QUESTIONS AND ANSWERS BY PRACTICAL MEN NEW FEATURE

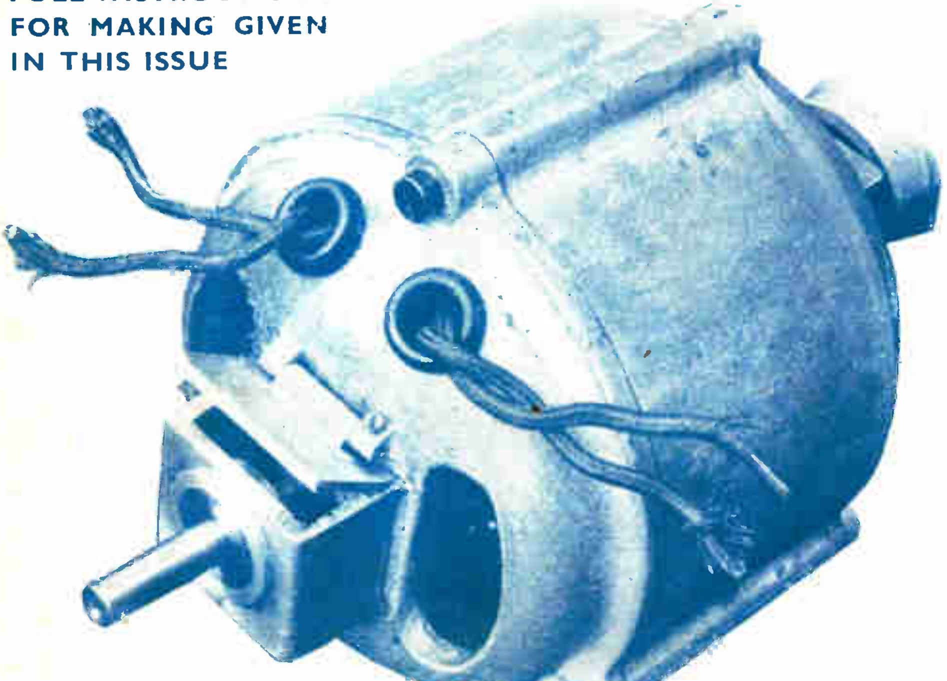
The PRACTICAL ELECTRICAL ENGINEER

A MONTHLY MAGAZINE OF ELECTRICAL PROGRESS

VOL. II.—No. 13 SEPTEMBER, 1933

DESIGN FOR A $\frac{1}{8}$ H.P. INDUCTION MOTOR

FULL INSTRUCTIONS FOR MAKING GIVEN IN THIS ISSUE



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The PRACTICAL ELECTRICAL ENGINEER

A MONTHLY SURVEY OF MODERN PRACTICE IN ELECTRICAL ENGINEERING

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A Striking Example of how Science can help Business.

We hear many examples in these days of how science is being brought to bear on improving the production side of industry. A striking example of this is given on pages 6-11, where are shown some details of the use of the Weston illumination meter. While there are, of course, other instruments of a similar high standard available, they all have one point in common, they enable the busy, practical man to demonstrate to his customer, i.e., the works manager, whether his lighting is up to the standard which will give the best output. Years ago photometry was regarded as a science which could only be practised in the photometric laboratory. To-day it is still a science, but it has been brought out of the laboratory and made easily available to installation engineers and contractors to whom it should prove the means of securing new business during the coming winter months.

Further Development of Gas-discharge Tubes.

We have already referred in a previous issue to the "Osira" discharge lamp. The development and practical application of the electric discharge lamp is one of the most important recent advances in the technique of light production, and the latest development is the Mazda Merera lamp. It will be remembered that the "Osira" lamp works at a low temperature. The Merera lamp, however, has a double-walled bulb, the inner container of which becomes exceedingly hot while the lamp is in operation. Readers will be interested in the description of this new development, which appears on page 3. It is a subject on which we hope to keep our readers fully informed in forthcoming issues.

For Wireless Engineers.

The subject of alternating current bridge methods of electrical measurement is one which has for years been regarded by electrical engineers as a highly technical one, and we believe that one or two very learned treatises have been devoted to the subject. We are glad to be able to publish an article which illustrates some practical methods of using an alternating current bridge for measuring and comparing inductances such as are used in wireless receivers. The principle employed is, of course, similar to that of the Wheatstone bridge and anyone who is familiar with the principle of this will have no difficulty in following the methods described in the article on page 33.

Our Motor Design.

The original design for a $\frac{1}{8}$ h.p. induction motor, which is given in the article on page 21, has been included at the special request of several readers. It is not suggested that it would be cheaper to make such a motor than to purchase one of the many excellent designs obtainable from electrical manufacturers. There are, however, hundreds of electrical engineers who, we believe, will thoroughly enjoy building this little machine from the instructions given. It cannot be denied that there is a pleasure to be obtained from seeing it work which will appeal not only to the student but to the engineer who believes in using his hands as a relaxation from using his brains. Incidentally, an actual motor has been constructed by the designer, and has been running very satisfactorily, and as the instructions for making it are quite clear, no difficulty should be experienced by those readers who decide to build the motor.

Development in the Mercury Arc Rectifier.

It is interesting to think that had the Thyratron or grid-controlled mercury vapour rectifier reached its present state of perfection ten years ago, it is not inconceivable that the present grid system would have been planned on entirely different lines. There is no doubt that the possibility of dealing with very large currents by means of the Thyratron rectifier is of very great importance in the future development of electrical transmission and distribution. As will be seen from the article on page 14, the Thyratron makes it possible not only to rectify currents of hundreds of amps, but to stop or start them or to control their magnitude, the power necessary for control being only of the order of a few milliwatts.

Planning a Distribution System.

The problem of planning the distribution system for a house is one that requires a good deal of care, as not only must immediate requirements be considered, but some provision should be made for future extensions. In the article on page 15 Mr. J. V. Brittain, A.M.I.E.E., deals with the problem in a thorough manner, and his article will, we think, be of considerable interest to many of our readers.

Telecontrolled Radio.

The idea of being able to place a wireless set in some out-of-the-way place, and then be able to control it from anywhere in the house has a tremendous fascination about it. A practical means of doing this has recently been placed on the market by Halford Radio, Ltd., whose system of telecontrolled radio consists of an operating unit and a small control box suitable for carrying about in one hand and which has a length of flex attached to it so that it can be plugged in at any point in a room where most convenient, after, of course, the house has been suitably wired. Thus, you can sit in a comfortable armchair or lie in bed, with the control box by your side, and choose any station that your wireless set is capable of receiving. Practically any modern set can be converted for telecontrol, the only essentials being that the condenser spindles must permit of attachment to the drive of the operating unit; the volume control must be of the variable bias type; and it must be possible to fit the wave-change switch without disturbing the balance of the receiver.

Safety in Mines.

For many years mining engineers have been seeking a solution to the question of providing an adequate lighting system in coal mines. The main consideration is, of course, that it must be free from danger when operating in the presence of firedamp or coal dust. While battery lamps have been improved considerably, the fact that their candle power is limited, since weight has to be considered, makes them unsuitable for the purpose. On page 40 will be found details of a self-contained pneumatic electric lamp and generator, operated from compressed air line, which has been specially developed for improving the lighting of collieries without increasing the danger of explosion.

A Visit to the Cossor Works.

We were recently privileged to spend an interesting morning at the works of Messrs. A. C. Cossor, Ltd., where we watched the evolution of a valve from the raw materials to the finished article. Each valve takes roughly three hours to make, during which time it goes through about 20 named processes. Some of the machines for certain processes are capable of dealing with as many as 64 valves at a time.

The efficient manner in which the Cossor people are turning out their products in readiness for the coming winter months is an encouraging sign of the healthy state of the radio industry.

Questions and Answers by Practical Men.

We believe that many readers will welcome the new feature under the above heading, which appears on page 44. It is our aim to help readers as much as possible with practical problems that crop up in the course of everyday work, and we feel that one of the best methods of doing this is to obtain the advice of practical men in the industry, who may have found themselves faced with similar difficulties from time to time. If you have a problem, or if you have an answer to any question published, we shall be interested to hear from you. Any answers published will, of course, be paid for at our usual rates.

The Mazda Mercra Lamp

A FURTHER DEVELOPMENT OF GAS-DISCHARGE TUBES

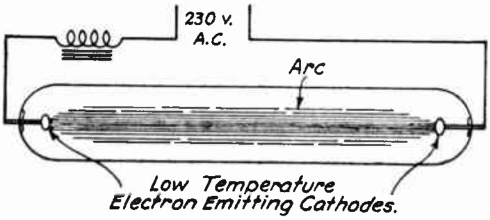
Readers will remember the recent article dealing with the "Osira" lamp. Another development of gas-discharge tubes is the Mazda Mercra lamp, developed by the British Thomson-Houston Co., details of which are given in this article

SHOWING THE USE OF MAZDA MERCRA LAMPS FOR FLOODLIGHTING THE ROYAL BATH HOTEL, BOURNEMOUTH.

THE problem of obtaining still higher efficiencies from electric lamps continues to engage the attention of some of the best brains in the electrical industry. The Mazda Mercra lamp is the most recent development. Briefly, it consists of a special form of mercury vapour lamp, with a double-walled bulb. The inner glass container becomes exceedingly hot while the lamp is in operation; the outer container is separated from it by a vacuous space, as shown in the diagram at the foot of the following page.

Consumes 400 Watts.

There were many practical difficulties that had to be overcome before the high-power gas-discharge lamp became a practicable light source capable of operation on the usual voltages; but these difficulties have been overcome in the B.T.H. Lamp Works and Laboratories, and lamps have been constructed in the form shown in one of the diagrams. The lamp illustrated operates on 230 volts A.C., and consumes 400 watts. The hot cathodes are of the self-exciting electron-emitting type, i.e., they are heated only by the energy of the discharge; and the high temperature of the vapour necessary for the efficient production of the light is maintained by surrounding the inner tube (containing the electrodes and the metallic vapour) by a vacuum jacket.



THE MAZDA MERCRA LAMP.

Suitable for street and highway lighting, floodlighting, etc.

Changes that Occur When Lamp is Switched On.

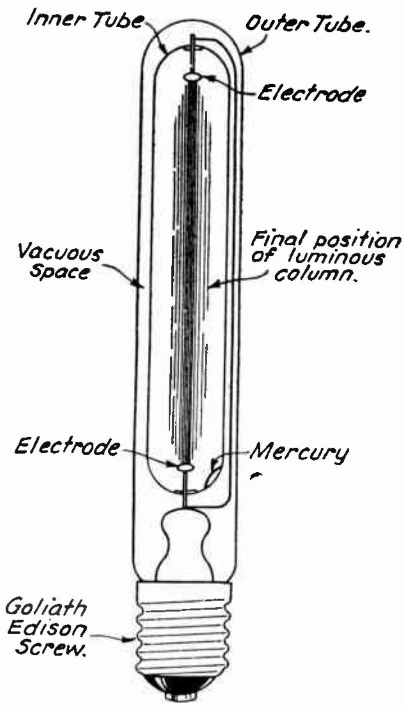
It is especially interesting to observe the changes in the form of the arc and the luminous output when the lamp is first switched on and is quickly heating up. At first the lamp is filled with a uniform pale blue glow. As the temperature rises and the vapour pressure increases, the luminous column leaves the walls of the tube and narrows down until finally it appears as a brilliant narrow cord in the centre of the tube. It is at this final stage that the luminous output is high, and also the quality of the light is much improved as compared with that of the ordinary mercury glow.

Efficiency is 40 Lumens per Watt.

Spectrographic records of Mazda Mercra lamps have been taken during this rapid warming up process, and the progressive increase in the red radiation is clearly indicated. The lamps need a small stabilising choke in series with them, and power factor can be corrected readily by means of a condenser. The efficiency of the lamps is approximately 40 lumens per watt.

Floodlighting and Road Illumination.

A photograph of the Royal Bath Hotel, Bournemouth, flood-lit with Mazda Mercra lamps in specially designed projectors, is shown on the previous page. Lanterns designed to cast narrow fan-shaped beams and to establish even road illumination and favourable driving conditions, are generally employed in the modern highway lighting schemes using the new gas discharge lamps.



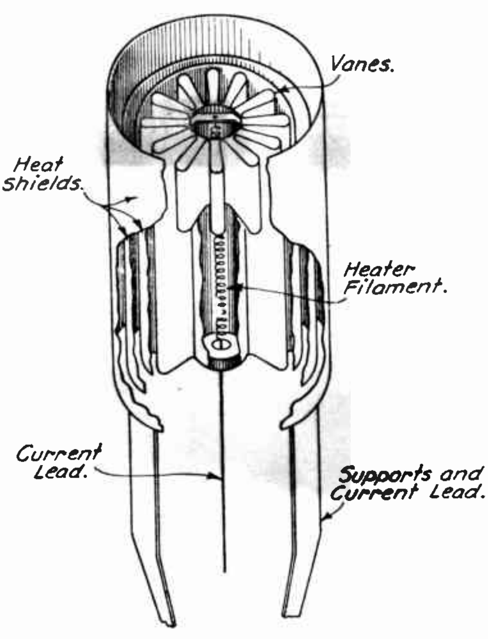
DETAILS OF THE MAZDA MERCRA GAS DISCHARGE LAMP.

This operates on 230 volts A.C., and consumes 400 watts.

Further Cathode Developments.

The cathodes used in the present Mazda Mercra lamps are of small size, suited to the 400-watt capacity of the lamps; but it is interesting to note that it would be possible to arrange lamps of very high power. The cathode in question is known as the indirectly heated, heat-shielded cathode. It differs from the ordinary hot cathode, in that its electron emissive surface is of much greater area than that of its heat radiating surface, and furthermore, the heat losses are reduced by the use of a number of polished metal heat-shields. It consists usually of a cylindrical metal structure containing a large number of vanes coated with the electron-emitting material.

As many as possible of these electron-emitting surfaces are packed into the pot-like container, which is surrounded by two or more heat shields, and the net result is a cathode of high electron emission and low heat loss—in other words, one of high efficiency. Another advantage of this type of structure is that loss of emitting material is reduced by the heat shields, and liability to troubles due to diminution of activity and glass blackening is thereby lessened. The diagram on the right shows the general arrangement of a cathode of this type.



A HEAT-SHIELDED CATHODE.

Three Examples.

Some idea of the efficiency and relative sizes of these heat-shielded cathodes can be obtained by consideration of three examples. A very small non-heat shielded cathode is used in certain standard Mazda valves; it consumes 4 watts and permits of anode current of 20 to 50 mA. The next example is a heat-shielded cathode in a Mazda Thyratron; it takes 50 watts and will give an anode current of six amperes. Finally, there is a large-size heat-shielded cathode consuming 300 watts and giving a current of 100 amperes.

Chief Use for Special Cathodes.

The chief use of these special cathodes in future gas discharge lamps will probably be in such applications as floodlighting, and for beacon lights. Cathodes that will deliver an anode current of 1,000 amperes have been made for B.T.H. "Thyratrons," and this cathode comparison has been mentioned to indicate that cathode design will not determine the limit of capacity of luminous discharge lamps. The possibility of constructing very efficient and exceptionally large single sources of light is of considerable interest.

SODIUM VAPOUR LAMPS.

Whilst the mercury lamp for high efficiency needs a vapour pressure of one or two atmospheres, other metal vapour lamps may be constructed in which the requisite pressure is only a few thousandths of a millimetre of mercury, that is to say, a small fraction of one atmosphere. The chief among these to be produced so far is the sodium lamp, and Mazda lamps of this nature have been developed and demonstrated.

The sodium lamp makes no pretence of giving a colour rendering approximating to daylight. In fact, the light from it is virtually monochromatic and is, of course, yellow.

How the Yellow Light is Produced.

The sodium lamp has a separately heated hot cathode, with one or more anodes in a bulb, which, for heat conservation, is mounted inside a vacuum jacket. The lamp is filled to a suitable pressure with one of the rare gases such as argon, and contains a little sodium. The electrical characteristics are not appreciably altered by the presence of the sodium, a trace of which, however, converts the faintly luminous glow of the rare gas into a brilliant yellow light. The lamp starts with a low-voltage arc of from one to five amperes in the rare gas, and the energy liberated in this heats up the sodium until finally a temperature of about 200° C. is reached. At this temperature the sodium vapour is at such a pressure that a bright yellow light is produced.

Other Problems that Have to be Considered.

The further development of both mercury and sodium lamps, which is being pursued actively in the B.T.H. works, presents many problems connected with electrical discharges in gases.

We are indebted to the engineers of the B.T.-H. Co. for the information given above. We hope through their courtesy to keep our readers informed of further developments.

THE ILLUMINATION METER

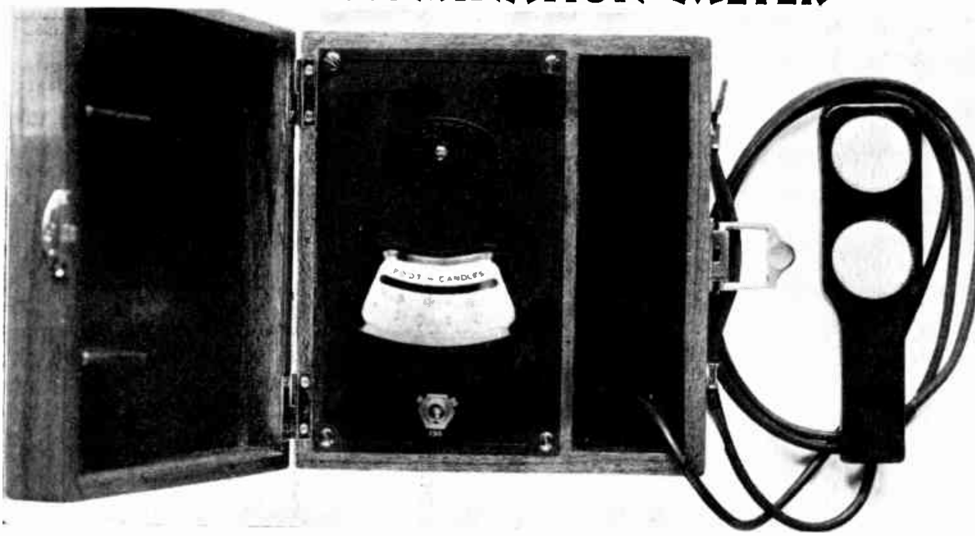


Fig. 1.—The Weston Portable Illumination Meter.
This enables the intensity of illumination to be seen at a glance. It consists of two " Weston " cells connected to a microammeter, with a scale calibrated to give a correct reading in foot candles.

THE late Mr. Leon Gaster was one of the pioneers of illuminating engineering in this country, and owing largely to his efforts the scientific study of illumination has been practised by electrical engineers and consultants for many years.

The recent innovation of the portable illumination meter, of which the " Weston " instrument is an excellent example, has now rendered it possible for the busy installation engineer to deal with the subject of illumination in a scientific manner without having to make elaborate calculations on the subject.

Fig. 2.—The Foot Candle and the Lumen.
The foot candle is the illumination received from a source of one candle at a distance of 1 foot. The lumen is the flux of light falling on a spherical surface 1 square foot area distant 1 foot from a standard candle flame. The amount of light caught on the sheet of paper above is approximately one lumen.

Minimum Illumination Necessary for Different Classes of Work.

Tables issued by the Electric Lamp Manufacturers' Association show at a glance the minimum illumination which is necessary for different classes of work. A table of typical values appears on page 10.

Is the Intensity Sufficient ?

Equipped with one of the portable illumination meters, the installation

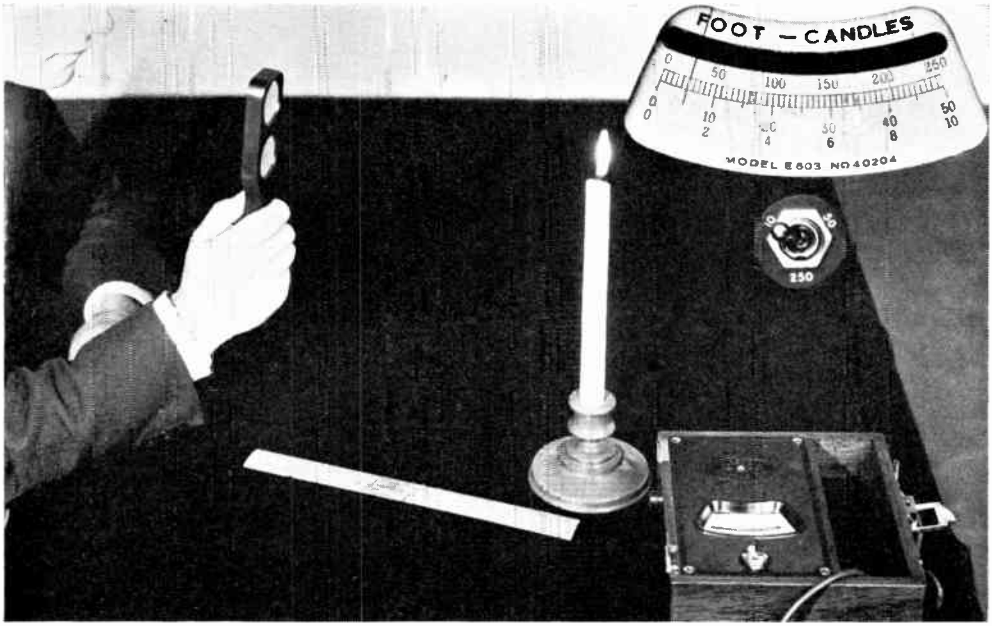


Fig. 3.—Measuring a Foot Candle With the Weston Illumination Meter.
Notice that the discs are being held 1 foot away from a standard candle, thus giving a scale reading of 1 foot candle on the lower scale.

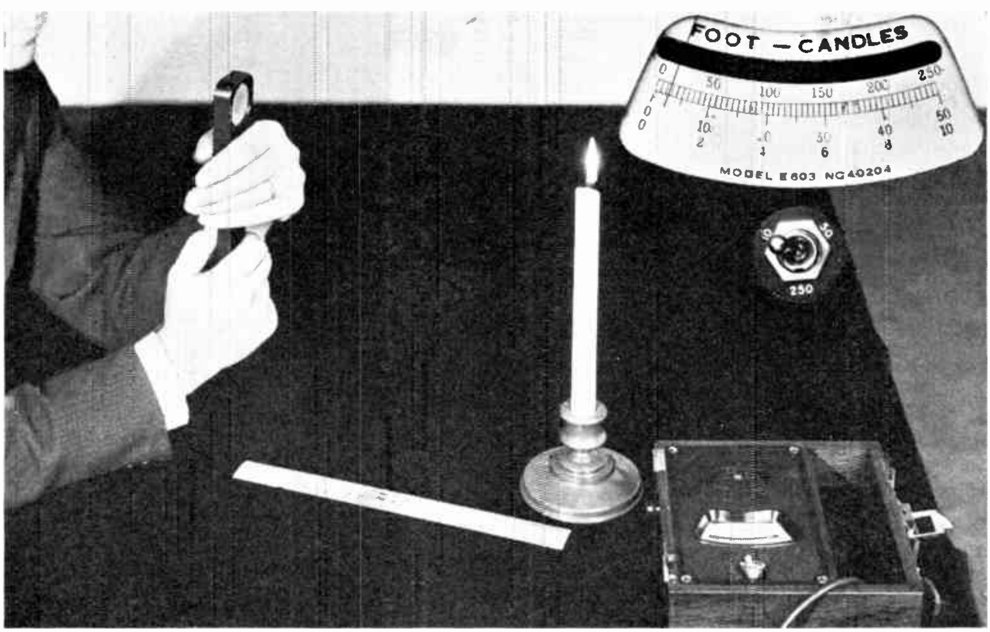


Fig. 4.—One Disc Only Gives Half the Deflection.
The above photograph illustrates a useful property of this instrument. By covering up one disc the scale readings are exactly halved. If half the remaining disc is covered the scale readings must be multiplied by four to give the true foot candles.

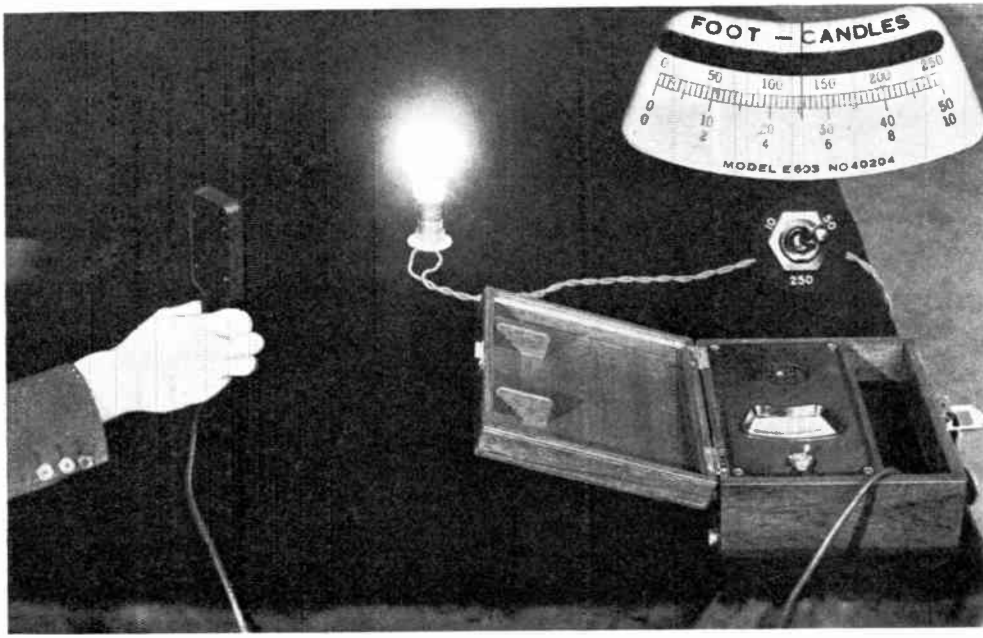


Fig. 5.—MEASURING THE BRIGHTNESS OF A 40-WATT PEARL MAZDA LAMP.
Note that instrument switch is on the 50 mark, indicating that the centre scale must be used. The reading obtained is 25½ foot candles.

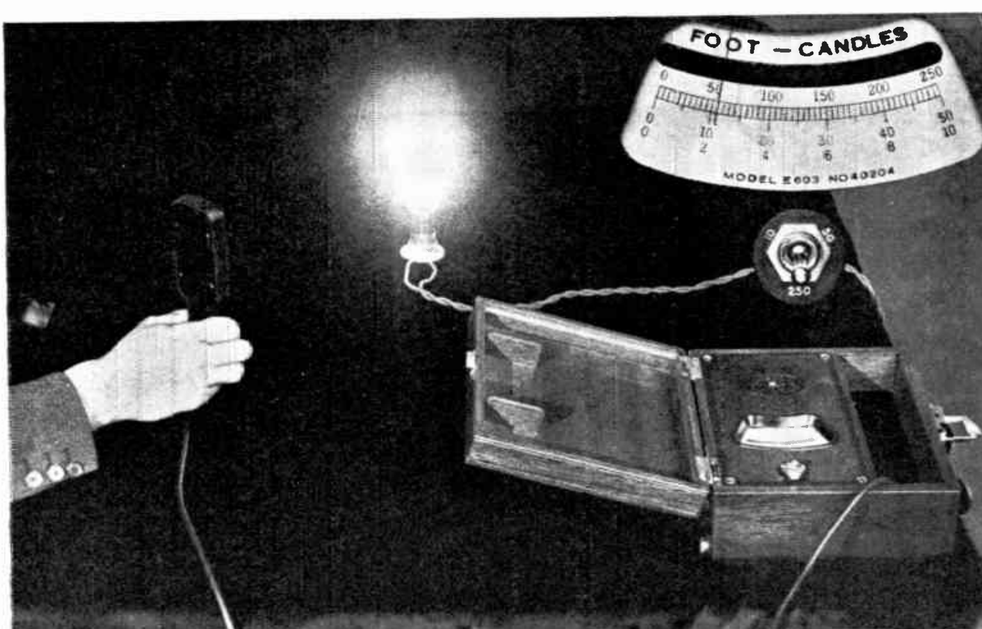


Fig. 6.—MEASURING THE BRIGHTNESS OF A 60-WATT PEARL MAZDA LAMP.
Here the instrument switch is in the 250 position, so that the top scale must be used. The reading is 55 foot candles.

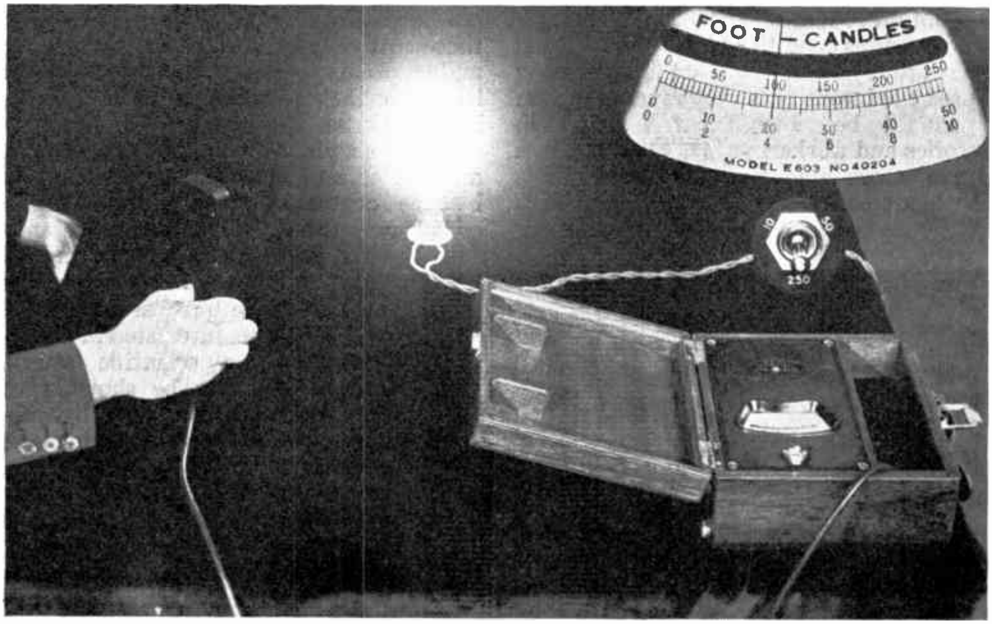


Fig. 7.—Measuring the Brightness of a 100-Watt Pearl Mazda Lamp.
It will be seen that the reading in this case is 100 foot candles. In all cases the discs are being held approximately 12 inches from the light source.

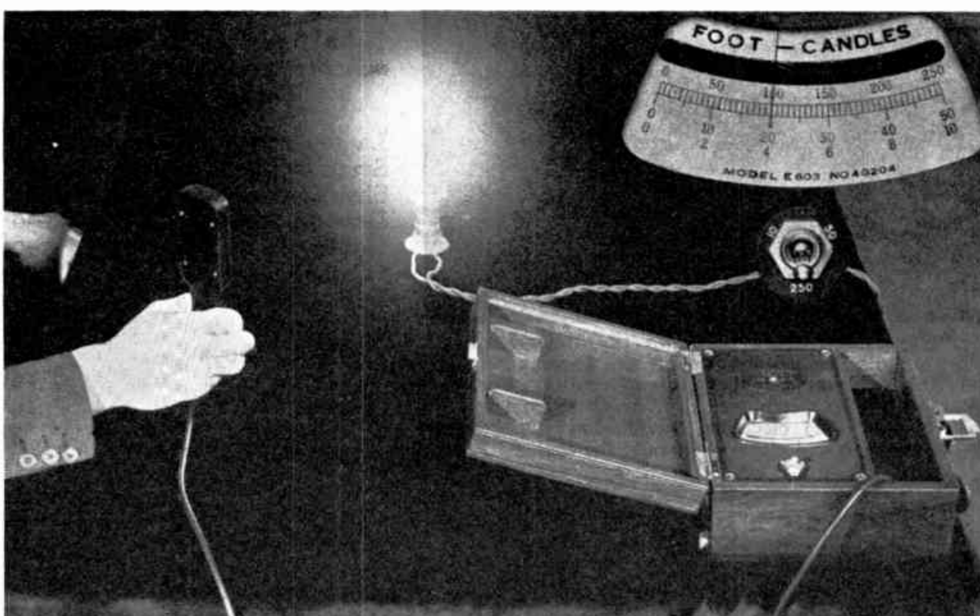


Fig. 8.—A Striking Result.
Here a 100-watt clear glass Mazda lamp is being used in place of the 100-watt Pearl Mazda shown above. The intensity of illumination is, however, exactly the same, viz., 100 foot candles.

engineer can visit a works, office or factory, and obtain readings of the actual lighting under various conditions. It will be found that in many cases where artificial lighting is used the intensity is very much less than it should be. Insufficient lighting in factories and workshops is not only a cause of eye strain amongst operatives, but it also tends to reduce the output and may contribute to the occurrence of accidents.

Fig. 9.—ARTIFICIAL LIGHTING IN AN OFFICE.

On the disc immediately under the 60-watt lamp the illumination is found to be 3.7 foot candles. For most efficient work the recommended intensity is from 11 to 13 foot candles. The electrical installation engineer will advise the use of a desk lamp to meet the case.

Causes of Inefficient Lighting.

Although the spread of knowledge of the principles of illumination amongst architects and consulting engineers has led to the provision of adequate lighting in the majority of new buildings, there are still thousands of workshops, offices, factories, and houses where the existing lighting leaves much to be desired. Lamps and reflectors become obscure through accumulation of dust; reflectors are not always those best adapted to the purpose in view, and on occasions lamps are kept in service long after their specified useful life.

New Business.

There should be quite an appreciable amount of new business to be obtained by the contractor who can buy, beg, or borrow a portable illumination meter to take with him when calling on some of his customers. Business men and the general public are not, of course, interested in illumination as a scientific study, but if they can be shown that by modernising their lighting they can lessen eye strain, increase output, or avoid accidents, very few of them will refuse to consider the comparatively trifling expense which may be involved in this.

The accompanying pictures do not illustrate any elaborate scientific experiments. Using a portable illumination meter is about as simple as reading the voltmeter or ammeter, and rather easier than reading an electricity meter.

Table Showing Minimum Illumination Necessary for Different Classes of Work.

	Foot Candles.
Large Stores	15–20
Small Shops ..	10–15
Showrooms	15–20
Drawing Offices ..	25–50
Hotels—General rooms	7–9
Offices	11–13
Public Halls ..	7–9
Bakeries	8
Assembly Shops ..	8
Laundries	10
Machine Shops ..	10
Warehouses	3
Textile Mills—	
Cotton—	
Carding rooms	5
Warping and weaving ..	8
Silk—	
Throwing, etc.	12
Light weaving	8
Wool—	
Light weaving	8
Combing	4

Fig. 10.—DAYLIGHT ILLUMINATION IN AN OFFICE.

Here the reading has been taken on a table near two windows. The illumination reading is found to be 39.5 foot candles. Compare this with the reading obtained by artificial light. See Fig. 9.

Fig. 11.—ANOTHER READING ON THE SAME OFFICE TABLE.

When the disc is held directly facing the windows the illumination is found to be 75 foot candles. The previous picture shows that the horizontal illumination on the same table is roughly one-half of this value.

SYNCHRONISING TURBO-ALTERNATORS

By W. T. WARDALE, A.M.I.E.F.

To synchronise an alternator of any size, the speed of the set must give exactly the same periodicity as the system, the voltage of the incoming machine must be the same as that of the system or slightly higher, and the incoming machine must reach the crest and bottom of the wave in exact step with the system. Fig. 1 shows the instruments used for synchronising. The voltmeters for the system and the machine have been omitted to keep the diagram simple. In Fig. 1, R, W and Y indicate the phase windings. The machine is connected to the busbars through the oil switch.

Excite the Exciter Field.

Whilst the turbine is being run up to speed, excite the exciter field and see that its voltage comes up steadily with the speed of the turbine. This proves the exciter to be in order. On the exciter attaining half its working voltage, close the main field switch and adjust the current in the main field to the point at which the machine synchronises easily; this point is usually marked. Adjust the machine volts so that when full speed is signalled, the machine voltage will be slightly higher than that of the system.

Now Watch the Synchroscope.

Then put synchronising plug into holes S.P.S.P. and watch the synchroscope. The pointer will revolve slowly in one direction or the other according to whether the machine periodicity is higher or lower than that of the system. If the machine is a little above full speed the synchroscope pointer will travel in a clockwise direction very slowly.

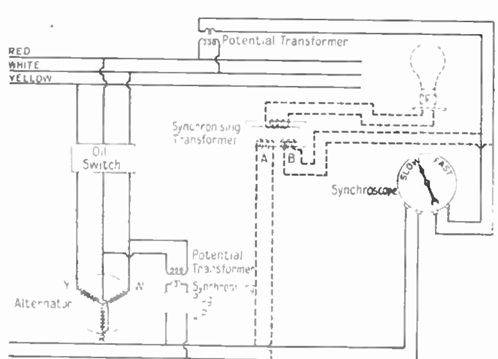


Fig. 1.—THE INSTRUMENTS USED FOR SYNCHRONISING.

Signal for the speed to be lowered a little, or, if on a modern switchboard, lower the speed yourself by means of the special switchboard control. Get the pointer just crawling in a clockwise direction and when the pointer is in the position shown, or rather nearer to the vertical, close the oil switch promptly. The machine is now on the bars and you can signal to the turbine driver to open the stop valve and so bring the load gradually on to the machine.

A Simple Process.

The explanation of the process is simple. Leads from two of the phases on each machine, in this case, R and W, are taken to a small potential transformer, which gives a very low tension supply, say, 110 volts, to the synchronising leads when the four-pin plug is inserted in the holes S.P. and S.P. These leads go to one side of the synchroscope. The other side is connected to a similar low tension supply taken from the system, through the transformer. The two sets of leads are so connected inside the synchroscope, that when the system and the machine are out as regards periodicity, a small motor or a set of vanes will revolve.

Now note carefully that the greater the difference in periodicity between the machine and the system the faster will be the speed of the motor or vanes, and hence

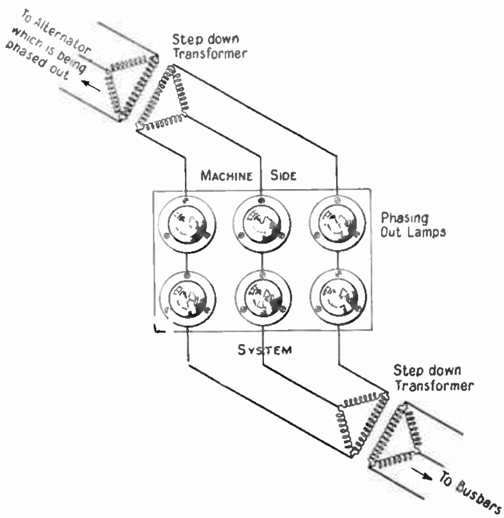


Fig. 2.—Showing the Use of Phasing-out Lamps for Synchronising Alternators.

of the synchroscope pointer to which they are attached.

The Synchroscope Connections.

The internal connections of the synchroscope are so arranged that when the machine periodicity is higher than the system the pointer revolves with the clock, but that when the machine periodicity is lower than the system the pointer will turn in an anti-clockwise direction. The connections are usually made so that when the arrow of the pointer is vertical the machine and the system are rising and falling in absolute agreement.

Therefore, get the voltage right, then the synchroscope pointer revolving very slowly in a clockwise direction, and when the arrow is almost vertical, say at "*five minutes to,*" close the oil switch.

Two Points to Watch.

Watch two points: never close the oil switch after the arrow has passed the vertical position, and, if you have to bring the speed of the set up from too low, and so cause the pointer to stop revolving anti-clockwise and start turning with the clock, do not take the first turn which comes up after the change of direction. The pointer has had to be stopped and reversed, and is going really quicker than it appears; that is, it is travelling too fast with the clock and the system and machine are too far out to synchronise. Let the first two revolutions in the new direction pass, and then make any further slight adjustment to the speed of the set to give just the crawl on the pointer which is best for synchronising.

The Lamp Method.

The method of using phasing-out lamps is not employed on the most modern plants. The connections are shown in Fig. 1. The synchronising transformer, it will be seen, has two primary windings, A and B, in *opposition.* The single secondary winding supplies a synchronising lamp. When the system and the machine are in synchronism, the windings A and B being in opposition, will allow no voltage to rise in the secondary winding, and the lamp will be *dark.* When the system and the machine are dead out of phase, the lamp will glow brightly. This method may be used with any voltage on the alternator, as all instruments and plugs are at low tension. It is, however, not fine enough when dealing with really large sets, and so is not much used to-day.

Putting a New Alternator into Service.

When a new alternator is about to be put into service for the first time, it is first necessary to know that the phases in the new machine and the system rotate in the same order. It must be, say, R.W.Y. for both machine and system, or any other combination desired; but it must not be R.W.Y. for the machine and R.Y.W. for the system. A simple method of checking this point is to take the busbar leads through a transformer and bring them out, giving a low tension supply on each phase. A similar transformer is then connected to the machine main terminals, and the machine run up excited and to proper speed. The two low tension supplies are then connected to a bank of lamps as shown in Fig. 2. Each phase from the machine on to the top contacts, and the same phase from the system on to the bottom contacts, this, of course, being done through small switches. The lamps should be chosen so that if the dead out of phase voltage is, say, 220, then the lamps will stand it. Two 115-volt lamps in series on each phase would suffice with a L.T. pressure of 110 volts.

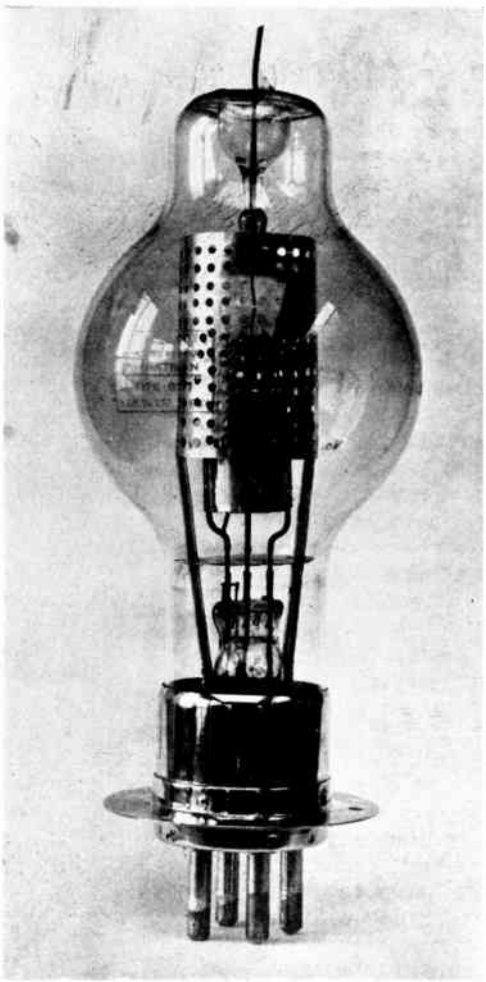
If the two sets of phases, machine and system are rotating together in the *same sequence*, the lamps will all glow and darken together. If they do not, then shut down the set and cross over two of its high tension terminals. Run up again and if the lamps darken and glow together, the change over has succeeded.

If, however, they are not yet correct, then shut the set down again, and *first restore the crossed over leads* to their *original position*. Then cross over the two E.H.T. leads at the other end, and run up again.

The Hot-cathode Thyratron Valve

THE latest development in rectifying practice is exemplified in the Mazda Thyratron valve, which is a hot-cathode grid-controlled mercury-vapour rectifier. A grid or control electrode is provided between cathode and anode, and it is possible not only to rectify currents of hundreds of amps., but to start or stop them, or to control their magnitude, the power necessary for control being only of the order of a few milliwatts.

The photograph given here shows a typical hot-cathode Mazda Thyratron valve which is being made for use in high speed spot and seam welders, and many and diverse are the applications of the different sizes of Thyratrons.



The Madza Type BT7 Thyratron Valve.

Possibilities of Future Development.

The possibility of dealing with very large currents by means of the Thyratron or grid-controlled mercury vapour rectifier is one which has very great possibilities in the future development of electrical transmission and distribution. Had this discovery been brought to its present state of perfection 10 years ago it is not inconceivable that the present grid system would have been planned on entirely different lines.

Power Transmission.

The use of grid-controlled mercury-vapour rectifiers renders it practicable to transmit large amounts of power at high voltages on direct current. Such a system of power transmission has certain advantages as compared with the present A.C. system. It would be fatuous to suggest that there is any possibility of the existing system being altered in the near future, but there can be no doubt that the extended use of the Thyratron principle may effect great changes in heavy electrical engineering practice during the next few years.

Planning the Distribution System for a House

By J. V. Brittain, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.E.E.

In this article, the author deals with the method of distribution employed for a small six-roomed house and for a larger house using electricity for most domestic purposes, and explains how the various requirements of the Regulations are fulfilled

THE distribution of electricity to various parts of a house requires a certain amount of care in planning with a view to providing for all the points and services which will be required and avoiding any unnecessary cable runs. It is also worth while in better-class work to make some provision for extensions, or at least to make the system such that extensions are easily added without upsetting the whole layout.

There is also the matter of protection. By this is meant the provision of a satisfactory arrangement of fuses which are correctly graded according to the circuits which they control so that each circuit is adequately protected. By adequate protection is meant that should the current in any circuit approach a value at which the cable is likely to get hot it will be immediately disconnected by means of the fuse blowing. It should be borne in mind that to-day there are very few supply authorities who do not have fairly strict rules as to their requirements in switch and fuse gear and if an installation does not come up to their requirements they will not, of course, connect up.

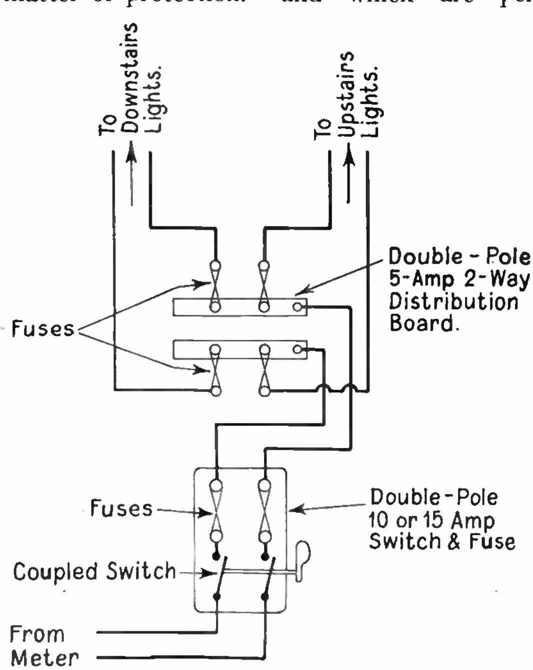


Fig. 1.—Typical Distribution Arrangement for a Small Six-roomed House.
This incorporates a double-pole switch and fuse, together with a two-way distribution board.

The Regulations.

The main guidance for the wiring of buildings for both light and power is found in the *Regulations for the Electrical Equipment of Buildings* which are issued by the Institution of Electrical Engineers and which are periodically reviewed. These regulations are now accepted as standard by the majority of electricity supply authorities and are also used by insurance companies as the requirements for a satisfactory installation.

There is a definite section of these regulations which deals with *distribution* and the interpretation of certain portions of this section will be dealt with in this article. There are, however, one or two main points which apply to every installation and these are as follows :—

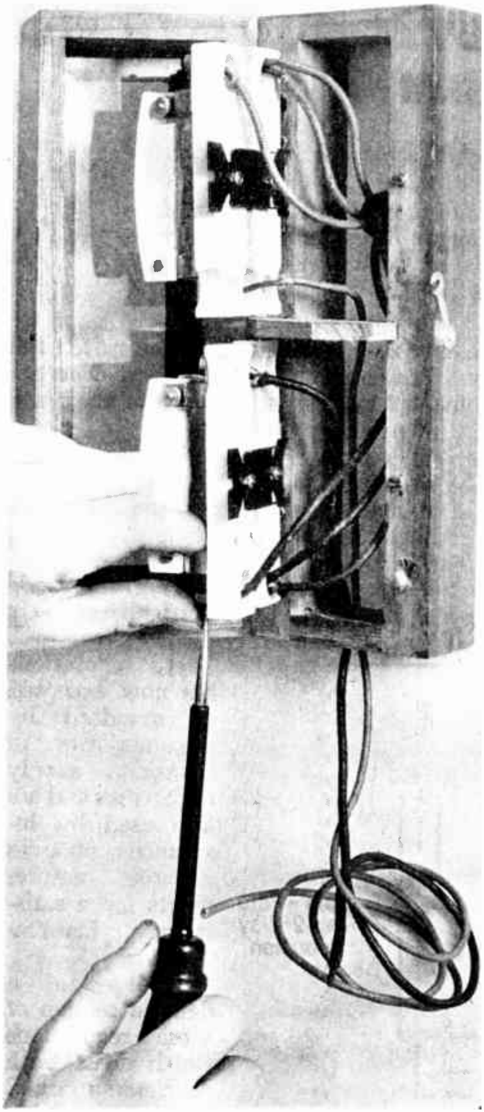


Fig. 2.—A Two-way Fuse Board showing Connections.

When connecting up fuse wires care must be used to ensure that the red and black wires of each circuit are connected to the upper and lower carriers opposite each other, as these form a pair.

Suitable Controlling Apparatus.

(a) *Every installation shall be adequately protected by suitable controlling apparatus which shall be easily accessible to the consumer and situated as near as possible to the point of entry of the service main.*

This means, of course, that the control gear must be in a convenient position where the main comes in and this is carried out by the erection of the meter board at some point previously agreed upon. It is only natural that the supply authority will not allow long lengths of cable to run about the house or building without any protective gear.

Both Lines Must be Isolated Simultaneously.

(b) *For a two-wire supply there must be a double-pole linked switch and a fuse in each conductor.*

This refers to the provision of a switch which will isolate both lines *simultaneously* and a pair of fuses. The regulation also allows circuit breakers, but these are not yet much used for house wiring and will not be dealt with here. Most readers will be familiar with the ordinary iron-clad double-pole switch and fuse which is normally used. The ironclad type is, however, being displaced to a large extent by switchgear made of insulating material such as bakelite. This is particularly the case in the smaller sizes.

Sub-distribution Board.

(c) *Every final sub-circuit shall be connected to a sub-distribution board.*

As practically the smallest installation is divided into at least two circuits some arrangement must be provided to give separate fuses on each circuit. This means that as a rule a double-pole distribution board is required, but there are one or two cases where this extra feature is combined with the main control switch, and this will be explained later.

How These Requirements are Fulfilled.

In order to explain how these and various other requirements are fulfilled two examples will be taken: first, the lighting of a small six-roomed house and, secondly, a modern villa using electricity for most domestic purposes.

A Small Six-roomed House.

The normal control gear for a six-roomed house is shown in Fig. 1, and it will be seen that this incorporates a double-pole switch and fuse, together with a two-way distribution board. There are several reasons why a small installation like this should be divided into two circuits. One of these is that the number of points on one circuit must always be limited to a reasonable figure and another is that should one fuse blow, the whole house will not be plunged into darkness.

Method of Distribution.

In Fig. 1 the leads from the meter first come to the main switch and fuse which may be of the ironclad type or made of bakelite or a similar material which is an insulator. There are many different types of these on the market which are quite satisfactory. The size or rating on this switch fuse is usually 10 amps. at 250 volts. This is the smallest size which should be used as apart from its capacity as a controlling switch there is the consideration of mechanical robustness. A smaller switch would be too frail to be reliable for this duty.

Capacity of the Fuses.

From the main switch and fuse, leads are taken to the distribution board which in this case is double-pole two-way. As the circuits which it protects are lighting circuits the capacity of the fuses will be 5 amps., which is the smallest size of distribution board made.

Division of Lights into Two Circuits.

The division of the lights into two circuits depends slightly on the actual layout of the house, but it is found most convenient to divide them into downstairs and upstairs. There will then be about four lights on each circuit, and this will be quite satisfactory.

Using a Splitter.

An alternative method of distribution for this type of installation is the use of a *splitter*. Since there are only two circuits the distribution board proper can be combined with the main switch and fuse and instead of the two pieces of gear we get a unit comprising a double pole switch with two pairs of fuses. This is shown diagrammatically in Fig. 3 and it will be realised at once that this type of gear means a saving both in money and time. A splitter also has the advantage that the supply MUST be cut off before any of the fuses are examined. With the arrangement in Fig. 1 the distribution board can be opened while the main switch is still on and so a shock may be felt. A large proportion of the smaller houses now being built are therefore fitted with splitters. These are made in the 10-amp. size similarly to the ordinary switch and fuse and are obtainable both in ironclad and all insulated types.

Distribution in a Larger Home.

In our larger house we have to provide for both lighting and power and it will be

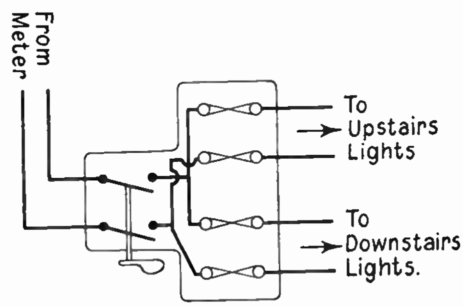


Fig. 3.—DIAGRAM ILLUSTRATING THE USE OF A SPLITTER.

This is an alternative method of distribution. Since there are only two circuits, the distribution board proper can be combined with the main switch and fuse.

assumed that electricity is used for practically every purpose for which it would be found useful. Before actually planning the layout it is advisable to summarise the actual points that will be required and we will take these as follows :—

Lighting.

Reception rooms . ..	6 points.
Kitchens, garage, etc. ..	5 points.
Bedrooms, etc.	6 points.

Heating.

15-amp. plugs in reception rooms and bedrooms, etc.	6 points.

Cooking.

One 4kW. cooker with plug for kettle	1 point.

Washing.

One 15-amp. plug for washer	1 point.

Hot Water.
One connection to immersion heater .. .. .. 1 point.
Refrigerator.
One 5-amp. plug .. .. 1 point.

Separate Control Gear for Lighting and Heating.

In order to provide for these services it will be necessary to have separate control gear for lighting and heating with the usual separate special circuit controlling the cooker. It is now necessary to decide how the circuits shall be split up and although there are many variations in the permissible arrangement there are certain features which are definitely desirable in a good installation. The actual requirements of the local supply authority will affect the distribution considerably and these requirements must be taken into account when putting any scheme into practice. Alternatively, where the regulations laid down are not very strict a somewhat simpler arrangement can be put in although it is not possible to "get away" with very much now that wiring installations are receiving so much attention.

Three-way Lighting Distribution Board.

With reference to the lighting this can be grouped practically as tabulated above. The grouping already given will probably be quite convenient and a three-way lighting distribution board will be required. This is shown in Fig. 4 and it should be noted that the lighting is entirely independent of any other part of the installation. There are separate leads from the meter and a separate main switch and fuse is provided. The rating of this main switch and fuse should be 15 amps. in this case as the total current which could be taken on lighting would be more than is usually considered suitable for a 10-amp. switch and fuse.

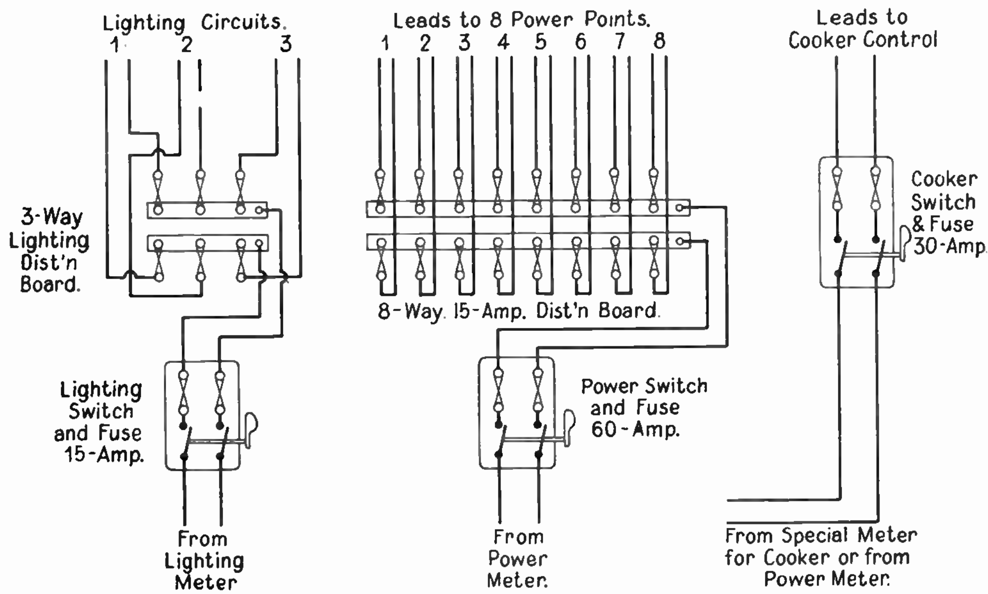


Fig. 4.—DISTRIBUTION SCHEME FOR A LARGER HOUSE.
Note that the lighting is entirely independent of any other part of the installation.

When a Four-way Distribution Board Should be Used.

If the amount of lighting was much in excess of that tabulated above a four-way distribution board would be desirable as it has been accepted that 7 points are the most which should be put on one lighting circuit. The dividing up of the lighting into a larger number of circuits also has the advantage that in the case of trouble on

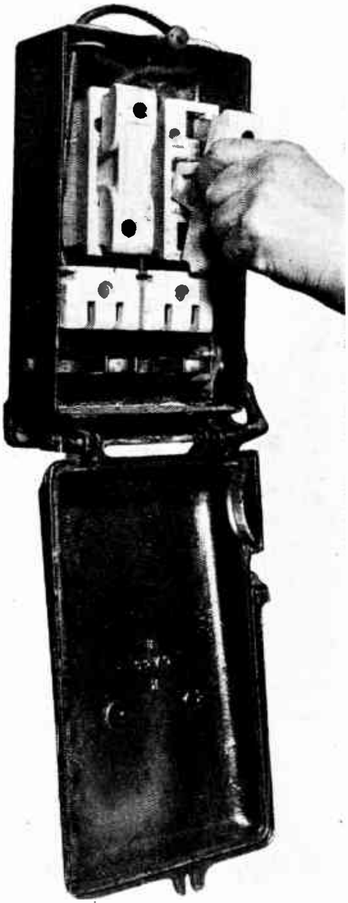


Fig. 5.—An Ironclad Main Switch and Fuses of an Installation.

one circuit there are not so many rooms put in darkness.

Heating or Power Circuits.

With reference to the heating or power circuits it is here where a fair amount of variation may occur. First there are 8 main heating points (i.e. points using 15-amp. plugs), comprising the 6 points for fires, the washer and the immersion heater. It is assumed that the hot water heater is in the nature of an auxiliary heater in the ordinary hot water tank.

Only Two Points Allowed on One Circuit.

The number of points which can be put on one circuit is definitely limited to two with points rated above 10 amps. but there are several authorities who will only allow ONE 15-amp. point on each circuit. In order to make full provision for a case like this an eight-way distribution board would be required and this is shown in the arrangement of Fig. 4. The capacity of the distribution board would have to be at least 15 amps. per way—this being the size usually marketed for this purpose. Certain makers list a 20-amp. range which of course will be quite suitable.

Why the Number of Points is Limited.

The reason for limiting the number of points on one circuit can readily be understood when it is realised that 3-kW. fires are often used where electrical heating is in regular use and a 3-kW. fire on 230 volts takes approximately 13 amps. If, therefore, there were two points on one circuit and both these were in use to the fullest extent at the same time, the total current would be 26 amps., which is too large for one circuit.

The Main Control Switch and Fuse.

The main control switch and fuse for heating or power circuits will have to be able to break the circuit with the maximum current flowing. It can be assumed, however, that all the points will not be full on at the same time. If this were so the capacity of the main switch would have to be 120 amps. The size of switch and fuse which would generally be installed for this purpose would be the 60-amp. size. This switch and fuse will isolate all the heating supply and is fed by separate leads from the meter as shown in the diagram.

The Smaller Power Points.

The question of the smaller power points must now be dealt with and in the schedule given there is only one of these—namely the refrigerator point. It is usual in a case like this to allow a small capacity

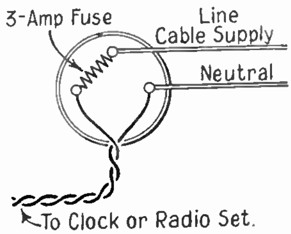


Fig. 6.—Diagram showing the Principle of the Fused Plug Point.

point to be added to a circuit especially when the load which is likely to be connected is not large. The refrigerator point would therefore in this case be added to the circuit supplying the washer since the latter would only be in use for short periods. A refrigerator for household use takes very little current and it is also not very usual for an electric washer to be fitted with electrical water heating although the 15-amp. plug is provided for this purpose in case it is wanted. The washing mechanism would be quite in order fed from a 5-amp. plug.

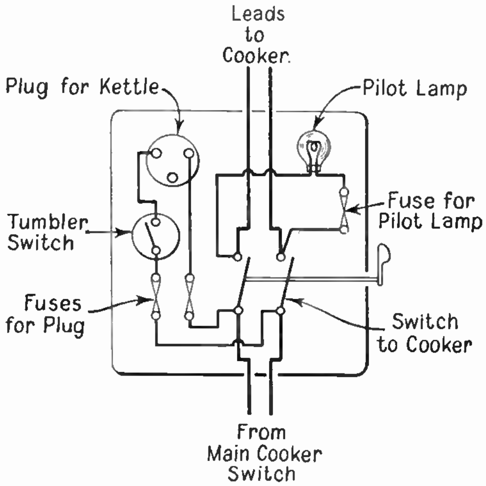


Fig. 7.—Cooker Control.
Showing fuses protecting plug and pilot lamp.

Wiring to the Smaller Plug Must Not be Less than that Connecting Larger Plug.

It should be mentioned in connection with this extra plug point (which is connected in parallel with the 15-amp. plug), that the wiring which supplies the smaller plug must not be less than that connecting the larger plug. This is on account of the size of fuse which protects the circuit. This fuse will blow presumably at 15 amps. and the conductors supplying the 15-amp. plug will carry this amount of current quite safely. If now the extension to the 5-amp. plug was carried out with wire suitable for only 5 amps. this would be unsafe in the case of a fault which allowed a current of, say, 12 amps. to pass. This current of 12 amps. would not blow the fuse and the cable to the 5-amp. plug would thus be dangerously overloaded. This situation would also arise in the case of some apparatus being incorrectly connected to a 5-amp. plug such as a 3-kW. fire. If possible distribution gear should always be arranged to provide for these possibilities.

Fused Plugs for Electric Clocks and Radio Sets.

The question of electric clocks and radio sets is also one which requires attention and these are provided for by means of *fused plugs.* The principle of these is shown in Fig. 6 where the clock or radio plug is connected as an extension to the 15-amp. heating plug in the same room. The current taken by a clock or radio set is so small that it is quite allowable to add this to a 15-amp. plug but since this apparatus is usually connected by means of " flex " it is necessary to provide a fuse before the size of conductor is stepped down. In this case it will be seen that should a fault develop in the circuit supplied by the flex the fuse (which would be about a 3-amp. fuse) would prevent the current from reaching a value which would damage the flex or other apparatus.

The Cooker Circuit.

With reference to the cooker, it is usual to provide an entirely separate circuit for this and the part which would be at the main control board is shown in Fig. 4. This control switch is usually a 30-amp. double-pole switch and fuse—generally ironclad—and this again has a separate feed from the meter. This switch is in the nature of a main control and the actual cooker control will be seen from Fig. 7. This cooker control is situated as as near as possible to the cooker at the other end of the leads to the cooker.

Special Ironclad Switch.

This cooker control unit is a special ironclad switch which includes a pilot lamp to indicate when the power is on to the cooker. This pilot lamp ensures the supply to the cooker being switched off when it is not in use.

How to Make a $\frac{1}{8}$ H.P. Squirrel Cage Induction Motor

By K. H. Greenly, B.Sc. (Eng.)

In the following article will be found full details for constructing a $\frac{1}{8}$ h.p. squirrel cage induction motor for A.C. mains. All the components or raw materials are easily obtainable and the design has been especially developed for practical men who own or have access to a 3-in. or larger screw-cutting lathe and a modest stock of other workshop appliances

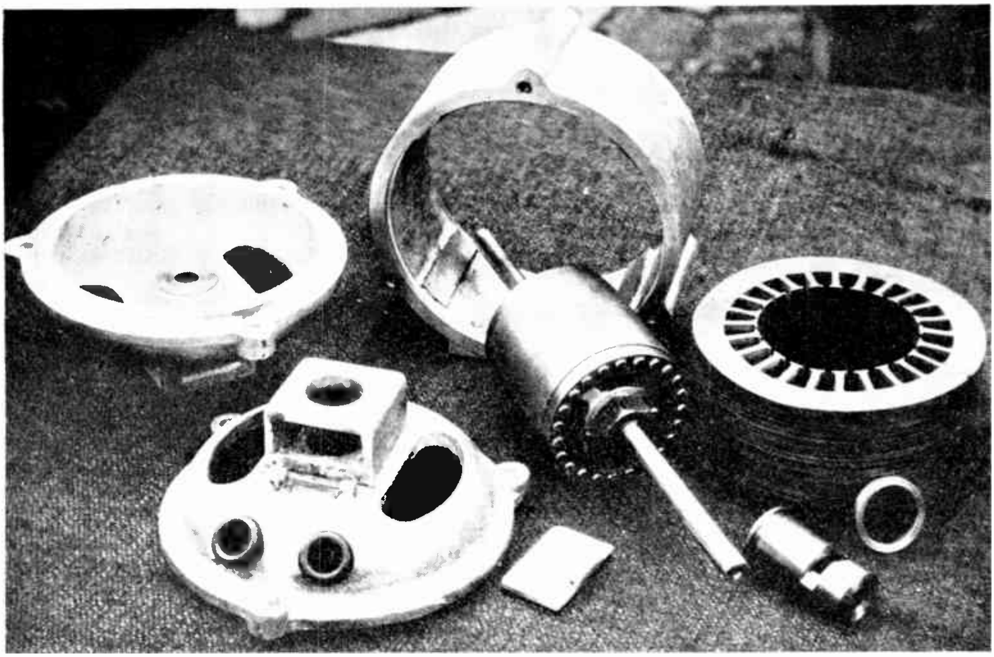


Fig. 1.—A View of the Component Parts Required for the $\frac{1}{8}$ h.p. Induction Motor.

An induction motor has been chosen for the sake of simplicity of construction. The armature winding is formed by 23 copper bars connected together by end rings. An actual motor has been built from the specification given and has given satisfactory results on test.

In Fig. 1 is an assembly of the various components. These may be divided into four main heads :—

(*a*) The stator stampings corresponding to the field magnets of a D.C. machine.

(*b*) The rotor assembly and shaft.

(*c*) Body casting in aluminium.

(*d*) End covers (aluminium) with bearings and lubricators.

From the photograph and the general arrangement drawing it will be seen that to avoid machining a large surface and to facilitate the fitting of the stator stampings in the machine body, the latter casting has four internal facings or " lands" $\frac{1}{2}$ in. wide and raised $\frac{1}{16}$ in. above its inner surface. They are also of slight

MATERIALS REQUIRED FOR CONSTRUCTION

Castings.

Two End Covers (Aluminium).
One Outer Casing (Aluminium).
Two Bearings (Gunmetal).
Two Lubricator Rings (Brass).
Two Lubricator Covers (Aluminium).
Two Rotor Spiders (Aluminium).
Two Rotor Short-circuiting Rings (Copper).

Stampings.

8 Dozen Stator Stampings, as specified } Stalloy.
8 Dozen Rotor Stampings, as specified. } Stalloy.

Wire and Insulating Material.

$1\frac{1}{4}$ lbs. No. 25 S.W.G. Copper Wire, Enamelled and Single Cotton covered.

$\frac{1}{4}$ lb. No. 32 S.W.G. Copper Wire, Double Cotton Covered.

6 ft. No. 8 S.W.G. Copper Wire, Bare.

One Sheet 10 mils. (.010") Leatheroid, 10 in. by 9 in

One Sheet Vulcanised Fibre, 32 mils. (.032") thick, size 6 in. by 3 in.

6 yards Cotton Tape, $\frac{1}{2}$-in. wide.

2 yards 5-amp. Flex.

2 ins. Ebonite Rod, 1-in. diameter.

Raw Metallic Material.

1 ft. $\frac{9}{16}$-in. Round Bright Mild Steel.

1 ft. $\frac{1}{8}$-in. Round Bright Mild Steel.

3 ins. $\frac{1}{16}$-in. Brass Pin Wire.

$\frac{1}{2}$ in. $\frac{3}{16}$-in. Round Bright Mild Steel.

Two Mild Steel Nuts, tapped $\frac{1}{2}$-in., 26 threads per inch.

Three Mild Steel Bolts, $\frac{1}{4}$-in. diameter, $3\frac{3}{8}$-in. long under head.

Three $\frac{1}{4}$-in. Whit. Nuts for the above.

Two $\frac{7}{16}$-in. Steel Washers.

Two $\frac{1}{32}$-in. by $1\frac{1}{4}$-in. Split Pins.

Small quantity of Tinman's Solder, Chatterton's Compound, Oil-resisting Varnish for Windings, and Paint for Motor Metalwork.

value in cooling as air may circulate more readily through the machine when running.

The End Covers.

The end covers are provided with oil-boxes, lubrication being effected by the time-honoured ring oiler system. They are bored to receive the gun-metal bearings and spigoted into the body casting to preserve the alignment. Furthermore, this spigot serves the purpose of clamping the stator stampings and must be just long enough to bolt right home face to face with the body, and at the same time grip the stator. It will be found that there is a certain amount of springiness in this group of stampings, sufficient to allow enough latitude in fitting. The rotor is again of Stalloy stampings of the same depth, viz., $2\frac{1}{4}$ in., as the stator, but 2.492 in. diameter outside as compared with the latter's 2.500 in. inside diameter. The air-gap of .004 in. obtained is a rather close one which will make for efficiency though .006 in. or even .010 in. could be tolerated.

How the Stampings are Supported on the Shaft.

The stampings are supported on the

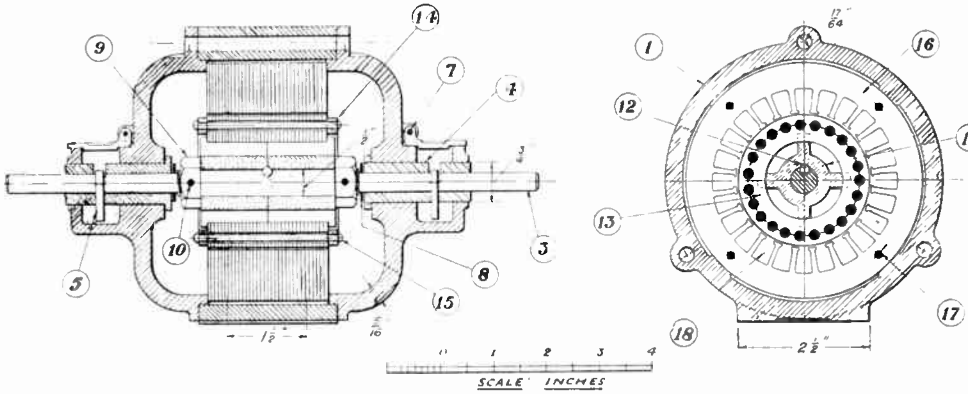


Fig. 2.—Here we see the General Arrangement of the Various Components.

shaft by a pair of cast aluminium spiders secured by a snug instead of the usual key and keyway, and bolted up from each end. It will be noted that the shaft is extended beyond the rotor at each end so that the drive may be taken from either side.

CONSTRUCTION.

Riveting Up the Stator Laminations.

Eight dozen laminations will make up the $2\frac{1}{4}$ in. depth required for the stator. As they are very accurately stamped and quite flat, there will be no difficulty in obtaining a smooth assembly if certain points are watched. On the edge of each plate will be found a small nick from which they may be registered up. One side is covered with a whitish insulating compound ("Insuline") whose purpose is to prevent eddy currents straying from one lamination to the next.

The notch will be found very convenient for location and each stamping should be placed the same way up on the last, in the correct register, so that the notches resolve themselves into a long groove. The position of these notches can just be seen on the extreme right in Fig. 1. Before riveting up through the four holes provided, check the depth by lightly squeezing the stampings up in the vice or clamp. Soft iron rivets should be used, and any slight burrs on the outside of the assembly cleaned off with a file.

Machining the Outer Casing.

The overall diameter of the body casting being a little under 6 in., it may be swung in a 3 in. lathe.

The facing and boring is a face plate job for a small lathe, and the casing bolt holes are convenient for bolting the job up during this operation. It may be

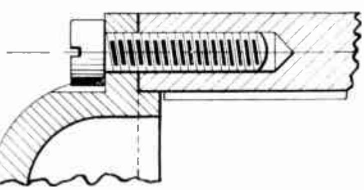


Fig. 4.—Showing Alternative Method of Securing End Covers.

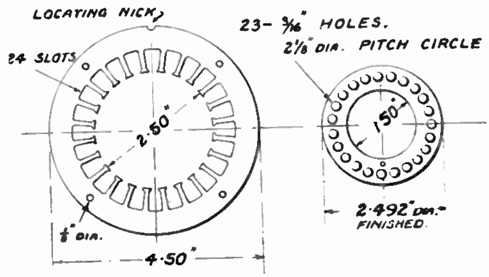


Fig. 3.—Details of the Stampings.

necessary to drill special holes in the face plate to accommodate these, but this is an advantage as the same holes may be used for mounting the end covers. There are two alternatives open in the matter of casing bolts, i.e., through bolts, a clearance fit through the carcase or stud bolts tapped into it. In either case, they should be $\frac{1}{4}$ in. diameter. If the former method is adopted, first mark out the casing carefully on each side, drill $\frac{3}{16}$ in. for a depth of about $\frac{1}{2}$ in. and tap $\frac{1}{4}$ in. Whitworth. Short set-screws through the face plate screwed into these holes will then secure the casting rigidly enough for ensuing operations, the holes being afterwards drilled through $\frac{1}{4}$ in. clearance.

Fig. 5 shows the casting rigged up for the first machining operations. The internal "lands" should be carefully bored to a good fit with the stator stampings and these should be tried in several positions in case they are not quite in register at some particular spot round their periphery. Before this casting is removed, face the ends, and counterbore to $4\frac{3}{4}$ in. diameter, for a depth of $\frac{3}{16}$ in. full.

Jigging the Carcase Casting.

The corresponding counterbore at the reverse end *must* be quite concentric with the first. Some form of jig to locate the as yet unfinished casting is essential, and a thin disc of brass or aluminium bolted through the face plate suggests itself. The photograph shows the jig plate bolted to the face plate through the slots and skimmed up to a push fit in the work.

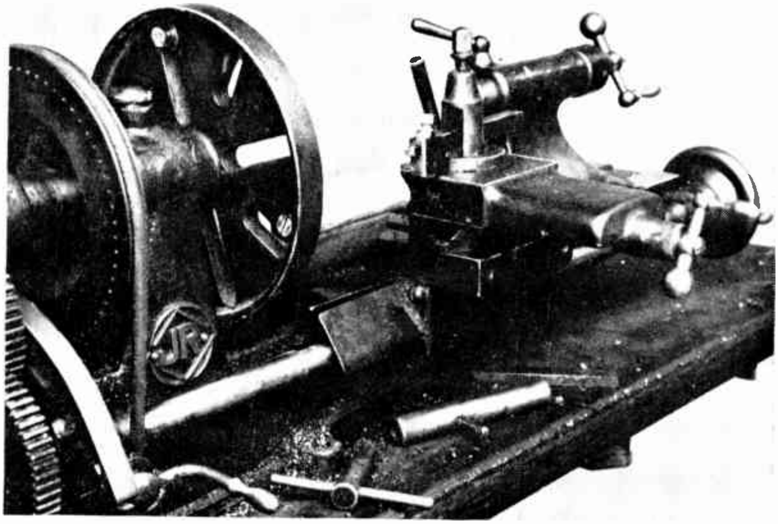


Fig. 5.—The First Operation in Facing the Motor Carcase.

The End Covers.

The end covers should be marked out and drilled to suit the carcase and using the same holes bolted to the face plate, bored $\frac{3}{4}$ in. for the bearing bush, and the front boss faced. Here again, before the work can be reversed for turning the spigot, an arbor, held either in the chuck or between centres, must be made up (Fig. 7) in order to ensure perfect alignment of the rotor and stator. The gun metal bearings are a plain turning job, but a point to watch is the relieving of the sharp corner at the inside shoulder about $\frac{1}{64}$ in. for a length of $\frac{1}{32}$ in.

When machining is completed the oiler slot is filed away far enough to allow a clear run for the oiling ring when resting on the shaft. Oil ways leading from this slot towards each end of the bush should be cut with D-shaped chisel, finishing in an annular groove whose purpose is to prevent the lubricant working out.

The Rotor.

The main work on the carcase is now complete, and the rotor assembly should next be tackled. The rotor-shaft is a straightforward between centres job on which little comment is necessary. If a travelling steady is available it should be used, and in any case the last few cuts must be very light and the tailstock adjusted if the lathe has any tendency to turn tapered.

A length of 4 in. (bare) in the centre of the shaft is left $\frac{1}{2}$ in. diameter, and screw

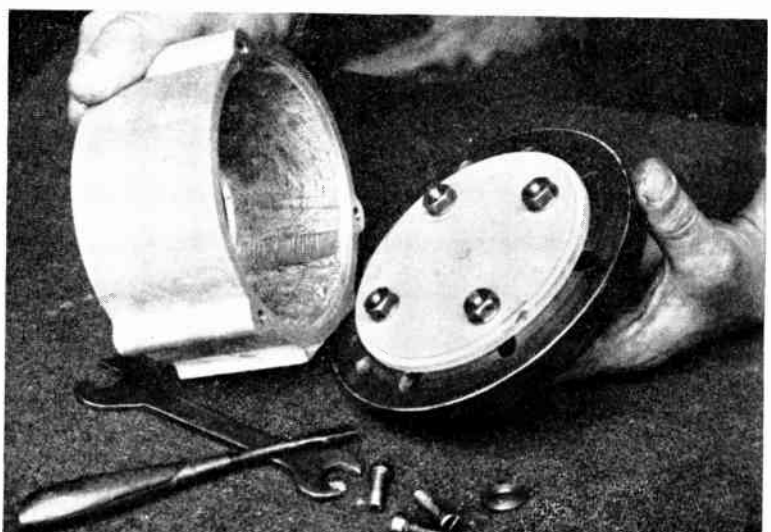


Fig. 6.—Registering the Jig for Machining the Carcase.

cut 26 T.P.I. at each end for a length of $\frac{1}{2}$ in. while the rest is reduced to $\frac{7}{16}$ in., a good running fit on the bearings. A shallow hole $\frac{3}{16}$ in. diameter accommodates the snug or "dutchman."

The rotor spiders are best held in a 4-jaw chuck for boring and facing the inner surface, after which the arms of the "star" may be turned to fit the rotor stampings either on a special arbor or on their own shaft. The final fitting of the snug should be left until the stampings are ready for assembly. There must be just sufficient stampings to allow the two halves to press firmly against them and at the same time engage the snug with no trace of looseness. A badly fitting snug will be a constant source of trouble and may eventually fail.

The Short Circuiting Rings.

A pair of copper rings will be required drilled with 23 holes .161 in. diameter (No. 20 drill) at $2\frac{1}{8}$ in. diameter pitch circle. In the absence of a dividing head a single stamping makes an excellent jig for marking out the holes. The two rings should be clamped together and drilled without parting, and two locating marks made for reference when the time comes for the final assembly.

The 23 $2\frac{5}{16}$-in. long rotor bars should be cut from No. 8 S.W.G. copper wire, previously softened, if necessary, and the assembling of the rotor can then be commenced.

Assembling the Rotor.

As in the case of the stator laminations, a small locating hole will be found in each rotor stamping, through which a piece of thin copper wire may be temporarily threaded to keep the stampings in place, but it is important that no futher riveting shall be commenced until the laminations are safely on the spiders.

The exact number will have to be arrived at by trial and error. It must be remembered that once the bars are in position the snug cannot be got at save by completely dismantling the whole rotor. The same precautions with regard to the insulated side of the stampings should be observed as in the case of the

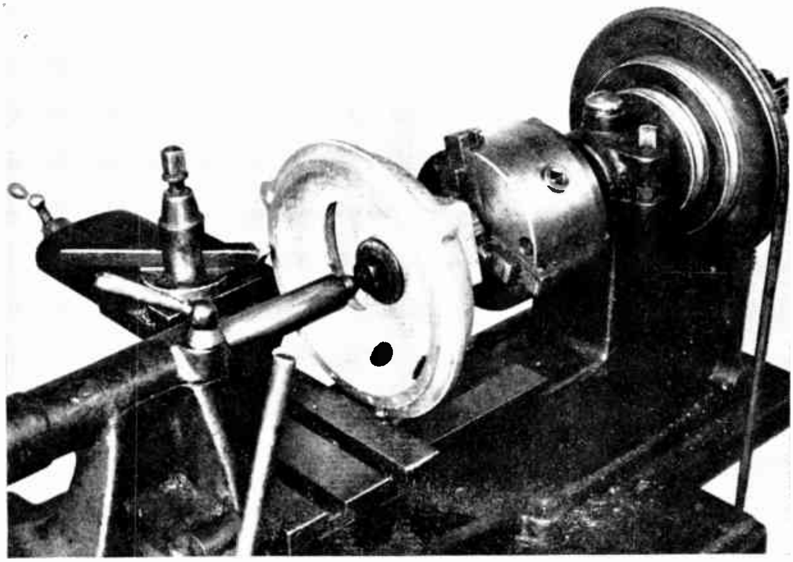


Fig. 7.—TURNING THE SPIGOT OF THE END COVER CASTING ON A SPECIAL ARBOR.

stator. Having got the laminations safely housed on the spiders and clamped up by the shaft nuts, the riveting up of the rotor bars can be proceeded with. Do not forget location marks on the short circuiting rings. The actual riveting may be a two handed job unless the vice jaws are used as an anvil, but care should be taken not to damage or bend the shaft. The ends of the bars must be scrupulously clean to ensure a good electrical connection (the more complete the short circuiting the higher the efficiency) and also to facilitate the subsequent soldering up. When the heads

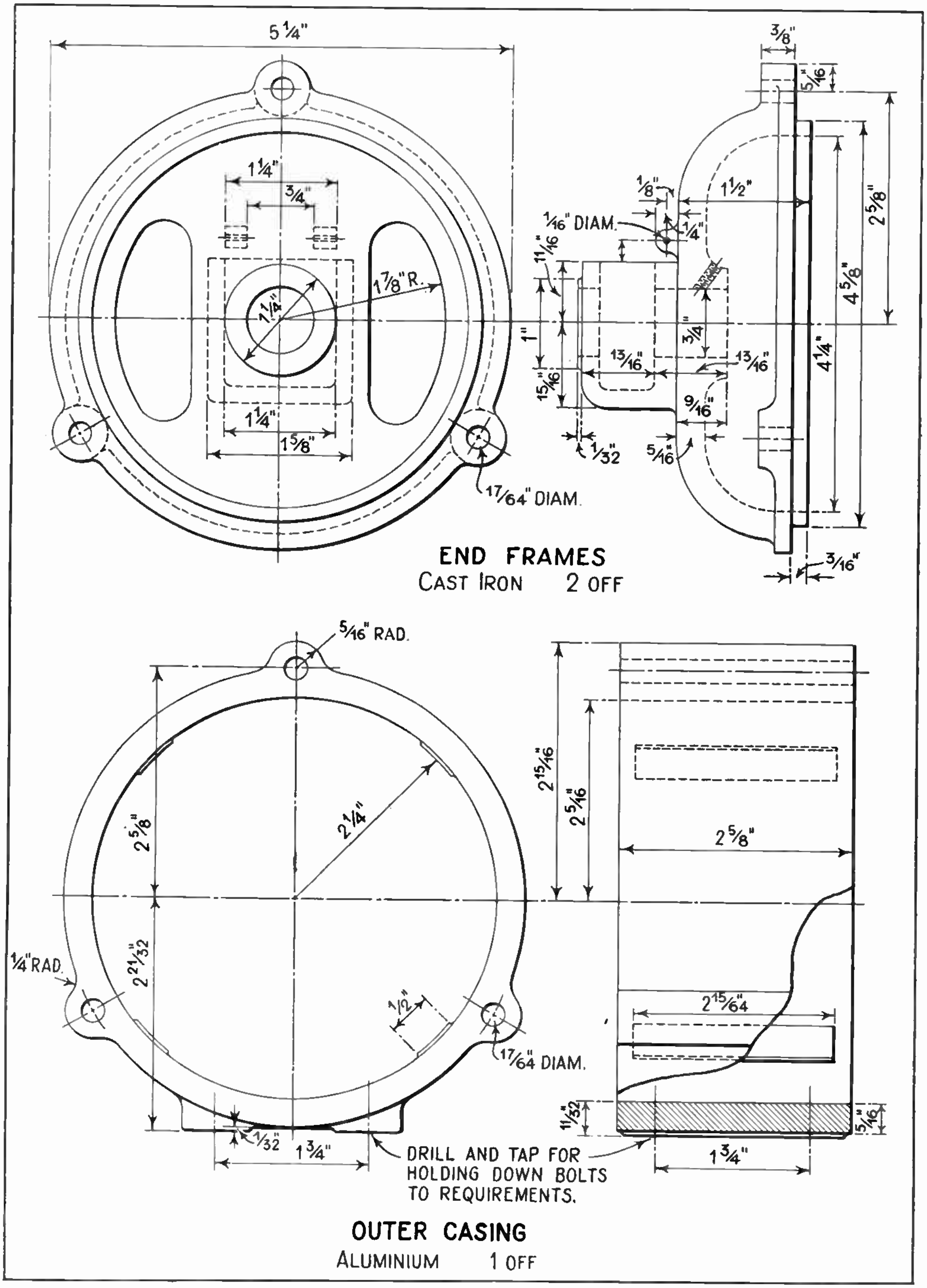


Fig. 8.—SHOWING DIMENSIONS OF THE END FRAMES AND OUTER CASING.

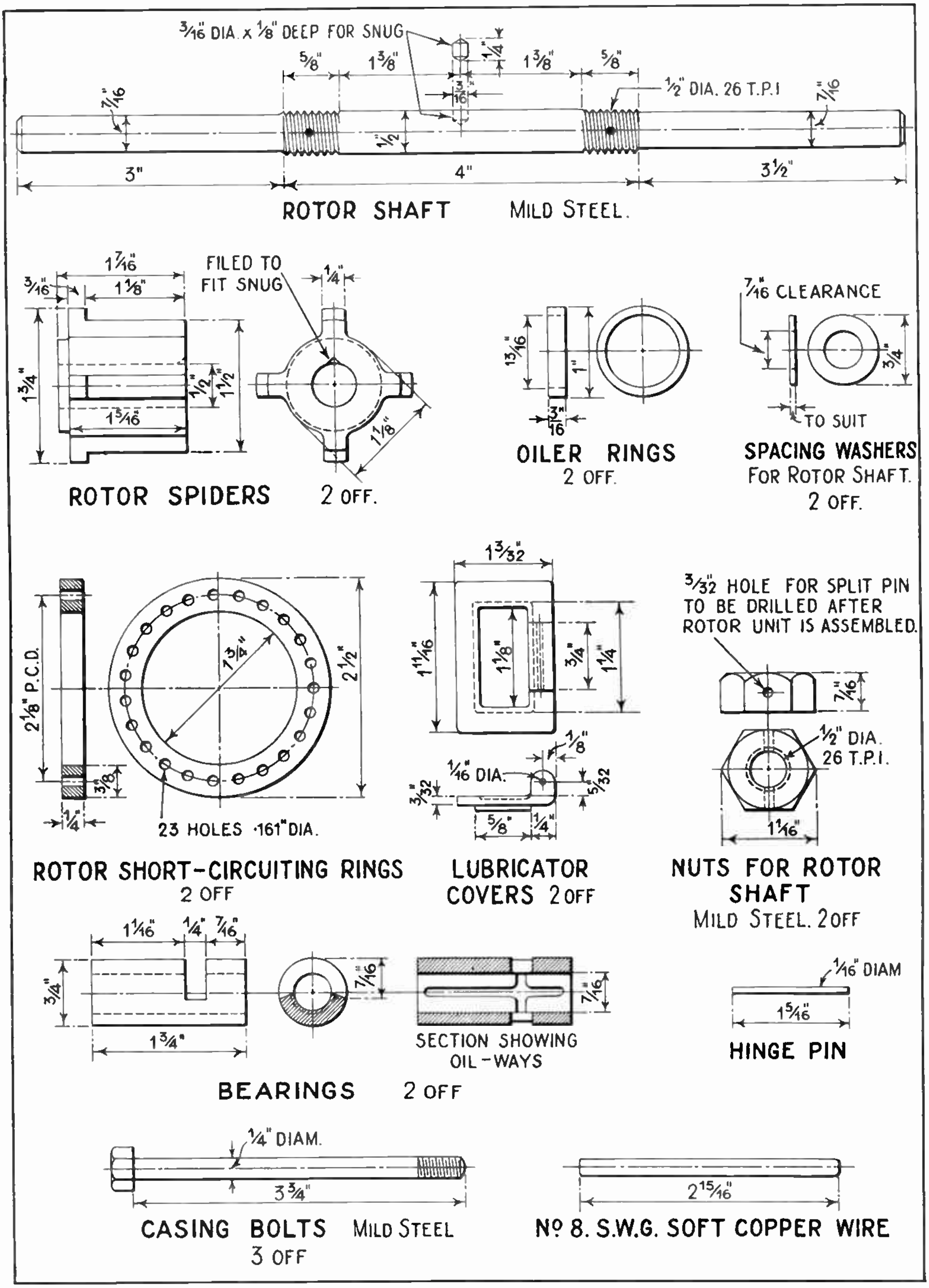


Fig. 9.—SHOWING DIMENSIONS AND DETAILS OF VARIOUS PARTS OF THE MOTOR.

have been brought over a final shaping may be accomplished with a cup-shaped "snap" (Fig. 10). As a precaution the nuts are finally drilled $\frac{3}{32}$ in. and pinned with a split cotter.

The whole job should now be heated up together with the shaft vertical and plenty of soft solder run round the heads of the rivets, dealing with one end at a time. A non-corroding flux should be used.

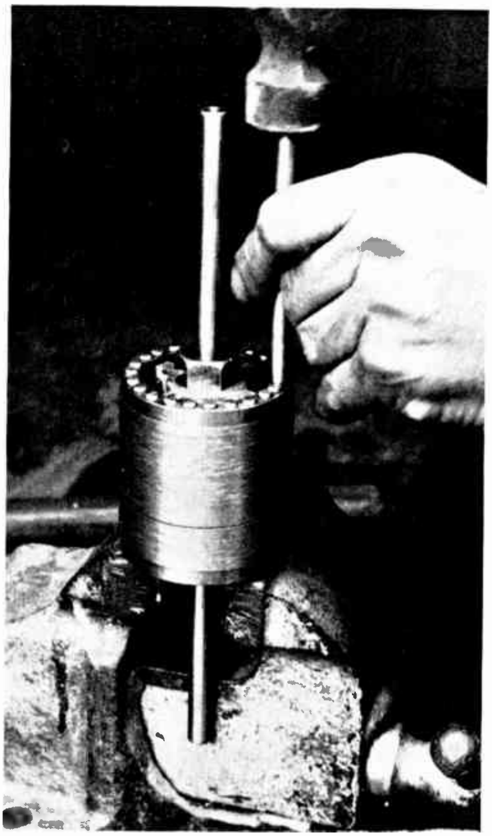


Fig. 10.—RIVETING UP THE ROTOR BARS.

Reducing the Rotor to Size.

There will probably be a number of high spots and burrs standing up in the laminations which must be taken down before the rotor will clear the stator teeth. However, it is best to avoid turning the surface as there will be a tendency for one lamination to be forced into good electrical contact with the next, so partially defeating the object of preventing the flow of eddy currents through the iron core. The rotor unit may be mounted in the lathe between centres and carefully filed or ground down until it is 2.492 in. in diameter, and all roughness removed. As against the 2.500-in. bore of the stator, this will provide an air gap of .004 in.

Checking Rotor for Balance.

The rotor cannot be deemed complete until it has been checked for balance. As a matter of fact, if the earlier marking out and machining has been reasonably accurate, there should be little the matter with it ; but even a slight error in balancing is going to make itself noticeable at 2,800 r.p.m.

A suitable rig for the purpose may be very simply improvised from two domestic knives set into a couple of pieces of 3 × 2 in. timber, as illustrated in Fig. 11. They should be very carefully checked for level both along the blades and at right angles to them before the rotor is rested across them. It will be easier to chalk the light side and then carefully remove any blob of solder or high rivet head equally from each end ring opposite the mark until the rotor shows no tendency to spin to rest in any particular place.

It is scarcely possible to check it for dynamic balance, but as long as the static balancing is reasonably accurate no trouble should ensue.

Trial Assembly.

A trial assembly can now be made. Carefully tap the stator laminations into the casing with a wooden mallet, avoiding damage to the teeth, until it just covers the raised facings inside the casting. One end cover with bearing complete can then be slipped on, and the rotor shaft run into it. The oiler ring must, of course, be assembled at the same time as the gunmetal bearing is driven home into the casting. The other end casting is now ready for fitting and the casing bolts lightly tightened up. The rotor must run without a trace of stickiness anywhere. Check the air gap for evenness at three or four points round the circumference, say at 12, 3, 6 and 9 o'clock, revolving the rotor a quarter turn each time. There should be very little variation at any point, as each part is accurately registered by the various spigots and facings, and it is unlikely that anything more than 1 or 1½ "thous" difference will be noted. The shaft should run, of course, quite freely, and the mechanical side being in order, the machine can be dissembled for winding.

Winding the Stator.

The process of winding the stator may not be anticipated with much keenness, but there is no need to be apprehensive of many difficulties. A plain two-pole winding of this type is a good deal easier to put on than, say, the winding of a drum armature, and providing a few elementary rules are followed, failures are unlikely.

For starting purposes, a separate winding is provided, placed at right angles to the running coils and switched on for an instant at starting only, and then disconnected from the mains. In Fig. 13 the disposition of the running and starting coils is illustrated, the former being shown by heavy lines and the latter by light.

The starting coils are wound with a much finer gauge of wire than the running coils, and occupy less slot space in the stator—eight slots as compared with 16 in this machine. The difference in resistance between the two is sufficient to alter the phase of their respective currents and converts the winding temporarily into a two-phase one, biasing the fields in a certain direction. The rotor will pick up in speed in that direction until it is near synchronism and the auxiliary winding must then be cut out of circuit immediately.

We shall therefore need two separate sets of coils, producing four poles for starting and two for running. In Fig. 12 the stator is drawn as it would be photographed by a panoramic camera making a complete revolution at its centre. The teeth are represented by black rectangles and the space between them is, of course, the slot space available for housing the conductors. For the sake of simplicity each heavy line indicates not one wire, but a bundle of conductors running through that particular slot.

Why Coils are Concentric.

It will be noticed that the coils are concentric, i.e., they are not lapped one ahead of the next, as in a drum armature winding, and, furthermore, the direction of rotation is reversed between the two pole groups. This is necessary to produce opposite poles at a spacing of 180 degrees, considering the starting and running coils separately.

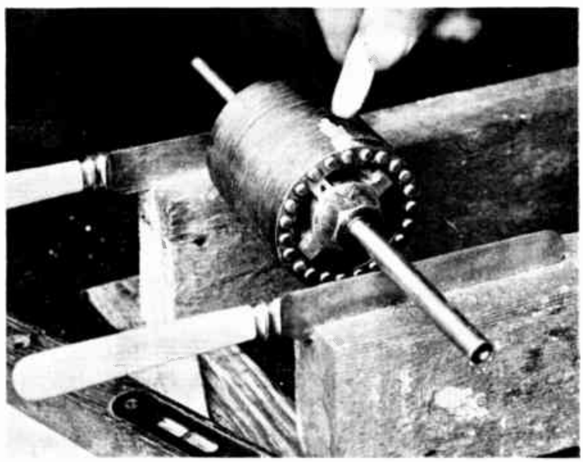


Fig. 11.—How to Balance the Rotor.

A suitable rig for the purpose can be improvised from two knives set into two pieces of 3 × 2 in. timber. It will be found easier to chalk the light side and then carefully remove any blob of solder or high rivet head from each end ring opposite the mark.

The Running Winding.

Referring again to Fig. 12 we can trace out the method of winding. Commencing with the running winding, the first coil consists of 85 turns of 25 S.W.G. wire spanning slots 9 to 4 in an anti-clockwise direction. Continuous with this are a further 85 turns each between slots 10 and 3, 11 and 2, and 12 and 1, all in the same direction. The end leading

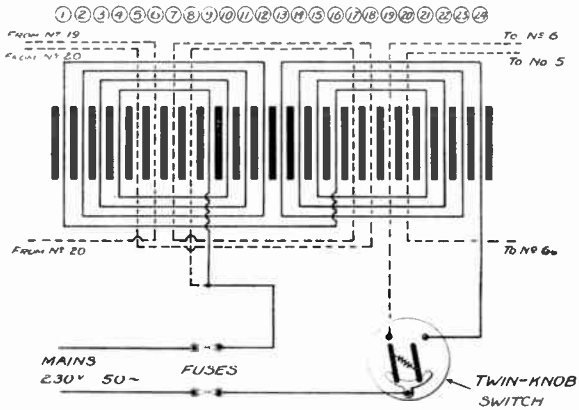


Fig. 12.—A DEVELOPMENT OR "PANORAMIC" SKETCH OF THE WINDINGS.

Note how each opposing coil-group has its direction of winding reversed when seen from the centre of the stator tunnel. The running winding is shown by full lines and the starting winding by dotted lines.

to the developed winding diagram and assist in tracing the connections. Each slot must be lined with a strip of 10 mil leatheroid cut to such a length as to overhang at each end about $\frac{1}{8}$ in. and wide enough to cover the whole inside surface and be flared out at the slot opening as shown in Fig. 16.

The protection this offers will prevent damage to the wire as it is slipped into the narrow space between the teeth; the ends can be trimmed after the slot has been filled, folded in and the opening closed with a strip of $\frac{1}{32}$ in. fibre $2\frac{1}{4}$ in. long by $\frac{3}{16}$ in. wide, which will effectively prevent any wire becoming displaced in subsequent service.

from No. 1 is continued to the opposite side of the stator and 85 *clockwise* turns laid between slots 16-21, 15-22, 14-23 and 13-24.

The Starting Winding.

The starting turns are accommodated in the remaining eight slots. The 32 gauge wire is used here, and the first two coils to lay on are Nos. 8 to 17 and 7 to 18 (clockwise), 150 turns each. The end leading from No. 18 is passed across to No. 20 slot and is used to start the last two coils, 20 to 5 and 19 to 6, again 150 turns per slot, but wound in an anti-clockwise direction.

The accompanying table gives the details of a winding for 220-250 volts, 50-cycle single phase supply:—

Running winding	Gauge of wire ..	25 S.W.G. enamelled and single cotton covered
	Conductors per slot	85
	Slots per complete coil	8
	Coils per phase ..	2
Starting winding	Gauge of wire ..	32 S.W.G. double cotton covered
	Conductors per slot	150
	Slots per complete coil	4
	Coils per phase ..	2

What to Do Before Winding is Begun.

Before winding is begun, the slots are numbered from 1 to 24 to conform

Important Points to Remember.

Having studied Figs. 12 and 13, the actual winding can be started. The most important fundamentals are as follows:—

Never let the wire get kinked; work the wire gently into the space between the stator teeth without resort to ham-

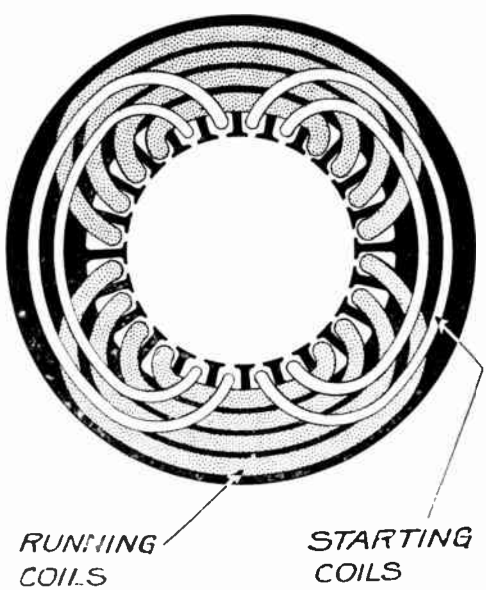


Fig. 13.—END VIEW OF THE STATOR.

Showing the disposition of the starting and running windings.

mering; and, finally, do not damage the insulation.

For the running coils enamelled and single cotton covering has been specified. For amateur use it forms an ideal insulation, far superior to plain enamelled covered, though a good deal more expensive. The single cotton covering affords a strong fibrous insulation, is quite difficult to damage and at the same time takes up less space than the common double cotton covering.

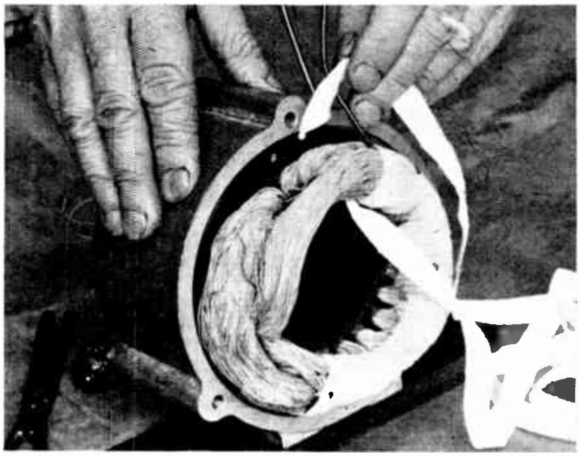


Fig. 14.—Taping the Finished Windings.
Plain white linen tape is employed here, secured at intervals with a touch of Chatterton's compound.

First, the Running Coils.

The running coils should be tackled first. It will be found easier to handle the stator if it is slipped into the body casting and all subsequent operations performed with the two units assembled. It is really quite immaterial where the windings are begun, so long as the coil pitch is correct. Hand winding is best for these coils as the natural stiffness of the 25 gauge wire is sufficient to keep the turns in place. The bobbin should not be passed through the stator tunnel, but a loop of wire formed and one conductor at a time fed into its particular slot. The end or "dead" turns not enclosed by the stator iron must be carefully formed to a small arc and not pulled tightly to a sharp corner, but if too much wire is left here it may be difficult to house the bundles in the end covers.

Now the Starting Coils.

The starting coils are best wound on two sizes of wooden former and afterwards housed in the remaining slots. A few conductors at a time are carefully slipped in, and when the whole of one side of a coil has been accommodated the leatheroid insulation should be tucked in and the slot closed by a fibre strip. However, there is the disadvantage of having to connect the appropriate ends of the coils together in the correct polarity. The actual sizes of the formers are best obtained by trial, as much will depend on the running winding previously laid on.

Testing Polarity of Windings.

It is a wise precaution to test with a compass needle. Deal with the starting and running windings separately. Connect the leads of one of these to a 2 or

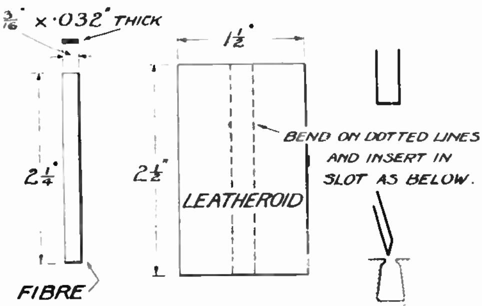


Fig. 15.—Details of Insulation for the Stator Slots.

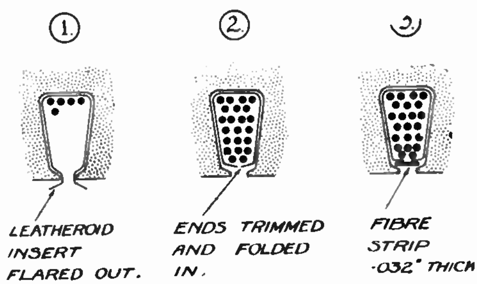


Fig. 16.—How the Stator Slots are Insulated.

4-volt accumulator, and with the stator lying horizontally on the bench, lower a small compass needle into the bore, keeping it quite close to the stator teeth. As the needle is passed round, it should indicate two quite definite unlike poles at 180 degrees to each other, concentrated at the centre of the appropriate winding.

If everything is in order, the remaining winding may be dealt with in the same way, and the end turns taped. For this purpose plain white linen tape ½ in. broad will answer very satisfactorily, and may be held in place by a touch of Chatterton's compound where required.

The stator can then be thoroughly dried out in an oven before the windings are "doped." It is important from the point of view of insulation to dispel any moisture in this way first. Any good oil-resisting varnish may be used, applied quite liberally and allowed to run right down into the slots from each side.

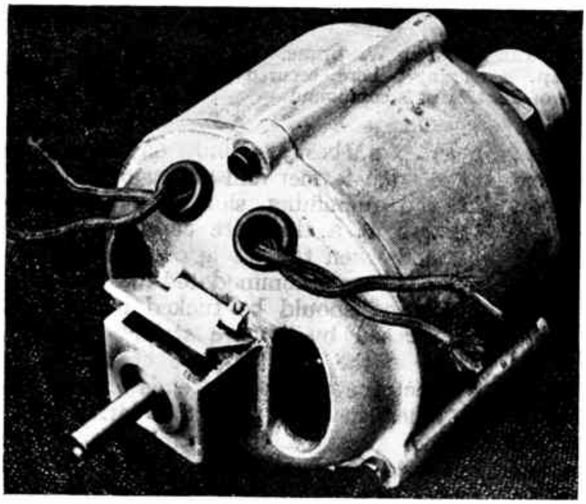


Fig. 17.—GENERAL VIEW OF THE COMPLETED MOTOR. The leads to the starting winding are on the left; the leads to the running winding on the right.

Assembly of Motor.

The motor is now ready for assembly. Be careful not to damage the windings as the end covers are put on. When tightened up they should clear the winding by a fraction of an inch, but if there is any tendency for the windings to be squeezed up, a layer of thin presspahn round the inside of the covers will obviate a possible "short" to earth. The starting and running coil leads may be brought out through insulating bushes in the end covers direct to the switchboard, or, alternatively, via an insulated terminal box.

Cutting Out the Auxiliary Winding.

As previously mentioned, the auxiliary winding is required only for a short time while the motor is speeding up, after which it must be cut out of circuit. The easiest way of accomplishing this is by means of a special type of switch known as the "twin knob." In appearance it is similar to a tumbler lighting switch, with the exception that there are two levers, one recessed into the other, which control two sets of contacts. While the hand is on the switch, both knobs are operated, and the starting and running circuits are made simultaneously, but when the hand is removed the inner knob is returned by a spring and breaks the starter circuit.

Connections to Mains.

The actual connections to the mains are shown in the winding diagram Fig. 12. There is always a momentary rush of current at starting, amounting to four or five times the full load current, i.e., 3 to 4 amps. The supply leads must therefore be fused to at least 5 amps., but there is no reason why the machine should not be run from lighting mains if required in a portable capacity such as for fan driving.

Finally a word about the availability of the material. The Queen's Engineering Co., of 60, Queen's Road, Battersea, S.W.8, are supplying a complete kit of components in the unfinished state, comprising castings, stampings, wire and insulating materials and full-sized blue prints at the inclusive price of 45s.

Sets of castings and stampings are also available as separate items.

PRACTICAL DETAILS OF A BRIDGE METHOD OF MEASURING AND COMPARING INDUCTANCES

THE following particulars relating to the measurement or comparison of inductances such as L.F. chokes, intervalve and output transformers may prove of assistance to experimenters who are desirous of conducting their own tests and measurements.

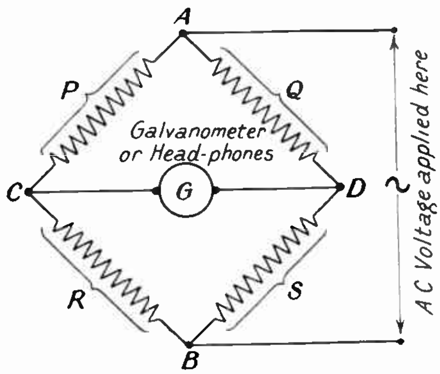


Fig. 1.—A SIMPLE BRIDGE CIRCUIT. Where the arms P, Q, R and S are all equal in value.

The basic circuit is that of the Wheatstone Bridge and is illustrated in Fig. 1.

The four arms of the bridge are of equal value and the bridge is supplied with alternating current at points A and B, whilst the galvanometer or detector is connected across C and D. Under these conditions the bridge will "balance" and the galvanometer will show no deflection.

The Circuit Actually Employed.

The circuit actually employed is shown in Fig. 2 and will be seen to be a modification of that in Fig. 1. The "arms" of the bridge are P, Q, R and S, and it will be noted that P, Q and R are identical. The arm S consists of two resistances in series—N a fixed resistance and X a variable resistance. This arm is shunted by a variable condenser C, and the inductance under test L. The self capacity of the inductance coil, shown in dotted lines, acts as if it were in parallel with C.

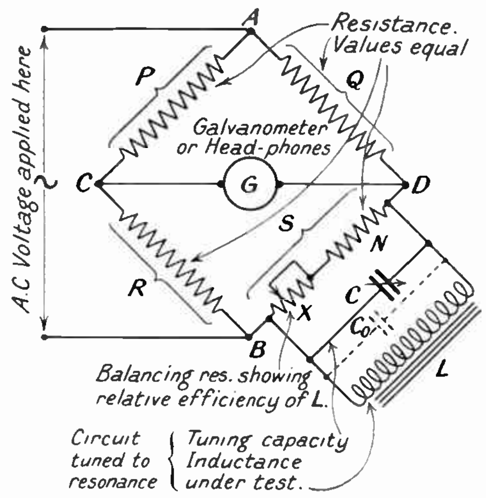


Fig. 2.—THE ACTUAL BRIDGE CIRCUIT EMPLOYED FOR THE INDUCTANCE MEASUREMENTS DESCRIBED IN THIS ARTICLE.

Alternating current is fed to the bridge at A and B, and the galvanometer or detector is connected across C and D.

Prior to describing the operation and values of components required it will be worth our while to consider the principle employed.

The Principle Employed.

To obtain a balance it is necessary in this form of bridge that the arms have the same electrical value. Now arms P, Q and R are made equal at the commencement, therefore arm S is the one to be considered.

Referring to Fig. 3A, we see the equivalent of arm S, where the capacity C and the inductance L are in parallel across the resistances N and

X in series, the whole combination forming the arm S.

Now this looks very complicated, but it is not so bad as it looks. If we resonate the inductance L by means of capacity C to the frequency of the supply, we then have in place of C and L what is known as a dynamic resistance Rd, and our equivalent electrical circuit becomes that shown in Fig. 3B. Since two resistances in parallel give a sum total less than either of them taken singly, it is obvious that if the sum of N and X in series with Rd in parallel is to equal that ot the other arms then the value of N and X (without Rd in parallel)

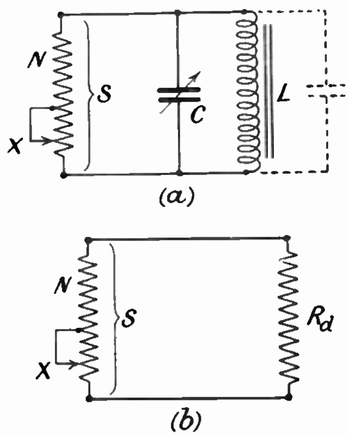


Fig. 3.—THE ARM S.

At (A) we see the equivalent of arm S, where the capacity C and the inductance L are in parallel across the resistances N and X in series, the whole combination forming the arm S. (B) shows the equivalent electrical circuit when L is resonated by C to the frequency of the supply, so that in place of C and L there is a dynamic resistance Rd.

must be greater than any of the other arms. Therefore, we make resistance N equal to the other arms and use the variable resistance X to compensate for the effect of Rd, the dynamic resistance, in parallel.

The Component Parts of the Bridge.

For general purposes arms P, Q and R may consist of 1,000 ohms resistance each. Resistance N should then be 1,000 ohms, and resistance X 0 to 50 ohms variable (calibrated). These resistances should have low inductance or preferably be non-inductive.

The galvanometer, G, should be sensitive and suitable for use with alternating current. If the frequency is suitable a pair of telephones may be used. A resistance in place of the galvanometer with an amplifier transformer-coupled to it may be used if necessary and a variable shunt may also be needed across the galvanometer, which can be set to requirements when adjusting the bridge.

The A.C. Supply to the Bridge.

This should preferably be taken through a transformer and the variable and fixed resistances should be shielded and the shields earthed and the transformer should have a shield between primary and secondary which should be earthed. These precautions will minimise electrostatic effects due to hand capacity, etc.

The Variable Capacity.

The value required will depend upon two factors—the inductance of the choke or transformer and the frequency used when measuring. If 50 cycles be taken as the lowest frequency likely to be used, then for inductances from 10 to 50 hys. a capacity variation of from .22 mfd. to 1.0 mfd. will be required.

A table is given showing the capacity values required for various inductance values at a frequency of 50 cycles.

TABLE OF CAPACITY VALUES FOR USE TO RESONATE VARIOUS VALUES OF INDUCTANCE AT 50 CYCLES.

Inductance L in Henries.	Capacity C in Microfarads.
10.14	1.0
20.28	0.5
30.00	0.338
40.00	0.251
50.00	0.228
60.00	0.169
70.00	0.144
80.00	0.126
90.00	0.112
100.00	0.101
150.00	0.067
200.00	0.050
250.00	0.040

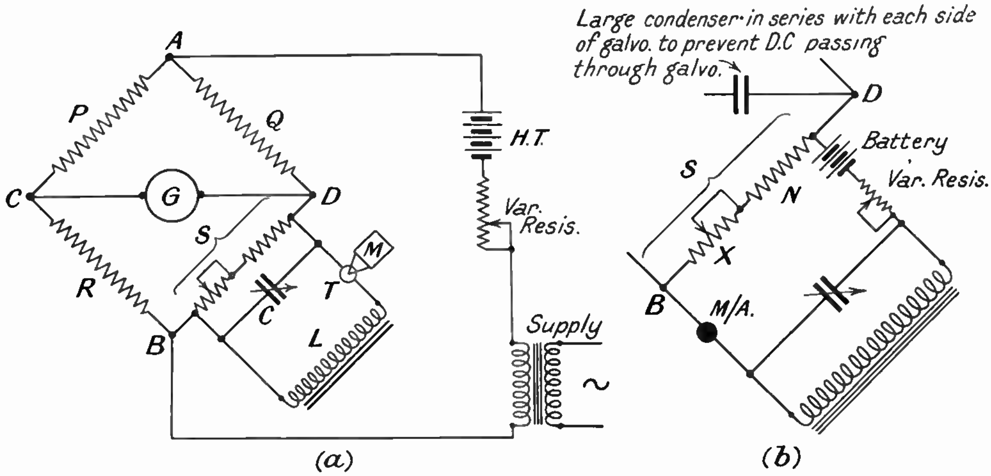


Fig. 4.—TWO METHODS OF APPLYING A POLARISING CURRENT TO THE INDUCTANCE UNDER TEST.

These values may be obtained from the combination in parallel of various other values such as 4, 3, 2 and 1 giving 10 units or 5, 2, 2 and 1 or 3, 3, 2 and 1 or 5, 3, 1, 1. To cover the range from .001 to 1.111 mfd. a total of 12 condensers is all that is required. These may consist of groups as follows :—

.001 mfd.	.01 mfd.	.1 mfd.
.002 mfd.	.02 mfd.	.2 mfd.
.003 mfd.	.03 mfd.	.3 mfd.
.004 mfd.	.04 mfd.	.4 mfd.

It is worth while obtaining these with a reasonable accuracy and most reliable firms will supply these for a slight extra charge.

Use Condensers of Reasonably Good Power Factor.

Condensers possessing a reasonably good power factor should be used if considerable accuracy is desired, otherwise poor condensers may introduce considerable loss into the tuned circuit L.C. For general comparison purposes it is not essential to use expensive condensers and reasonably good ones of the non-inductive variety will be found to suffice.

Method of Adjusting for Test.

Having set up the bridge the first thing to be done is to see if the zero setting is in order.

Disconnect the test inductance L and the variable capacity C.

Set the variable resistance, X, to zero and a balance should now be obtained since, by construction, the resistances P, Q, R and N were made equal. For preliminary tests the voltage across the bridge points A and B need not be high —say two to four volts. The maximum voltage which may be applied to the bridge will depend upon the safe current carrying capacity of the components and it should be borne in mind that, if the resistances are allowed to warm up, their values will in all probability change.

Connect across B and D a resistance of 100,000 ohms, and observe the galvanometer deflection. If too small increase the value of the galvanometer shunt or the volts on the bridge. Next bring the bridge back to balance by varying X a few ohms. Then remove the shunt resistance and reset X to zero when the bridge should again balance. At balance there should be no galvanometer deflection or, if phones or an amplifier be used, the sound should be nil or at a minimum.

To Operate Bridge.

Connect up the variable capacity C and the test inductance L, and switch on the A.C. supply to bridge. Vary the capacity till deflection or sound is at a minimum—

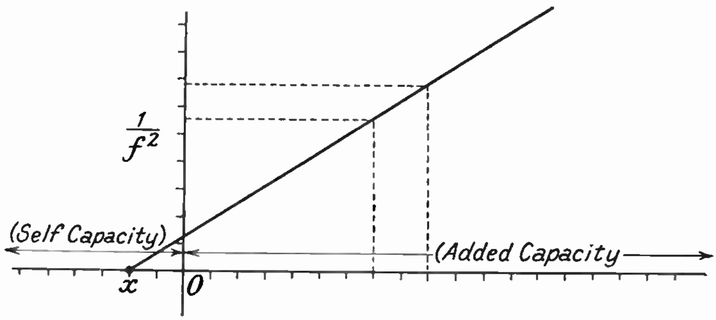


Fig. 5.—METHOD OF PLOTTING A GRAPH FOR DETERMINING SELF-CAPACITY.

would be equal to the square root of 314 × L (squared) + r (squared). If r is only a very small proportion of the value $2 \pi f$ L it can usually be neglected.

An example is given of an actual measurement showing how these figures are obtained.

a perfect zero will *not* be obtained. Then next vary X until a minimum or perfect zero is obtained. From the values of the capacity and X we can now ascertain the inductance value and the value of the dynamic resistance Rd and from these other values may be obtained.

The *inductance* is equal to L, where L is given by :—

(1) $L = \frac{1}{4\pi^2 C f^2}$ henries (neglecting the self-capacity C_0) ;

(2) Or $L = \frac{1}{4\pi^2 (C + C_0) f^2}$ henries (including the self capacity).

If our supply frequency be 50 cycles, then L is equal to:—

$$L = \frac{10.15}{C \text{ mfd.}} \text{ henries (1)}$$

$$\text{or } L = \frac{10.15}{(C + C_0) \text{ mfd.}} \text{ henries (2)}$$

The *dynamic resistance* is equal to :—

$$Rd = \frac{N^2}{X} + N \text{ ohms or to } \frac{(N + X)\ (N)}{X}$$

If N was made equal to 1,000 ohms, then

$$Rd = \frac{1{,}000{,}000}{X} + 1{,}000 \text{ ohms.}$$

Since the dynamic resistance Rd is equal to $\frac{L}{Cr}$ where r is the effective resistance and since L and C are known r can be calculated. Once this value r has been secured the impedance of the choke or coil can be calculated for the frequency at which it was measured and will be found equal to Z where Z is given by $\sqrt{(2 \pi f L)^2 + (r^2)}$ which at 50 cycles

Further Variations with the Circuit.

In Fig. 4 two methods are shown for applying a polarising current to the inductance under test so that its inductance value may be read for various values of D.C. flowing. It will be found that this is a very important factor, especially with L.F. intervalve transformers and chokes as, after the polarising current reaches a certain value the inductance value commences to fall with increased polarising or "magnetising" current.

In Fig. 4A, the A.C. is measured by means of a thermo-couple T and a meter M, whilst in Fig. 4B the D.C. is measured by the milliammeter M/A.

In order to minimise the effect of any D.C. on the galvanometer suitable condensers are inserted in series with it.

Ascertaining the Self-capacity.

To do this it is necessary to observe the change of variable capacity with various frequencies (keeping the volts on the bridge constant the whole time), and to plot a graph as in Fig. 5. The amount of self capacity is shown as $o\,x$ and is measured in terms of the same units as the added capacity.

Effect of Leakage Inductance.

If, say, the primary of a transformer be connected to the bridge and the inductance measured (with the secondary open-circuited) it will be found, when the secondary is short circuited, that the balance is upset and if the value of inductance remaining be measured it will be very much less than before. This inductance value is the "leakage inductance," and it should not be high in the case of a good transformer—about 1 per cent.

Many other interesting experiments may be carried out in a like manner and much useful information obtained.

It will be noticed that the setting of the variable resistance x is a measure of the dynamic resistance Rd of the tuned circuit LC. The higher this dynamic value the less value of x and vice versa.

If we set resistance N at 1,000 ohms we can very speedily obtain the dynamic resistance value from the formula

$$\text{Rd} = \frac{\text{N}^2}{x} + \text{N}.$$

An Example.

The bridge was originally balanced with 1,000 ohms in each arm and N = 1,000 ohms. The inductance L was added and it was found that in order to resonate this to the supply frequency of 50 cycles a value of C = .05 mfd. was required. Further, in order to secure the best balance the variable resistance x had to be set at a value of 5 ohms.

What was the value of :—

(1) The inductance ;

(2) The dynamic resistance ;

(3) The effective resistance, r, of the inductance ;

(4) The impedance of the inductance—by itself—at the supply frequency of 50 cycles.

The self capacity C_0 being low was neglected.

Ans.

(1) The inductance $\text{L} = \dfrac{1}{4\pi^2 f^2 \text{C (mfds.)}}$

$$= \frac{10.15}{\text{C (mfds.)}} = \frac{10.15}{.05} = 203 \text{ henries.}$$

(2) The dynamic resistance $\text{Rd} = \dfrac{\text{N}^2}{x} + \text{N}$

$$= \frac{(1{,}000)^2}{5} + 1{,}000 = 201{,}000 \text{ ohms.}$$

(3) Effective resistance r.

Now $\text{Rd} = \dfrac{\text{L}}{\text{Cr}}$ therefore 201,000

$$= \frac{203}{\text{Cr}} \text{ henries} = 201 \times 10^3\, r = \frac{203}{.05 \times 10^{-6}}$$

$$= 10{,}050\, r = 203 \times 10^6 \text{ and } r = 20{,}199 \text{ ohms.}$$

(4) Impedance $= \sqrt{r^2 + (2\pi f \text{L})^2}$

$$= \sqrt{(20{,}199)^2 + (203 \times 314)^2}$$

$$= \sqrt{(20{,}199)^2 + (63{,}742)^2}$$

$$= 66{,}910 \text{ ohms.}$$

Tabulating these results we obtain :—

(1) Inductance L = 203 henries.

(2) Dynamic resistance Rd = 201,000 ohms.

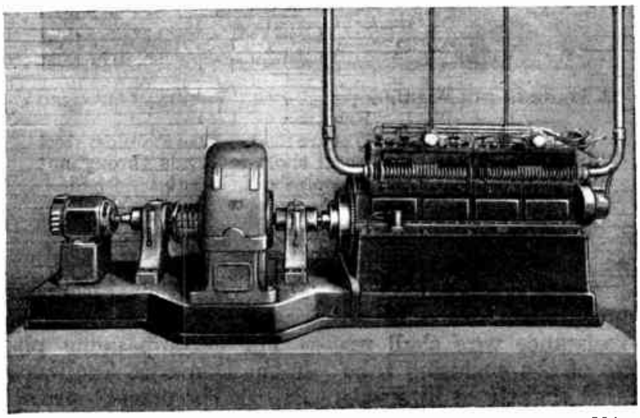
(3) Effective resistance r = 20,199 ohms.

(4) Impedance Z = 66,910 ohms.

A PETROL ENGINE DRIVEN ALTERNATOR

An interesting application of a large petrol engine to the driving of electrical generating plant is illustrated by the 100 kVA standby motor-alternator supplied to the Congella Power Station, Durban. It is a "straight-eight" Parsons engine, with cylinders giving a minimum of 150 h.p. at 1,500 r.p.m. continuously.

The alternator driven by this petrol engine is of the standard G.E.C. 3-phase revolving armature type.



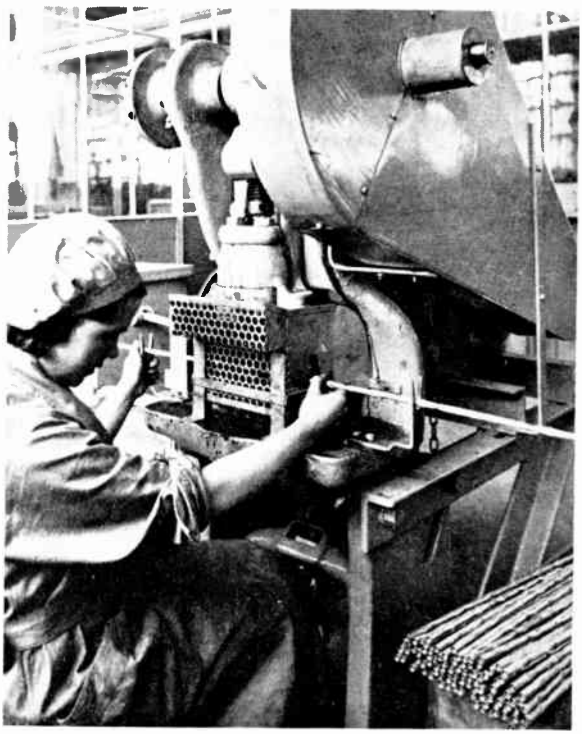
150 H.P. 1,500 R.P.M. PETROL ENGINE DRIVING 100 KVA 390 VOLT G.E.C. ALTERNATOR AT THE CONGELLA POWER STATION, DURBAN.

A New Heating Element for Electric Cookers and Water Heaters

IN the early days of electric cookers, users were often disappointed at the length of time required for boiling kettles and saucepans placed on top of the range. This was due to the fact that the heating elements were embedded in a mass of metal which had first to be heated before the heat could be transmitted to the cooking utensil.

The "Torribar" heating elements which have been developed by the British Thomson-Houston Company, and which are used in the construction of "Hotpoint" cookers and water heaters provide a practical solution of this serious difficulty

The "Torribar" element consists of nickel chrome wire embedded in magnesium oxide which is contained in thin tubes of stainless steel. In order to ensure that the resistance wire shall remain at the centre of the enclosing tube the latter is indented slightly at intervals throughout its length. This holds the central wire securely in place whilst the insulating powder is inserted. A later process removes the indentations. The complete tube with resistance wire is then bent to any desired shape for insertion in the heating or cooking appliances. In use, the heat from the central wire passes easily through the magnesium oxide and causes the steel tube to glow with a dull red heat. Vessels can be placed directly on the element without any danger of causing either electrical or mechanical damage. The magnesium oxide is a reasonably good conductor of heat and yet gives perfectly good insulation between the resistance wire and the walls of the steel tube.



A Stage in the Manufacture of the Torribar Heating Element.
Showing how indentations are made in the stainless steel tubes, two at right angles at short intervals throughout the length to centralise the spirals in the tube.

How Torribar Elements are Manufactured.

The accompanying photographs taken in the Domestic Appliances Factory of the British Thomson-Houston Works at Rugby show some of the stages in the manufacture of this new type of heating element.

FITTING THE TERMINALS AND FERRULES TO THE TORRIBAR HEATING ELEMENTS.

The complete process step by step is as follows :—

Winding and Cutting the Resistance Spirals.

First comes the winding by machine of the Nichrome wire into spirals to form the heating element. This is then cut into exact lengths as required by the voltage on which they will ultimately work. Each length is then inserted in a tube of stainless steel.

How the Spirals are Centralised in Tubes.

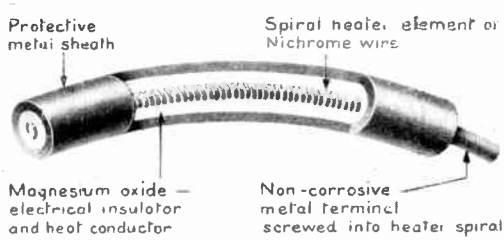
At the commencement of this operation the spirals are securely held at each end of the tubes by terminals. Next, indentations are made in the tubes, two at right angles at short intervals throughout the whole length, thus centralizing the spiral in the tube.

The tubes are then filled with dry magnesium oxide, and the ends sealed. The spirals are now firmly secured by the magnesium oxide in the centre of the tubes, and the indentations are next taken out by " swaging " machines.

Annealing and Swaging.

The tubes are then annealed, afterwards again passing through a " swaging " machine, which reduces their diameter and compresses the magnesium oxide into a homogeneous mass so that the spirals are held rigidly concentric with the tube. The magnesium oxide acts as an electrical insulator, but at the same time freely conducts the heat from the spiral to the outer steel sheath, which when in use glows with a visible red heat. Thus the finished element is immune from oxidization or damage from spilt liquids.

The final stage in the manufacture of the heating elements is the bending operation, and assembly of the ferrules and terminals.



A SECTION OF PART OF A TORRIBAR HEATING ELEMENT.

Pneumatic Electric Lighting for Fiery Mines

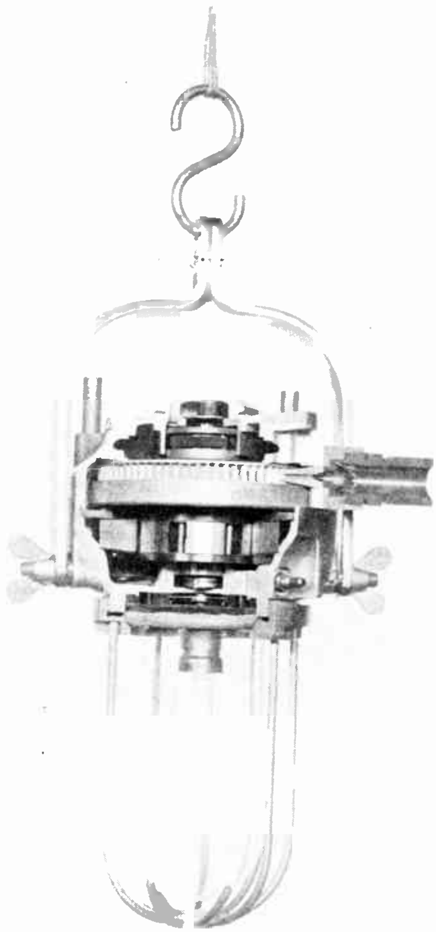
By R. Harcourt Woodall, A.M.I.E.E.

The article gives details of a self-contained electric lamp and generator operated from compressed air line, specially designed for improving the lighting of collieries without increasing the danger of explosion. Hints on installing and servicing are given.

THE question of providing an adequate lighting system in coal mines has been a problem for mining engineers for many years. Such a system to be applicable in all instances must be free from danger when operating in the presence of firedamp or coal dust. Battery lamps have been improved considerably, but their candle power is limited, since weight has to be considered, and it is not feasible to increase the lighting power of the hand or cap safety lamp beyond 9 c. p.

For the efficient running of a colliery, this light ng power is inadequate. It has been proved that poor illumination is one of the chief causes of accidents, and in addition, is responsible for a large amount of dirt being brought up with the coal.

The M-L pneumatic electric lamp was introduced to meet the need for better illumination, both at the working face and in the roads.



60-watt Pneumatic Electric Lamp.
The alternator casing is partly cut away to illustrate the construction.

A Power Plant in Miniature.

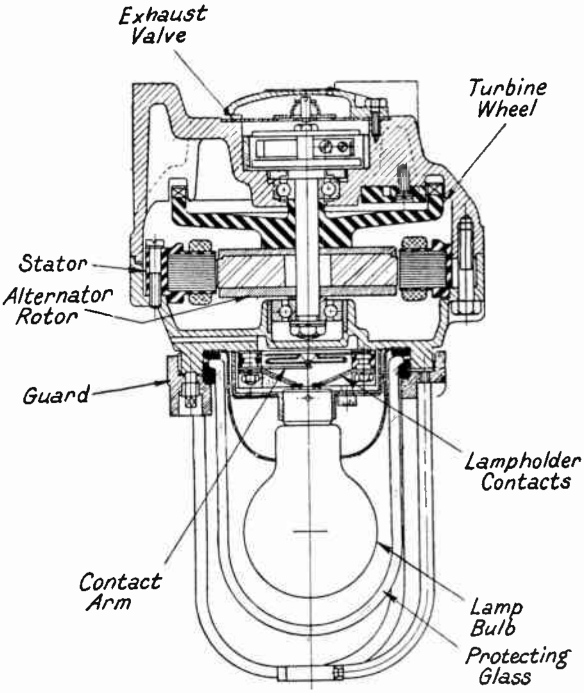
The lamp is self-contained and is designed to operate from a compressed air main. Briefly, it comprises an air turbine coupled to a permanent magnet alternator, the whole being contained in a substantial casing consisting of two castings bolted together.

Air at any pressure between 40 and 100 lb. per square inch is fed into the lamp through a connection, a filter and a reducing valve.

The Air Delivery.

This reducing valve automatically reduces the air pressure to 40 lb. per square inch so that with increased air pressures on the line, there is no fear of the turbine overspeedi ng.

A piston carrying a small valve is pressed back against a spring and the valve, moving in its seat, controls the flow of air so as to maintain a constant pressure on the jet. The spring pressure is adjusted by a screw which having once been set at the works, requires no further adjustment. It is therefore locked with a key and a brass cap is screwed on.



SECTION OF 60-WATT LAMP ASSEMBLY.
Note the air-driven turbine and alternator mounted on a vertical spindle above the lamp.

The air passes from the reducing valve through the nozzle, which is of rectangular cross-section, and impinges on the turbine wheel, carried on a shaft running on two ball bearings. The wheel consists of a bakelite moulding with the blades formed on the periphery.

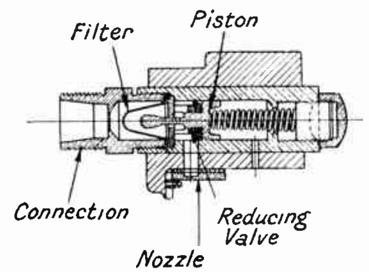
The Air Turbine.

The turbine is of the two stage type, the air traversing the vanes first of all in an inwards direction, then through a transfer port and through the vanes in the opposite direction. This increases the efficiency of the turbine.

The Alternator.

The turbine wheel is driven at about 8,000 r.p.m. On the same spindle is carried the alternator rotor, which consists of an 8-pole cast cobalt magnet held by copper rivets between two brass plates. The copper rivets act as " damping bars " and prevent the demagnetization of the magnet, by allowing for the induction of " eddy " current in themselves by any opposing field.

The rotor runs in the alternator stator which consists of a laminated " Stalloy" core having 8 poles carrying the windings. The laminations are moulded into a bakelite former so that the winding can be carried out without further insulation of the slots. It should be noted that as the windings are stationary, there are no brushes or rubbing contacts and therefore there is no risk of a spark occurring. The



SECTION OF CONNECTION, FILTER AND REDUCING VALVE, THROUGH WHICH COMPRESSED AIR IS FED INTO THE LAMP.

cutting of the lines of the magnetic field which is produced by the magnet, by the conductors, causes an electromotive force to be induced in the latter.

The Lamp Holder.

The two ends of the winding are connected across the lamp holder contacts which are carried on a bakelite moulding. This moulding also houses a flexible walled chamber, the interior of which is in communication with atmosphere through a small port to the exterior of the casing. The top diaphragm carries a silver contact point and is in electrical connection with one end of the stator winding. This point normally makes contact with another fixed point carried on an arm which is connected to the other end of the winding. When the turbine is stationary, the alternator is short-circuited.

It is arranged that when air is supplied to the lamp, there is always a back pressure of about 2 lb. per square inch inside the body of the lamp and inside the protecting glass. This excess of pressure acts on the flexible diaphragm and causes the points to separate. The bulb then lights.

Safety Features.

It will be realised that if the protecting glass is broken by a piece of coal or if any attempt is made to remove the glass (normally this is locked in position by a special key), the back pressure vanishes and the lamp is immediately short circuited. The back pressure is controlled by a spring loaded exhaust valve.

There are a number of small holes in the body castings through which a scavenging stream of air flows while the lamp is operating. Any gas which may have gained access to the lamp while it has been standing is thus driven out before the lamp lights up.

An additional feature is a centrifugal type of governor which prevents the racing of the turbine in the event of the bulb burning out. Two brass weights lined with Ferodo pads fly outwards when the speed becomes excessive and engage with a steel drum. The air, before reaching the exhaust valve, passes through the governor and keeps this same reasonably cool.

A stout guard, carrying the locking screw mentioned above, is provided to prevent the glass being accidentally broken.

Capacity of the Lamp.

The alternator described above is rated to give 60 watts at 25 volts and a standard opal gas-filled bulb of this rating is used. The candle power is approximately 90. It should be noted that the actual bayonet holder is of the shock-absorbing type to ensure long life of bulbs. The consumption of free air per minute at 40 lb. per square inch is approximately 8 cubic feet. The weight of the lamp complete is 16 lb.

A Smaller Model.

A smaller model similar in principle to the above, has a series of holes in the top casting for the exhaust air, in place of the exhaust valve. A cowl fixed over these holes prevents the exhaust air from disturbing any coal dust. The governor is omitted, sufficient regulation being provided by the reducing valve.

A sectional photograph of this smaller lamp is given in Fig. 3. The bulb employed is of 12 v. 36-watt rating, the candle power being approximately 50. The consumption of free air per minute at 40 lb. is 4 cubic feet. A frosted protecting glass is used with this lamp.

Other Applications.

These lamps have many other applications, apart from their use in fiery mines. They can be used with advantage for providing illumination for tunnelling operations, for quarry work, in fact in any location where an air supply is available and where an electric supply is not at hand. Also they can be used in any explosive atmosphere, such as in a petrol tank, a chemical factory, etc.

SERVICE HINTS.

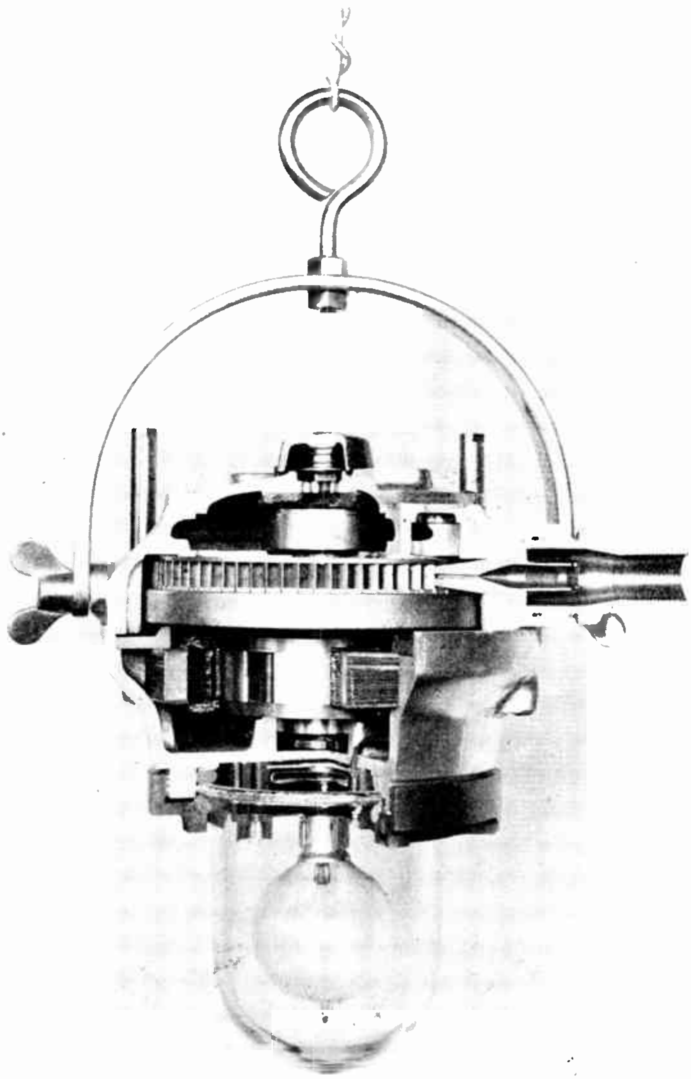
Since there are over 1,200 lamps of this type installed in the leading collieries of Great Britain, the following hints are given for the benefit of colliery electricians who may have to instal or service them.

Installation.

When installing a lamp, it should be borne in mind that a ½-in. pipe is ample for carrying the necessary air. A cock should be inserted in the pipe for the purpose of cutting off the air supply when disconnecting the lamp. The lamp can be adjusted to any desired position by slackening the two wing nuts which hold the lamp rigid with the strap which carries the hook. It is important to see that the guard ring which clamps the protecting glass in position is locked before the lamp is put into use. A special key is provided for this purpose.

Lubrication.

The lubrication of the bearings of the lamp is carried out by means of a special grease gun, through the two nipples situated on the side of the lamp. If in continuous use, a charge of oil should be given to each bearing every two days. An absorbed oil such as Vaughan's " L.1 " must be employed. A heavy grease will slow up the turbine with resulting loss of output. Having filled the gun, screw on to the nipple and turn the handle until some resistance is felt. Then turn handle through one complete turn, afterwards unscrewing the gun from the nipple.



PART SECTIONAL VIEW OF 36-WATT PNEUMATIC ELECTRIC LAMP.

Attention to Air Filter.

The air filter which is clamped between the valve seat and the hose connection is an extremely important component, and the lamp should on no account be run without it. It prevents dirt in the air supply from getting into the nozzle or on to the blades of the turbine. If allowed to get through, dirt could completely block the nozzle, causing the turbine to stop. Naturally, the filter will require cleaning at periods and it is recommended that this operation be carried out about once a fortnight.

Hunting for Trouble.

In the event of the lamp refusing to function when the air is on and the turbine running, the bulb should first of all be examined to see whether this is burnt out or has a broken filament. If this is intact, an examination should be made to see whether there is a leak between the glass and the metal casting in which this is seated. Two rubber rings are used to effect an airtight joint. It will be realised that any air leak at this point will cause the points to come together, short-circuiting the alternator and extinguishing the light.

If this joint is in order, the only other likely cause of failure is the stopping up of the hole from the outside of the casting to the inside of the flexible walled chamber. This would have the effect of operating the safety device. A piece of wire should be used to clear the obstruction.

Replacement of Bulbs.

It is important when replacing a bulb, to employ one of the correct rating. This should be definitely of the gas-filled type to comply with the requirements of the Mines Department.

Dismantling of Lamps—60-watt Model.

When it becomes necessary to dismantle the lamp for cleaning or examination of the bearings, the exhaust valve cover and valve itself should be removed by unscrewing the three hexagonal headed screws. Then the six bolts holding the two body castings together should be removed. The two castings should now come apart, the spindle, rotor and turbine wheel coming away with the top casting; the stator, etc., coming away with the bottom casting to which the lamp guard, etc. are fixed. If there is any difficulty in separating the castings, hold the lamp by the guard with the stirrup hanging downwards and tap with a wooden mallet.

To dismantle the rotor, turbine wheel, etc., remove nut holding bottom ballrace and withdraw spindle through top ballrace. Do not attempt to adjust the diaphragm.

After reassembly, tap the top governor plate with a mallet to place the bottom ballrace in its normal position. It is important to make certain that iron filings, etc., are not picked up by the magnet unit when the lamp is down, since the airgap is small and any foreign body in the gap may make the rotor foul the stator.

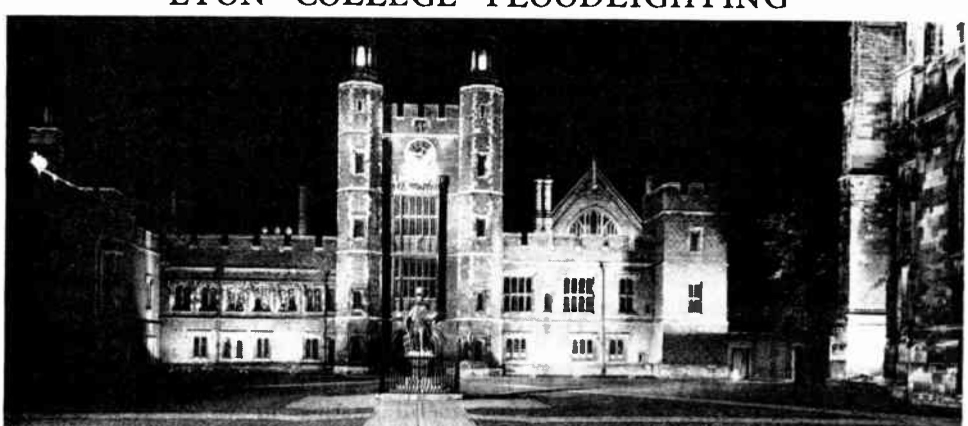
Dismantling of Lamps—36-watt Model.

First remove the three screws which hold the two body castings together. The rotor, turbine wheel, etc., on the spindle will come away with the top casting. The lock nut holding the lower ballrace should be removed and the spindle can be drawn through the upper ballrace and the hole in the upper casting. The top bearing can be removed by withdrawing lock nut.

Cleaning of Reducing Valve.

First of all remove hose connection and filter and draw out valve seat. The piston and valve can then be withdrawn for cleaning together with the spring. Do not disturb the adjusting screw. Grease the spring well and replace it with the larger end towards the adjusting screw.

ETON COLLEGE FLOODLIGHTING



A Striking Example of Floodlighting Effect Carried Out by the General Electric Co., Ltd., at Eton College Recently.

Nearly 100 floodlights were used, giving a total illumination of some 5 million beam candles. A special feature was the method of controlling the lighting by dimmers, which allowed a constant change of light and shade effects.

Questions and Answers by Practical Men

Readers are invited to send problems of practical interest. Letters should be addressed to "The Practical Electrical Engineer," 8-11, Southampton Street, Strand, W.C.2. Envelopes to be marked "Problem" in the top left-hand corner

QUESTION 1.

The sub-station (traction) at which I am employed has two H.T. feeders and three interconnectors (one of these interconnectors feeding a static sub-station for office lighting and power). The accompanying diagram shows the protection arrangements on each feeder; the reverse relays being of the B.T.-H. type and the leakage relays are Metropolitan-Vickers type. The interconnectors are protected by double-pole self-resetting inverse time-lag overload relays and leakage relays. I wish to know the voltage of the potential transformers (ratio 60 : 1), i.e., across the outer conductors, and desire to know the formulæ for determining this voltage. I should also like to know something of the working of the reverse relays and interior connections.

L. A. J. B.
(Tottenham).

ANSWER.

Reverse current relays are used in A.C. transmission systems to prevent the flow of a reverse current in a system of parallel feeders.

Meaning of a Reverse Current.

Since an alternating current reverses its direction every half period, the meaning of "reverse current" is not too obvious. What is meant, is the direction of flow of the mean power developed. Under normal circumstances, the difference in phase between the voltage and current may vary between certain limits, depending upon the power factor of the system generally. If the phase difference becomes 90 degrees, then the power developed is zero, but if this phase difference exceeds 90 degrees, then the alternating current becomes "reverse." In the case of an alternator, or feeder from it to a sub-station, the machine will absorb more power in a period than it will give out; the power being supplied from another machine which will be connected in parallel with the system, and therefore the mean power transmitted by the feeder will be reversed.

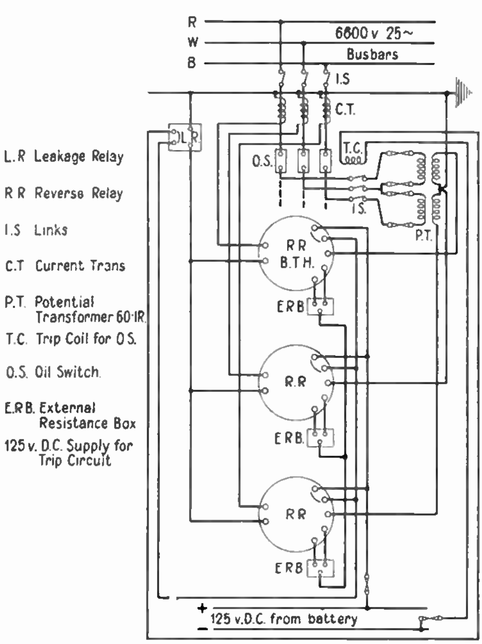


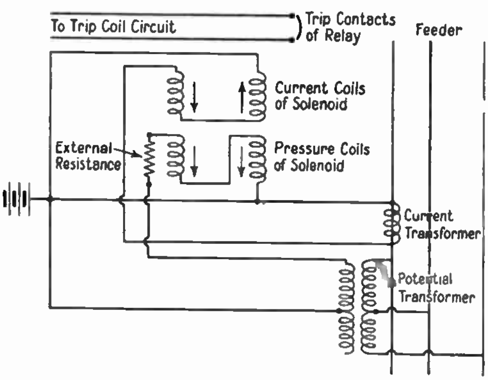
Diagram Showing Protection on Each Feeder of a Two-feeder Sub-station.

Construction and Action of the B.T.-H. Reverse Current Relay.

The relay consists of two differentially wound solenoids, with plungers coupled by a balance arm. The solenoids act in opposition and tilt the balance arm towards one coil or the other according to whether the main current be normal in direction or reverse. When the main current is forward the coils of one solenoid help each other, whilst those of the other solenoid are in opposition. When the current is reverse then the coils of the solenoid which were assisting each other are now in opposition, and the coils of the solenoid which were in opposition are now assisting each other.

The current coils of the solenoids are connected in series and energised by the secondary current of a current transformer connected in the feeder which is to be protected.

The pressure coils of the solenoids are also connected in series and energised by the secondary current of a potential transformer whose primary winding is connected across the feeder.



THE EXTERNAL CONNECTIONS OF A B.T.-H. REVERSE CURRENT RELAY.

Complete protection to a three-phase feeder is given by installing a triple-pole relay.

When there is a reverse current the balance arm tilts and, by shortcircuiting two contacts in the relay, closes the trip circuit of the oil switch, which now opens and disconnects the feeder from the system.

The internal connections of the relay are given in the above diagram. The arrows are inserted to indicate the relative action of currents in the current and pressure coils of the solenoid.

Calculating the Secondary Voltage.

If the ratio of the potential transformer is 60 : 1 and the voltage on the primary between lines is 6,600, then the voltage of the secondary between lines will be

$$\frac{6{,}600}{60} = 110 \text{ volts}$$

The pressure coils of the solenoids are wound for 100 to 110 volts, with an external resistance which absorbs 30 to 40 watts.

The approximate voltage across the secondary winding of a transformer may always be obtained by dividing the primary voltage by the ratio of transformation, for example :—

Primary voltage, 33,000.
Ratio 30 : 1. (Step-down transformer).

$$\text{Sec. voltage} = \frac{33{,}000}{30} = 1{,}100 \text{ volts.}$$

Or :—

Primary voltage, 2,000.
Ratio 1 : 5. (Step-up transformer.)

$$\text{Sec. voltage} = \frac{2{,}000}{\frac{1}{5}} = 10{,}000 \text{ volts.}$$

QUESTION 2.

I would like to have some advice on how to build a transformer for arc welding, 250 volt, 60 cycle, A.C. I also want wiring diagrams for A.C. motors showing all connections from line to switchboards, with all meter connections and diagrams of transformers for single 2 and 3 phases.

P. J. K. (South Africa).

QUESTION 3.

I should be very glad if you could give me some information regarding an emergency stand-by installation for electric incubators and brooders.

These are at present running on 230 volt A.C. The consumption is about 7 kw. Is it possible to obtain an A.C. generator of this voltage and output?

J. and C. (Heathfield, Sussex).

QUESTION 4.

I wish to change a D.C. motor 2 b.h.p., 240 v., 1,550 r.p.m. (max.) to A.C. single phase, without loss of velocity, but am not sure of method to employ. Can you please enlighten me? R. E. S. (Manor Park).

Readers are invited to reply to the above questions. All replies published will be paid for at our usual rates, and should reach us not later than October 2nd, 1933. Address letters to "The Practical Electrical Engineer," 8-11, Southampton Street, Strand, W.C. 2.

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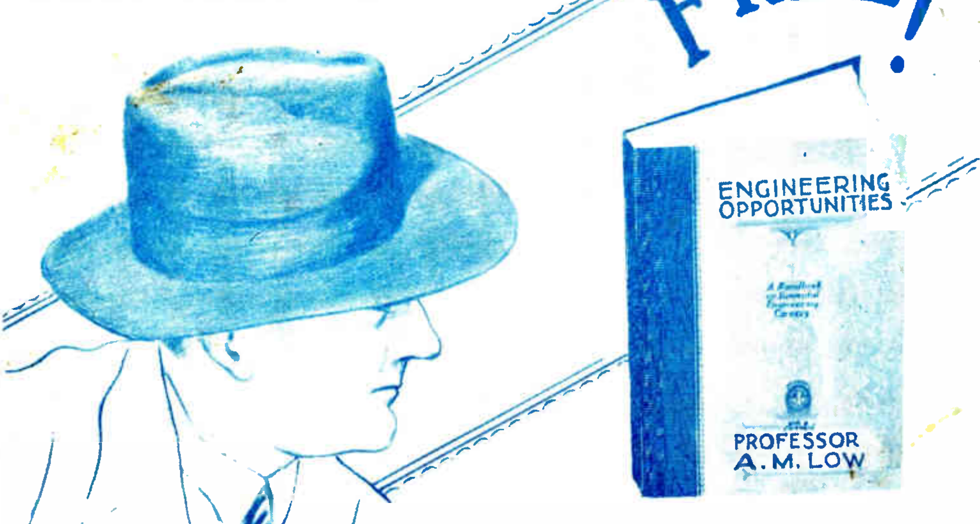

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