside buildings should be enclosed in steel casing; staples or holdfasts should be used for armoured or lead-covered cables.

Laying in Pipes or Conduits.

Cables in conduits. When armoured cables are not used, all cables and wires outside buildings should be laid in earthenware conduits with a separate duct for each cable, such as are supplied by Doulton & Co. When, however, the use of pipes is unavoidable, great care should be taken that the pipe is of sufficient diameter to obviate all risk of damaging the cables while they are being drawn in.

Depth at which laid. The pipes (or conduits) should be laid at such a depth as not to be liable to mechanical injury by traffic, and should as far as possible be protected from an enemy's fire. Where liability to heavy wheeled traffic exists, earthenware pipes should not be less than 3 feet, or iron pipes not less than 2 feet below the surface. Protection from shell fire should, wherever possible, be secured by the selection of a sheltered route. It is not possible without incurring undue expense to provide against the effect of a high-explosive shell bursting immediately over the cables, but burying at a depth of 1 foot will afford sufficient protection from splinters.

Earthenware (glazed) pipes may preferably be used, except where heavy traffic indicates that iron would be advisable.

Iron pipes should be of cast-iron with socket joints, carefully jointed and water-tight. Glazed stoneware drain pipes are suitable for the earthenware pipes and should be jointed with Portland cement (1 cement, 1 sand).

The pipes should be not less than 4 inches internal diameter, smooth internally, carefully laid in a perfectly straight line from point to point, with a suitable fall to a convenient point for drainage.

The pipes must be examined before being laid, to see that the interior is smooth. During the process of laying, a stout wire must be left in them to enable the interior to be scoured out by means of a stiff wire brush, in case cement should have come through the joints, so as to obstruct the cable when being drawn in.

The scouring process should be carefully performed as the pipes are laid, and before the cement has had time to set.

Drawing-in boxes.

Drawing-in boxes should be placed at every change of direction and at intervals not exceeding 50 yards in the straight. They may be of brick or concrete. If the pipes are laid 3 feet deep, or less, the drawing-in boxes may be brought up to the surface and covered with a cast-iron plate (inside dimensions 2 feet by 2 feet), or a stone set in a cast-iron or concrete frame.

If the pipes are laid more than 3 feet deep, the drawing-in boxes should be not less than 2 feet by 3 feet in plan, internally 1 foot 6 inches deep, covered with a stone slab and buried.

In all cases suitable means of lifting covers, by rings or otherwise, should be provided. The positions of all boxes, whether on the surface or buried, should be recorded on an accurate site plan.

The wires and cables should be drawn through in both directions from a central point, and all the wires required to be laid in one pipe should be drawn in together.

Joints in conductors.

All joints in the wire outside a building should be avoided. Where unavoidable, they should be situated at a box, and not drawn into the pipes.

The instructions as to method of laying, selection of route, records and terminating apply equally to lines in trenches or pipes.

Testing and Records.

Electric cables are very costly, and are liable to rapidly deteriorate if not properly stored and handled. Their care is, therefore, most important.

It must be borne in mind that it is quite impossible to tell, by visual inspection alone, whether a cable is serviceable or not. This can only be ascertained by electrical tests, which are described below.

To ensure that cables are properly looked after, a careful record of their condition and distribution should be kept in a cable book maintained for the purpose.

Preliminary testing.

Before the cables are taken out to the site, they should be carefully tested for conductivity and insulation resistance, the insulation resistance being measured between the conductors themselves, and also between the conductors and the lead sheathing. After these tests, the ends of the cores should be resealed with rubber tape and solution, as described on page 137, to prevent the entry of moisture, which is liable to set up chemical action between the conductor and the dielectric.

Testing before filling in.

After laying, a rough test should be taken and recorded of each cable before filling in the trench. After such test the ends of the cables must be properly identified and insulated with tape and solution.

Testing before jointing.

Before commencing to make the joints, the electrical test of the cores should be repeated, and final tests should be taken of the circuits after the jointing has been carried out.

Records of tests.

In all cases the tests should be taken as accurately as possible, and the records (including those received from Woolwich), entered in a book with dates, and carefully preserved, so that a complete electrical history of every length of cable used in the whole system may be available for reference. In the event of a fault occurring, its localisation is thus greatly facilitated. The records should also give the name of the manufacturer, identification number, Woolwich number, and date of receipt at station of each length of cable laid. The electrical apparatus used in making the tests should also be recorded.

Marking cables.

The marking should be in accordance with a pre-arranged system. Each core should be marked with the number of the cable to which it belongs, as well as with the core number, the former being in Roman numerals, and the latter in Arabic numerals. A convenient method of marking cores is to stamp the numbers on a piece of lead tubing, which is slipped on before the jointing is carried out.

Identification of routes.

Complete records and plans of the route of all trenches should be made at the time, showing the exact position of each trench, and benchmarks or stones should be placed at all joints and also at intervals to which the exact positions of the joint boxes can be referred. This much facilitates the subsequent repair of cables.

The routes of all buried cables whether in pipes or laid into the ground should be shown on a copy of Barrack Atlas Plans and Fortification Record Plans to be held by the D.O.R.E. and by C.R.E., so that they may be taken into account in dealing with drainage schemes, &c.

Methods of making tests.

The preliminary tests of the cable used for electric light should, where the necessary apparatus exists, be taken as regards insulation resistance with the reflecting galvanometer, the conductivity tests having been taken in the usual manner with the "coils, resistance, 10,000 ohms."

Deflection method of insulation test.

The method of measuring insulation resistance employed is known as the deflection method, and consists of comparing the deflection produced on a galvanometer by a battery through the unknown resistance with that produced on the same galvanometer by the same battery through a known resistance, the battery and galvanometer remaining in exactly the same condition during both tests. The reflecting galvanometer is generally used, and with high resistances the deflections on the galvanometer will be small, and may be taken as proportional to the current. The total resistances in circuit in either case will then be inversely proportional to the deflections obtained.

In order to obtain accurate results it may often be necessary to take the resistance of the battery and the galvanometer into account; but when the outside resistances amount to 100,000 ohms or more, these may be neglected.

When the unknown resistance to be measured with the reflecting galvanometer is a large one (such as, *e.g.*, the I.R. of cables), a "high resistance" of known value is required, in order to be able to compare the deflections due to them respectively. This known resistance should be as high as possible.

Megohm.

At some stations resistance boxes of about 95,000 ohms may still be found. One of these, made up to 100,000 ohms by placing it in series with an ordinary box of coils, is very suitable. At others a specially constructed "megohm" (1,000,000 ohms) exists. This latter may be made locally by rubbing a lead pencil on a strip of paper fixed between two terminals placed about 3 inches apart, and by then scraping away the width of the strip until the desired value is obtained. Such a resistance, however, varies considerably, decreasing as it becomes heated by the current or otherwise. It is therefore not very reliable.

Assuming that only a box of 10,000-ohm coils is available, the procedure is as follows:—

Constant of galvanometer.

The "constant" (K) of the galvanometer should first be found. This is defined to be "that resistance through which the (total unshunted) current from a given battery produces a deflection of one division on the galvanometer scale."

A battery of not less than 30 Leclanché cells (giving an E.M.F. of about 45 volts) should be employed. At stations where accumulators are available, the necessary volts may be conveniently obtained from them.

The total resistance in circuit, *i.e.*, box of coils, shunted galvanometer and battery, is made up to 10,000 ohms. With this resistance in circuit a deflection d is obtained. If, as is probable at first, a shunt S is employed, only $\frac{1}{s}$th part of the total current is passing through the galvanometer; it therefore follows, as the deflections may be considered to be proportional to the currents producing them, that a deflection of $d\ s$ would be obtained on the unshunted galvanometer by the whole battery current. A deflection of one division would be obtained with a resistance of 10,000 $d\ s$ ohms, for the currents in the two cases (C_1 and C_2), and the resistances are inversely proportional; for—

Formula for constant.

$$C_1 : C_2 : : ds : 1 : : \frac{1}{10{,}000} : \frac{1}{K};$$

$$\therefore K = 10{,}000\, d\, s \text{ ohms},$$

$$= \frac{ds}{100} \text{megohms}.$$

The resistance (I), which is to be measured is now inserted in the place of the other, and a deflection $d_2\, s_2$ is similarly obtained. The value of (I) calculated from the following relation—

Formula for insulation resistance.

$$I : K : : \frac{1}{d_2\, s_2} : \frac{1}{1}$$

$$\therefore I = \frac{K}{d_2\, s_2} \text{ megohms}.$$

If any other resistance is used instead of the 10,000 ohms in the first instance, the above equations must be altered accordingly. Once the constant has been obtained no change must be made in the conditions ot battery, position of magnet, &c., or the constant will alter. It is well to check the constant periodically while carrying out a succession of tests.

Use of shunt.

The shunt should be short-circuited until the necessary connections, &c., are made; then the $\frac{1}{999}$ shunt should be inserted and the "short" removed, and so on. As large a deflection as possible should be obtained for the constant; to ensure this the controlling magnet must be raised nearly to the top of its slide bar, and may even have to be turned over with the ends pointing upwards. It must be remembered that in this condition the galvanometer is very sensitive and will be affected by any iron substance in the vicinity; a knife or bunch of keys carried by any person moving near—or even heavily-nailed boots—may influence the deflection.

As this method is used mostly for cable testing, some practical details necessary to ensure accurate results will be given here. It is essential that all the instruments, &c., used shall be quite clean, dry and free from dust. One or two sheets of paraffined paper, which should be warmed daily to ensure their being thoroughly dried, should be inserted under each. It follows that none of the instruments should be screwed down to a table or fitted into special places; if this is done the desire for neatness and symmetry will probably result in loss of insulation.

Preparation of cables.

The cable, when the test is taken, should be entirely immersed in water, except a few inches at each end; one end should be connected to a lead from the testing room, a second lead being connected to a copper earth-plate in the cable tank. The leads should not be permanently laid, but should be run out as required, special leads being kept for this purpose only.

Although the insulation of cables when first made is very high—over 10,000 megohms per 1,000 yards—yet, if the insulating material is exposed to the weather, it soon deteriorates; so that the insulation of the ends of cables and cores which have been left exposed for purposes of identification and test is always less than that of the rest of the cable. To obtain reliable tests it is therefore necessary to cut a short length off each end and to specially prepare both ends.

The ends should be prepared as for an ordinary joint, with a 1½-inch length of bare wire and ½ inch of insulation tapered off. The outer surface of the insulating material for about 3 inches below the taper should then be carefully cleaned of any trace of tape, felt, or similar material, and the surface of the rubber scraped with a knife, care being taken to handle this cleaned portion as little as possible. The whole end of each core should then be dried and warmed by a spirit lamp, or in some other way, and dipped in molten white paraffin. The wire at one end of each core must then be cleaned ready to connect to the lead, care being again taken to hold the core by the wire and not to handle the paraffined portion.

Both ends of the lead connected to the cable should be similarly treated, and the connection between the lead and cable made by a brass connector.

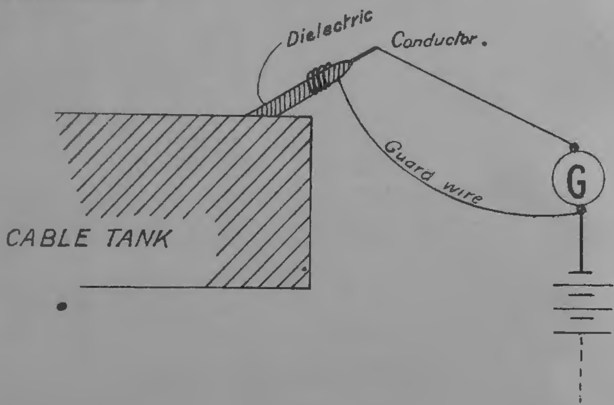


Fig. 80.

Unless these preparations are very carefully taken, the tests will be merely of the insulation of the ends of each core and not real tests of the cables themselves.

To further guard against this, what is known as " a guard wire " should be employed; this consists of a connection from the same pole of the battery as is connected to the galvanometer, wrapped round the dielectric close to the end, the object being to prevent such surface leakage as is unavoidable from passing through the galvanometer and thus impairing the value of the test. A diagrammatic sketch is given in Fig. 80.

It is quite useless to attempt to take a careful test for I.R. on a wet day or even in damp or foggy weather.

Cables act as condensers.

Long lengths of cables act as condensers, and thus, even when the insulation is perfect, there is, on first closing the circuit, a flow of electricity into the cable, and this continues until the cable is fully charged, and would produce a deflection on the galvanometer. This is on account of the "capacity" of the cable. As it becomes electrified the rate of flow of the current decreases gradually, and thus some time elapses before electrification is complete. For very accurate work it is therefore necessary to wait some little time after closing the circuit before completing the test; but for ordinary work the deflection should be read at the expiration of one minute.

To avoid undue oscillations of the galvanometer while the cable is being charged, the short-circuit peg should be inserted at first, and, near the completion of the minute, the shunts should be carefully tried in turn, as described above, when balancing. Great care must be taken not to touch any of the metal work of the box of shunts while moving the pegs.

In recording the tests, insulation resistances over 10 megohms per 1,000 yards are recorded as "over 10" only, so that small deflections which obviously correspond to a higher insulation need not be very accurately determined. For instance, with a constant of 500 an insulation of 10 megohms would correspond to a deflection of about 50 divisions per 1,000 yards of length, so that deflections considerably less than this, say 20 and under, need not be accurately determined.

The further tests, which must be taken after the cables have been laid out, should also be made as accurately as possible, but as for this purpose it will be necessary to employ portable apparatus, the same degree of accuracy cannot be obtained.

Testing apparatus.

For the purpose of these further tests and for subsequent periodical tests, a set of apparatus has been issued (§ 9731, List of Changes), but when meggers are available for issue this set will become obsolete :—

Apparatus, testing, position-finding cables.
Case.
Coil, resistance, 1 ohm.
Generator, hand, 100 volt.
Magnet, bar.
Stand, circular.

which are used in conjunction with :—

Coils, resistance, 10,000 ohms	(§ 8737, List of Changes).
Galvanometer, horizontal	(§ 7571, ,,).
Wire, covered, C 5	(§ 4190, ,,).

and, for conductivity resistance only, a battery of four Leclanché cells of any available type.

The conductivity resistance should be measured by the Wheatstone Bridge method, in the usual way, using the Leclanché cells.

The insulation resistance should also be measured by the Wheatstone Bridge method, using the 1-ohm coil and the magneto-generator.

This coil must be inserted in the circuit of the 10,000-ohm box, between the left bridge arm and the adjustable coils, by opening the link and connecting on to the terminals on either side. Care must be taken to see that the coil when so inserted forms an additional ratio coil in the left arm, *i.e.*, the galvanometer connection must be made to the junction between the 1-ohm coil of the arm and the 1-ohm coil of the adjustable resistance, and not to the junction between the 1,000-ohm and 1-ohm coils of the arm.

The latest pattern of 10,000 resistance coil, described in para. 8737, List of Changes, is arranged so that the permanent connection of the galvanometer key is connected direct to the adjustable resistance.

In previous patterns this connection was led to the end of the bridge arm. When, therefore, the 1-ohm coil is inserted into a box of this type, the galvanometer key must be discarded in order that the connection to one terminal of the galvanometer may be made at the junction of the 1-ohm coil and adjustable resistance.

The effect of introducing the extra coil is to raise the multiplying power of the bridge to 1,000, thereby extending its range to 10 megohms (§ 9274, List of Changes).

In all insulation tests care must be taken to prevent incorrect results being obtained through leakage over ends of cable, from instruments, &c.

Use of magneto-generator.

In order to give sufficient sensitiveness to the arrangement, the magneto-generator, giving a pressure of 100 volts on its terminals at a speed of 100 revolutions per minute, must be used under these conditions.

The handle of the generator must be turned continuously at as uniform a rate as possible while the test is being made, and the negative pole should be connected to line.

At stations where an ohmmeter has been issued in connection with a "generator, electric, hand" for testing electric light circuits, this instrument may be used for insulation tests of cables.

Megger.

The latest instrument supplied for testing cables is called "Megger, 500 volts, 100 megohms." It consists of an 500 volt generator combined with 100 Ω ohmmeter in one case. These instruments are supplied with a five years' guarantee, provided the seals are unbroken; care should be taken to prevent unnecessary removal of the lead seal.

It can be used for all classes of tests, but if accuracy is required the precautions as to preparing the ends of cables, insulation of instruments, &c., detailed above must be carefully followed.

The megger when in use should stand on a steady base, and the handle must be turned in a clock-wise direction, increasing the speed till the clutch is felt to slip; this occurs at about 100 revolutions a minute; at any speed above this the voltage is constant.

Periodical tests.

Periodical tests of cables which have been laid should be made at intervals of not more than 12 months, and should be taken in the manner above described for tests during construction. The results should invariably be recorded in the book used for the records of the preliminary tests, together with a note of the state of the weather and comparative dampness of the ground.

Joint Boxes.

Box, joint, lead-covered cables.

The " box, jointing lead-covered cables " is illustrated in List of Changes in War Material, para. 8881.

The box consists of a cast-iron trough of rectangular section with cover secured by 12 bolts. The underside of the cover is formed with a rib fitting into a corresponding groove in the body.

Between these a piece of soft lead tubing is inserted to form a watertight joint, the tubing being carefully laid in the groove and pressed into same by the rib on the cover.

Each end of the box contains two chambers. The cables pass through these and are sealed watertight.

The same pattern of box is used for all descriptions of lead-covered cables, the inner and outer flanges which close the sealing chambers being changed to suit the particular description of cable employed; the pattern of flange required should be specified in demands.

As K and L cables will very rarely be used in these boxes, flanges are not provided for these cables. They should be made locally when necessary.

When the box is used as a T-box, or when only one cable is passed through it, the openings not required should be closed by blank inner and outer flanges.

The cables should be carefully marked at the exact points where they enter the boxes, and the outer flanges and lead washers should then be slipped over them.

Insertion of cables in boxes.

The outer covering should next be stripped back to the points marked on the cables, and the armouring wires turned back at right angles at the same point and cut off, allowing the ends to project about ⅜ inch, so as to prevent any strain coming on the core, when the outer flanges have been bolted on to the box. A tight joint should be made between the cable and flange by suitable packing of tarred yarn or wood wedges.

Sealing cables.

Both inner and outer flanges are then fixed by screwing up the nuts of the side bolts, and the joint is made watertight by pouring marine glue, or other suitable sealing compound, through the hole in the top of the chamber. Care must be taken to completely fill this chamber by pouring in more from time to time as the hot compound cools and settles down. When set, the plug should be re-inserted in the filling-hole.

The spanners issued with the " vice-jointers " will fit the plug in these boxes of the latest manufacture.

In heating the glue the fire used should not be more than sufficient to melt it, so that all risk of over-heating may be avoided. It is essential that the chambers should be warmed before pouring in the compound. A blow-lamp is provided for heating the chamber, and a special ladle for melting and pouring the glue.

The slack of the lead-covered cores should be coiled inside the box in such a way that the joints come uppermost. Care should be taken that there are no sharp bends in the cores, especially at the flanges, where the lead covering is very liable to be injured. All sharp edges of the holes in the flanges should be removed beforehand.

Chambers not used should have the blank flanges screwed down but not filled with compound. Red lead should be used with the lead washer of outer blank flange to make the joint watertight.

In order to facilitate the jointing of the cores and to allow for reduction of length, should it be necessary at any time to cut out bad joints, sufficient slack should be left on each cable in each box.

In cases where sufficient slack is not available, or where it is not necessary to rejoint the whole of the cores, cables, electric, A_1, A_2, or A_4, may be inserted, but this necessitates replacing a single joint by two joints.

Depth of boxes.

The boxes are intended to be laid either flush with the surface where wheeled traffic is not anticipated and protection from shell fire is not required, or buried at such a depth as may be necessary.

Brick pits are not required in conjunction with buried boxes, except as stated. If it is required to make a joint in K or L group cables a suitable vice must be made locally, as the " vice jointers " is only intended for the cores of B group cables.

SPLICING.

When joint boxes cannot be obtained, or it is found impracticable to use them, a splice may have to be made in a cable.

To make a splice the following instructions should be followed :—

Removal of armouring.

The iron-wire armouring to be carefully taken back for about 3 or 4 feet from each end of cable for future recovering after splice is made, care being taken that the " lay " of the wires is preserved as far as possible, to facilitate subsequent " marrying " ; then cut 1-foot length of the whole of the cores clean away, so as to allow sufficient armouring to safely protect the splice when made. Jointing and insulating should then be carried out as described later.

The centre lead-covered core should now be spirally coated with white spun yarn to the necessary size to receive the outer lead-covered cores ; fill the scores between the outer lead-covered cores with white spun yarn, the whole of the cores to be then bound tightly together by two layers of white spun yarn, laid on reverse to each other.

Replacing armouring.

Now replace the armouring that had been taken back for the convenience of making the joint, and " marry " the wires composing the armouring. The " marriage " of the wires is effected by cutting off a suitable length from every alternate wire at either end, and by fitting each long wire of one end in between two long wires of the other end.

The whole of the splice is to be firmly served with tarred spun yarn in the usual manner.

JOINTING.

Precautions.

The hands and the insulated conductor must be perfectly clean and dry before commencing to make a joint.

Dielectric should be removed from the wire by a diagonal cut with a jointer's scissors, leaving the dielectric neatly tapered, carefully avoiding nicking the wires.

The very greatest care should be taken that the tinned surface of the copper conductor is not scratched or damaged in any way; experience has shown that when rubber comes in contact with copper, the free sulphur which is always to be found in small quantities in the innermost lapping of rubber, attacks the copper conductor, sulphide of copper is formed, and this renders the conductor brittle and useless.

The copper also, in its turn, attacks the innermost layer of rubber, on which the insulation depends.

Consequently, in handling joints with a file or pliers, the utmost care should be taken not to leave any copper untinned.

The wires are to be cleansed with naphtha.

In addition, it is of great importance to see that no indiarubber solution comes in contact with the bare wires, solution should be used very sparingly.

Soldering.

Soldering irons should never be allowed to get too hot and "burn." This always gives rise to an excessive lurid green flame, and is not only injurious to the "copper bit," but burns all the tinning off them, thereby giving extra labour, and wasting time in re-tinning.

Irons may be cleaned with emery cloth, or carefully with a suitable file, they should be *well tinned*, and hot enough when used to be unbearable when placed about 1½ inches from the cheek. The irons should be wiped when taken out of the stove before applying to the joint.

Quick soldering is essential, as continued application of heat seriously weakens copper wire and makes it brittle. Too great a heat causes solder to "rot," and become useless. Too much attention cannot be paid to the soldering irons, as it is perfectly hopeless to attempt to solder a joint with a dirty iron, a badly-tinned iron, or an iron that is not hot enough.

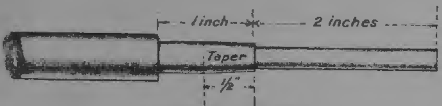
Resin only must be used as a flux.

The lead-covered conductors should be covered with a lead sleeve, or in the case of a three-way joint, with a sleeve and a piece of lead sheet, after insulating. If a sleeve is not available, lead sheet should be substituted, and indiarubber tubing should be used for any joints in insulated conductors not lead-covered. The sleeve or tube must be slipped over one of the conductors before starting jointing.

The hands should be carefully washed after dealing with lead-covered cables.

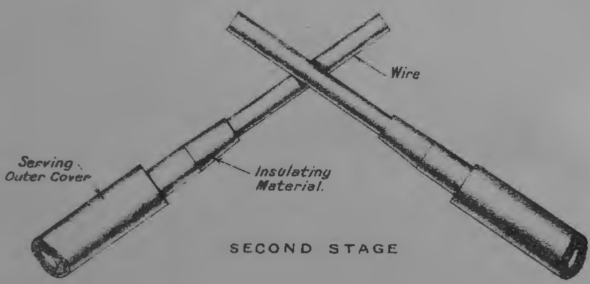
STRAIGHT JOINT, SINGLE WIRE UNDER 16 W.G.

Figure 84.



FIRST STAGE

Figure 85.



SECOND STAGE

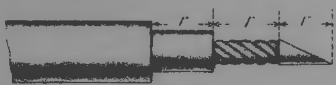
Figure 86.

COMPLETE.

STRAIGHT JOINT { SINGLE WIRE. 16 W.G. AND LARGER; 3 STRAND. 7 STRAND. SMALL WIRES.

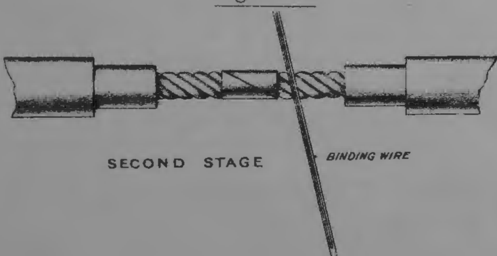
SCARFED JOINT.

Figure 81.



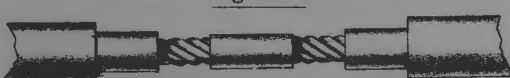
FIRST STAGE

Figure 82.



SECOND STAGE

Figure 83.



COMPLETE.

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Details of Jointing.

Single-wire, 16 *W.G., and larger.*

Straight joint (Figs. 81, 82, 83).—

Strip off the armouring, jute, lead, and taping, if any exists, for a length of about 3 inches—if necessary, secure the ends by serving.

Remove about 2 inches of the insulating material and carefully clean the wire with naphtha.

Scarf the ends of the wires with a suitable file till the two ends fit.

Adjust the jointers' vice and grip the conductors close to the insulation, the scarfed faces being opposed to each other in a vertical plane.

Secure one end of a piece of binding wire (*i.e.*, "wire, jointing and binding, AA_{11}"), to one clamping screw of the vice, and take a few open turns tightly round the joint from one joint to the other to keep the scarfs in position for soldering. With very little solder on the bolt, sweat the scarfed faces together. Remove the binding wire and smooth the joint with a file, taking great care not to remove the tinning or cut into the wires on either side.

Take a piece of binding wire, 8 feet long, bent in four, and place the double bight on the left-hand clamping screw of the vice. Cut through the single bight so as to have four free ends. This will prevent the wires from over-riding during the binding.

With the four wires side by side, bind over the wires from a point ¼ inch to the left side of the scarf, to a corresponding point on the right side, pressing the turns close up together with the thumb nail and pulling them tight. Secure the free ends round the right-hand clamping screw of the vice.

Sweat through the joint and binding wire, cut away the loose ends, and smooth the joint over as before.

T-joint—

Strip and clean the branching wire and about 1½ inches of the main wire as above.

Place the branching wire across the other, twist it round it four or five times, and sweat up as above.

Single Wires—under 16 *W.G.*

Straight joint (Figs. 84, 85, 86).—

Strip and clean the wires as in para. 60, place the two wires across each other, the crossing point being the middle of the bared part.

Grip the crossing point with pliers and twist one of the free ends round the standing part of the other wire. Do the same with the other, straighten the joint and trim up the ends, taking care that no projecting end is left.

Sweat up and clean the joint as above.

T-joint—

As described above.

3-*Strand Wires and* 7-*Strand Small Wires.*

Straight joint (Figs. 81, 82 and 83).—

Remove covering, &c., for about 3 inches and insulation for about 2 inches, as above.

Unlay, clean, and lay up again the ends of the wires, sweat them up solid for a distance of about 1 inch from the tip.

Scarf the soldered ends with a suitable file and proceed as for single wire.

T-joint (Figs. 96 to 101).—

Strip about 6 inches of the cable to be tapped and bare about 3 to 3½ inches of the wire, clean the wires and re-tin them if necessary.

Strip about 4 inches and bare about 3 inches of the other cable.

Unlay all the wires of the branch cable, clean and straighten them, and lay up half the length again and divide the other half 2 and 1, or 4 and 3, in a fork. Place the fork across the through cable, and lay the wires tightly round the standing part one-half at a time, one-half to the left and one-half to the right, with the same lay as the standing part.

Smooth off the wires, remove projections, and sweat up the joint as above.

Y-joint can also be made thus—

Solder up both conductors solid, scarf the end of the branch cable, file out a small nick in the through cable, lay the scarf in this recess, and bind over with AA_{11} wire, finally solder as before.

7-*Strand*, 14 *W.G. and Upwards.*

Straight joint—

May be made the same as for small wires, or, as in Figs. 87 to 90.

Strip about 7 inches and bare 6 inches of the wires, unlay, clean and straighten the wires.

Cut off 3½ inches of the centre wire at each end.

Lay up the wires again up to the end of the centre wire and splay the six ends in the form of a cone.

Marry the two splayed ends and twist the six wires of one cable, one by one round the other cable, against the lay of the standing parts, taking care that they do not over-ride, repeat this with other cable. Tighten up with the pliers, see that no ends project and sweat up as before.

This method is preferable if any strain is likely to come on the conductor.

Method of jointing E.L. cables 19 strand and over.

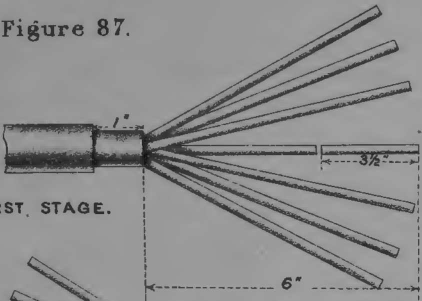
Preparation of Cable Ends.

(1) Remove armouring as necessary and lead covering for 3 inches.

Bare 1½ inch of the conductors and clean the outer strands—without disturbing their lay—with naphtha. If the cable is not in good condition it will be necessary to unlay, clean, re-tin, and re-lay

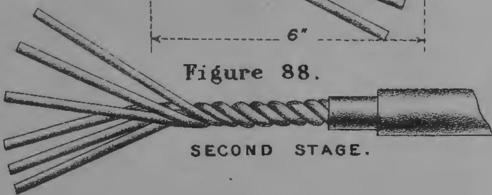
STRAIGHT JOINT 7 STRAND 14. W.G. & UPWARDS.

Figure 87.



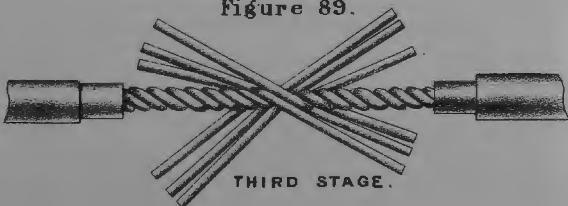
FIRST. STAGE.

Figure 88.



SECOND STAGE.

Figure 89.



THIRD STAGE.

Figure 90.

COMPLETE.

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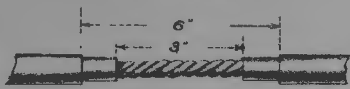
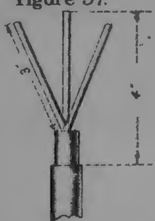
"T" JOINT 3 STRAND WIRE.

Figure 96.



FIRST STAGE.

Figure 97.

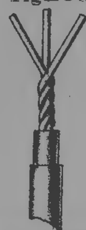


SECOND STAGE.

Figure 98.

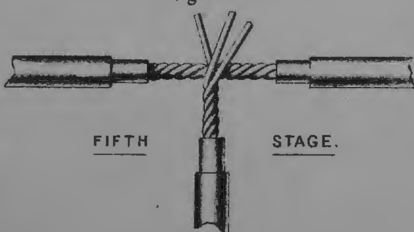
FOURTH STAGE.

Figure 99.



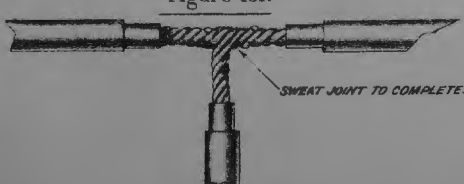
THIRD STAGE.

Figure 100.



FIFTH STAGE.

Figure 101.



SIXTH STAGE.

3781.

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the outer strands. The remaining 1½ inch of insulation should be protected by a few layers of tape.

Secure the outer strands with two turns of No. 16 G.I. wire whilst a few turns of No. 26 tinned copper binding wire are placed in position near the end.

Remove the G.I. wire and solder solid, either by using a bolt or dipping in a pot of molten solder, using powdered resin as a flux.

Then remove the binding and file ends up square.

Manufacture of Sleeve.

(2) Take a piece of No. 18 gauge sheet copper 3 inches wide and 1⅝ inches long and thoroughly clean it, and by using a ½-inch mandrel convert it into a split-tube, the length when finished being 3 inches. (These sizes are for a 37/15 cable.)

Then drill two holes ⅛ inch in diameter diametrically opposite the slot at a distance of ⅜ inch from each end. Clean the split-tube inside and out, also at the ends and slot, and cover it with a thin coat of pure tallow.

Then roll the tube in finely powdered resin and dip it into a pot of molten solder. Whilst hot, wipe inside and out with a rag to remove superfluous solder.

For cleaning the inside of the tube (after tinning) a "pull through" should be made. This consists of a piece of wire bent in two and pieces of rag secured in the bight.

NOTE.—If preferred, the sheet may be tinned flat, and then formed into the sleeve.

Jointing.

(3) Slip a lead sleeve 12 inches long and 1 inch in diameter along one of the cables, and place the two ends to be jointed in the split-tube (which should be a tight fit), and if the ends do not butt nicely, they should be filed until they do so.

The joint is completed by pouring molten solder from a small ladle into the slot of the tube, the small ladle being replenished from a large ladle containing molten solder, which is held underneath the joint to catch any drips. In carrying out this operation the joint should be kept perfectly level, and the application of molten solder should cease when it runs from the small holes near the end of the tube.

All superfluous solder should then be wiped from the completed joint, which should be allowed to cool gradually. In order to prevent damage to the insulation, the application of the solder should cease after half a minute.

NOTE.—Figs. 91, 92, 93, 94, 95 are cancelled.

T-joint—

As for 7-strand wires, but a length of 4 and 4½ inches for 19-strand and 5 and 5½ inches of 37-strand conductors should be bared.

Y-joints can be made as for 7-strand wires, but the outer wires of the branch cable should be laid back and 3 or 4 inches of the wires cut off, the butt soldered up for 1 inch, scarfed and laid in a nick in the through cable as described above.

The outer wires will then be straightened and divided into a Y, and laid up round the through cable right and left as in T-joint, the whole will then be soldered up.

Insulation.

General. The insulation of joints is usually effected with indiarubber tape and solution.

Indiarubber tape is issued in tins containing 2 ozs.

Solution is now issued in collapsible tubes of 3 ozs.

Tins or tubes of indiarubber solution should never be left open, and great care should be taken to prevent water getting into them.

Indiarubber tubing at present is only provided of $\frac{1}{2}$-inch and $\frac{3}{8}$-inch inside diameter, for cables too large for these, primed tape and shellac should be used for outside covering.

The indiarubber tubing, if used, should be quite dry and clean, inside and out.

I.R. Tape. Indiarubber tape should be stretched gradually and perfectly evenly; if the tape be very old, it is well to warm it slightly before stretching it, say, by keeping it in the pocket, or by passing it through warm water, as described below. Care must be taken not to overdo the stretching, so as to cause the tape to lose its elasticity. Should this result be inadvertently produced, the tape can be restored to its normal condition by warming it slightly.

A good way of warming tape, when hard, is to unroll and pass it through a bath of hot water at a temperature of about 150° F., and then through cold water before recoiling. This prevents the sticking which occurs if the roll of tape is put bodily into hot water.

The tape must be perfectly dry before use.

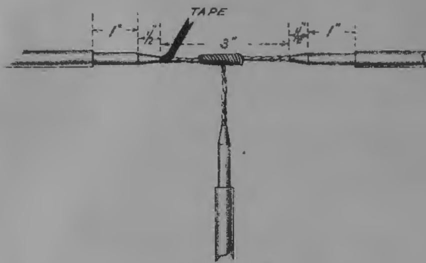
Tape which is too old to stretch evenly or presents a hard cracked surface, or is soft and inelastic, should not be used.

The most important part in making an insulated joint, or insulating a cable end, is to lay the tape serving over the insulating material of the core in such a manner as to cause it to unite perfectly with the core, both on the tapered portion and beyond the taper. Care must be taken that the serving is commenced on the bare wires, and not on the tapered part of the insulating material, and that the serving is not carried, even ever so little, over any part of the insulating material before commencing to use indiarubber solution, at the same time the solution must not come in contact with the bare wires.

Serving with indiarubber tape, whether with or without indiarubber solution, should always be done in the following manner:—Cut the ends of the piece of tape to a point and stretch it out till there are no dark spots in it. Wind it tightly round the object to be

"T" JOINT 3 STRAND WIRE.
DETAILS OF INSULATION.

Figure 102.



1ST STAGE

SHOWING COMMENCEMENT OF INSULATION.

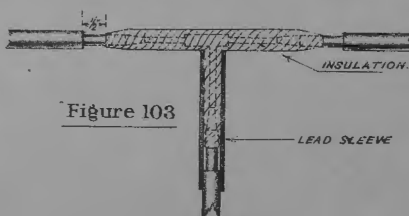


Figure 103

2ND STAGE

SHOWING INSULATION COMPLETED

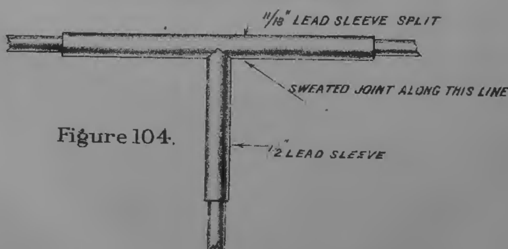


Figure 104.

COMPLETE.

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served, stretching the tape in doing so till it is only half its normal width, and making each turn overlap the preceding turn by half its stretched width ; the tape being consequently laid on helically.

It is well to use the third finger of the right hand for smearing on the solution, thus leaving the thumb, fore and second fingers, free for serving with. Care must be taken not to allow the hands or fingers to become covered with solution, as it is then very difficult to produce good work. On completing the serving, the end of the tape should be held in position with the fingers until it adheres. Rubber solution should be very sparingly used.

Details of Insulation.

Insulating ends.

To *insulate the ends* of insulated conductors proceed as follows :—

Cut the conducting wires off close to the insulating material.

Remove the tape carefully from the insulating material for not less than 2 inches.

Pull the insulating material just over the ends of the conducting wires.

Make sure that the end is perfectly dry and free from grease by warming with a spirit lamp or wiping with a cloth steeped in naphtha.

Rub a little indiarubber solution well into the insulating material where the tape has been removed. Take a piece of indiarubber tape of suitable length. Commence serving, using solution, at a point ½ inch from the end of the cable ; after serving two turns round the cable pass the tape over the end of it, bring the tape back and serve another turn in the usual way, next to the first turns ; pass the tape again over the end in such a way that it crosses the previous turn at right angles ; serve back, working away from the end of the cable to the point where the tape has been removed ; serve forward again, getting two more turns as before over the end, and continue as above until the end is properly covered with tape.

Apply more indiarubber solution over the serving, and slip over it a piece of vulcanised indiarubber tubing, if available, with its ends turned up, until half the tubing is on the cable core. When it is in position apply more solution at its ends, thus filling up the empty half of the tubing, and turn down the ends.

Turn the projecting half of the indiarubber tubing back on to the other half. Tie tightly with twine as in a two-way joint.

Insulating joints.

Joints should be insulated as follows (Figs. 102, 103, 104) :—

Cut away any insulation damaged during the soldering operation. Bare the insulation for about 2 inches on each side of the joint by removing the tape or other protective covering. Scrape the rubber lightly and remove all threads and dirt, taking great care not to cut the rubber. Trim the ends of the rubber to a taper, ½ inch long (but the lengths of taper will vary with the thickness of the insulation), the pure rubber, if possible, being just exposed at the bottom of the taper. The tapers must on no account be exposed to the air for a longer time than is necessary, and must be kept scrupulously clean and dry; if by any means they become in the least dirty, they must be wiped over with a piece of clean rag, free from fluff, damped with naphtha.

Two-way joints.

For a two-way joint commence serving with indiarubber tape on the bare wire just beyond the point of the tapered portion of the insulating material, and wind first over the bared wires, *using no solution*. As soon as the bared wires are covered, apply a little indiarubber solution to both sides of the tape, and also to the insulating material, and continue the serving up the tapered part, and along the conductor for a further distance of ½ inch. Then serve back over the joint, continuing to use a little indiarubber solution; carry the serving over the tapered portion of the insulating material, and along for a further distance of ½ inch on the other side of the joint. Then serve again over the joint, now carrying the serving to the top of the taper on the other side of the joint. On reaching this point serve back again over the joint to the top of the other taper.

After this, continue the serving forwards and backwards, always using solution, until the tape is served up nearly to the diameter of the lead covering of the conductor.

Sleeves.

The lead sleeve is now to be drawn back over the joint and its ends carefully soldered to the lead core. This is a difficult operation requiring considerable skill. The temperature of the soldering iron requires very careful attention. If too hot, it will burn through the lead core—if too cold, the solder will not adhere properly to the lead. Before the lead sleeve is slipped over the core the ends should be scraped clean, the cleaned surface extending about 1 inch down the inside of the tube. The ends should also be slightly opened out. The cores should be cleaned in the same way where the ends of the sleeve are to be soldered.

A little tallow is then smeared on the clean surface of the lead and a little finely-powdered resin sprinkled over it. A few drops of solder are then dropped into the end of the sleeve and the soldering iron passed round to complete the joint. This operation should be done quickly, or the lead core will burn, and only sufficient heat should be applied to make the solder adhere thoroughly to the surfaces of the lead.

Where lead sleeves are not available, indiarubber tubing should be used. The joints in this case must be finished over the rubber tape with a covering of double-primed tape and shellac varnish.

More indiarubber solution should then be applied over the serving, and the indiarubber tubing drawn, with its ends turned up, over the joint. When it is in position immediately over the joint, apply more solution at its ends, and turn them down.

Tie each end of the tubing tightly with twine, about ½ inch from the end. Pass the twine round the tubing, and tie with a thumb-knot; then bring the ends round to the other side, and secure them with a reef-knot, thus making two completed turns of twine round each end of the tubing.

For a three-way joint, commence serving on the bare wire just beyond the point of the tapered portion of the insulating material of one cable, and wind first over all the bared wires, using no solution. As soon as the bared wires are covered, apply indiarubber solution to both sides of the tape, and also to the insulating material, and continue the serving up the tapered part of the insulating material, and for a further distance of ½ inch of the cable. Then serve back to the joint, and then up the taper of the branch cable, and along this cable for ½ inch. Then serve back again down over the joint, continuing to use indiarubber solution; carry the serving over the tapered portion of the insulating material, and ½ inch along the first cable, and so on to the required thickness. Three-way joints.

The lead sleeves on the branch cable will then be slipped up to the joint and the end soldered, and the through cable will be wrapped with lead sheet which will be soldered along the joint, also to the lead sleeve and the sheathing of the cable. Sleeves.

STORES FOR JOINTING.

The following special stores are used for laying, testing, terminating, and jointing cables or covered wires, and should be demanded according to requirements, or in accordance with authorised establishments.

The estimated quantity of materials required for jointing cores of a B group cable is shown below. Each core jointed in a multicore cable is reckoned as one joint.

Should chests be required for carrying tools and materials, they must be provided locally.

Designation.	Remarks.	
**Apparatus, testing, P.F. cables*—*		
Cases	For holding one ohm resistance coil, magnet, and circular stand.	
Coils, resistance, 1 *ohm.*		
Generator, hand, 100 *volts.*		
Magnet bars.		
Stands, circular.		
Bottles, glass, narrow-mouthed, 16-oz.	For naphtha	
Bottles, tin, methylated spirits, 1½ pints.		
Bowls, hand.		
Boxes, connecting, armoured cable—		
Single cored, straight	For *B* 2, *Mark I,* cable	When joint boxes are not available or it is impracticable to use them.
Multiple cored, ordinary	For *B* 4, *Mark I,* cable	
Multiple cored, shore end ...	For *B* 7 and *B* 9, *Mark I,* cables	

* The "Megger, 500 volt, 100 megohms," will be supplied in future in lieu of these stores.

Designation.	Remarks.
Boxes, joint, cables, lead-covered ...	With flanges to suit the nature of cables to be laid, *vide* Vocabulary.
Boxes, tallow.	
Coils, resistance, 10,000 ohms.	
Drivers, screw, G.S., 9-inch.	
Files—	
Bastard, flat, 12-inch.	
Bastard, half-round, 10-inch.	
Bastard, half-round, 8-inch.	
Smooth, half-round, 8-inch.	
Galvanometers, horizontal.	
**Generators, electric, hand* ...	500 volts, for testing electric light circuits.
Hammers, fitters, 24-oz.	
Irons, soldering—	
3-lb., ½-inch groove.	
4-oz. hatchet head.	
9-oz.	
Tinman's, large.	
Knives—	
Clasp	
Ladles, pouring, 1 quart.	
Lamps, blow, spirit, Mark II.	
Mallets, serving.	
Megger, 500 volts, 100 megohms ...	For testing E.L. and P.F. cables.
**Ohmmeter*, 50 *megohms*	Testing electric light circuits.
Pliers—	
Gas, 9-inch.	
Sidecutting, 8-inch, Mark III.	
Sidecutting, 5-inch.	
Pots—	
Fire, telegraph mechanics.	
Melting.	
Rule, G.S., 4-fold.	
Saws—	
Cutting metal, 6-inch.	
Cutting metal, blades, 6-inch.	
Dovetail, iron back.	
Scissors, trimming, Mark II.	
Spanners, McMahon, 9-inch, Mark II.	
Towels, hand, hospital.	
Vice, jointer's.	

MATERIALS.

		Quantity per 25 joints.
Cloth, emery, No. F	... .	¼ quire.
Cordage, spun yarn—		
Hemp, 3-thread, tarred	For spliced joints	5 lbs.
Cotton, waste, coloured	... ...	2 lbs.
Glue, marine.		
Lead sheet, 0·068-inch	4 lbs. per square foot; for covering ⊥-joints in lead-covered electric cables ...	48 lbs.

* The "Megger, 500 volt, 100 megohms," will be supplied in future in lieu of these stores.

Designation.	Remarks.	Quantity per 25 joints.
	MATERIALS—*continued.*	
Methylated spirits	... ...	2 quarts.
Naphtha, coal tar	... ...	$\frac{3}{4}$ pint.
Resin, black	... ...	$\frac{1}{2}$ lb.
Sleeves, lead	For covering joints in lead-covered cables, diameters measured internally	
$\frac{7}{16}$-inch × 12-inch	For *B* 4, *Mark I*, *B* 7 and outer cores of *B* 9, *Mark I*	25
$\frac{1}{2}$-inch × 12-inch	For K 11 L 11	25
$\frac{9}{16}$-inch × 12-inch	For centre cores of *B* 9, *Mark I*	25
$\frac{11}{16}$-inch × 12-inch	For *B* 2. *Mark I*	25
1-inch × 12-inch	For K 19 and *L* 19, *Mark* I	25
Solder, tinman's, soft	... ...	1 lb.
Solution, I. R., 3-oz. tubes ...	... ...	3 tubes.
Tallow, Russian	... ...	$\frac{1}{4}$ lb.
Tape, I. R.	... ...	1 lb.
Tape, double primed, 1-inch ...	Primed with rubber on both sides, not used with lead sleeves	2 lbs.
Tubing, I. R.—		
$\frac{1}{4}$-inch	Not used with lead sleeves	$6\frac{1}{2}$ ft.
$\frac{3}{8}$-inch	Not used with lead sleeves	$6\frac{1}{2}$ ft.
Tubing, lead	Issued with boxes as required.	
Wire, special iron galvanised, No. 16 W.G.	Soft, for binding	2 lbs.
Wire, special, copper tinned, No. 26 W.G.	For binding electric joints	1 lb.
Wire, special, copper tinned, No. 30 W.G.	For binding electric joints	1 lb.
Varnish, shellac	For coating double-primed tape used for protecting joints without lead sleeves	$\frac{1}{2}$ pint.

CHAPTER VIII.

Employment of Lights in Fortresses—Methods of Direction. Communications.

Contents.

General.

In the first two chapters the light was considered first from the point of view of the best conditions for the arc and second for the best means of projection. It is now proposed to consider the best way of using the projected light for coast defence purposes ; that is, for illuminating objects on the water :—(1) to ascertain with certainty the presence of a vessel or boat, and whether it is friendly or hostile ; (2) to illuminate hostile vessels in such a way that the maximum gun fire can be brought to bear on them with the least possible delay.

These two conditions are not identical, as it is possible to detect vessels at ranges and under conditions of illumination which would be insufficient for effective gun fire.

Principles of Illumination.

The visibility of any object depends on two factors ; (1) the observer and his position with reference to the object ; (2) the degree of illumination of the object.

The observer is affected by—

(*a*) His distance from the object illuminated.
(*b*) His position with reference to the source of light, or of other lights in the neighbourhood.
(*c*) His eyesight and degree of training.

The degree of illumination depends on—

(*d*) The strength of the source of light and the method of projection.
(*e*) The distance from the light to the object.
(*f*) The size, colour, and shape of the object.
(*g*) The angle formed at the object between the line of sight of the observer and the line of light.

These different conditions affect the visibility in different ways, thus—

(a) The visibility of an object to an observer varies as the square of the distance.

(b) The effect of being near the source of light or any other brightly illuminated object is to alter the focus of the eyes, which naturally adapt their focus to the brightest object and so make other objects less distinct. Such effect is much reduced by using field-glasses of low power, or even by screening the eyes with the hands. As a general rule the observer is best placed at some height above the lights or if to a flank, then at a distance not less than one-tenth of the average range of the light.

(c) It is well known that some individuals with good sight by day are almost blind at night, also it is possible by training and practice to very much improve the power of vision at night.

(d) The means of obtaining the best strength of light are discussed in earlier chapters.

(e) The intensity of illumination from a constant source of light varies as the square of the distance to the object.

(f) Different objects vary considerably in visibility; it is obvious that the larger they are the more easily they are seen; black objects are much less visible than those of a light colour; the escaping steam from a funnel will often enable a vessel to be detected; a vessel moving fast throws up a considerable bow wave, which is very visible; any points which reflect the light such as windows or brass fittings, also assist the observer.

(g) If a spherical object illuminated from a single source of light is looked at from various directions it will appear more or less brightly illuminated, according to the relative position of the observer and the light. The best results will be obtained when the observer and light are nearly side by side. When the observer is exactly on the opposite side to the light, the object appears black, silhouetted against the light.

Effects of atmosphere.

Both these sets of conditions are affected very considerably by the state of the atmosphere. Mist, rain, snow and fog all reduce the illumination of the object by refracting rays of light away from the direct line and also hinder the view of the observer by interposing an illuminated screen between him and the object.

In very thick fog or heavy snow or rain, the interruption of the light is so great as to make the lights useless.

If the atmosphere is exceptionally clear and free from moisture, there is little or no illumination of the atmosphere itself and the light appears to be almost non-existent, unless turned on a vessel or other object. In such a case an inexperienced observer may think the light is burning badly.

It results from the above that an observer placed on the flank and on the same level as a dispersed light will, un'ess the air is very clear, only see objects which are in the edge of the light nearest to him and objects in the further edge will be obscured. With dispersed lights it is thus specially important that the observer should be on a higher level than the light.

If a light is depressed so as to strike the water within view of the observer it will be reflected off the surface and continue as a rising light, obscuring objects below it from view. For this reason lights are usually placed low and worked as nearly horizontal as possible.

If two concentrated lights are placed so as to cross they interfere with one another in two ways. First, the atmosphere at the point where they cross is doubly illuminated and makes it difficult for the observer to see objects beyond; this is often referred to (in error) as one light "cutting off" another; the second effect is to screen objects behind the point of intersection from the view of observers at either light.

Comparative effect of concentrated and dispersed lights.

A dispersed light has evidently less power than a concentrated light from a lamp and projector of equal power and size. From Chapter II, it will be seen that the vertical heights of the two forms of light are the same but the horizontal dimensions vary and depend on the conical angle of rays projected by the reflector. The amount of light on any object will decrease just in proportion as the cone of rays increases, so that if the illumination from a concentrated light with a cone of $2\frac{1}{2}°$ is taken as 1 (on an object at a given range) the illumination from a 16° reflector on the same object, will be $\frac{2\frac{1}{2}}{16}$, or about $\frac{1}{6}$ and the illumination from a 30° or 45° will be $\frac{1}{12}$ and $\frac{1}{18}$.

Or this may be stated in terms of the distances at which these different lights give equal illumination. The illumination, as we have seen, varies with the square of the distance, so the above lights will give equal illumination at distances represented by

$$\sqrt{1} \quad \sqrt{\tfrac{1}{6}} \quad \sqrt{\tfrac{1}{12}} \quad \sqrt{\tfrac{1}{18}}$$

Further, the visibility of an object varies directly as the illumination and inversely as the square of the distance, so that, assuming the observer is near the light and approximately at the same distance from the object as the light, the distances at which an object illuminated by these lights will be equally visible to the observer will vary as

$$\sqrt[4]{1} \quad \sqrt[4]{\tfrac{1}{6}} \quad \sqrt[4]{\tfrac{1}{12}} \quad \sqrt[4]{\tfrac{1}{18}}$$

Assuming a concentrated light gives an effective illumination at 2,000 yards, the dispersed lights should be equally effective at 1,275, 1,075, and 970 yards respectively. This comparison is only really true in vacuo when the beam itself would be absolutely invisible. In practice the following figures may be taken as a guide in arranging defences in Home Waters.

			Yards.
For concentrated light ..	..	..	2,000
„ 16 degrees dispersion	..	..	1,500
„ 30 „	..	..	1,200
„ 45 „	..	..	900

Tactical Use of Lights.

For tactical purposes all electric lights may be classified as (a) moving, (b) fixed. Classification.

A *moving* light can be moved horizontally or vertically through an angle which is only limited by the construction of the emplacement or local features of the ground. Such a light can be directed accurately on any target within its field of action and can be kept readily on such a target. It is exposed to fire from any point within its angle of traverse.

A *fixed* light is a light kept steadily on one bearing and elevation for the illumination of one definite portion of water only; it can be given adequate protection from the fire of any vessel not actually illuminated by the light.

Direction of lights.

A moving light is controlled with electric motors by an officer or N.C.O., R.E., in a directing station, who also watches the focusing and burning of the lamp, and gives orders as to these by telephone to the emplacement. For a fixed light he has only to watch the elevation, burning and focusing, and gives all orders for changes by telephone.

A concentrated moving light is usually called a "search light," or search beam.

A concentrated fixed light is called a "sentry" light or beam.

Dispersed lights are usually fixed, though some are made capable of traverse, and in such case will have electric motors for control from a directing station.

Superposed lights.

When it is required to increase the range beyond the power of one light two or more lights may be "superposed," that is, arranged so as to illuminate the same piece of water.

Arrangements in defence.

In arranging lights in a defence it is convenient to consider them under three heads :—

(1) Outpost lights for observation at the front limit of the defences.
(2) Fighting lights or fighting areas for the medium armament.
(3) Fixed areas for the anti-torpedo boat defence, usually placed at the back of the defences.

Outpost lights.

Outpost lights are usually arranged in pairs, one as a sentry beam and one as a search light. It is desirable that both lights should be fitted with motor traversing and elevating gear, so that they can be placed on any bearing; of these the sentry beam is the most important, as it has been found that however carefully a search light is worked there is a possibility of passing over approaching vessels, especially if the latter are on the alert and lie motionless when the light is on them. But a vessel running through a sentry beam should be seen with certainty.

If, however, only a sentry beam is provided on a fixed bearing, it is possible for a hostile boat to approach the outer edge of the light quite unseen, and either fire on the emplacement or wait in the darkness till a temporary obscuration of the light (as when changing carbons) enables them to slip through in the darkness. The addition of a search light prevents this, as it can search over the whole water outside the sentry beam; it can also be used as a sentry beam while the latter is out of action, and if a vessel is detected crossing the sentry beam, it can be followed by the search light till it is picked up by the fighting lights of the defence. When an entrance is wide, a pair of search and sentry lights is required on each side of the channel.

Fighting lights.

Fighting lights are usually concentrated moving lights arranged in pairs or groups, connected to an E.L. post i/c officer or N.C.O., R.E., who is in close communication with the battery commander of the guns they serve. When fighting lights serve more than one battery, one battery commander is selected to give orders to the officer or N.C.O. R.E., i/c the E.L. Post and the others conform, or in special cases all the lights may be kept in the hands of a senior artillery officer, and the batteries then engage on their own responsibility any targets which are illuminated.

In small defences the same lights are used for observation and fighting, in such cases the battery commander is usually made responsible for both services, so as to avoid any break of responsibility at a critical moment.

Considerable practice is required to properly manipulate fighting lights so as to fully illuminate the target and at the same time avoid interfering with neighbouring lights. The target should be kept as far as possible in the centre of the beam so that the fall of shots which miss the target may be observed.

Fighting areas.

Fighting areas are used whenever the width of the channel is such that dispersed lights can be used to advantage. These are best arranged in groups of two or three lights placed side by side, each group being conneced to a director.

When guns are placed on both sides of a channel, each side should have its own fan of lights, radiating from a point near the guns. It is important in such cases to keep the lights at a low level with the guns above.

Similar areas are arranged for the inner *anti-torpedo boat* defence, but in such cases several fans may be arranged over the same area, and all their directors must be connected for general control to an officer called an O.C. E.L. at some central station. This officer will watch the general illumination, arrange for any shifting of lights while changing carbons and for the use of spare lights. The directors will, as before, watch focusing, burning and elevation.

DETAIL OF CIRCUITS
EMPLACEMENT BETWEEN ENGINE ROOM AND DIRECTING STATION

It will be seen from the above that it is very important not to change carbons or otherwise stop the running of the light without first informing the artillery officers concerned. To ensure that several lights do not change carbons simultaneously at least half an hour's notice should be given to directors.

Directing Stations.

Electric light directors require specially constructed cells to provide protection from the weather for the instruments and *personnel*. They should be made as small and inconspicuous as possible, with an arc of view which includes all the water covered by their lights. They are best placed about 50 feet higher than the lights, and if to a flank, they must be on the side nearest the enemy.

The fittings required will be one motor switch and resistance for each traversing or elevating motor, the pair for any one light being placed together.

Communications required.

Communication by speaking tube or telephone will be required to the O.C. E.L., to the R.A. officer responsible for the tactical control of the lights, to each emplacement or group of emplacements, and to each engine room.

The connections to the emplacements and engine room may be brought to a "concentrator" or 5 or 10 line switch, but separate telephone instruments should be provided for the connections to higher authorities. The instruments used should be "telephone sets, office." All telephone circuits should be metallic.

In the case of a large group of three or more fixed lights, it may be desirable to provide a bell circuit to each emplacement and arrange a code of rings for stopping, starting, or for small changes in elevation or direction. The directing station can be lit by incandescent lights connected to the power leads for the motor switches.

Arrangement of circuits.

Fig. 105 shows a typical arrangement of circuits between a directing station, engine room, and emplacement.

Excluding spare wires, the connections required are:—

Between engine room and emplacement.—

2 leads suitable for 120 amperes.

2 for current to incandescent lamps.

Between engine room and directing station.—

2 for current for motor circuits and incandescent lamps. The motors will not work satisfactorily if the D.P. at the switch in the directing station falls much below 75 volts. This should be the basis for calculating the nature of the cable required, taking the current at the rate of 2 amperes for each motor and 1 ampere for each lamp.

2 for telephone circuit.

Between directing station and emplacement.—

2 for elevating motor.

2 for traversing motor (4 leads if dials are used).

2 for telephone circuit.

The connections of the motor circuits are shown in Fig. 106.

The patterns of cable and wire suitable for the above are described in Chapter VII.

Cables for telephone circuits and cables carrying power should be laid in separate pipes or trenches. Where this is not done the telephone instruments should be "protected" by heat coils. Inside buildings the telephone and power wires should be separated as far as possible.

PROJECTOR 90 c/m MARK III AND IV.
BASE CONNECTIONS FOR MOTORS AND LAMP.

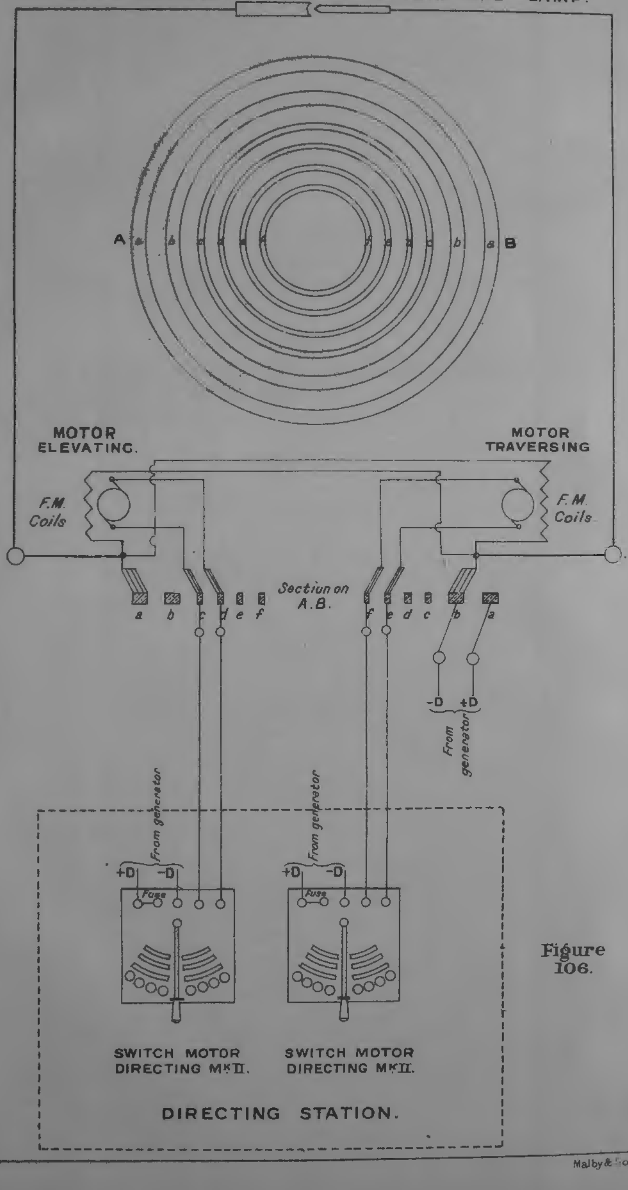

Figure 106.

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CHAPTER IX.

Personnel—Instructions for Running.

Contents.

Personnel.

The personnel usually available for manning the electric lights may comprise any of the following :—

Royal Engineers—

Officers.

Mechanists. { Electricians. / Engine Drivers trained for E. L. duties.

N.C.O.'s and men, including some specially trained as—

Electricians.
Engine Drivers.
Telephonists.

R.E. Reserve—

Officers.

R.E. Territorial Force—

Officers, N.C.O.'s and men.

Local Forces in Channel Islands and Abroad—

Officers, N.C.O.'s and men.

Local Native Forces—

N.C.O.s and men.

Civilian Labourers—

European or Native.

In distributing these for work, the guiding principle should be to fit each officer or man into the position he is best qualified to fill, without regard to which branch he comes from. At the same time, if the training of the local forces is sufficiently good, certain lights in groups of lights may be allotted to them, though as a general rule the advantage of local knowledge and training is so great that some regular officers or N.C.O.s should be associated with all parties of auxiliary troops. Distribution.

It is most important that the distribution of the personnel should be carefully arranged in peace time, so that, on an emergency there may be no delay in manning the defence electric lights.

For this purpose the following tables should be kept at all stations :—

(*a*) A table showing the numbers of officers, N.C.O.'s and men required and available for manning the defence electric lights.

(*b*) A table showing the numbers of officers, N.C.O.'s and men to be detailed for each installation (1) on mobilisation and (2) during the precautionary period prior to mobilisation. This table should show the numbers of each trade required.

(*c*) A table showing how accommodation for the above is provided on mobilisation.

(*d*) A nominal roll of the N.C.O.'s and men actually available at the station and the detail of their distribution in accordance with Table (*b*). This table should be prepared in pencil and kept corrected to date ; it should be used for the distribution of the personnel at weekly electric light practices as far as possible.

The following distribution of personnel has been found sufficient for one relief of a group of two or more lights worked from the same engine room :—

At each Directing Station.—

1 Officer or N.C.O. in charge.

1 man per light at the directing switches for each moving light.

1 man per station for telephones.

At the Lights.—

1 N.C.O. (Electrician) in charge of the group of lights.

1 man per emplacement to attend to lamp and telephone.

1 man extra for each search light fitted for dial traversing.

At the Engine Room.—

1 man per engine (one to be a selected N.C.O. or man to superintend).

1 man for switchboard and telephone.

The above are the bare numbers required, so that it is very desirable to have a small percentage of spare men to replace casualties or help in case of a breakdown. If the latter is serious, it may be necessary to call on another relief to assist.

Reliefs. Experience has shown that if the period of darkness does not exceed 14 hours, two reliefs will suffice.

The best arrangement, found by experience, is to change rounds at midnight, the relief coming off duty in the morning, coming on again first the next evening. By this arrangement each relief will have a long period of rest on alternate days.

If the period of darkness exceeds 14 hours or it is necessary to run the engines during daylight for charging accumulators, a third relief may be necessary.

Officers. Officers are usually detailed to O.C. E.L. stations and to directing stations of moving lights, but it is not always possible to provide an officer as a relief. In such cases a reliable N.C.O. should be detailed to act for the officer and the latter should take his rest as opportunity arises.

In small defences, mechanists may act as the relief or may be in charge of directing stations or engine rooms, but in large defences they should be detailed in general charge of two or more groups of lights which they should visit throughout the night. Mechanists.

It cannot be too strongly impressed on all ranks that the continuous running of all lights in a defence under war conditions will involve a very heavy strain on the personnel allotted, and that, therefore, every possible effort should be made to diminish work by establishing a well-ordered routine and keeping all the plant in the best possible condition. General.

Instructions for Running.

The following diagrams, &c., should be posted in the various buildings :—

In Directing Station.

(1) A plan on any convenient scale showing the area covered by the lights, with positions of the channels of approach and of our own batteries. If orientated on a table in the station, this may be of considerable use in watching for hostile vessels.
(2) A diagram of the telephone or other connections from the directing station.
(3) Any special instructions for telephone communication.
(4) Copies of local standing orders for manipulation of lights.

In Emplacement.

(5) Diagram of electrical communications.
(6) Copies of local standing orders as to starting, stopping, opening shutters, &c.
(7) Instructions for care of reflectors.
(8) Instructions for manipulation of lamp, changing carbon, &c.

In Engine Room.

(9) Diagram of all electrical connections.
(10) Copies of local standing orders as to starting, stopping, &c.
(11) Instructions for management of engines.
(12) Instructions for care of generators.

Instructions in pamphlet form for the working of defence electric light apparatus are issued to all stations for use of individual officers and men. Instructions.

CHAPTER X.

Incandescent Lighting off Defence Plant.

Contents.

General.

As a general rule a defence electric light installation is situated inside a fort or battery and, whenever the armament consists of light or medium Q.F. guns, incandescent lamps are necessary for the illumination of the gun emplacements, shell and cartridge stores, &c., at night. The defence generating plant is generally utilised for this purpose, accumulators being provided which may, in war time, be charged during the day.

Voltage of incandescent circuit.

The details of maintaining an accumulator battery will be found in Volume III, and the present chapter deals only with the details of the circuits and the practical sizes of batteries in use in connection with defence plant.

The voltage of the circuit should always conform to the voltage of the defence plant, *i.e.*, 60-volt lamps should be used throughout in most cases, or 100-volt lamps at stations where 120-volt generators are in use. It may, however, on account of the size or scattered nature of the installation and consequent cost of the large mains necessitated by the use of 60-volt lamps, be more convenient and economical to select a higher voltage. The accumulator battery for such an installation may be charged—

Methods of charging.

(*a*) By the employment of a special generator driven off the second fly wheel of one of the defence engines. In this case the pulleys of both the defence and special generators must be attached to their armature spindles by means of a special clutch gearing, so that the two may be independent.

(*b*) By the employment of a " booster " or motor generator to give the necessary increased voltage.

(*c*) By employing two defence generators coupled in series. If this method is employed, a 120-volt circuit should be selected and the battery may consist of about 67 cells. Except in large incandescent installations this method is wasteful of power and personnel and has also the disadvantage that under no circumstances can the battery be charged when the defence lights are running, or the incandescent circuit run direct from the generator.

(*d*) The battery may be charged in two or more sections connected in parallel. This is a cumbersome method, necessitating the use of an adjustable resistance in each section to ensure that the charging current is correct in each case, and a special "series" to "parallel" commutator would be desirable.

All these methods present certain disadvantages and only very exceptional circumstances should justify their employment. A comparatively large number of 60-volt lamps can be run at a considerable distance from the battery if the service pattern 150 ampere 37/15 cable is used for the mains and the additional cost of this heavy cable will rarely exceed the cost of special machines as in (*a*) or (*b*), or be more expensive in the end than (*c*).

Sizes of batteries in use.

A service 16-unit generator is capable of charging a battery for a 60-volt installation with a capacity of 1,200 ampere hours, but a battery of more than 1,000 ampere hours and a maximum discharge rate of 200 amperes will rarely be required, and the sizes of batteries installed in connection with defence plant will generally be found to vary between 400 and 700 ampere hours' capacity. The voltage drop between the battery and the most distant lamp should not, as a rule, exceed 4 per cent. The working voltage of each cell may be taken at 2, and the voltage on charge at 2·6. On this basis the battery should consist of not more than 35 cells, 11 of which should be "make-up" cells. This number of "make up" cells is necessary to prevent the correct voltage at the lamps from being exceeded when the lighting and charging are taking place concurrently. With such a battery it may be found necessary at the end of a charge to speed-up the generator to 100 volts, which can be done without risk of injury to the plant. Should, however, the battery be at such a distance from the generator that the drop of voltage in the charging mains is considerable, it will be advisable to reduce the number of cells rather than exceed any further the normal speed of the engine. The number of cells should not be reduced to less than 33, and in this case there should be 9 "make-up" cells.

Accumulator chamber.

The accumulator room should be in a central position as regards the buildings, etc., to be lighted, so that the voltage at the lamps may vary as little as possible with the requirements of the load, but it will be seen from the preceding paragraph that it should also be as near to the generator as possible. The exact position is practically determined by the relative cost of the charging and distributing mains, and it will generally be found more economical to increase the size of the charging mains. The switchboard should be contained in a separate room or annexe. Ample room for the battery should be provided, so that all the cells are readily accessible. If space permits, the cells should be arranged in one tier on wooden stands 18 inches high for lead-lined wooden boxes, or 2 feet 6 inches high for glass cells up to 450 ampere hours' capacity. A room 18 feet by 10 feet should suffice for the battery described above. The room should be thoroughly ventilated from the outside and all doors and windows should be left open when the cells are being charged, as the gases given off form an explosive mixture. Smoking or lighting matches near the accumulator room should be strictly forbidden. The cells are usually connected by lead burning the lugs, but at stations abroad it is advisable to use brass bolts and nuts, as the process of lead-burning requires special apparatus and is not at present included in the course of instruction for electricians at the E.L. schools. The bolts and nuts should be coated with vaseline and all wood and metalwork in the chamber as well as the insulation of the leads, if cables are used, should be coated with antisulphuric enamel.

Arrangements of circuits.

Accumulators may be used with any system of distribution which admits of their regular charge and discharge, the distributing board system being now almost universally adopted. Circuits in connection with Defence E. L. Plant should always be arranged so that the lighting may be done from the generator, or accumulators, or both together, or the cells may be charging while the lighting is being done. Figure 107 shows the arrangement of the circuit required in its simplest form which is shown in greater detail in Figs. 108 and 109A.

Engine-room switchboard.

A typical diagram of the connections on the switchboard in an engine room containing two generators is given in Fig. 108. The single pole switches on the positive side of the arc light circuit shown in Fig. 77, Chapter VI, are replaced by double pole change-over switches of a suitable type and are connected as shown so that either generator may be used to charge the battery. It will be noticed that the ammeter is in circuit on the negative side whether the generator is charging the battery or running the light. An adjustable resistance frame, 200 amperes ·25 ohms, is shown in the positive main to accumulator switchboard. Two of these frames may be found necessary. An adjustable resistance in the shunt coil of the generator and a rheostat switch on the engine room switchboard is a better method of controlling the charging current, but is not at present a service store. The generator used for charging should be converted into a shunt wound machine for the time being by cutting out the series coils. This is best done at the machine itself.

Connections when generators are paralleled.

The circuit to accumulator battery is very much simplified when all the generators in the engine room are arranged for parallel working. The mains to accumulator switchboard are permanently connected to the negative and equalizing bus-bars through suitable fuzes, as shown in Fig. 109, and any of the generators can be used to charge by closing one or other of the switches A. Care should be taken that the switches B are left open so as to disconnect the circuits to the emplacements from the bus-bars. It will be seen that any generator used for charging is connected as a shunt wound

ACCUMULATOR INSTALLATIONS.

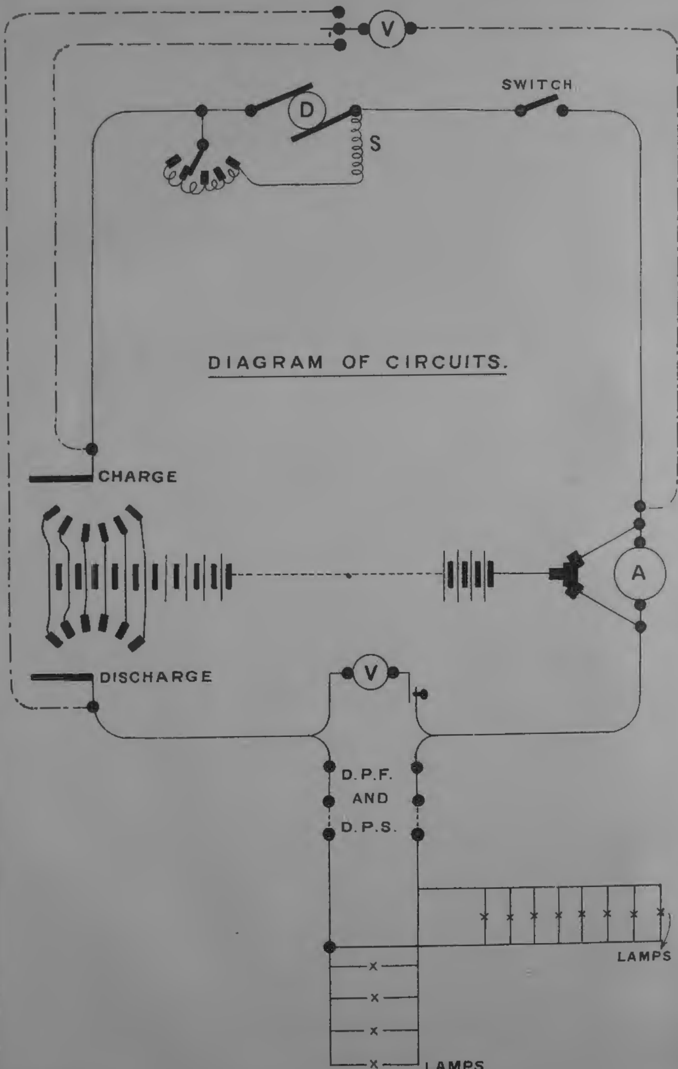

Figure 107.

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ACCUMULATORS INSTALLED WITH DEFENCE E. L. PLANT.

DIAGRAM OF CIRCUITS.

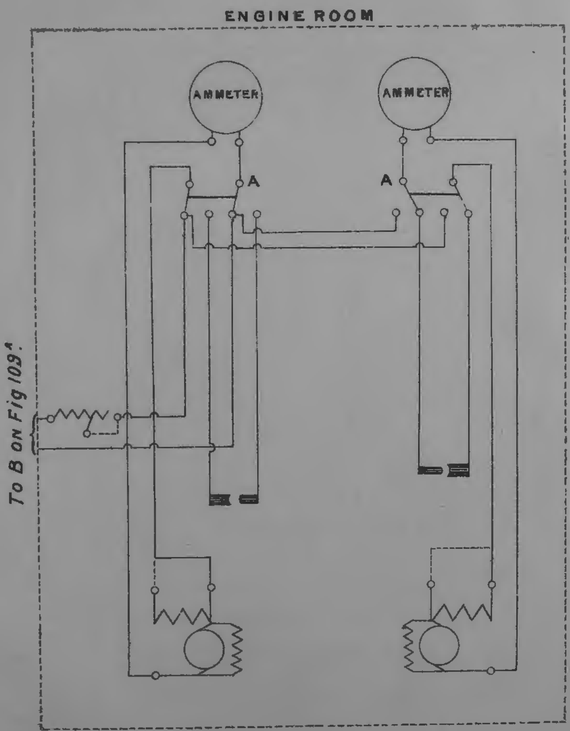

Figure 108.

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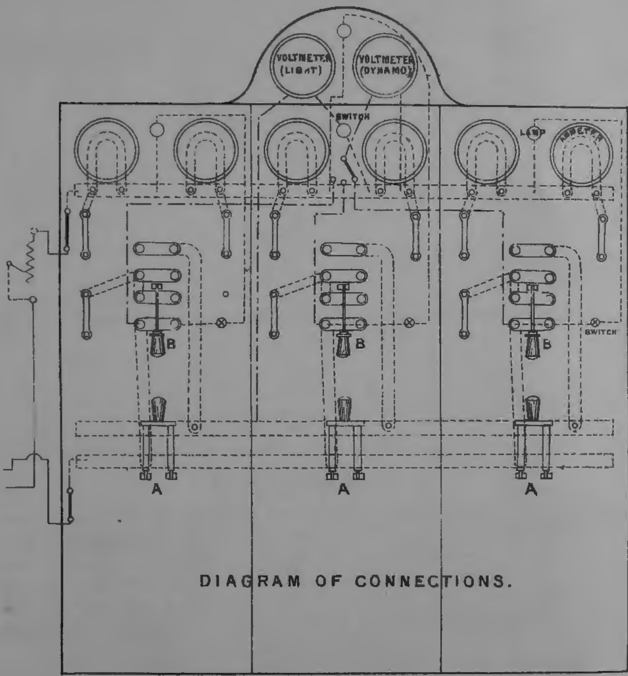
ACCUMULATORS INSTALLED WITH DEFENCE E.L. PLANT.

DIAGRAM OF CIRCUITS.



ENGINE ROOM SWITCH BOARD.

Figure 109.

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BOARDS SECONDARY BATTERY.

TABLET CONTAINING DIAGRAM OF CONNECTIONS.

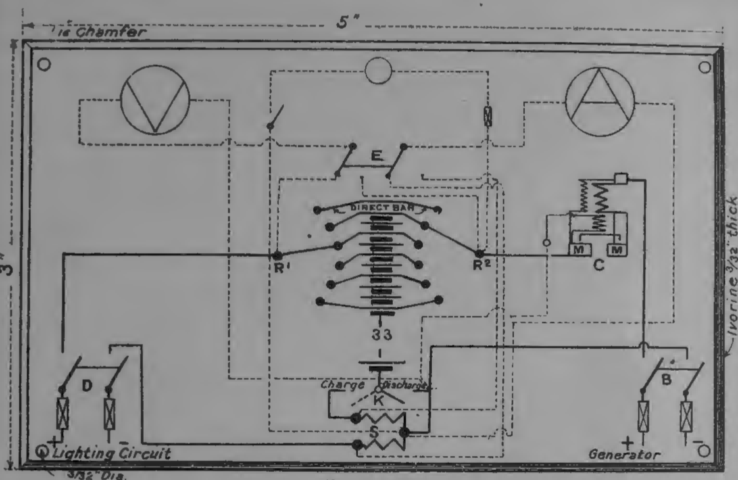

FIG. 109A.

TABLET CONTAINING DIRECTIONS.

5" × 3"

DIRECTIONS.

A. AMMETER. V. VOLTMETER C. CRAWLEY CUT OUT.

B. GENERATOR D.P. SWITCH. D. CONTROL D.P. SWITCH LIGHTING CIRCUIT.

E. COMBINED SWITCH FOR AMMETER AND VOLTMETER.

R¹. R². RADIAL SWITCHES. K. CHANGE-OVER SWITCH.

S. TWIN SHUNT FOR AMMETER.

TO CHARGE ONLY: CLOSE B, MOVE R² TO CELL REQUIRED, CLOSE K ON CHARGE SIDE. LEAVE D OPEN.

TO CHARGE & RUN LIGHTS SIMULTANEOUSLY: CLOSE B, MOVE R¹, R² TO CELLS REQUIRED, CLOSE K ON CHARGE SIDE. CLOSE D.

TO DISCHARGE ONLY: CLOSE D, CLOSE K ON DISCHARGE SIDE. LEAVE B OPEN. MOVE R¹ TO CELL REQUIRED.

TO READ VOLTS OR AMPERES IN ANY CIRCUIT: MOVE SWITCH E. TO STOP FOR THAT CIRCUIT.

TO RUN LIGHTS DIRECT FROM GENERATOR: MOVE R¹. R². TO TOP (DIRECT) STOPS. CLOSE B. PLACE FORK INTO MERCURY CUPS. LEAVE K OPEN. CLOSE D.

FIG. 109B.

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CRAWLEY AUTOMATIC CUT OUT.

DIAGRAM OF CIRCUITS.

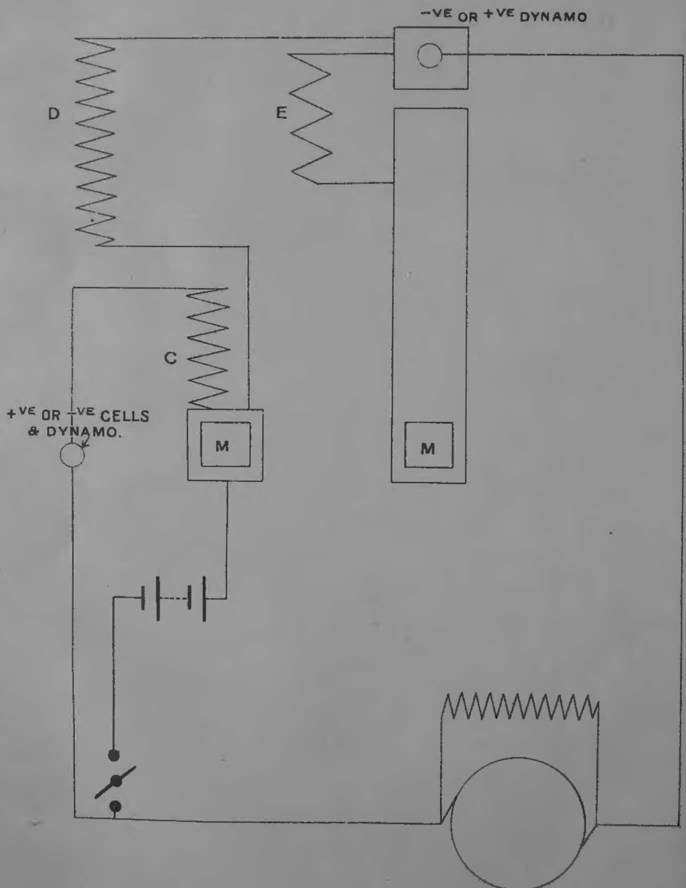

Figure 110.

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machine without any alteration to the connections at the machine terminals, and that the incandescent lighting may be run from the bus-bars or the battery charged (up to a certain limit) when the defence lights are running.

Accumulator switchboard.

A common form of accumulator switch board is used in connection with Defence E. L. Plant as shown in Fig. 109A. The mains from engine room are brought to a double pole switch B. The positive pole of the battery is connected to switch R_2 which has a pair of terminals for each "make up" cell and a spare pair for running the lighting direct from generator. The negative pole of the battery is connected to the 2-way "charge and discharge" switch K and the lighting circuits are controlled from a double pole switch D and D.P. fuze. With switch K in the "charge" position it will be seen that on closing switch B the generator is connected to the battery through switch K on the negative side, and on the positive side through the automatic cut out switch C and switch R_2. The object of the former is to prevent a reverse current from battery to generator and a good form of this switch is described below with detailed diagram.

With the switch K at "discharge" the battery is connected to the lighting circuit through switch R_1 on the positive side and through switch K on the negative. The ammeter is in circuit during either charge or discharge. A 2-way switch is provided for the voltmeter connected to either side of the step switches R_1 and R_2 so that the voltage can be read during charge or discharge.

The step switch R_1 is necessary to allow of extra cells being thrown in or cut out according to the requirements of the load. This is effected on the "discharge" switch R_1. As these cells will not have such a heavy duty to perform as the remainder of the battery they will be fully charged before the remaining cells come up and are cut out as they rise on the "charge" side of the switch. Care should be taken during charge that the switch on the discharge side is not on a higher step than that on the charge side or the intermediate cells will be discharged if there is any load on the lighting circuit. The top pair of contacts are not connected to the battery at all and when both the switch levers are on these contacts the generator is connected direct to the D.P. switch D. It is immaterial when running direct whether switch K is in the "charge" or "discharge" position.

Crawley's switch.

A diagram of the connections in Crawley's automatic switch is given in Fig. 110.

The action of the switch is as follows:—On closing the main switch, the coil C is energised by the battery and its coil becomes magnetised. The differential coil D is also excited by a current depending for its direction and magnitude on the difference between the voltage of the battery and generator. As soon as the latter exceeds the former by about 6 volts the coil C is repelled from D and the circuit between battery and generator is completed across the mercury cups by the dipper. Coil E is then magnetised by the charging current in the same sense as coil D (which is then short circuited) and holds the dipper down in the mercury cups so long as the charging current continues to flow. As soon however as the current in coil E falls to zero, the dipper is released and the circuit broken.

It will be seen that the switch fulfils two functions. It prevents a reverse current from battery to generator and it automatically closes the circuit for charging when the voltage of generator has reached a certain percentage above that of the battery.

Setting up.

In setting up the switch the mercury cups should be about three-quarters full, with slightly more mercury in the right hand cup, so that the dipper strikes the mercury in both cups simultaneously. The switch should be connected as shown in Fig. 109A, the positive main from generator and the positive pole of the battery (switch R_2) being joined to similarly marked terminals on the switch, and the terminal marked "negative of cells and dynamo" joined by a fine wire to the negative main. This connection is shown in Fig. 109A to the generator side of the main switch.

Instructions for charging.

The following instructions should be observed for charging with this form of switchboard and the connections described above :—

1. Convert the generator into a shunt wound machine in the manner already directed.

2. To ensure that the polarity of the generator is correct, pass a current from the battery through the field magnet coils for a few minutes before starting the engine.

To do this the following procedure is necessary :—

In the engine room.—

(*a*) Raise the brushes off the commutator and put in all the resistance in the adjustable resistance frame.

(*b*) Close one or other of the switches A (to the left) leaving the other over to the right (Fig. 108)

or

close one or other of the switches A and open all the switches B (Fig. 109).

At the accumulator switchboard.—

(*a*) Put the switch K at "charge."

(*b*) Close the main switch B and the step switch R_2 (on the charge side).

The circuit will then be completed through the shunt coil D of the auto-switch (Fig. 110). With the Crawley switch this current may be intensified by pressing the dipper into the mercury cups by hand but with other patterns of switch which are polarized this may demagnetise or even reverse the polarity of the permanent magnets and should not be done.

In any case the dipper should be released before the main switch is opened.

(c) Having noted the voltmeter reading, open the voltmeter switch in the engine room and break the circuit by opening the main switch. If the circuit is broken before the voltmeter switch is opened the discharge from the shunt coil will probably damage the voltmeter.

If the generators are connected in parallel as in Fig. 109 switch B should be closed before breaking the circuit. This will provide a byepass for the discharge from the shunt coil through the automatic shunt resistance of the arc light circuit.

3. To start a charge.—

In the engine room.—

Start the engine and lower the brushes. Put in all the resistance in adjustable resistance frame and as soon as the voltmeter reads about 5 per cent. more than its former reading close one or other of the switches A, Fig. 108 (to the left) leaving the other over to the right.

or,

Close one or other of the switches A and open all switches B, Fig. 109.

Note the reading of ammeter and adjust resistance or if necessary alter the speed of the engine until the current is correct.

At the accumulator switchboard.—

(b) Place the "charge" lever of switch R_2 on the top step and the "discharge" lever on a step suitable for the voltage of the lamps, but about 4 per cent. lower rather than higher as the E.M.F. of the battery will rise.

Place switch K at charge and close the main switch B.

During the charge the following points should be attended to:—

The current should be kept constant at the normal charging rate for the particular battery. To maintain the current it may be necessary to increase the speed of the engine until the voltage at the generator rises to 100 which can be done without risk of injury to the machine.

The voltage and specific gravity of each cell should be taken from time to time and any cell which does not come up with the others in this respect or which does not gas freely with the others towards the end of the charge should be carefully examined for pieces of paste or scale sticking between the plates and so short circuiting the cell.

(c) If found, these should be carefully removed with a piece of paraffined wood or ebonite. Ebonite L and T cleaning rods are usually supplied with the battery for this purpose. The cell should be cut out during discharge by disconnecting it and bridging over the gap with a suitable conductor, always, however, re-inserting the cell during charging.

The "make-up" cells should be cut out as they come up by the switch lever on the charge side of switch R_2.

If the lighting is being done at the same time the voltage at the

D.P. switch D must be kept constant by moving the switch lever on the discharge side of switch R_1 as the E.M.F. of the battery rises.

At the completion of the charge, the engine should be slowed down until the dipper comes out of the mercury cups when the circuit should be broken by opening the main switch B.

During discharge switch K is put to discharge and the switch lever on the charge side of switch R_2 on the " off position " or the highest step. The switch lever on the discharge side is regulated in accordance with the requirements of the load, but it is advisable to discharge the " make up " cells to some extent to keep them in a healthy condition.

A full charge should always be given, *i.e.*, the charging should be continued until the cells gas freely and the E.M.F. of each has risen to 2·5 or 2·6 volts. Nothing tends to destroy the plates more rapidly than partly charging the cells and then exhausting them.

It is necessary to re-charge the cells when the S.G. of the electrolyte has fallen to about 1·180 the exact figure depending on the type of cell. On no account should the E.M.F. of a cell be allowed to fall below 1·8 volts. The discharge must be stopped when this point is reached and in cases where there is no electrician on the spot in charge of the battery it is often advisable to insert an automatic cut out between the battery and the distributing bars which will operate when the voltage has reached this limit. A good form of switch for the purpose is supplied by Messrs Dorman and Smith.

CHAPTER XI.

Field Electric Lighting.

Contents.

Electric lighting has not yet been definitely introduced into the British Army organisation for work in the field, but a certain amount of experience was obtained with such plant during the South African War, and experiments have since been carried out and patterns sealed to govern the supply of such plant should it be required on an emergency. General.

The general arrangement has followed that adopted for fortresses, except that when small projectors are used two or three lights are often run off one power-wagon.

As weight was a very important consideration, every part of the apparatus has had to be redesigned.

The size of projectors adopted are 90-cm., 60-cm. and 35-cm. in diameter. Projectors.

The reflectors are usually of metal, but as a completely satisfactory pattern of metal reflector has not yet been evolved, a proportion of glass reflectors are carried for each projector.

The frame which holds the reflector can be readily detached from the body of the projector, so that it can be exchanged if damaged or if it is required to change the pattern of reflector. One or more spare frames, fitted with reflectors, are carried for each projector.

The projector is made as light as possible by the use of aluminium, so that it can be carried by hand. The 90-cm. projector can be carried by four men; the 60-cm. or 35-cm. by two.

The projector is traversed or elevated by hand in accordance with orders conveyed by buzzer, telephone or whistle.

The weights of the different patterns complete with reflectors are:—

	Lbs.
90-cm.	700
60-cm.	280
35-cm.	80

Lamps. Lamps of the automatic horizontal type are provided for each pattern of projector.

The carbons in use with these lamps are :—

	Positive. Mm.	Negative. Mm.
In 90-cm. projector	20	30
In 60-cm. projector	16	23
In 35-cm. projector	12	18

Projector carriage. The 90 and 60 cm. projectors for field use are mounted on a limbered carriage similar in design to that for a field gun, the projector being on the body, with one spare reflector frame; the cable and spare stores on the limber.

The projector is fitted on a hinged platform, so that it may be carried in a vertical position when limbered up.

The projector is directed roughly by moving the trail of the carriage, and it is capable of all round traverse. The projector is elevated and depressed by rack and pinion gear. In both cases slow motion is provided.

The projector is fixed in a socket on the platform, so that it can be readily detached and moved by hand into positions where the carriage cannot be taken. A tripod stand for use in such cases is carried on each projector carriage.

A pattern of portable expanding tower, with a maximum height of 30 feet, has been tried for use in flat country where height is not readily obtainable. It is carried on a separate cart drawn by two horses.

The limber of the projector carriage carries the cable required on a drum, with arrangements for paying out and winding up the cable by hand or off the wheel. There is also a locker for spare reflectors, tools, &c.

The carriage, with limber, is drawn by four horses.

Total weight behind the team :—

	Cwts.
With 90-cm. projector	30
With 60-cm. projector	26

The 35-cm. projectors are carried in any convenient wagon, and lifted out by hand and worked on tripods or on the ground. Three projectors, with leads and spare reflectors, can be carried in one G.S. wagon.

Cables. The cables used with 90-cm. projectors are two lengths of $\frac{19}{16}$, each 300 yards long. The cable for the 60-cm. projector is a 400-yard length of twin lead $\frac{7}{15}$, unarmoured, but extra strongly braided.

The cable for the 35-cm. projector is 400 yards of twin $\frac{7}{18}$.

Fortress mobile lights. When mobile projectors are used with mechanical traction the carriages are similar to the above, except that the limbers are fitted for mechanical draught.

Power wagon. Two patterns of power wagon have been evolved: (*a*) For field use, with horse draught; (*b*) For fortress use on land fronts, sieges, &c. Field use.

The first consists of a 15 horse-power internal-combustion engine, burning heavy oil, mounted on a frame of the ordinary field type, with No. 199 axle and No. 43 wheels. The front carriage has a full lock.

The generator is of 9 kilowatts, direct coupled to the engine, and runs at 1,000 revolutions.

The total weight of the wagon is 48 cwts.; it is drawn by six horses.

Fortress and siege use.

The second type is automobile of 20–25 horse-power, burning heavy oil, with a 12½ kilowatt generator. It is fitted with gear for dragging the projectors and limbers.

It weighs 4 to 6 tons.

Instruments, switches, &c.

Combined volt and ammeters are used at the projector, bolted on to the arm of the projector, internally illuminated, dial reading to 120 volts 120 amperes, suited to both sizes of projector. Fortress instruments are used on the generator wagon. Weather-proof switches are used.

No shunt resistance or automatic switches are used. The engine driver is made aware by signal when the load is coming on or off.

Telephones and cable are provided of similar type to that used by infantry in the field.

Electrical Details.

The current and voltage adopted as the normal for field lights are given in the following table, which also shows the loss in leads and voltage required at the generator:—

Size of Projector.	Current.	Voltage at Lamp.	Volts Lost in Leads.	Volts at Generator.
90-cm.	90	56 v.	22	80
60-cm.	55–60	50 v.	31	82
35-cm.	20–25	45 v.	32	80

With three 35-cm. lights the total current is 60*a*. The length and pattern of lead adopted comply with the above conditions. No adjustable resistance is required as the lead is always in circuit.

The cross section of the lead has been made as low as possible to save weight, and the lead will heat considerably if enclosed or even kept coiled on the drum while running. For this reason it is desirable to run nearly the whole cable off the drum whatever the distance from the engine to light.

It may often be convenient to use the power plant for running small arc or incandescent lamps in camp. To facilitate this, each generator has an adjustable resistance in its shunt circuit by which the voltage can be raised to 200, enabling two small arc lamps to be run in series.

Personnel.

The *personnel* required to man the above plant in war is about 12 rank and file per power wagon, of whom 4 should be electricians, 4 engine drivers, and 4 of other trades. In addition there should be 1 officer, 1 mechanist, and 1 sergeant to each two sets, also trumpeters and artificers as required. A section (2 power wagons, 2/60 cm., 3/35 cm.) occupies 90 yards on the road, and requires 15 pairs of horses, 15 drivers, 2 mounted N.C.O.'s.

Vulnerability of Lights.

Though it is possible to take the range of a light, it is a very difficult and small target to hit. Shields are carried on the trail carriage to protect operator and lamp.

Metal mirrors when hit are as a rule punctured or dented and the light is not impaired.

In semi-permanent defences head cover can be easily constructed to keep off most shrapnel bullets.

Plain mirrors, when available, may be used for reflecting the beam, very little light is lost, and the projector and detachment can be then completely concealed under cover.

Methods of Using the Lights.

In attack. In attack, the large or medium sizes are most useful. In fairly open country they should come into action at about 800 to 1,000 yards from the defence, and can be used (1) to dazzle the defenders; (2) to illuminate ground to be passed over by the attack; (3) to give direction to the attack and assist in co-operation of adjacent units; (4) to assist in a feint attack; (5) to assist R.A. fire at distances up to 2,000 yards.

They are most effective if they can be placed on an elevation so as to shine over the heads of the attackers on to the defenders' positions. In such cases the diffused light is sufficient to illuminate the ground over which the attack is advancing and the attackers rifle sights, while the defenders will be dazzled by the direct rays. This latter effect is increased by a dispersal of the attacking lights so as to concentrate on the defenders from several points of the compass.

In defence. For the defence, lights can be used (1) to search the front of the position, especially in observing defiles or roads by which the enemy must advance; (2) as sentry beams thrown across a flat plain from a position on one flank; (3) as dispersed lights, forming a band of illumination a short distance in front of the line of trenches.

As the terrain is rarely flat, the conditions are very different to those in coast fortresses, so that large searching lights should be avoided, except to dazzle the attackers and oppose their searching lights, and the defence will be best served by a number of small dispersed lights, each with its bearing and elevation adapted to a definite piece of ground. All lights must be sited on somewhat high ground, otherwise the shadow from a bush or rise in the ground may give cover up which the enemy can creep.

The defending troops should be on a lower level than the lights, and the main line of obstacles should be at the inner limit of the lighted area. When showing across the front the lights should be somewhat to a flank of the defending troops, otherwise the defenders' target is best illuminated when the beam meets it at right angles. When sited 300 to 400 yards behind the fire trenches great assistance is afforded to aimed rifle fire.

General uses for field search lights are :—

(1) Distant signalling.

(2) When not in the presence of an enemy, to illuminate the construction of bridges at night or entrenchments, redoubts, &c.

(3) To light camping areas :—

(4) To guide a column back to camp in hilly or close country.

Drill for Using Lights in Attack.

To get the best use of lights in the attack a preliminary reconnaissance is important. This will include sheltered positions for the power wagons, and the sites for projectors, with route for connecting cable, also the position of the officer charged with the direction of the lights, who should be connected to the projectors by telephone.* In selecting these positions, the maximum length of lead for the class of light must be considered. It is also desirable to arrange that the route of the cable should not be crossed by wheeled traffic.

On approaching the position the power wagon will be ordered to halt at the place selected, while the projector wagon will move forward at the pace ordered by the officer, the carriage will be unlimbered, and the limber will return at a walk, paying out the cable. Care must be taken to leave sufficient slack cable at the projector end to allow of small changes of position.

The following drill is arranged for a party of 1 officer and 10 N.C.O.'s and men.

With practice a light should be got into position and start running in about 10 to 15 minutes from the time of halting the power wagon.

The detachment consists of 1 N.C.O. and 9 men.

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* One officer can only efficiently direct two lights, though all should be under *one* head for transmission of orders. The small lights can be best directed by the officer or N.C.O. actually by the light.

Duties on taking up a Position.

Preliminary. The wagons are brought up near the position and halted. The numbers all dismount and examine their respective stores and plant.

Allotment of duties. N.C.O., in charge generally.

No. 1 is the senior electrician, and in general charge of the electrical gear.

No. 2 is the dynamo attendant and assistant to No. 1.

No. 3 is the telephone man at projector.

No. 4 is the telephone operator for E.L. director station.

No. 5 is the senior engine driver.

No. 6 is an engine driver and assists No. 5.

Nos. 7, 8, 9 are spare men, and act as reliefs during long continuous runs; one must be an electrician and one an engine driver.

Successive duties for each number.

Number 1—

(*a*) Ascertains during the first halt (near the position) that all the plant is correct, receiving reports from the other numbers.

(*b*) Waits further orders; sent through mounted N.C.O.

(*c*) Accompanies projector and limber to selected site. Gives, "Action—front."

(*d*) Pulls off 20 yards slack cable: when ready orders limber to drive on.

(*e*) Takes out all stores required (ascertaining what mirror is required), assisted by No. 3 and 4; makes connections and prepares for running.

(*f*) Reports when ready, and switches in when volts registered.

Number 2—

(*a*) During first halt looks round dynamo.

(*b*) Accompanies projector and limber to selected site, pacing the distance, and informs section officer.

(*c*) Return with limber to engine.

(*d*) Selects the actual site for the engine-wagon; points out same to mounted N.C.O.

(*e*) Leads limber close to engine plant.

(*f*) Connects up, cleans commutator, remains at dynamo till light is running steady, then joins his light and assists No. 1.

Number 3—

(*a*) Accompanies section officer to site selected, carrying post or lamp.

(*b*) Remain at site, indicating same by lamp if at night.

(*c*) When limber arrives, and takes out his stores, prepares for running out telephone line.

(*d*) Tests circuit with No. 4.

Remains at projector, transmits all orders received to No. 1, using the head receiver.

Number 4—

(*a*) Accompanies section officer to site selected; bring direction post, and places this in position as ordered.
(*b*) Assists No. 1 to pull off cable and remove all stores required from the limber.
(*c*) Receives instructions for the E.L. director's site.
(*d*) Straps in his cable drum and tests circuit with No. 3; lays out telephone circuit.
(*e*) Reports at once when circuit is through.
(*f*) Transmits all orders as required, and must be prepared to change position.

Number 5—

(*a*) During first halt has general look round and, when ordered, starts his blow lamps.
(*b*) Accompanies engine to final position.
(*c*) On receiving orders *when* to start up he prepares for running, (or) starts immediately teams have been led away.

Number 6—

Assists No. 5.

Mounted N.C.O. (half section)—

(*a*) Accompanies section officer to selected site.
(*b*) Returns to plant and leads them up the shortest and best way.
(*c*) Leads back limber; transmits orders *when* to start up.

The spare men—

Accompany projector to the site; lay out cable and prepare trenches when it crosses any roads.

The team remains hooked into the engine plant until the limber returns. The engine is led into the site selected by No. 2, and when connections are complete all teams unhook and retire under cover to a safe distance.

Duties on leaving position.

Duties of each number.

Section will retire (advance). *Prepare to limber up.*

"Section will retire (advance)—Prepare to limber up"—

Number 1—

(*a*) Opens carbons slowly, then switches off.
(*b*) Assisted by No. 2 runs projector back into best cover for limbering up.
(*c*) Disconnects cable and brings projector to travelling position.
(*d*) Returns stores to trail box and prepares other stores for limber boxes; fetches in aiming posts.
(*e*) When limber arrives, limbers up, assisted by No. 2.
(*f*) Packs all stores in limber, and gives order to retire at the trot.

Sub-section walk, march, trot.

"Sub-section—Walk, march, trot"—

Number 2—

(*a*) Assists No. 1 to run projector under cover.
(*b*) Doubles back to limber and gives "To limber up" to mounted N.C.O. and No. 5.
(*c*) Disconnects and packs up engine connection.
(*d*) Gives order to teams to walk, march, and halt as required.
(*e*) Secures end of cable and assists No. 1 to limber up and pack up, and then mounts on limber seat.

Number 3—

(*a*) Disconnects his telephone when he has ascertained that No. 4 has received the order. Leaves it near projector with No. 1.
(*b*) Double back to limber and mans one handle for picking up cable.
(*c*) When limber arrives at projector he at once doubles back to his section wagon.

Number 4—

(*a*) Picks up his telephone line and leaves it near projector with No. 1.
(*b*) Doubles back to limber and mans the other handle of the cable drum.
(*c*) When limber arrives at projector see telephones packed, then doubles back to hind section wagon.

Note.—Nos. 3 and 4 can catch hold of the projector to help themselves along.

Number 5—

(*a*) Receives order from No. 2, and eases engine.
(*b*) Packs up all loose tools and stores.
(*c*) Stops engine and shuts up doors.
(*d*) Reports to mounted N.C.O. when ready to move, and mounts on seat.

Number 6—

Assists No. 5.

Mounted N.C.O.—

Receives orders from No. 2.
(*a*) Sees projector teams hooked into limber and sends them forward, directed by No. 2.
(*b*) When engine stops sees engine teams hooked in and forms engines and section wagon ready to retire (or advance).

APPENDIX I.

TREATMENT TO BE FOLLOWED IN CASE OF A DANGEROUS SHOCK.

It is not likely, with the pressures in use in the Service, that this contingency will arise; it is just conceivable, however, that by the accidental breaking of the shunt coil of a dynamo, or similar circumstance, a man might be rendered unconscious.

In such an event, the proper course to pursue is to treat the patient as if apparently drowned, and with this in view, the instructions on this subject issued by the Royal Lifeboat Institution are appended in full.*

Directions for Restoring the Apparently Drowned.

The leading principles of the following Directions for the Restoration of the Apparently Dead from Drowning are founded on those of the late Dr. Marshall Hall, combined with those of Dr. H. R. Silvester, and are the result of extensive inquiries which were made by the Royal National Lifeboat Institution in 1863–4 amongst Medical Men, Medical Bodies, and Coroners throughout the United Kingdom. These directions have been extensively circulated by the Institution throughout the United Kingdom and in the Colonies. They are also in use in His Majesty's Fleet; in the Coast-guard Service; at all the Stations of the British Army at home and abroad; in the Light Houses and Vessels of the Corporation of the Trinity House; the Metropolitan and Provincial Police Forces; the Metropolitan School Board Schools; and the St. John Ambulance Association.

I.

Send immediately for medical assistance, blankets, and dry clothing, but proceed to treat the patient instantly on the spot, in the open air, with the face downward, whether on shore or afloat; exposing the face, neck, and chest to the wind, except in severe weather, and removing all tight clothing from the neck and chest, especially the braces.

The points to be aimed at are—first, and immediately, the restoration of breathing; and secondly, after breathing is restored, the promotion of warmth and circulation.

The efforts to restore breathing must be commenced immediately and energetically, and persevered in for one or two hours, or

* These instructions are printed by permission of the Royal Lifeboat Institution.

until a medical man has pronounced that life is extinct. Efforts to promote warmth and circulation, beyond removing the wet clothes and drying the skin, must not be made until the first appearance of natural breathing; for if circulation of the blood be induced before breathing has recommenced, the restoration to life will be endangered.

II.—To Restore Breathing.

To Clear the Throat.—Place the patient on the floor or ground with the face downwards, and one of the arms under the forehead, in which position all fluids will more readily escape by the mouth, and the tongue itself will fall forward, leaving the entrance into the windpipe free. Assist this operation by wiping and cleansing the mouth.

If satisfactory breathing commences, use the treatment described below to promote warmth. If there be only slight breathing—or no breathing—or if the breathing fails, then—

1.—INSPIRATION.

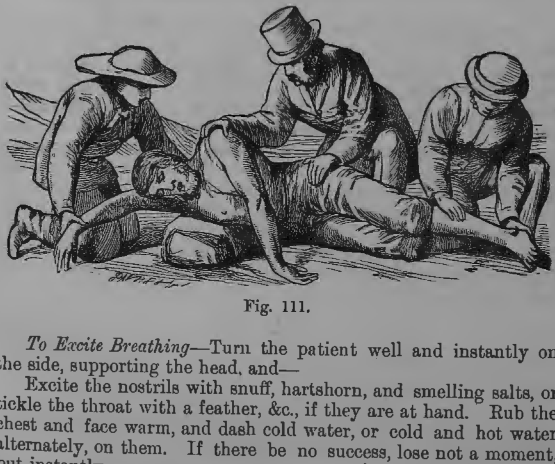

Fig. 111.

To Excite Breathing—Turn the patient well and instantly on the side, supporting the head, and—

Excite the nostrils with snuff, hartshorn, and smelling salts, or tickle the throat with a feather, &c., if they are at hand. Rub the chest and face warm, and dash cold water, or cold and hot water alternately, on them. If there be no success, lose not a moment, but instantly—

To Imitate Breathing—Replace the patient on the face, raising and supporting the chest well on a folded coat or other article of dress.

Turn the body very gently on the side and a little beyond, and then briskly on the face, back again, repeating these measures cautiously, efficiently, and perseveringly, about fifteen times in the minute, or once every four or five seconds, occasionally varying the side. (By placing the patient on the chest, the weight of the body forces the air out; when turned on the side, this pressure is removed, and air enters the chest.)

On each occasion that the body is replaced on the face, make uniform but efficient pressure with brisk movement, on the back between and below the shoulder-blades or bones on each side, removing the pressure immediately before turning the body on the side.

During the whole of the operations let one person attend solely to the movements of the head and of the arm placed under it. (The first measure increases the expiration—the second commences inspiration.)

The result is respiration or natural breathing, and if not too late, life.

Whilst the above operations are being proceeded with, dry the hands and feet, and as soon as dry clothing or blankets can be procured, strip the body, and cover or gradually reclothe it,

2.—EXPIRATION.

Fig. 112.

The foregoing two Illustrations show the position of the Body during the employment of Dr. Marshall Hall's Method of inducing Respiration.

but taking care not to interfere with the efforts to restore breathing.

III.

Should these efforts not prove successful in the course of from two to five minutes, proceed to imitate breathing by Dr. Silvester's method, as follows:—

Place the patient on the back on a flat surface, inclined a little upwards from the feet; raise and support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder-blades.

Draw forward the patient's tongue, and keep it projecting beyond the lips; an elastic band over the tongue and under the chin will answer this purpose, or a piece of string or tape may be tied round them, or by raising the lower jaw, the teeth may be body forces the air out; when turned on the side, this pressure is removed, and air enters the chest.)

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To Imitate the Movements of Breathing.—Standing at the patient's head, grasp the arms just above the elbows, and draw the arms gently and steadily upwards above the head, and keep

1.—INSPIRATION.

Fig. 113.

them stretched upwards for two seconds. (By this means air is drawn into the lungs.) Then turn down the patient's arms, and press them gently and firmly for two seconds against the sides of the chest. (By this means air is pressed out of the lungs.)

Repeat these measures alternately, deliberately, and perseveringly, about fifteen times in a minute, until a spontaneous effort to respire is perceived, immediately upon which cease to imitate the movements of breathing, and proceed to induce circulation and warmth.

2.—EXPIRATION.

Fig. 114.

The foregoing two Illustrations show the position of the Body during the employment of Dr. Silvester's Method of inducing Respiration.

IV.—Treatment after Natural Breathing has been Restored.

To Promote Warmth and Circulation.—Commence rubbing the limbs upwards, with firm grasping pressure and energy, using handkerchiefs, flannels, &c. (By this measure the blood is propelled along the veins towards the heart.)

The friction must be continued under the blanket or over the dry clothing.

Promote the warmth of the body by the application of hot flannels, bottles, or bladders of hot water, heated bricks, &c., to the pit of the stomach, the arm-pits, between the thighs, and to the soles of the feet.

If the patient has been carried to a house after respiration has been restored, be careful to let the air play freely about the room.

On the restoration of life, a teaspoonful of warm water should be given; and then, if the power of swallowing have returned, small quantities of wine, warm brandy-and-water, or coffee should be administered. The patient should be kept in bed, and a disposition to sleep encouraged.

General Observations.

The above treatment should be persevered in for some hours, as it is an erroneous opinion that persons are irrecoverable because life does not soon make its appearance, persons having been restored after persevering for many hours.

Appearances which generally Accompany Death.

Breathing and the heart's action cease entirely; the eyelids are generally half closed; the pupils dilated; the tongue approaches to the under edges of the lips, and these, as well as the nostrils, are covered with a frothy mucus. Coldness and pallor of surface increase.

Cautions.

Prevent unnecessary crowding of persons round the body, especially if in an apartment.

Avoid rough usage, and do not allow the body to remain on the back unless the tongue is secured.

Under no circumstances hold the body up by the feet.

On no account place the body in a warm bath unless under medical direction, and even then it should only be employed as a momentary excitant.

APPENDIX II.

TREATMENT TO BE FOLLOWED IN CASE OF INJURY BY ACIDS.

I.—Immediate Treatment of Wounds of the Skin Caused by Acids.

EXCLUDE the air by means of lint steeped in sweet oil, arranged so as to cover the affected part. Then place a layer of cotton wool over the lint, and secure by a bandage.

II.—Immediate Treatment of Wounds of the Eye Caused by Acids.

Wash out the whole eye carefully with a strong alkaline solution, then apply two cocaine discs and cover up the eye with a handkerchief or bandage.

To apply the discs, pull down the lower eyelid and place the discs on it by means of a small camel's hair brush, then allow the lid to resume its normal position. The man should be sent to hospital as quickly as possible in a cab.

If the shock from severe pain is great, the patient should lie down and stimulants may be given.

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