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PART 15

A PRACTICAL WORK WRITTEN BY EXPERTS

tank. If this is not possible arrangements must be made for the cable connections to be disconnected and the complete transformer rolled or lifted to some convenient place where inspection can be carried out. If rolling the transformer in this way is likely to be necessary, it may be an advantage to have swivelling rollers fitted.

The foundation should be firm and free from vibration. Continuous vibration may set up movements in the windings and thus in time lead to a breakdown. On a level floor it is not necessary to bolt down the transformer.

A concrete floor should be provided where possible. Any other firm floor will serve, provided that it is strong enough for the concentrated weight of the transformer. As a guide to what is required it may be assumed that a 100 K.V.A. transformer, with oil, will weigh about a ton, and one of 25 or 30 K.V.A. about half as much.

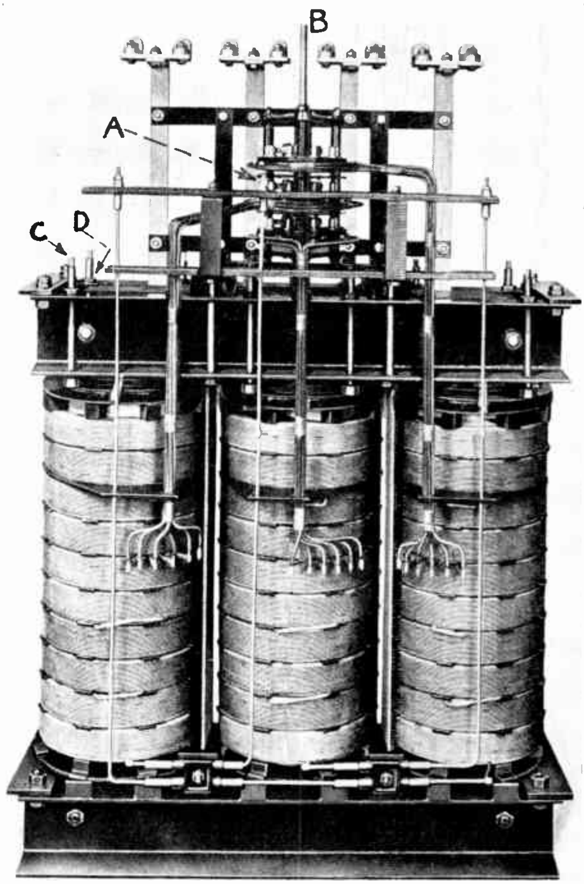


Fig. 7.—CORE AND WINDINGS OF THREE-PHASE TRANSFORMER.

Showing: A, 3-phase tapping switch operated from outside the tank by a handle on the end of the shaft B; and C, hand-adjustable coil supports, with squared end for spanner, and locknut at D.

Positions to Avoid.

Locations subject to excessive temperature rise should be avoided. Thus a transformer should not be installed over or near a steam main or close to a boiler. Furnace transformers have to be installed close to the furnace, to reduce the length of heavy current cables, and in such cases shields of asbestos sheet or other heat-insulating material must be provided, and artificial aids to ventilation, such as the provision of a fan, may be found necessary.

OPERATION.

The attention needed during ordinary operation is very little. Care should be taken that the transformer temperature is not allowed to exceed the maximum specified by the makers. This figure will probably be quoted on the name plate, and usually is 90° C., corresponding to a temperature rise of 50° C. above a maximum air temperature of 40° C.

Causes of Excessive Temperature.

Excessive temperature may be caused by:—

(*a*) Overload.

(*b*) Other abnormal conditions, such as incorrect voltage or frequency.

(*c*) Insufficient ventilation.

(*d*) A fault in the transformer.

The cure of the first three causes is in each case obvious. The faults which

A

may occur in transformers are dealt with later.

The oil must be kept up to the correct level. Ordinarily very little evaporation takes place ; any rapid lowering of the oil level points to a leak in the tank.

Fitting a Breather.

The transformer may be fitted with a breather, although this is not usual unless the primary voltage exceeds 11,000. This device consists of a small chamber connected to the top of the tank by means of a pipe and filled with calcium chloride or some other substance which absorbs moisture from the air. Its purpose is to dry the air which passes into the transformer tank when the air above the oil contracts on cooling. When fitted, the drying agent should be inspected regularly and renewed if it appears to be wet ; this will be every week, perhaps, in damp weather.

Avoid Switching-in More than Necessary.

Switching-in of transformers should be reduced to a minimum. The sudden rush of current needed to magnetise the iron circuit imposes a certain mechanical strain on the windings, which, if repeated frequently, may lead to movement of the coils and consequent damage to the insulation. The no-load current of a modern transformer is so low (in the neighbourhood of 1 per cent.) that there is no need to switch off when power is not required for short periods.

MAINTENANCE.

After a new transformer has been in service for two or three months advantage may be taken of a week-end or holiday, when supply can be interrupted, for an examination. When possible choose dry weather and first clean out the substation. The cover should be removed, the connections to the terminals undone, and the tank and core lifted, as already described.

Make a Thorough Mechanical Examination.

First make a thorough mechanical examination of all connections, nuts and bolts, etc., tightening any found loose. In the case of transformers with a number of coils or tappings connected in parallel, it is very necessary to make sure that all common connections are tight, or some coils may take more load than the others and be damaged. The bolts which pass through the iron laminations will probably need tightening, and these, being insulated from the magnetic circuit, should be tested with a "Megger" for insulation resistance to the laminations by connecting one lead from the "Megger" to the bolt and the other to the laminations ; the points of contact with the iron may need scraping to remove paint, which is an insulator. A very high reading is not necessary ; provided that there is not a short-circuit reading, the condition of the insulating sleeves and washers may be assumed to be satisfactory. At the same time measure the insulation resistance of the windings to the core and compare the readings obtained with the resistance measured after drying-out.

Coil Shrinkage.

After a few months in use the coils of transformers usually shrink somewhat, and it is necessary to compensate for this shrinkage. Means for taking up the shrinkage may be provided in the form of adjustable coil supports, shown in Fig. 7. These can be screwed down as much as necessary, care being taken not to exercise too much force or some of the windings may be forced out of position. Enough force should be used to take up all slack and for a fair resistance to be felt when using a short spanner with one hand. Tighten the lock-nuts after this operation. If these adjustable supports are not fitted the packing pieces between the top of the coils and the yoke can be

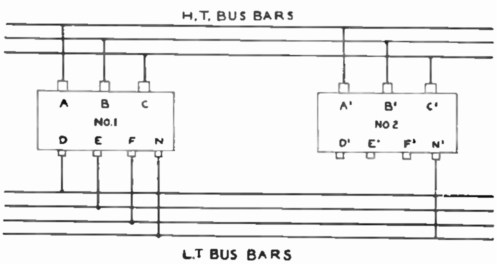


Fig. 8.—CONNECTIONS FOR PHASING-IN A THREE-PHASE TRANSFORMER.
The switchgear is omitted for simplicity.

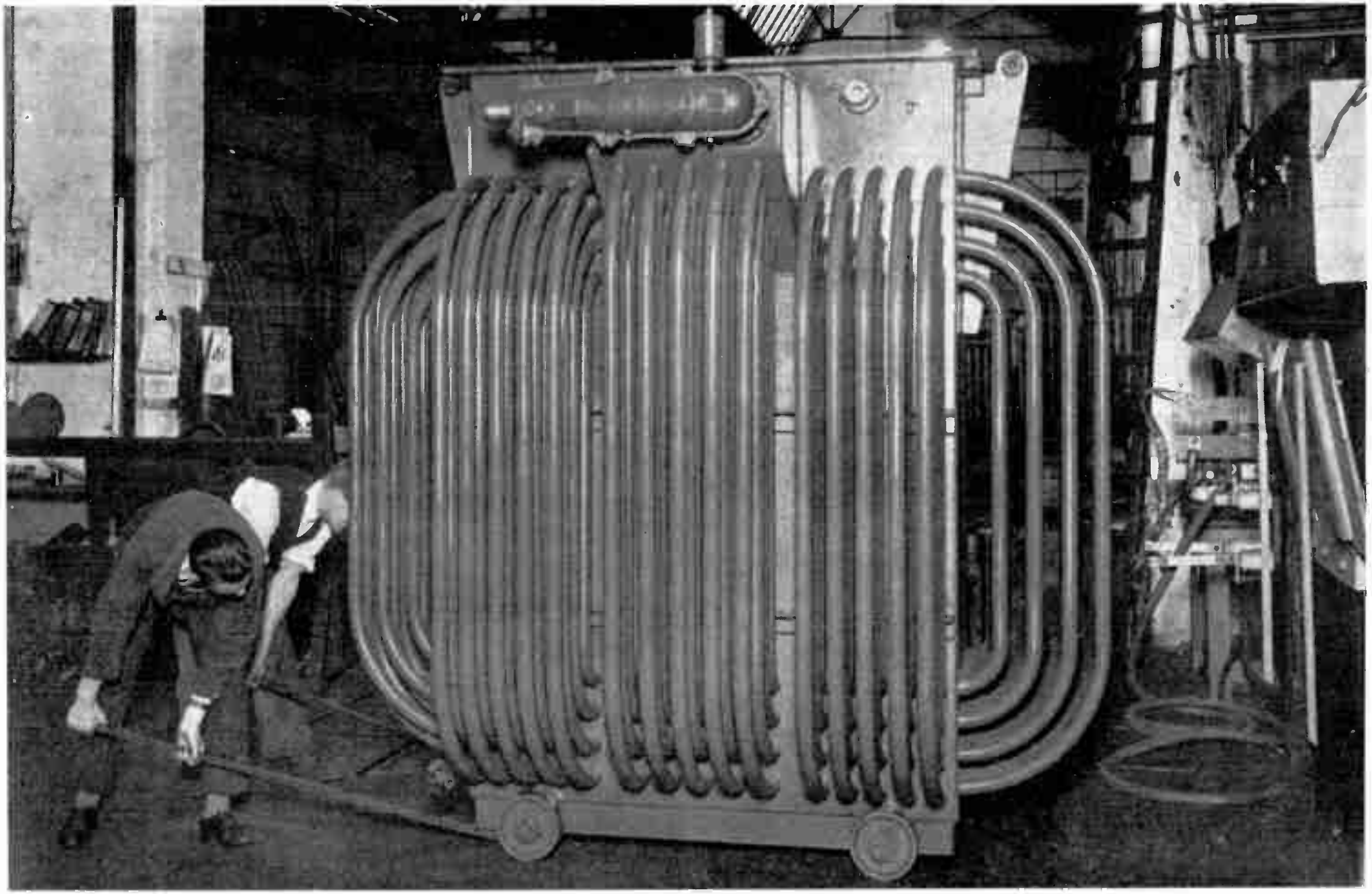


Fig. 9.—LEVERING TANK INTO POSITION. (*Johnson & Phillips, Ltd.*)

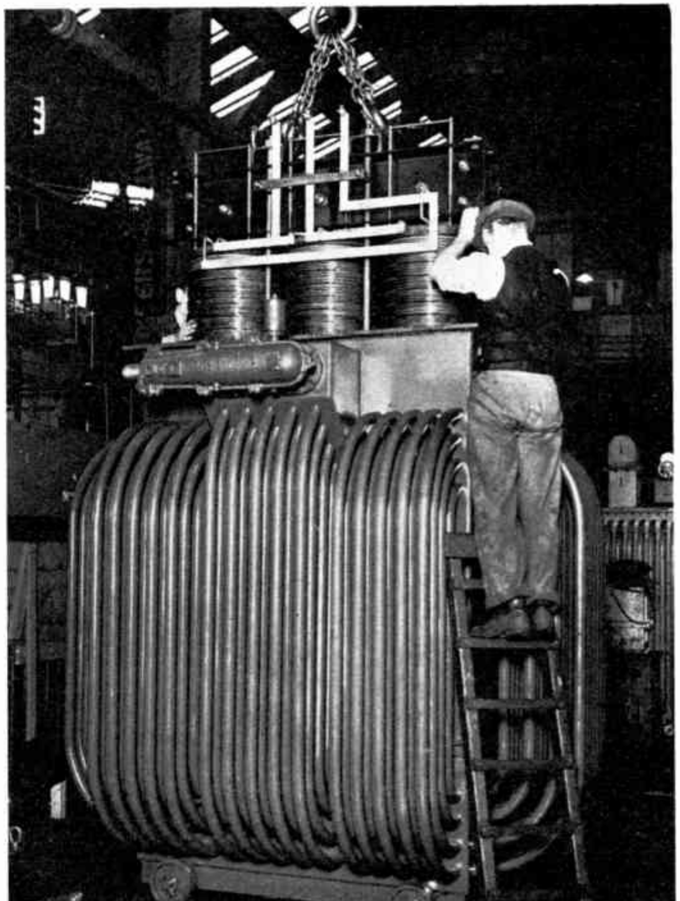


Fig. 10.—Transformer Half-Lifted From Tank.
Showing L.T. side. (*Johnson & Phillips, Ltd.*)

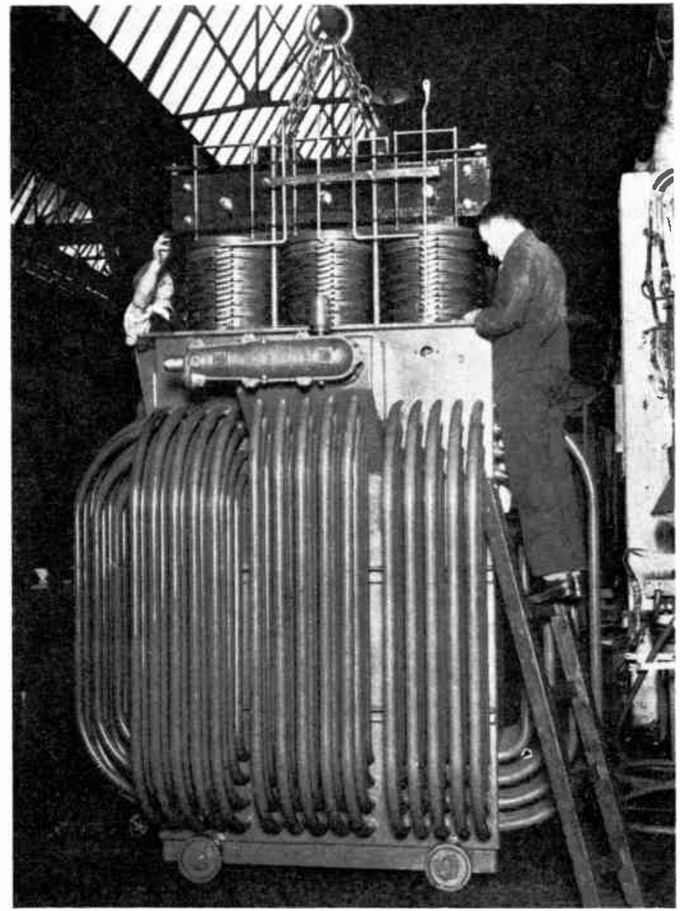


Fig. 11.—Transformer Half-Lifted From Tank.
Showing H.T. side. (*Johnson & Phillips, Ltd.*)

tightened (Fig. 2), new pieces being inserted if necessary. These new pieces may be of well-dried hard wood, or, preferably, of insulating material obtained from the transformer makers.

The oil should be examined for signs of sludge (dealt with in more detail later) and the level corrected if necessary. The core may then be lowered, the connections replaced and the tank cover fitted.

After the first one or two inspections the period between examinations may be increased, but it is recommended that an annual examination should be made. Any sign of abnormal operation, such as high temperature or a louder hum, should be investigated immediately.

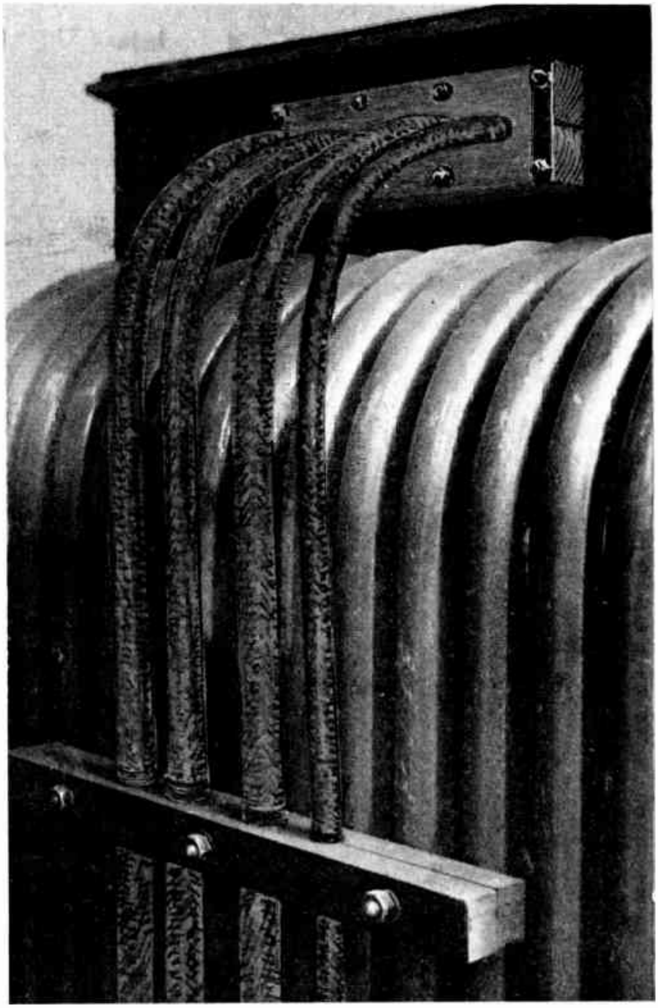


Fig. 12.—Wood Cleat Secured to Side of Transformer to Support the L.T. Cables.

Transformer Oil.

Special oil is needed for use in transformers. The oil serves the dual purpose of insulating and cooling medium, and should conform to the specification of the British Engineering Standards Association. Suitable oil may be obtained from the transformer makers.

Damage Caused by "Sludge."

There are two normal kinds of transformer oil—the standard grade and a special non-sludging variety. All transformer oil, when exposed to bare copper, and especially when warm, forms in time a thick greasy sludge, which is deposited on the windings and in the ducts provided for the flow of cooling oil. As soon as the free circulation of oil is impeded in this way the transformer operates at a higher temperature, sludge is formed faster, and if the regular inspection is omitted, or the high temperature ignored, a serious breakdown may be caused. Under normal conditions, and with a well-designed transformer, this formation of sludge is slow, taking some years even with ordinary oil, but it cannot be prevented entirely, hence the necessity for regular inspection.

So-called "non-sludging" oil forms sludge at a much slower rate, but under continued high temperature conditions some sludge will be deposited.

Cleaning the Oil Ducts.

Cleaning a transformer which has become badly covered and choked with sludge may involve removal of the yoke and windings to enable the oil ducts to be cleaned—a job for the makers; and although the transformer may appear to be in good condition, damage may have been done to the insulation, due to high local temperature in the windings, which will manifest itself finally by a breakdown.

The insulating properties of oil are greatly impaired by the presence of dust or dirt. During inspection, therefore, care should be taken to prevent impurities getting into the tank; under the heading of impurities, of course, moisture must be included. The tank should never be left uncovered for any length of time, and inspection should not be carried out in exceptionally dusty or damp conditions.

A Filter Press or Centrifugal Purifier.

Where a number of transformers are used a filter press or centrifugal purifier may be installed for the periodical reconditioning of transformer oil. With the filter press oil is pumped through a number of filter plates in series, the filters being removed in turn as they become moist and dirty. The centrifugal purifier throws out the dirt and moisture in the oil, and is very suitable for use where a large volume of oil has to be treated.

Transformer oil is liable to give off an inflammable vapour. It is therefore dangerous to bring a naked flame near the oil surface or in a tank unless the tank is empty and well ventilated.

TRANSFORMER TROUBLES.

The following is a list of the chief causes of transformer failure. The precautions to be taken to avoid most of these causes have been dealt with in the previous sections, but are repeated in brief form for convenience of reference.

(*a*) The insulation of core clamping bolts may fail, permitting the circulation of eddy currents and causing local heating which may damage coil insulation. The cause is often vibration due to looseness, which may be detected by an increase in the normal quiet hum of the transformer on load. Proper inspection should lead to loose bolts being detected and tightened in time. The cure is to trace the faulty bolt or bolts by a systematic " Megger " test (see notes under " Maintenance ") and replace the insulating bushes and washers.

(*b*) Loose core and tie bolts may permit vibration, leading in time to displacement of turns in the windings or rubbing between turns, resulting in failure of insulation between turns. Such failures cause local overheating, which quickly leads to a serious insulation failure. Here again inspection should reveal such likely causes of failure, or an increase in the hum may point to looseness and vibration. If undetected, the resulting failure will necessitate a partial or complete rewind of the transformer by the makers.

(*c*) Short circuits between turns may also be caused by mechanical stresses set up by external short-circuits or by repeated switching on load. This cause of failure will probably give no warning; but at the regular inspection a careful examination should be made for any displaced coils. It is unlikely that defects of this nature can be corrected without removing the winding.

(*d*) Over-adjustment of the adjustable coil supports, or careless tightening of packing pieces, may force turns out of position, leading to rubbing, destruction of insulation and short-circuit. Care in adjustment of supports will prevent this trouble. The cure, like (*b*) and (*c*), will probably be expensive.

(*e*) Insulation failure may follow the absorption of moisture by the oil, or may be caused by accidental over-pressures due to lightning or surges on the system. The first of these causes can be guarded against; the second is not likely to occur except on transformers connected to overhead lines and not protected by lightning arrester equipment.

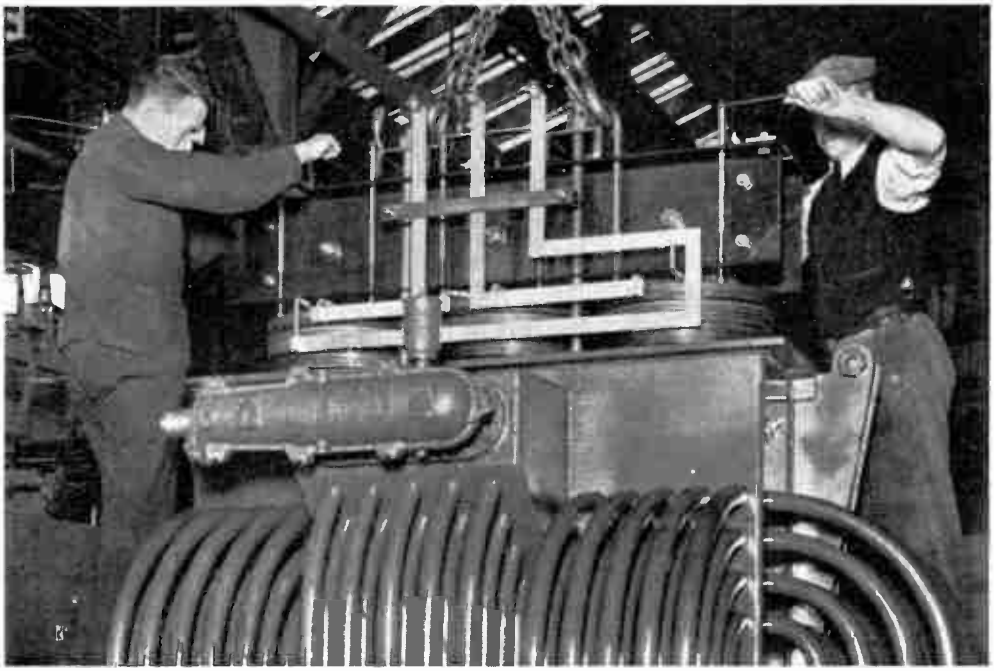


Fig. 13.—Tightening of Adjustable Coils. (*Johnson and Phillips, Ltd.*)

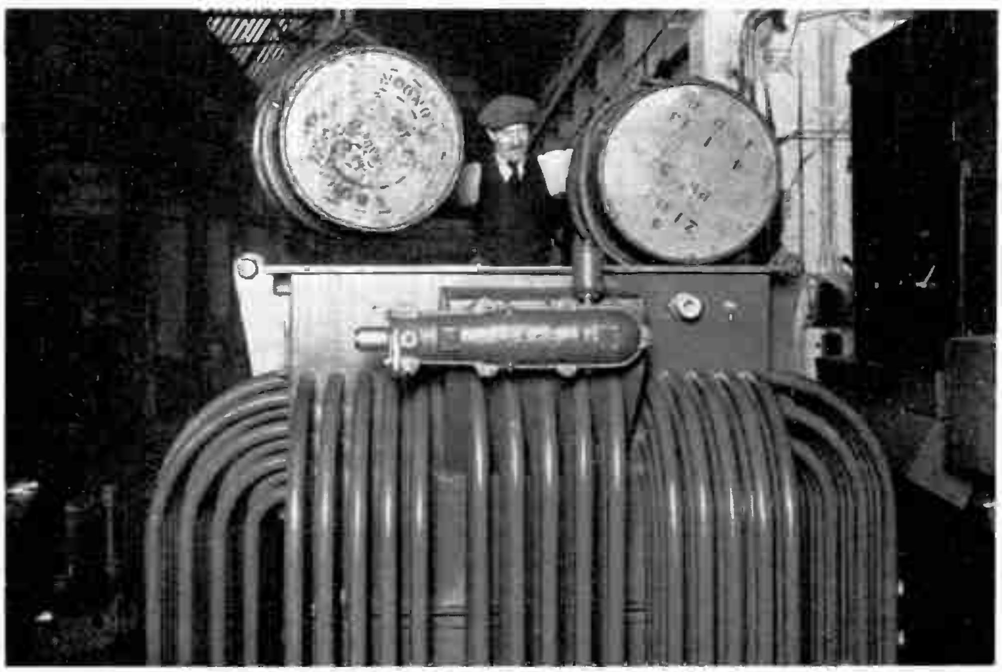


Fig. 14.—Oil being Poured into Tank after Final Examination. (*Johnson and Phillips, Ltd.*)

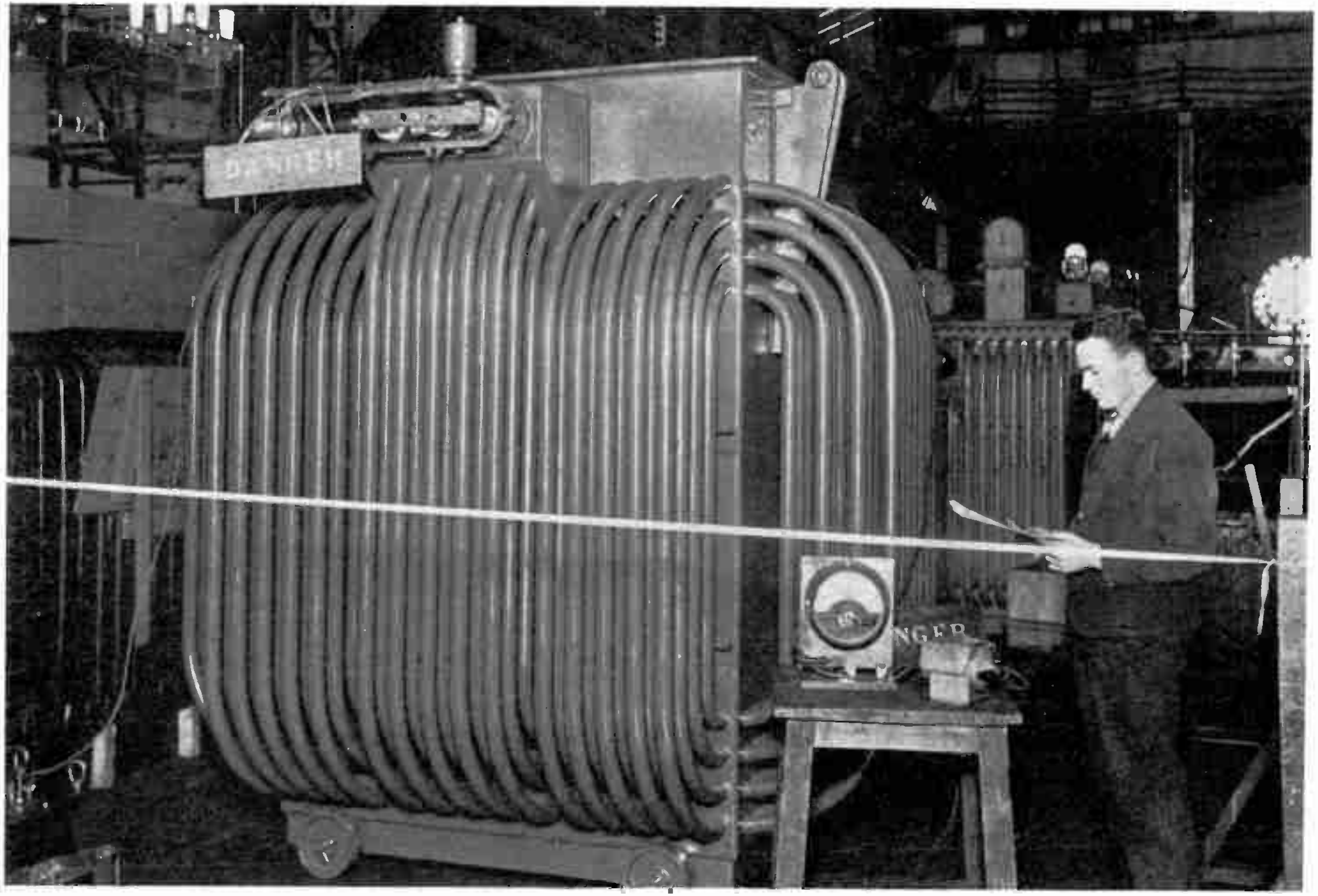


Fig. 15.—DRYING OUT BY SHORT CIRCUIT.
Showing short circuit on L.T. side. (*Johnson and Phillips, Ltd.*)

(*f*) Overheating, due to overload, continued use of a transformer when badly sludged, very bad ventilation of the transformer room or low oil level. If the oil level drops below the tops of the cooling tubes, oil circulation immediately ceases and excessive temperature rise will result.

The steps to be taken to avoid troubles due to these causes are obvious, and if the cause of overheating is removed promptly no harm may be done to the windings or insulation. In unattended sub-stations it is wise to fit maximum indicating thermometers which indicate the highest temperature reached since the pointer was last set back; or an attachment may be provided to close a bell circuit which gives an audible warning of high temperature.

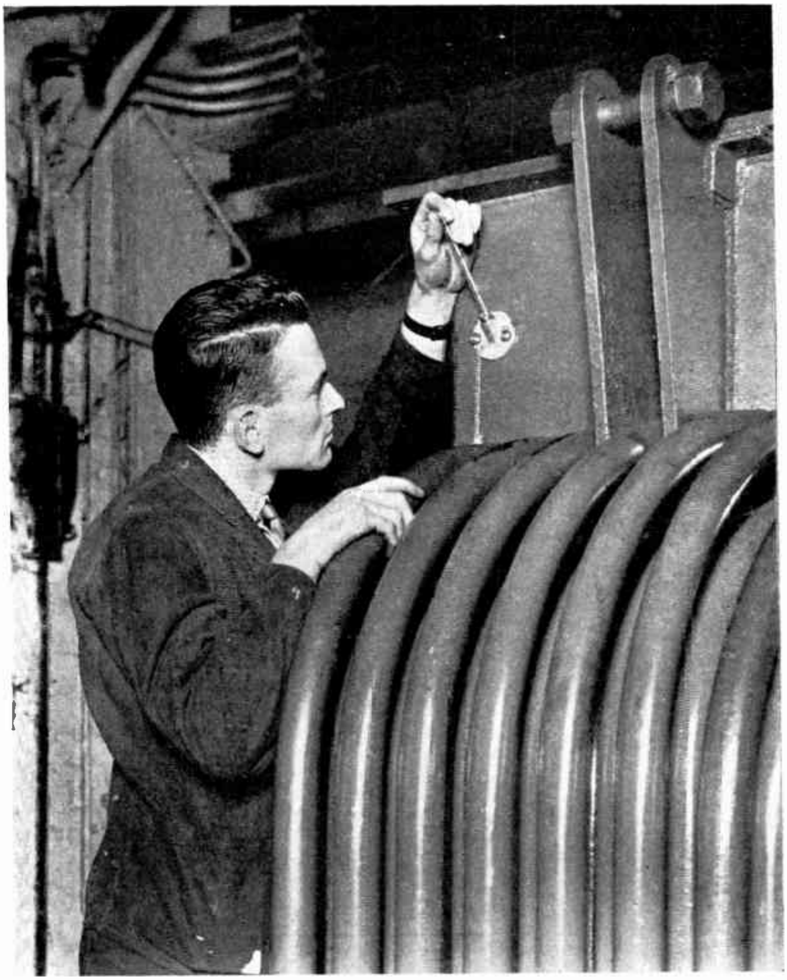


Fig. 16.—PLACING THERMOMETER INTO POSITION IN POCKET. (*Johnson & Phillips, Ltd.*)
This should be done before switching on.

(*g*) Loose terminals, bad joints in conductors, etc., leading to local overheating of coils. These troubles should be detected before they become serious by careful examination at the time of the regular inspection, when all nuts should be tightened.

(*h*) Incorrect connections, use on wrong system voltage or frequency, or mistaken connection of voltage adjusting tappings. Wrong connections will probably result in the oil circuit breaker on the primary side tripping immediately it is switched on. If this happens immediately suspect wrong connections or accidental short-circuits. Most cases of use on wrong voltage or frequency will also result in a very big current rush when the transformer is switched on, or in rapid overheating. If such symptoms are observed when a new transformer is put into service, check the particulars on the rating plate with the known details of the H.T. supply, and with the L.T. system if the transformer has to operate in parallel with another. In this connection the following details should be noted.

USE OF TRANSFORMER ON INCORRECT VOLTAGE OR FREQUENCY.

Transformers should never be used on pressures appreciably higher than the normal pressure for which they are designed. It is seldom that cases arise in which a higher operating pressure is required, but at times a transformer may in emergency be used on a lower pressure. This is permissible, but the output is reduced in proportion ; the normal full load current must not be exceeded, either on the primary or secondary side.

Ordinary slight variations of frequency, such as are met with on supply systems, are not of great importance. Larger variations, such as the use of a 50-cycle transformer on a 40-cycle system, however, should not be allowed without careful investigation of the possible effect. In general, no transformer should be used on a lower frequency than that for which it was designed, owing to the greatly increased iron loss and magnetising current at the lower frequency. It might be possible to use the transformer on the lower frequency at a lower pressure and correspondingly reduced output, but such cases should be investigated by the manufacturers. On higher than the designed frequency the conditions are more favourable. Actually, a 25-cycle transformer, for example, should be capable of giving a greater output on 50 cycles, but to get the full advantage of the possible extra output the coils would probably require rewinding to be able to carry the increased current. Here again the manufacturers should be consulted before a transformer is operated on a higher frequency than that stated on the rating plate.

QUESTIONS AND ANSWERS

What is the ideal location for a transformer ?

The foundation should be firm and free from vibration. A concrete floor should be provided where possible. Locations subject to excessive temperature rise should be avoided. A transformer should not be installed over or near a steam main or close to a boiler.

What are the causes of overheating of a transformer ?

(*a*) Overload.
(*b*) Other abnormal conditions such as incorrect voltage or frequency.
(*c*) Insufficient ventilation.
(*d*) A fault in the transformer.

What is a breather, and what is its purpose ?

A breather consists of a small chamber connected to the top of the tank by means of a pipe and filled with calcium chloride or some other substance which absorbs moisture from the air. Its purpose is to dry the air which passes into the transformer tank when the air above the oil contracts on cooling.

What is the no-load current of a modern transformer ?

This is in the neighbourhood of 1 per cent.

What defect is likely to develop in a transformer after a few months' use ?

Coil shrinkage.

What is the remedy for this ?

Means for taking up the shrinkage may be provided in the form of adjustable coil supports.

Why is oil used in power transformers ?

(1) For insulating.
(2) As a cooling medium.

What are the two kinds of transformer oil ?

The standard grade and a special non-sludging variety.

THEATRE LIGHTING

By M. MANSELL and L. G. APPLEBEE.

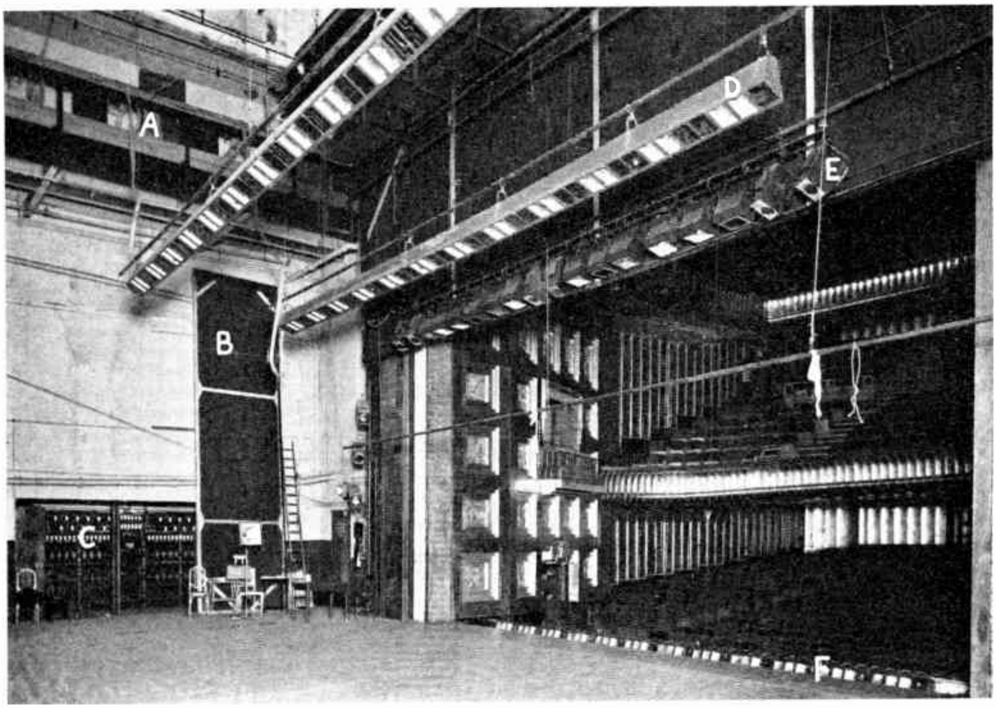


Fig. 1.—GENERAL VIEW OF STAGE LIGHTING AT SAVOY THEATRE, STRAND.
Showing A, flys ; B, wing ; C, switchboard ; D, magazine batten ; E, combined spotting and flood lantern ; F, footlight.

IN dealing with the question of theatre lighting we propose to deal with the stage section of the theatre first, and by this we mean all the lighting that is controlled from that portion of the building.

In order that the reader shall visualise the stage section, a glossary of stage terms (including electric) which are used in the theatre are enumerated below, with positions as shown in Fig. 2.

THE STAGE SECTION.

STAGE.—Sometimes called *The Green* or *The Back*. That portion of the theatre on which the performance takes place (Fig. 1).

AUDITORIUM.—Sometimes described as the front of house. That portion of the building on the public side of the proscenium wall (*see* Proscenium Wall).

DECORATIVE LIGHTING.—That section of the auditorium lighting which is controlled from the stage switchboard.

CYCLORAMA.—A curved background used in Continental theatres, rapidly becoming very popular in this country, particularly with the small repertory and amateur theatres. The "Seecol" tri-colour system of cyclorama lighting is extremely adaptable, as, unlike its Continental rivals, it allows its use other than for scenes in which a cyclorama is used.

By varying the intensity of the component circuits in a combination of the three primary colours of the spectrum by means of dimmers specially wound to C.D. specification prepared by Messrs. Ridge & Aldred, the well-known lighting consultants, it is possible to obtain

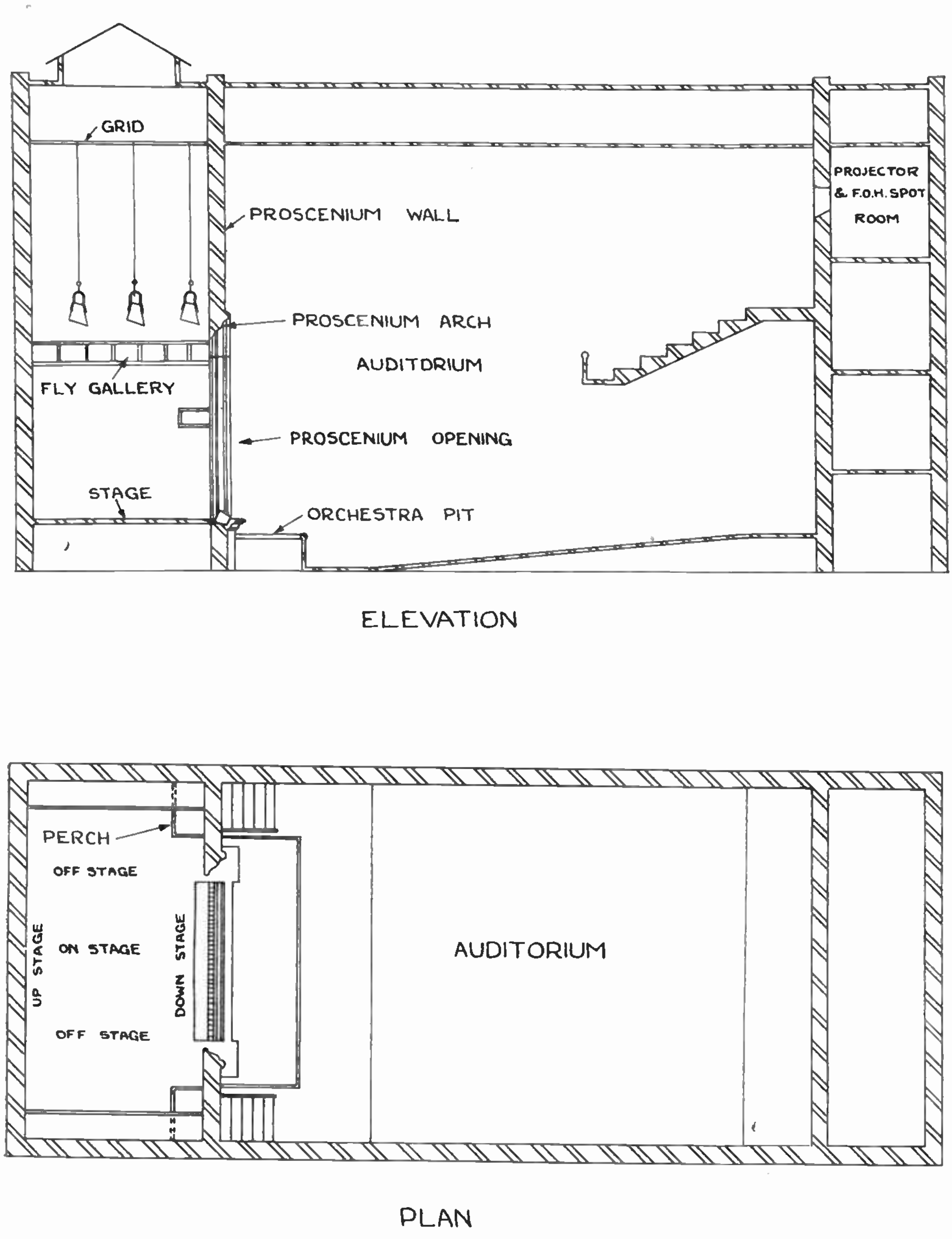


Fig. 2.—The Plan and Elevation of a Typical Stage Section.

natural sky effects with such perfection that it is impossible for the audience actually to see the cyclorama background, the impression being that of looking into infinite space.

The cyclorama may be constructed of canvas or plaster. The Continental practice is to use canvas, which can be rolled up by a motor, out of the way of other scenes when not required.

PROSCENIUM WALL.—The main wall between the stage and auditorium.

PROSCENIUM OPENING.—The opening in the proscenium wall which permits the audience to view the stage.

PROSCENIUM ARCH.—The topmost height of the proscenium opening.

"UP" STAGE.—Towards the back wall, away from the proscenium wall.

"DOWN" STAGE.—Towards the proscenium wall and the audience.

"OFF" STAGE.—Towards the side walls of the stage.

"ON" STAGE.—Towards the centre of the stage between the side walls.

PERCH.—A small platform about 8 to 12 feet above stage level on the proscenium wall, from which "limelight" or spotlights are worked.

FLYS.—The platforms or galleries on either side wall of the stage, from which the hanging scenery is operated. They are about 24 feet above the stage level (Fig. 3).

GRID.—A lattice-work of either hardwood or steel about 50 feet above the stage level to which the pulleys are fixed for the ropes to operate scenery.

BRIDGE.—A cradle similar to that used by decorators, suspended from the grid, from which special lighting effects can be operated (Fig. 3).

PROMPT and O.P.—These symbols denote in stage terms the particular side of the stage. The prompt side is always that on which the stage manager (or prompter) takes up his position. Sometimes this is on the right and sometimes on the left (Fig. 4).

The symbol "O.P." means opposite prompt.

FOOTLIGHT.—The section of lights fixed to the front of the stage flooring, on the public side of the proscenium wall. This is sometimes called the "float," a relic of the past when floating wicks in a bath of oil were used.

BATTENS.—The lengths of lights suspended from the grid to illuminate the stage and scenery. They are usually placed about 7 feet apart, between the proscenium and back walls.

CHAMBER SET.—A scene of an interior, to which there is a ceiling, which would only allow the first batten to be used below ceiling level.

CHAMBER PLUG.—A plug point fitted in the flys to which chandeliers and hanging lamps used in chamber sets can be connected.

BATTEN PILOT.—A separate circuit in the battens to provide a light on the stage for rehearsals, cleaners and such work as is necessary when the curtain is not raised, or the public are not present.

CURTAIN.—When this is in the form of heavy tapestry or tinsel, or other fancy material, opening in the centre, it is called the tableau curtain or "Tabs."

When in the form of a painted canvas stretched on a wood frame, it is known as the "Act Drop." In these forms the curtain is generally called by the stage staff the "Rag."

The fireproof curtain is always known as "The Iron."

DIMMER.—A variable resistance, so designed that the lighting can be raised or lowered in intensity, from full candlepower to a complete black-out without a flicker.

DIP.—A relic of the days of gas and candles, now used to denote a heavy plug fitted under the stage, to which flexible cables can be connected for the portable apparatus used on the stage. A malleable iron trap with a slot for the cables is usually fitted flush with the stage. These dips are sometimes called stage plugs (Fig. 4).

"LIME."—Another term which has survived the gas days. Limelight was obtained by impinging on a piece of lime a mixture of oxy-hydrogen. The electric arc replaced this method, and now the gas-filled projector lamp has at any rate in the smaller theatre replaced the arc. These lights are used for spotting the artists individually, and are still spoken of as "Limes" in some theatres.

WINGS.—The portions of the scenery which are braced to the stage on either side.

LENGTHS.—A strip of holders with wire guards, which are still used in many theatres to hang behind the wings to light windows and backings off stage.

WING FLOODS.—The modern way of lighting exteriors of windows and backings. Usually consists of a 500 or 1,000-watt gasfilled lamp with suitable reflector on telescopic stand with heavy base (Fig. 4).

SPECIAL EFFECT BOARD.—A large ironclad switch with special terminals to which the mains for temporary switchboards travelled by touring companies can be connected (Fig. 4).

The above list, together with the diagram, will give the reader a good idea of the stage terms he is likely to meet with, and enable him to interpret the "language" of the stage. We will now deal with the stage installation step by step from the company's mains and explain the rules and regulations which affect the sections of the work.

In all cases the regulations are those of the London County Council, which embody most of the rules of authorities in other parts of the country, and those for electrical equipment of buildings, as issued by the Institute of Electrical Engineers.

INTAKE.

The main switches—meters—and other electrical apparatus in connection with the intake from each supply must be installed in an enclosure. The enclosure should be in a dry position, of adequate size, constructed of fire-resisting material and ventilated to the open. The enclosures provided are exclusively for the accommodation of such apparatus, and water and gas pipes must be excluded therefrom. Means must be adopted to the satisfaction of the Council to prevent smoke or gases passing into the enclosure.

When the Pressure Exceeds 250 Volts.

If a transformer on which the pressure exceeds 250 volts is installed, the enclosure has to be under lock and key, which key must be kept in a lock-up case outside the enclosure. If the transformers are installed by the supply authority, the authority's emergency telephone number has to be clearly painted on the door to the enclosure.

Wiring Systems that May be Used.

Only the wiring systems in the following classes described in clause 87 of the I.E.E. regulations may be used :—

Class R. (Armoured cables.)
Class T.1. (Screwed conduits.)
Class T.2. (Metal conduits, not screwed.)

Even though the authorities allow the use of the metal conduits, not screwed, it is not recommended.

It will be seen that lead-covered and like systems of wiring are not allowed.

It should be noted that the use of wood for mounting or enclosing electrical apparatus is not looked on with favour. If used it *must* be of English oak, teak or mahogany, but the authorities prefer a totally enclosed job.

Three- or Four-wire Systems.

To satisfy the L.C.C., three- or four-wire systems, except in special circumstances, must be divided at or near the intake for lighting, into two-conductor services, from which all main lighting circuits must be taken.

Local authorities outside the London area vary in this respect, and the L.C.C. are *open to consider* three- or four-core cables being used for sub-mains.

How the Intake is Split Up.

The installation at the stage intake must be split up, one set of cables being taken to the stage switchboard to feed the stage, orchestra, stage locals, and the auditorium decorative lighting, and separate mains to feed the circuits for the dressing or retiring rooms, exits and staircases from the stage and dressing rooms.

STAGE SWITCHBOARD.

As the modern tendency is for three-phase supply, the necessity of balancing the stage lighting and assembling the controls on all three phases into a small space has made it necessary that the stage switchboard be entirely dead front—the whole of the current-carrying metal being situated behind the main panels, or so protected as to prevent accidental shock.

Connections Must be Accessible.

All connections to stage switchboards must be readily accessible, and the board should therefore be mounted in such a position that access can be obtained to the back as well as the front. A local pilot light should be provided to give adequate illumination of the back of the board when required. Internal connections on stage boards should all be carried out with bare conductors or cables, insulated with rock-bestos or other similar fire-resisting material.

Dimmers.

In the majority of cases the dimmers, when metallic, are part of the switchboard structure, and internal wiring is thus subject to a certain amount of rise in temperature, therefore all V.I.R. conductors should finish at terminals as distant from the dimmers as possible. From these terminals the conductors are continued to the various control points, with leads insulated with a fire-resisting covering. The dimmers must be placed in an accessible position, and should be controlled by means of levers carried on shafting, each "colour" section being carried on its own colour shaft. These levers should be capable of working the dimmers individually or of being locked to the colour shaft, so that all on one colour may be operated together by a master lever.

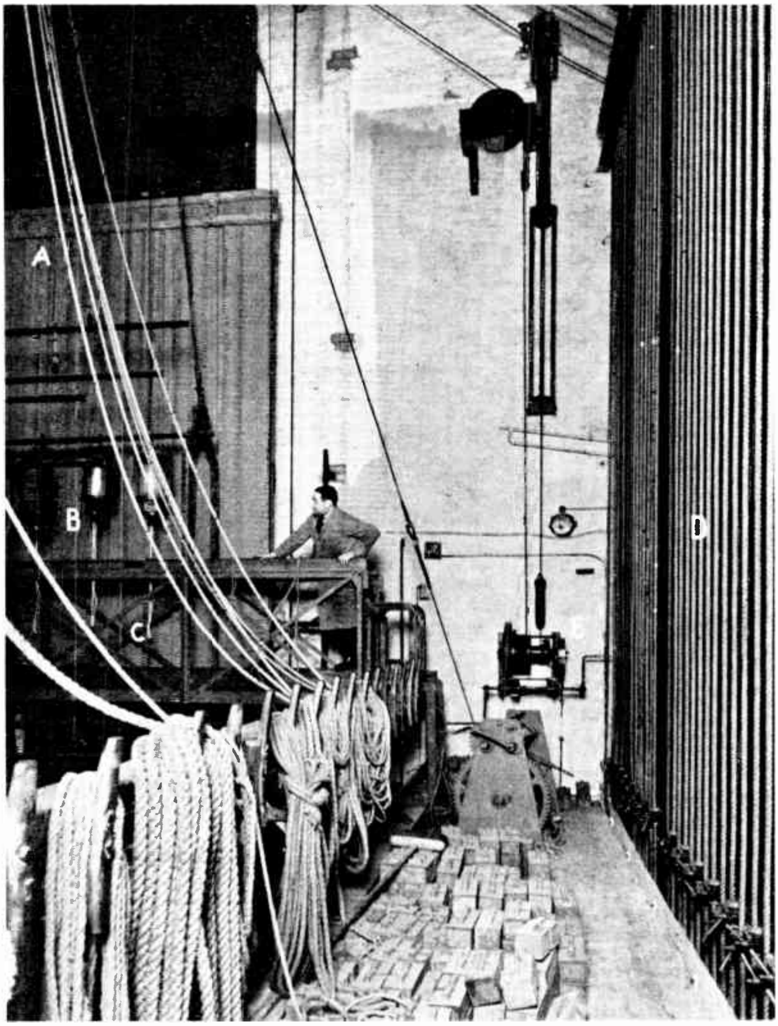


Fig. 3.—The Flys in a Modern Theatre.

The counterweight gear is shown on the right, whilst the old-fashioned rope gear appears on the left. An operator can be seen in position on a bridge with some of the lighting apparatus. The act drop is shown in its position when raised. A, act drop; B, cyclorama lanterns; C, bridge; D, counterweight gear; E, fire curtain winch.

Liquid Dimmers.

In some theatres liquid dimmers are met with (Fig. 9), these being coupled by their tracker wire (a steel-stranded galvanised rope, $\frac{5}{16}$ in. in circumference) to wheel levers mounted on shafts at the switchboard, in a similar manner described for metallic dimmers.

Liquid dimmers are usually placed in a room beneath the stage, as near under the stage switchboard as possible, so that the number of tracker-wire guide pulleys is reduced to a minimum.

The liquid dimmer has the advantage over the metal type in that varying loads up to 30 and 40 amperes can be dealt with in one unit, but from a maintenance point of view the liquid dimmer has many disadvantages, as the liquid is constantly evaporating and requires "topping." This is a job that requires skill and patience, as to set the dimmers so that there is no jump at the beginning and end of the "dim" is intricate and tiresome.

Dimmer Controls.

Many designs are on the market regarding

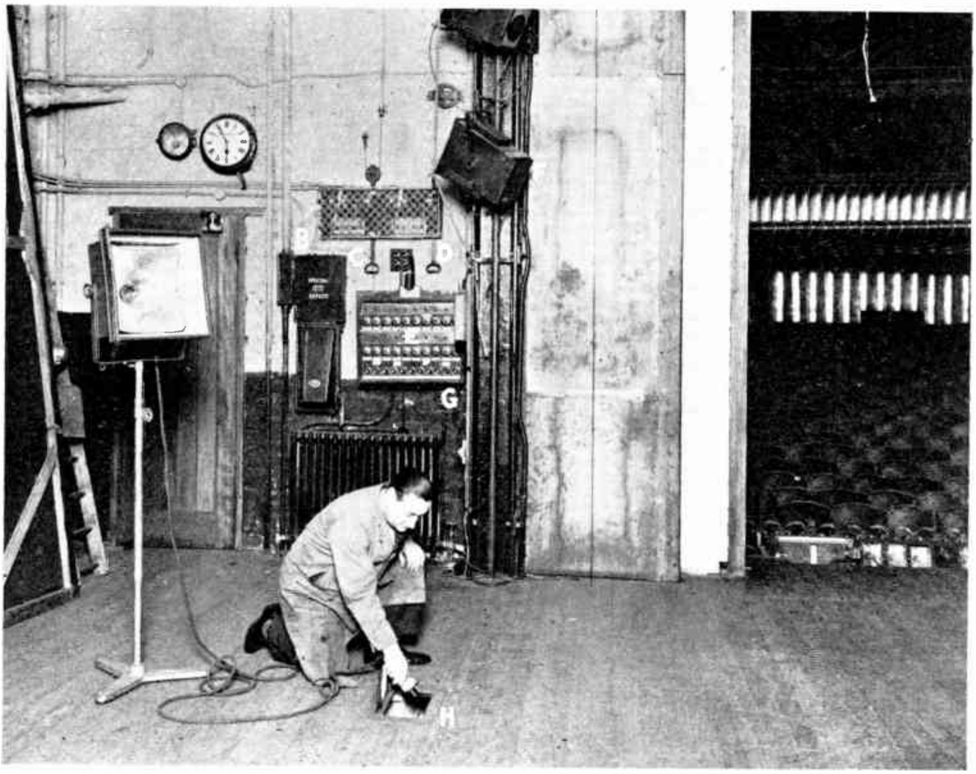


Fig. 4.—A VIEW OF THE PROMPT CORNER AND VARIOUS SECTIONS OF STAGE LIGHTING.
A, wing flood ; B, special effect ; C, fire curtain control ; D, sprinkler control ; E, signal board ; F, " limes " ; G, prompt corner ; H, dip.

the dimmer control section with interlocks—grand master cross connection control, etc.—but we do not propose to enter deeply into these, as the reader when he meets a job of this type cannot do better than consult a firm of experienced stage switchboard manufacturers, such as the Strand Electric and Engineering Company of Floral Street, Covent Garden, who specialise in theatrical lighting apparatus.

How Stage Lighting Installations are Divided and Controlled.

Most stage lighting installations to-day are divided into four sections, each section a different colour, and the controls are accordingly arranged in colour banks, with a master switch to each. On three-phase boards this becomes a problem, which is usually solved by the use of remote control triple-pole contactors. The best practice is to mount these contactors away from the stage (usually underneath) on account of the noise in operation. The sub-mains are then fused and carried up to the " colour " bus-bars on the stage board.

The framework of the board must always be independently earthed. Conduits are usually bonded to a sheet steel trough at the top of the board.

Economy in space is a big advantage of the metallic dimmer, and looking at the question from all points we strongly recommend this type, as with the exception of the dips most loads on the stage are constant, and the dip dimmers can be made with a plus and minus one-third capacity. (Fig. 11.)

STAGE SWITCHBOARD PLATFORM.

The platform provided for the stage switchboard must be of fire-resisting construction, and the floor must be of

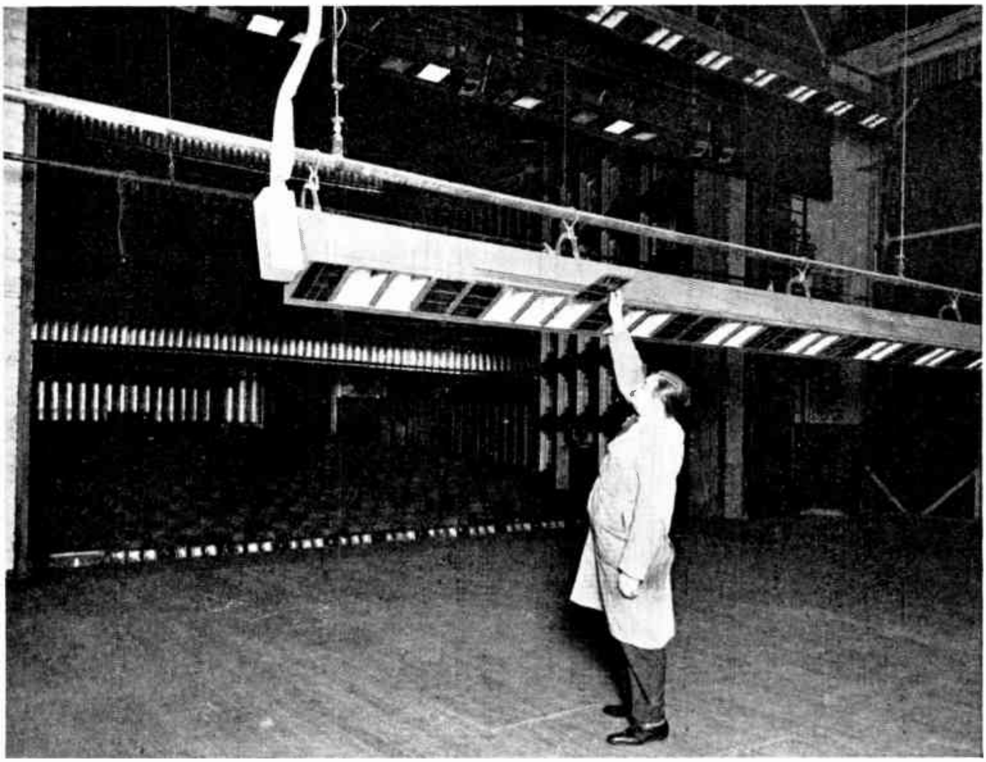


Fig. 5.—A Batten Lowered on Counterweight Lines for Replacing Lamps.
This illustration also shows the ease with which colours can be changed by the use of gelatine mediums.

non-conducting material, or should be covered with an insulating mat. Guard rails, step ladders, and handrails must be of English oak, and any metal within reach of a person on the platform has to be satisfactorily protected.

From the stage switchboard the wiring in screwed conduit is run to the various circuits, such as :—

1. *Battens.*—Terminating in a special connector box, usually fixed to the fly rail, the connections from this box being taken to the batten by means of a flexible multicore asbestos-covered cable, which is efficiently anchored to the connector box by clamp grips, to take the weight of the cable off the terminals.

2. *Footlight.*—The same as the batten connections, except that in this case V.I.R. connections are carried to the footlight in a flexible metallic hose from the connector box, which is usually fixed under the stage.

3. *Dips.*—These usually consist of 25-ampere "Stage" sockets, mounted in iron boxes, just below the stage level, with a heavy malleable hinged iron cover trap let into the stage.

4. Other stage points as required by the stage specialists, on the perches, bridges, etc.

5. Points in the auditorium, generally in front of circles, for serving spot and floodlights.

6. Auditorium decorative.

Regulations Regarding Battens.

The London County Council regulations regarding battens, footlights and lanterns, are as follows :—

"The outer cases of battens, footlights, lanterns and similar fittings shall be of

B

hard metal of not less than 20 B.G. (.039 in.). If wood be used for the construction of portable lengths it shall be teak or English oak, of such thickness as may be approved by the Council.

" Battens, lanterns and similar fittings shall be efficiently ventilated, and the cases and all metalwork shall be earthed. The lamps and any part of such apparatus liable to become hot shall be so arranged and guarded as not to endanger scenery, etc. The guard shall be of wire mesh or the heat of the modern gasfilled lamp quickly destroys the lacquered surface. The modern method therefore is to use coloured gelatine screens. Care should be taken to use only gelatine which is non-inflammable, and does not fade quickly. *A word of warning.* There are many makes of colour mediums on the market sold as " non-flam " that are highly inflammable, and should be avoided as their use will certainly be condemned by the L.C.C. or any other licensing authority.

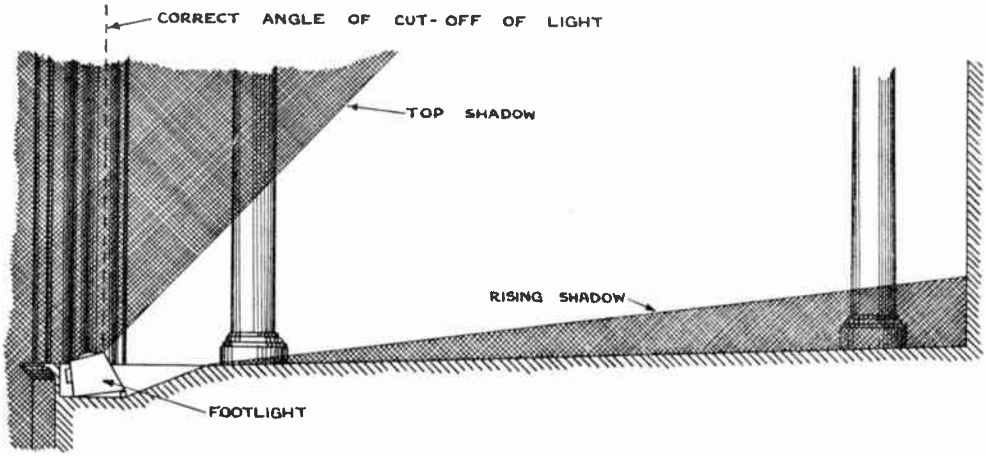


Fig. 6.—Common Faults in Footlight Design.

such type as will afford ventilation, and where practicable shall be at a distance of at least 1 in. vertically and 3 in. horizontally from the casing of the lamp or holder." (See Fig. 5.)

The number of lamps in the batten must conform to the I.E.E. ruling in regard to the number of points to each sub-fuse, and each lamp in a batten has to be regarded as a point.

STAGE LIGHTING IN AUDITORIUM.

Should any lantern be required to be fixed in the auditorium for stage purposes, it must be contained in a suitable enclosure.

COLOUR EFFECTS.

Colour lighting on the stage is produced by either colouring the lamps with a lacquer or by means of coloured mediums. The first method is rapidly dying out, as

Designing the Footlights and Battens.

A word regarding their design will not be amiss.

The footlight must be so designed that it illuminates the actor at whatever position he occupies on the stage. In order to do this the lamp itself, irrespective of its reflector, must not be sunk below the stage, otherwise a rising shadow will result, which will increase as the actor passes up stage. The result is disastrous from a stage lighting point of view, as Fig. 6 will show.

Further, when the actor is standing near the footlight, the reflector must be so designed that the light is thrown up on to his face.

All this sounds very simple, but there is the public to be considered, and the footlight must not project above the stage so as to obscure the view of those sitting in the stalls of the dancer's feet. In practice, a well-designed footlight will only be 3¼ in. above the actual stage level. In addition the reflector must be designed to give a wide side distribution of light when a shallow scene is being played.

Battens.

The opposite effect is desired in the battens, the light being required to illuminate the area, as described in Fig. 7. Great care must be taken that they are designed and positioned so that scenery being hauled up and down from the grid does not catch and lodge on any projections.

Batten Suspensions.

The battens should, if possible, be suspended on counterweight gear, of the same design as that used for the scenery, to enable them to be raised or lowered with the minimum of effort and time.

If this is not possible then the alternative is by means of stranded-steel lines and a winch, as shown in Fig. 10. Again, great care should be taken with this method. The pulleys should be at least three to four inches in diameter, whilst the grip on the steel rope by means of which they are "tied off" must be carefully fitted. The chains must be of closed link, and supplied by the makers under a guarantee. Also the winch must be self-sustaining, and fitted with a ratchet and pawl, which *must* be in mesh when the batten is stationary.

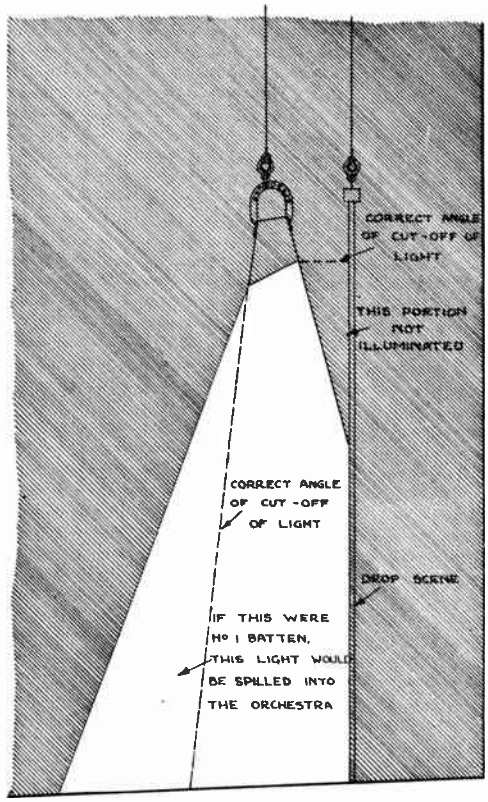


Fig. 7.—COMMON FAULTS IN THE DESIGN OF STAGE BATTENS.

ARCS.

The use of arc lamps (other than cinema projectors) in the theatre is very extensive. They are desirable for the following :—

(1) As a spot for following the artists. For this purpose they are usually operated from the perches and front of house, preferably from a special chamber above the main ceiling, or at the back of the gallery, whilst in cinemas they are part of the equipment of the bio box.

(2) For effect lanterns, to present optical illusions on the stage, such as "rain," "lightning," "snow," "flames," etc.

(3) Where greater illumination is required this is obtainable from gasfilled lamps.

In each case D.C. is definitely necessary on account of the fact that A.C. arcs for stage work are a nuisance, due to the humming noise created by the alternations of the current. Therefore, if D.C. is not available from the mains, a motor generator or mercury rectifier should be installed.

RESISTANCES.

It is advisable to have a fair margin of voltage from the supply source, beyond that required at the arc-lamp terminals, and this excess of voltage has to be absorbed in the resistance. At first sight this may be regarded as wasteful, but it

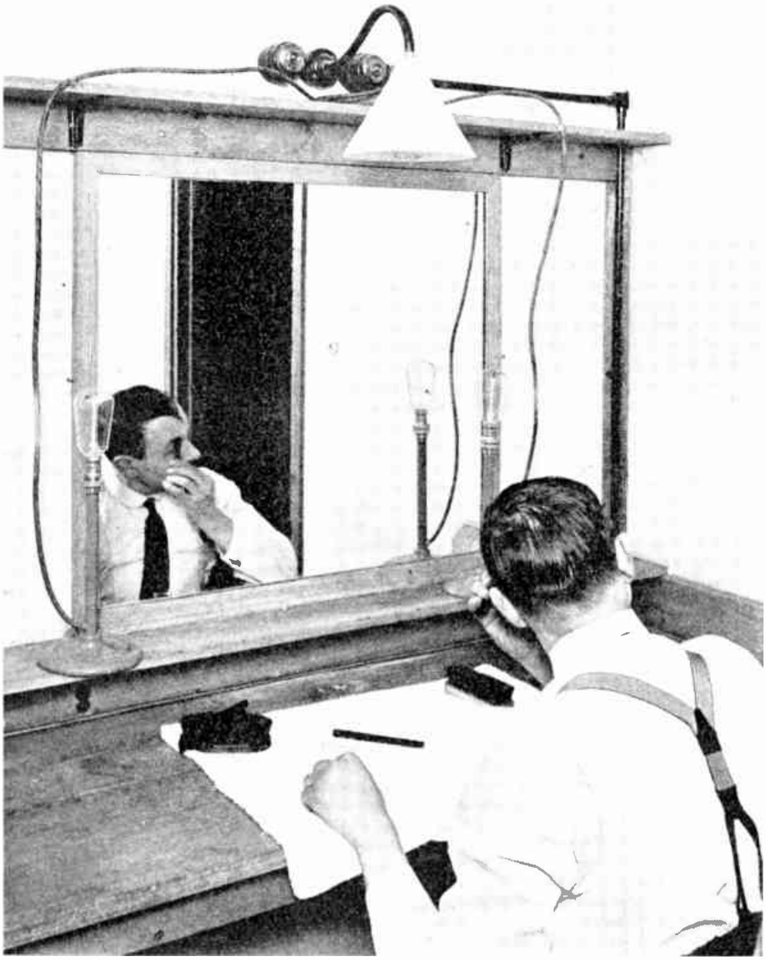


Fig. 8.—The Best Way of Lighting a Dressing-room.

flare, with the risk of breaking condensers.

It can be taken as a safe guide that between 30 and 50 volts should be dealt with by the resistance. This happy medium should make working the arc a comfortable job.

Types of Resistances.

Resistances may be of the fixed or variable current type, and where moderate currents are used, say, 20 to 30 amperes, the fixed type are quite satisfactory. Where larger currents are required the resistances should be designed so that the arc can be "struck" with a reasonably small current, which can be gradually increased to the maximum required. This makes "burning in" more simple, and prevents a previously well-formed crater being destroyed by a sudden rush of current. Variable current resistances are made in two types. The current in one case is regulated by a number of switches in parallel, each switch bringing in an additional section of resistance. This type is to be preferred always on high voltage, as the control, being by means of "quick break" switches, prevents burning of contacts. It is also to be preferred for heavy currents, as the heat generated in the resistance is better distributed.

must be borne in mind that the special resistances used by arc lamps function electrically similar to the way fly-wheels act mechanically. That is to say, they prevent sudden increases or diminutions in the value of the current which may be caused by an alteration in line voltage, or by a sudden change in the formation of the carbon crater.

Further, the liability of the arc going out is reduced and feeding is lessened.

On the other hand, a limit should be set to the voltage to be absorbed, on the grounds of economy and because too high a voltage tends to make the carbons

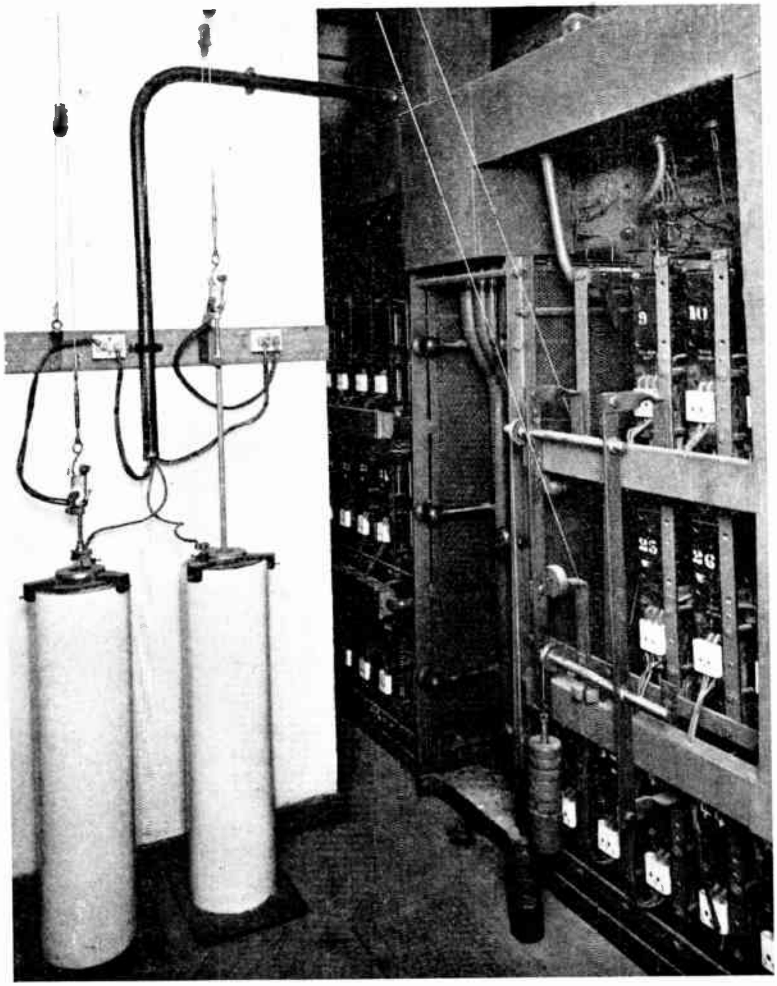


Fig. 9.—THE BACK VIEW OF A SWITCHBOARD.
Where metallic and liquid dimmers are used.

The other type of resistance is regulated by means of a multi-contact radial switch, and is quite satisfactory on low voltages, and where the maximum current does not exceed 40 amps.

Location of Resistances.

The location of resistances in a theatre or cinema is an important matter, and the local authorities' rules should always be consulted. Generally speaking, they are not permitted in operating rooms or where inflammable material is liable to come in contact with them. The resistance coils should be enclosed with a ventilated cover to prevent accidental contact, and should never reach such a temperature that a piece of dry paper would char if brought into contact with the coils.

DIMMERS.

The remarks regarding location protection and heating permissible apply to dimmers similarly to resistances. The method of operating dimmers from a stage switchboard has been referred to earlier, but care should be taken where metallic dimmers are being used that there is an adequate number of contact studs between the "dim and "full on" position. From an artistic point of view, the type of dimmer in which the contact brush slides on turns of wire wound on a former cannot be excelled, as a very large number of contact points are economically provided. It cannot be said, however, that they are mechanically satisfactory, the risk of breakdown being very great. They should, therefore, never be used where financial considerations permit the more expensive stud type. Dimming is either good or bad, and is bad whenever the light is diminished or raised in perceptible steps. It has been found that 80 steps of resistance are necessary for reasonably good results, and 100 to 120 contacts should be provided whenever possible. With this larger number of contacts it is possible to design a dimmer that will deal satisfactorily with a load varying down to 50 per cent. of maximum, but when this is a definite requirement it should always be specified to the dimmer manufacturer.

Dimmers for Cyclorama Lighting.

For cyclorama lighting dimmers should always be wound to C.D. specification as standard dimmers used for this purpose are quite useless, it being impossible to get the micrometer control of the component colours necessary to obtain the delicate tints of sunset and sunrise, which can be so beautifully portrayed with suitable apparatus.

SIGNALS.

It is customary for the stage manager to have a set of signals operated from the P. corner, which are both visual and audible. The visual signals take the form of two lamps in series, one at the signal control board, and the other at the position it is to be read. Two lamps in series are used, so that the stage manager would be aware of a failure of current. Facilities are generally provided for the stage manager to signal to the following points :—

Switchboard.	Perch, P.
Orchestra.	Perch, O.P.
O.P. corner.	Up stage, right.
Under Stage.	Up stage, left.
Flys, P.	F.O.H. spots.
Flys, O.P.	

The signal lamps are generally housed in a sheet-steel box with two bull's-eye lenses, one coloured red for "warning" and one green, which is always known as the "go" signal.

For the audible signals a quiet buzzer is installed, so that in the event of a failure in the light a signal can still be transmitted (Fig. 4).

Buzzers (or bells) are usually installed in refreshment rooms and vestibule in the front of house, in order that the stage manager may signal a few minutes before the rise of the curtain.

So much for the actual stage wiring

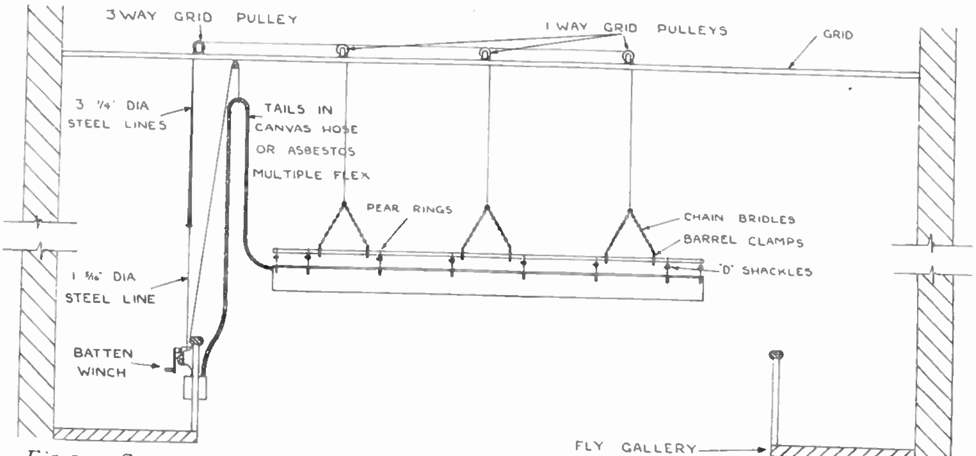


Fig. 10.—Showing Use of Stranded-Steel Lines and a Winch for Suspending Battens.

and installing of apparatus. We will now consider the separate circuits to feed the dressing rooms and local lighting.

DRESSING ROOMS.

These require special care, and the points should finish in a heavy bracket over each mirror, and all pendants should be conduit construction. Flexible pendants should never be used. If standard lamps beside the mirrors are installed they must have a heavy base so that they cannot be overturned, and if metal, earthed. The flex must be of heavy cabtyre (Fig. 8).

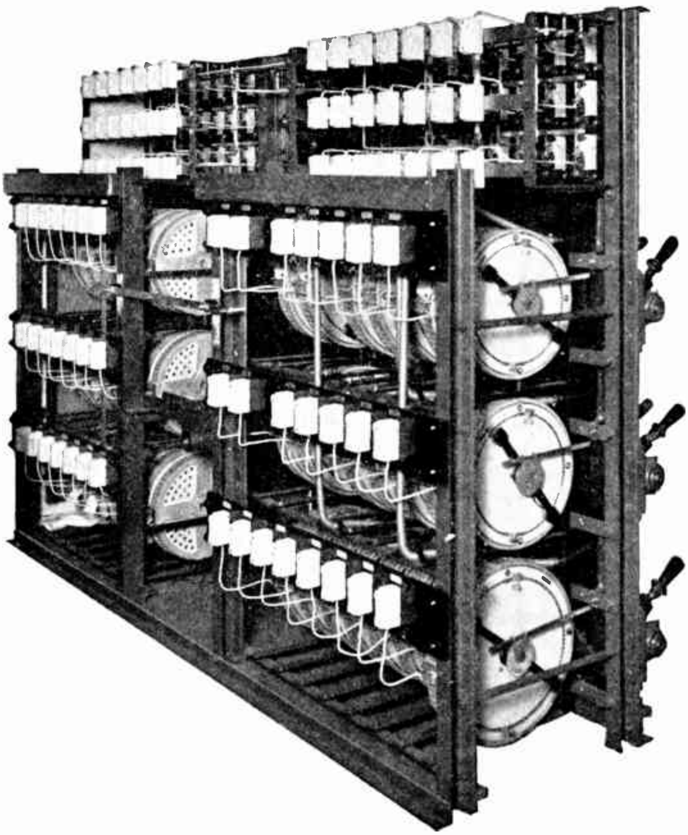


Fig. 11.—The "Cecil" Remote Control Colour-changing Dimmer.

Local Lighting.

Local lighting such as corridors and staircases which form the means of escape from any stage, platform, dressing or retiring room, and the exit notices from same, must be provided with two independent systems of lighting. See paragraph headed "Safety Lighting."

THE SECTION OF THE THEATRE OTHER THAN STAGE.

In the stage section we have dealt rather fully with the type of stage that is used more for the theatre or playhouse where stage plays or variety is the performance, and we now pass to the remainder of the building, our remarks applying in this case for any type of entertainment, whether it is a stage play, cinema, circus, exhibition, dance hall or skating rink. The various licensing authorities in this country have wiring rules for this part of the building, and, like the stage, in the main they practically agree

DIAGRAM OF A TYPICAL STA

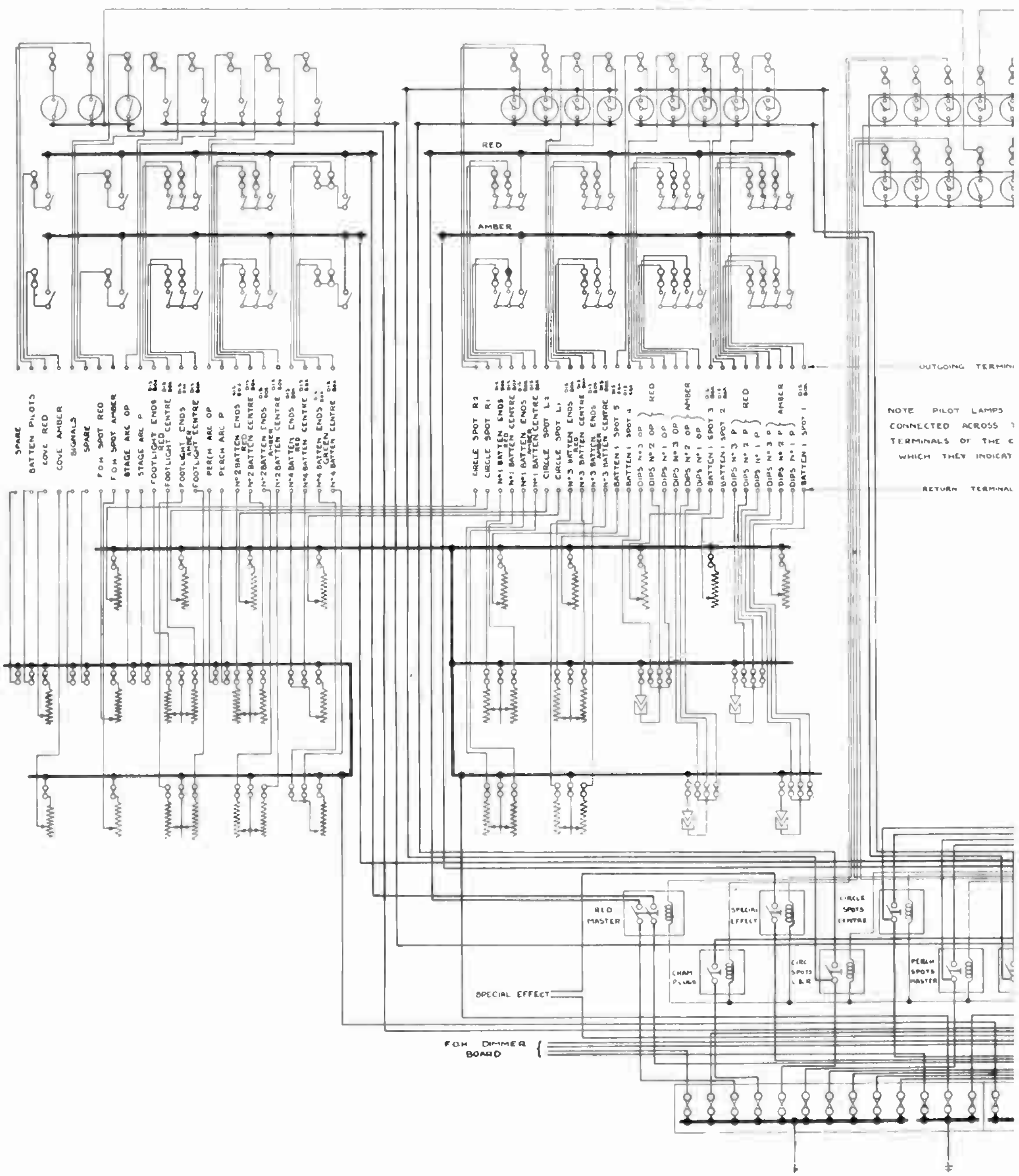
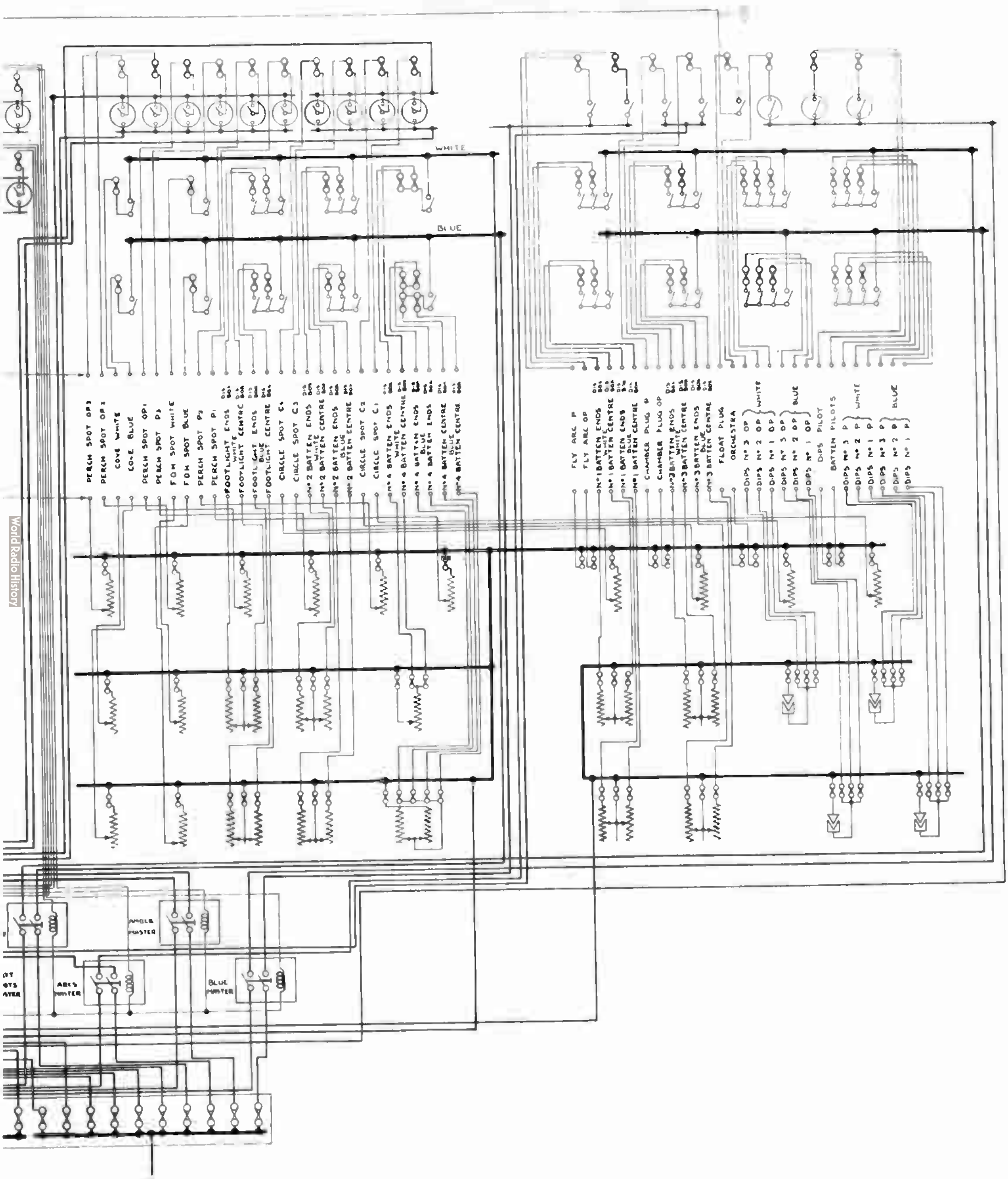


Fig. 12.—This shows the connections for the stage lighting equipment a

LIGHTING INSTALLATION.



ıe Shakespeare Memorial Theatre. *(Strand Electric & Eng. Co., Ltd.)*

with those of the London County Council Fire Brigade.

Safety Lighting.

All portions of the premises to which the public are admitted must be connected to the original supply. (Should the cables come from the same power station, even though they are fed from two distinct machines, the source is regarded as the same. In the West End of London it is

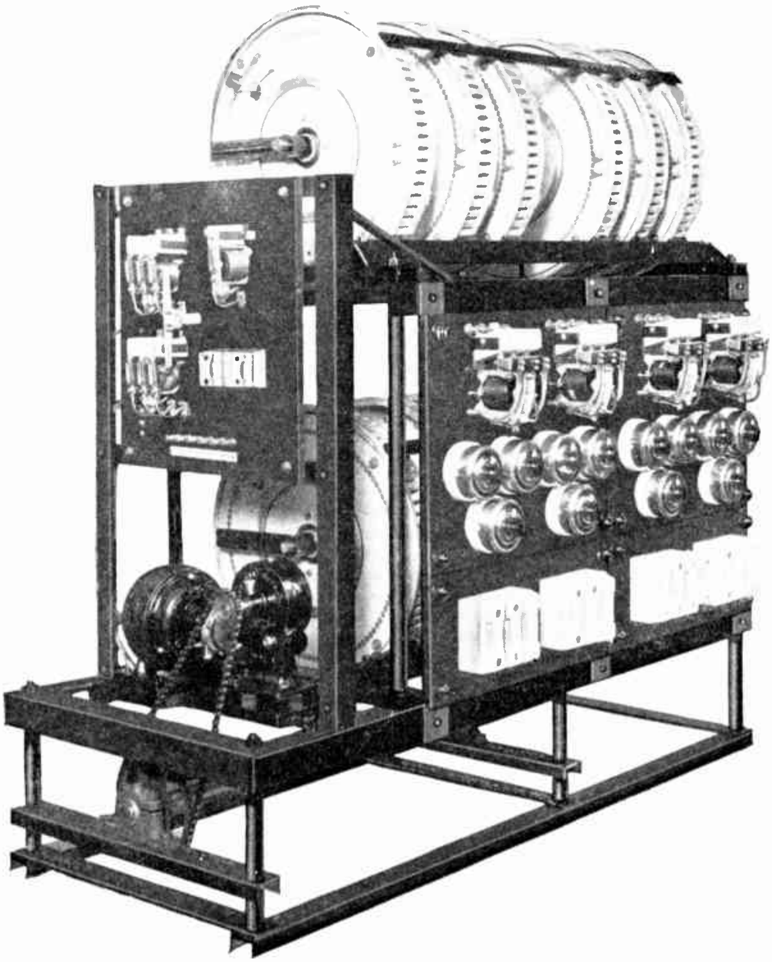


Fig. 13.—Back View of a Three-phase "Dead Front" Stage Switchboard and Dimmer Regulator.

provided with two independent systems of lighting, and these two systems must not originate from the same source. For example, if the main lighting is from an electric supply company, the other system may be from :—

(*a*) Electric street mains, in no way possible to connect to two distinct supply companies, but as the grid system develops this may become ineffective if the companies ultimately link up in any way.)

(*b*) A battery.

(*c*) Gas.

(*d*) Oil lamps. (Not burning paraffin or other mineral oil.)

(*e*) Candles.

The last two are rather remote, but even now there are houses using these methods.

One of the above systems is accepted as the "safety lighting" called for in the Cinematograph Act of 1909.

The degree of lighting maintained in each system must not be less than is sufficient to enable the public to see their way out of the premises.

Each system must be so installed that a fault in one cannot in any way affect the other.

Exit Signs.

Over each exit door in the auditorium, and certain doors in the corridors, etc., selected by the licensing authorities, an illuminated sign with the word "Exit" in 7-inch letters must be fitted. Every such direction sign must be illuminated by the two systems of lighting, and must never be extinguished or dimmed during the time the audience is within the building.

In addition, no other sign must be used inside the building that is internally illuminated.

Fireproof Shades.

Decorative shades, fittings, etc., used in the theatre must be of incombustible material, unless they have been specially treated to render them non-inflammable.

Safety Hangings for Fittings.

All decorative fittings in the public portion of the building must be provided with a secondary suspension; such suspension must be independent of the flexible cable carrying the current.

Auditorium Dimming.

The auditorium decorative lighting should, in all theatres, be made to "dim," if only for the health effect on the public eyesight, apart from the artistic atmosphere given to the opening of the show.

How Dimming is Carried Out.

The dimming can be carried out in several ways—first, it can be operated from the stage switchboard by hand, and, secondly, if a cinema, it can be hand operated from the bioscope operating box. The most modern way is for the dimmers to be placed in some convenient room reserved for electrical gear, and operated by means of a remote controlled motor. This has the advantage of control from two or more positions, as push buttons can be placed on the stage, in the bio box, and in as many other positions as desired.

The tendency to-day, in the cinema, is for colour lighting in the auditorium and motor driven dimmers, which by the simple operation of a push button set the necessary machinery going, which raises the lights and then commences to blend the colours into various shades by means of the dimmers. The operator is then left clear to carry out other duties, and when ready for the next picture a press of the button and the colour mixing dies down ready for the picture to open.

They can be made to carry out prearranged changes of colour which have the effect of completely altering the decorative appearance of a building. The design of these dimmers is an expert business, and it is amazing what has been done in this direction, but these problems should always be put to the dimmer manufacturer, who always seems to have another card up his sleeve when something more intricate than usual is asked for.

The actual cinema picture and talking apparatus we have not dealt with, as these are the subject of separate articles, and we have confined ourselves to the peculiar conditions that arise with the contractor and electrician who installs apparatus in the theatre.

If the reader or student desires to probe more deeply into the use of the apparatus in lighting of stage plays, sometimes called the art of stage lighting, we recommend him to read "Stage Lighting," by Harold Ridge, which deals with the subject from a stage producer's point of view.

HOW TO MAKE SIMPLE BATTERY CHARGERS

FOR A.C. AND D.C. SUPPLIES

By A. W. JUDGE, and H. J. BUTLER.

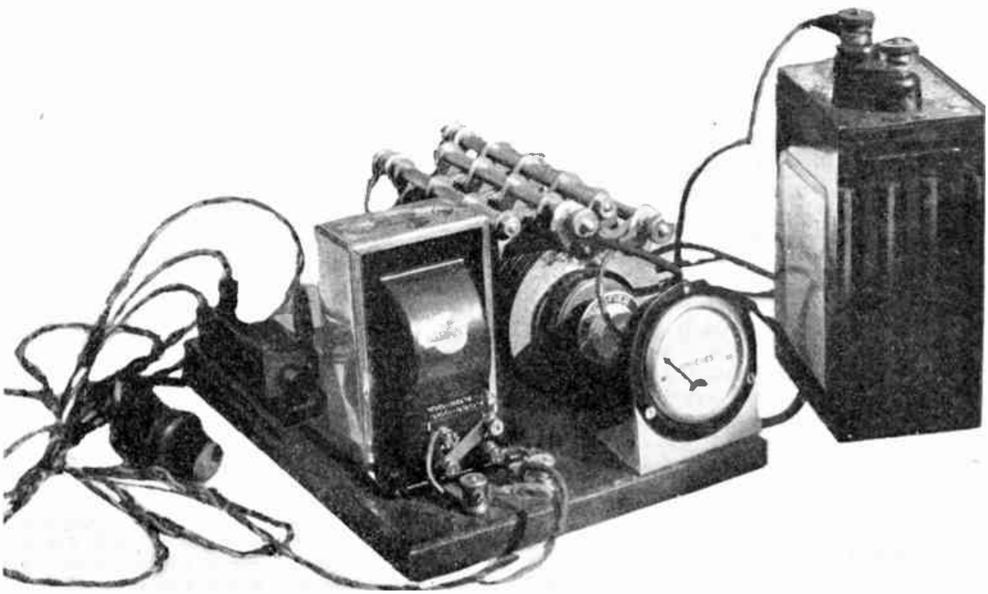


Fig. 1.—THE COMPLETE L.T. CHARGER FOR A.C. MAINS.
Showing the transformer, dry rectifier, ammeter, etc.

THIS article describes the method of constructing simple and inexpensive small battery chargers from A.C. or D.C. supplies.

BATTERY CHARGER FOR A.C. SUPPLY.

The battery charger here described is capable of giving a maximum steady charging current of 2 amperes, from a 230-volt alternating current source of supply.

It can, of course, be used for any other A.C. supply voltages between 200 and 240 volts with little alteration in the amperes output.

Uses of the Charger.

The battery charger in question is particularly suitable for the charging of 2, 4 and 6-volt wireless batteries, and it has frequently been used to charge up a 6-volt car lighting and starting battery. Further, it can also be employed for a 12-volt motor-car battery by charging each 6-volt half of the battery at a time ; it will naturally charge at a lower rate than the more elaborate garage chargers.

If the reader's source of alternating current supply is 100 to 120 volts, the only alteration necessary in the case of the battery charger described is to alter the terminal connections on the Igranic transformer shown at C in Figs. 2 and 3.

Components Used.

The following is a list of the actual components used in building the battery charger illustrated in the photograph :—

1 Westinghouse rectifier, Type A4.
1 Igranic or Ferranti power transformer, 220 to 12 or 14 volts. (Terminals are also provided on this transformer for 110-volt supply.)
1 10-ohm resistance ; this was built up by the writer.
1 0-3 ampere ammeter.
1 bakelite electric lamp adaptor.
2 yards Glazite wire and 2 terminals.
Baseboard, $8\frac{1}{2}$ inches by 6 inches by $\frac{5}{8}$ inch, in deal.

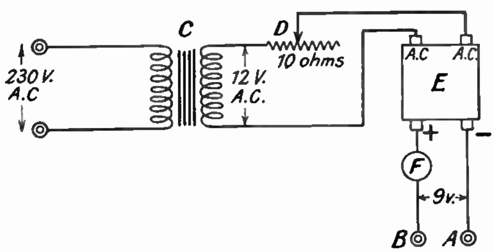


Fig. 2.—Circuit Diagram of L.T. Battery Charger for A.C. Supply.

Explaining the Principle of the Charger.

Before one can charge an ordinary low tension battery from an alternating current source of supply it is necessary to convert the alternating current voltage from its high value of 230 or 110 volts (according to the supply voltage provided in the house, or district) down to a low voltage. This latter voltage is a little higher than the greatest voltage of the batteries to be charged ; for most purposes about 8 volts is sufficient. Having stepped down this voltage to the figure mentioned, this low voltage alternating current must be converted into direct current of nearly the same voltage. It is this direct current supply that is used for battery charging purposes.

Actually, the so-called direct current obtained from the rectifying unit is not perfectly uniform, but is constantly fluctuating above and below a mean value of the voltage in question. Whilst this kind of direct current is not suitable for heating the valves of a wireless set, without the addition of smoothing chokes and fixed condensers, it is perfectly satisfactory for battery charging purposes.

The Circuit Employed.

Once the principle of the charging apparatus previously outlined is understood, the reader should experience little difficulty in following the circuit diagram illustrated in Fig. 2.

Commencing from the left-hand side it will be seen that the 230-volt alternating current supply from the mains (taken from a wall plug or lamp adaptor) is fed direct to the transformer C. This is a special transformer consisting of the usual primary and secondary windings and core plates. The ratio of the number of turns of the secondary to those of the primary windings is roughly about 20 to 1, so that the 230-volt A.C. supply to the secondary winding is transformed down to about one-twentieth of its original value, that is to say, the primary voltage is, roughly, about $\frac{230}{20}$, or $11\frac{1}{2}$.

In order to be able to regulate the value of the charging current obtained from this device it is a most convenient plan to insert a small variable resistance of about 10 ohms in one of the transformer output leads ; this resistance is shown at D in Fig. 2.

Passing Current Through a Rectifier.

Now the $11\frac{1}{2}$ volts alternating current is transformed, or rectified, into direct current by passing it through a " rectifier." There are many kinds of A.C. rectifiers on the market, of which that known as the dry plate or metal rectifier is the most convenient and efficient to employ.

This rectifier consists of a number of discs or plates of copper and copper oxide clamped together in a special manner. It has the property of allowing current to flow through it in one direction only, so that if alternating current is fed into it at one end, only direct current can be taken out at the other end.

Output Current.

The dry rectifier is shown at E in Fig. 2. It will be seen that there are two input terminals, marked A.C., and two output terminals, marked " Plus " and " Minus " respectively. There is a small drop in voltage through the rectifier, amounting in the present case to about 3 volts. The output current from the rectifier, at about 9 volts, is taken to the terminals A and B of the charger. These are the battery charging terminals. An ammeter, F, reading from 0 to 3 amperes should be inserted in the positive lead from the rectifier unit E.

Assembling the Components.

Fig. 3 shows the layout of the components on the baseboard. These parts should be screwed down in approximately the positions shown and then wired up according to the arrangement shown in Fig. 2.

An insulated type of wire of about 18 S.W.G., preferably Glazite, or tinned copper wire with Systoflex sleeving slipped over it, should be used to make the connections.

Although there is no objection to making screw-down contacts or joints, it is better to solder all connections; this ensures permanence to the finished charger.

In regard to the resistance unit, this is readily made by winding about 4 yards of 26 S.W.G. Eureka or Nichrome resistance wire on a piece of slate, bakelite or fibre. The former used measured 3 inches by 1 inch by ½ inch and was of rectangular section with the 1-inch side horizontal. A sliding or rotating contact arm should be fitted in order to vary the resistance value. One end of the resistance wire is connected to one of the dry rectifier A.C. input terminals, and the moving arm, or slider, to one of the output terminals of the transformer, as shown in Fig. 2.

Using the Battery Charger.

It is important to observe one or two simple precautions when using the charger described.

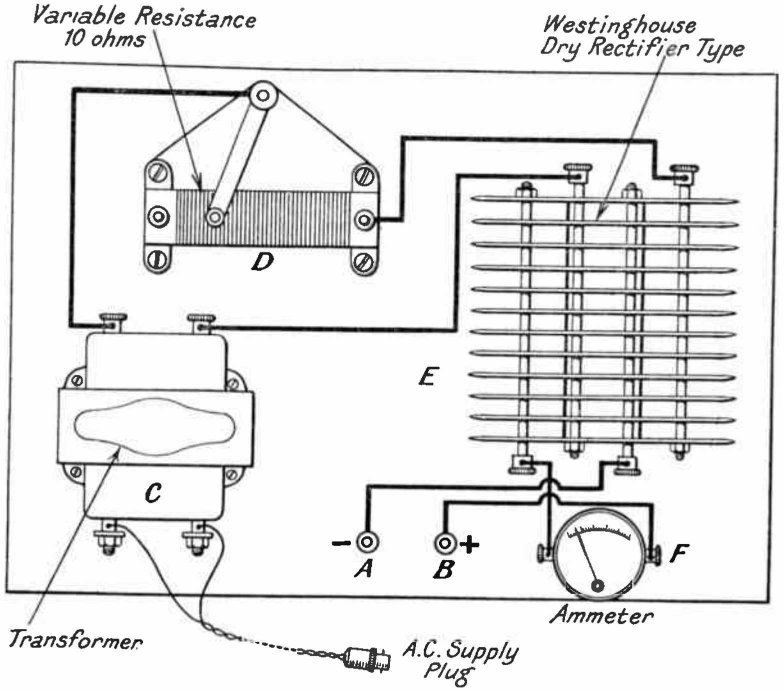


Fig. 3.—Layout of L.T. Battery Charger to Operate from A.C. Mains.

In the first place, *always* connect up the charger to the battery to be charged first, i.e., before inserting the A.C. supply plug in its socket or holder. Connect the positive terminal of the battery to the positive terminal B (Fig. 2) of the charger, and negative battery terminal to the negative terminal A.

Secondly, before switching on the A.C. supply current see that the resistance arm or slider is in the position that puts all of the resistance in the circuit. Thus, in the case of the unit shown in Fig. 3, the contact arm will be on the extreme left-hand side.

Now switch on the A.C. supply, when it will be noticed that the ammeter probably reads very low—usually about $\frac{1}{4}$ to $\frac{1}{2}$ ampere. Next, move the slider arm of the resistance D to the right so as to take out some of the resistance, and therefore to increase the current as shown by the ammeter. The best charging current value for most small wireless receivers is about $1\frac{1}{2}$ to 2 amperes. No greater current should be taken from this battery charger, otherwise both the rectifier unit and the transformer will be working above the maximum current values laid down by the manufacturers and will heat up.

A Convenient Battery Charging Arrangement.

A particularly convenient method of charging a wireless battery in place in the cabinet of the receiver is shown in Fig. 4.

In this arrangement, by means of a double-pole single-throw switch, the battery may either be connected to the wireless receiver or to the charger. Thus, when the battery is not actually in use for wireless purposes, the switch can be thrown over and the battery left "on charge." After the wireless has been switched off at night, the charger can be connected up by means of the switch and the battery left "on charge" through the night.

Here it should be mentioned that by using the smaller, and cheaper, Westinghouse unit known as the Type A3, a convenient trickle charger is available for the wireless set. This unit will give up to 1 ampere charging rate for a 6-volt battery. The A4 unit used for the charger described gives a maximum of 2 amperes at 6 volts.

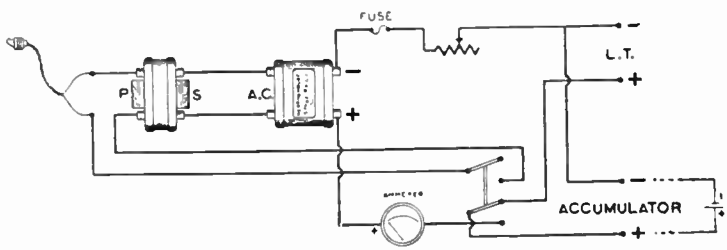


Fig. 4.—A Convenient Circuit Arrangement for Charging the L.T. Batteries of Wireless Receivers from A.C. Mains.

BATTERY CHARGER FOR D.C. SUPPLY.

This charging set is simply a switchboard for putting the low tension batteries in circuit with the house lighting, so that when the lights are in use the battery may be charged. It enables anyone with D.C. mains to charge their low tension batteries without extra cost. The switch on the charging board is arranged alternatively to place the battery on charge or connect it to the set. It may be used in conjunction with any size of 2, 4 or 6-volt accumulator.

Material and Parts Required.

The following are the components required to make the charging board:—

Baseboard, 8 by 12 inches by $\frac{3}{8}$ inch plywood.

Two battens, $\frac{7}{8}$ inch by 3 by 12 inches.

5-ampere porcelain fuse.

Triple pole change-over switch.

6 insulated terminals—3 red and 3 black.

Short lengths of 16 S.W.G. insulated wire for wiring the panel.

4 brass 1-inch looking-glass or lip plates for hanging the charging set.

The change-over switch is a "Utility" type.

Making the Set.

The first step is to square up the baseboard, then cut the two battens each 12 inches long. Screw the battens to the board and drill the holes for the six terminals with a $\frac{5}{32}$-inch drill. The two terminals for the mains connection are 2 inches apart, while the other four terminals are set out in two pairs, each $1\frac{1}{2}$ inches apart, the outside terminals being $1\frac{1}{2}$ inches from the side of the panel. The terminals are placed about $\frac{3}{4}$ inch from the edges of the panel (see Fig. 5). Cut an oblong hole to take the switch (Fig. 7), mount the terminals, the switch and the fuse. It will be necessary to drill two holes for wires to the fuse. To do this, screw the fuse temporarily in position, then mark the board through the connecting collars with a nail or other pointed article. Then remove the fuse and drill the two holes about twice the size of the wire to be used. Finally, connect up the set, as shown in Fig. 6. The wiring of the set is done with 16 S.W.G. insulated wire, all connections being made behind the board. All the joints, except those to the fuse are soldered (Fig. 8). Start the wiring by soldering the two connections between the switch contacts 2 and 9, and 1 and 6 (Fig. 6). The other wires are quite straightforward, and may be fixed in any order, while keeping the wires well spaced they should be as short as possible. It should be noted that one of the points (3) on the switch is left blank. The board is now mounted on the wall next to the house fuse-board with the four lip plates mentioned in the list of parts.

Fig. 5.—FRONT VIEW OF L.T. CHARGING SET TO OPERATE FROM D.C. MAINS.
Switch in "down," or charging, position.

Connecting Up to the Mains.

The set is for preference connected to the earthed side of the supply mains. The earthed main may be distinguished from the other main in the following way: Connect up a spare lampholder with two insulated wires, so that one wire is long enough to reach the nearest gaspipe or water pipe. This end is then bound to the pipe and a lamp put in the holder. Remove the covers of the house supply main fuses and touch the bared end of the other wire from the lampholder on each fuse in turn. The lamp will light when connection is made to one of the fuses, but will not light at all when connection is made to the other. The latter fuse is the one in the earthed side of the mains. The main switch should be off while the set is connected up. The fuse wire is then removed from this fuse and the wires, which are to run to the charging set, are connected at each end to this house fuse. These should consist of 3/.029 in. lighting cable.

Polarity of the Mains.

Although it is usual for the negative side of the mains to be earthed, it must not be taken for granted that it is so. To determine which of the wires from the main fuse is negative, switch on one of the lights in the house and dip the two bared ends of the wires from this fuse into a cup of salt water. The negative wire immediately becomes surrounded with gas bubbles, while the positive wire gives off practically none. The negative wire, thus distinguished, is connected to the negative mains terminal on the charging set, and the other to the positive (see Fig. 5). The other two pairs of terminals are then similarly positive and negative, the positive accumulator terminal on the board being connected to the red or positive terminal of the accumulator. This is important.

Operation of the Set.

It will be seen that the low tension battery may be kept near the switchboard, and two wires convey the low tension to the set. If this arrangement is carried out, there is no need to disconnect the battery from the set every time it is desired to charge. To

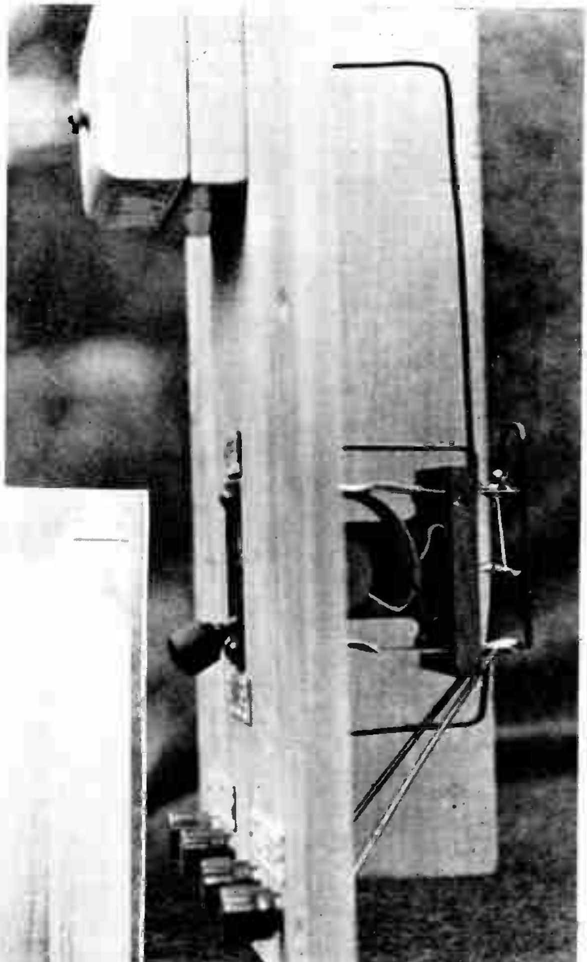


Fig. 6.—Side View of L.T. Charging Set for D.C. Mains.
With switch in charging position.

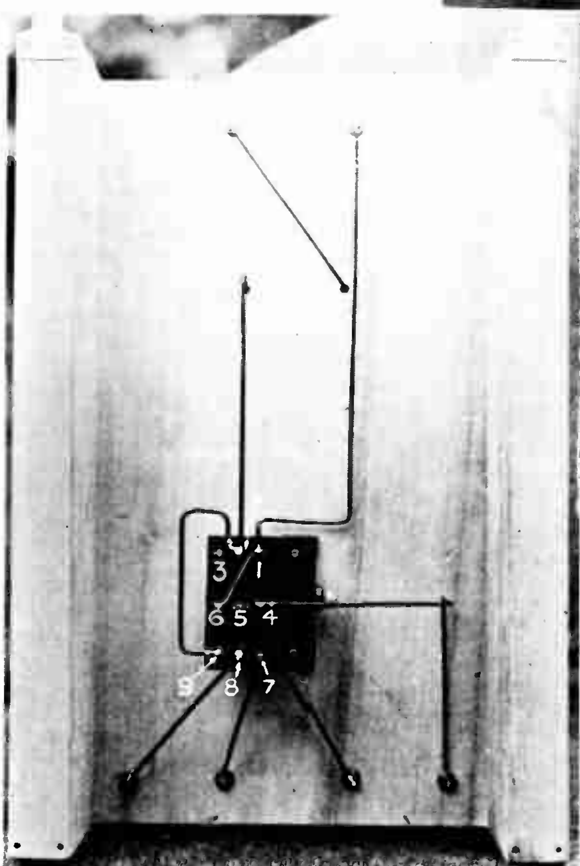


Fig. 7.—Back View of L.T. Charging Set for D.C. Mains.
Showing back of change-over and wiring.

charge the battery, all that is necessary is to put the changeover switch in the "down" position (that is, contacts 1 and 4, 2 and 5, and 3 and 6 are connected) while the wireless set is out of use, and when the wireless is to be used, put the switch up (that is, contacts 4 and 7, 5 and 8, and 6 and 9 are connected). It is

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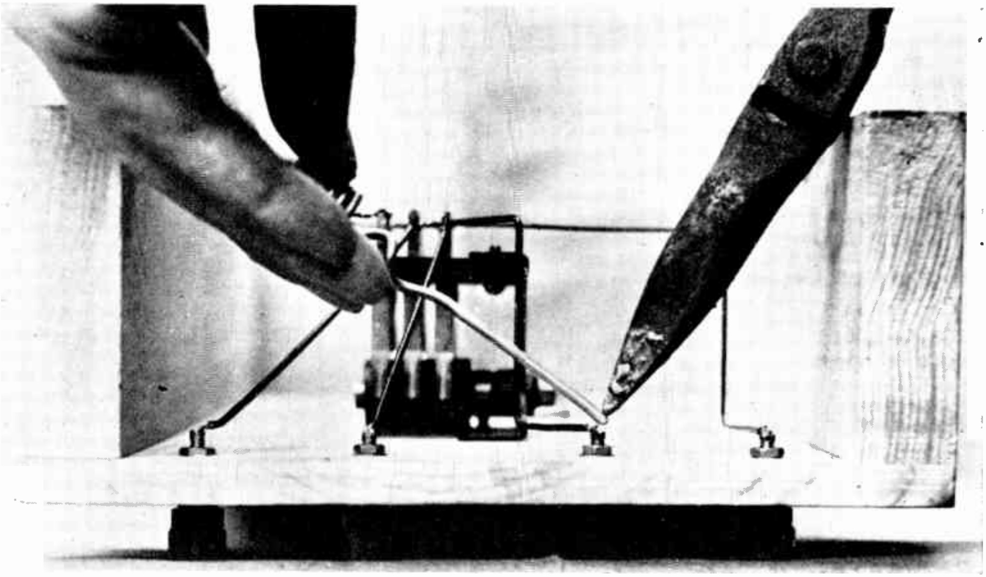

Fig. 8.—SOLDERING THE CONNECTIONS ON L.T. CHARGING SET FOR D.C. MAINS.
Hold the point of a piece of resin-covered solder between the hot soldering iron and joint.

advisable to switch off the house mains when changing over the switch on the charging board, otherwise the switch may be damaged if there are many lights burning in the house. If it is not convenient to use the switch-board in the above manner, as with a portable set, the pair of terminals "to set" are not used, and the accumulator is simply connected to the left-hand pair of terminals when it is desired to charge it. With this type of charging set the low tension is always kept in the charging position whenever the wireless set is out of use, more especially in the summer when little light is used. The wiring of the change-over switch is so arranged that it is impossible to connect the battery to the mains when the wireless set is in use, thus avoiding any risk of damaging the valves. It must be remembered that the change-over switch on the panel must not be left in the central position, nor may it be left in the "charge" position when no battery is connected to the board, or the supply to the house lights will be cut off.

THE INSTALLATION AND ERECTION OF MEDIUM AND LARGE SIZED ELECTRIC MOTORS

By ROBERT RAWLINSON.

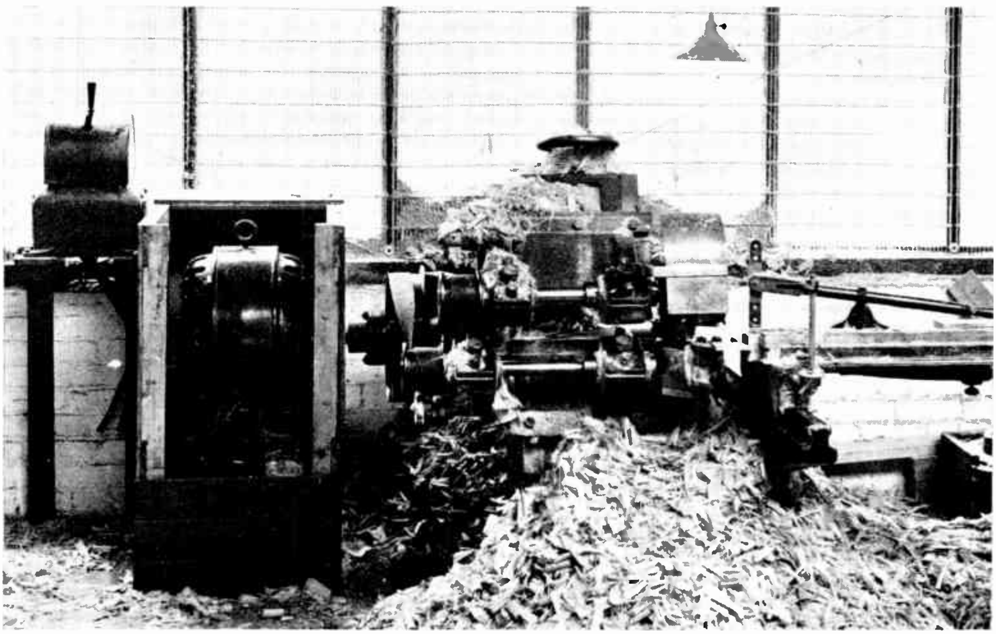

Fig. 1.—ELECTRICALLY DRIVEN WOODWORKING TOOL.

The method of protecting the motor against piled-up wood shavings should be noticed. The high boarding at the ends of the motor and the low wooden barrier in front of it prevent its being buried; at the same time, the ventilation is not obstructed. (*Metropolitan-Vickers.*)

THE importance of the proper erection and installation of an electric motor is seldom realised. It frequently happens that this important matter is left to the tender mercies of some quite unsuitable person, with the natural result that the full advantages of the machine's characteristics are never obtained, and many points of potential failure are created in the wiring and drive arrangements.

Let us suppose that a certain factory has decided to install additional plant and that electric motors will form the motive power for the various machines. In this imaginary case we will examine every aspect of installing the motors; we will, in fact, proceed as though we had to do the job, and will put down all the features we would consider in such circumstances.

The motors, which have just been received, are lying in the store. Let us start the installation immediately by unpacking them and carrying out a thorough inspection.

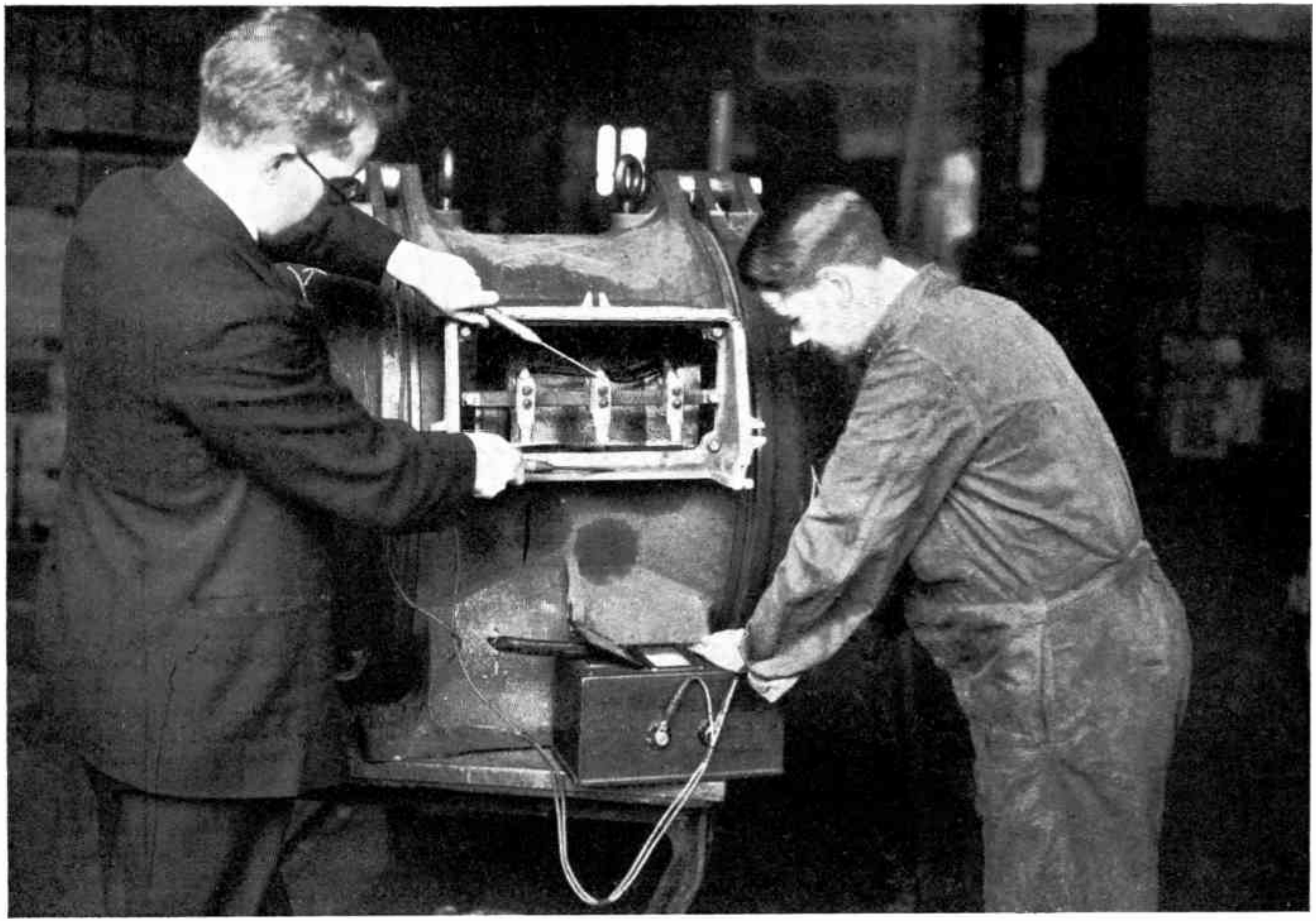

Fig. 2.—TESTING THE INSULATION RESISTANCE OF A MOTOR.
This should be done before a motor is put to work. Note that one connection from the instrument is held in contact with one of the winding terminals, while the other connection is placed upon the motor frame. If the reading obtained is lower than given in Table 1, the motor should be dried out or repaired. (*Metropolitan-Vickers.*)

Unpacking and Checking the Motor.

As soon as a motor is received it should be carefully unpacked, taking care not to damage the packing material excessively, since there will probably be a fairly high charge on this if it is not returned within a month or so. After the machine has been freed from all packing material, the apparatus which has been received should be checked against the advice note so as to ensure that there has been no loss in transit. If it is found that the advice note and items received do not agree, or if any parts are broken, a letter should be sent immediately to both the carriers and manufacturers, giving full details of the loss or breakage. To comply with the railway companies' rules, this letter should be sent within three days of the delivery of the material, and care should be taken to do this, since otherwise considerable difficulty will be experienced in upholding a claim.

Inspect All Parts.

After unpacking and checking, the machine should be wiped or brushed down to remove all small pieces of wood wool, packing paper, dust, etc., and a careful inspection of all the parts should be made to see that nothing has become loose during carriage. Sometimes a machine is interfered with during transit, terminal box lids and covers being left loose. Everything should be well tightened up before proceeding with the installation.

Test Insulation Resistance Between the Windings and Frame.

If it is possible the insulation resistance between the windings and frame should now be tested by means of a " Megger " or similar instrument. It often happens that motors are stored by factors or stockists for long periods, and in some cases the storehouse is damp or the machine may become wet during carriage. When any of these things happen the insulation is lowered, and it may be dangerous to connect the motor up until it has been dried out.

Drying Out the Motor.

To decide whether drying out is necessary, the insulation resistance should be measured. If it is found that the resistance, when measured between any terminal and the frame, is less than is given in Table 1, the motor should be moved to a warm, dry place where the air is free from dust and where the temperature does not exceed 90° C. (194° F.).

Another Method of Drying Out.

Very often it will be impossible to find such a situation (down a mine, for instance), and in these cases carbon lamps or heaters may be placed around the motor, and inside it if it is of a fair size. These will give a certain amount of heat, and if the atmosphere is reasonably dry this method is satisfactory, though slow. Another way in which the insulation may be dried out is to pass a current through the windings from a *low voltage* source. The current should be adjusted so that the temperature read by a thermometer placed on the windings never exceeds 70° C. (158° F.), and it is quite safe to

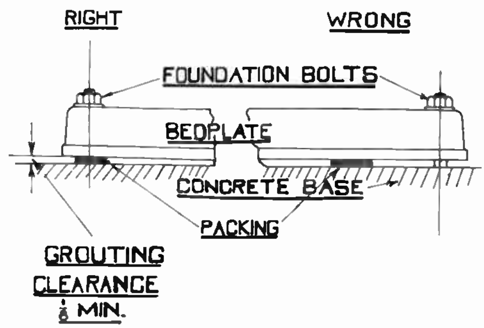

Fig. 3.—Packing up a Bedplate for Grouting In.

Showing the right and wrong ways of packing up a bedplate to provide the ⅛ in. grouting clearance. Note that on the left the packing is placed as close as possible to the foundation bolt, whereas in the incorrect method shown on the right, the packing is placed some distance from the bolt. The wrong method will result in the bedplate being bent or distorted when the foundation bolts are tightened down. The packing should consist of sheet iron or sheet steel, not wood.

start off with the current at the full load value as given on the motor nameplate, taking care, of course, to reduce the current value if the thermometer reading reaches the above figure.

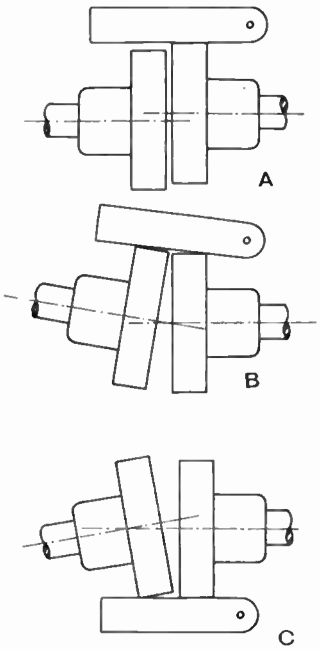

Fig. 4.—Lining Up Couplings.

The two half couplings are here shown in various states of malalignment and out of centre, and a straight edge is shown across the flanges in each case. The lack of alignment is at once obvious when the contact between the straight edge and *both* coupling flanges is inspected; note also how the distance between the two coupling faces differs at the top and bottom edges in those cases where the shafts are inclined to each other. In A the shafts are parallel but out of centre; in B the couplings are on the same centre but the shafts are inclined to each other; C shows the shafts both inclined and out of centre.

Heating Should be Continuous.

Whichever method of drying out is adopted, the heating should be continuous and carefully controlled so that it does not rise too high, thus scorching and damaging the insulation; or fall too low, permitting re-absorption of moisture. In order to ascertain how the drying out is proceeding, "Megger" readings should be taken every 12 hours and the drying should be continued until the figures obtained are constant and have remained at the same amount for four successive readings.

The figure finally obtained should not be less than one megohm in the case of motors for normal voltage (up to 2,000 volts) circuits; for high voltage machines the manufacturer should be consulted when the insulation resistance is less than that given in Table I.

TABLE I.

Minimum Insulation Resistances for Industrial Type Motors of 1 h.p. and over.

Supply Voltage as stamped on Motor Nameplate.	Minimum insulation Resistance on Setting to Work.
Below 2,000 volts	1.0 meghom
2,000/3,000 ,,	1.5 ,,
3,000/4,000 ,,	2.0 ,,
4,000/5,000 ,,	2.5 ,,
5,000/6,000 ,,	3.0 ,,
6,000/7,000 ,,	3.5 ,,
7,000/8,000 ,,	4.0 ,,
8,000/10,000 ,,	5.0 ,,

INSTALLATION.

Deciding the Location of the Motor.

Having made sure that everything is in order and ready, we can proceed with the installation. The first thing to be done is to put down a suitable foundation, but before doing this let us consider the place in which the motor is to be installed. The most desirable point about the location for an electrical machine is that it should be dry. Unless the motor is one of the totally enclosed varieties (see page 151) there is a danger that any excessive moisture in the atmosphere will lower the insulation to such a level that the normal voltage of the supply circuit will break it down. For this reason the situation should be dry, although special forms of insulation and enclosure can be obtained to combat moisture-laden atmosphere. For further details of these the reader is directed to the article beginning on page 149.

Danger from Dust or Fumes.

If any considerable amount of dust or fumes are in the air an ordinary screen-protected type motor will most certainly suffer damage, and for this reason care should be taken to ensure that the location for the motor is reasonably clean and free from atmospheric contamination. Another point to watch is that the local temperature is not too high. For normal motors, an air temperature of 40°C. (104°F.) is the maximum which should be tolerated, unless a specially designed machine has been ordered. If the manufacturer is told at

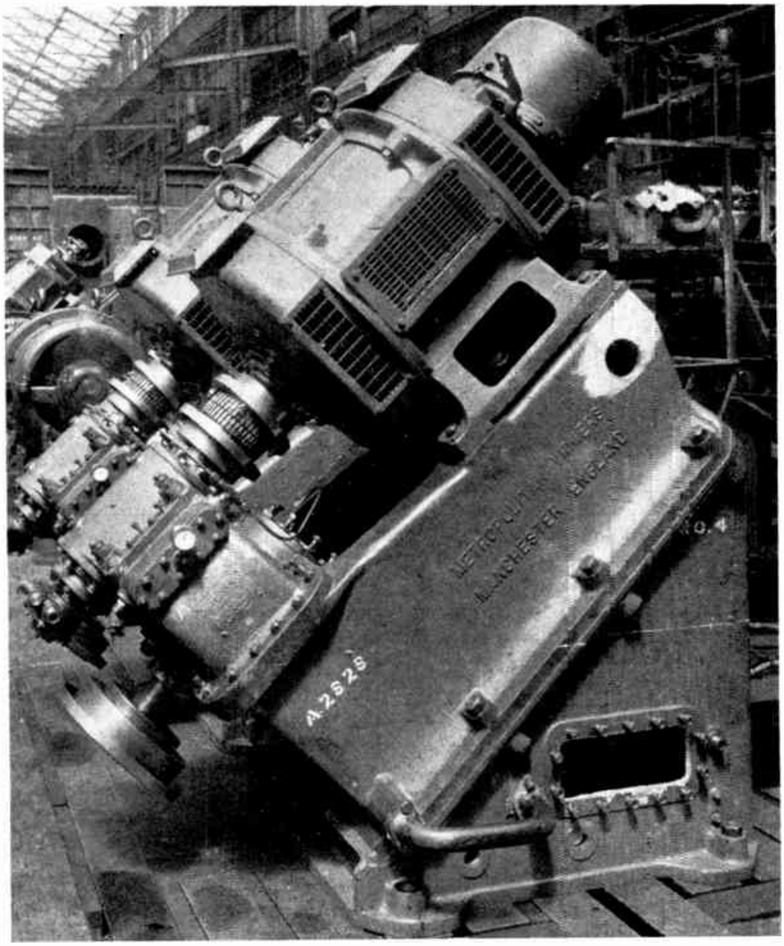

Fig. 5.—LARGE SLIP-RING MOTORS FOR AN IRRIGATION SCHEME.

These form a good illustration of flexible coupled and gear drives. The covers are removed from the flexible couplings which are of the all-metal variety. The gears are contained in the cases at the left-hand side and the alignment is assured by the strong cast-iron bedplates. These motors are designed to run with their shafts at 45° above horizontal, as shown, and the operating handle of the brush lifting and short circuiting gear may be seen just below the uppermost portion of the motor. This is "Handle C" to which later reference is made. (*Metropolitan-Vickers.*)

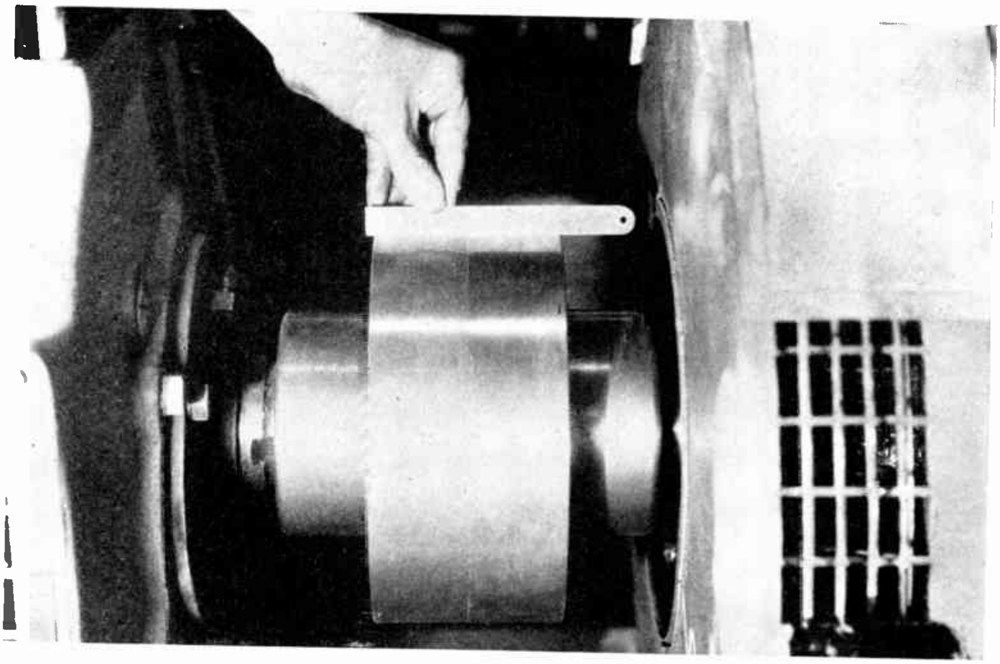

Fig. 6.—LINING UP A COUPLING (1).

A straight edge placed across the coupling flanges makes full contact only when the shafts are in line, always providing that the flanges are of exactly the same diameter. (*Metropolitan-Vickers.*)

the time of ordering that the atmospheric temperature is high he can take steps to see that no damage will be done to the motor.

The Ideal Location.

Let us now summarise our conclusions. The ideal location for an electric motor should be :—

1. Dry.
2. Clean.
3. Cool (not exceeding 40° C. [104° F.]).

Any departure from these desirable states will require offsetting, either by the designer or the installer of the motor, and as it is best that the design should be as suitable as possible the maker should be informed of any abnormal site conditions.

Protecting the Motor.

While we are on the subject, it is as well to sound a note of warning. There is a practice which is very easy to fall into and which will most certainly result in damage to the motor.

If it happens that the site conditions are bad, perhaps wet or dusty, it is a natural thing to endeavour to protect the machine. This is a very proper thing to do, providing care is taken that the ventilating air supply of the motor is not interferred with.

Protected Motors Must Never be Covered.

A protected, screen-protected, or drip-proof type motor must never, under any circumstances, be covered by a box or case. If this is done the ventilation will be affected and the motor will burn out if a load of reasonable size is placed on it for any length of time. When the site conditions are bad a special form of motor should be used to combat these. The reader is referred to " Types and Applications of D.C. Motors," page 149, and to the equivalent article on A.C. machines, for details of these special motors.

Planning the Foundations.

The foundations should be firm, solid and level, and the motor or its bedplate or

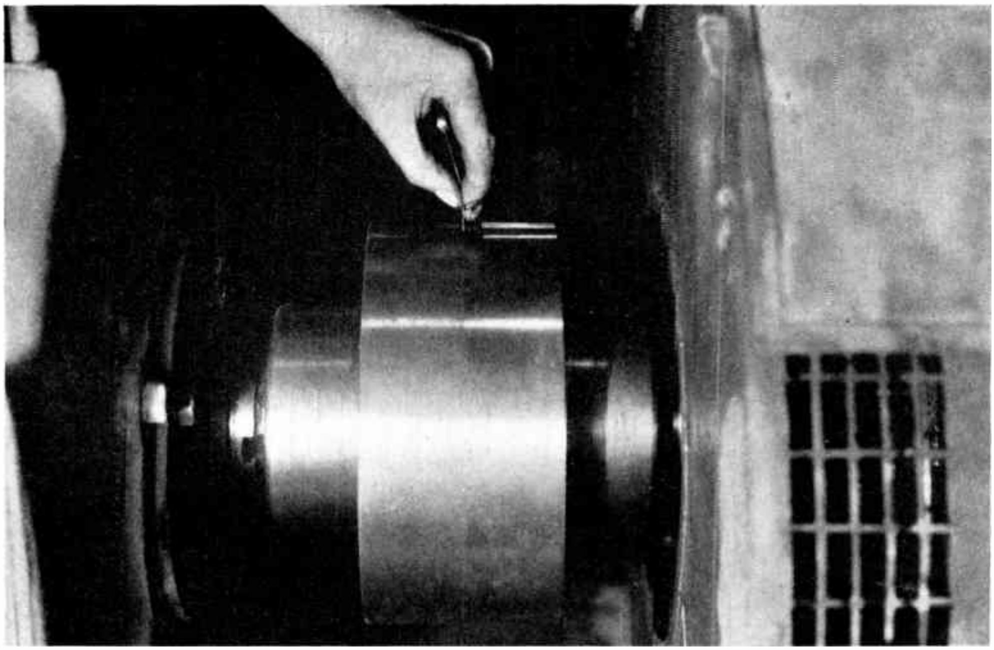

Fig. 7.—Lining up a Coupling (2).
The distance between the coupling faces should be measured by a feeler gauge at four points 90° apart. If all four measurements are equal, the shafts are in line. (*Metropolitan-Vickers.*)

slide rails should be securely bolted down. The best material for the foundations is concrete or stone, and since concrete bases are so easy to shape they are almost universally used.

Strictly speaking, if the drive conditions are good, i.e., if the belt is not too tight or if vibration is not present, a motor up to about 50 h.p. may be used without specially prepared foundations. In this case the machine should be mounted upon strong timbers, which will in turn be secured to and supported from the floor or walls of the building in which the motor is installed, providing these are of sufficient strength. It seldom happens in industrial practice, however, that the drive can be kept so sweet and smooth as to enable a foundation to be dispensed with, and whenever the installation is to be permanent, or even semi-permanent, it will pay to put in a good concrete foundation.

Bolting a Motor to the Steelwork.

This, of course, only applies to those cases where the motor is to be mounted on an earth floor. It is quite in order to bolt a motor to the structural steelwork of a building, for instance, providing the steelwork is of sufficient strength. In any case, the sole object to aim at is that the motor shall be well supported and firmly secured so that it will not move or vibrate when running.

Size of Concrete Foundation.

A concrete foundation should be carried down to solid earth and should be sufficiently large to prevent vibration and give a good grip to the holding down bolts. It can generally be said that a concrete base should be about 6 inches larger in both length and breadth than the motor feet, bedplate or slide rails ; these dimensions refer to the top of the foundation base, of course ; further mention is made of the taper on the sides of foundations. As regards the depth of foundation, for motors up to 10 h.p. an ordinary concrete workshop floor (or a good brick floor) about 3 to 4 inches thick and bedded on well-

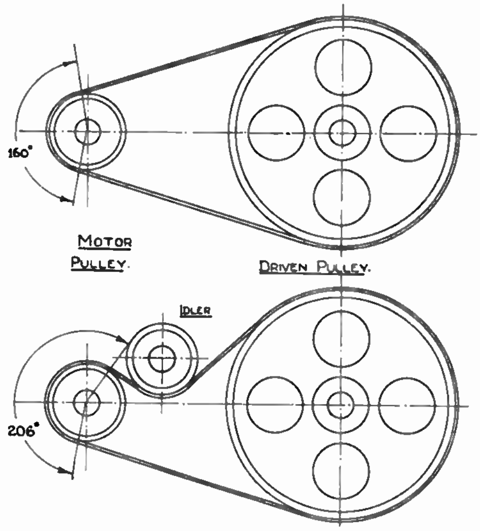

Fig. 8.—The Use of an Idler Pulley.
In short centre distance or large ratio belt drives, the use of an idler pulley will, very often, make an otherwise impossible drive perform satisfactorily. Observe how the arc of contact on the motor pulley has been increased by nearly 30 per cent. in the above drawing. This may quite easily mean the difference between a bad and troublesome drive and one which runs smoothly and efficiently.

rammed earth is quite adequate. Above this size the depth of foundation, assuming average solid ground, well rammed both below and around the foundation pad, should be as follows :—

10 to 25 h.p.	..	6 to 8 inches deep
25 to 50 h.p.	..	8 to 10 ,, ,,
50 to 75 h.p.	..	10 to 15 ,, ,,
75 to 100 h.p.	..	15 to 24 ,, ,,

These figures assume average drives; for special drives, shock loading and larger powers, the motor makers should be consulted. It should also be noted that the figures given above refer to the depth of concrete below the ground level. The height of plinth, etc., must be added to the depths given.

When Solid Ground Cannot be Reached.

In cases where it is impossible to reach solid ground a larger foundation is required, and this must be of sufficient area to support the weight of the motor and the force of drive, such as belt or chain pull. It may be stated at this stage that when doubt is felt as to the exact nature and carrying capacity of the subsoil, the local surveyor should be consulted.

Solid Rock Foundation.

In those rare cases where the foundation can be placed on solid rock, it is, of course, quite sufficient to grout the fixing bolts into the rock strata, simply providing a concrete facing when the nature of the rock or appearances demand it.

How to Make a Concrete Foundation.

When making a concrete foundation it is necessary, first, to excavate the ground to the size and depth of the finished foundation base. This foundation pit should be carried well down, and around its outside edge a wooden mould should be erected to shape the plinth or that part of the concrete base which projects above the floor. This mould should provide for all cable trenches and any pipes or other details which are to be carried through or under the foundation. Care should also be taken that the foundation is properly drained.

Two Methods of Fixing the Foundation Bolts.

It is usual to shape the sides of the concrete base so that it is larger at the bottom than the top, and a suitable figure for this taper is about 2 inches per foot. Another thing to which attention must be paid is the fixing of the foundation bolts, and for this purpose either the foundation bolts may be placed in position and the concrete allowed to solidify round them, or else holes may be left in the concrete base into which the bolts may subsequently be grouted.

The Most Satisfactory Method.

The latter method is the simplest and most satisfactory, and we will therefore devote our attention to it. In order to leave foundation bolt holes in the concrete, wooden forms should be prepared which are the shape and size of the holes which are required. It should be remembered that it will be necessary to withdraw these forms from the solidified concrete, and for this reason they are usually made of box section, the sides being very lightly fastened together so that the box may be dismantled and withdrawn one side at a time.

Position of the Bolts.

Having prepared these forms, they should be placed in position in the foundation pit so that one hole is provided for each foundation bolt. The positions of the bolts are given on the manufacturer's outline drawing, and care should be taken that the foundation bolts are placed in the right positions to give correct alignment with the driven shaft or belt pulley when the motor is finally fastened down.

Arranging the Bolt Holes.

The bolt hole form should be arranged so that about 2 inches of it will project above the finished concrete bed. In passing, it may be mentioned that foundation bolt forms are usually made of about $\frac{1}{2}$-inch timber, while the foundation plinth mould may consist of 1-inch planks, planed on the inside faces and braced at frequent intervals (say, every 18-24 inches) along the outside. All woodwork should be thoroughly wet before the concrete is poured.

Making and Mixing the Concrete.

When all is ready the concrete should be mixed and for this type of foundation the following proportions should be used:—

1 part cement ; 3 parts sharp sand ; 6 parts broken stone.

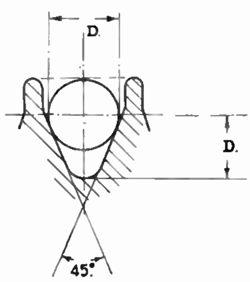

Fig. 10. — GROOVING OF A ROPE PULLEY.

This shows a common form of groove for a rope pulley. Note particularly that the rope must never reach the bottom of the groove, otherwise all driving force is lost.

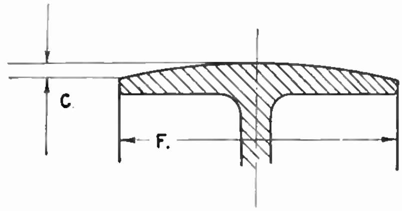

Fig. 9.—CROWNING OF A BELT PULLEY.

The dimension "C" is the crowning; as mentioned in the text, $\frac{1}{4}$ in. on diameter per foot of pulley face is a good figure. This means that when F is 12 in., C should be $\frac{1}{8}$ in.; when C is $\frac{1}{8}$ in., we have, of course, $\frac{1}{4}$ in. on the diameter.

Sufficient concrete should be mixed to make the whole foundation at once when this is of small size. For larger foundations the concrete should be mixed and fed continuously if possible, to ensure that the whole base is a homogeneous mass.

To make good concrete the following precautions should be observed. The ingredients should be thoroughly mixed in the dry state and then sufficient water should be added gradually to make a thick paste when well worked in. On no account should sea-shore sand be used, since it invariably contains salt, and is usually not sufficiently sharp to produce good concrete. The mixed concrete should not be allowed to stand before being used ; in any case, concrete which has been mixed over 15 minutes should not be employed.

How to Fill the Mould.

The mixture should be fed into the mould and smoothed down with a shovel. When the filling is completed the concrete should be rammed down with a medium heavy rammer until water just shows on the top surface. This method will give a dense and solid foundation mass which will eliminate all settling and those consequent changes of alignment which are such a prolific source of trouble.

As soon as the concrete has set the wooden mould and foundation bolt pockets should be removed, and if it is necessary the surface or sides of the base should be patched and any small holes filled.

Fixing the Motor in Position.

We are now ready to fix the motor in place and the best way is to mount the machine, fitted with its pulley, pinion or coupling, upon its bedplate or slide rails and to put the foundation bolts in the bedplate or slide rail holes provided for them. The foundation bolt nuts are screwed on to the bolts, leaving these hanging below the motor base. The whole unit is then lowered on to the prepared concrete foundations, each foundation bolt being placed in the pocket cast for it.

ROUGH LINING UP AND PUTTING IN PLACE.

Having reached this stage we must carefully line up the motor with the driven shaft or pulley. When the motor drives a shaft through a flexible or solid coupling it is essential that the shafts are exactly in line and on the same centre; the following procedure should be adopted.

Fixing the Shafts Exactly in Line.

The driving and driven half couplings having been fitted on their respective shafts they should be brought close to each other so that they are as nearly as possible in the same relative positions as they will finally take up. If it is clear to the eye that the motor coupling is lower than the other, the motor should be wedged up so that the shafts are as nearly in line as can be judged by the eye. If, on the other hand, the driven coupling is the lower, arrangements must be made to lift the driven machine or to cut down the top of the concrete bed so as to lower the motor. In any case, when the shafts are on the same centre line the motor or slide rail base should be at least ⅛ inch wedged up from the concrete foundation. This space will be filled up later with the grouting mixture.

Levelling Up the Motor Shaft.

Having now made the centre heights agree and allowed the ⅛ inch grouting clearance mentioned above, the motor shaft should be levelled up, by spirit level, taking care to keep the couplings on the same centre line. This may be ensured by making all adjustments of level, such as the insertion or removal of packing, etc., at that end of the machine which is without a shaft extension. At this stage the motor and the driven machine should be roughly in line, providing always that the driven shaft has been levelled; this, by the way, should always be done, otherwise there is a danger of endthrust and bouncing, thus ruining the thrust collars and bearings.

GROUTING IN.

The final very accurate alignment should be left until later. We may now proceed to grout in the foundation bolts; for this purpose the following concrete mixture should be prepared:—

1 part cement, 1 to 2 parts sharp sand.

The same remarks as before regarding sea-shore sand apply here; the cement and sand should be intimately mixed while they are dry, and sufficient water should then be employed to produce a smooth paste which should be just thin enough to pour. Only enough of this mixture should be made to fill one foundation hole at a time and immediately the mixing is completed the paste should be poured into the pocket around the foundation bolt. Each pocket should be completely filled and when this has been achieved, the top of the mixture will be level with the top of the foundation base.

ALIGNING.

The grouting should be allowed to set hard and when this has happened the foundation bolts should be screwed up so that they just nip the bedplate. The final lining up should now be carried out in the following manner. First of all check that the centre heights have remained unaltered by placing a straight edge, such as a steel rule, across the two machined outside flanges of the couplings. When the centre heights are the same the straight edge will touch each flange along its whole length, whereas, when one shaft is lower than the other, or when the couplings are on the same centre, but the shafts are inclined to each other, the straight edge will only touch the flanges

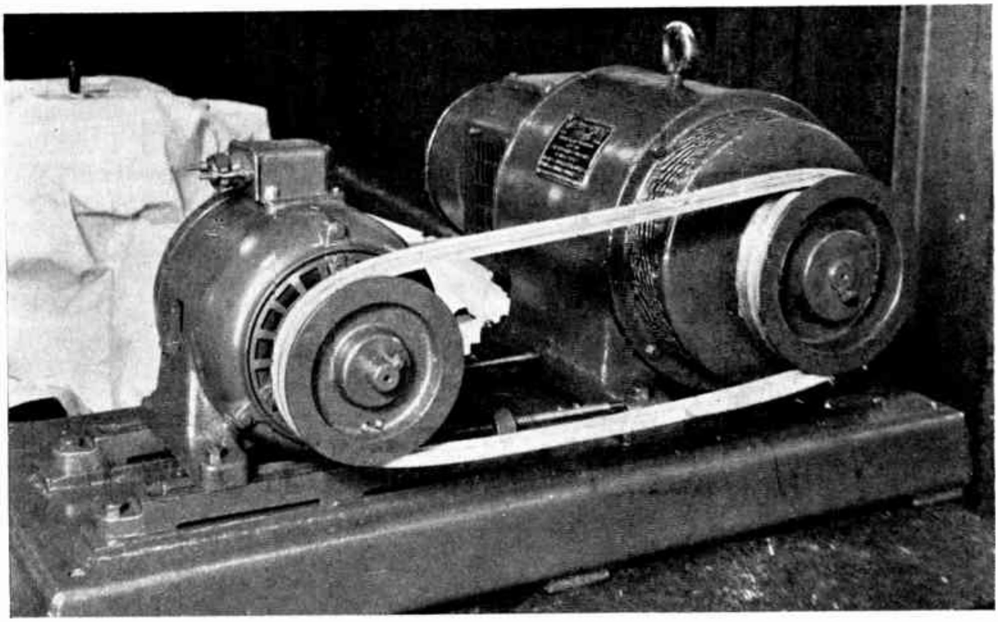

Fig. 11.—A SHAPED-BELT DRIVE.

This drive is interesting since it shows the grooved type pulleys used with this type of belt. Note also the gib-headed taper keys and the balancing holes in the left-hand pulley. The slide rails should also be observed and the cable clamp on the small motor terminal box is worthy of note. The machines form a motor-alternator set for experimental work. (*Metropolitan-Vickers.*)

at one or two points. This method of aligning is made clear by the drawings and photographs. It may be used to check the centre height, the straight edge being placed on top of the couplings, and it may also be employed for the horizontal alignment by using the straight edge on the coupling sides.

Using a Feeler Gauge.

The final alignment may be effected by using a feeler gauge to check the distance between the coupling faces at four points 90° apart. Neither coupling should be revolved until all of the four measurements have been taken, and if the machines are accurately in line these measurements will be equal.

Adjustment of the motor position should be made until the alignment is complete, as shown by the following :—

1. A straight edge makes full contact with both coupling flanges, both at the top and on each side.
2. The distance between the coupling faces, when measured at four points 90° apart, should be the same.

FINAL FIXING.

Having effected this, the foundation bolts should be tightened hard down, the machine still being packed up $\frac{1}{8}$ inch from the foundation top, and after checking the alignment with the tightened foundation bolts, the final grouting should be carried out. A dam about 1 inch high made of wooden strips should be erected around the bedplate. A suitable size for this wood is 1 inch square and it should be arranged so that there is about 1 inch clearance between the sides of the bed and the inside of the wooden frame. When this is ready, a concrete mixture should be made up, using the same proportions as for the foundation bolt grouting (1 cement to 2 sand). Sufficient of this mixture should be made to complete the job at one pouring, and as soon as it is mixed pouring should commence, care

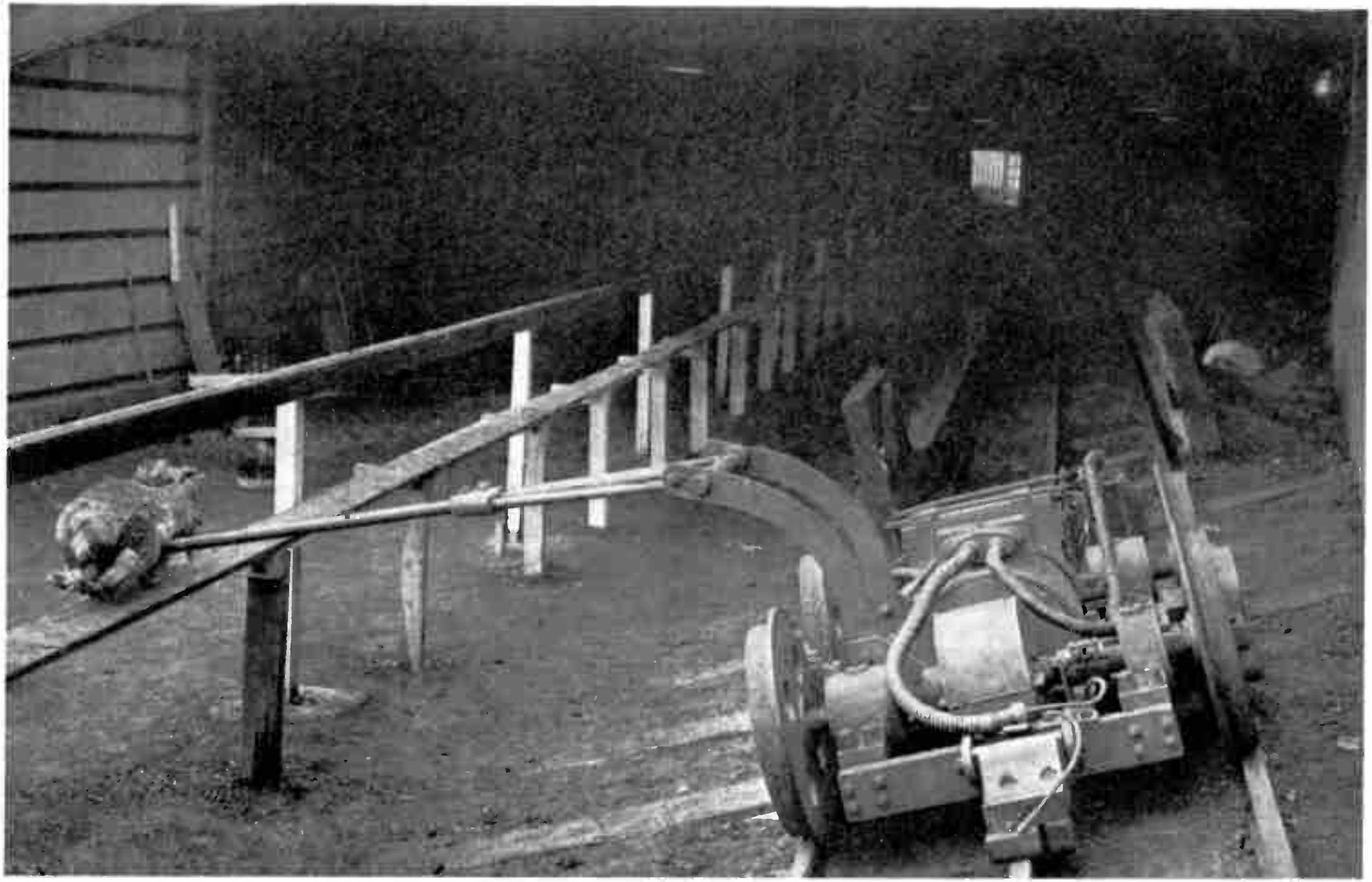

Fig. 12.—THE ELECTRIC HARE.

This illustration shows the application of a motor to driving an electric hare. Note the flexible tubing to withstand vibration and the live rail and pick-up shoe. (*Metropolitan-Vickers.*)

being taken to work the paste well into the ⅛-inch grouting clearance, and, finally, filling up around the bedplate until the mixture is level with the top of the 1-inch framing.

Check the Alignment Again.

This final grouting should now be allowed to set hard; when it has done so the framing should be removed and the concrete trimmed up to present a finished appearance. The foundation bolts should be pulled down as tightly as possible, and the alignment should be checked again to ensure that it has not altered. With a properly designed and constructed foundation it will be found that the machines have remained in line, so that we may now fit the coupling bolts and turn the whole equipment round a few revolutions by hand, just to ensure that everything is as it should be.

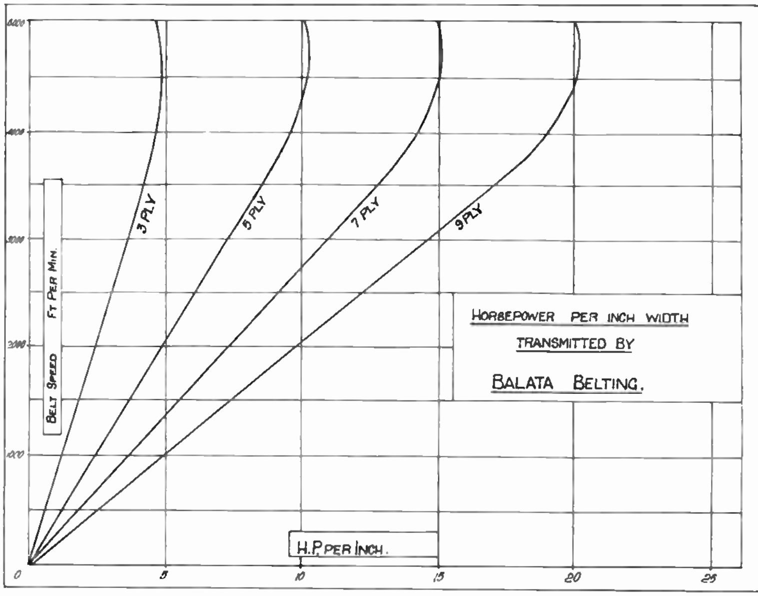

Fig. 13.—Curve showing belt horse power with Balata belting.

Final Notes on Coupled Drives.

Before we leave coupled drives to consider those of the belt, chain and geared variety, it should be stated that a flexible coupling should always be used in those cases where the motor and the driven machine are mounted on separate bedplates. The rigid type of coupling requires such extremely accurate alignment that its use should be confined to those cases where the motor and the driven equipment are mounted on a combined bedplate or else to the very largest sizes of motors. All couplings, however (either rigid or flexible), demand accurate alignment for satisfactory operation. Lack of this will result in broken shafts and ruined bearings, even when flexible couplings are employed, and the flexible coupling itself will be very quickly ruined when the lining up is bad.

BELT DRIVES.

The remarks on belt drives given on page 243 and onwards in the article entitled " Installing Small Motors " will be equally applicable to the larger machines with which we are now dealing, always excepting, of course, that round belts are never used for large horse power drives. In considering belt drives, therefore, the reader is referred to the above-mentioned article. This should be read in conjunction with the following notes, which refer mainly to drives of medium and large horse power.

When a belt drive is used the belt should be flexible and the joint should be smooth and free. The pulleys should be well balanced and, except in special cases, should be of the crowned face type.

Vertical Belt Drives Should be Avoided.

Vertical belt drives (drives in which the driven pulley is directly above the motor pulley) are bad practice and they

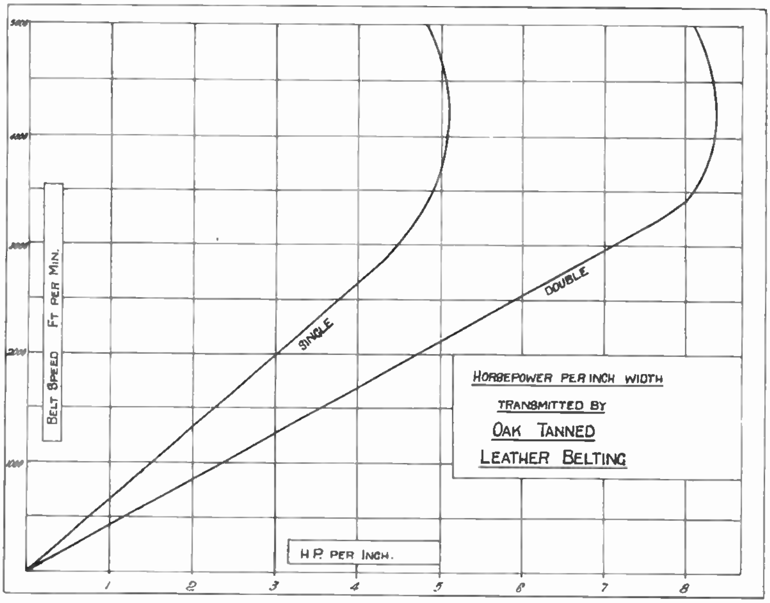

Fig. 14.—Curve showing belt horse power with oak tanned leather belting.

should be avoided wherever possible. Unless special precautions are taken trouble may be expected with any belt drive in which the distance between the centres of the two pulleys is less than four times the diameter of the larger one, and the same may be said of pulley diameters. The larger pulley in a plain belt drive should never be more than six times the diameter of the smaller, but in certain cases it may be impossible to use a long centre drive and sometimes one is forced to break the rule regarding pulley diameters. In these cases a jockey or idler pulley is employed and this is fitted close to the smaller pulley, thus increasing the arc of contact and allowing a good drive to be obtained without excessive belt tension.

Correct Adjustment of Belt.

When the motor is running the belt, if properly adjusted, should transmit the full load without slipping, and it must run without flapping on the slack side or else it will soon be ruined. At the same time the belt should not be tightened up to such an extent that it feels board hard when stationary. Both excessive and too little belt tensions are harmful; the first results in broken or bent shafts and damaged bearings, while a slack belt gives a noisy drive and is dangerous, since the belt may break or come off and hit workpeople in the vicinity.

Correct Way to Fit a Belt.

A belt should never be forced on to its pulleys since this causes stretching of one side with consequent bad running and shortened life. The correct way to fit a belt is to move the motor along its slide rails to the limit of its travel towards the driven pulley. The belt should then be placed on both pulleys and the belt adjusting screws should be tightened up to regulate the belt tension.

Speed at which Belting Should be Run.

The maximum speed at which belting should be run is 5,500 feet per minute, and the pulley sizes should be regulated accordingly. Above this belt speed the drive tends to become noisy and it is preferable, in the interests of sweetness of drive and belt life, to keep the belt speed below about 4,500 feet per minute, if possible. It will generally be found that this can be done, and to obtain the size of belt for any given horse power and belt speed it is only necessary to use the following curves, which show the horse power transmitted per inch of width by the various commercial types of belting.

Installing a Motor for Belt Drive.

When installing a motor for belt drive the foundation and grouting work is exactly the same as has already been

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