Russell H. Ross
Mpls. Co
Duluth

SWITCHING EQUIPMENT

GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y.

Nov., 1930

GEA-888
Supersedes 87000E

Wemco Swbd Cleats.

Are obtained from Joseph Woodwell Co.,
Wood Street & Boulevard of Allies, Pittsburgh, Pa.

1000 S#286357 Cleat anchors w/ Nails.

SWITCHING EQUIPMENT

GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y.

General Electric switching equipment is designed and constructed in strict compliance with the standards prescribed in the Underwriters, National Electrical, and National Electric Safety Codes. All persons engaged in the installation, maintenance, or operation of switching equipment should familiarize themselves thoroughly with these codes and recommendations, and should practice them at all times.

If further information is desired, address the nearest office of the General Electric Company.

CONTENTS

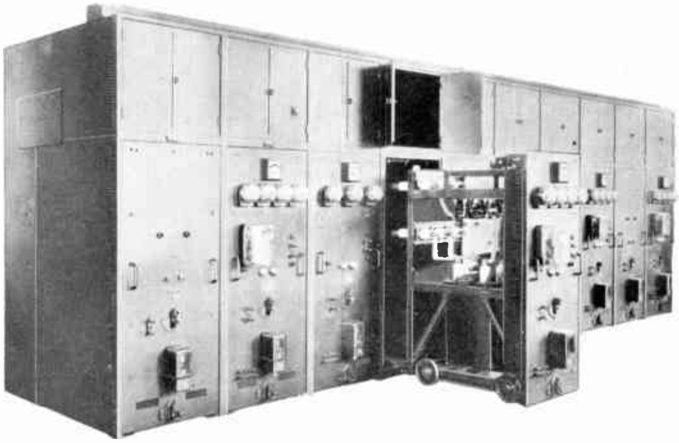


Fig. 1. Removable-truck-type Switchboard with Superstructures

Fig. 2. An Alternating-current 90-inch Steel Switchboard

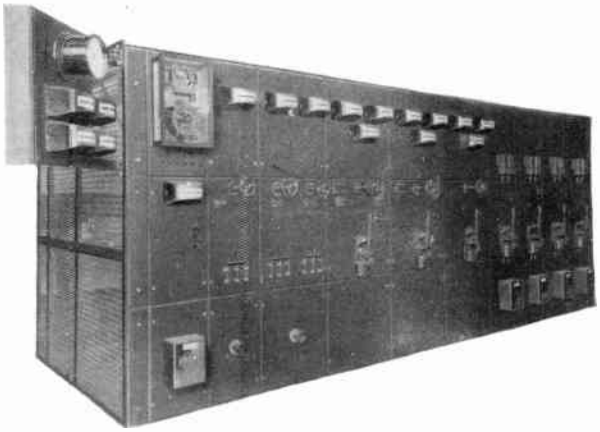


Fig. 3. Standard 90-inch Switchboard

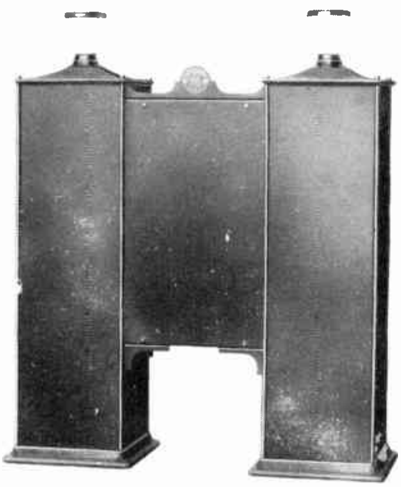


Fig. 4. Floor Stand with Extension Panel for Instrument and Control Equipment

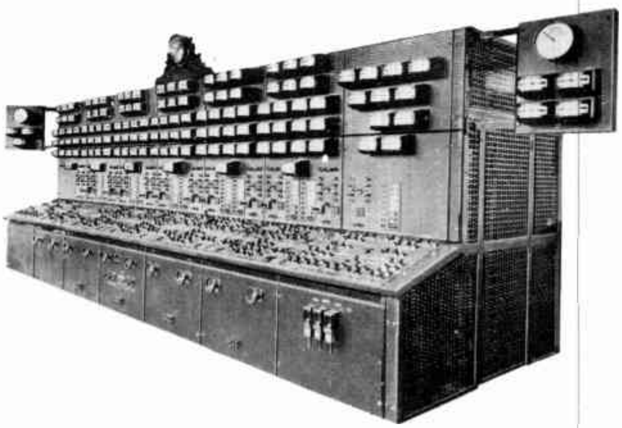


Fig. 5. A Generator, Feeder, and Transformer Bench-type Switchboard for Large Central Stations

SWITCHING EQUIPMENT
SWITCHBOARDS

In all buildings where electricity is generated, converted, transformed, or utilized to any great extent, the control of the equipment is arranged, in so far as practicable, for the most convenient attention and operation. The control and indicating devices are mounted on some form of structure at a particular point, and the whole assemblage is known as a switchboard.

The design of switchboards is dependent upon the kind and capacity of apparatus to be controlled, the types of devices to be used, the buildings in which the switchboards are to be installed, and upon future additions and alignments with existing installations.

General Electric switchboards are usually built of slate, ebony-asbestos, rolled metal, or marble.

Switchboards may be divided into the following classes:

1. Live-front boards (vertical).
2. Live-front boards (bench).
3. Dead-front boards.
   a. Safety enclosed, vertical.
   b. Safety enclosed, sectional.
   c. Safety enclosed, truck.

Special designs are also built when necessary to meet unusual requirements. Some examples of different classes of switchboards are illustrated in Fig. 1, 2, 3, 4, 5, 6, and 7.

Standard vertical switchboards are made in heights of 48, 64, 76, 90, and 99 inches. The width varies and the thickness extends through a range of from 1 to 3 inches, depending upon the material used and the weight and operating characteristics of the equipment mounted thereon.

Bench boards are used primarily where the vertical type does not give sufficient display and mounting surface within a certain optical and operating range.

Dead-front boards are particularly adapted for use where workmen are frequently in the vicinity.

Special switchboards are built in various styles. Fig. 6 shows such a board designed to harmonize with the architecture of the surroundings. Fig. 7 shows a unique arrangement built as a miniature representation of the equipment controlled.

Slate

The slate used in the construction of General Electric switchboards is of the highest quality obtainable. It is furnished either in natural black with oil finish, or in dull black lacquered (marine finish). Marine-finished switchboards are used particularly for matching existing installations.

The maximum voltage limit for primary apparatus carried directly upon natural black slate boards is 1200 alternating or direct current. For marine-finished slate, the maximum limit for primary apparatus carried directly upon the slate boards is 550 volts for direct current, and 440 volts for alternating current.

Marble

Marble is used sometimes where material with higher insulation qualities than those of slate is desired, but more often where it is preferred for appearance. It is, however, more easily stained or defaced. The various shades and markings of marble panels commonly used are illustrated in Fig. 8.

In many cases, the General Electric Company is called upon to match existing switchboards. It should be borne in mind that the matching of marble can be only approximate, even if the new material is ordered from the same quarry as the previous material. This usually takes more time than if the material were taken from stock. In choosing marble to match existing installations, the customer should refer to Fig. 8 and specify the grade desired.

The maximum potential limit for marble panels is 3500 volts.

Ebony-asbestos

A special grade of ebony-asbestos is used as a switchboard material on account of its excellent mechanical and dielectric characteristics. Its strength per unit weight as compared to other materials, together with its high resistance to atmospheric conditions makes it desirable for switchboard use. The usual potential limit for this material is 4500 volts.

These panels will not warp, shrink, or crack and are not impaired by moisture. The exposed surface is sprayed with a dull-black lacquer having high electrical qualities, and is unaffected by moisture or oil.

Any slight blemishes such as oil, grit, or finger marks can be readily removed by soap and water or carbon tetrachloride (Carbona) applied with a soft cloth. The lacquered surface should not be rubbed, as this operation tends to polish.

EQUIPMENT FURNISHED WITH SWITCHBOARDS

When switchboard orders are placed on the General Electric Company, specifications are prepared listing the main apparatus to be supplied. The specifications, however, do not include certain miscellaneous equipment which is also furnished and which is as follows:

(a) Panel-supporting frame with mounting bolts and necessary fittings, and fittings for attaching wall braces. (Pipe for panel braces to be furnished by purchaser.)

(b) Necessary resistors, reactors, and other auxiliaries to complete the instrument. (Meter or relay equipment furnished by the Company.)

(c) One card holder for each circuit.

(d) Necessary material for small wiring for interconnecting instruments, meters, relays, and other apparatus mounted on the panels or on a structure integral with the panel-supporting frame. (For panels as indicated by E, Fig. 9 and 11, this material is assembled on the panels. For benchboard panels and structure integral with switchboard or benchboard panels as indicated by A, B, C, D, and F, Fig. 9, 10, and 11, this material is furnished in bulk unassembled.)

(e) Supports for shunts, current and potential transformers, etc., when mounted on the switchboard or on a structure integral with panel-supporting frame. (When the switchboard is not completely assembled at the factory, the pipe for framework and oil circuit breaker supports, wire, rods, tubes, and bars for connections and buses are not fabricated at the shops of the General Electric Company, but are furnished in bulk, in commercial lengths, with the necessary fittings.)

(f) All iron and steel parts fabricated by the General Electric Company are painted before shipment. Unfabricated parts are furnished unpainted.

(g) Standard doors for the front of oil circuit breaker compartments but no other doors unless specified. General Electric standard cell hardware for circuit breakers (except see paragraph "j" following).

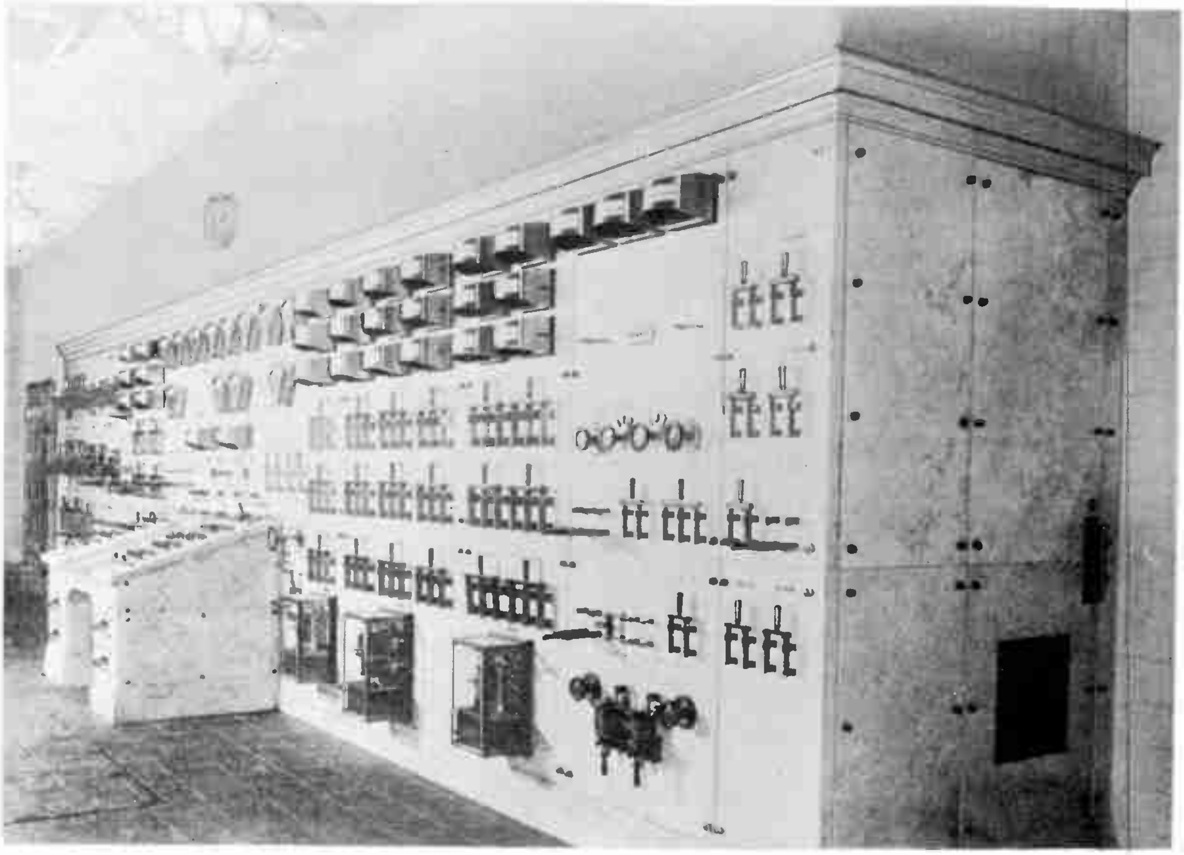


Fig. 6. Switchboard Built to Correspond with Architecture of Building

(h) One set of fuses for such fuse supports as are specified for power circuits; two sets of fuses for fuse supports as specified for the primary potential transformer circuits; and two sets of fuses for such other purposes as are deemed necessary.

(i) Oil for all apparatus requiring it.

EQUIPMENT FURNISHED BY PURCHASER

(Unless Otherwise Expressly Agreed)

Certain equipment is necessary for switchboard installation which is not furnished by the General Electric Company unless expressly named in the detail specifications when the order is placed. Such equipment, to be provided by the purchaser, is as follows:

(j) Foundations, floors, and walls (including all structural steel, bolts, nuts, or inserts in or on them, concrete, brick or woodwork, floor or wall braces); and supports on or against which panels, compartments, and buses will rest.

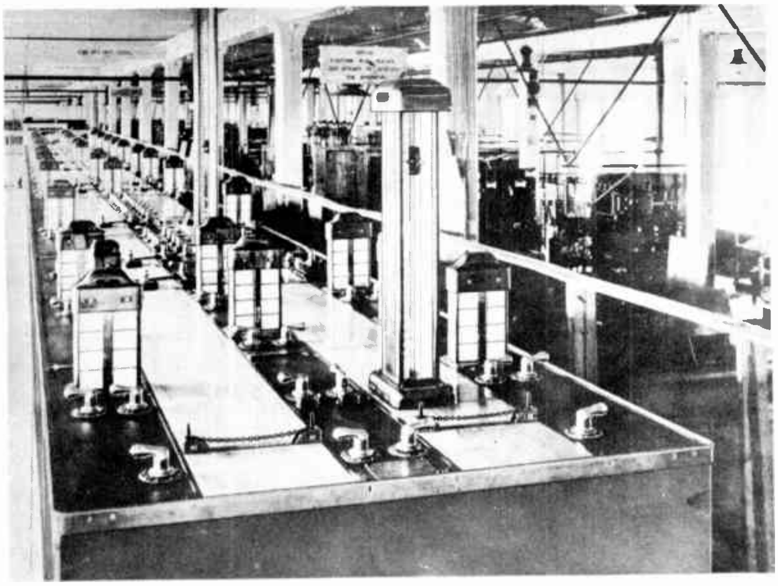


Fig. 7. Switchboard with Controlled Apparatus Built in Miniature (Lock Control Board of Panama Canal)

(k) Instrument and control wiring when not mounted on the switchboard or a structure integral with the panel supporting frame; cables to connect generators, exciters, transformers, etc., to the switchboard apparatus, and lightning arresters to the main lines; conduit for instrument and control wiring and main cables, and supports for cables and conduit.

(l) Insulation and taping required for buses and their connections, because the taping and insulating can best be done after the buses and connections have been installed for service.

(m) Metal connecting rods for remote-controlled devices.

(n) All coverings for openings in walls or floors. All insulators and bushings in or on floors, walls, ceilings, and concrete or brick structure.

(o) Material for barriers, shelves, and partitions; and doors for busbar or other compartments (except see paragraph "g").

(p) Suitable drawings of the station buildings, showing the location of all openings in walls, all ducts and conduits, floor beams, etc., which have a bearing on the proper execution of the work under agreement.

SHIPMENT

Switchboards are inspected and checked, and then packed carefully by men experienced in the handling and packing of electric equipment. To simplify installation work, it is sometimes feasible to ship switchboards completely assembled with their equipment and supports. This is the general practice in case of dead-front-type, truck-type, and large switchboard panels with complex equipment and wiring (see Fig. 12). On the other hand, for convenience in shipment and handling, large switchboards are sometimes packed dismantled (see Fig. 13 and 14). The several panels of the switchboard are usually boxed separately.

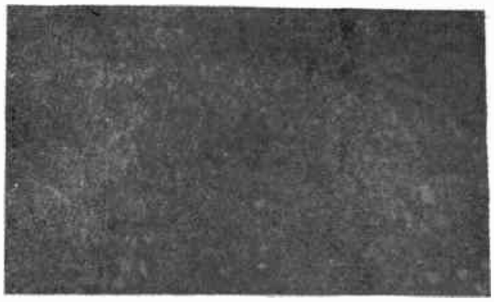
Shipping memorandum accompanies each shipment, and lists all separate or dismantled parts, or the complete equipment if shipped complete. Numbers are stenciled on the packing cases, the numbers in turn being placed on the shipping memorandum opposite the equipment which the cases contain. Reference to the switchboard assembly drawings and wirings is also made on the shipping memorandum. If changes have been made on these drawings, the date and number of latest revision are specified so that up-to-date installation drawings can be identified directly from the shipping papers.

RECEIVING AND HANDLING

Upon receipt of a switchboard, open all boxes sufficiently to examine the contents and check the material with the shipping memorandum. If parts are broken or missing notify the nearest

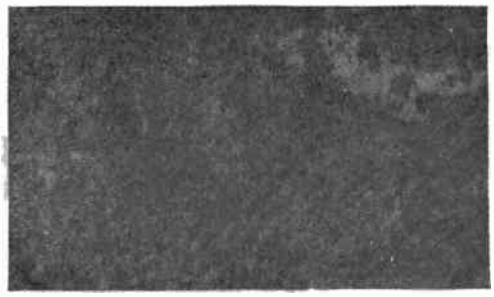
A Mottled

B Mottled

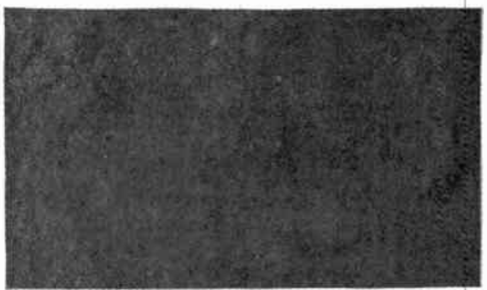


B Light Mottled

C Mottled

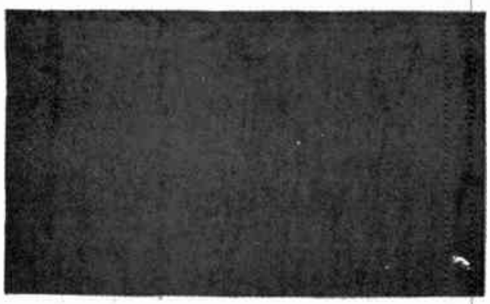


B Clouded



C Clouded

B Striped



C Striped

Fig. 8. Blue Vermont Marble Used in General Electric Switchboards

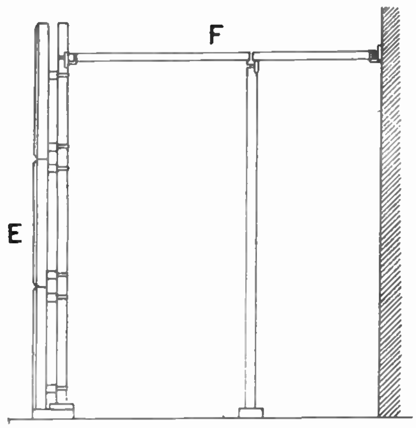


Fig. 9

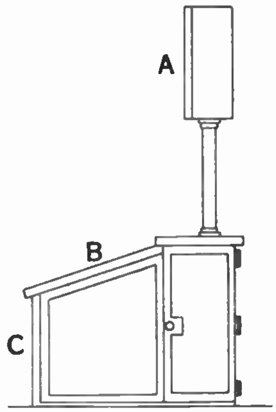


Fig. 10

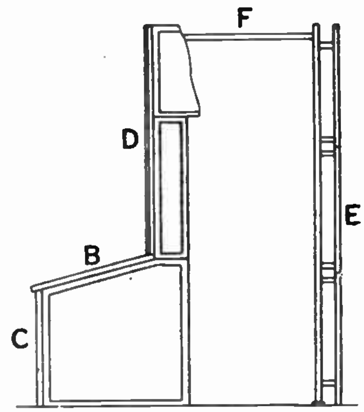


Fig. 11

sales office of the General Electric Company at once, and present a claim to the transportation company.

Boxes containing apparatus for immediate use should be moved directly to the switchboard floor. The boxes may be conveniently lined up beside one another in front of the permanent location of the panel sections which they contain.

UNPACKING

Great care should be exercised in unpacking electric equipment so that nothing may be broken or marred, and so that no screws, nuts, bolts, or other miscellaneous material will be left in the packing material. Small fittings are usually packed in bags to avoid mixing with the excelsior; but these bags may break during shipment, and a careful examination should be made of the packing material before it is destroyed so that no small parts will be lost.

Use nail pullers or small wrecking bars to open the cases, and avoid the use of chisels, sledges, or crow bars. Check each part with the shipping papers as it is removed from its case.

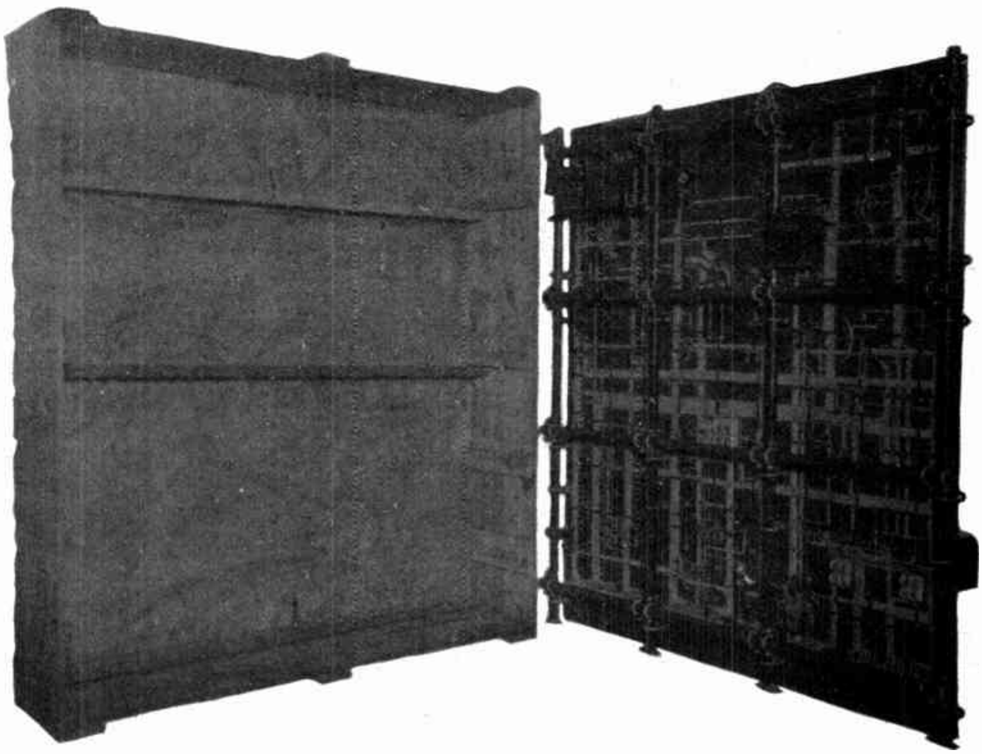


Fig. 12. Method of Packing Switchboard with Complex Wiring. The four cross pipes are temporary for shipping purposes only

Instruments and meters are generally shipped mounted upon the panels of which they are a dependent part, but some are of such design that they are more safely shipped separately. Care in unpacking this apparatus is particularly essential so that no injury to jewel bearings or delicate mechanisms will result from excessive vibration or sudden jars.

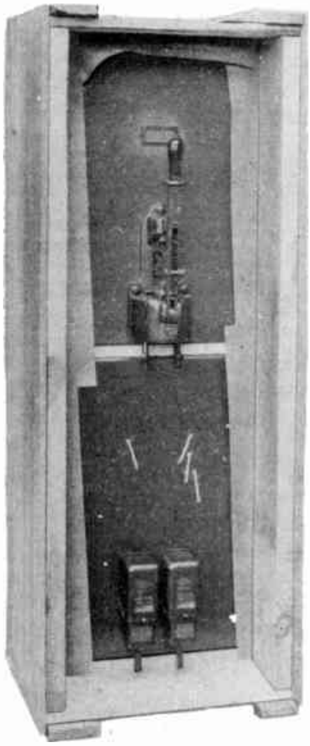


Fig. 13. Method of Packing Small Switchboards (Front View)

STORAGE

If material is not needed for some time, it should be placed in a dry storeroom. Conditions such as dampness caused by rain or changes in atmosphere, cement dust, etc., should be guarded against. As a suggestion, record of this material should be kept by an assigned stock clerk whose duty is to make note of all material received or withdrawn. Large pieces may be left in their boxes, while small pieces are best unboxed and distributed in the storeroom for convenience. By piling the boxes in tiers and knocking out their front ends, they may be utilized for bins.

Protect all apparatus from dampness, dirt, falling debris, and other unfavorable conditions which exist in a new or unfinished building. All parts which are liable to rust should be oiled. All apparatus packed in excelsior should be unboxed, as excelsior absorbs moisture.

On large installations, the shipping notices or memoranda may be found too bulky for quick and frequent reference. In such cases, the purchaser may find it more convenient to list the material on small cards when unpacking. (See suggestion for card on page 11.) He may even desire to assign arbitrary numbers to each part, so that these can be selected and withdrawn by laborers using the number reference only.

Instruction Books covering the principal devices should be detached from the apparatus and placed in responsible hands. Installation or adjustment should never be attempted with any piece of apparatus until the Instruction Book which accompanies it has been thoroughly read and understood. Additional copies of such instructions may be obtained from the General Electric Company on request. The request should give the nameplate rating of the apparatus.

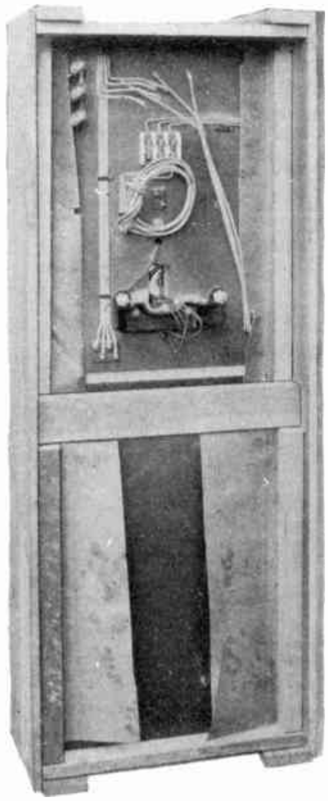


Fig. 14. Method of Packing Small Switchboards (Back View)

LOCATION OF SWITCHBOARD

The switchboard and switching equipment in the modern power plant are seldom self-contained devices; many pieces of apparatus are necessarily located some distance away from the board proper. Much assistance can usually be rendered the purchaser in the selection of proper location, if drawings or sketches of the station are provided when the order is placed. It is also safe to say that, with full knowledge of the available space and conditions, a better or more suitable switchboard can always be produced. Many details can be adapted to meet different conditions without affecting cost. The data available with the order usually place the switchboard either in the made-to-order or the ready-made class.

In settling the location of switching equipment, first consideration must always be given to personal safety. Continuity of service demands inspection, cleaning, and repair with minimum interruption of service. Ample space is the best safeguard and for that reason aisles should always be liberal—particularly so for the operation of disconnecting switches, and for inspecting and adjusting other equipment. (See Fig. 15.)

Before attempting to install the board, the customer should become familiar with the regulations of the National Electric Safety Code, and with any other local rules that may apply. Where local rules govern the design of a switchboard, the General Electric Company should be informed accordingly so that the completed switchboard will meet these rules.

In ordering switchboards, it is essential that the manufacturer be advised of the altitude at which the switchboard shall operate. This is very important since the insulating quality of air decreases rapidly at high altitudes as well as the current-carrying capacity of apparatus. If a board which has been designed for a normal location is to be placed at a higher altitude, the conditions should be referred to the General Electric Company for approval before such change is made

Switchboard equipments designed for indoor installation should not be located in places where they are exposed to excessive moisture such as driving rain or condensation drip. They should be installed in dry places of uniform temperature, and where they are reasonably free from corroding fumes, abrasives, and dust. Any contemplated deviation from this rule should be described when the order is placed. Necessary precaution should also be taken that high wind does not carry the arc from air circuit breakers to ground.

Rheostats and resistances should be so located as to obtain sufficient ventilation, and so that one cannot transmit heat to another, or to other apparatus.

Space for future growth should always be allowed so that additional equipment can be installed with the least interference to service and with the highest factor of personal safety. It will be noticed on reference to Fig. 16 that the switchboard, as well as the machines, has been installed with the intention of providing space for future growth. Note the blank panels and spacious distribution of equipment.

FOUNDATION

The switchboard should stand on a level foundation sill made of hardwood or channel iron (see Fig. 17, 18, 19, and 21). The sill must be rigid and heavy enough so that the panels will not be thrown out of line by settling. Standard 6-inch channels are best, although hardwood sills 7 by 2 inches may be used and are recommended where insulated framework is required. The sill should be securely anchored. Drill the channel sill for anchor bolts to suit floor construction.

Fig. 20 shows a method of grouting the channels. A small brick pier should be built at each end, and sand or plaster piled along the sides of the channel to prevent the cement from leaking out. The mixture should be about one part sand to one part cement and should flow freely. By pouring it into the piers until the level rises above the top of the channel, a head will be produced which will force the cement underneath the channel.

Suggestion for Card:

Drawing Number..
Item Number..
Description..
Shipping Memo. No..
Location, Bin No..
Number of pieces..
Withdrawn by......................................Date..................
....
....

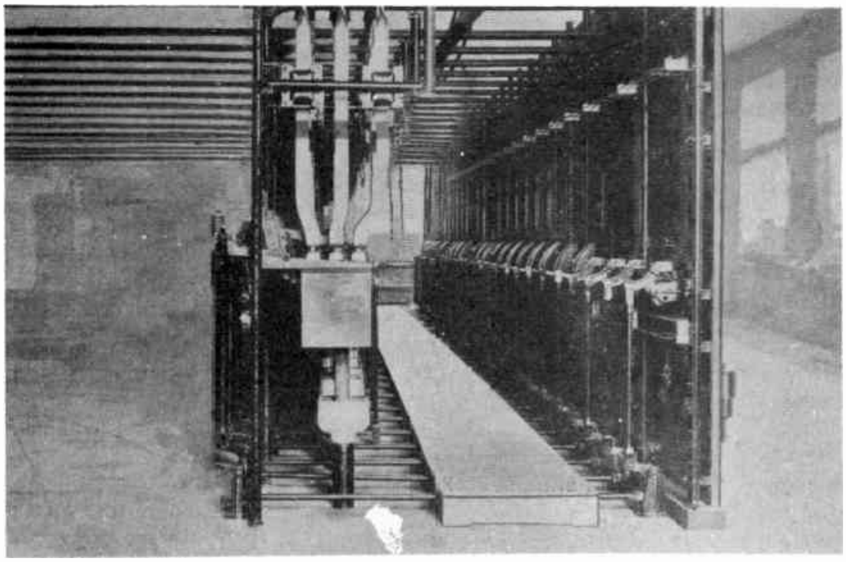


Fig. 15. Switchboard Installation Wherein Ample Space is Provided Behind the Panels to Permit Inspection and Adjustment of Apparatus. Operating rods should, wherever possible, be run beneath the floor or in covered trenches in the floor. The construction shown above is sometimes permissible with metal or slate gangway; but the question of head room must then be considered

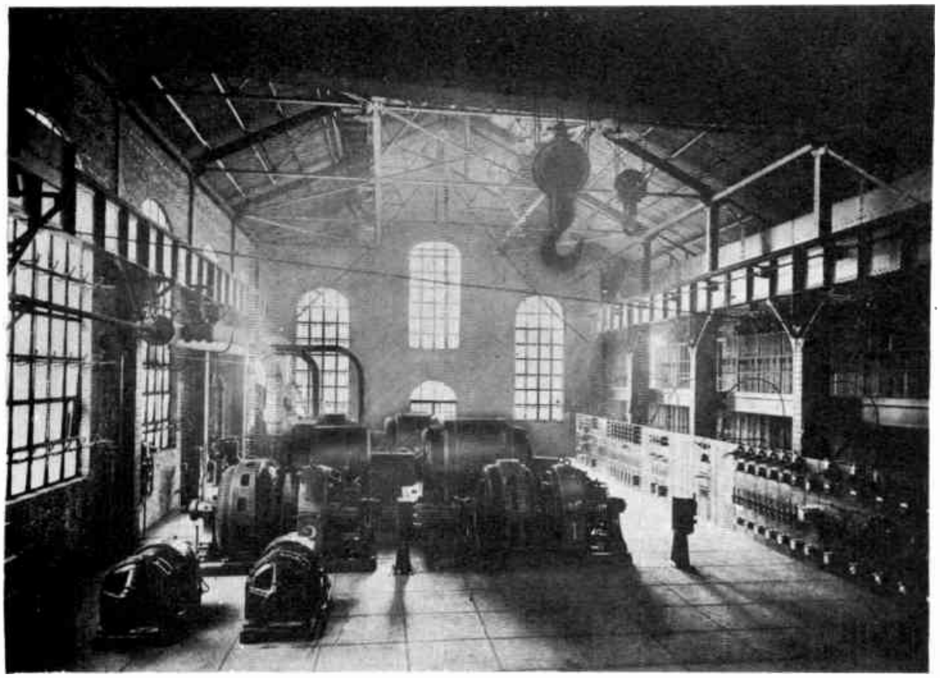


Fig. 16. An Installation Wherein Provision is Made for Future Growth. Note the blank panels and spacious distribution of equipment

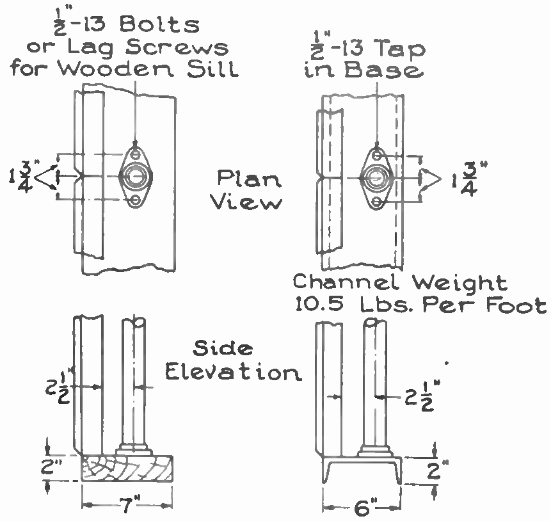


Fig. 17. Standard Sill and Switchboard Sub-base Arrangements

The tapped holes in the sill should be plugged with wood before pouring the cement, or the bolts for the floor flanges should be screwed into the channel temporarily to the maximum depth, in order to prevent the cement from filling them and making it difficult to fasten the flanges to the channel.

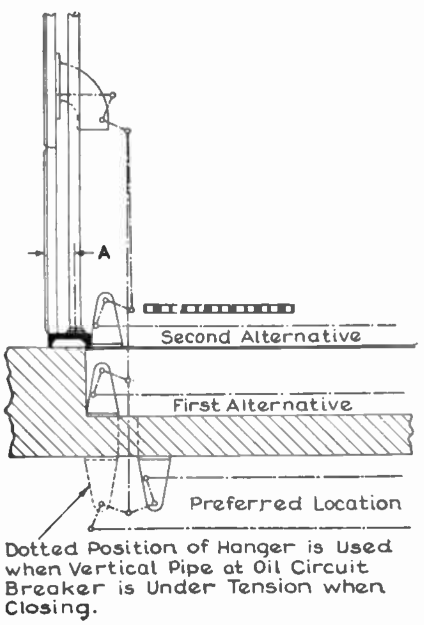


Fig. 18. Arrangement of Channel Base, Panel Sub-base, and Panel Supports, Showing Preferred and Alternative Locations of Lower Vertical Hanger for Pipe Mechanism, for Remote-controlled Oil Circuit Breakers

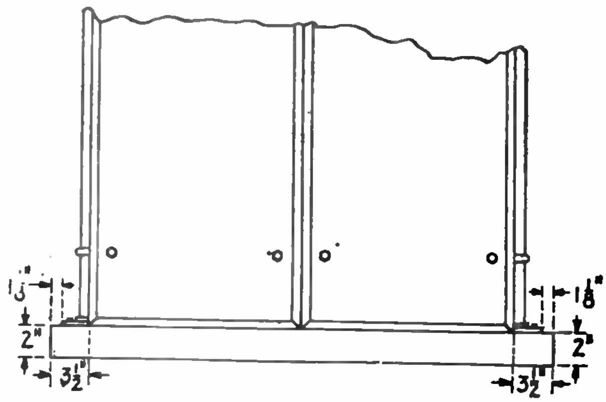


Fig. 19. Arrangement of Channel Base When End Grill is Not Used

The grouting should be allowed to set for twenty-four hours before mounting the panels on the sill.

It cannot be too strongly emphasized that the leveling, anchoring, and grouting of the sill are important operations and the final appearance of the switchboard is dependent largely upon the care and patience exercised.

The method of anchoring panel braces is dependent on construction of the wall. Heavy panel equipment requires solid fastenings. Expansion bolts, through bolts, or an angle iron bolted along the wall may be used.

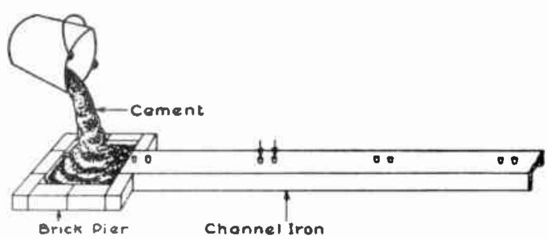


Fig. 20. Method of Grouting Sill

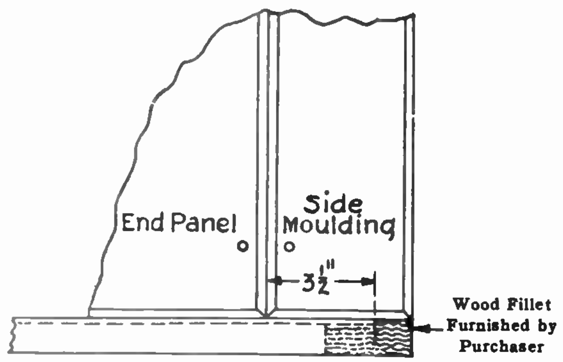


Fig. 21. Arrangement of Channel Base When End Grill is Used

ERECTION

The panel frame consists of either 1¼-in. upright pipe supports, angle irons, or, in cases where the equipment is exceptionally heavy, channel irons. Fig. 22 represents the standard method of bracing switchboard panel supports.

Regardless of frame construction and method of shipping panels, whether assembled or dismantled, the middle panel should be erected first, plumbed, and braced securely. If the supports are shipped separately the framework should be set up and plumbed first, then the panels bolted to it, first loosely to avoid cracking, and then securely. Flexible leatheroid washers are placed between frame and panels to prevent cracking of the panels when the bolts are tightened, and to align the front surfaces of the panels (see Fig. 23). If shipped on supports, each panel will be set up adjacent to

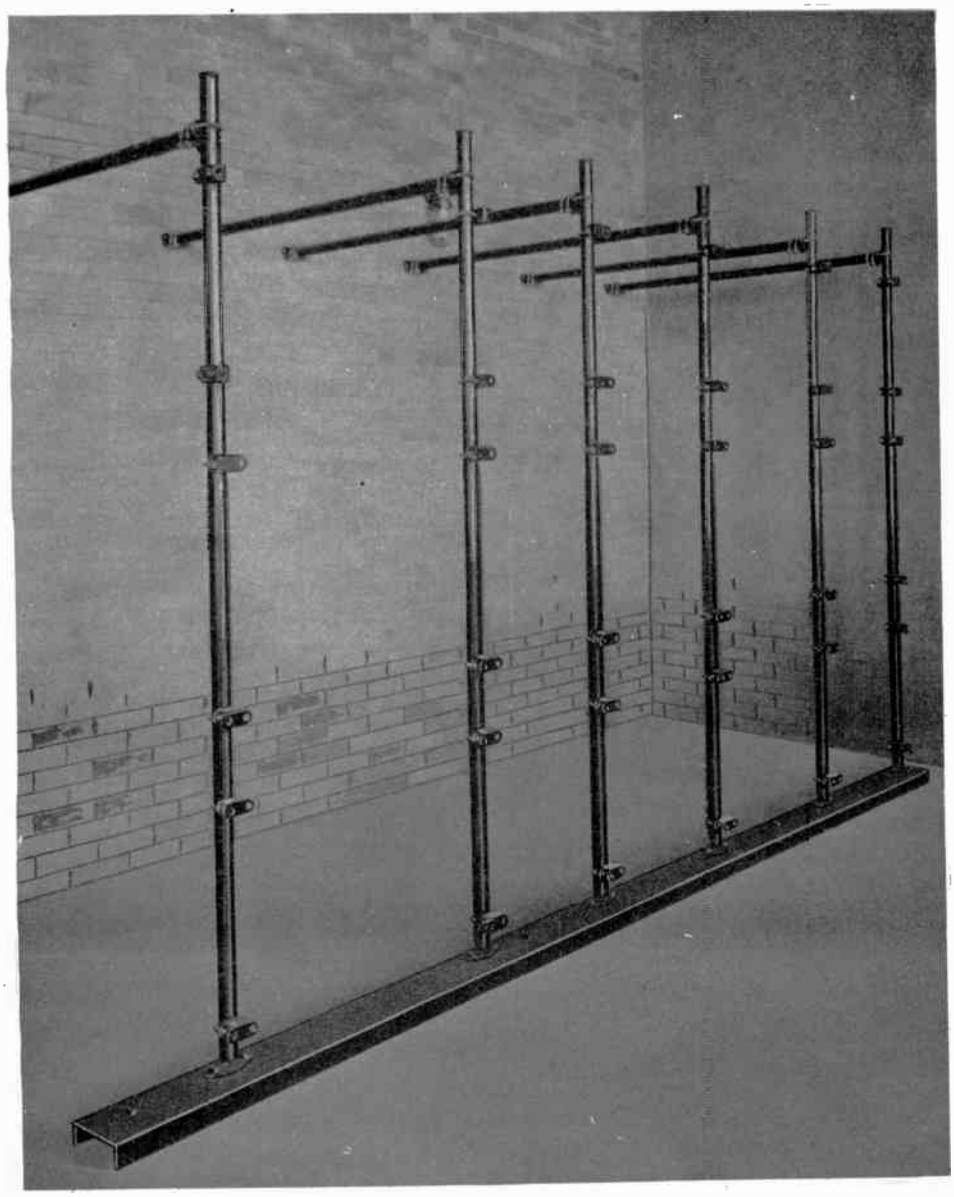


Fig. 22. Pipe Frame Structure for 90-inch Board

The best results in a finished switchboard are obtained by first setting the frame structure accurately. Plumb and align it carefully before bolting it to the sill and wall.

the fixed panel and anchored in place. Shimming should be done between the sill and bottom edge of panels to plumb the free edge as illustrated in Fig. 24 and 25. Sometimes it may be necessary to file the edges of two adjacent panels by means of a hacksaw blade inserted between them, in order to fit them more closely.

The installation work is somewhat simpler when the panels are shipped assembled on their supports but even then plumbing and shimming may be necessary, as in Fig. 24 and 25

Benchboards are sometimes shipped assembled, but more frequently knocked down. When erecting the board the sills are leveled and bolted in place first, then the frameworks are set up and anchored to the sills. Now the vertical sections below the bench, and then the bench sections are erected, always starting from the middle of the board. Lastly the instrument sections are set up. The grille or sheet iron work should be fitted, but should not be bolted into place before the wiring has been done. Fig. 26 shows typical benchboard construction.

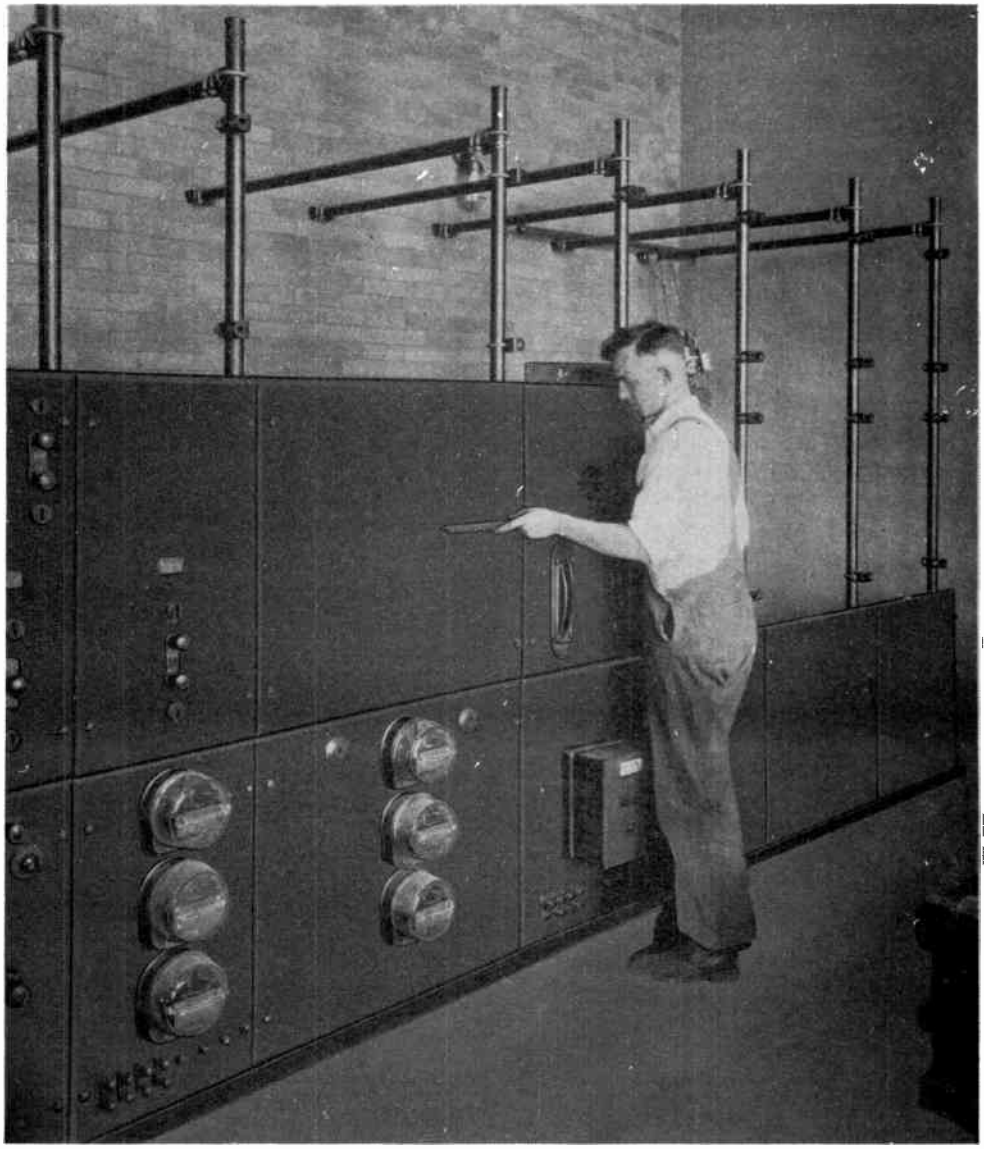


Fig. 23. Erecting a Switchboard of Three-section Panels Which Have Been Shipped as Individual Sections

Leatheroid washers are placed between the panels and pipe fittings to align the front surface of the board. Each row of sections is leveled and aligned completely before the panel bolts are tightened.

FRAME STRUCTURE

The frame structure for supporting General Electric switchboards is generally made of 1¼-inch pipe with threadless fittings. Fig. 27 illustrates standard General Electric switchboard pipe fittings, while some of their uses are exemplified in Fig. 28 and 29. The fittings are adaptable to pipes of standard sizes as carried by local dealers in this material. They are used because of their stiffness and weight, their ease of assembling and adjustment, and attractive appearance. Note the suggested method of bracing a switchboard when the board extends across a window or other opening in the wall (Fig. 30).

All such structures should be well braced together to avoid any flexibility that might tend to affect operation of oil circuit breakers, or transmit jars from them to the panels. The threadless clamp fittings offer in this respect the best facilities for perfect adjustment.

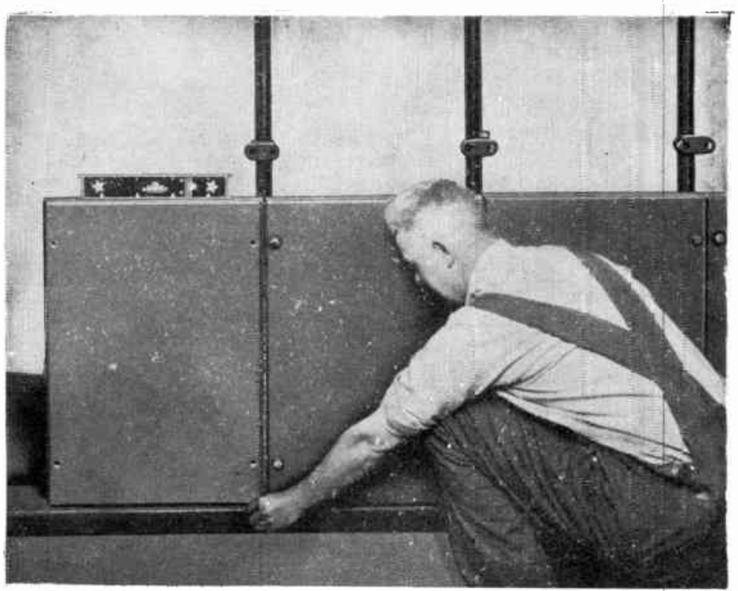


Fig. 25. Spacers are Placed Under the Lower Inside Corner of the Panel When an Opening Appears at the Bottom

In heavy capacity installations, avoid carefully any complete magnetic circuits around a conductor carrying a great amount of current.

Make sure of an effective ground and that paint on pipes or fittings does not prevent a good connection. There should never be more than three clamped or screwed joints in series for each ground connection.

Pipe caps should be slipped on the exposed ends of all pipes to improve the general appearance of the installation.

All metal work should be painted from time to time for protection and appearance.

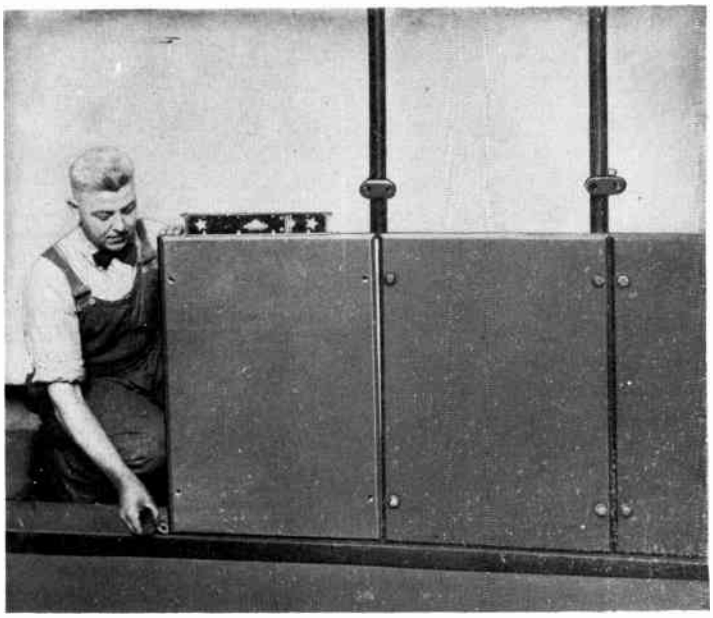


Fig. 24. Spacers are Placed Under the Lower Outside Corner of the Panel When an Opening Appears at the Top

CONCRETE STRUCTURE

Concrete cells and compartments are extensively used today for supporting switching equipment of medium-high potentials, but accuracy and care are essential to the construction of the forms. If they are not true, the concrete will be misshaped and difficulty will be experienced when installing the equipment.

On account of the high strength required, the narrow cross sections necessary, and the smooth surface desired, a concrete rich in cement should be used. The concrete mixture best suited for this work is about one part of cement, two parts of fine aggregate, and three parts of coarse aggregate.

Portland cement that meets the standard requirements of the American Society for Testing Materials should be used.

The coarse aggregate should consist of crushed stone, gravel, air-cooled blast-furnace slag, or other approved inert materials with similar

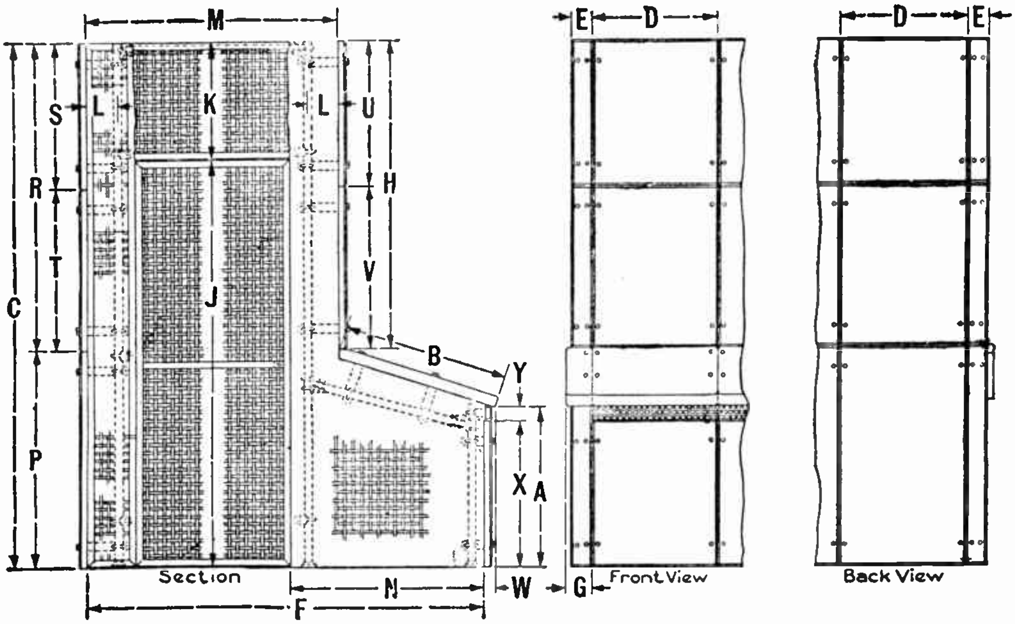


Fig. 26. Typical Benchboard Construction

DIMENSIONS IN INCHES

A	B	C	D	E	*F	G	H	J	K	L	*M	N	P	R	†S	†T	†U	†V	W	X	Y
30⅞	32	90, 101	24, 28, 32, 40	4	75	5	‡48, 59	78½	11½, 22½	6	48	36	42	48	28	31	28	31	3	28	2⅞

*When board is mounted against wall this dimension is ½ in. greater.
†For three-section back panels and two-section instrument panels only.
‡ For two-section back panels and one-section instrument panels only. (This refers to 48-in. dimensions only.)

characteristics. It should be composed of hard, strong, durable particles free from injurious amounts of soft, friable, thin, elongated pieces, alkali, and organic or other harmful matter. The maximum size of the aggregate for walls and barriers more than three inches thick should be such that it will pass a 1-inch screen, but should not be less than one-half inch. Not more than five per cent should pass a quarter-inch screen. For shelves and barriers thinner than three inches, the aggregate should be smaller and should pass a screen with one-half inch openings.

The water for concrete should be clear and free from oil, acid, alkali, organic matter, or other deleterious substances. It should preferably be equal in all physical and chemical properties to potable water. The strength of concrete varies with the amount of mixing water used. Five and one-half to six gallons of mixing water per sack of cement is approximately the correct quantity for constructing concrete bus-compartments. More than this amount reduces the strength.

Concrete should be mixed in a batch mixer for at least one minute after *all* the materials, including the mixing water, are in the drum. When concrete is mixed by hand it should be on a water-tight platform. The cement and fine aggregate should first be mixed dry, being turned over until a mixture of uniform color is obtained. The coarse aggregate should then be added, and the whole mass turned at least three times to a uniform mixture. Next, the water should be put into the batch and the entire mixture turned again at least three times, or until a homogeneous mass of the required consistency is obtained.

Care should be taken in placing the concrete to see that it is thoroughly worked around the reinforcing rods and that the faces of the concrete are well spaded. This will insure a good bond to the steel and will keep exposed surfaces free from stone pockets. For thin walls or inaccessible portions of the forms where the use of a spade is impractical, the concrete should be forced into place by tapping or hammering the forms.

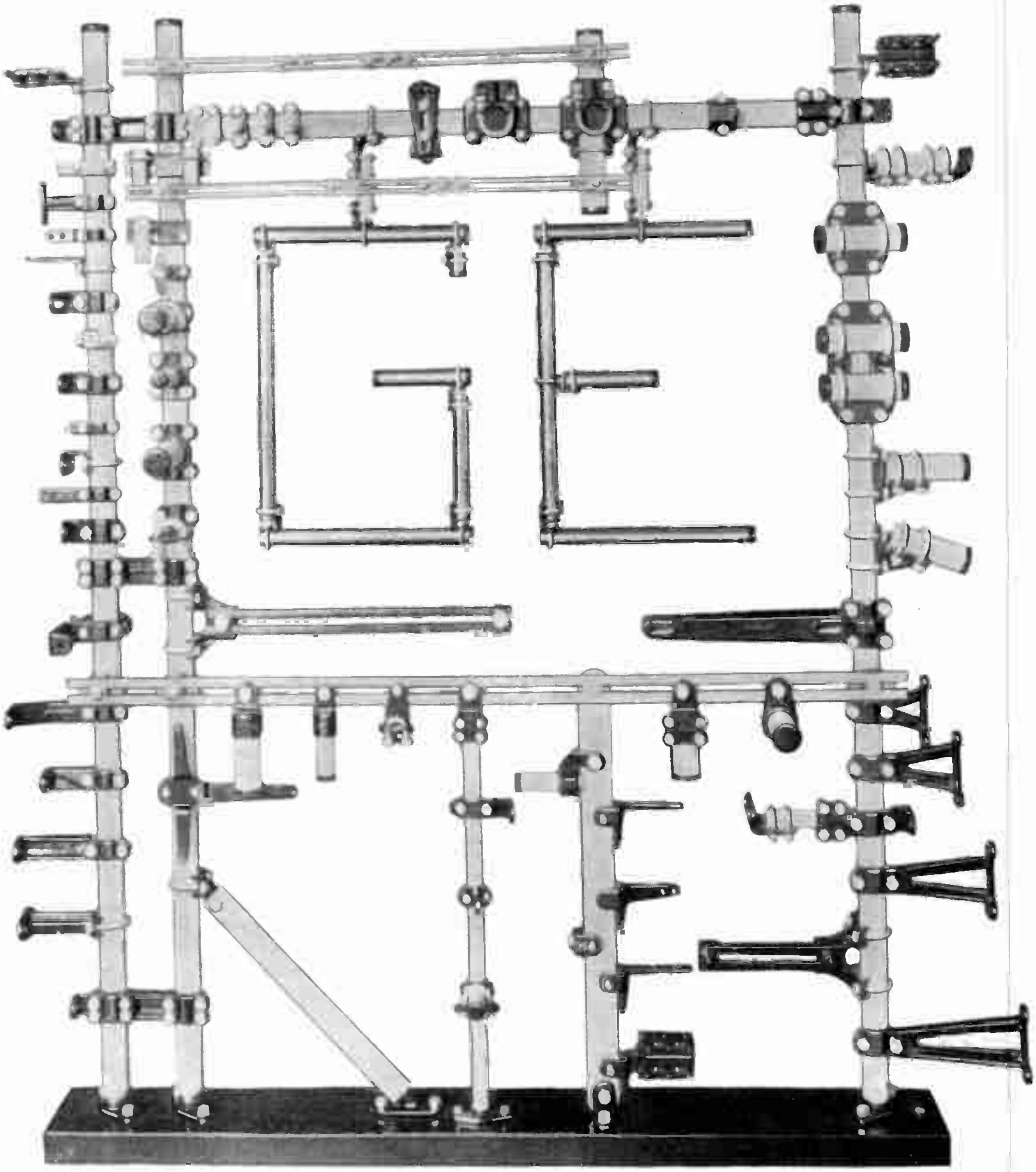


Fig. 27. **Standard Switchboard Pipe Fittings**

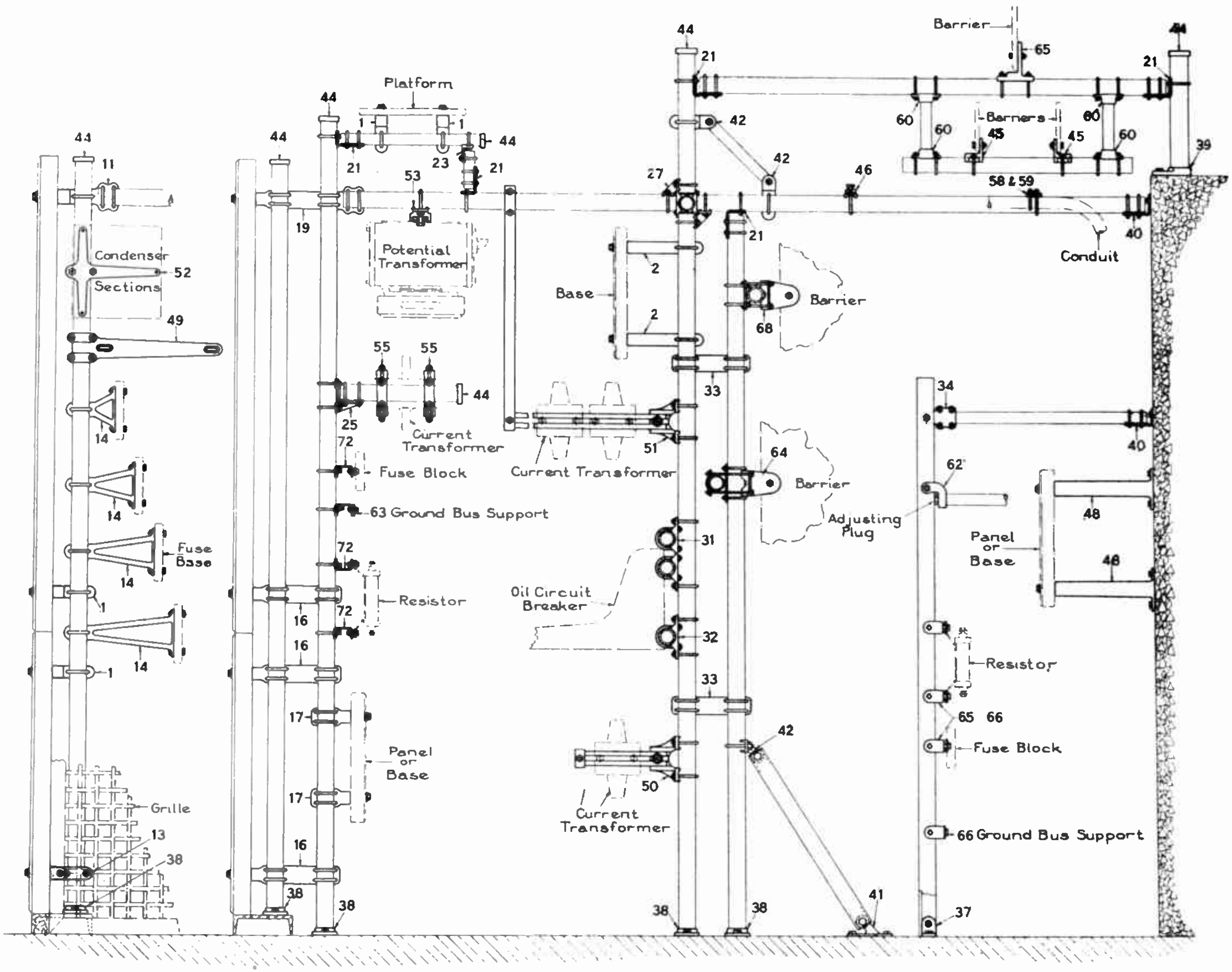


Fig. 28. Illustration to Show Application of Switchboard Pipe Fittings

Reinforcing rods, which are used very extensively to give additional strength to concrete structures, should be used with extreme consideration in building switch and bus compartments. They may be used without hesitation, however, in the foundation and substructure where they are most needed, but their use is not recommended for switch cells.

Place the horizontal barriers in position, grout them in, and cast a base even with the lower precast slab. When the base has set sufficiently, the lower forms for the vertical barriers and the outside longitudinal wall, as shown in Fig. 32, may be set up. This wall should be cast only up to the second precast horizontal barrier and leveled off carefully to give an even

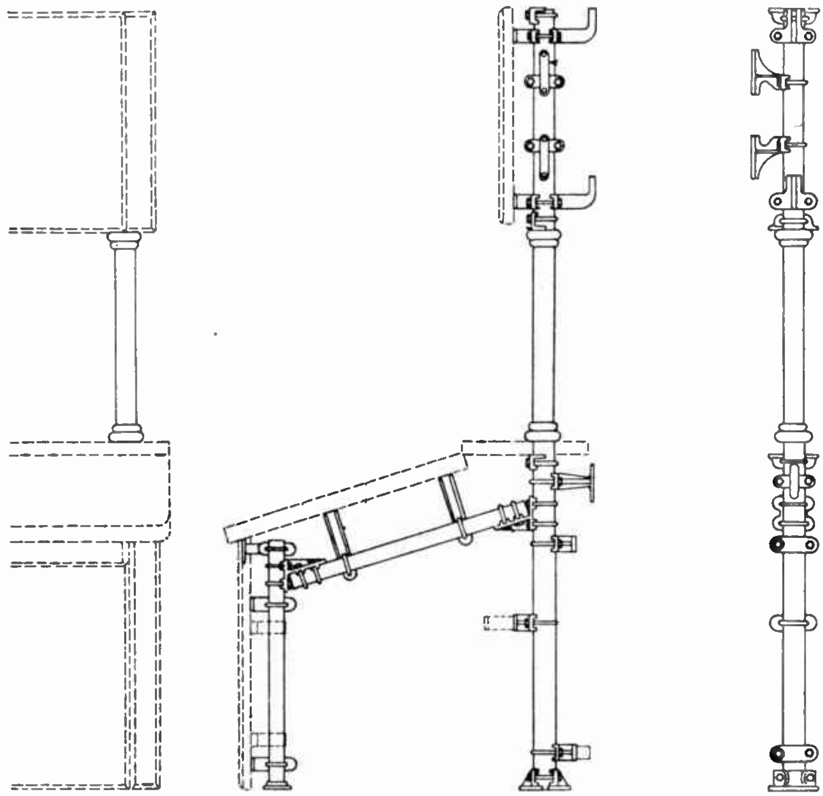


Fig. 29. Applications of Benchboard Fittings

bearing surface for the second row of precast barriers. The top of the vertical barriers and the part of the wall which is not to be covered by the precast slab should be made rough so as to unite better with the concrete placed on top of it.

The second and third bus compartments should be cast similarly to the lower bus compartment as described above, care being taken to brace the forms properly to assure a perfect line up (see Fig. 33).

A plan showing forms in position for casting vertical barriers and outside wall of the bus compartment is given in Fig. 34.

The upper part of the main longitudinal wall of the busbar compartment and the vertical barriers should be cast in one block to produce a monolithic structure and to increase the

Compartments with shelves either of soapstone or precast concrete are simpler to build than those of monolithic construction. The difficulty in the use of reinforcing bars is overcome by employing precast units. Experienced men for supervision of this work are not so essential as for the monolithic type of construction.

The following method is suggested for constructing all compartments.

The center or longitudinal wall (or back wall for single-bus arrangement) must be cast first and not simultaneoulsy with the barriers. This will allow access to the center wall while placing the concrete and will permit finishing it when the forms are removed. Fig. 31 illustrates how far the wall should be built before the bus compartments are started.

strength of the compartments. If through pipes for the support of disconnecting switches or other apparatus are to be cast in the concrete, certain precautions should be taken. The forms should be made in sections to facilitate their removal from around the pipes, and to avoid damaging the green structure (see Fig. 35 and 36).

For concrete structures in an unheated station, joints are recommended every forty or fifty feet to prevent cracking due to expansion and contraction. They should be constructed with a key or notch and have several thicknesses of tarred felt between the sections. All expansion joints should be carried through the foundation and no reinforcing steel should be allowed to extend across a joint.

The forms should be built of dressed and matched lumber at least ⅞ inch thick, thoroughly braced in all directions exposed to the pressure of the concrete. Before the concrete is placed, the inside of the form should be brushed once or twice with crude oil or soft soap to prevent sticking. A better method is to use paraffine wax dissolved in kerosene. It is advisable to design the forms so that they can be taken down without wrecking. In addition to the advantage of saving the forms, it permits removing them earlier and allows the surface of the concrete to be rubbed down without much effort.

Setting of anchor bolts and inserts with the required accuracy calls for considerable forethought. These must be fastened to the form

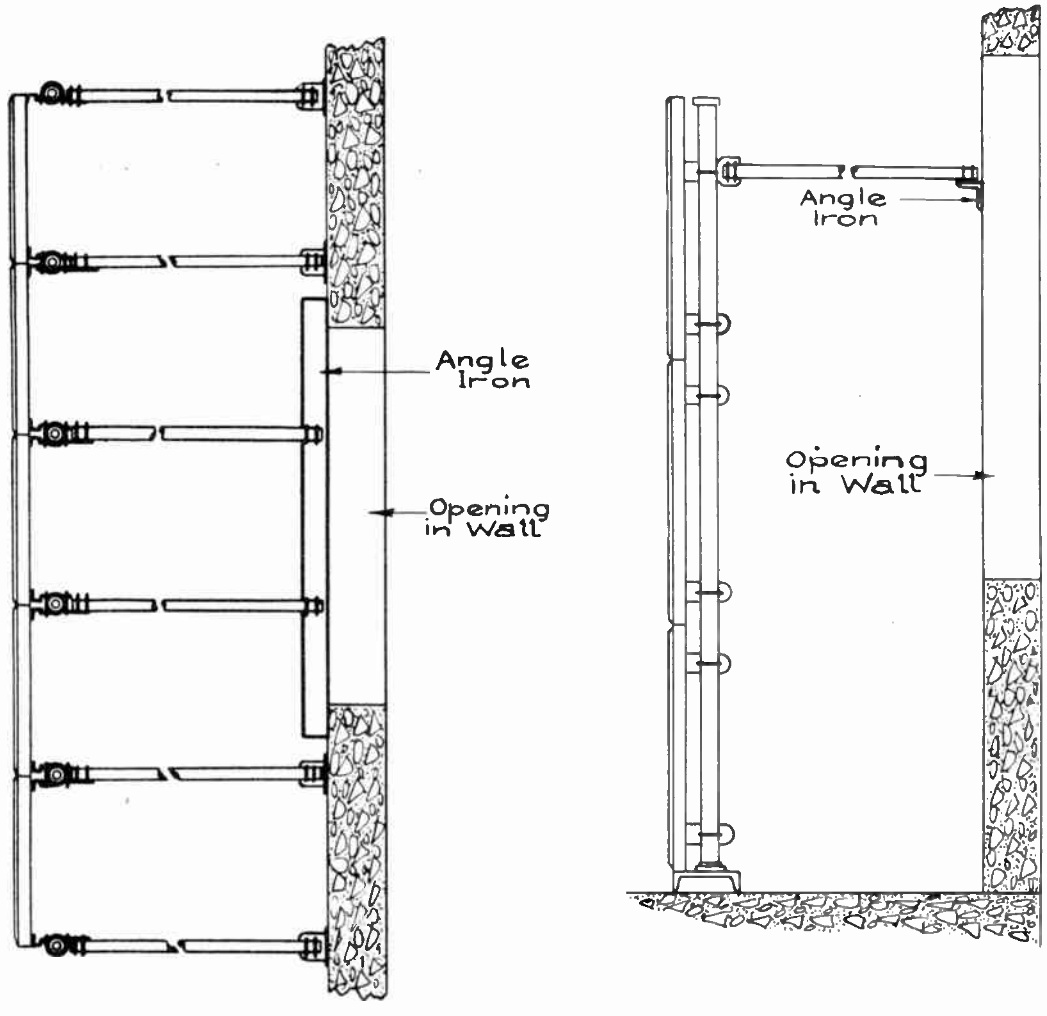


Fig. 30. A Suggested Method of Bracing a Switchboard When It Extends Across a Window or Other Opening in the Wall. (An angle iron is bolted across the opening and the rods are fastened to it)

to prevent their becoming loose when the concrete is placed or spaded, and permit the easy removal of the forms. Templates should be used for setting and checking locations of all anchor bolts.

An important factor in the strength of concrete is proper protection after placing. All concrete should be exposed to extreme dampness or allowed to harden under wet coverings the first ten days.

Detailed information on concrete work may be obtained from the Portland Cement Association, 111 West Washington Street, Chicago, Ill.

Finishing and Painting of Concrete Structures

By rubbing down the surface of a concrete structure before it has become too hard, a smooth finish can be obtained by very little work. After it has hardened, it may be rubbed

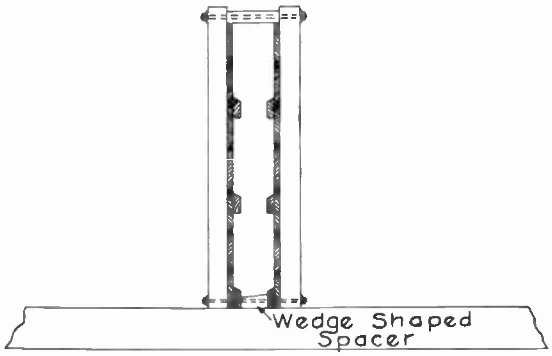


Fig. 31

down with carborundum blocks, but with greater effort. Smoothing-over with cement wash is seldom successful, and should not be practised.

It is often desirable to paint concrete structures for appearance, and to preserve them in cleaner condition. Care should be taken to avoid the use of strong metallic paint for high-potential compartments and cells. Linseed oil paint will not permanently adhere to a concrete structure without the previous application of some solution for neutralizing the action of the alkali in the cement, which has a tendency to saponify linseed oil. A solution made by mixing one pound of zinc sulphate with one gallon of water is often recommended for washing the structure to prepare it for the paint. It may be sprayed or brushed as seems most convenient. The same class of paints used on wood may be used successfully on cement some time after application of the neutralizing wash. This may be either interior flat wall paint of any color for a flat surface, or interior gloss paint for a gloss surface. The pores should not be sealed up before the under surface is dry.

Many reputable manufacturers of high-grade paint carry special paint for concrete work that may be used without hesitation. Their directions should be followed in each case.

QUICK-HARDENING CEMENT

The time taken for a concrete structure to harden so that the forms may be taken down

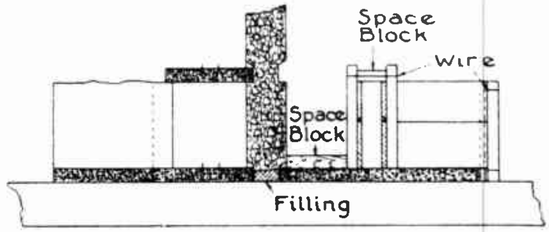


Fig. 32

and the equipment bolted in place is often a serious item in the installation work. For conditions where the extra cost of the cement is warranted by a saving in time, quick-hardening LUMNITE CEMENT may be used advantageously. This material behaves similarly to Portland cement, except that it reaches a strength after twenty-four hours at least equal to that of Portland cement after months of aging.

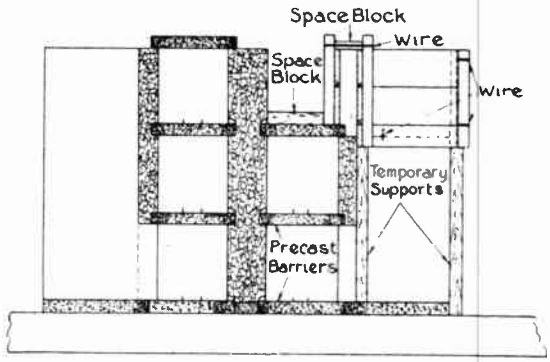


Fig. 33

In using this cement the same proportions of sand and coarse aggregate may be employed as with Portland cement. Two things must, however, receive very careful consideration. First, sufficient water should be sprayed on the structure during the curing period, else the strength will not come up to the normal. Second, the forms should be varnished, or treated in some equally efficient manner, to prevent absorption of moisture from the concrete, otherwise the surface will have no strength. Metal forms are far superior to wooden forms for this kind of concrete.

BRICK STRUCTURES

Under certain conditions, it is preferable to use brick for cells and bus compartments in place of concrete. While control conduits, anchor bolts, and inserts are somewhat harder to take care of, there are compensating advantages. Shelves are then usually made of precast

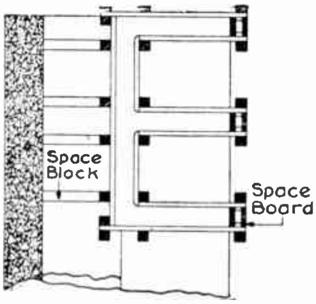


Fig. 34

concrete, or of soapstone; and the walls and barriers are made of some kind of brick in keeping with the character of the building.

The bricks should be set in a mortar consisting of two parts of best quality Portland cement and six parts clean, sharp, screened sand. To this should be added after mixing one-half part lime putty (made from newly slacked lime and allowed to settle).

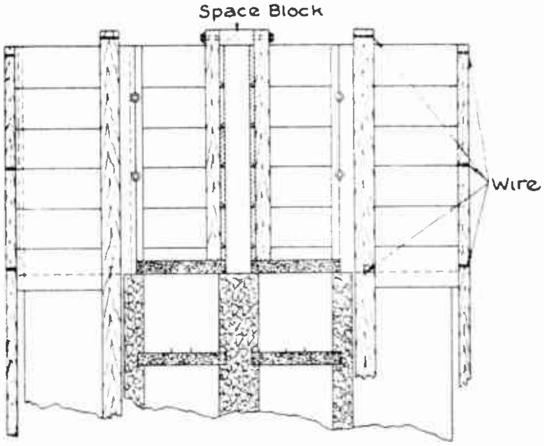


Fig. 35

All copper connections used in masonry compartments or cells, which are dependent for length, bending, or drilling on the accuracy of the structure, should always be made on the ground after the structure has been erected. These structures cannot be built to exact dimensions without comparatively high cost.

DRAWINGS

Factory drawings, typical examples of which are shown in Fig. 37 and 38, are made up for most switchboards, and blue-print copies of them are sent to the purchaser. The wiring diagrams are made up to accord with a standardized sequence of connections, and a standardized set of symbols is used which represents the various devices that make up the installation. The symbols which appear in these drawings are illustrated in Fig. 39, with the names of the devices which they indicate. In some cases it is necessary to show conditions diagrammatically as in Fig. 41.

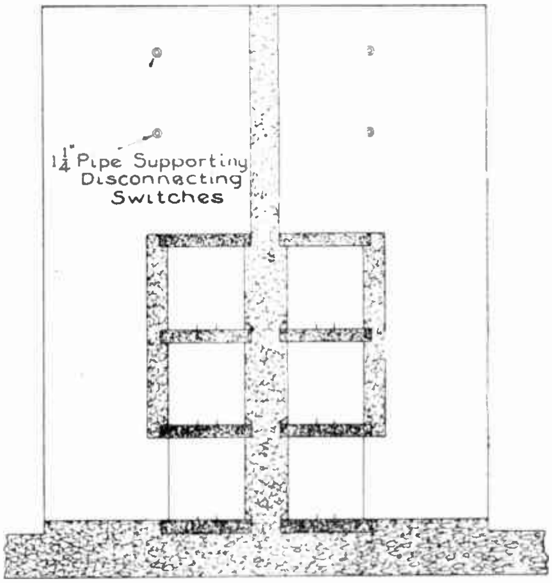


Fig. 36

After a switchboard has been installed and placed in operation, the switchboard drawings should be gone over by the purchaser. Notations should be made on them of any deviation which may have been made during installation, such as changes in order of panels, distance to wall, direction of cables, electrical connections, etc. The prints so marked should be returned so that the proper records can be made to take care of future orders, changes, and extensions.

MAIN CONNECTIONS

The main connections, when made up by the General Electric Company, are assembled and marked. It is then a simple matter for a purchaser to install them, by referring to the assembly drawings which bear detail numbers corresponding to those stamped, stenciled, or tagged on the details. It is important to check these drawings to see that they contain the latest revisions according to the shipping memoranda.

Special attention should be given to all joints, whether clamped, bolted, or soldered; all contact surfaces must be clean and smooth. Clamping and bolting must be such that the

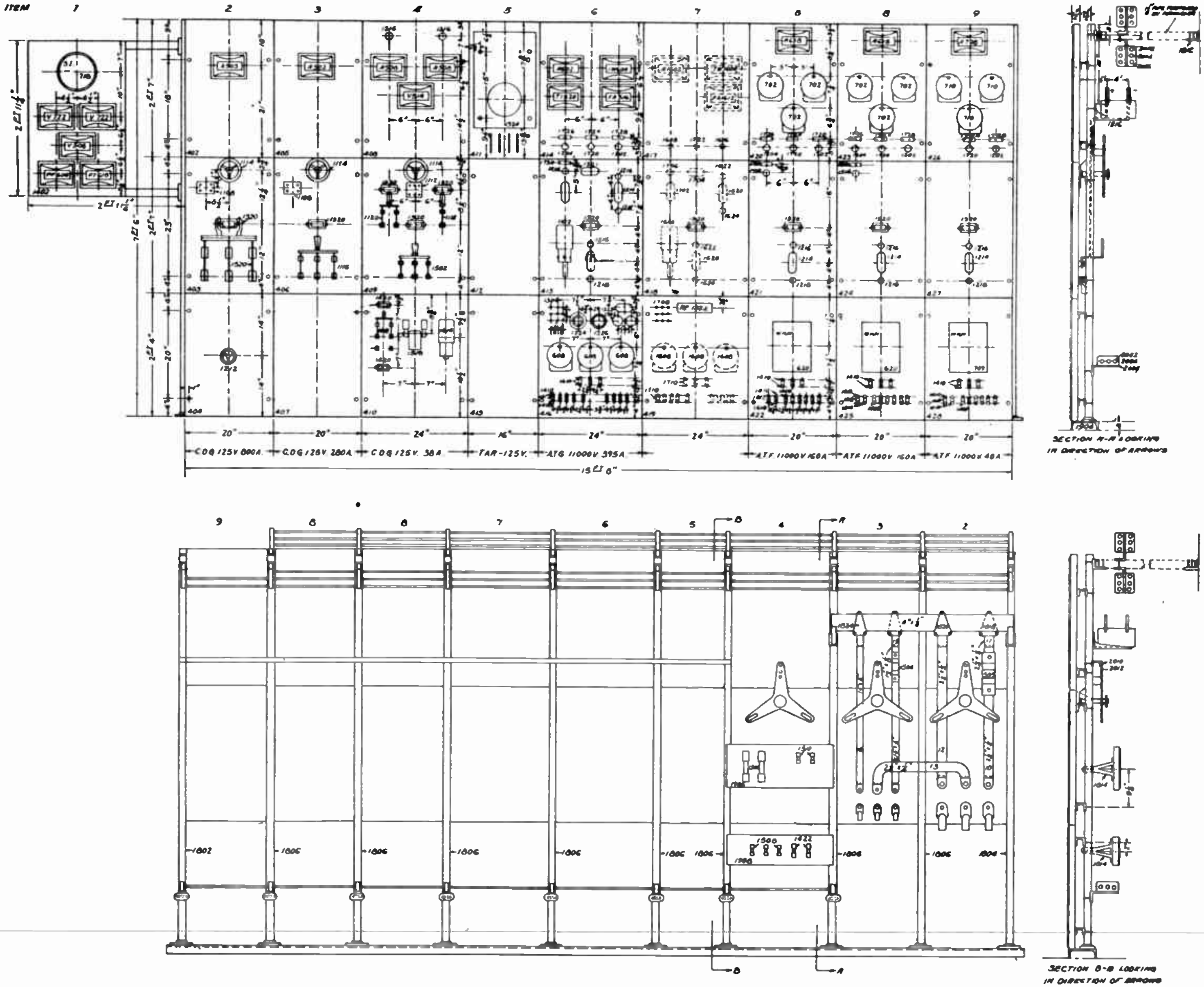


Fig. 37. Standard Front View Diagram Typical of General Electric Switchboards (Reduced to one-tenth of its original size)

a	Auxiliary Switch open when main switch is open
AM	Ammeter
b	Auxiliary Switch closed when main switch is open
CB	Circuit Breaker
CC	Closing Coil
CR	Control Relay
CSW	Control Switch
CT	Current Transformer
FI	Frequency Indicator
FU	Fuse
GD	Ground Detector
LG	Lamp Green
LR	Lamp Red
PFI	Power-factor Indicator
PT	Potential Transformer
PP	Potential Plug
RC	Reactor
RE	Receptacle
Res	Resistor
RH	Rheostat
RL.2	Inverse Time Limit Relay
RL.3	Definite Time Limit Relay
SI	Synchronism Indicator
SH	Shunt
SW	Switch
TC	Trip Coil
TD	Testing Device
TI	Temperature Indicator
VM	Voltmeter
WM	Wattmeter
WHM	Watthour Meter

This drawing shows electrical connections only; the relative location of apparatus must not be read from it. Instrument and meter connections may differ from the typical connections given in the individual instruction books.

For arrangement of ground buses, see M-2165088. Secondary leads from below.

NOTICE TO PURCHASER

Refer to contract for material to be supplied by the General Electric Company. The amount of such material is not increased by anything shown on this drawing.

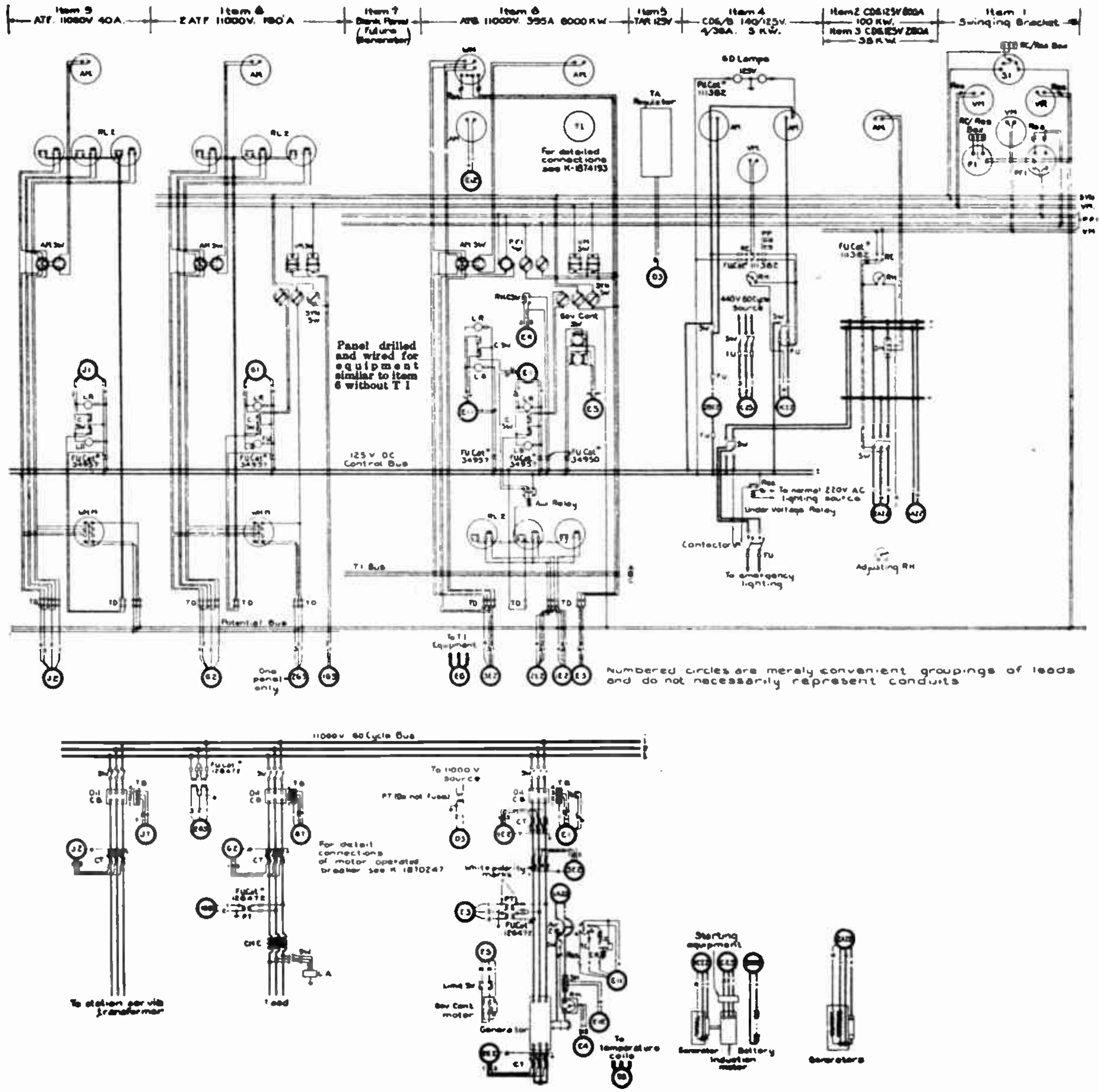


Fig. 38. Standard Wiring Diagram Typical of General Electric Switchboards (Reduced to one-tenth of its original size)

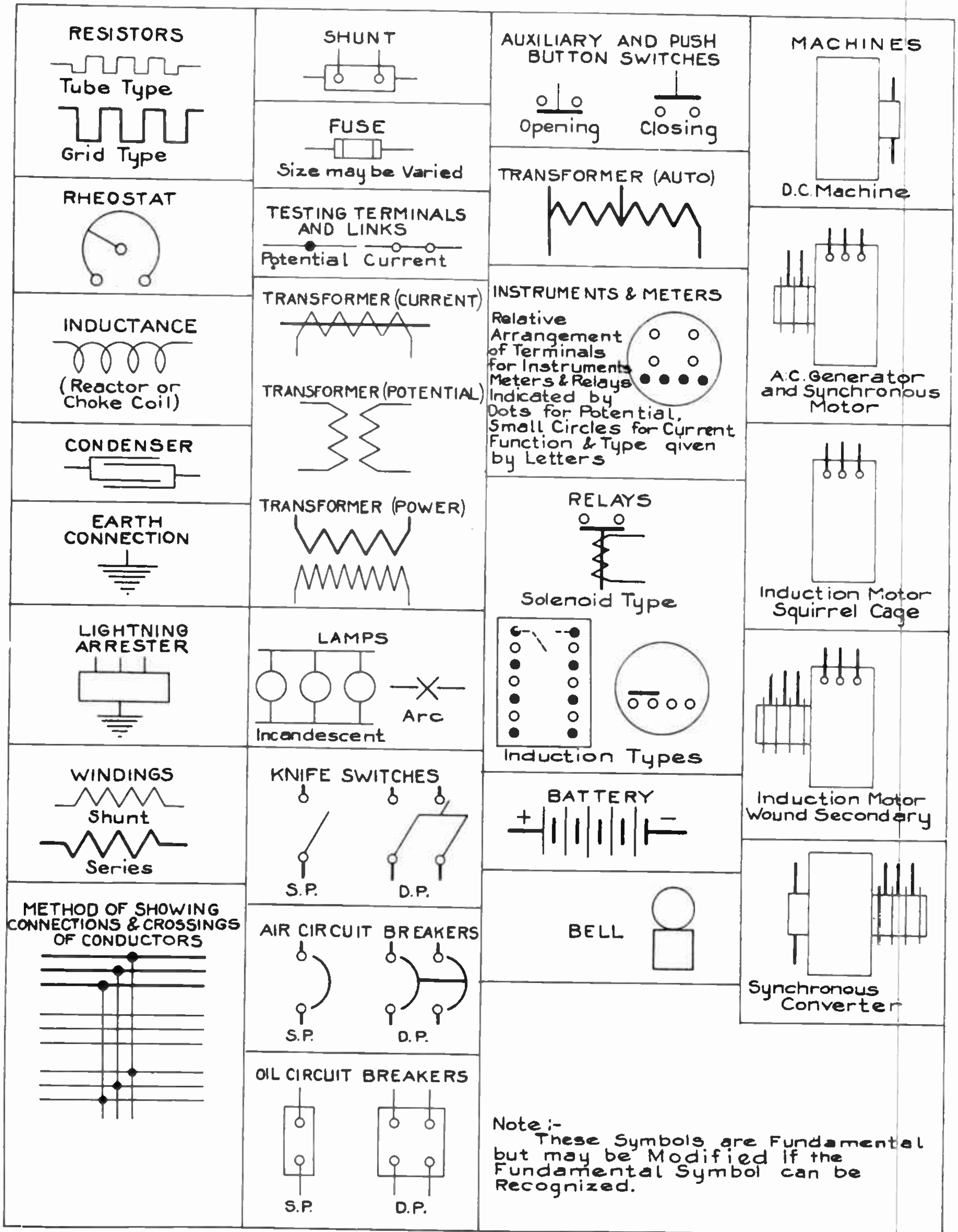


Fig. 39. Standard Symbols Used in General Electric Connection Diagrams

pressure is evenly distributed, and that there is no possibility of the opening of a joint through vibration or temperature changes. This is particularly important where the connections and their joints are insulated after installation. Lock washers and lock nuts are sometimes necessary.

The conductivity of a bolted or clamped joint is proportional to the pressure applied at the joint; and inversely, a poor joint may heat until the surface is annealed and oxidized, which in turn causes increased heating.

In soldered connections, the solder has greater resistance than the copper and, therefore, will heat if not sufficiently distributed over the entire joint. A heavy overload may cause sufficient heating to melt the solder, and care must be taken that there is no strain or tendency to separate such joints.

Soldered connections should be made to insure greatest possible contact area. It is therefore necessary to use a good grade of soldering paste to effect this condition. The General Electric Company manufactures and recommends Soldering Paste No. 293.

In clamping connections, iron clamps with steel bolts may be used for direct-current work; but for alternating-current connections and buses, the clamps must be so constructed as to guard against magnetic circuits around individual conductors, particularly for heavy circuits. A typical back-of-board arrangement is illustrated in Fig. 40.

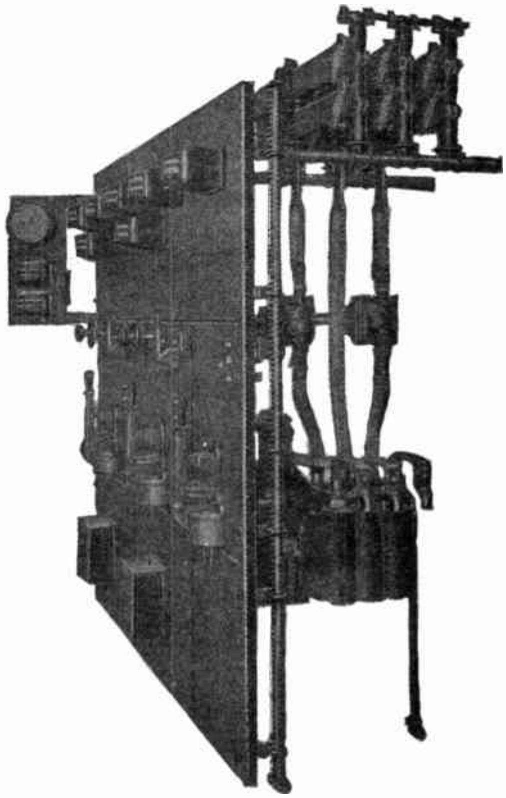


Fig. 40. Typical Back-of-board Connections

All contacts of busbars and copper conductors must be thoroughly cleaned with emery and vaseline or oil. A coating of vaseline on the contact surfaces before they are bolted together will retard oxidation in the joint. It is also recommended that the purchaser extend this operation to the entire surface of joint. It is recommended that the purchaser extend this operation to the entire surface of the bars that are not to be insulated after installation, and then give them a coat of transparent lacquer to prevent tarnishing and to preserve a bright appearance. It is important that lacquer does not flow on the contact surfaces, and it is, therefore, best to do this work after the joints have been made. All traces of oil must be removed before applying

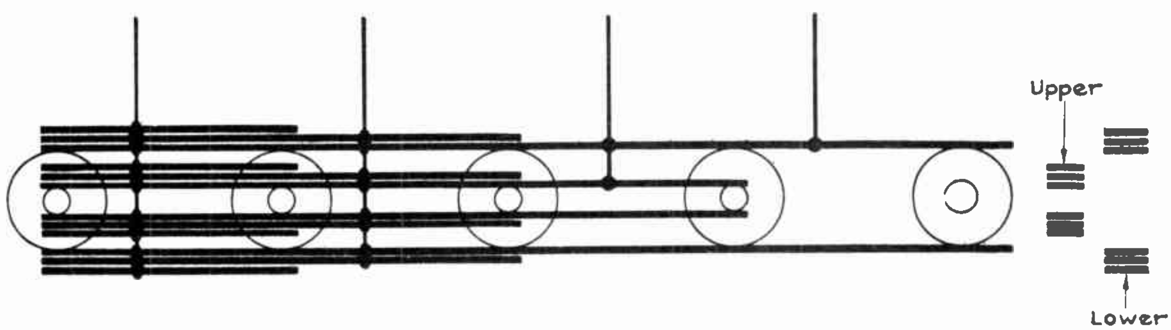


Fig. 41. Diagrammatic Plan View of Double-tier Bus

(This is the practice that is followed on all switchboard drawings where such forms of buses are a part of the switchboard equipment. Although the diagram shows the four sections of the bus spread out in a row, it should be understood that the sections shown on the outside of the larger circles are actually below the sections next to the smaller circles. The scheme is used so that connections to any section of a bus may be shown definitely.)

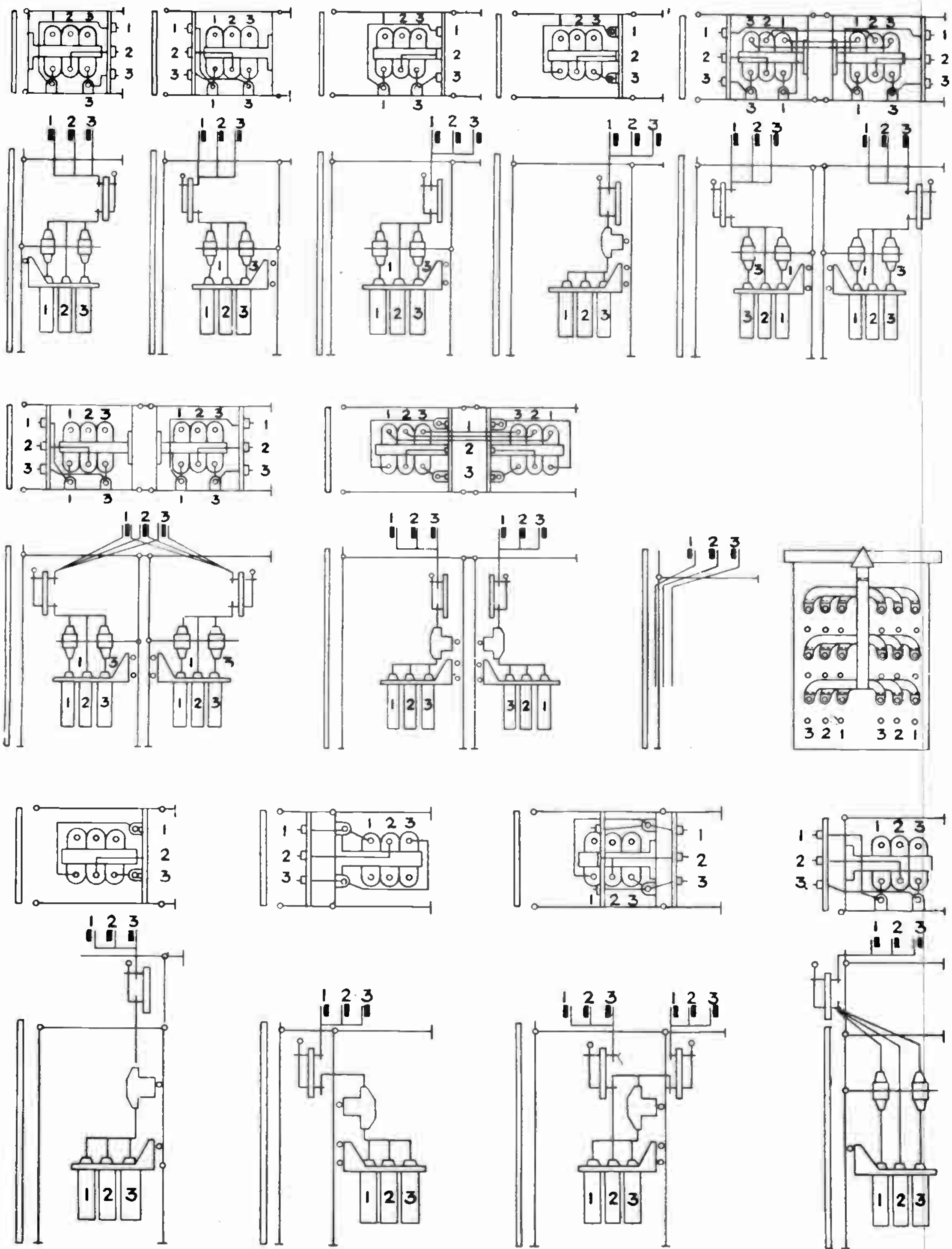


Fig. 42. Arrangement of Apparatus and Connections (3-phase Switchboard)

the lacquer. When changing buses that have been lacquered, the new contact surfaces should be washed clean with alcohol and then carefully scraped.

For the sake of appearance as well as for convenience in caring for the equipment, uniformity and consistency in the order and arrangement of conductors should be carried as far as practicable. For instance, on direct-current boards the positive bus and connections may be located nearest the board, nearest the top, and at right facing back of board. On alternating-current boards, phase 1 may occupy same position as would the positive. Fig. 42 and 43 show General Electric standard practice for order of phases in alternating-current arrangements.

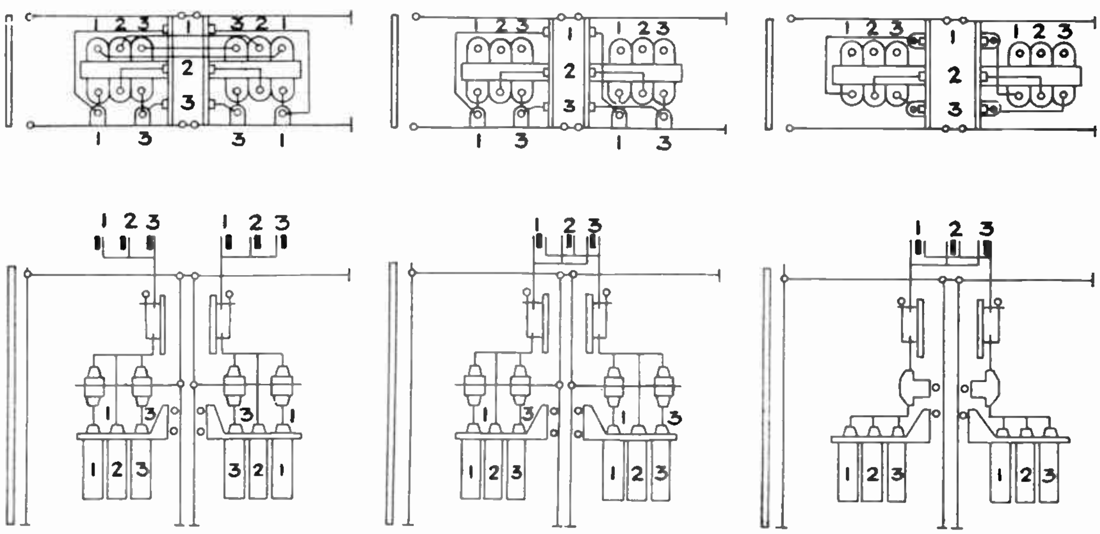


Fig. 43. Arrangement of Apparatus and Connections (3-phase Switchboard)

Complications will naturally arise when the equipment is mounted away from the switchboard. It then becomes necessary to determine how far this uniformity should be carried through the station and to lines. Local conditions and size of the power system are the governing factors.

Some of the larger stations paint different conductors in different colors. This usually extends also to steam, water, air, oil pipes, etc., and must, therefore, be developed for the station as a whole when required.

All buses and connections on the switchboard are designed on the basis of maximum temperature rise of 30 deg. C. above room temperature. This limitation and mechanical stability determine in general the size and shape of switchboard conductors. For smaller current capacities, round conductors are frequently used as follows:

Bare rod $\frac{1}{4}$ in. dia.	Up to 100 amp.
Bare rod $\frac{5}{16}$ in. dia.	Up to 150 amp.
Bare rod $\frac{3}{8}$ in. dia.	Up to 200 amp.
Bare rod $\frac{7}{16}$ in. dia.	Up to 250 amp.
Bare rod $\frac{1}{2}$ in. dia.	Up to 300 amp.
Insulated wire No. 1/0 B.&S.	Up to 175 amp.
Insulated wire No. 4/0 B.&S.	Up to 300 amp.

Fig. 44, page 30, shows a method of approximating amount of copper required for heavy buses. Any special conditions should be referred to the manufacturer for advice, with data on local conditions because ventilation greatly affects the results. The following tabulation presents the properties of unit wires of aluminum, copper, galvanized iron, and galvanized crucible steel.

PROPERTIES OF UNIT WIRES

(1 Cir. mil. ft.)

Aluminum	
Weight in lb.	0.000000916
Resistance in ohms at 15° C.	16.16
Copper	
Weight in lb.	0.00000303
Resistance in ohms at 15° C.	10.074
Galvanized Iron	
Weight in lb.	0.00000264
Resistance in ohms at 0° C.	74.548
Galvanized Crucible Steel	
Weight in lb.	0.0000026
Resistance in ohms at 0° C.	116.85

1 Cu Bar 1/4" x 4" Bare 1350 Insulated 1200 Amps
2 " " " " " 2250 " 1800 "
3 " " " " " 2750 " 2200 "
} 80% of Bare Amps. Bare Values from Bunndy Catalogue

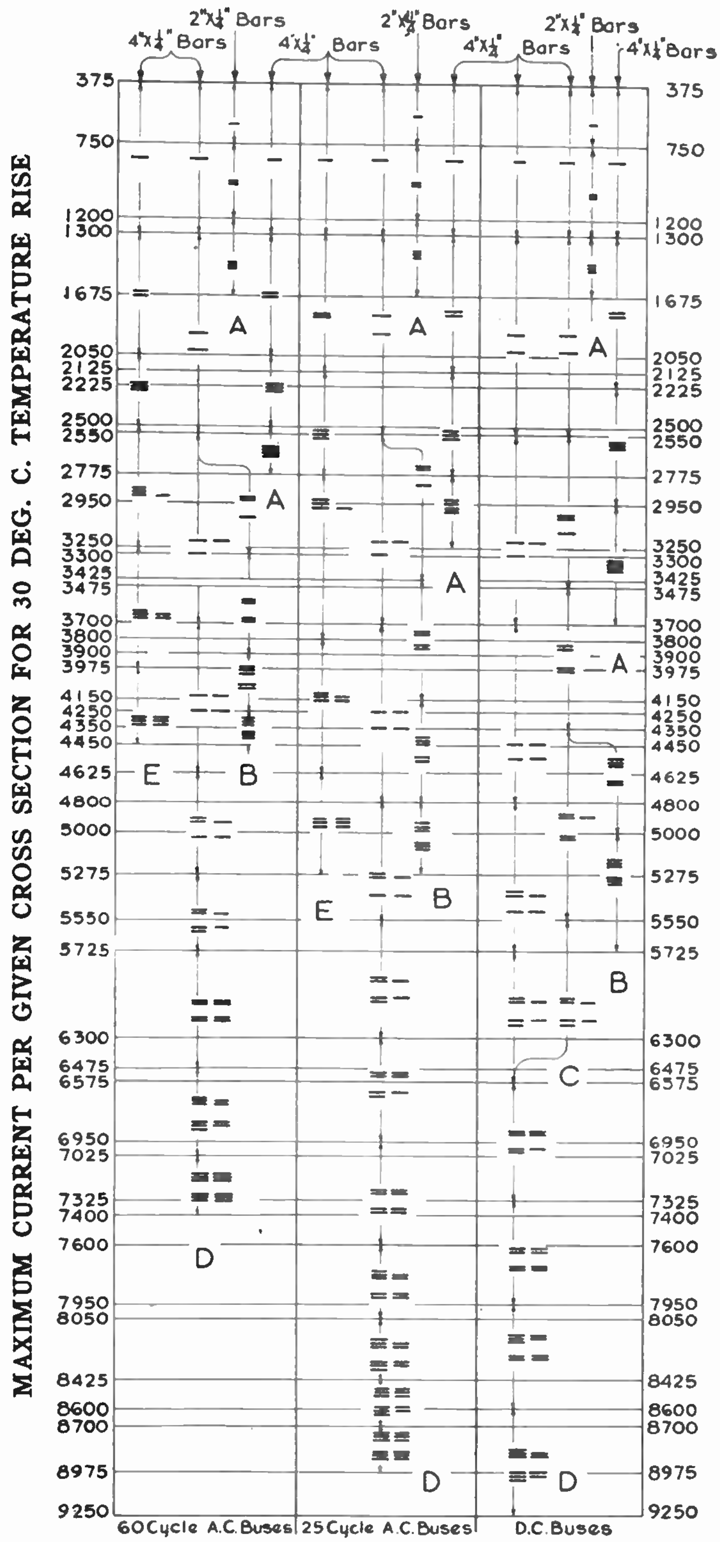


Fig. 44. Diagrammatic Illustration of Size, Number, and Arrangement of Busbars for Various Conditions

This chart of recommended bus arrangements indicates the proper number of 2- or 4-in. by ¼-in. bars, the proper tapering scheme for different capacity buses, and their correct arrangements for direct-current, 25-cycle alternating-current, and 60-cycle alternating-current circuits under the most commonly encountered conditions. These conditions are indicated on the chart by the letters A, B, C, D, and E, which are explained as follows:

A—For installations where the ultimate capacity of the bus will not exceed the limit given, i.e., 3700 amperes direct current, 3250 amperes at 25-cycle alternating current, and 2775 amperes at 60-cycle alternating current.

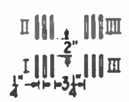
B—For a direct-current bus where maximum installations will not exceed 5725 amperes, 5275 amperes for 25-cycle bus, and 4450 amperes for 60-cycle bus.

C—For a direct-current bus where the maximum capacity of the bus exceeds 5725 amperes but is not greater than limit given.

D—For direct-current or alternating-current bus when the maximum capacity exceeds the maximum capacity given for C or B, respectively.

E—For an alternating-current bus where the maximum capacity is not greater than B, and where minimum spacing of phases is required.

For capacities above the maximum indicated on the chart, the problem should receive special consideration.



Arrangement Of Laminae For The Maximum Bus Bar Section.

Recommendations are given for a temperature rise of 30 deg. C. over room temperature, and the ampere ratings shown are maximum ratings on this basis. The chart is computed on the basis of using transpositions and paralleling connections to give the best distributions of current in each individual lamination.

Rigid supporting of all conductors is necessary, not only for appearance, but to withstand any electromagnetic stresses that abnormal conditions may produce. The short-circuit force measured in pounds involves several factors, as for instance, frequency and reactance of circuit, construction of supports, spacing and shape of conductors, etc. Problems of this nature, encountered in the installation of a switchboard, should be referred to the manufacturer for advice. A method is shown in Fig. 45 whereby busbar supports are offset to accommodate additional bars.

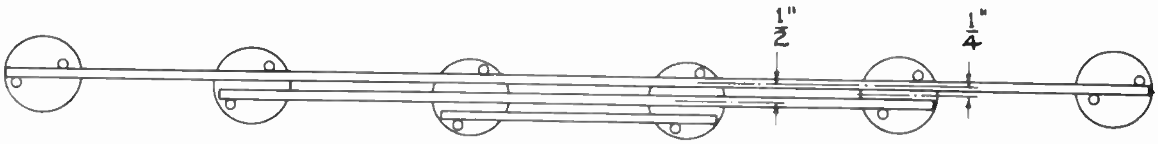


Fig. 45. Method of Offsetting Busbar Supports

Where the bus is held by two pins in the top of the insulator, and where adjustment is made for additional bars in the bus by turning the insulator, it becomes necessary to offset the supports as illustrated.

In alternating-current installations, iron parts, such as supports, conduits, floor beams, etc., must not be placed between the different conductors of a circuit in a manner to form magnetic loops around a single conductor; and in dealing with capacities of about 2000 amperes and above, care must be taken to avoid large masses of iron in close proximity to the circuit, otherwise the iron will heat. This applies even to reinforcing material in concrete compartments.

To avoid "corona effect" on high-tension conductors the following sizes should be used as minimum for the spacings given in the following table:

Volts	Sizes B.&S.
35,000	No. 6
50,000	No. 4
73,000	No. 1
115,000	No. 4/0

The following rules apply (up to 15,000 volts) for:

Direct-current switchboards.

Alternating-current switchboards with lever switches.

Alternating-current switchboards with oil circuit breakers on panel or panel frame.

Alternating-current arrangements with remote-controlled oil circuit breakers on pipe framework, or in cells when the buses are mounted on open framework.

Rectangular bars are supplied for buses, and material for insulating the bars is supplied only when requested by the customer. If the customer is furnishing his own bus and bar connections, he must be careful in bending round conductors so that the conductors shall not be cracked at the bend. Make the bend on a sufficient radius to avoid this. Bend all connections and conductors before attaching them, so that no breakage of apparatus will be encountered. Formulas for determining the developed length of rectangular copper bars with various forms of bends are shown in Fig. 46. A tabulation is contained on page 32 which shows the size of bolt holes and their spacings for copper bar bolted connections. When special connections involve long runs with difficult bends, wire may be used as a conductor.

For rigidity, one and one-half inch by one-eighth inch should be the smallest section used for oil circuit breaker connections. Long vertical bars of this size should be as nearly straight as possible, and should not exceed approximately five feet in length unless a stay insulator is supplied.

The following plan is followed by the General Electric Company in relation to the use of insulated wire:

(a) When the length of the greater number of connections in one circuit will be such that the insulated portion of the conductor (after stripping the ends) will be one foot or less, rectangular bars are chosen in preference to wire.

(b) For short pieces (where eight inches or less of insulation would be left after stripping the ends) these connections should be made of bare rod, and the construction force is relied upon to insulate properly the connection when completing the installation.

STANDARD CABLE TERMINALS

General Electric cable terminals are of ample design for all conditions of service if properly installed. The temperature-rises in them on normal loads and overloads are less than in the cables for which they are used.

Too much importance can never be attached to the soldering of the terminals and to bolting or clamping them. Unsoldering of cable joints under overloads is the result of poor soldering,

STANDARD BOLTING FOR BUS AND CONNECTION BARS

(All Dimensions in Inches)

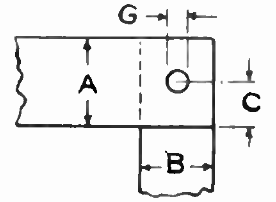


Fig. a

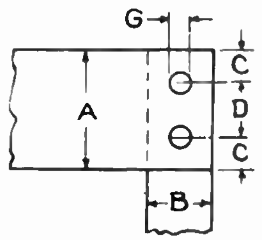


Fig. b

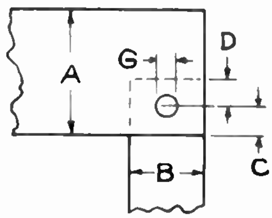


Fig. c

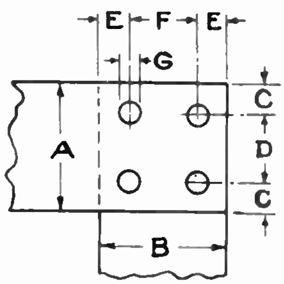


Fig. d

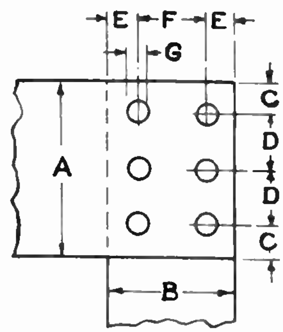


Fig. e

Bars A	Bars B	Fig.	C	D	E	F	G	Bolts
1	1	a	1/2				15/32	3/8
1 1/2	1	a	3/4				15/32	3/8
1 1/2	1 1/2	a	3/4				5/8	1/2
2	1	a	1				15/32	3/8
2	1 1/2	a	1				5/8	1/2
2	2	a	1				5/8	1/2
2 1/4	1	a	1 1/8				15/32	3/8
2 1/4	1 1/2	a	1 1/8				5/8	1/2
2 1/4	2	a	1 1/8				5/8	1/2
2 1/4	2 1/4	a	1 1/8				5/8	1/2
2 1/2	1	b	1/2	1 1/2			15/32	3/8
2 1/2	1 1/2	b	1/2	1 1/2			15/32	3/8
2 1/2	2	b	1/2	1 1/2			15/32	3/8
2 1/2	2 1/4	b	1/2	1 1/2			15/32	3/8
2 1/2	2 1/2	d	1/2	1 1/2	1/2	1 1/2	15/32	3/8
3	1	b	5/8	1 3/4			15/32	3/8
3	1 1/2	b	5/8	1 3/4			15/32	3/8
3	2	b	5/8	1 3/4			5/8	1/2
3	2 1/4	b	5/8	1 3/4			5/8	1/2
3	2 1/2	d	5/8	1 3/4	1/2	1 1/2	15/32	3/8
3	3	d	5/8	1 3/4	5/8	1 3/4	15/32	3/8
4	1	c	1	1/2			15/32	3/8
4+	1	c	1	1/2			15/32	3/8
4	1 1/2	b	3/4	2 1/2			15/32	3/8
4	2	b	3/4	2 1/2			5/8	1/2
4	2 1/4	b	3/4	2 1/2			5/8	1/2
4	2 1/2	d	3/4	2 1/2	1/2	1 1/2	15/32	3/8
4	3	d	3/4	2 1/2	5/8	1 3/4	15/32	3/8
4	4	d	3/4	2 1/2	3/4	2 1/2	5/8	1/2
5	1 1/2	c	1	3/4			5/8	1/2
5+	1 1/2	c	1	3/4			5/8	1/2
5	2	c	1	1			5/8	1/2
5+	2	c	1	1			5/8	1/2
5	2 1/4	c	1	1			5/8	1/2
5+	2 1/4	c	1	1			5/8	1/2
5	2 1/2	d	1	3	1/2	1 1/2	15/32	3/8
5	3	d	1	3	5/8	1 3/4	5/8	1/2
5	4	d	1	3	3/4	2 1/2	5/8	1/2
5	5	d	1	3	1	3	5/8	1/2
6	2 1/2	d	1 1/4	3 1/2	1/2	1 1/2	15/32	3/8
6	3	d	1 1/4	3 1/2	5/8	1 3/4	5/8	1/2
6	4	d	1 1/4	3 1/2	3/4	2 1/2	5/8	1/2
6	5	d	1 1/4	3 1/2	1	3	5/8	1/2
6	6	d	1 1/4	3 1/2	1 1/4	3 1/2	5/8	1/2
8	3	d	1 1/2	5	5/8	1 3/4	5/8	1/2
8	4	d	1 1/2	5	3/4	2 1/2	5/8	1/2
8	5	d	1 1/2	5	1	3	5/8	1/2
8	6	d	1 1/2	5	1 1/4	3 1/2	5/8	1/2
8	8	d	1 1/2	5	1 1/2	5	5/8	1/2
10	4	e	1 1/2	3 1/2	3/4	2 1/2	5/8	1/2
10	5	e	1 1/2	3 1/2	1	3	5/8	1/2
10	6	e	1 1/2	3 1/2	1 1/4	3 1/2	5/8	1/2
10	8	e	1 1/2	3 1/2	1 1/2	5	5/8	1/2

poor bolted contact, or both. The practice of soldering in rope-core cable without first removing the core is never recommended. The core may be bored out with a wood bit, and a metal plug of proper size inserted in its place.

Weight of cables and magnetic stresses must not be transmitted to the terminals; proper supports must be provided for the cable.

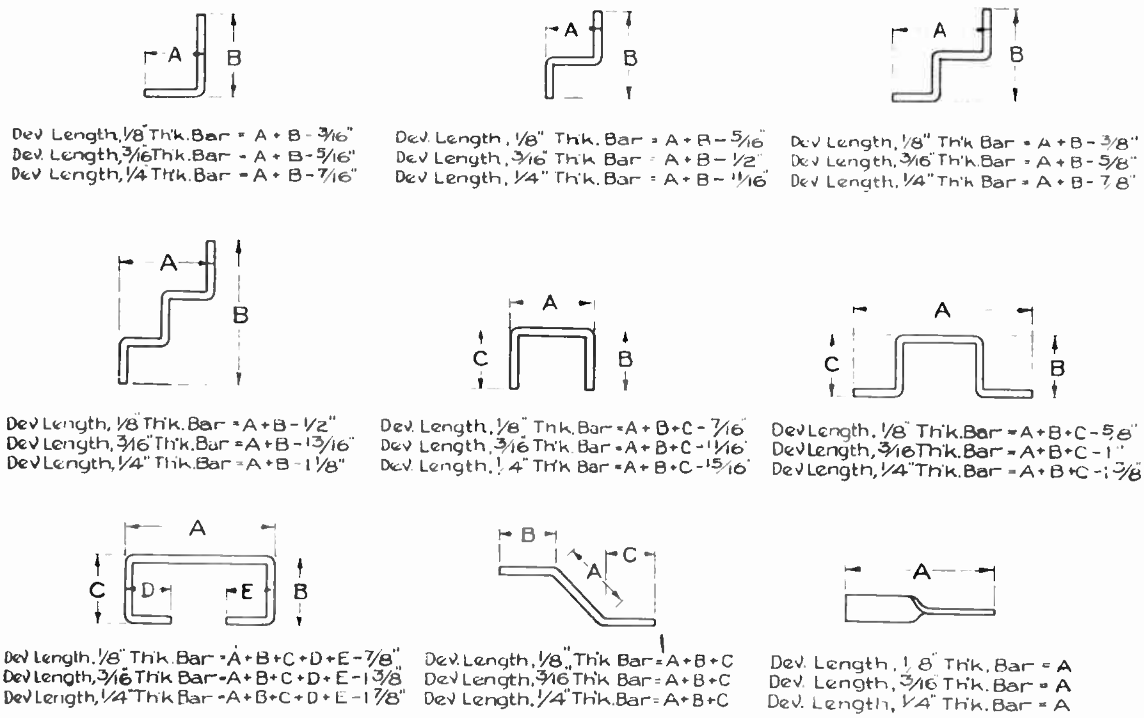


Fig. 46. Formulas for Determining Developed Length of Copper Bars with Various Bends (Bars are bent with a 3/8-in. radius)

The following tabulations show the current-carrying capacity of conductors and cables which are recommended under certain specified conditions. These conditions include station, substation, and switchboard wiring and connections to and from apparatus of all kinds. They do not include internal connections of apparatus nor connections from the interior of apparatus to connection boards or terminals, the size of these being dependent upon design conditions. All connection boards, terminals, etc., should be arranged to use the number and sizes of cables as described in the following text and tabulations:

Index to Terminals and Cables

Selection of Terminal Sizes

(1) All apparatus, exclusive of synchronous converters, maximum rated. (Includes machines, switchboards, transformers, etc.) Select from Table No. 1 according to maximum current.

(2) All new apparatus, "A" rated (exclusive of synchronous converters). Increase normal current by 25 per cent and select terminals from Table No. 1.

(3) All new apparatus, "B" rated (exclusive of synchronous converters). Increase normal current by 50 per cent and select terminals from Table No. 1.

(4) To avoid making sweeping changes, old machines "A" or "B" rated, or such machines

with a maximum rating may use terminals as per Table No. 2 up to and including 1075 amperes computed to include the overload rating. For larger ampere capacities, use Table No .1. Switchboards will follow Table No. 1 in all cases. This may result in the switchboard and machine using slightly different terminals, but this should cause no inconvenience.

(5) Induction motors, with squirrel-cage winding. Select terminals from Table No. 1.

(6) Synchronous converters. Tables No. 3 and 4 assign terminal sizes for each standard machine.

(7) Direct-current equalizer cables. Table No. 6 shows the size equalizer to be used after the main cables have been determined from the foregoing instruction.

Method of Figuring Maximum Current

For alternating-current apparatus, the kv-a. rating and not the kw. rating should be used to determine the current capacity.

The voltage used in calculating the maximum current should be the exact voltage rating of the machine.

In as much as many cables and switchboard devices will reach their maximum temperature in one or two hours time, such overload ratings must be considered as continuous ratings in so far as the selection of terminals is concerned. The only reason for departing from this rule and permitting the use of terminals listed in Table No. 2 is as stated in (4).

Cable Sizes

The carrying capacity of a cable depends largely on local conditions. For example, a 500,000-cir. mils cable may carry from 300 to 600 amperes with approximately the same temperature rise.

It is obvious, therefore, that all conditions must be known before selecting the size of cable and that the standardization of cable terminals must be such as to provide for the largest size of cable which necessity may require.

Great care has been exercised in standardizing the terminal sizes so that each size of terminal can be used for three sizes of cables as given in Table No. 7.

Listing of Terminals on Outline Drawings

Outline drawings specify the diameter of cable holes for all terminals provided for external cable connections. The size of cable which should be used therein is of no concern to the designer of machine or switchboard. But in order to give the customer some idea of what size cable may be used, the outline drawing gives the "Maximum cir. mils cross section of copper which will ordinarily be required."

See example below.

The arrangement of cables, when more than one is used per phase for alternating-current work, is particularly important. Therefore, outline drawings of such apparatus bear a caution as follows:

"The arrangement and spacing of cables or bars shall be such as regards self and mutual induction and proximity to magnetic metals, etc., that each conductor of any phase will carry its pro rata of the total current."

EXAMPLE

Connections	Number of Terminals per Phase or Polarity	Size in Inches of Cable Hole in Terminals	Max. Cir. Mils Cross Section of Copper Ordinarily Required
Main leads	2	1.699	2—1,250,000 cir. mils
Field Leads	1	.419	1/0 AWG
Exciter Leads	1	.586	4/0 AWG

TABLE NO. 1

SIZES OF MAIN LINE TERMINALS TO BE USED ON ALL MAXIMUM RATED MACHINES AND ALL NEW A AND B RATED MACHINES

(The current rating of an "A" or "B" machine is determined by including the overload.)

Maximum Ampere Capacity	Size of Terminal in Inches (Diameter Cable Hole)	Max. Cir. Mils Cross Section Ordinarily Required
8	.137	No. 12 AWG or 19/25
15	.137	No. 10 AWG or 19/22
25	.20	No. 8 AWG
35	.20	No. 6 AWG
50	.25	No. 4 AWG
70	.3125	No. 2
110	.419	No. 1/0
130	.461	No. 2/0
175	.586	No. 4/0
225	.669	300,000 cir. mils
290	.776	400,000 cir. mils
360	.881	500,000 cir. mils
450	.944	600,000 cir. mils
550	1.084	750,000 cir. mils
675	1.209	1,000,000 cir. mils
775	1.461	1,250,000 cir. mils
900	1.699	1,500,000 cir. mils
1075	2.012	2,000,000 cir. mils
1300	2—2.012	2—1,250,000 cir. mils
1750	2—2.012	2—1,500,000 cir. mils
2100	2—2.012	2—2,000,000 cir. mils
2600	4—2.012	4—1,250,000 cir. mils
3100	4—2.012	4—1,500,000 cir. mils
4200	4—2.012	4—2,000,000 cir. mils
5200	6—2.012	6—1,500,000 cir. mils
6200	6—2.012	6—2,000,000 cir. mils

NOTE.—A rating—normal load continuous—25 per cent overload for 2 hours.
B rating—normal load continuous—50 per cent overload for 2 hours.

TABLE NO. 2

SIZES OF TERMINALS FOR OLD A AND B RATED MACHINES

Normal Ampere Rating of "A" Machines	Normal Ampere Rating of "B" Machines	Diameter in Inches of Cable Holes	Maximum Size of Cable
9	9	.137	No. 12 AWG or 19/25
14	14	.137	No. 10 AWG or 19/22
24	24	.20	No. 8 AWG
36	36	.20	No. 6 AWG
56	56	.25	No. 4 AWG
84	84	.3125	No. 2 AWG
124	124	.419	No. 1/0 AWG
169	169	.586	No. 3/0 AWG
184	184	.586	No. 4/0 AWG
224	224	.625	250,000 cir. mils
264	264	.669	300,000 cir. mils
324	324	.776	400,000 cir. mils
374	374	.881	500,000 cir. mils
499	499	1.084	750,000 cir. mils
649	649	1.209	1,000,000 cir. mils
749	749	1.461	1,250,000 cir. mils
860	860	1.699	1,500,000 cir. mils

For larger current capacities, see Table No. 1.

TABLE NO. 3

SIZES OF CABLES AND TERMINALS FOR 240/275-VOLT SYNCHRONOUS CONVERTER

"B" Rating 240/275 V.	Max. Rating 240/300 V.	D-c. Cables	A-c. Cables	Starting	Equalizer
3-Phase					
100 kw.	*120 kw.	500,000 cir. mils	500,000 cir. mils	500,000	500,000
150 kw.		1,000,000 cir. mils	1,000,000 cir. mils	400,000	400,000
200 kw.		1,250,000 cir. mils	1,250,000 cir. mils	500,000	500,000
300 kw.		2—1,000,000 cir. mils	2—1,000,000 cir. mils	400,000	1,000,000
6-Phase with or without Booster					
150 kw.	*180 kw.	1,000,000 cir. mils	400,000 cir. mils	400,000	400,000
200 kw.	*240 kw.	2— 750,000 cir. mils	750,000 cir. mils	4/0	750,000
300 kw.	328/440	2—1,000,000 cir. mils	1,000,000 cir. mils	400,000	1,000,000
500 kw.	530/660	2—2,000,000 cir. mils	2,000,000 cir. mils	500,000	2,000,000
750 kw.	800/1000	4—1,250,000 cir. mils	4—1,250,000 cir. mils	500,000	2—1,250,000
1000 kw.	1060/1330	4—2,000,000 cir. mils	2—2,000,000 cir. mils	1,000,000	2—2,000,000

* Rated 270 volts instead of 240/300 volts.
For larger machines use bar connections.

TABLE NO. 4

SIZES OF CABLES AND TERMINALS FOR 600-VOLT SYNCHRONOUS CONVERTERS

For special converters having voltage ratings different from those listed in Tables No. 3 and 4, select terminals according to current ratings given in Table No. 4. If calculated current falls between the ratings given, choose the next larger rating.

"B" Kw.	Rating Nor. Amp.	Maximum Rating Kw.	Maximum Rating Amp.	D-c. Cables	A-c. Cables	Starting	Equalizer
3-Phase							
100	166	120	200	4/0	4/0	4/0	4/0
150	250	180	300	400,000 cir. mils	400,000 cir. mils	400,000 cir. mils	400,000 cir. mils
200	333	240	400	500,000 cir. mils	500,000 cir. mils	500,000 cir. mils	500,000 cir. mils
300	500	360	600	750,000 cir. mils	750,000 cir. mils	750,000 cir. mils	750,000 cir. mils
400	666	480	800	1,250,000 cir. mils	1,250,000 cir. mils	500,000 cir. mils	500,000 cir. mils
6-Phase							
300	500	360	600	750,000 cir. mils	400,000 cir. mils	400,000 cir. mils	400,000 cir.mils
400	666	480	800	1,250,000 cir. mils	500,000 cir. mils	4/0	500,000 cir.mils
500	833	600	1000	2— 750,000 cir. mils	750,000 cir. mils	4/0	750,000 cir.mils
750	1250	900	1500	2—1,000,000 cir. mils	1,000,000 cir. mils	400,000 cir. mils	1,000,000 cir.mils
1000	1666	1200	2000	2—1,500,000 cir. mils	1,500,000 cir. mils	400,000 cir. mils	1,500,000 cir.mils
1500	2500	1800	3000	4—1,250,000 cir. mils	2—1,250,000 cir. mils	500,000 cir. mils	2—1,250,000 cir.mils
2000	3330	2400	4000	4—1,500,000 cir. mils	2—1,500,000 cir. mils	750,000 cir. mils	2—1,500,000 cir.mils

STANDARD TERMINALS FOR ABOVE CABLES

Size of Cable	Diameter in In. of Cable Hole	Size of Cable	Diameter in In. of Cable Hole	Size of Cable	Diameter in In. of Cable Hole
4/0	.586	750,000	1.084	1,500,000	1.699
400,000	.776	1,000,000	1.209	2,000,000	2.012
500,000	.881	1,250,000	1.461		

LOCAL CONDITIONS AND TERMINALS AND CABLES

The application of cable terminals should be determined from the foregoing instructions. In order to select proper cables for interconnection between machines, switchboards, transformers, etc., a thorough knowledge is necessary of how the cables are to run in the station and of other local conditions bearing on the current capacity of cables.

The sizes of terminals proposed under Table No. 1 are intended to provide for the largest cables which will ordinarily be employed. Under favorable circumstances such cables are unnecessarily large, which accounts for the latitude given for using smaller cables as listed under columns "Y" and "Z" in Table No. 8. But careful consideration must be given to the following points before determining on the use of smaller cables. In fact, occasion may arise when larger cables than those listed in column "X" may be necessary.

(1) Whether cables are single or multiple conductor.

(2) If hemp core is used as recommended.

(3) The nature and thickness of the insulating covering.

(4) Whether circulation of air is free or restricted for cables supported in the open—a very important factor.

(5) When run in ducts, if the heat can be readily carried away from all ducts.

(6) If self or mutual inductance will disturb the distribution of current between conductors of the same or different circuits.

(7) The room temperature. This is important in determining whether the total temperature will be injurious to the insulation.

(8) If cables are adjacent to or affected by other heat-producing equipment.

(9) If alternating-current cables are in proximity to any magnetic metal.

It is obvious from the above that no set rules can be made for selecting the size of cables, but as a general guide Table No. 9 may be used.

Where more than two cables are used in multiple per phase on 50- or 60-cycle circuits, a very careful study of all conditions is necessary in order to determine the proper physical arrangement of cables to minimize mutual induction.

TABLE NO. 5

SIZES OF CABLES AND TERMINALS FOR RAILWAY MOTOR-GENERATOR SETS

Based on average operation at normal rated load and favorable conduit layout. Applicable only under above conditions and for railway service.

For alternating-current cables and terminals, use Condition "X," Table No. 8, based on full load.

Direct Current

Machine No.	Rating Normal Amperes	Terminal Size of Cable Hole	Main Cables per Circuit Size in Cir. Mils	Equalizer Cable Size in Cir. Mils
		600 Volts		
200	333	.881	500,000	500,000
300	500	1.084	750,000	750,000
500	833	2—1.084	2— 750,000	1— 750,000
750	1250	2—1.209	2—1,000,000	1—1,000,000
1000	1667	2—1.699	2—1,500,000	1—1,500,000
1500	2500	4—1.461	4—1,250,000	2—1,250,000
2000	3333	6—1.461	6—1,250,000	3—1,250,000
		1500 Volts		
300	200	.669	300,000	300,000
500	333	.881	500,000	500,000
750	500	1.084	750,000	750,000
1000	667	1.461	1,250,000	600,000
1500	1000	2—1.209	2—1,000,000	1—1,000,000
2000	1333	2—1.461	2—1,250,000	1—1,250,000
		3000 Volts		
1000	333	.881	500,000	500,000
1500	500	1.084	750,000	750,000
2000	667	1.461	1,250,000	600,000
3000	1000	2—1.205	2—1,000,000	1—1,000,000

TABLE NO. 6

SIZES AND NUMBER OF EQUALIZER CABLES AND TERMINALS

The following table shows the sizes of equalizer cables and terminals to be used after the main cables and terminals have been determined.

Main Cables		Equalizer Cables	
Size in Inches of Cable Holes in Terminal	Maximum Size of Cables	Size in Inches of Cable Holes in Terminal	Maximum Size of Cables
.137	19/25	.137	19/25
.137	19/22	.137	19/22
.20	No. 8 AWG	.20	No. 8 AWG
.20	No. 6 AWG	.20	No. 6 AWG
.25	No. 4 AWG	.25	No. 4 AWG
.3125	No. 2 AWG	.3125	No. 2 AWG
.419	1/0	.419	1/0
.461	2/0	.461	2/0
.586	4/0	.586	4/0
.669	300,000 cir. mils	.669	300,000 cir. mils
.776	400,000 cir. mils	.776	400,000 cir. mils
.881	500,000 cir. mils	.881	500,000 cir. mils
.944	600,000 cir. mils	.944	600,000 cir. mils
1.084	750,000 cir. mils	1.084	750,000 cir. mils
1.209	1,000,000 cir. mils	.881	500,000 cir. mils
1.461	1,250,000 cir. mils	.944	660,000 cir. mils
1.699	1,500,000 cir. mils	1.084	750,000 cir. mils
2.012	2,000,000 cir. mils	1.209	1,000,000 cir. mils
2—1.084	2— 750,000 cir. mils	1.084	750,000 cir. mils
2—1.209	2—1,000,000 cir. mils	1.209	1,000,000 cir. mils
2—1.461	2—1,250,000 cir. mils	1.461	1,250,000 cir. mils
2—1.699	2—1,500,000 cir. mils	1.699	1,500,000 cir. mils
2—2.012	2—2,000,000 cir. mils	2.012	2,000,000 cir. mils
4—1.209	4—1,000,000 cir. mils	2—1.209	2—1,000,000 cir. mils
4—1.461	4—1,250,000 cir. mils	2—1.461	2—1,250,000 cir. mils
4—1.699	4—1,500,000 cir. mils	2—1.699	2—1,500,000 cir. mils
4—2.012	4—2,000,000 cir. mils	2—2.012	2—2,000,000 cir. mils
6—1.461	6—1,250,000 cir. mils	3—1.461	3—1,250,000 cir. mils
6—1.699	6—1,500,000 cir. mils	3—1.699	3—1,500,000 cir. mils
6—2.012	6—2,000,000 cir. mils	3—2.012	3—2,000,000 cir. mils

TABLE NO. 7

CABLES THAT WILL FIT STANDARD TERMINALS

(This tabulation is given for general interest)

Dia. in Inches of Cable Holes	CABLE SIZES					
	Without Rope Core		With Rope Core			
.137	19/22	19/25				
.20	No. 6 AWG	No. 8 AWG 19/22				
.25	No. 4 AWG	No. 6 AWG No. 8				
.3125	No. 2 AWG	No. 4 AWG No. 6				
.419	1/0 AWG	No. 2 AWG No. 4				
.461	2/0 AWG	1/0—No. 2 AWG				
.586	4/0 AWG	2/0—1/0 AWG				
.669	300,000 cir. mils	4/0 AWG	2/0 AWG			
.776	400,000 cir. mils	300,000 cir. mils	4/0 AWG			
.881	500,000 cir. mils	400,000 cir. mils	300,000 cir. mils			
.944	600,000 cir. mils	500,000 cir. mils	400,000 cir. mils			
1.084	750,000 cir. mils	600,000 cir. mils	500,000 cir. mils	750,000 cir. mils		
1.209	1,000,000 cir. mils	750,000 cir. mils	600,000 cir. mils	1,000,000 cir. mils*	750,000 cir. mils	
1.461	1,250,000 cir. mils	1,000,000 cir. mils	750,000 cir. mils	1,250,000 cir. mils*	1,000,000 cir. mils	750,000 cir. mils
1.699	1,500,000 cir. mils	1,250,000 cir. mils	1,000,000 cir. mils	1,500,000 cir. mils*	1,250,000 cir. mils	1,000,000 cir. mils
2.012	2,000,000 cir. mils	1,500,000 cir. mils	1,250,000 cir. mils	2,000,000 cir. mils*	1,500,000 cir. mils	1,250,000 cir. mils

* Cables thus marked are slightly larger than the terminal holes; therefore, the copper strands must be shifted toward the center after the rope is removed.

The current-carrying capacity of a cable for a fixed temperature rise is dependent on many factors, such as: the diameter of the cable, which determines its radiation surface; the thickness and kind of insulation, which determine the temperature drop to allow for a certain flow of heat; the position of the cable which may allow for free air or restricted circulation of air; and the installation of cables in ducts where the heat dissipation is a function of the duct. It is obvious that definite current ratings cannot be assigned to the various sizes of cables; therefore, many curves were prepared to show suitable ampere ratings for cables of all classes and operating under various conditions with the result that there was a wide spread between the maximum and the minimum safe rating for each size of cable. This spread was divided into three zones known as X, Y, and Z. The X zone, or condition, was the most unfavorable, and the Z the most favorable ordinarily met with in practice.

Table No. 9 is a general guide to show the application of the X, Y, and Z conditions for different sizes of cables suspended in free air and in ducts with different kinds of insulation.

It will be noted that the classifications are not applied beyond 1075 amperes; that is, they stop at the last rating of single cables. The reason is that it is impracticable to assign ratings for large groups of cables in multiple without knowing the exact conditions. For direct-current cables in multiple, the heat from one cable will affect the temperature of another; with the cables closely spaced, the flow of circulating air may be seriously reduced. For alternating-current cables paralleled in groups, similar disadvantageous

TABLE NO. 8

STANDARD SIZES OF CABLES AND TERMINALS

For old "A" and "B" rated machines, use Table No. 2.
For synchronous converters, use Tables No. 3 and 4.
For equalizer cables, use Table No. 6.
For squirrel-cage induction motors, use Condition "X", Table No. 8.

Select size of terminal from these sizes.

Alternative cable ratings depending on local conditions. Select size of cable from succeeding columns.

Maximum Ampere Capacity	Size in Inches of Terminal (Dia. of Cable Hole)	Condition "X"	Condition "Y"	Condition "Z"
8	.137	19/25	19/25	19/25
15	.137	19/22	19/25	19/25
25	.20	No. 8	19/22	19/22
35	.20	No. 6	No. 8	No. 8
50	.25	No. 4	No. 6	No. 6
70	.3125	No. 2	No. 4	No. 6
110	.419	1/0	No. 2	No. 4
130	.461	2/0	1/0	No. 2
175	.586	4/0	2/0	1/0
225	.669	300,000 cir. mils	4/0	2/0
290	.776	400,000 cir. mils	300,000 cir. mils	4/0
360	.881	500,000 cir. mils	400,000 cir. mils	300,000 cir. mils
450	.944	600,000 cir. mils	500,000 cir. mils	400,000 cir. mils
550	1.084	750,000 cir. mils	600,000 cir. mils	500,000 cir. mils
675	1.209	1,000,000 cir. mils	750,000 cir. mils	600,000 cir. mils
775	1.461	1,250,000 cir. mils	1,000,000 cir. mils	750,000 cir. mils
900	1.699	1,500,000 cir. mils	1,250,000 cir. mils	1,000,000 cir. mils
1075	2.012	2,000,000 cir. mils	1,500,000 cir. mils	1,250,000 cir. mils
1300	2—1.699	2—1,250,000 cir. mils	2—1,000,000 cir. mils	1—1,500,000 cir. mils
1750	2—1.699	2—1,500,000 cir. mils	2—1,250,000 cir. mils	2—1,250,000 cir. mils
2100	2—2.012	2—2,000,000 cir. mils	2—1,500,000 cir. mils	2—1,250,000 cir. mils
2600	4—2.012	4—1,250,000 cir. mils	2—2,000,000 cir. mils	2—1,500,000 cir. mils
3100	4—2.012	4—1,500,000 cir. mils	4—1,250,000 cir. mils	2—2,000,000 cir. mils
4200	4—2.012	4—2,000,000 cir. mils	4—1,500,000 cir. mils	4—1,250,000 cir. mils
5200	6—2.012	6—1,500,000 cir. mils	4—2,000,000 cir. mils	4—1,500,000 cir. mils
6200	6—2.012	6—2,000,000 cir. mils	6—1,500,000 cir. mils	4—2,000,000 cir. mils

All cables 750,000 cir. mils and larger should have rope core. This is essential for alternating-current circuits and generally advantageous for direct-current circuits.

Single-conductor lead-covered cables above 600,000 cir. mils, 25 cycles, and 3/0 AWG, 60 cycles, should be used only after special consideration has been given to the lead-sheath current.

TABLE NO. 9

GUIDE FOR CHOOSING "X," "Y," OR "Z" CONDITION

Single-conductor Cable

Maximum Ampere Capacity	In Free Air: Varnished Cambric or Paper, Up to 750 V.	In Free Air: Varnished Cambric or Paper, Up to 3500 V.	In Free Air: Varnished Cambric or Paper, Up to 15000 V.	In Free Air: Rubber, Up to 750 V.	In Ducts: Varnished Cambric or Paper, Up to 750 V.	In Ducts: Varnished Cambric or Paper, Up to 3500 V.	In Ducts: Varnished Cambric or Paper, Up to 15000 V.	In Ducts: Rubber, Up to 750 V.
175	Z	Z	Y	Y	Z	Y	Y	Y
360	Z	Y	Y	Y	Y	Y	Y	Y
675	Z	Y	Y	Y	Y	Y	Y	X
1075	Z	Y	Y	Y	X	X	X	X

Twin- or Triple-conductor Cables

Maximum Ampere Capacity	In Free Air: Varnished Cambric or Paper, Up to 15000 V.	In Free Air: Rubber, Up to 750 V.	In Ducts: Varnished Cambric or Paper, Up to 15000 V.	In Ducts: Rubber, Up to 750 V.
175	Y	X	Y	X
550	Y	X	X	X

For voltages above 15,000, special consideration must be given to dielectric losses as well as to thermal properties of cables.

conditions will be met, and in addition, the distribution of current between conductors due to self and mutual inductance may be so great that the temperature of any individual cable will be far in excess of that which the insulation can safely and properly withstand. It is, therefore, suggested that anyone not familiar with the grouping of heavy cables, alternating-current or direct-current, should not be guided by these tables, but should seek information from the General Electric Company.

CABLE AND CONDUIT DATA FOR POWER STATIONS

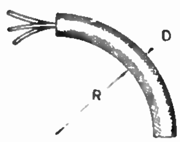
(1) Refer to pages 35 to 40 for ampere capacity of cables.

(2) All cables tabulated herein, 750,000 cir. mils and larger, have rope core.

(3) Conduit sizes are approximately 35 per cent greater in diameter than largest cable recommended for them. Length of run and number of bends are dependent upon cable diameters and type of covering of cables. Cables approximately 1.25 inch diameter or less can be pulled in conduit runs 100 feet in length having not to exceed the equivalent of three 90-deg. bends, a bend at which a cable is introduced not being included. For larger cables, bends should be avoided, manholes and pull boxes being used at turning points.

(4) CABLE ENDS

Non-Leaded: Minimum	Non-Leaded: Recommended	Leaded: Minimum	Leaded: Recommended
R = 6D	R = 9D	R = 6D	R = 12D



(5) Ducts should, wherever possible, be properly drained.

(6) When there is sufficient assurance that no moisture will come in contact with cables, weatherproof braided covering may be used; otherwise leaded cables are recommended.

(7) Condulets should be used on all iron conduit terminating at apparatus such as motors, rheostats, etc. Bushings are sufficient back of switchboards and at apparatus provided with terminating boxes, which fit conduit.

(8) Conductors on only a single apparatus should be carried in same conduit.

(9) Conduit smaller than three-fourths inch should be used only on lighting circuits.

(10) Cable end bells are recommended with lead covered cable multi-conductor, 750 volts and above, single-conductor, 2000 volts and above, and in all cases where paper insulation is used.

(11) For alternating-current circuits, multi-conductor cables are recommended. Single-conductor leaded cable should not be used for alternating current except in special cases. Do not run single-conductor alternating-current cables in iron conduit.

(12) Where many conductors are paralleled, consult the General Electric Company with reference to distribution of ducts to best advantage for heat dissipation and induction effects.

(13) Where fiber conduit is laid in concrete, use Harrington or equivalent joint. Otherwise use screw joints.

CABLE AND CONDUIT DATA FOR POWER STATIONS

Size of Cable in B.& S. or Circular Mils	Bare Diam. in In. (Always Use Cable Instead of Wire When Run in Conduit)		On Insulators	In Conduit or Ducts Dry				In Conduit or Ducts Wet			
			VARNISHED CAMBRIC								
			Double Braid Flame-proof	Double-braid Weatherproof				Lead Covered			
				Single Con-ductor	Nominal Size of Conduit	Triple Con-ductor	Nominal Size of Conduit	Single Con-ductor	Nominal Size of Conduit	Triple Conductor	Nominal Size of Conduit
600 VOLTS											
No. 12	0.081 wire 0.092 cable	Thickness of insulation	3/64	3/64	½						
		Outside dia.	0.21	0.26							
No. 8	0.128 wire 0.147 cable	Thickness of insulation	3/64	3/64	½						
		Outside dia.	0.27	0.35							
No. 6	0.162 wire 0.186 cable	Thickness of insulation	1/16	1/16	½	3/64-1/64	¼	1/16-3/64	½	3/64-1/64-1/16	1¼
		Outside dia.	0.38	0.42		0.78		0.42		0.78	
No. 4	0.204 wire 0.234 cable	Thickness of insulation	1/16	1/16	¾	3/64-1/64	1¼	1/16-3/64	¾	3/64-1/64-5/64	1¼
		Outside dia.	0.42	0.47		0.91		.046		0.91	
No. 2	0.258 wire 0.296 cable	Thickness of insulation	1/16	1/16	¾	3/64-1/64	1½	1/16-1/16	¾	3/64-1/64-5/64	1½
		Outside dia.	0.51	0.55		1.04		0.56		1.04	
1/0	0.325 wire 0.375 cable	Thickness of insulation	5/64	5/64	1	1/16-1/64	2	5/64-1/16	1	1/16-1/64-3/32	2
		Outside dia.	0.61	0.66		1.32		0.67		1.32	
2/0	0.365 wire 0.419 cable	Thickness of insulation	5/64	5/64	1	1/16-1/64	2	5/64-1/16	1	1/16-1/64-3/32	2
		Outside dia.	0.65	0.70		1.41		0.71		1.41	
4/0	0.460 wire 0.533 cable	Thickness of insulation	5/64	5/64	1¼	1/16-1/64	2½	5/64-5/64	1¼	1/16-1/64-7/64	2½
		Outside dia.	0.75	0.81		1.75		0.85		1.75	
250,000	0.576	Thickness of insulation	3/32	3/32	1¼	5/64-1/32	2½	3/32-5/64	1¼	5/64-1/32-7/64	2½
		Outside dia.	0.89	0.89		1.88		0.93		1.88	
300,000	0.631	Thickness of insulation	3/32	3/32	1¼	5/64-1/32	3	3/32-5/64	1¼	5/64-1/32-7/64	3
		Outside dia.	0.99	0.99		2.01		0.99		2.01	
400,000	0.729	Thickness of insulation	3/32	3/32	1¼	5/64-1/32	3	3/32-5/64	1¼	5/64-1/32-1/8	3
		Outside dia.	1.09	1.09		2.24		1.09		2.24	
500,000	0.815	Thickness of insulation	3/32	3/32	1½	5/64-1/32	3	3/32-3/32	1½	5/64-1/32-1/8	3
		Outside dia.	1.17	1.17		2.44		1.20		2.44	
600,000	0.893	Thickness of insulation	7/64	7/64	2	3/32-1/32	3½	7/64-3/32	2	3/32-1/32-1/8	3½
		Outside dia.	1.28	1.28		2.68		1.31		2.68	
750,000	1.14	Thickness of insulation	7/64	7/64	2½			7/64-3/32	2½		
		Outside dia.	1.54	1.54				1.56			
1,000,000	1.35	Thickness of insulation	7/64	7/64	2½			7/64-3/32	2½		
		Outside dia.	1.75	1.75				1.77			
1,250,000	1.56	Thickness of insulation	4/32	4/32	3			4/32-7/64	3		
		Outside dia.	1.99	1.99				2.04			
1,500,000	1.78	Thickness of insulation	4/32	4/32	3½			4/32-7/64	3½		
		Outside dia.	2.23	2.23				2.26			
2,000,000	2.14	Thickness of insulation	4/32	4/32	3½			4/32-7/64	3½		
		Outside dia.	2.59	2.59				2.62			

Use rubber insulation (No. 12 to No. 6). Use wire instead of cable (No. 4 to 4/0). Rope core (750,000 to 2,000,000).

(14) For control cables, see description opposite and table on page 49 and for conduit sizes, see "Conduit Sizes for Control Cable," page 45.

(15) For lighting circuits, use No. 10 to No. 14 A.W.G. standard cable insulated per N.E.C. For portable lights, use No. 12 A.W.G. standard (packing house cord).

CONTROL CABLES FOR STATION WORK

Type A cable is 19 single conductors No. 25 A.W.G. tinned wires.

Continuous current-carrying capacity is 12 amperes.

Resistance per 1000 feet is 1.8 ohms.

CABLE AND CONDUIT DATA FOR POWER STATIONS

(Cont'd)

Size of Cable in B.& S. or Circular Mils	Bare Diam. in In. (Always Use Cable Instead of Wire When Run in Conduit)		On Insulators	In Conduit or Ducts Dry				In Conduit or Ducts Wet			
			VARNISHED CAMBRIC								
			Double Braid Flameproof	Double-braid Weatherproof: Single Conductor	Nominal Size of Conduit	Triple Conductor	Nominal Size of Conduit	Lead Covered: Single Conductor	Nominal Size of Conduit	Triple Conductor	Nominal Size of Conduit
3000 VOLTS											
No. 12	0.081 wire 0.092 cable	Thickness of insulation	4/32	4/32	¾						
		Outside dia.	0.44	0.45							
No. 8	0.128 wire 0.147 cable	Thickness of insulation	4/32	4/32	¾						
		Outside dia.	0.51	0.53							
No. 6	0.162 wire 0.186 cable	Thickness of insulation	4/32 (Use wire instead of cable, No. 6 to 4/0)	4/32	¾	1/16-1/16	1¼	4/32-1/16	¾	1/16-1/16-5/64	1¼
		Outside dia.	0.54	0.56		0.97		0.57		0.97	
No. 4	0.204 wire 0.234 cable	Thickness of insulation	4/32	4/32	1	1/16-1/16	1½	4/32-1/16	1	1/16-1/16-5/64	1½
		Outside dia.	0.58	0.61		1.07		0.62		1.07	
No. 2	0.258 wire 0.296 cable	Thickness of insulation	4/32	4/32	1	1/16-1/16	2	4/32-1/16	1	1/16-1/16-3/32	2
		Outside dia.	0.64	0.67		1.24		0.68		1.24	
1/0	0.325 wire 0.375 cable	Thickness of insulation	4/32	4/32	1¼	1/16-1/16	2	4/32-1/16	1¼	1/16-1/16-3/32	2
		Outside dia.	0.70	0.75		1.41		0.76		1.41	
2/0	0.365 wire 0.419 cable	Thickness of insulation	4/32	4/32	1¼	1/16-1/16	2½	4/32-5/64	1¼	1/16-1/16-3/32	2½
		Outside dia.	0.74	0.80		1.51		0.84		1.51	
4/0	0.460 wire 0.533 cable	Thickness of insulation	4/32	4/32	1¼	1/16-1/16	3	4/32-5/64	1¼	1/16-1/16-7/64	3
		Outside dia.	0.84	0.91		1.84		0.95		1.84	
250,000	0.576	Thickness of insulation	4/32	4/32	1½	5/64-1/16	3	4/32-5/64	1½	5/64-1/16-7/64	3
		Outside dia.	0.99	0.99		1.94		1.00		1.94	
300,000	0.631	Thickness of insulation	4/32	4/32	1½	5/64-1/16	3	4/32-5/64	1½	5/64-1/16-7/64	3
		Outside dia.	1.05	1.05		2.07		1.05		2.07	
400,000	0.729	Thickness of insulation	4/32	4/32	2	5/64-1/16	3½	4/32-3/32	2	7/64-1/16-1/8	3½
		Outside dia.	1.15	1.15		2.32		1.18		2.32	
500,000	0.815	Thickness of insulation	4/32	4/32	2	5/64-1/16	3½	4/32-3/32	2	5/64-1/16-1/8	3½
		Outside dia.	1.23	1.23		2.50		1.27		2.50	
600,000	0.893	Thickness of insulation	4/32	4/32	2	3/32-1/16	4	4/32-3/32	2	3/32-1/16-1/8	4
		Outside dia.	1.31	1.31		2.74		1.35		2.74	
750,000	1.14 (Rope core, 750,000 to 2,000,000)	Thickness of insulation	4/32	4/32	2½			4/32-3/32	2½		
		Outside dia.	1.57	1.57				1.59			
1,000,000	1.35	Thickness of insulation	4/32	4/32	2½			4/32-7/64	2½		
		Outside dia.	1.78	1.78				1.83			
1,250,000	1.56	Thickness of insulation	4/32	4/32	3			4/32-7/64	3		
		Outside dia.	1.99	1.99				2.04			
1,500,000	1.78	Thickness of insulation	4/32	4/32	3½			4/32-7/64	3½		
		Outside dia.	2.23	2.23				2.26			
2,000,000	2.14	Thickness of insulation	4/32	4/32	3½			4/32-7/64	3½		
		Outside dia.	2.59	2.59				2.62			

Type B cable is 19 single conductors No. 22 A.W.G. tinned wires.

Continuous carrying capacity is 20 amperes. Resistance per 1000 feet is 0.86 ohms.

Conductors to have open spiral wrap of cotton, $\frac{3}{64}$ in. No. 333 and 353 rubber, vulcanize plain.

Single-conductor cables will be finished with two 10/1 weatherproof braids; multiple-conductor cables will have the single conductors braided with 18/1 different colored braids as given in table below and finished over-all with 0.010 DF tape and single braid 10/2-ply weather-

CABLE AND CONDUIT DATA FOR POWER STATIONS

(Cont'd)

Size of Cable in B.& S. or Circular Mils	Bare Diam. in In. (Always Use Cable Instead of Wire When Run in Conduit)		On Insulators	In Conduit or Ducts Dry				In Conduit or Ducts Wet			
			VARNISHED CAMBRIC								
			Double Braid Flame-proof	Double-braid Weatherproof				Lead Covered			
				Single Conductor	Nominal Size of Conduit	Triple Conductor	Nominal Size of Conduit	Single Conductor	Nominal Size of Conduit	Triple Conductor	Nominal Size of Conduit
8500 VOLTS											
No. 12	0.081 wire 0.092 cable	Thickness of insulation	↑ Use wire instead of cable								
		Outside dia.									
No. 8	0.128 wire 0.147 cable	Thickness of insulation	83/2								
		Outside dia.	0.76								
No. 6	0.162 wire 0.186 cable	Thickness of insulation	8/32	8/32	1¼	4/32-4/32	2	8/32-5/64	1¼	4/32-4/32-[illegible]	2
		Outside dia.	0.79	0.81		1.40		0.85		1.40	
No. 4	0.204 wire 0.234 cable	Thickness of insulation	8/32	8/32	1¼	4/32-4/32	2½	8/32-5/64	1¼	4/32-4/32-[illegible]	2½
		Outside dia.	0.83	0.86		1.50		0.90		1.50	
No. 2	0.258 wire 0.296 cable	Thickness of insulation	8/32	8/32	1¼	4/32-4/32	2½	8/32-5/64	1¼	4/22-4/32-[illegible]	2½
		Outside dia.	0.89	0.92		1.66		0.96		1.66	
1/0	0.325 wire 0.375 cable	Thickness of insulation	8/32	8/32	1½	4/32-4/32	3	8/32-5/64	1½	4/32-4/32-[illegible]	3
		Outside dia.	1.00	1.05		1.83		1.04		1.83	
2/0	0.365 wire 0.419 cable	Thickness of insulation	8/32	8/32	1½	4/32-4/32	3	8/32-5/64	1½	4/32-4/32-[illegible]	3
		Outside dia.	1.05	1.09		1.93		1.09		1.93	
4/0	0.460 wire 0.533 cable	Thickness of insulation	8/32	8/32	2	4/32-4/32	3	8/32-3/32	2	4/32-4/32-4/32	3
		Outside dia.	1.14 ↓	1.20		2.20		1.23		2.20	
250,000	0.576	Thickness of insulation	8/32	8/32	2	4/32-4/32	3½	8/32-3/32	2	4/32-4/32-4/32	3½
		Outside dia.	1.25	1.25		2.32		1.28		2.31	
300,000	0.631	Thickness of insulation	8/32	8/32	2	4/32-4/32	3½	8/32-3/32	2	4/32/4/32-4/32	3½
		Outside dia.	1.30	1.30		2.44		1.34		2.44	
400,000	0.729	Thickness of insulation	8/32	8/32	2	4/32-4/32	4	8/32-3/32	2	4/32-4/32-4/32	4
		Outside dia.	1.40	1.40		2.64		1.43		2.64	
500,000	0.815	Thickness of insulation	8/32	8/32	2½	4/32-4/32	4	8/32-3/32	2½	4/32-4/32-4/32	4
		Outside dia.	1.49	1.49		2.83		1.52		2.83	
600,000	0.893	Thickness of insulation	8/32	8/32	2½	4/32-4/32	4½	8/32-7/64	2½	4/21-4/32-4/32	4½
		Outside dia.	1.56	1.56		3.00		1.63		3.00	
750,000	1.14 ↑ Rope core	Thickness of insulation	8/32	8/32	3			8/32-7/64	3		
		Outside dia.	1.82	1.82				1.87			
1,000,000	1.35	Thickness of insulation	8/32	8/32	3			8/32-7/64	3		
		Outside dia.	2.05	2.05				2.08			
1,250,000	1.56	Thickness of insulation	8/32	8/32	3½			8/32-7/64	3½		
		Outside dia.	2.26	2.26				2.29			
1,500,000	1.78	Thickness of insulation	8/32	8/32	3½			8/32-4/32	3½		
		Outside dia.	2.48	2.48				2.54			
200,000.0	2.14 ↓	Thickness of insulation	8/32	8/32	4			8/32-4/32	4		
		Outside dia.	2.84	2.84				2.90			

proof for two-conductor 19/25 A.W.G. cable to ten-conductor 19/25 A.W.G. inclusive, and two-conductor 19/22 A.W.G. to eight-conductor 19/22 A.W.G., inclusive. The other cables will be finished with 0.010 DF tape and single-braid 8/3-ply weatherproof. Two-conductor cable will be taped flat and the other multiple-conductor cables will be stranded up without jute fillers except the five- and six-conductor cables which will have a jute center, and the eight- and nine-conductor cables will have one conductor of each built up with jute to take the other conductors of the cables.

The single conductors will have a single-braid

CABLE AND CONDUIT DATA FOR POWER STATIONS

(Cont'd)

Size of Cable in B.& S. or Circular Mils	Bare Diam. in In. (Always Use Cable Instead of Wire When Run in Conduit)		On Insulators	In Conduit or Ducts Dry				In Conduit or Ducts Wet			
			VARNISHED CAMBRIC								
			Double Braid Flame-proof	Double-braid Weatherproof				Lead Covered			
				Single Con-ductor	Nominal Size of Conduit	Triple Con-ductor	Nominal Size of Conduit	Single Con-ductor	Nominal Size of Conduit	Triple Conductor	Nominal Size of Conduit
13,500 VOLTS											
No. 12	0.081 wire 0.092 cable	Thickness of insulation									
		Outside dia.									
No. 8	0.128 wire 0.147 cable	Thickness of insulation									
		Outside dia.									
No. 6	0.162 wire 0.186 cable	Thickness of insulation									
		Outside dia.									
No. 4	0.204 wire 0.234 cable	Thickness of insulation									
		Outside dia.									
No. 2	0.258 wire 0.296 cable	Thickness of insulation	12/32	12/32	2	6/32-6/32	3	12/32-3/32	2	6/32-6/32-1/64	3
		Outside dia.	1.23	1.23		2.05		1.24		2.05	
1/0	0.325 wire 0.375 cable	Thickness of insulation	12/32	12/32	2	6/32-6/32	3½	12/32-3/32	2	6/32-6/32-1/8	3½
		Outside dia.	1.29	1.29		2.27		1.33		2.27	
2/0	0.365 wire 0.419 cable	Thickness of insulation	12/32	12/32	2	6/32-6/32	3½	12/32-3/32	2	6/32-6/32-1/8	3½
		Outside dia.	1.34	1.34		2.37		1.37		2.37	
4/0	0.460 wire 0.533 cable	Thickness of insulation	12/32	12/32	2	6/32-6/32	4	12/32-3/32	2	6/32-6/32-1/8	4
		Outside dia.	1.45	1.45		2.61		1.48		2.61	
250,000	0.576	Thickness of insulation	12/32	12/32	2½	6/32-6/32	4	12/32-3/32	2½	6/32-6/32-1/8	4
		Outside dia.	1.50	1.50		2.71		1.53		2.71	
300,000	0.631	Thickness of insulation	12/32	12/32	2½	6/32-6/32	4	12/32-3/32	2½	6/32-6/32-1/8	4
		Outside dia.	1.55	1.55		2.84		1.59		2.84	
400,000	0.729	Thickness of insulation	12/32	12/32	2½	6/32-6/32	4½	12/32-1/64	2½	6/32-6/32-3/64	4½
		Outside dia.	1.65	1.65		3.07		1.71		3.07	
500,000	0.815	Thickness of insulation	12/32	12/32	2½	6/32-6/32	4½	12/32-1/64	2½	6/32-6/32-3/64	4½
		Outside dia.	1.74	1.74		3.25		1.80		3.25	
600,000	0.893	Thickness of insulation	12/32	12/32	3			12/32-1/64	3		
		Outside dia.	1.81	1.81				1.88			
750,000	1.14 (Rope core)	Thickness of insulation	12/32	12/32	3			12/32-1/64	3		
		Outside dia.	2.09	2.09				2.12			
1,000,000	1.35 (Rope core)	Thickness of insulation	12/32	12/32	3			12/32-1/8	3½		
		Outside dia.	2.30	2.30				2.36			
1,250,000	1.56 (Rope core)	Thickness of insulation	12/32	12/32	3½			12/32-1/8	3½		
		Outside dia.	2.51	2.51				2.57			
1,500,000	1.78 (Rope core)	Thickness of insulation	12/32	12/32	4			12/32-1/8	4		
		Outside dia.	2.73	2.73				2.79			
2,000,000	2.14 (Rope core)	Thickness of insulation	12/32	12/32	4½			12/32-1/8	4½		
		Outside dia.	3.09	3.09				3.15			

18/1 weatherproof only, underneath the lead covering. The two-conductor cable will be braided with the colored cotton and leaded flat. The other multiple-conductor cables will be leaded over the 0.010 DF tape omitting the outer braid.

Over-all dimensions of cables from one to twelve conductors are tabulated below.

No. Conductors	TYPE A			TYPE B		
	Thickness Lead in Inches	Over-all Diameter in Inches		Thickness Lead in Inches	Over-all Diameter in Inches	
		Braided	Leaded		Braided	Leaded
1	3/64	0.28	0.312	3/64	0.317	0.349
2	3/64	0.308x0.526	0.312x0.530	3/64	0.345x0.600	0.349x0.604
3	1/16	0.548	0.608	1/16	0.626	0.686
4	1/16	0.601	0.661	1/16	0.687	0.747
5	1/16	0.663	0.723	1/16	0.761	0.821
6	1/16	0.727	0.787	5/64	0.835	0.926
7	1/16	0.727	0.787	5/64	0.835	0.926
8	5/64	0.798	0.889	5/64	0.919	1.010
9	5/64	0.871	0.962	5/64	1.023	1.094
10	5/64	0.940	1.030	3/32	1.105	1.208
12	5/64	0.960	1.030	3/32	1.105	1.208

CONDUIT SIZES FOR CONTROL CABLE

CABLE		BRAIDED INSULATION			LEADED INSULATION		
Makeup Conductor	Size of	Outside Diameter of Cable in Inches	Conduit Size in Inches	Inside Diameter of Conduit in Inches	Outside Diameter of Cable in Inches	Conduit Size in Inches	Inside Diameter of Conduit in Inches
1	19/25	0.28	¾	0.824	0.32	¾	0.824
	19/22	0.32	¾	0.824	0.36	¾	0.824
2	19/25	0.28x0.50	¾	0.824	0.32x0.53	¾	0.824
	19/22	0.32x0.57	¾	0.824	0.36x0.61	¾	0.824
3	19/25	0.55	¾	0.824	0.62	¾	0.824
	19/22	0.63	¾	0.824	0.71	1	1.049
4	19/25	0.61	¾	0.824	0.68	1	1.049
	19/22	0.70	1	1.049	0.77	1	1.049
5	19/25	0.675	1	1.049	0.74	1	1.049
	19/22	0.77	1	1.049	0.85	1¼	1.38
6	19/25	0.74	1	1.049	0.81	1	1.049
	19/22	0.85	1¼	1.38	0.96	1¼	1.38
7	19/25	0.74	1	1.049	0.81	1	1.049
	19/22	0.85	1¼	1.38	0.96	1¼	1.38
8	19/25	0.80	1	1.049	0.91	1¼	1.38
	19/22	0.92	1¼	1.38	1.03	1¼	1.38
9	19/25	0.87	1¼	1.38	0.98	1¼	1.38
	19/22	1.03	1¼	1.38	1.11	1½	1.61
10	19/25	0.945	1¼	1.38	1.05	1¼	1.38
	19/22	1.12	1½	1.61	1.23	1½	1.61
12	19/25	1.015	1¼	1.38	1.10	1½	1.61
	19/22	1.17	1½	1.61	1.29	1½	1.61

Above table is based on conduit being 30 per cent larger than outside diameter of cable, for three bends and 100-ft. runs. Use larger percentage for longer runs and more bends.

Fig. 47. Outdoor Transformer Installation
When using conduit for outdoor connections, it is important that it be so arranged that water cannot enter it and that it is not swayed by wind.

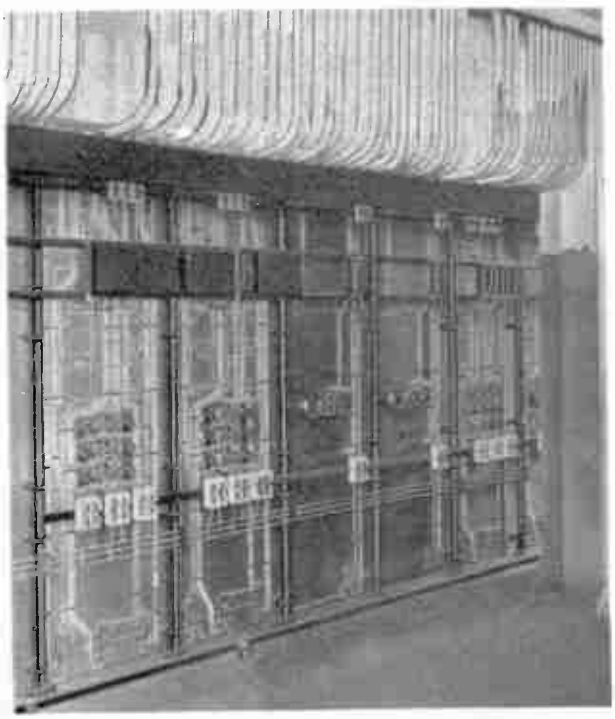


Fig. 48. Instrument and Control Board Wired to Conduits that Terminate at the Top of the Board

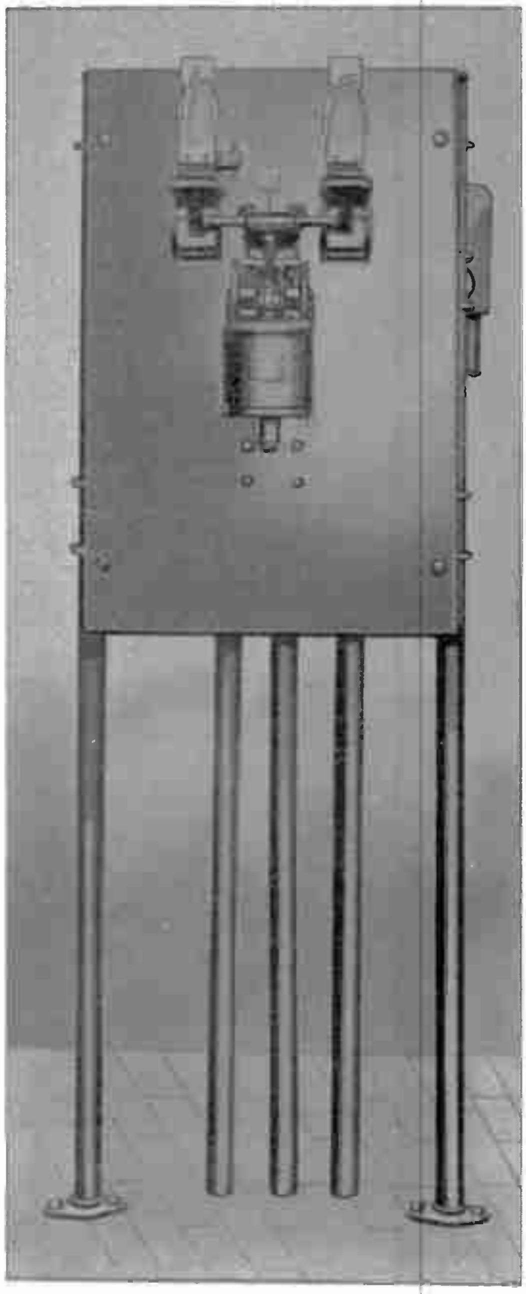


Fig. 49. Solenoid-operated Field Switch Panel without Sub-base

On isolated panels, it is often an advantage to omit the sub-base. However, when this is done, the floor conduits should be brought up above the lower edge of the panel. This will afford a protection to the cables and will improve the appearance of the installation.

SECONDARY AND SMALL WIRING

Flat wiring, an example of which is shown in Fig. 48, is the standard practice of the General Electric Company. A special method is used in the connecting of all devices in so far as possible.

The exciter bus potential is not recommended as a source of control, owing to the fact that the variation in potential is of too great a range. The use of batteries or some other permanent direct-current source is recommended for control purposes. The maximum permissible potential drop in control leads is 12½ per cent, and the potential on all control devices should be measured at the device.

All secondary connections from current and potential transformers to instruments should be metallic; the use of the earth as one of the conductors is permissible only in very special cases.

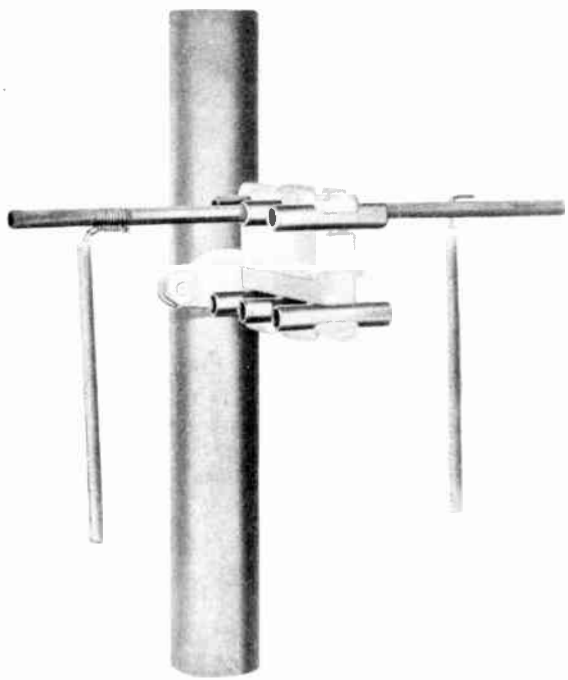


Fig. 50. Support for Control and Potential Buses

The buses consist of $\frac{3}{16}$-in. copper tubing. They are shipped in standard lengths and when installed they are joined by sleeves. The illustration shows the approved method of connecting control and potential leads, the leads not yet having been sweated in place. Control connections are joined to the bus by wrapping a few turns of tinned copper ribbon over the bus and wire and soldering the joint. Potential and other light current-carrying connections are made by inserting the connections through a hole drilled in the bus. This connection must be soldered also. In some cases it is advisable to insulate the bus after installation, by means of a single or double layer of adhesive tape.

Metallic conduit is recommended for all instrument and control leads between switchboard and other equipment, but care should be taken that all leads of one circuit are placed in one conduit. Control leads should not be placed in the same conduit with secondary leads; and it is well to make provision so that any reasonable repair

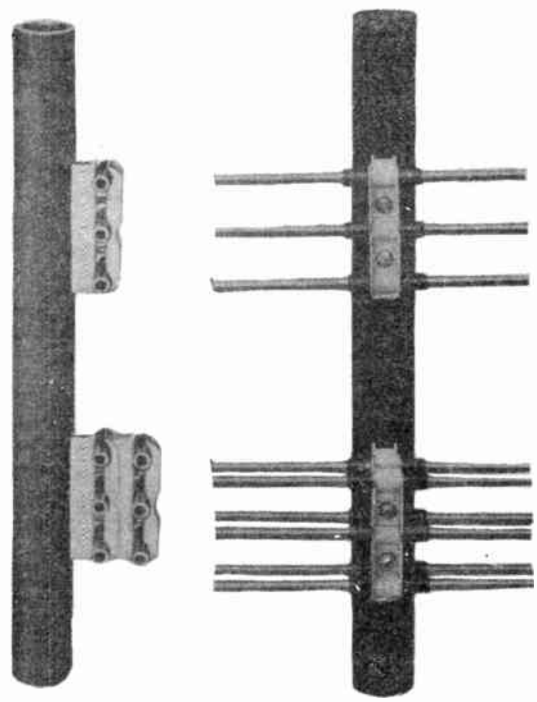


Fig. 51. Potential Bus Supports Mounted Directly on Pipe

The support, Fig. 50, is designed for the greatest amount of flexibility in adjustment during installation. This feature may be abandoned when installing the switchboard if it is desirable to save space, by drilling and tapping the pipe supports for the screws holding the cleats as shown above. It is evident that this cannot be done until all pipes and fittings have been permanently fixed.

or changes can be made without jeopardizing the continuity of service. If the secondary and control leads do not run beyond the switchboard room, they frequently enter the switchboard through conduits overhead; otherwise the best practice is to embed the conduits in the switchboard floor, terminating about two or three inches above the finished floor, and as close to the terminal boards as possible (see "A" Fig. 52). The top of the conduits must be provided with bell mouths or bushings to prevent injury to the insulation on the wires. The openings are filled by wooden plugs or oakum after connections have been completed.

The inside of the conduit should be about 35 per cent larger than the cable used in it. Uniformity of size, even if larger than necessary, is an advantage in appearance, as well as in purchasing the material. Sharp bends in the conduit must be avoided; and the number of bends between outlets held down to not more than three or four. During construction work all conduit ends should be sealed by corks or wooden plugs until the cables are pulled in. Joints should be water-tight, particularly if laid in concrete; but provision should be made for drainage to eliminate any water that may accumulate through condensation or accident. All conductors of a single or polyphase circuit must be run in the same iron conduit; or fiber conduit may be used for individual conductors. A wire or steel tape should be used in pulling the cable through the conduit. This work is materially lessened if talc or soapstone powder is blown into the conduit or dusted on the cable. It is very important to clean the inside before pulling the cable through.

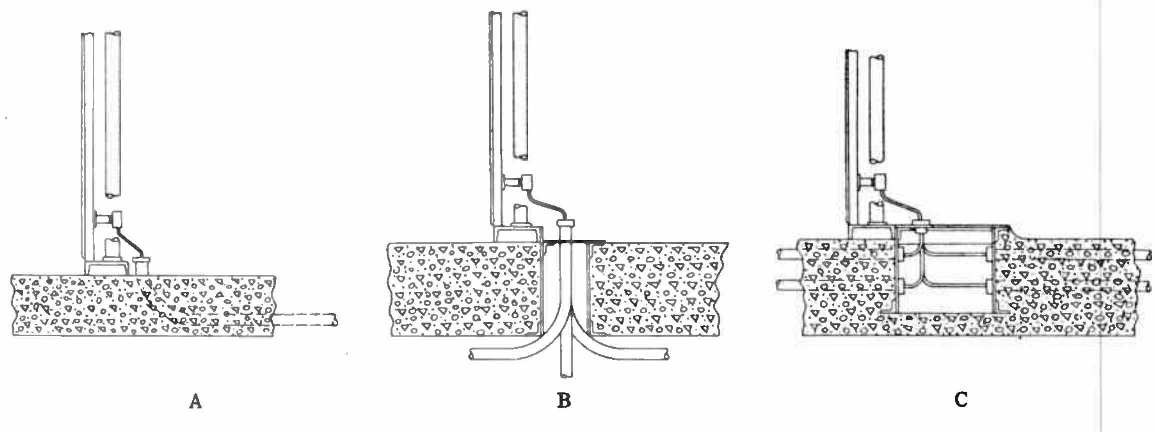


Fig. 52. Methods of Bringing Conduit to Switchboard

Another method of entering the board from below is to let the conduits terminate in a trench just back of the switchboard sill. In a plate projecting slightly over the switchboard side of this trench are set insulating bushings for bringing up the leads to the board. Removable plates cover the trench. This arrangement permits a certain amount of crossing of leads out of sight, so that they can be brought up to the board immediately below the terminal points.

To make the connections easier, multi-conductor cable is usually furnished with different-colored braid on each conductor. General Electric standard cables are made according to the scheme shown in the table on page 49.

Multi-conductor stranded cable should be used in conduits for secondary and control leads. This should never be smaller than the equivalent of No. 12 A.W.G.; and heavier if required for current capacity, or for strength for pulling it through conduit with several bends. The size of conductor must, of course, first be checked for permissible potential drop. Weatherproof finish is satisfactory if not subjected to dampness in the conduits; otherwise, lead-covered cable should be used.

For exposed wiring on back of board, and on framework, solid wire may be used, but with flame-proof covering. In cleating wiring to the panels, a fixed order of leads is followed as far as practicable; for instance, for each panel or circuit the current leads may be brought up at the left facing rear of board, the potential to right, and control leads between.

Control and potential buses are run the entire length of the switchboards of the larger class. Standard supports are used for these buses and a standardized method of making connections to these buses has been established (see Fig. 50 and 51).

INSULATION

Rubber mats should be placed in front of switchboards as a measure of increased safety. Tile of high insulating quality serves the same purpose and is more substantial and satisfactory. Such a tile is on the market and is recommended. It is prepared for setting in asphalt compound and is made with a rough surface to provide good footing. This is an important factor both in front of a switchboard and in operating aisles, as it reduces the possibility of slipping.

The main switchboard wiring for high-tension alternating current should be insulated and carried on suitable insulators securely mounted on rigid supports.

It is the aim in all switchboard wiring to obtain accessibility and at the same time to prevent the danger of trouble which may occur on one conductor involving other conductors.

To prevent the weakening of the insulation, avoid sharp turns, corners, and edges. The radius of bend for rubber-covered, varnished-cambric or lead-covered cable should never be less than six times the outside diameter of the cable. With small braided conductors, the radius of bend may be five times the outside diameter of the cable.

All cable and wire joints should be safely insulated.

When conductors are carried in compartments, or high enough above the station floor to preclude the danger of accidental touch or contact, they may be bare, relying on safe distances and suitable insulators.

The buses are an important part of the installation, carrying the whole energy of the plant in a confined space. This makes it essential to use extreme care, both in the selection of proper materials for construction and in the quality of the workmanship. When building bus compartments, arrangements should be made so that the joints are accessible for inspection and for such other work as may be necessary. Connections between switches and buses are practically part of the buses, and the same care should be given to this part of the installation. In the switchboard room, or where connections are accessible from aisles, no bare connections above 750 volts should be allowed. Those for about 11,000 volts and above are usually so far out of reach as to be harmless and so well protected by space insulation as to preclude the necessity for wrapped insulation. The switchboard manufacturers cannot furnish these connections insulated because the taping should be continuous over the connections and

CONTROL CABLES FOR STATION WORK (Cont'd)

Color Scheme

The following is the color scheme for braids on single conductor or multiple-conductor cables:

No. of Conductors	Size No.	Color
2	1	Black
	2	White
3	1	Black
	2	White
	3	Red
4	1	Black
	2	White
	3	Red
	4	Green
5	1	Black
	2	White
	3	Red
	4	Green
	5	Red and white
6	1	Black
	2	White
	3	Red
	4	Green
	5	Red and white
	6	Green and white
7		Center—blue
	1	Black
	2	White
	3	Red
	4	Green
	5	Red and white
	6	Green and white
8		Center—blue
	1	Black
	2	White
	3	Red
	4	Green
	5	Red and white
	6	Green and white
	7	Black and white

No. of Conductors	Size No.	Color
9		Center—blue
	1	Black
	2	White
	3	Red
	4	Green
	5	Red and white
	6	Green and white
	7	Black and white
	8	Green and red
10	1	Center { blue
	2	red and black
	3	Black
	4	White
	5	Red
	6	Green
	7	Red and white
	8	Green and white
	9	Black and white
	10	Green and red
12	1	Center { blue
	2	red and black
	3	blue and white
	4	Black
	5	White
	6	Red
	7	Green
	8	Red and white
	9	Green and white
	10	Black and white
	11	Green and red
	12	Green and black

the terminals or lugs. This is considered part of the installation material. It is recommended that the customer also insulate all connections and terminal lugs for circuits below 750 volts using enclosed switches or oil circuit breakers. (See Tables of Insulation below and on page 51) While the lever switch with bare live parts is in itself a caution notice, the oil breaker, for instance, being enclosed, inspires confidence and invites dangerous contact with terminals and connections. It should, of course, be borne in mind that a carefully wrapped conductor may not be safe to handle alive.

In general, the connections installed in compartments, and those operating at 15,000 volts and above, are not insulated. Since insulation has a tendency to increase the temperature rise of a conductor, the customer should not insulate connections designed to be left bare without first consulting the manufacturer.

Under various conditions, it becomes necessary to insulate rods or rectangular bars for safety as well as operating purposes. The table at the right shows the thickness of insulation for various operating potentials.

VOLTS		Layers of 0.012 In. Thick V. C.
Above	Up to and Including	
	1,000	3
1,000	2,000	4
2,000	3,000	4
3,000	4,000	5
4,000	5,000	6
5,000	6,200	7
6,200	7,600	8
7,600	8,800	9
8,800	10,000	10
10,000	11,600	11
11,600	13,400	12
13,400	15,400	13
15,400	17,400	14
17,400	19,400	15
19,400	21,200	16
21,200	23,200	17
23,200	25,000	18
25,000	26,800	19
26,800	28,000	20
28,000	30,400	22
30,400	32,800	24
32,800	35,200	26
35,200	37,600	28
37,600	40,000	30

APPROXIMATE AMOUNT OF INSULATION REQUIRED TO TAPE ONE LINEAR FOOT OF RECTANGULAR BAR

VOLTS		INSULATION		SIZE OF RECTANGULAR COPPER BAR				
Above	Up to and Including	0.012 Thick 1½ in. Wide Varnish Cambric	1-in. Wide Non-elastic Webbing	1½ x 3/16 Inches	2 x ¼ Inches	2½ x ¼ Inches	3¼ Inches	4 x ¼ Inches
		*Layers ½ Lap Winding		WEIGHT OF INSULATION IN OUNCES				
	1,000	3		2.4	3	3.7	4.3	5.5
			1	1	1.2	1.4	1.6	2
1,000	3,000	4		3.2	4	4.9	5.7	7.3
			1	1.1	1.3	1.5	1.7	2.1
3,000	4,000	5		4.1	5.2	6.3	7.3	9.3
			1	1.2	1.4	1.6	1.8	2.2
4,000	5,000	6		5	6.4	7.7	8.9	11.3
			1	1.3	1.5	1.7	1.9	2.3
5,000	6,200	7		6	7.6	9.1	10.5	13.3
			1	1.4	1.6	1.8	2	2.4
6,200	7,600	8		7	8.8	10.5	12.1	15.3
			1	1.5	1.7	1.9	2.1	2.5
7,600	8,800	9		8.1	10.1	12	13.8	17.4
			1	1.6	1.8	2	2.2	2.6
8,800	10,000	10		9.3	11.4	13.6	15.6	19.6
			1	1.7	1.9	2.1	2.3	2.7
10,000	11,600	11		10.5	12.7	15.2	17.6	21.8
			1	1.8	2	2.2	2.4	2.8
11,600	13,400	12		11.7	14.1	16.8	19.4	24
			1	1.9	2.1	2.3	2.5	2.9
13,400	15,400	13		12.9	15.6	18.5	21.5	26.2
			1	2	2.2	2.4	2.6	3

One gallon No. 480 grey paint will cover approximately 49 sq. ft. of insulated bars (two coats).

*It will be understood from a consideration of Fig. 53 that a so-called layer of ½-lap winding is in reality 2 layers of insulation. Usage of the term "layer" which has been substituted for the correct word "winding" has established the belief that in winding a bar there is only one thickness of tape. However, actually two thicknesses are obtained, for in the ½-lap winding process the tape is lapped back over itself 50 per cent as the winding is carried out to the end of the bar.

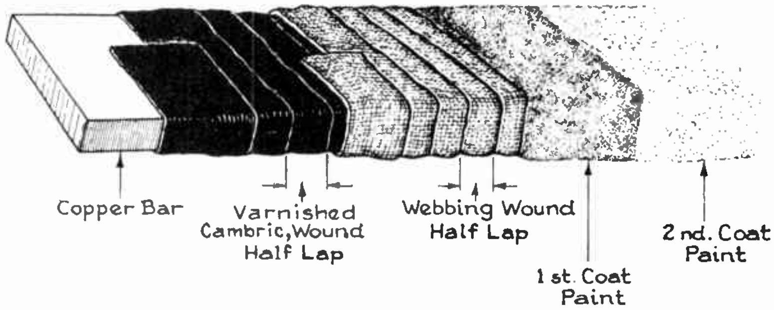


Fig. 53. Diagrammatic Illustration to Show Half-lap Winding

The list indicates the number of 0.012-inch-thick layers of varnished cambric required for insulating rectangular bars and rods.

The table is based on one-half-lap winding. Make as many wraps as required by the tabulation and then apply a layer of good insulating compound to the outside wrapping. Over this wind cotton tape to hold the varnish cambric. The cotton tape should then be covered with two coats of gray flame-resisting paint. The amount of tape required to insulate different bars is shown in table at the bottom of page 50.

The following table gives the space insulation in air between conductors and between conductors and ground for different voltages as

TABLE SHOWING SPACE INSULATION IN AIR BETWEEN CONDUCTORS, AND BETWEEN CONDUCTORS AND GROUND FOR DIFFERENT POTENTIALS

(This applies to installation work only and not to apparatus)

Voltage of Circuit	Distance between Polarities in Inches — In Air — Recommended	Minimum	Arc-over Kilovolts	On Surface — Recommended	Minimum	Distance to Ground in Inches — In Air — Recommended	Minimum	Arc-over Kilovolts	On Surface — Recommended	Minimum
125	¾	½	10	1	¾	¾	½	10	1	¾
250	1	¾	15	1¼		1	¾	15	1¼	1
600 a-c. / 750 d-c.	1¾	1	20	2		1½	1	20	2	1½
1200 a-c. / 1500 d-c.	2	1½	29	2½		2	1½	29	2½	2
2500 a-c. / 3000 d-c.	3	2½	40	3		2¾	2¼	38	2¾	
3500	3½	3	45	3½		3	2½	40	3	
4500	4	3½	50	4		3½	2¾	42	3½	
7500	5½	4	54			4½	3	45		
15000	9½	5	63	Figures in these columns apply to slate, marble, and ebony-asbestos up to 1200 volts, 3500 volts, and 4500 volts respectively.		7	3½	50	Figures in these columns apply to slate, marble, and ebony-asbestos up to 1200 volts, 3500 volts, and 4500 volts respectively.	
15001	12½					7				
25000	18					10				
37000	24					14				
50000	31					18				
73000	44					25				
88000	52					30				
110000	64					37				
132000	76					44				
154000	89					51				
220000	125					72				

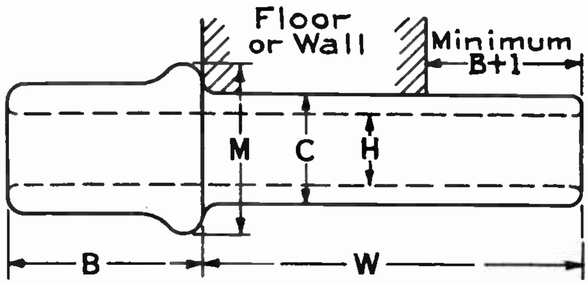
NOTE.—The recommended clearances are used to compensate for variations in workmanship in installation work and for better appearance and accessibility.

Minimum distances may be used in general design for rigid connections only. Where it is not possible or practical to maintain these values, equivalent insulation must be provided by use of barriers, taping, or other proper means.

Arc-over spacings given above are needle gap values.

Distances are suitable for altitudes up to 4000 feet. Above 4000 feet, add 5 per cent for every 1000 feet.

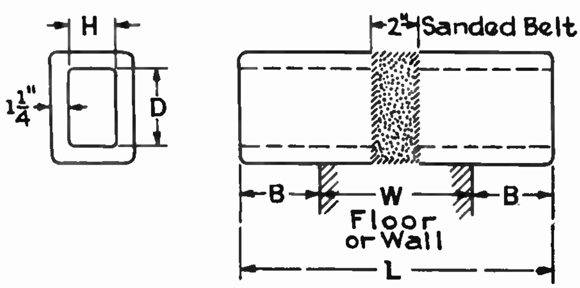
This table does not apply to the design of switching apparatus.



FLOOR AND WALL BUSHINGS

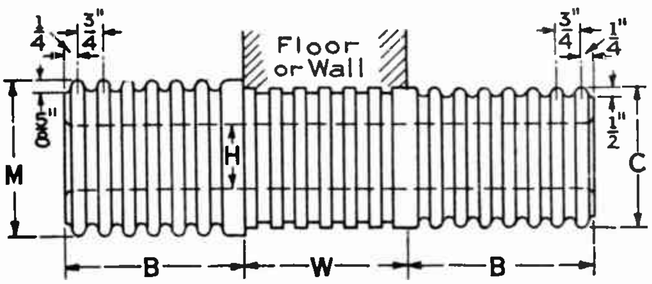
Locke Insulator Mfg. Co. Cat. No.	Voltage	Dimensions in Inches			
		H	C	B	M
7148	0 to 250	1	2	1	2¾
7150	0 to 250	1½	2½	1	3¼
7152	0 to 250	2	3	1	3¾
7153	0 to 250	2½	3½	1	4¼
7154	0 to 250	3	4	1	4¾
7155	251 to 1650	1	2	2	2¾
7157	251 to 1650	1½	2½	2	3¼
7159	251 to 1650	2	3	2	3¾
7160	251 to 1650	2½	3½	2	4¼
7161	251 to 1650	3	4	2	4¾
7162	1651 to 3300	1	2	3	2¾
7164	1651 to 3300	1½	2½	3	3¼
7166	1651 to 3300	2	3	3	3¾
7167	1651 to 3300	2½	3½	3	4¼
7168	1651 to 3300	3	4	3	4¾

Standard lengths available with dimension "W" 4, 6, 8, 10, 12, 14, 16, 18 inches.
When ordering, specify the number of laminae and width and thickness of busbar.



Locke Insulator Mfg. Co. Cat. No.	Voltage		Dimensions in Inches	
	1650	3300		
	B	B	H	D
9557	2	4	2	3
9558	2	4	2	3½
9560	2	4	2	4½
9562	2	4	2	5½

Standard lengths available with dimension "L" 8, 12, 16, 20 inches.
When ordering, specify the number of laminae and width and thickness of busbar.



FLOOR AND WALL BUSHINGS

Locke Insulator Mfg. Co. Cat. No.	Voltage	DIMENSIONS IN INCHES			
		H	C	B	M
7100	2001 to 5000	1	3	3	3½
7106	2001 to 5000	1½	3½	3	4
7112	2001 to 5000	2	4	3	4½
7118	2001 to 5000	2½	4½	3	5
7101	5001 to 7500	1	3	4½	3½
7107	5001 to 7500	1½	3½	4½	4
7113	5001 to 7500	2	4	4½	4½
7119	5001 to 7500	2½	4½	4½	5
7102	7501 to 12000	1	3	6	3½
7108	7501 to 12000	1½	3½	6	4
7114	7501 to 12000	2	4	6	4½
7120	7501 to 12000	2½	4½	6	5
7103	12001 to 15000	1	3	7½	3½
7109	12001 to 15000	1½	3½	7½	4
7115	12001 to 15000	2	4	7½	4½
7121	12001 to 15000	2½	4½	7½	5
7105	15001 to 25000	1	3½	10½	4

Standard lengths available with dimensions "W" 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24 inches.
When ordering, specify the number of laminae and width and thickness of busbar.

applicable to power switchboard practice. It should be noted that this does not apply to distribution cabinets, panel boards, or to the apparatus itself.

In all cases where conductors are carried through walls or floors, whether such conductors are insulated or not, some form of bushing should be used. However, this rule does not apply to conductors carried in conduit.

The tabulations on pages 52 and 53 list the bushings which are recommended by the General Electric Company for this purpose.

GROUNDS AND GROUND CONNECTIONS

Good, permanent, low-resistance grounds are essential. The efficiency is defeated by poor ground connections, which weaken the protection and may cause an ultimate loss of the apparatus. Careful attention given to construction and maintenance of grounds is amply justified by the greater reliability of protection obtained. The greater the importance of the service, the greater is the need for good grounds and a regular system of testing and inspection.

Before actually installing the ground elements, determine the character of the soil, the depth of permanent water or moisture level, and the general topography of the section to avoid the possibility of placing the grounds in unsuitable places in a pocket of earth entirely isolated by rock strata from the main earth section. Many valuable data along these lines can be obtained from the Government Geologic Survey Reports and also from the city and county engineering department records. In many cases an actual investigation will have to be made.

The number of grounds depends upon the character of the soil and the size of the installation. In no case should less than two grounds be installed. Where accurate records are to be kept

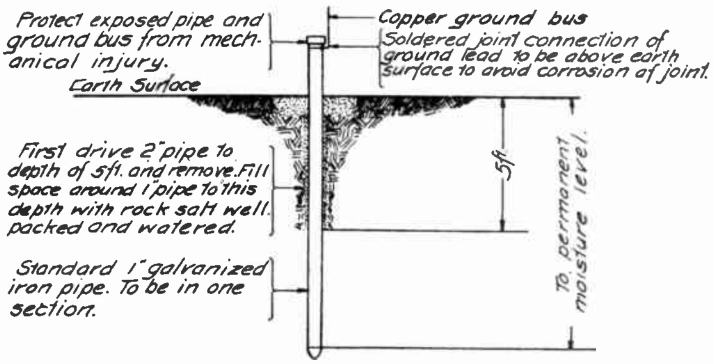


Fig. 54. Pipe Ground Element

of ground resistance in order to calculate the resistance of each pipe ground (see page 55), at least three such pipe grounds should be made with the individual pipes at least six feet apart. For the average power or lighting station the installation of four such grounds should be sufficient.

There are two kinds of grounds—pipe and plate.

The pipe ground is usually a 1-inch galvanized iron pipe driven into the ground to the permanent moisture level (Fig. 54). When installing a pipe ground, first drive a 2-inch pipe to a depth of five feet. Then remove it. Place the 1-inch pipe in this hole and pack rock salt around it. Then drive the 1-inch pipe down to the permanent moisture line. Soak the rock salt with water. A method of making connection to a pipe ground is shown in Fig. 55.

The plate ground is usually a copper plate placed below the moisture line (see Fig. 56). The plate is usually packed in charcoal which is covered with six inches of sand. The top of the sand is even with, or below, the permanent moisture level. The hole is then filled with the excavated soil. The stranded copper cable is fastened to the plate with copper rivets and straps.

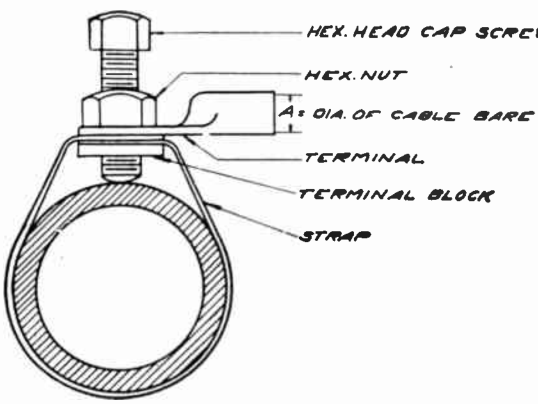


Fig. 55. Pipe Ground Connections

Sometimes two or more pipes are spaced at least six feet apart to get the maximum benefit of each and are connected together with heavy copper strip.

Probably the best way is to have a ground cable entirely around the station—a station loop. The grounds from the apparatus are fastened to this. In small stations there should be at least two ground pipes or plates buried in the earth on opposite sides of the station. Larger stations require four pipes or plates, one on each side of the station. The pipes or plates and station

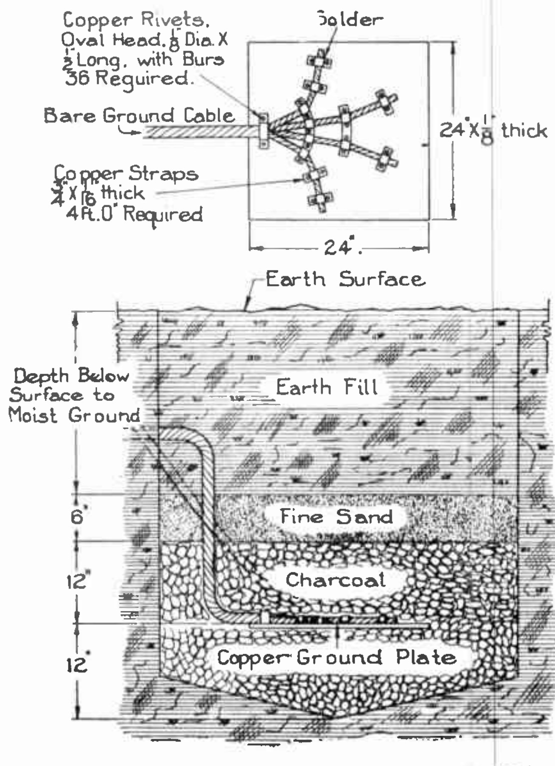


Fig. 56. Method of Making a Plate Ground

loop must be connected together as directly as possible.

Connect these earth pipes or plates to the iron framework of the station and also to any water mains, metal flumes, or trolley rails that are available.

Connect all of the grounded station apparatus to this ground except the lightning arresters, which should be connected to an independent ground but interconnected with the main station ground.

Use stranded copper cable from the station bus to the ground plates. A solid cable embedded in the concrete floor is likely to break if the concrete floor cracks or settles. Stranded cable, because of its ability to untwist and stretch, is not so likely to break.

Do not pass the grounding cable through any metal pipe. The pipe will act as a choke coil and hold back the flow of the ground current.

Have the panel ground bus considerably above the floor. If it is lying on the floor, the ground leads from the instruments to the cable are liable to be stepped on and broken.

Solder all splicings of the ground cable. Do not rely upon solder alone for the connection between the cable and the ground plate, but use rivets and clamps to make certain of this connection (see Fig. 56). If the splicing is clamped only, oxidization will cause a high resistance ground. A clamp splicing must have all of the space around the clamp filled with solder.

Make a systematic examination of the grounds and ground connections periodically. A record kept on file and showing exact plans of the location of the ground plates, ground wires, and pipes, with a brief description, will be helpful in this work.

The actual electrical efficiency of the ground connection can be determined only by a measurement of its resistance. The resistance of a single pipe ground properly installed and maintained has an average value of about 15 ohms. Where there are at least three ground pipes or plates, not less than six feet apart, the actual resistance of each ground can readily and accurately be determined. With three grounds identified as A, B, and C, the series resistance of A plus B, B plus C, and C plus A, can be obtained by the fall-of-potential method. Solution of the three equations will give the individual resistances. The method of measuring is as follows: Connect a 110- or 220-volt supply from either an alternating- or direct-current source across two of the ground pipes. Use a regulating rheostat and an ammeter to limit the current to a safe value (5 to 10 amperes) if the ground resistance is low. Measure the drop across the two grounds by a suitable voltmeter, allowing a few minutes after the closing of the circuit for constant conditions to be reached. The voltage drop divided by the current gives the resistance of the two grounds in series.

For example, assume the three grounds as A, B, and C, measured with a current of five amperes and a drop of 80 volts across A plus B. This gives a total value of resistance of A plus B, of 16 ohms. Similar measurements show B plus C equals 18 ohms, and C plus A equals 10 ohms.

$$A+B=16 \quad (1)$$
$$B+C=18 \quad (2)$$
$$C+A=10 \quad (3)$$

Subtracting	(2) from (1)	$C-A=2$ (4)
Adding	(3) and (4)	$C=6$ ohms
Substituting 6 in (2)		$B=12$ ohms
Substituting 6 in (3)		$A=4$ ohms

Where there are but two grounds available, this method will allow only the total resistance of the two grounds to be determined. It is evident, however, that this will indicate a high resistance in either ground, if it exists. Also, if the two grounds are operated in parallel, the maximum value of operating resistance can be but one-fourth of the measured series resistance.

A more approximate method of testing the condition of the earth connections is to divide the earth pipes in two groups and connect each group to opposite sides of a 110-volt lighting circuit with an ammeter in series. A current flow of 20 amperes indicates a satisfactory condition provided the earth pipes are properly distributed around the station.

Equipment to be Grounded

Panel supports should ordinarily be grounded except on grounded direct-current railway systems of 750 volts or less, where only the isolated polarity is brought to the panel. If such direct-current panels with ungrounded frames are installed in one board, together with alternating-current panels with grounded frames, the panel support between the two sections of switchboard should be grounded. Insulating caps for panel supporting bolts are supplied for this intermediate support.

Switchboard devices for operating at 150 volts or more above the ground should have their exposed bare metal parts, which are insulated from the current-carrying parts, permanently grounded. This rule covers, for example, alternating current instrument and meter casings, transformer frames, operating mechanism for switches, oil circuit breakers, rheostats, compensators, etc.

Instrument transformer secondaries should be permanently grounded at the transformers. Where secondaries cannot be grounded at any point, the secondary wiring must be insulated and installed safely to withstand primary potential.

It is standard practice to run one common ground bus, which is a copper strip, across the back of the switchboard, to which the apparatus mounted on the switchboard intended for grounding should be connected. The switchboard pipe framework, except when insulated, should be connected to this ground bus, one connection being made for every three pipe joints in series.

Steel work supporting high-potential switching equipment should be carefully grounded at several points in order to prevent the possibility of high voltage occurring between sections of the steel work. Ground connection for this service should be of liberal capacity.

ILLUMINATION

Sufficient illumination should be provided in the station, both for the front and the rear of the switchboard, so that the switchboard may be readily operated and instruments and meters conveniently read. It has been found that insufficient illumination and a badly arranged system of lighting units are responsible for considerable eyestrain and subsequent fatigue and possible accident. The illumination should be so arranged that all instruments and other parts which are to be kept under constant supervision are easily discernible without glare or reflection. Therefore, the subject of proper illumination should be given careful consideration. Lamp brackets on the board are not recommended.

It is strongly recommended that a separate emergency source of illumination from storage battery, lanterns, or other suitable source be kept immediately available. Emergency lights may be kept lighted continuously, or an emergency throw-over switch can be furnished to switch automatically all or part of the lights to an emergency source. Fig. 57 shows an elementary diagram for an emergency lighting scheme.

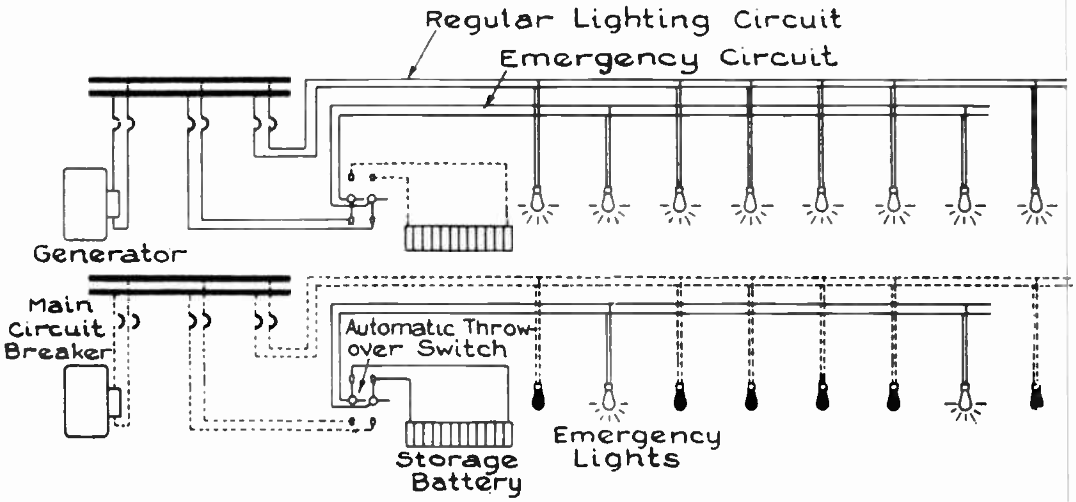


Fig. 57. Elementary Connection Diagram Showing Emergency Lighting Scheme

OPERATION

In as much as the switchboard controls all of the machinery and other apparatus in the station it is most essential to proper operation to become familiar with all general or special instructions referring to the apparatus.

Before putting the switchboard into service, all connections to instruments, meters, relays, etc., should be carefully traced and checked with the drawings. A preliminary trial should then be made to see that instruments, watthour meters, etc., indicate or record in the proper direction. In fact, before putting a switchboard into actual service, it is advisable to put current through all parts at reduced voltage in order to bring out any weak spots.

When putting the switchboard into actual service, every detail should be closely watched and anything out of the ordinary should be carefully noted and investigated. The switchboard should be subjected to periodical inspections of all parts. Attention should be given to the joints in cables, buses, connection bars, current-carrying studs, and to temperature rise, insulation, cleanliness, etc.

In making inspection or repairs near live parts, special care should be exercised to avoid accidentally short-circuiting or grounding any of the connections. The following instructions cover only in a general way the routine to follow, as it is obvious that details given, for instance, for direct-current railway power plant would not apply to a high-voltage, alternating-current power plant. The operator, however, is urged to familiarize himself with these details.

(1) Before each starting of the plant, be sure that all switches and circuit breakers involved are open and that no other device is in such condition as to cause trouble when voltage is thrown on the panels. See that all devices are properly marked with the name or number of the circuit controlled so that there will be no confusion.

(2) After everything is adjusted and running, take frequent readings of instruments to see that no device is overloaded to a dangerous point. This applies to conductors as well as to switches and instruments.

(3) Make periodic tests of instruments and meters to locate any inaccuracies, at the same time noting any parts which may need adjusting or repairing.

(4) Regularly inspect switches, circuit breakers, and relays to see that contacts are in good condition and that there is no sticking. On relays which have bellows, rub a little neatsfoot oil over the bellows to preserve its flexibility.

(5) Where oil circuit breakers are used, see that the tanks are supplied with G-E No. 6 Oil, where the temperature is always above 0 deg. Centigrade (32 deg. Fahrenheit). Where the temperature is likely to fall below 0 deg. Centigrade, use G-E No. 21 Oil.

These oils have been carefully prepared and specially treated for use in oil circuit breakers and have high insulating value and flash point, and have been subjected to the required tests at the factory.

(6) Do not open and close an oil circuit breaker successively a number of times (e.g., jogging a motor).

(7) Regularly inspect the back of panels and keep all joints in perfect condition. Do not allow dirt or refuse to accumulate behind switchboards.

(8) Clean the switchboard and equipment regularly, especially where they are subjected to dust. Air pressure should be used from an insulated nozzle, but extreme care must be taken to see that there is no moisture in the air system. There are several portable electric blowers on the market which give excellent results in cleaning both front and back of the switchboard. These hand blowers are usually very small, weighing about 7 lb., and are provided with a 20-ft. cord for attachment to an electric outlet.

Wiping is not recommended, because on front of board it has a tendency to polish all dull-black finish, and on the back it is decidedly dangerous.

(9) Knife switches in series with circuit breakers of the carbon break or magnetic blow-out type should be closed or opened after the circuit breakers have been closed or opened. When closing the switches, it is well to turn the face away from the switchboard to avoid having the eyes "flashed" in case the circuit breaker should open. It is recommended that all lever switches which are not frequently used be operated occasionally to keep the contacts in good condition.

(10) Disconnecting switches in series with oil circuit breakers on alternating-current circuits should never be opened until after the oil circuit breakers have been opened, but should always be closed before the oil circuit breakers have been closed. Manually operated oil circuit breakers with automatic attachments are arranged so that it is impossible for the breakers to remain closed in case of short circuit or dangerous overload. A trip-free relay can be furnished to accomplish the same result with electrically operated breakers in conjunction with overload relays.

(11) Go over the entire equipment and prepare a regular schedule for periodic test of instruments, meters, and relays, and inspection of other equipment. It is advisable to keep a card or blank for this purpose in the form of a questionnaire on which can be noted each point as observed.

Portable Testing Equipment

The following equipment is recommended for making the aforementioned tests:

(a) Portable voltmeter, Type P-3, alternating-current 150 volts scale.

(b) Portable ammeter, Type P-3, alternating-current 5/10 amperes. (For instrument, meter, and relay testing.)

GUIDE TO SELECTION OF PORTABLE TESTING INSTRUMENTS

Alternating-current Switchboard Instrument		Portable Instrument (Symbol letter refers to list of instruments given above)
Voltmeter, indicating or recording		(a)
Ammeter, indicating or recording		(b-f)
Single-phase wattmeter, indicating or recording		(d-f)
Polyphase wattmeter, indicating or recording		(d-f)
Single-phase or polyphase watthour meter		(e-f)
Frequency meter	Remove from switchboard for laboratory test	
Power-factor meter	Remove from switchboard for laboratory test	
Temperature meter	Remove from switchboard for laboratory test	
Synchroscope	Remove from switchboard for laboratory test	
Installing overload relay		(c-g)
Time-limit overload relay		(c-g-h)

(c) Portable ammeter, Type P-3, alternating-current 30/60 amperes. (For relay testing.)

(d) Portable wattmeter, Type P-3, single-phase, alternating-current 100-125 volts, 5/10 amperes, 500/1000 watts scale. (Two of these are needed if check of running load is to be made.)

(e) Portable test meter, Type IB-5, single-phase, alternating-current 110 volts, 1–10 amperes. (Two of these are needed if check of running load is to be made.)

(f) States portable phantom load device Type T manufactured by the States Co., Hartford, Conn.

Meter testing load box, 110 volts, 0.25 to 15 amperes, may be used instead of phantom load device.

(g) Relay testing load box 0.2 to 30 amperes, Cat. No. 2018910.

(h) Synchronous timer, Type MF-2, 110 volts, 60 cycles, Cat. No. 260350. (May be used on 50 cycles.)

Synchronous timer for 25 cycles not yet developed.

Portable power-factor meters are available if desired.

INSTRUMENT TRANSFORMERS

Instrument transformers are accurate devices for reducing pressures and currents to values convenient for measurement. They are divided into two general classes as follows:

Current Transformers

As their name implies, these devices reduce larger currents to values which can be readily measured and at the same time protect the measuring devices against the higher voltage of the line.

The secondary of a current transformer should never be opened when the primary is energized, since, under this condition, the normal small magnetizing current is increased to the full value of the line current and in consequence a high voltage, dangerous both to life and insulation, is produced across the secondary terminals. This excessive magnetization may also leave the core more or less polarized, depending upon the point on the wave at which it is interrupted, in which event the transformer, without demagnetization, is no longer suitable for accurate service. If it is desired to make any changes in the secondary connections with the instrument in service, the secondary of the transformer *must first be short-circuited.*

Potential Transformers

These are highly accurate power transformers of very limited volt-ampere capacity for use with various forms of pressure-measuring devices. Unlike power transformers, however, they are designed for transforming pressure only, not power. Furthermore, unlike the current transformer, their secondaries should *never* be short-circuited. When the secondary of a current transformer is short-circuited, the value of the secondary current does not change; whereas, a short-circuit on the secondary of a potential transformer will give rise to destructive secondary currents. The secondaries of current and potential transformers should always be substantially grounded.

Detailed information regarding the instrument transformers used on a particular installation should be obtained from the individual instruction books accompanying them.

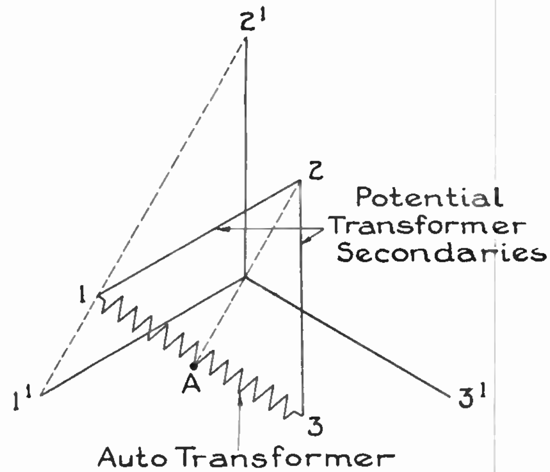


Fig. 58. Diagram Showing Use of Auto-transformer in Synchronizing

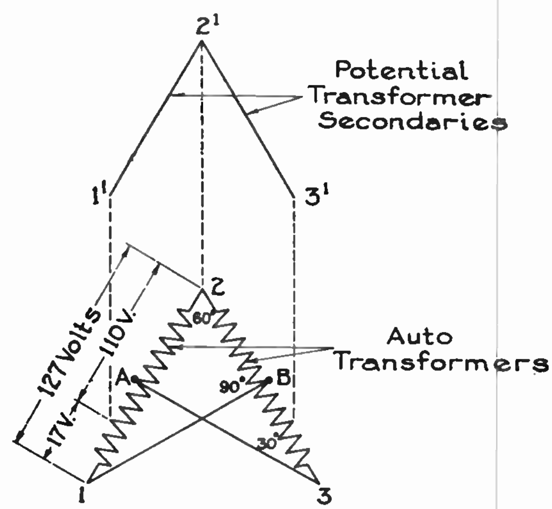


Fig. 59. Diagram Showing the Use of Double Auto-transformer with Reactive Volt-ampere Meter

Auto-transformers

Auto-transformers are frequently used in connection with switchboard devices to obtain voltages differing from the normal displacement of the circuit. For example, in synchronizing across a power transformer bank connected Y-Δ, the 30-deg. displacement of the line voltages must be rectified at the synchronizer. This is accomplished as shown in Fig. 58. In this figure

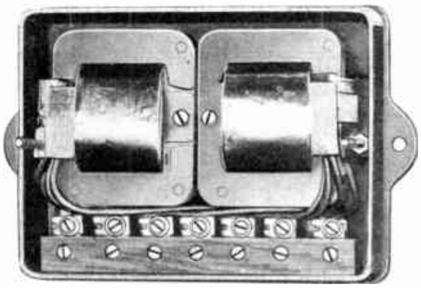


Fig. 60. **Double Auto-transformer for R.V.A. Instruments and Meters (cover removed)**

the voltages 1′-2′ and 1-2 are normally 30 deg. displaced in phase when the systems are in synchronism. To overcome this displacement at the synchronizing device, a small auto-transformer is connected across, say 1-3, on the delta side. This auto-transformer is equipped with a middle tap A and the synchroscope is energized from the voltage 1′-2′ on the Y side and A-2 on the Δ side, both of which voltages are in parallel when the systems are in synchronism.

When using a polyphase wattmeter to measure reactive volt-amperes, it is necessary to shift the phase angle of the voltages 90 deg. from their normal positions when measuring watts. This is accomplished by means of a double auto-transformer mounted in a common case as shown in Fig. 59 and 60. The auto-transformers are wound to give a total potential across the entire

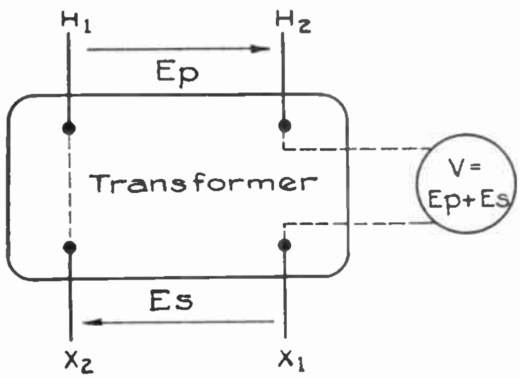


Fig. 61. Diagram Illustrating Additive Polarity

winding of 127 volts. They are equipped with a tap at 110 volts for connection to the secondaries of the potential transformers, and with another tap at 63.5 volts to supply the quadrature voltages A-3 and B-1 for the reactive volt-ampere meter. These voltages, A-3 and B-1, are 90 deg. displaced from the normal voltages 1′-2′ and 2′-3′, respectively; and if the potentials 1′-2′ and 2′-3′ are 110 volts, the potentials A-3 and B-1 are also 110 volts, that is 127 × cos 30 deg.

Transformer Polarity

The polarity of a transformer is determined by the relative direction in which the primary and secondary turns are wound upon the core. It is defined as either "additive" or "subtractive," depending upon the location of the primary and secondary terminals of like polarity. For example, in Fig. 61 the high-voltage terminal H_1

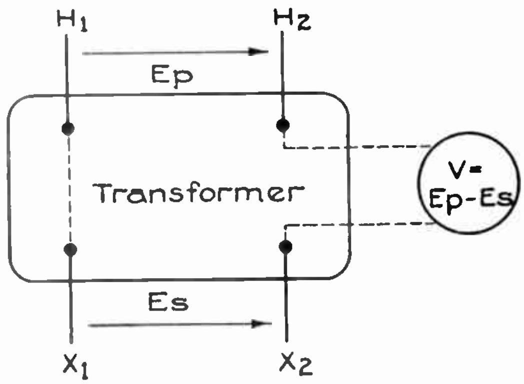


Fig. 62. Diagram Illustrating Subtractive Polarity

has the same polarity as the low-voltage terminal X_1, and the polarity is additive. The nomenclature is derived from the fact that if the terminals H_1 and X_2 be connected and voltage applied to the primary, the voltage across the terminals H_2 and X_1 will be the *sum* of the primary and secondary voltages. In a transformer of this polarity, the terminals of like polarity are diagonally opposite; whereas, when the polarity is subtractive, the terminals of like polarity stand adjacent, as shown in Fig. 62. The derivation of this term likewise arises from the fact that if H_1 and X_1 are connected and voltage applied to the primary, the voltage across H_2 and X_2 is the *difference* between the primary and secondary voltages.

These locations, adjacent and diagonal, apply more particularly to power transformers. The design of instrument transformers frequently precludes exact adherence to them, and in such transformers the relative location of the terminals should never be relied upon when connecting to secondary devices. To facilitate making such

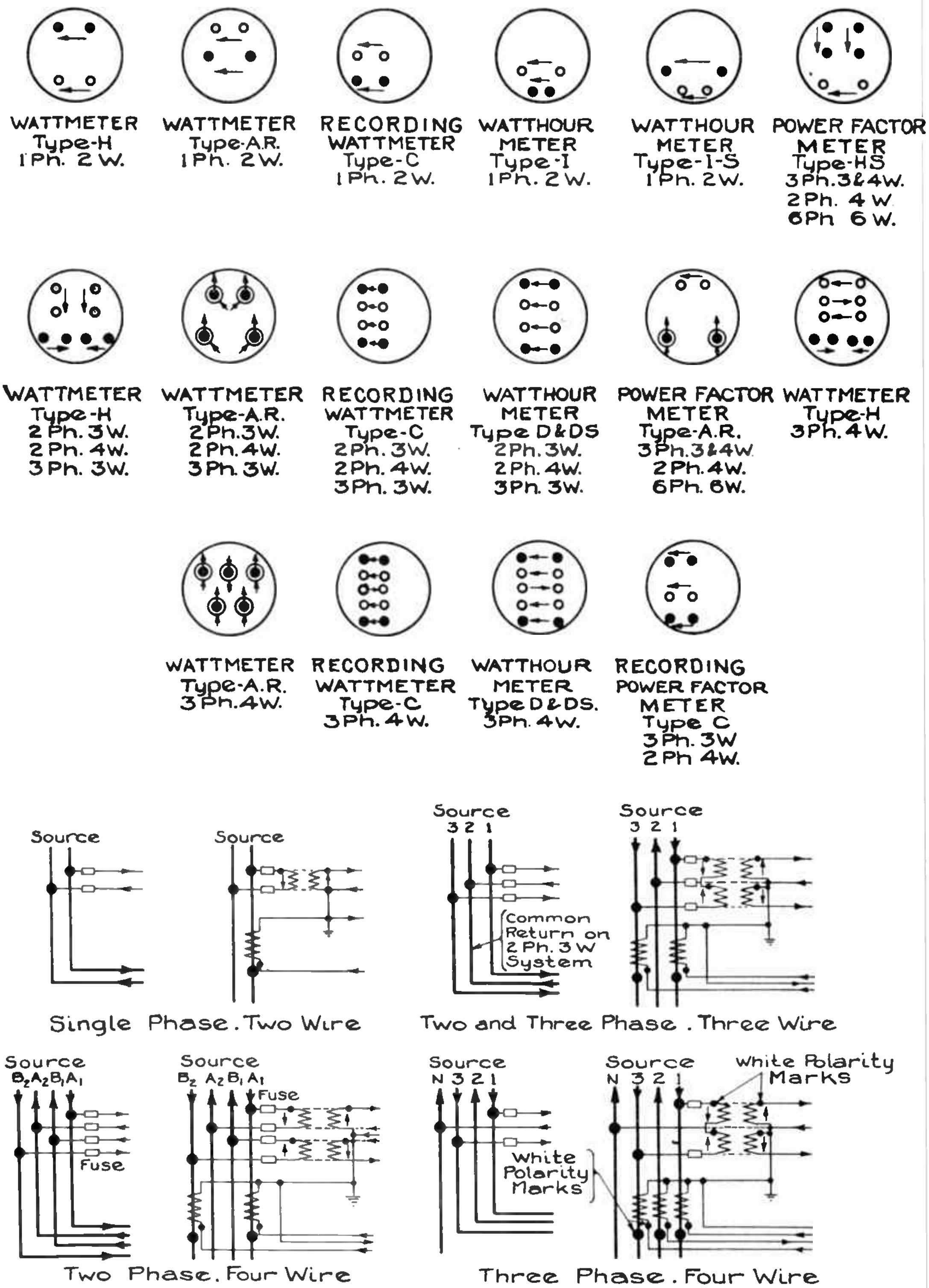


Fig. 63. Instantaneous Current Directions (Back View)

The arrows indicate the instantaneous directions through current and potential coils. However, instruments will read correctly if all arrows are reversed from those shown. Switchboard connection diagrams show but one of several possible equivalent connections.

connections, instrument transformers manufactured by the General Electric Company have one primary terminal painted white and marked H_1, and the secondary terminal of the same polarity also painted white and marked X_1. The H_2 and X_2 markings are omitted, since the identification of one primary and one secondary terminal is deemed sufficient. The significance of these markings is as follows:

If at any particular instant the primary current is assumed as flowing *towards* the H_1 mark, the secondary current at the same instant is flowing *away* from the X_1 mark.

The white markings are shown upon all switchboard connection diagrams covering the connections of instruments, meters, and other devices operated from the secondaries of current and potential transformers. The marks shown on the diagram should be carefully followed even though their relative location on the transformer does not agree with the relative location shown on the diagram.

INSTRUMENTS AND WATTHOUR METERS

The successful operation and accuracy of instrument equipment is dependent upon care in handling and periodic tests by experienced meter men. Before attempting to install or operate instruments or watthour meters, it is essential that reference be made to the instruction book covering them. These instruction books show a definite connection for the apparatus for an individual installation. It is not desirable, at times, because of complex wiring, to follow this connection when other devices are operated from the same transformer. A reference to Fig. 63 shows the relative instantaneous direction of current through instrument coils, from which several combinations in wiring can be obtained. For this reason, connections shown on the switchboard connection diagram may differ from those shown in the instruction book covering the individual device.

It is often necessary to increase the capacity of current transformers, which means a corresponding change in the instrument equipment. For watthour meters, only a new register and nameplate are required. This change can easily be made by the customer as the register is supported to meter frame by only four screws. Indicating instruments should be returned to factory for new scales.

POWER-FACTOR AND REACTIVE FACTOR

The power in an electric circuit is $EI\cos\phi$, where ϕ is the angular displacement between the voltage E and the current I. On a direct-current circuit, there is no displacement; ϕ is, therefore, 0° whose cosine is 1, and the power is then $EI \times 1$ or EI.

On an alternating-current circuit, ϕ usually has some appreciable value so that cosine ϕ is less than 1, and the power in such a circuit is consequently less than EI. $\cos\phi$ is known as the "power-factor" of the circuit and $I\cos\phi$ is the component of the total current which is in phase with the pressure or voltage. $\sin\phi$ is called the "reactive factor" and $I\sin\phi$ is the component of the total current which is in quadrature with the pressure. The former is the active, or power, component, while the latter is the reactive, or idle, component. On direct-current circuits there can be no reactive component since the sine of 0° is 0.

These relationships are shown in Fig. 64.

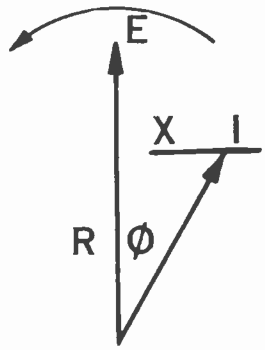


Fig. 64

E = Voltage
I = Current
ϕ = Displacement angle
R = Power component of I
X = Idle component of I
$ER = EI\cos\phi$ = watts = W
$EX = EI\sin\phi$ = reactive volt-amperes = RVA

$$\frac{RVA}{W} = \tan\phi$$

$$\sqrt{RVA^2 + W^2} = \text{Volt amperes} = VA$$

$$\sqrt{VA^2 - W^2} = RVA$$

$$\frac{W}{VA} = \cos\phi$$

$$\frac{RVA}{VA} = \sin\phi$$

In using power-factor and reactive volt-ampere meters, it should be borne in mind that at high power-factors (where ϕ approaches zero) the sine varies much more rapidly than the cosine with small changes in ϕ. Consequently, although an indication of say 97 per cent on the power-factor meter may seem reasonably high, it should not be forgotten that this represents a displacement angle of 14 deg. whose sine is 0.2419. So that though the power-factor is only 3 per cent from unity, the reactive factor is almost 25 per cent above zero.

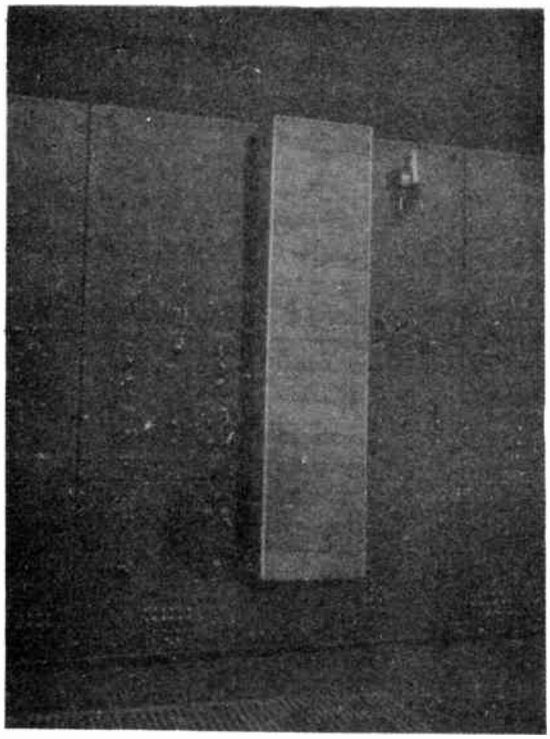


Fig. 65. Protective Covering for Instruments, Meters, and Delicate Apparatus

Such a covering is recommended when construction work is being done on or near the switchboard.

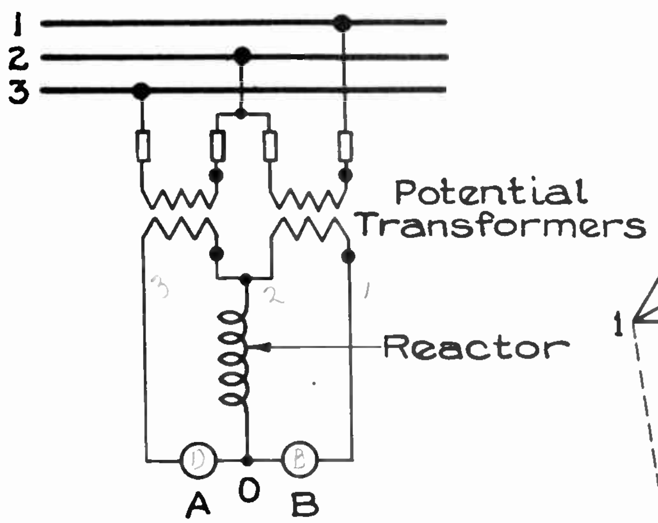


Fig. 66. Method of Connecting a Reactor in Conjunction with Lamps to Determine Phase Sequence

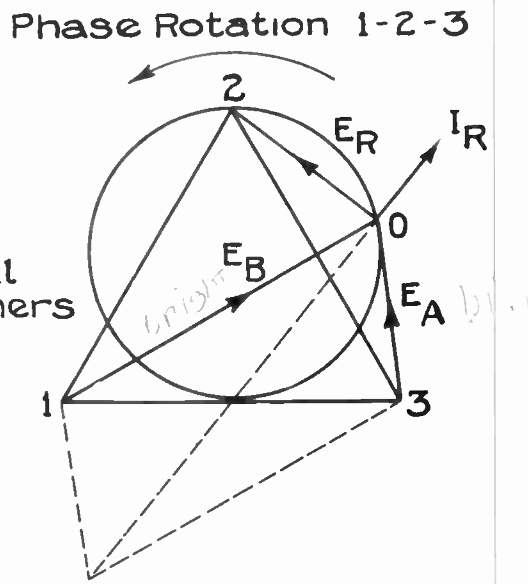


Fig. 67. Diagram Illustrating Phase Sequence in the Order of 1-2-3

PHASE SEQUENCE

For the purpose of synchronizing, the actual order of phase sequence is immaterial provided it is the same on both the systems to be synchronized. In connecting certain instruments such as power-factor meters and reactive volt-ampere meters, however, it is possible in the absence of information regarding the phase sequence of the system to connect these instruments in such a way that they will indicate lead when they should indicate lag and vice versa. When such devices are connected directly in the circuit of a synchronous motor, the correctness of the direction of deflection may be checked by increasing the field strength of the machine and noting if the pointer tends to move towards the side of the scale marked "lead." If it does so, the connections are correct; if it moves towards the side of the scale marked "lag" the potential connections to studs marked A and D on the power-factor meter should be *interchanged*, while the potential connections to the coils of the reactive volt-ampere meter should be *reversed*.

The connections shown on the switchboard connection diagram are based on a phase sequence in the order 1-2-3; that is, phase 2 reaches a maximum after phase 1, phase 3 after phase 2, and phase 1 after phase 3. If the sequence of the system is in the same order, the instrument should give the correct deflection when connected in accordance with the diagram. When the instrument is not connected to a synchronous motor, the sequence of the system may readily be determined by the method shown in Fig. 66. The reactor may be a coil of any kind having a reactance approximating the resistance of the lamps. Because of the presence of the reactor, the lamps will glow with unequal brilliancy, depending upon the sequence of the phases. For example, suppose lamp B is brighter than lamp A, then the voltage E_B across lamp B must be greater than the voltage E_A across lamp A, and the junction point O will fall on the *right*-hand half of the circle shown in Fig. 67. Since the currents in the lamps are in phase with the voltages E_B and E_A, they also will meet at the point O and the current in the reactor will have the phase I_R. The voltage across the reactor will be the voltage E_R from O to the upper corner of the triangle. Since we know that the voltage across a reactor leads the current flowing in it by 90 deg., it is evident that the phase rotation is in the direction shown by the arrow, and the sequence is in the order 1-2-3.

If, however, lamp A should be brighter, then the point O will fall on the left-hand half of the circle as shown in Fig. 68, and the current through the reactor will lie to the *left* of the reactor voltage, indicating a phase rotation opposite to that shown in Fig. 67 and in the sequence 3-2-1. Should the sequence of the system be found opposite to that on which the switchboard diagram connections are based, the connections to the studs marked A and D on the power-factor meter should be interchanged, and the connections to the potential coils of the reactive volt-ampere meter should be reversed.

A very simple check upon the direction of deflection of a power-factor meter is shown in Fig. 69. The instrument should be connected up as shown in the figure and a short-circuiting wire connected across the coil connected to the current transformer. If this short-circuit causes the needle to deflect towards the "lag" side of the scale, the potential connections are correct. On the other hand, should it cause a deflection toward the "lead" side, the potential connections to the studs marked A and D should be interchanged. After correct connections have been obtained, the short-circuiting connection should be removed.

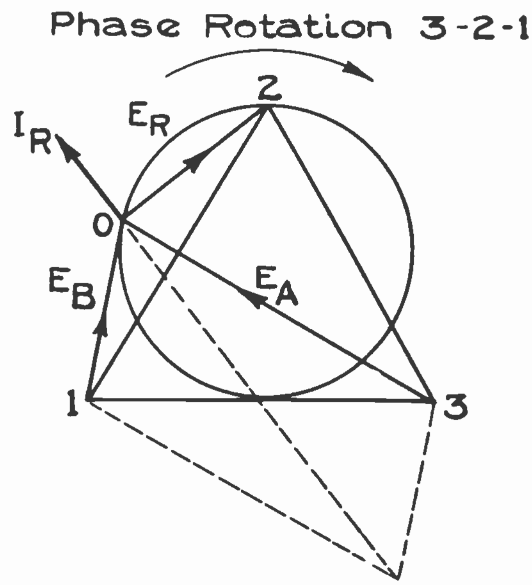


Fig. 68. Diagram Illustrating Phase Sequence in the Order of 3-2-1

SYNCHRONIZING

Before closing the paralleling breaker between two sources of polyphase alternating current, it must be ascertained that—

(1) The phase rotation of both systems has the same sequence.

(2) The voltages of both systems are of equal magnitude, and

(3) These voltages are rotating coincidentally in phase.

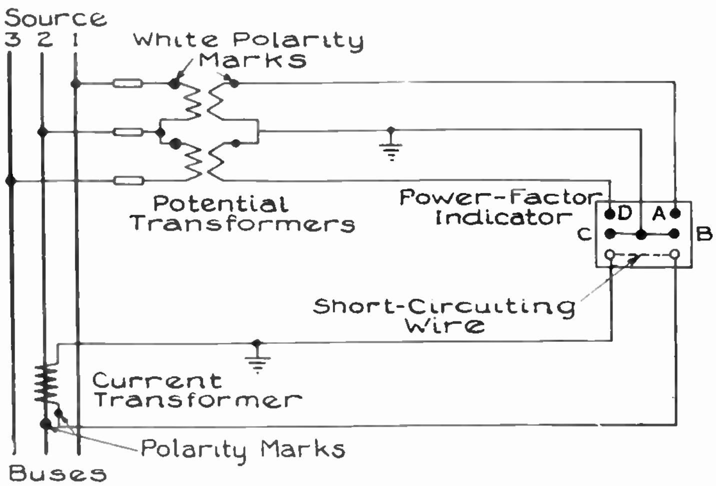


Fig. 69. Diagram of Connections for a Simplified Method of Checking the Direction of Deflection of a Power-factor Meter

Phase Sequence in Same Order

The first of these requirements may be determined by the method shown in Fig. 70. The phases as numbered at the terminal board of the new generator are temporarily connected to those poles of the breaker which on the other side are connected to corresponding phases of the bus; that is, machine phase 1 is connected to the same pole as bus phase 1, machine phase 2 to the same pole as bus phase 2, and machine phase 3 to the same pole as bus phase 3. The polarity of all the potential transformers should be the same, and care should be observed in connecting the lamps to insure that each pair is connected across corresponding phases of the new machine and the system. With normal voltage on both circuits, the pulsation of the lamps should be noted. If they all become bright and dark simultaneously the phase sequence of the new machine is the same as the rest of the system, and the circuit breaker connections may be made permanent. If, however, one pair of lamps is bright when the other pair is dark, the phase sequence of the new machine is the reverse of that of the system. To remedy this condition, two phases of the main cable of the new machine should be interchanged at the breaker or at the machine. Both pairs of lamps will now be found to become bright and dark simultaneously, and the breaker connections can be made permanent. Now that the phase sequences of the new machine and of the system are the same, it is necessary only to determine the moment of synchronism across one and the *same* phase of each, for at this moment the remaining phases must occupy coincident phase positions.

An alternative and possibly safer method is shown in Fig. 72. In this check all three lamps should become bright and dark simultaneously. If they do not, two of the phases most readily accessible on the new machine should be interchanged.

On truck panel installations and other switching equipments so designed that the circuit breaker terminals are not accessible when alive, this procedure should be followed, except that instead of testing across the circuit breaker terminals, the tests should be made across the stationary contact clips by blocking the safety shutters temporarily open, or back at the cables themselves if this is found to be more convenient.

Equality of Voltage

This may be obtained by means of the field rheostat and generator voltmeter. It is advisable

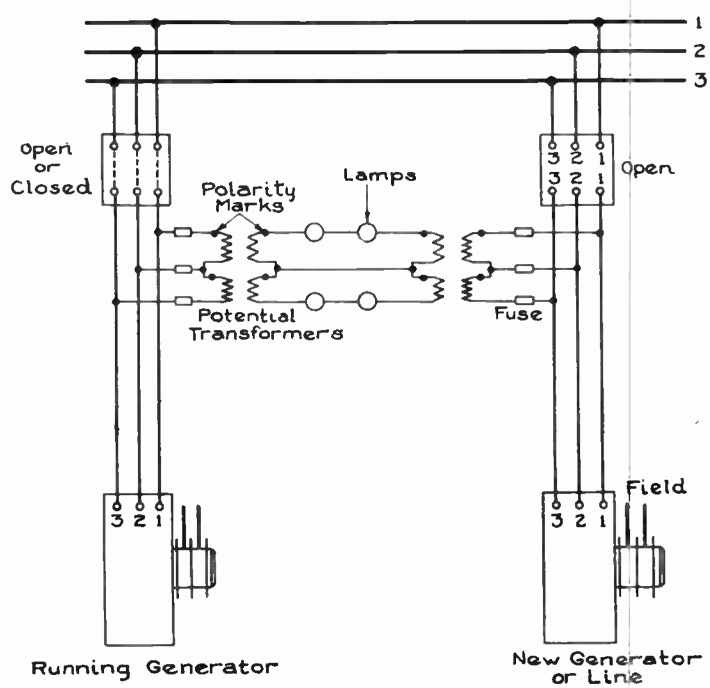


Fig. 70. Connection Diagram to Determine if Phase Sequence of Two Systems is in the Same Sequence

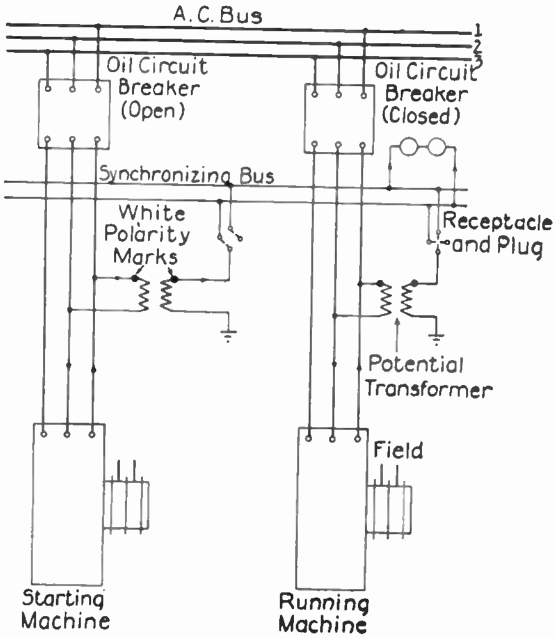


Fig. 71. Diagram of Connections for Dark-lamp Method of Synchronizing (Above 250 Volts, Lamps on Swinging Bracket)

to read voltage on all phases to be sure that each phase winding is in condition to be connected to the bus.

Coincidence of Phase

In some small installations the moment of phase coincidence is determined by means of lamps. These are usually mounted on a bracket visible to both the switchboard attendant and the engine operator. The connections for this method are shown in Fig. 71. With these connections, when the machine voltages are in synchronism, the voltage arrows across the lamps are in opposition. There is, consequently, no current in the filaments and the lamps are dark.

The indication given by lamps, however, is not close enough for accurate results, and a method employing a special device known as a synchroscope has been generally adopted. This device is shown in Fig. 73. It consists of a small motor whose field or stator is energized by the voltage of one phase of the running machine or bus. The rotor carries two windings, energized in quadrature by means of a phase-splitting device from the *corresponding* phase of the incoming machine, and rotates at a speed proportional to the difference in the speeds of the two systems. The direction of rotation of a pointer fastened to the shaft indicates whether the speed of the incoming machine should be increased or decreased. This is accomplished by means of the switch controlling the governor motor. When the pointer comes to rest on the mark at the top of the dial, the two systems are rotating at the same speed and in the same phase, and are, therefore, in phase synchronism. When it comes to rest in any other position the speeds are equal but the phases displaced, and the machines are not in phase synchronism.

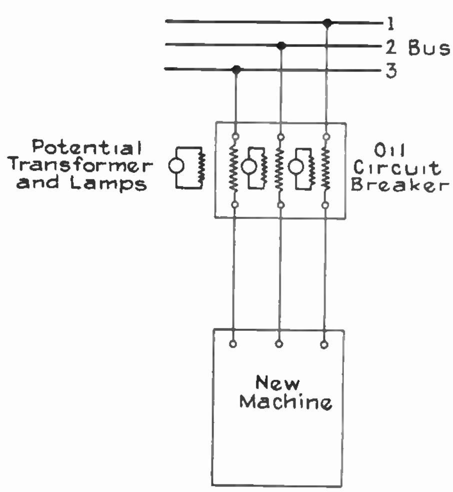


Fig. 72

Fig. 73. Synchroscope on Swinging Bracket

While exact synchronizing is desirable, it is usually difficult of attainment during the period available for the operation. A close approximation, however, may be obtained by closing the paralleling breaker just as the pointer is slowly approaching the top of the dial with the incoming machine running fast. Under these conditions the incoming machine will immediately take load, and this load will assist the synchronizing current in rapidly reducing the speed so that when exact synchronism is reached there will be little tendency to overshoot.

As the new machine takes up load, its field current should be gradually increased and the field current of the other machines correspondingly reduced in order to keep down cross magnetizing current to the minimum and at the same time maintain constant bus voltage. Load adjustment should be done by means of the governor and *not* attempted by means of the field rheostat as with direct-current machines. If the machines are of different sizes, the field currents should be proportional to the capacities and speeds of the individual units and also to the loads they carry; in other words, the field strength should be sufficient to maintain equal terminal voltages on all machines. Cross magnetizing currents are wasteful and should be avoided; they are not power currents but they heat the generators and prevent them from carrying their full rated load. It will frequently be found that when the apparent load indicated by the machine ammeters is just too great to permit the shutting down of one unit, equalization of the field strengths will reduce the ammeter readings to a value sufficiently low to permit this. On large units, magnetizing current is sometimes eliminated by means of individual voltage regulators on each machine, the exciters running independently. The position of the control magnet plunger on each regulator is controlled by a current transformer in each generator circuit connected in quadrature phase with the voltage on the magnet.

When the paralleling breaker is closed electrically, the time elapsing from the instant the control switch is closed until the breaker contacts meet should be duly allowed for in estimating the most favorable moment at which to operate the control switch.

Since the synchronizing current exerts a powerful twisting action upon the shafts and armature bars of both machines, care should be taken to keep its value within small limits. For this reason the paralleling breaker should never be closed when—

(1) The synchroscope shows any considerable phase displacement between the machines,

(2) The pointer is passing the synchronous position too rapidly, or

(3) The pointer is traveling away from the synchronous position.

A typical connection for the synchroscope is shown in Fig. 74. Connections for various other applications will be found in the individual instruction book accompanying the device, but for any switchboard installation the connections shown on the switchboard connection diagram should be carefully followed. The latter, when the conditions are unusual, may differ from any of the connections shown in the instruction book for the indicator. When connecting in accordance with the switchboard connection diagram, the potential transformer polarity marks shown thereon should be carefully observed and followed regardless of their actual physical location on the transformer case. In other words, if the switchboard diagram shows the white polarity mark connected to the synchronizing receptacle, this connection should be followed on the switchboard even though the locations of the polarity mark on the diagram and on the transformer do not agree.

On account of the importance of the function of synchronizing, the following final checks

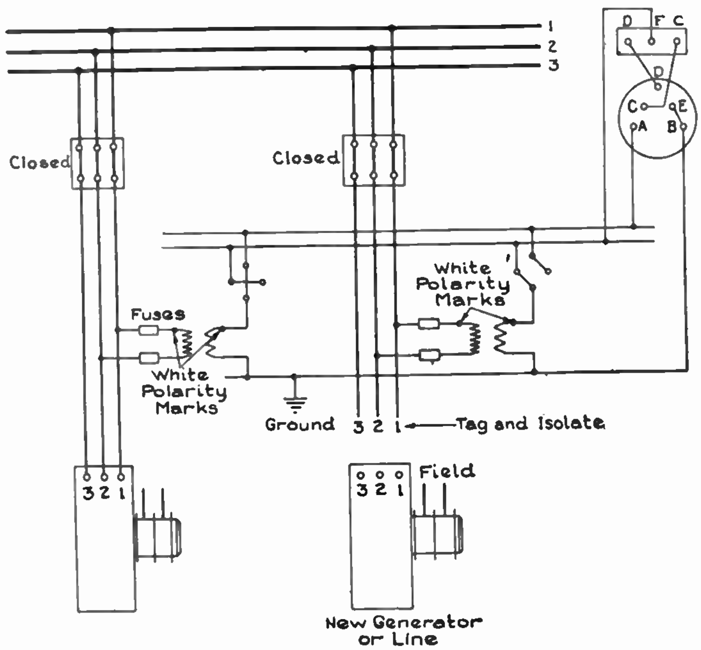


Fig. 74. Diagram Showing Typical Connection for a Synchroscope

should be made before actually attempting to put the new machine on the bus:

When the synchroscope is a new one, the position of the pointer should be checked by connecting points B and E, Fig. 74, together and to one side of a single-phase source of proper voltage, and points A and F together to the other side of the same source. If the pointer is properly set on the shaft it will point vertically upward to the synchronism mark.*

After being sure that the pointer is correct, carefully mark the leads at the terminal board of the new machine, then disconnect and isolate them as shown in Fig. 74. Insert the synchronizing plugs, one in the receptacle of a machine running on the bus and one in the receptacle of the new machine, then close the circuit breaker of the new machine. This will impress the same voltage on the stator and rotor of the synchroscope as in the preceding test and the pointer should point vertically upward. If this is found to be the case, the circuit breaker of the new machine should be opened and the connections to the generator terminal board made permanent. The new machine is now ready to be started and paralleled with the bus. If, instead, it points vertically downward the potential transformer secondary connections to the receptacle of the new machine should be reversed. Should it take up a position 120 deg. away from the synchronous position, an indication is given that the voltage of the new machine is taken across the wrong phase. Should the pointer take up any other position, such as 30 deg. away from the synchronous position, the connections should be carefully checked with those shown on the switchboard connection diagram, and if they are found to agree, the matter should be referred to the General Electric Company.

LIGHTNING ARRESTERS

Lightning arresters are necessary in most systems to prevent such potential rises, as a result of lightning disturbance, which might cause damage to the insulation of the electric equipment. It might be well to say that all abnormal rises of potential, no matter what their cause, are generally termed lightning disturbances and must therefore be guarded against.

Indoor-mounted lightning arresters must be mounted with sufficient spacing above their arcing gaps so that there shall be no condition of grounding to any structure in the immediate vicinity of the arresters. The location of arresters in outgoing and incoming lines should be such that all connections to the arresters are short and direct and of sufficient cross section to have high conductivity, thus decreasing the possibility of high inductance in the connections.

Iron connections to lightning arresters should never be used.

Lightning arresters should be installed so that there can never be a possibility of attendants or others coming in accidental contact with the lightning arrester installation. It is of paramount importance that the best possible ground be used.

Before installing and operating lightning arresters, read the instructions which cover the particular type of arrester which is used.

RELAYS

Relays in general are mounted directly upon the switchboard except in a few instances where it is found best practice to mount them on the pipe framework behind the panels, as for instance auxiliary relays on which adjustment is not required.

Relays are used in electrical circuits to detect practically all forms of line disturbances and to close or open their circuits under such conditions. In so doing, they control other protective devices connected in the affected circuit to open that circuit and thus relieve the controlled apparatus. They also function to close or open their contacts to control other auxiliary devices which give audible or visual indication of the positions of protective devices. That is, they may control the ringing of a bell, the sounding of a horn, or the lighting of a lamp to call the attention of an attendant to the fact that a particular oil circuit

Fig. 75. Type IA-201 Induction Over-current Time Relay

*For complete details of this check refer to the Instruction Book accompanying the synchroscope.

breaker is open. Fig. 75, 76, and 77 are illustrations of standard General Electric relays.

For instructions pertaining to relays, refer to the Instruction Book which covers the particular relay in question.

Fig. 76. Type PQ Standard Unit Instantaneous Circuit-closing Overcurrent Relay

Fig. 77. Type PQ Standard Unit Inverse-time-delay Circuit-closing Overcurrent Relay

OIL CIRCUIT BREAKERS

Oil circuit breakers are used in connection with alternating-current switchboards as protective devices for controlled apparatus. When the circuit in which a breaker is connected becomes affected by abnormal conditions of dangerous character, the breaker opens the circuit and thus relieves the connected apparatus. Breakers are rated according to their continuous current-carrying ability consistent with the standardization rules of the American Institute of Electrical Engineers. All ratings are based on circuits whose frequency does not exceed 60 cycles. However, on account of their structural design, breakers may have the same current-carrying capacity while their interrupting capacities may differ greatly.

The so-called OCO+OCO Duty Cycle is as follows:

The operating duty on which the standard interrupting capacity ratings of the General Electric Company's oil circuit breakers are based assumes that the breaker will interrupt a circuit under the conditions imposed by two unit operating cycles, with a two-minute interval between the two cycles, each cycle consisting of a closing operation followed immediately by an opening operation (i.e., without purposely delayed action). The breaker must perform its rated duty under these conditions without emitting flame and at the end of the duty cycle must be in substantially the same mechanical condition as at the beginning, and the main circuit-carrying parts must be in substantially the same condition as at the beginning. However, the interrupting ability of the breaker may be materially reduced, and it is not to be inferred, therefore, that the breaker may be reclosed without making inspection, and repairs where necessary.

Circuit breakers must not be subjected to current rushes greater than the short time capacities in r.m.s. amperes.

The duty, including a statement of the prescribed conditions, therefore, places a limit on the interrupting capacity of a breaker, and any change in duty or prescribed conditions will necessarily affect the rated interrupting capacity.

Methods of Mounting Oil Circuit Breakers

In all, there are four standard mountings of oil circuit breakers in connection with switchboards.

They are:

(a) On back of panel for small plant switchboards with panels 76 inches or less in height, for circuits up to and including 2500 volts (for railway work up to and including 600 volts), when the breakers do not exceed 800 amperes in capacity. See Fig. 78 for representative mounting.

(b) On panel frame for 90-inch switchboards up to and including 2500 volts (for railway work up to and including 600 volts), also for any panels with breakers above 800 amperes capacity. See Fig. 79 for representative mounting.

This mounting is not recommended when the greater number of breakers are 800 amperes or above in capacity. It is not a desirable mounting for double-throw breakers.

(c) On framework remote from panel for circuits above 2500 volts up to and including 6600 volts (for railway work above 600 volts). See Fig. 80 for representative mounting.

This mounting is recommended when the greater number of breakers are 800 amperes or over (not to interfere with rules for potential limitations). However, when only one or two breakers are 800 amperes or larger and quite a number are of lower capacity, all breakers should be mounted on panel frame.

It is also recommended for double-throw breakers, except in occasional cases where connections can be made satisfactorily for breakers mounted on back of panel, or on panel frame; also for large tank-type breakers up to and including 73,000 volts.

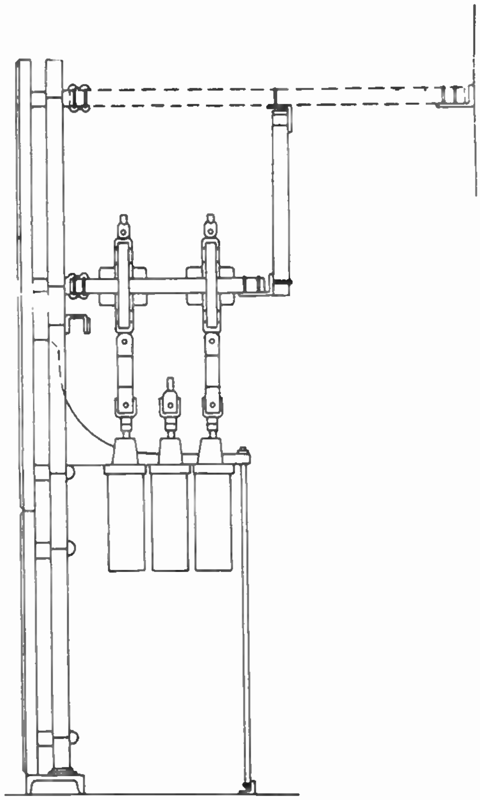


Fig. 78. Oil Circuit Breaker Mounted on Back of Panel

(d) In cells.

This mounting is for circuits above 6600 volts (for railway work 6600 volts and above), when the circuit breaker is suitable for cell mounting.

Standard arrangements of Types FKR-35 and FKR-132A oil circuit breakers are shown in Fig. 81 to 87.

For reasons of safety disconnecting switches should always be used with oil circuit breakers for isolating them from buses and energized circuits.

Operation

Switchboard breakers are operated either manually or electrically. Manually operated breakers make use of a lever mounted on the switchboard, on a pedestal, or on the floor. The lever may be either automatic or non-automatic in opening the breaker.

For instructions pertaining to the operation, installation, and maintenance of oil circuit breakers, see the Instruction Book which covers the particular breaker.

To Determine Ampere Capacity of Circuit (Motors)

The efficiencies of both alternating- and direct-current motors are likely to vary 10 or 15 per cent, and the power-factors of alternating-current motors vary over even a wider range.

The following formula is given to assist in determining the capacity of a circuit breaker for a particular circuit; the breaker should have an ampere capacity no less than overload input to the motor.

Current input =

$$\frac{\text{Horsepower output} \times 746 \times \text{Constant B}}{\text{Volts} \times \text{efficiency} \times \text{power-factor} \times \text{Constant A}}$$

Power-factor = 1 for d-c. motors

$$\text{Constant A} \begin{cases} 1 \text{ for d-c. motors} \\ 1 \text{ for single-phase motors} \\ 2 \text{ for two-phase motors} \\ 1.73 \text{ for three-phase motors} \end{cases}$$

Constant B

If "continuous rating" of motor is used, this constant will be unity; if "nominal rating" is used, it should be 1.5.

If the actual efficiencies and power-factors of motors to be controlled are not known, the following approximations may be used:

Efficiencies

Direct-current motors, 3 hp. and less, 0.80 to 0.85.

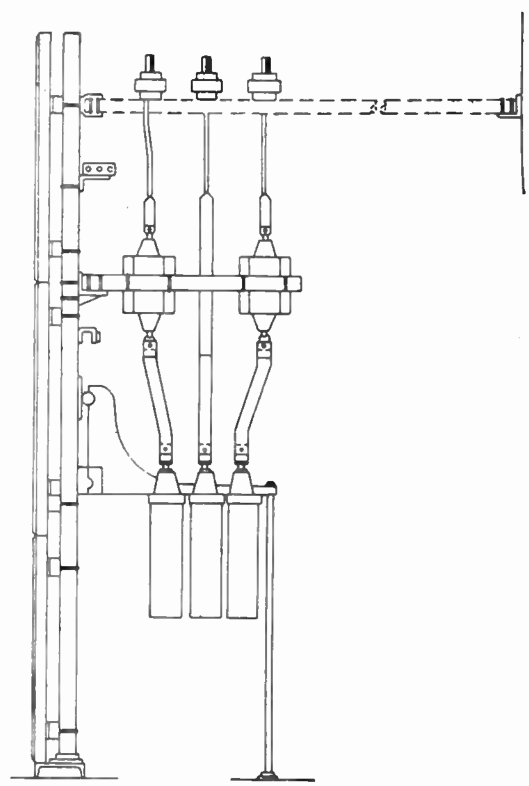


Fig. 79. Oil Circuit Breaker Mounted on Panel Frame

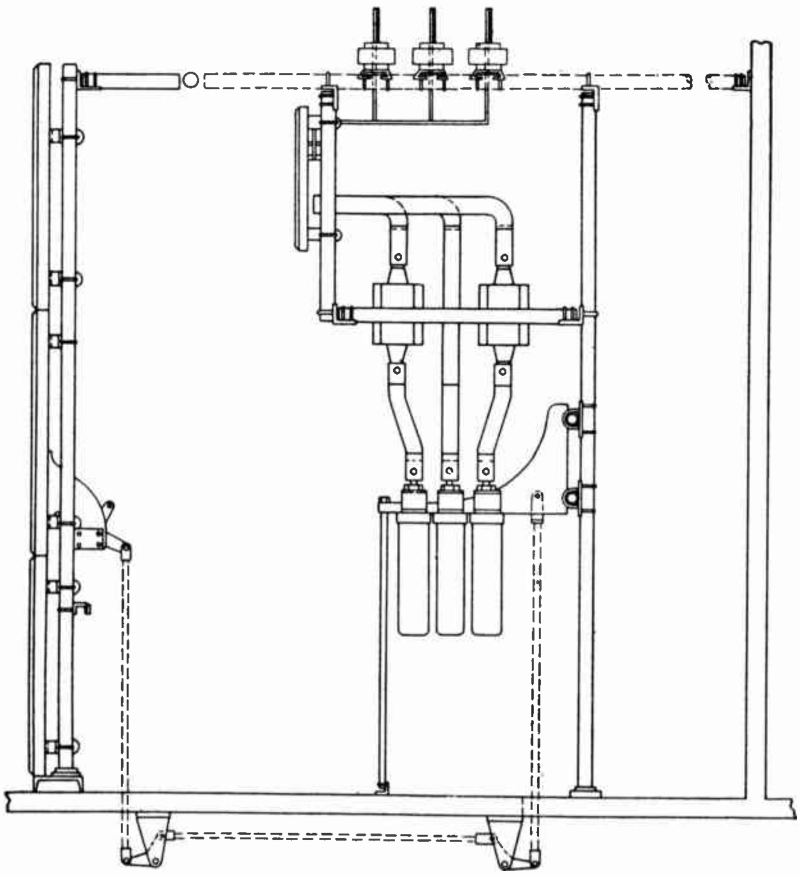


Fig. 80. Oil Circuit Breaker Mounted on Framework Remote from Panel

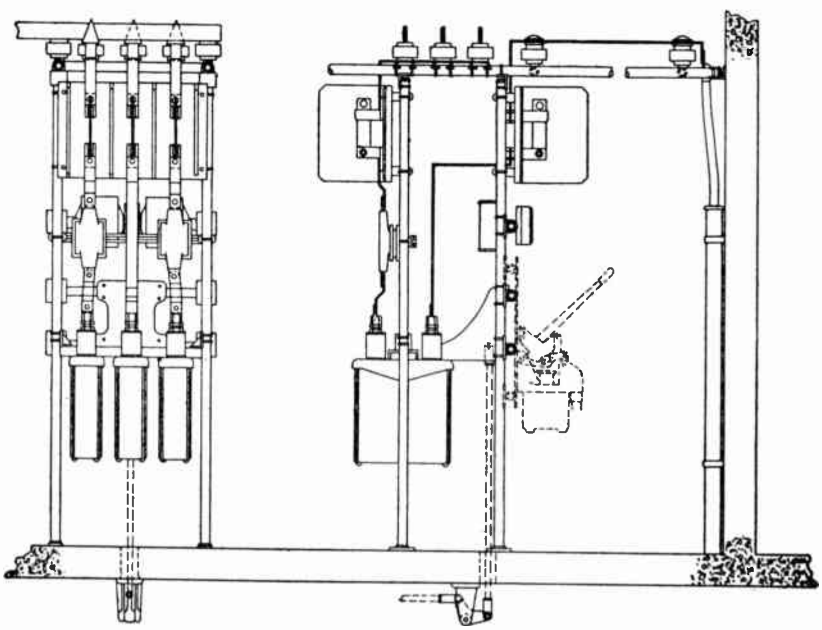


Fig. 81. Standard Arrangement of Type FKR-132 Oil Circuit Breakers, 2300 Volts

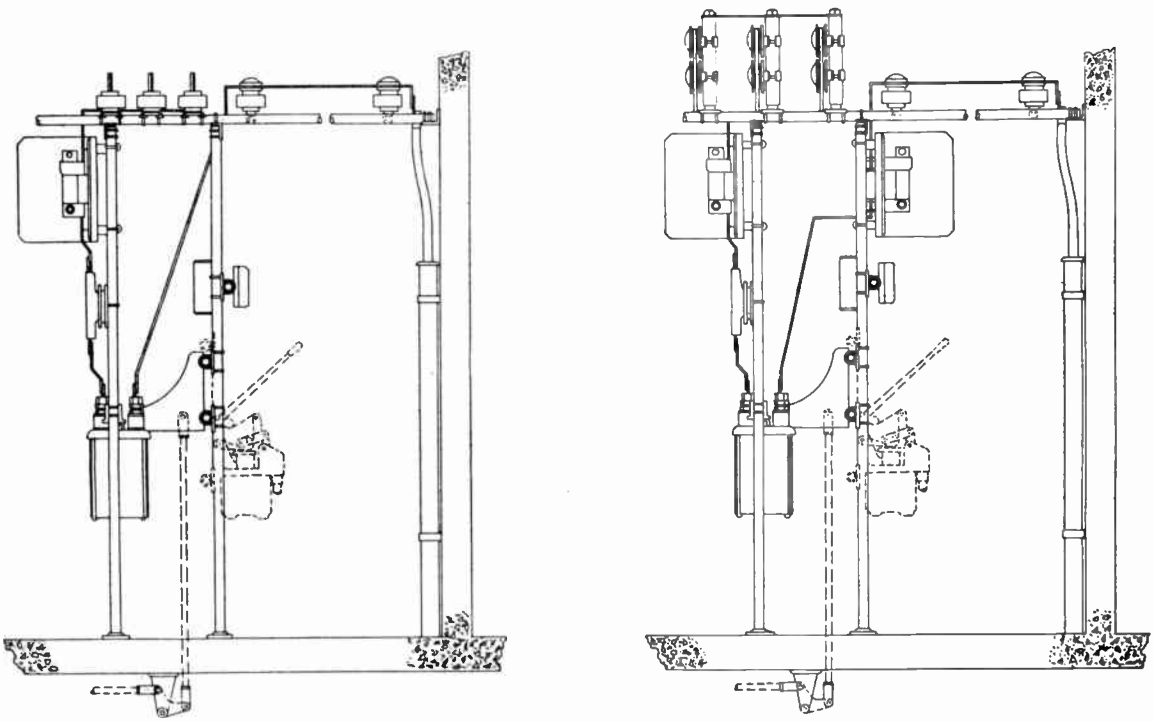


Fig. 82. Standard Arrangement of Type FKR-35 Oil Circuit Breaker, 2300 Volts

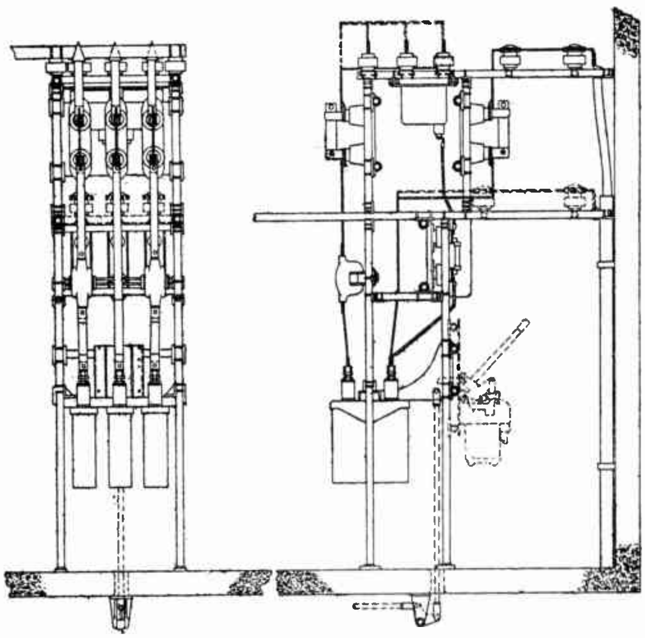


Fig. 83. Standard Arrangement of Type FKR-132A Oil Circuit Breaker, 6600 Volts

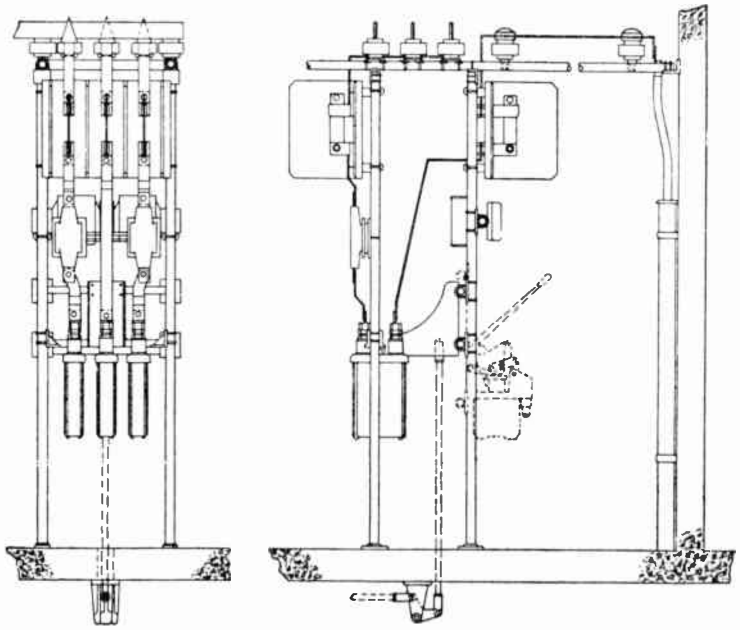


Fig. 84. Standard Arrangement of Type FKR-35 Oil Circuit Breaker, 2300 Volts

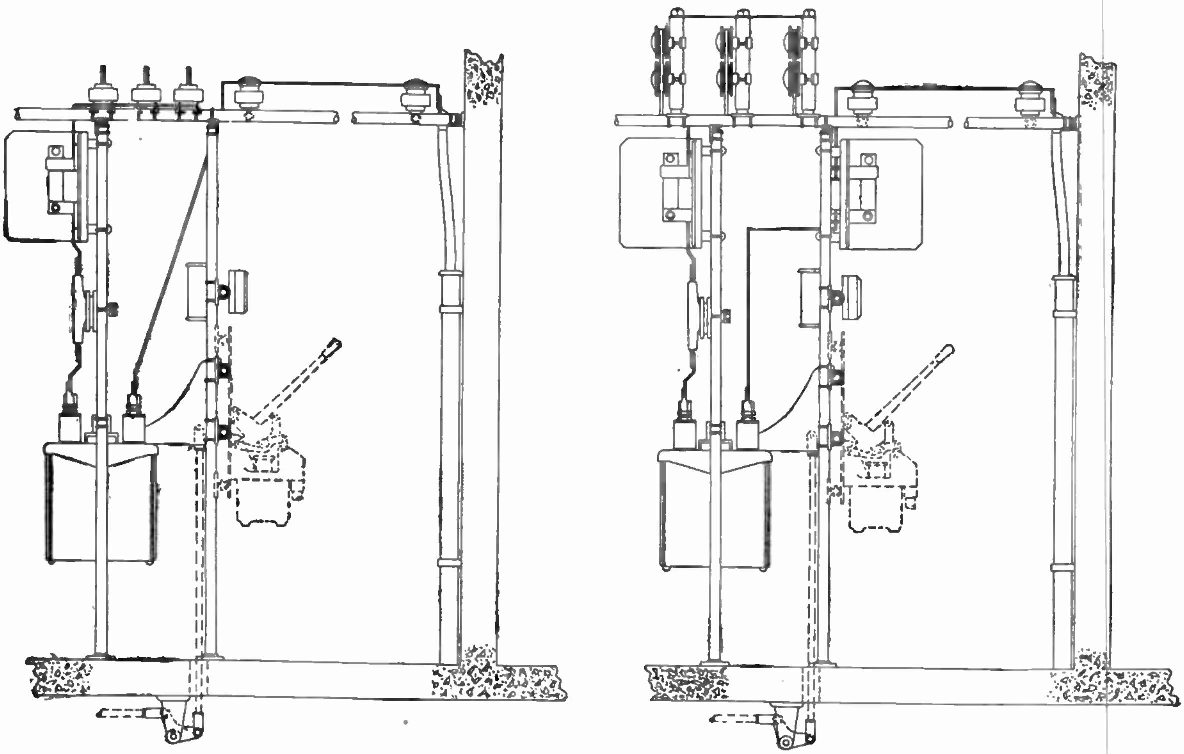


Fig. 85. Standard Arrangement of Type FKR-132A Oil Circuit Breaker, 2300 Volts

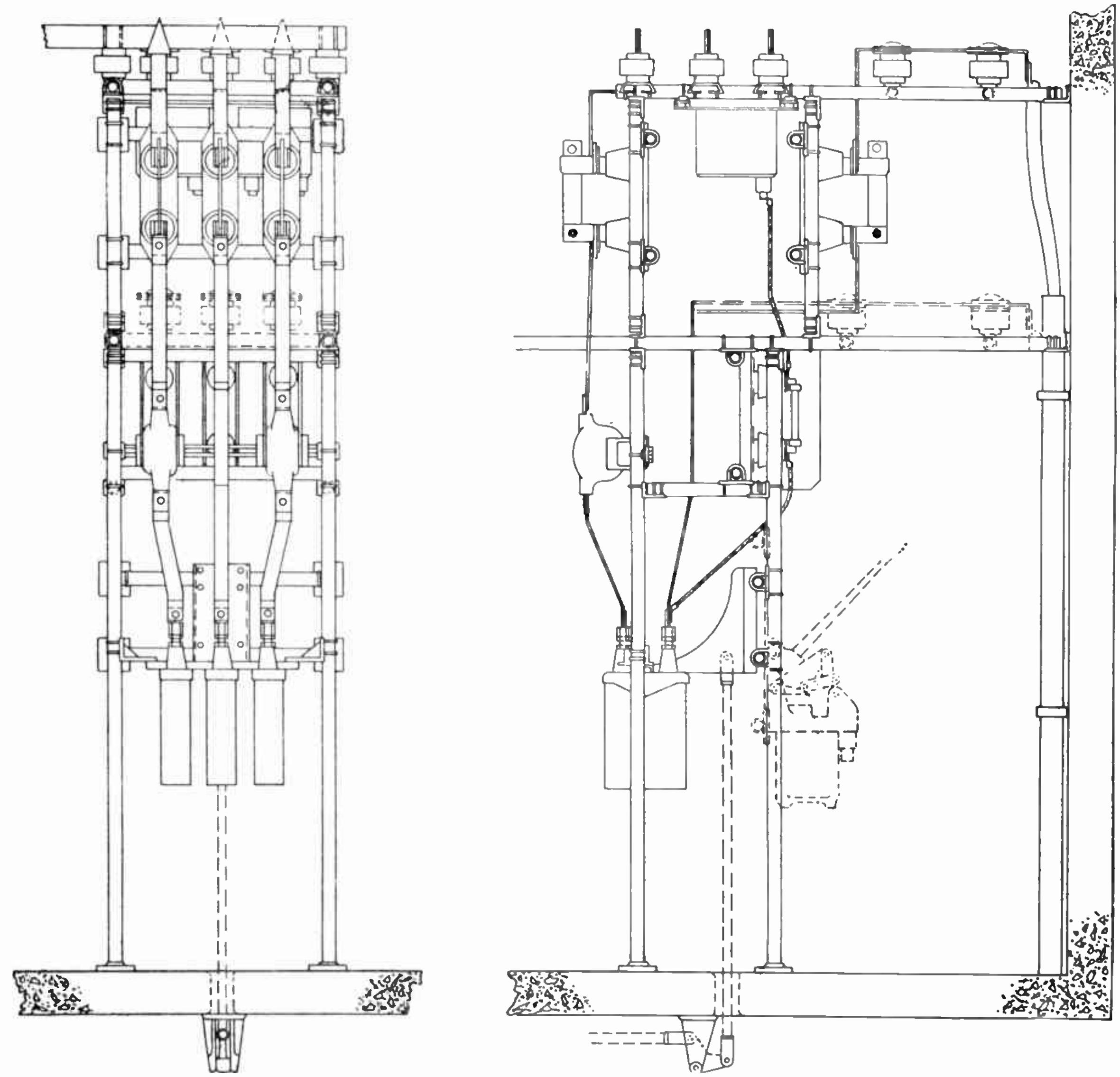


Fig. 86. Standard Arrangement of Type FKR-35 Oil Circuit Breaker, 6600 Volts

Direct-current motors, above 35 hp., 0.85 to 0.90.

Synchronous motors (at 100 per cent power-factor), 0.92 to 0.95

"Apparent" efficiencies (= efficiency × power-factor)

Three-phase induction motors 25 hp. and less, 0.70.

Three-phase induction motors above 25 hp., 0.80.

These figures may be increased slightly for single-phase and two-phase induction motors.

AIR CIRCUIT BREAKERS

Air circuit breakers are used as current-interrupting devices for all direct-current switchboards and occasionally for alternating-current switchboards. They are made in single-, double-, and triple-pole combinations. Standard air circuit breakers are illustrated in Fig. 88 and 89. They are used almost invariably as automatic devices to prevent harm to machines or other electric apparatus which might result from abnormal conditions in the circuit. The abnormal conditions may be short circuit or overcurrent, reverse current, undervoltage, unbalanced voltage in three-wire systems, phase reversal, etc.

To obtain some forms of protection it is necessary to use a relay in connection with the air circuit breaker.

For instructions pertaining to operation, installation, and maintenance of an air circuit

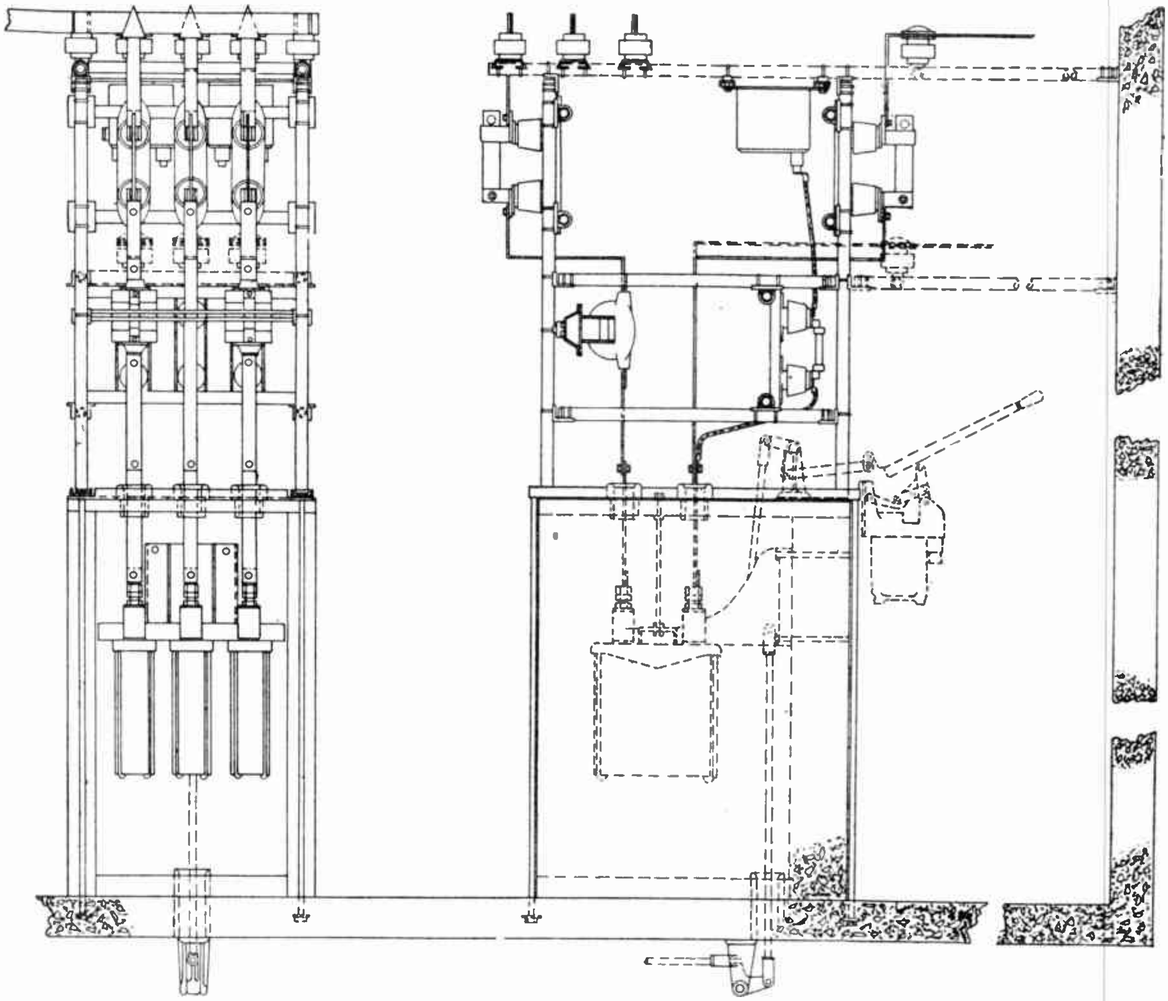


Fig. 87. Standard Arrangement of Type FKR-132A Oil Circuit Breaker, 15,000 Volts

breaker, refer to the Instruction Book which covers the particular air circuit breaker.

Selection of Air Circuit Breakers

Electric circuits are generally subjected to overcurrents of greater or less duration, and due consideration should be given to this fact in determining the current capacity of the breaker to be used. The construction of air circuit breakers is such that the maximum temperature is reached in a considerably shorter time than that of the apparatus protected, and they should therefore have a continuous capacity equal to or greater than the circuit or apparatus.

The selection of air circuit breakers by this method allows an ample factor of safety in the matter of heating and gives a good range of calibration. General Electric breakers are calibrated from a minimum of approximately 50 to 80 per cent to a maximum of 150 per cent or more of the rated capacity in the smaller sizes, and have a much greater range in the larger sizes.

When the ampere capacity of a circuit is known, the following case may be considered typical:

Normal capacity of circuit.......225 amperes
One-hour overload (25 per cent) capacity......................281 amperes
Capacity of circuit breaker.......300 amperes

For convenience we shall select a Type CP breaker to illustrate the description. This breaker has a minimum tripping point of 200 amperes, and a maximum point of calibration of 450 amperes.

Rise in temperature at normal load (225 amperes)—15 deg. C. (approx.).

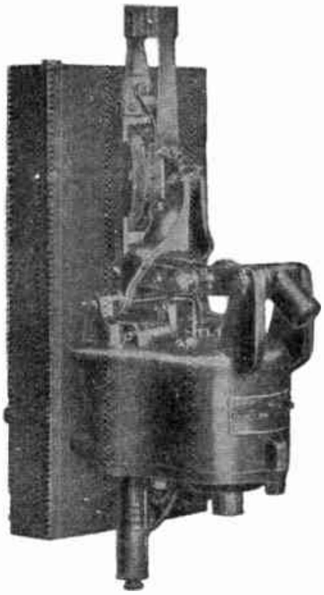


Fig. 88. 200-amp., 650-volt, Self-contained Solenoid-operated, Type CP-3 Circuit Breaker

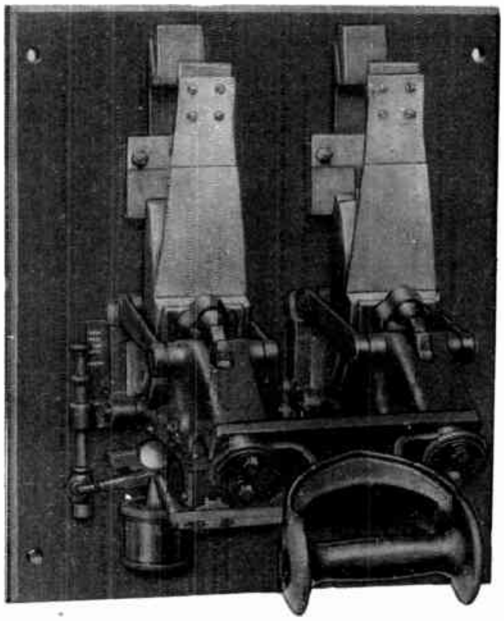


Fig. 89. Air Circuit Breaker, Type CK-8, 2000 Amp., 250 Volts, Double Pole, with Trip Free Handle and Two Time-delay Overcurrent Devices

Rise in temperature on one-hour overload (281 amp.)—23 deg. C. (approx.).

Rise in temperature at rated capacity (300 amp.)—26 deg. C. (approx.).

Minimum tripping point: 89 per cent of normal load.

Maximum calibration: 200 per cent of normal load; 160 per cent of one-hour overload.

AIR BREAK SWITCHES

Air break switches manufactured by the General Electric Company are designed to meet all the requirements of the National Board of Underwriters. When in proper adjustment, no part of these switches will exceed the heating limits specified in the Standardization Rules of the American Institute of Electrical Engineers when carrying its normal rated current, if the connections to the switch do not exceed this limit.

Disconnecting switches are not designed to open circuits under load even if the load is only the magnetizing current of transformers. They are for the purpose of disconnecting apparatus from the source of power after the circuit has been first opened by some form of circuit-interrupting device. When they are open, adjustment may be made to switchboard equipment without hazard to the maintenance men.

As a rule, disconnecting switches, when supplied as a part of switchboard equipment, are mounted on bases apart from the panels. Lever switches are mounted directly upon the switchboard panels. In cases where very heavy currents are carried by lever switches, two or more switches are connected in multiple.

S-P.S-T. S-P.S-T. D-P.S-T.

Fig. 90. Type LP-1 Lever Switches

7500 Volts | 15,000 Volts Moderate Duty—Type PB-1 | 25,000 Volts

7500 Volts | 15,000 Volts Heavy Duty—Type PC-1 | 25,000 Volts

7500 Volts | 15,000 Volts Extra-heavy Duty | 25,000 Volts

Fig. 91. Bus Supports for Indoor Service, Moderate, Heavy, and Extra-heavy Duty

Fig. 92. Typical Flat Conductor Fittings for Use with above Supports

Switch contacts should be kept in adjustment at all times to insure that they will carry their rated current without heating. Adjustment, if found necessary, should be made in the following manner:

Proper contact is obtained at the contact tongue when the laminated blades bear uniformly on all points of the tongue within the contact area. When the blade elements are assembled, the blades are parallel to one another. The blades should be curved inward slightly. This is accomplished by placing a steel rod between the blades and against the end of the holding screw, and delivering one or two hammer blows to the sides of the blades through a block of wood or hard fiber. The rod used should have a diameter approximately equal to the thickness of the switch blade.

The contact surfaces of switch blades should be coated with vaseline before testing for adjustment. This will prevent undue wear of the parts during adjustment.

The switch blades should then be moved until the tongue is inserted between the blades, and the surface tested for contact with a 0.002-in.-thickness gauge at all points which can be reached.

If good contact is obtained at the front of the blades and the thickness gauge can be inserted at the back, the blades should be withdrawn and the operation described above repeated. When properly adjusted, the switch blades should close easily over the beveled edges of the tongue.

The operations mentioned are not necessarily performed in the order named. The blades should be closed and contact tested with the gauge to determine the proper adjustment.

Do not use powdered emery or other similar abrasive to grind the tongue into contact with the blades. The use of an abrasive will injure the contact surface and cause the switch to overheat.

Where lever switches are not operated frequently, it is advisable to open and close them several times in succession each week so as to keep the contacts in good condition.

BUS AND CABLE SUPPORTS AND CLAMPS

The supports illustrated in Fig. 91 are for switchboard as well as station use where the potential does not exceed 25,000 volts. Above this range, post-type insulators, an example of which is shown in Fig. 96, are used. Supports are fitted with bases which permit turning of the insulator at any angle from 0 to 90 deg. They may be firmly locked in any position by means of bolts. They may be mounted on flat surfaces or 1¼-inch pipe. Bus support clamps, which are for use with the supports shown in Fig. 91, are illustrated in Fig. 92, 94, and 95.

In mounting bus supports, it is good practice to locate first the two which are at the ends of the bus or cable runs. Then stretch a line between the centers of these supports and mount the necessary intermediate supports in line with the end supports. If the mounting structure is flat, the bases of the supports are bolted flat against the mounting structure. If the mounting structure is of pipe framework, the supports are mounted to the pipes by means of yokes and nuts which are a part of the supports.

Supports as represented are used where busbars are mounted flat or on edge. In all cases, ¼-inch spacers are used between parallel bars of the same phase to permit proper ventilation. In some cases where bus runs are short, it may not be necessary to use spacers in as much as the clamped connections may suffice. However, in long bus runs, it is generally necessary to use copper spacers between the buses, held in place by means of clamps on the outside of the outer buses. Fig. 99, 100, and 101 show in progressive assembly the use of spacers.

Where the particular line of supports as shown in Fig. 91 cannot be used on account of the number of bars necessary to handle the capacity of the circuit, bus supports as represented in Fig. 98 are used. These supports are capable of withstanding exceptionally heavy electromagnetic stresses and carrying large numbers of buses.

A bus consisting of four 4- by ¼-inch laminations is the largest capacity which can be used with the ordinary type of bus support. Above this capacity, the buses are arranged in tiers and the proper supports should be chosen in accordance with the arrangement of buses as indicated in Fig. 44 on page 30.

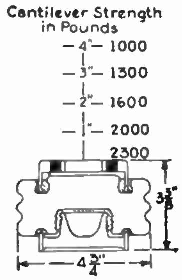
The type of bus supports should be chosen to take care of the ultimate size of the bus. That is, while the present installation may require only the ordinary type of bus support, future extension may require buses in tiers and the supports should be chosen accordingly.

Standard bus clamps are represented in Fig. 97.

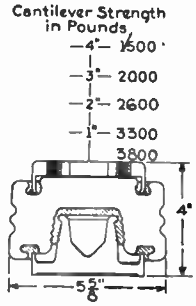
In bolting bus clamps in position, be sure to tighten the nuts uniformly so as to avoid breakage.

NAMEPLATES

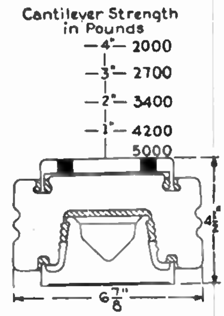
All panels of General Electric switchboards have identification nameplates which are usually mounted back of board. These nameplates show the voltage and current rating of the panel and a certain identification number. This number is the front view drawing number and the individual switchboard section number. The number should be used for all factory correspondence which relates to the switchboard or parts of it.



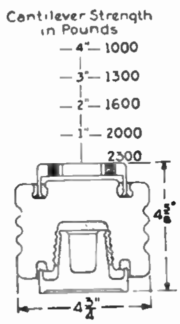
Tension.....3500 Lb.
Compression.25,000 Lb.
Arc Over....38,000 Volts
Type PB-1—Moderate Duty
7500 Volts



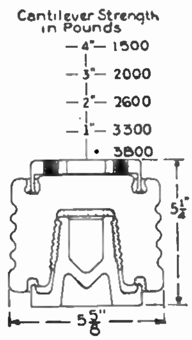
Tension.....5000 Lb.
Compression.25,000 Lb.
Arc Over...46,000 Volts
Type PC-1—Heavy Duty
7500 Volts



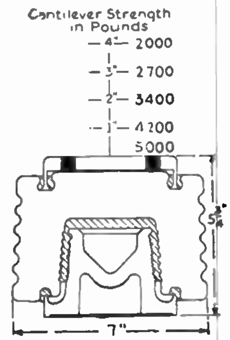
Tension.....7000 Lb.
Compression.60,000 Lb.
Arc Over....52,000 Volts
Type PD-1—Extra-heavy Duty
7500 Volts



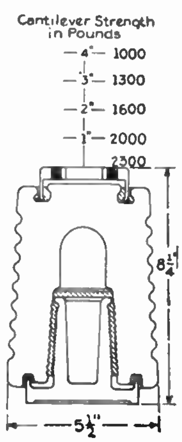
Tension.....3500 Lb.
Compression.25,000 Lb.
Arc Over....45,000 Volts
Type PB-1—Moderate Duty
15,000 Volts



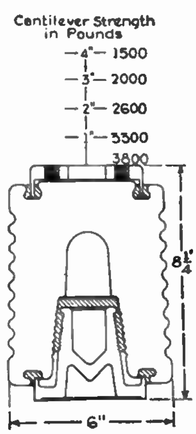
Tension.....5000 Lb.
Compression.30,000 Lb.
Arc Over....52,000 Volts
Type PC-1—Heavy Duty
15,000 Volts



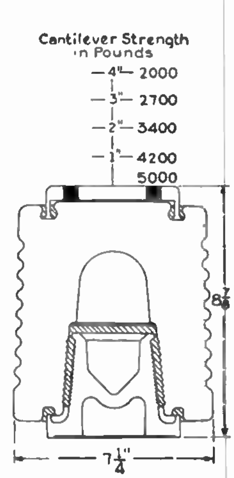
Tension.....7000 Lb.
Compression 55,000 Lb.
Arc Over....66,000 Volts
Type PD-1—Extra-heavy Duty
15,000 Volts



Tension.....3500 Lb.
Compression.40,000 Lb.
Arc Over....75,000 Volts
Type PB-1—Moderate Duty
25,000 Volts



Tension.....5000 Lb.
Compression.40,000 Lb.
Arc Over ...75,000 Volts
Type PC-1—Heavy Duty
25,000 Volts



Tension.....7000 Lb.
Compression.60,000 Lb.
Arc Over....75,000 Volts
Type PD-1—Extra-heavy Duty
25,000 Volts

Fig. 93. Outline Dimensions Indoor Bus Supports

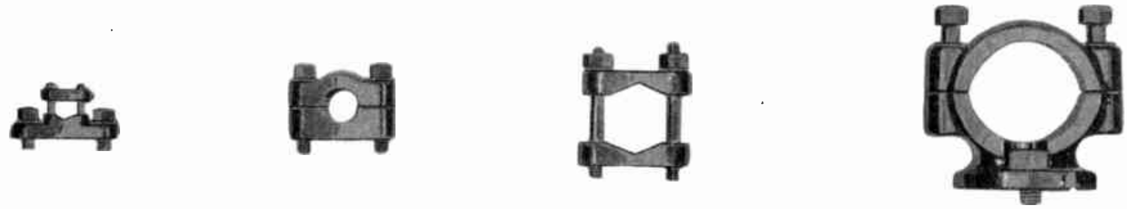


Fig. 94. Typical Round Conductor Fittings for Use with Supports Shown in Fig. 91

Fig. 95. Typical Base Fitting for Use with Supports Shown in Fig. 91

CARD HOLDERS

Card holders are used on switchboards where they are deemed necessary. They are made in different sizes. Contract form 11919-1 contains the clause, "The Company will furnish one card holder for each circuit." This applies to the main circuits controlled by the switchboard and constitutes a definite rule. Apart from this, it is not desired to make any set rules, in as much as judgment must be exercised to insure that our switchboards will be properly labeled to suit the convenience of the operator and that an acceptable appearance is obtained.

The smaller card holders are used in many cases for the sake of better appearance. The following points, for instance, are mentioned for general guidance:

We have three sizes of card holders, Pu-413426 which may be considered the standard, since it holds the larger size card; a smaller one, Pu-413425; and a very small one, Pu-1713728.

In general, only one card holder is required per circuit. This applies to double-throw oil circuit breakers, connecting one circuit to either of two buses, or to two or more single-pole, single-throw lever switches when used for the different leads of a single circuit.

Double-throw lever switches have card holders for each throw when practicable.

Fig. 96. Post-type Insulator for Bus Wire and Bus Tube Supports

Fig. 97. Standard Bus Clamp

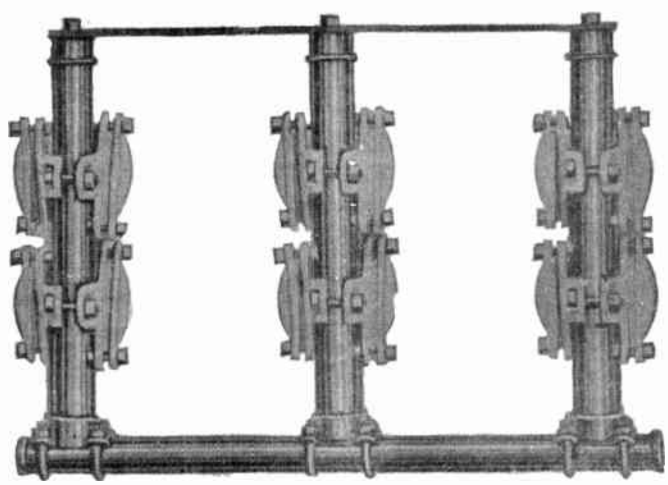


Fig. 98. Insulated Rod-type Insulator Showing Buses Arranged in Tiers

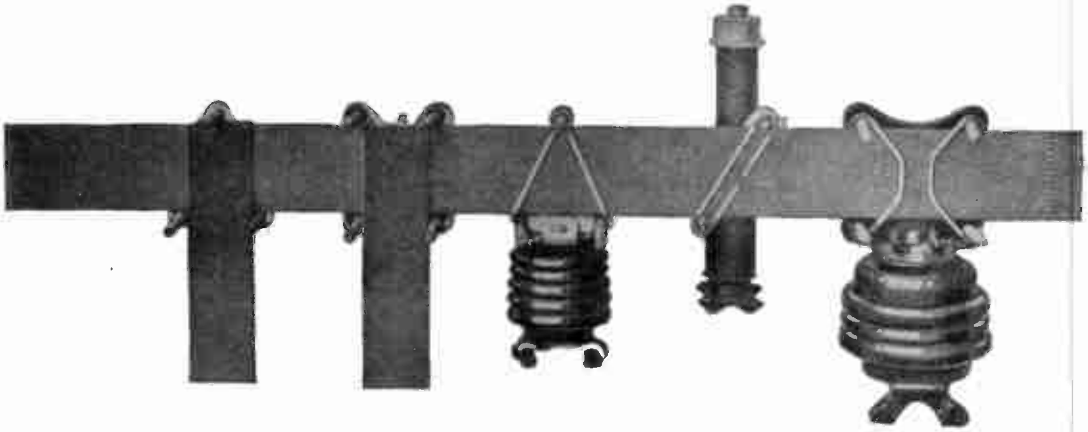


Fig. 99. When Multiple Bars are Used for Buses, it Becomes Necessary to Use Spacers. This practice provides a means of ventilation as well as a perfect paralleling of the bars. The method of using spacers is here shown in progressive assembly illustrations

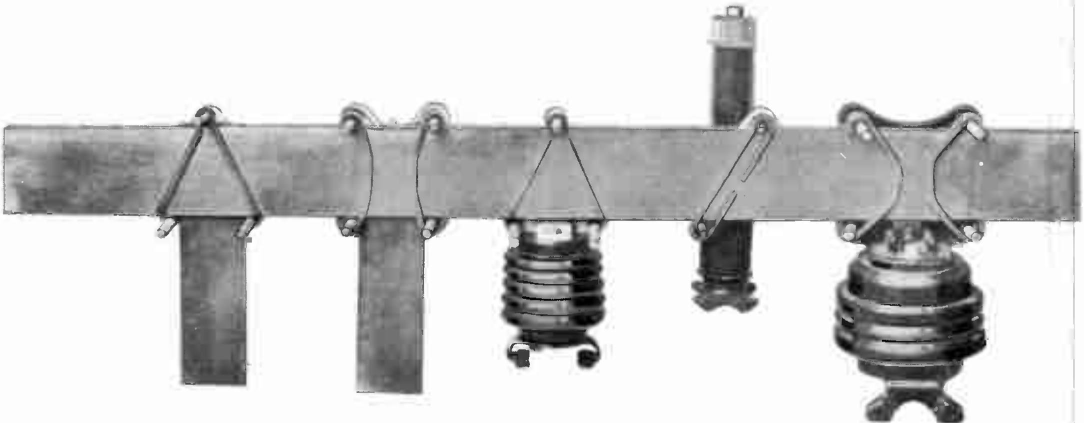


Fig. 100. Method of Using Spacers Shown by Progressive Assembly Illustrations. The second bar is positioned and the second set of spacers is in place (2nd step)

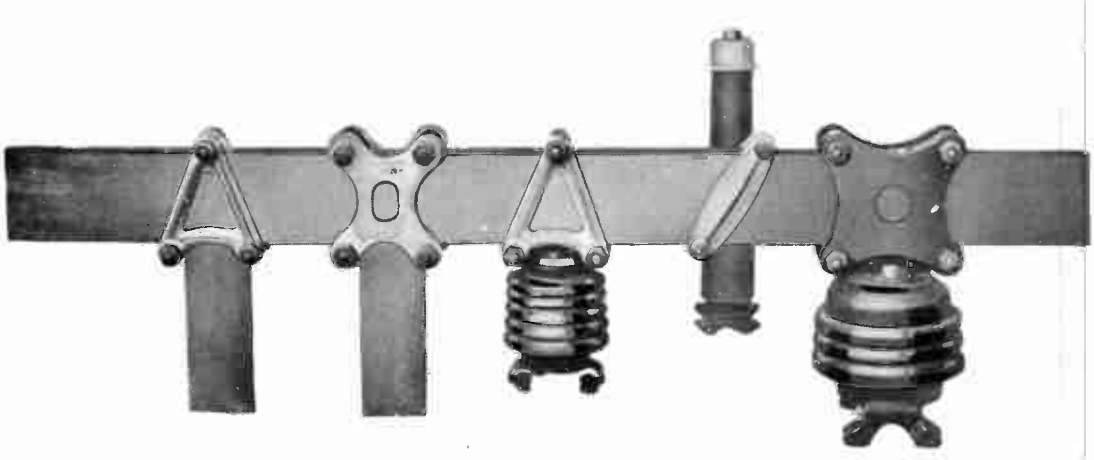


Fig. 101. Method of Using Spacers Shown by Progressive Assembly Illustrations. The third bar is placed over the second set of spacers and the bus clamps are fitted and tightened (3rd step)

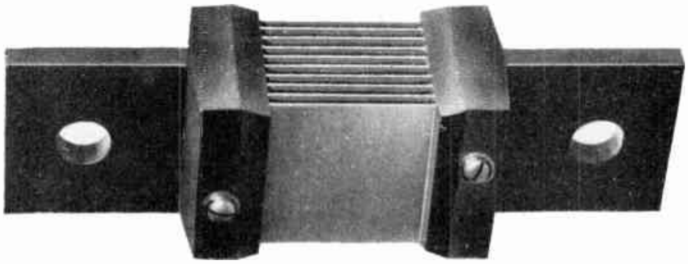


Fig. 102. Form 4 Shunt, 75-800 Amperes

Card holders are seldom necessary for auxiliary circuits on a panel such as the rheostat and governor control switches; but when their location is such as to leave doubt as to the function of the switch or device, a card holder, usually the small size, is supplied.

SHUNTS

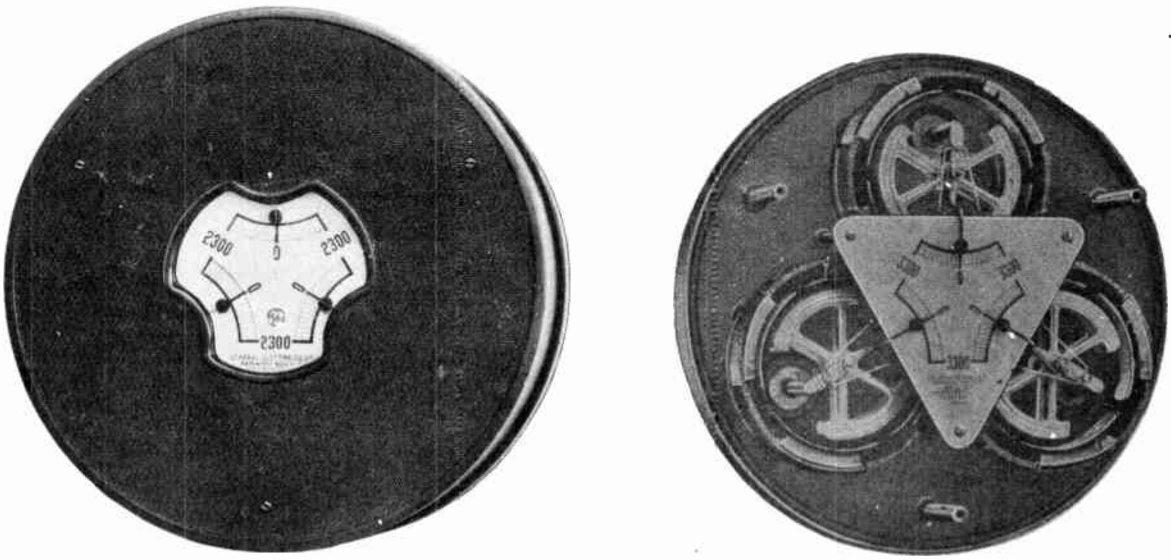
Shunts (see Fig. 102) are used in connection with direct-current instruments where the current is of such capacity that it is not practicable to pass the entire line current through the instrument. The shunt is a dependent part of an instrument and is supplied with a pair of leads which are precise only with the instrument and shunt with which they were calibrated. Instruments and shunts are supplied with numbers so that there will be no difficulty such as connecting up an instrument with a shunt other than the one with which it was intended.

Shunts are mounted behind the switchboard in the connection bars. They are located at a sufficient distance from the panels so that there will be no condition whereby apparatus on the panel will receive heat which might radiate from the shunt.

In handling a shunt, be sure to avoid damaging the leaves in any way, or the calibration may be affected. Leads must not be cut or changed.

GROUND DETECTORS

On ungrounded systems, alternating-current as well as direct-current, it is necessary to install some kind of equipment for detecting or reading leakage to ground to accord with N.E.C.S. rules. For low-voltage two-wire systems the simplest method is to connect two lamps of the system voltage in series across the two wires, with the connections between the two lamps grounded. Ground on one side will obviously short circuit and darken the lamp on that side. Above 300 volts, electrostatic or glower type of ground detector instruments is generally used. A typical General Electric ground detector is shown in Fig. 103.



Exterior

Interior

Fig. 103. Type E-7 Electrostatic Ground Detector

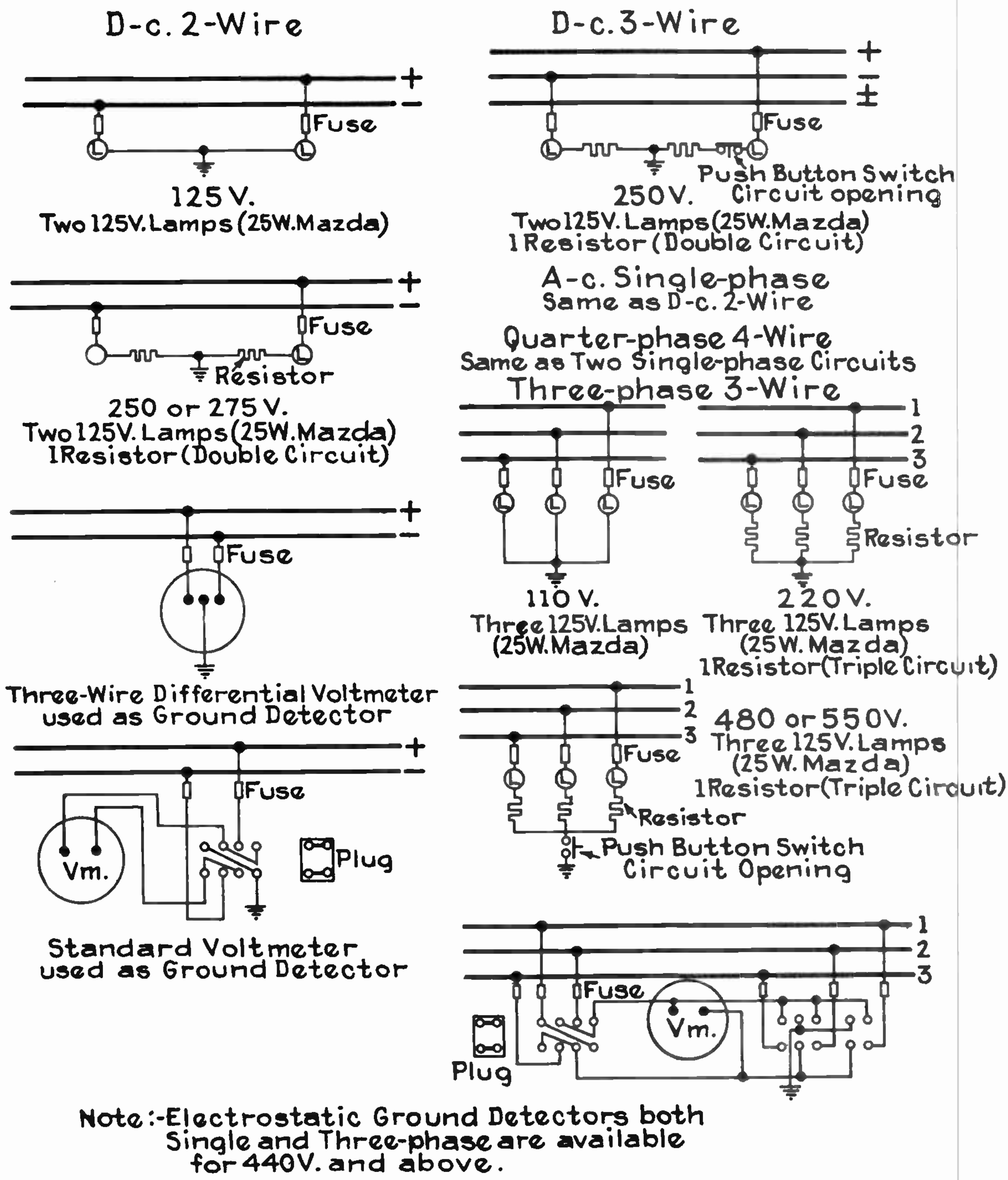


Fig. 104. Ground Detector Connections

A few connections for these ground detectors are shown in Fig. 105, while suggested connections for lamps as ground detectors are shown in Fig. 104.

Ground detectors should be mounted above switchboards only when the high voltage bus is located directly in the rear, and even then they should be mounted beyond the reach of an attendant. Where the buses are remote from the board, the instruments should be located near the buses and suspended from the ceiling.

Rheostats are not furnished with the switchboard; supports when required for rheostats or countershafts are to be furnished by purchaser.

Discharge resistors for machine fields are dependent upon the machine characteristics, and therefore are not furnished with a switchboard.

RESISTORS

The standard practice is to mount small resistors directly upon the back of the switchboard panels. Resistors have serial numbers stamped upon their nameplates. The nameplates of instruments and meters with which they are to be connected also contain the same serial number so that there will be no error, such as connecting a wrong resistor with a relay, meter, or other device. In connecting resistors with devices, be sure to check the serial numbers.

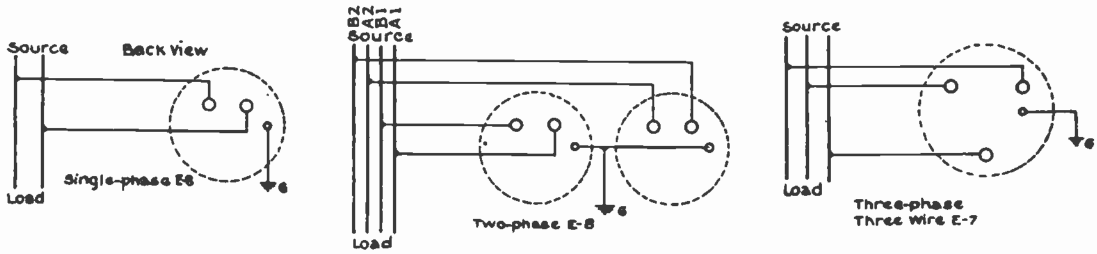


Fig. 105. Connections for Electrostatic Ground Detector, Types E-7 and E-8, 3300 Volts and Below

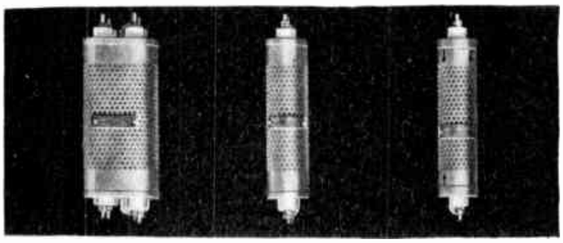


Fig. 106. Small Resistors for Mounting on Back of Switchboard Panel

RHEOSTATS

There are different arrangements for operating rheostats, depending upon the size of the rheostat and the local conditions. Exciter rheostats are usually operated by means of handwheels on the front of the switchboard, connected to the rheostats. For generators up to certain capacities, the handwheels for the operation of the exciter and generator rheostats are made concentric, the generator rheostat being mounted in a convenient location and operated by means of a chain and sprocket. Generators of the larger capacities generally have electrically operated rheostats, controlled from the switchboard by double-throw control switches.

Rheostats which are electrically operated are usually placed where most convenient, as these have no mechanical relation with the switchboard.

The locations shown in Fig. 107 for rheostats manually operated by means of a sprocket wheel and chain mechanism are the ones ordinarily feasible. In each specific case a location should be selected where the rheostat and mechanism will not interfere with cable leads or switchboard apparatus and where the countershaft, if required, will not exceed six feet in length.

Sprocket wheels, chains, wire turn-buckles, and countershafts are parts of the operating mechanism included in panel equipments when local conditions are known at the time of designing the switchboard.

BARRIERS

Barriers are used chiefly for the purpose of making a safer installation.

Barriers are used with switches for voltages above 750 volts up to and including 15,000 volts except where the switches are mounted out of reach of accidental contact and where switches are placed on adequate distances of center lines. They are also used with the quick-break type of lever switches above 500 volts rating. Above 15,000 volts, barriers are seldom used, since switches for this voltage are spaced sufficiently far apart and out of reach.

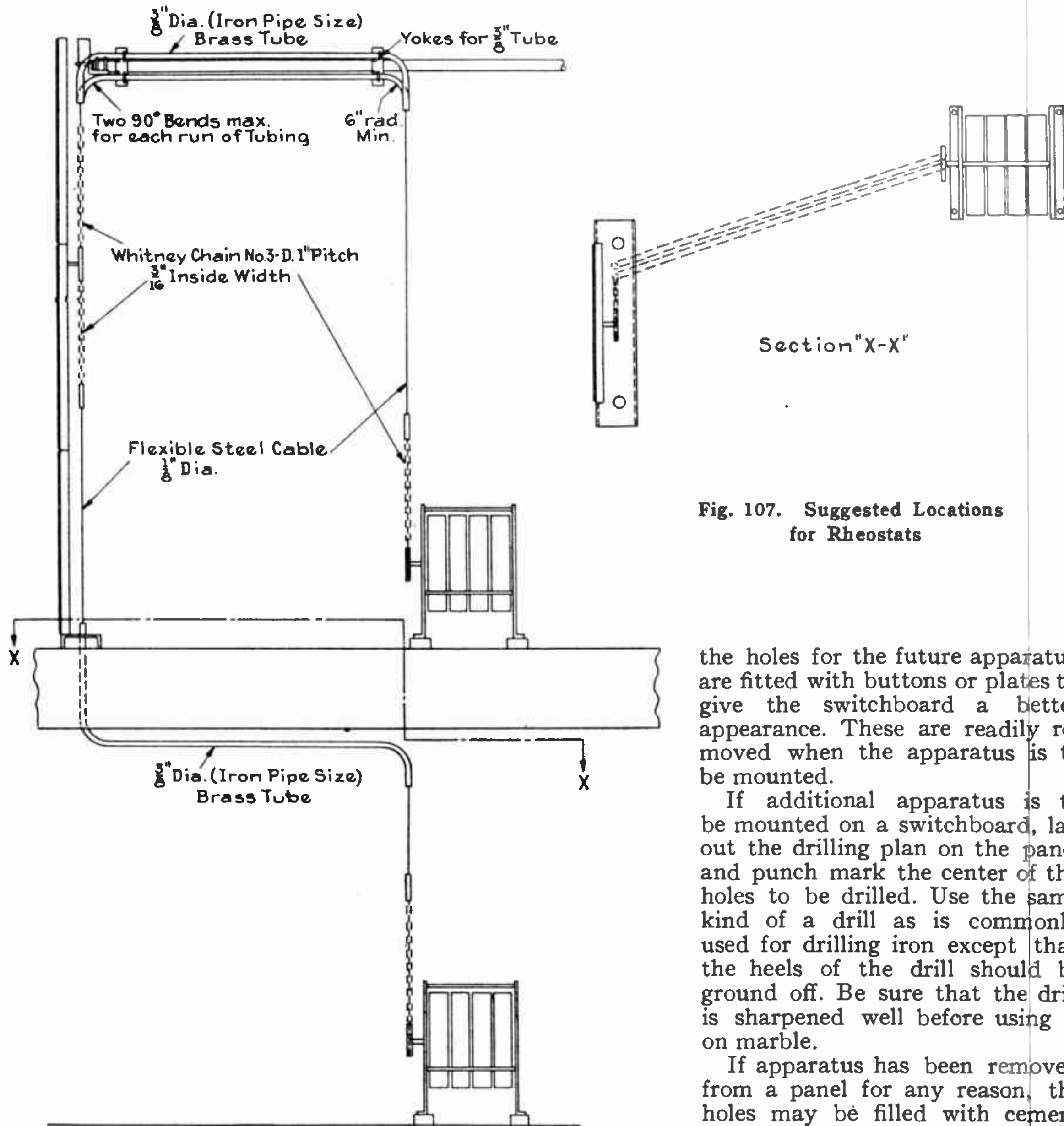


Fig. 107. Suggested Locations for Rheostats

Barrier s for apparatus mounted on panels are usually m ade of the same material as the panels. For pro tection around buses, asbestos barriers are generally used. For apparatus mounted on masonry cells, the barriers may be made of brick, concrete, soapstone, or ebony-asbestos.

SUGGESTIONS FOR SWITCHBOARD ATTENDANTS AND CONSTRUCTION MEN

Repair of Switchboards

Some switchboards are drilled to take future apparatus as demand necessitates. In such cases, the holes for the future apparatus are fitted with buttons or plates to give the switchboard a better appearance. These are readily removed when the apparatus is to be mounted.

If additional apparatus is to be mounted on a switchboard, lay out the drilling plan on the panel and punch mark the center of the holes to be drilled. Use the same kind of a drill as is commonly used for drilling iron except that the heels of the drill should be ground off. Be sure that the drill is sharpened well before using it on marble.

If apparatus has been removed from a panel for any reason, the holes may be filled with cement or plaster of paris darkened to the same color as the panel material. Buttons may be obtained to fill holes

INSTRUCTIONS FOR REFINISHING MARBLE PANELS WITH BLACK MARINE LACQUER

Material Required

General Electric marine lacquer No. 5075.
General Electric thinner (same number).
One gallon of each, mixed, will cover about 200 square feet panel surface.
On refinishing work, the covering capacity is somewhat great er.

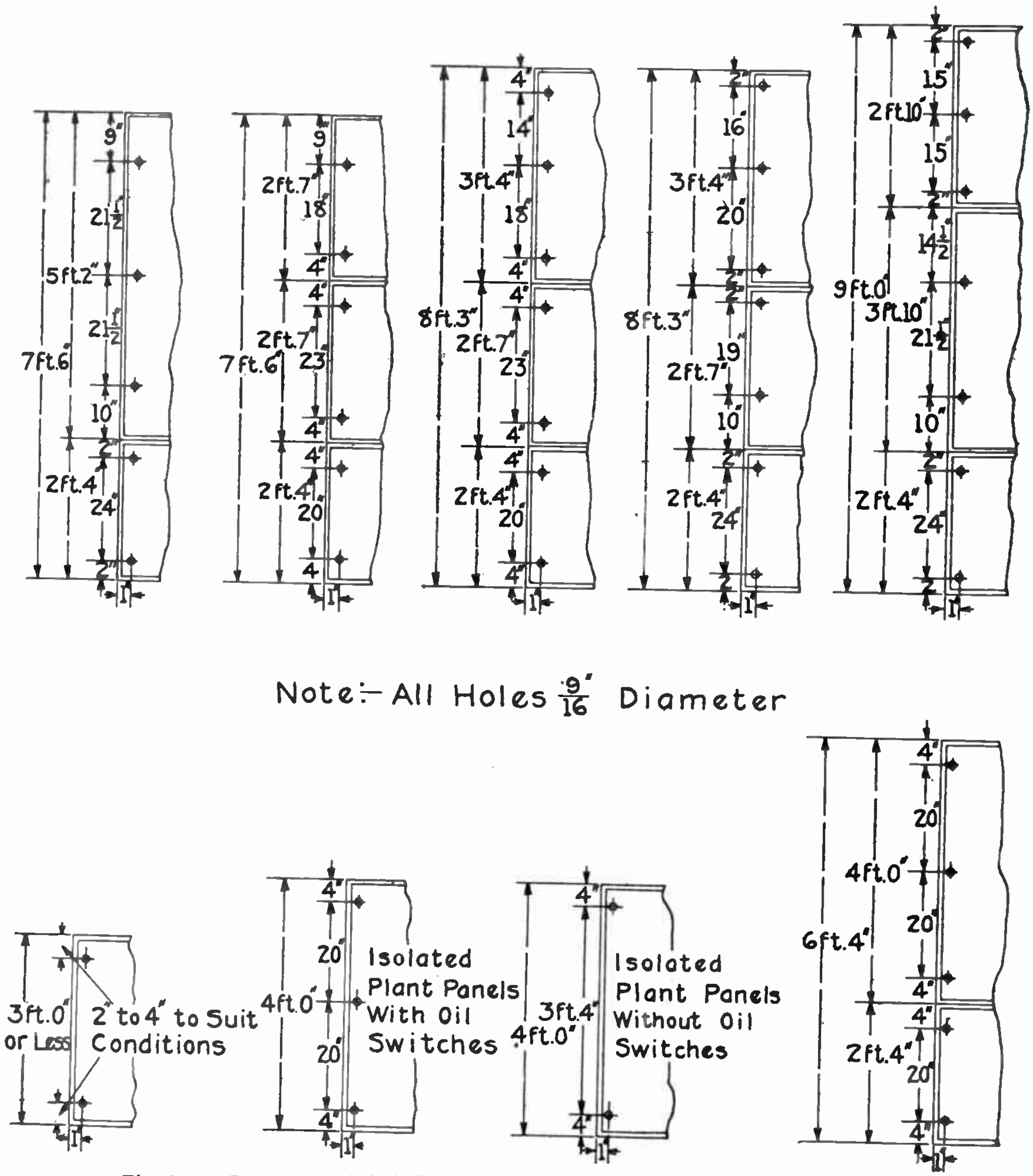


Fig. 108. Standard Bolt-hole Locations for Switchboard Panels of Various Sizes

NOTE.—Panels with heavy equipment such as large air circuit breakers sometimes require special location of supporting bolts.

Preparation

The panel surface must be thoroughly cleaned of oil or grease by gasoline or carbon tetrachloride, but this cleaning fluid must be carefully removed by a cloth moistened with the thinner.

The polish should be removed by pumice stone.

The panel equipment that cannot be removed should be carefully masked with paper as protection against the lacquer and thinner.

Application of Lacquer

The lacquer should be thinned to proper consistency, which usually requires about equal parts of lacquer and thinner. Apply either by spraying or by a camel's hair brush. In either case it should be allowed to flow out to give the best result. The service of an expert is usually required.

Marred slate panels may be repaired by oiling the mar if the switchboard is of natural

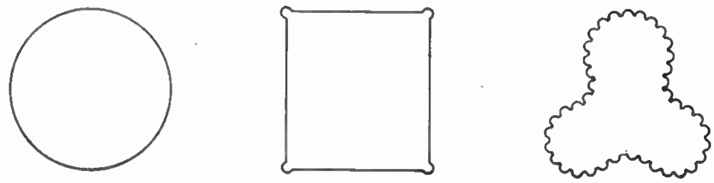
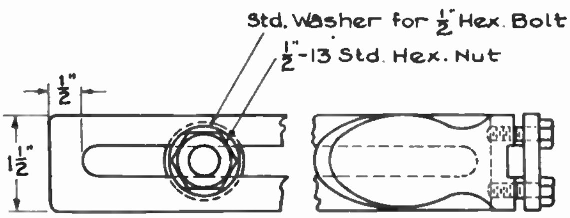


Fig. 109. Different Forms of Holes Which are Necessarily Made in Slate and Marble Switchboards

black slate. If the switchboard is of marine finish, the panel may be marined to conceal the mar.

Marble panels which receive oil stains may be repaired so that their original appearance will be practically restored by the application of a mixture of benzine and plaster of paris to the oiled spot. Allow the mixture to remain on the panel at least 48 hours.

Lacquer thinner may be used to remove marine finish from a switchboard. Soak a piece of waste with the liquid and rub the panels.



Panel Drilling

Drilling plans for the standard location of panel-supporting bolts for different sizes of switchboards are shown in Fig. 108. If additional apparatus is to be mounted upon a switchboard, it is sometimes necessary for the purchaser to do the drilling. Brace and drill for this purpose should be used from the front side of the panel, and the pressure should be removed from the brace before the drill has passed completely through. If the pressure is not removed, large pieces may be broken from the panel back.

If large round or irregular holes such as shown in Fig. 109 are to be made in a panel for mounting instruments, operating levers, etc., it is recommended that the drilling be carried out by a stone cutter.

In cases where a customer prefers to do his own drilling, an inexpensive tool, as suggested

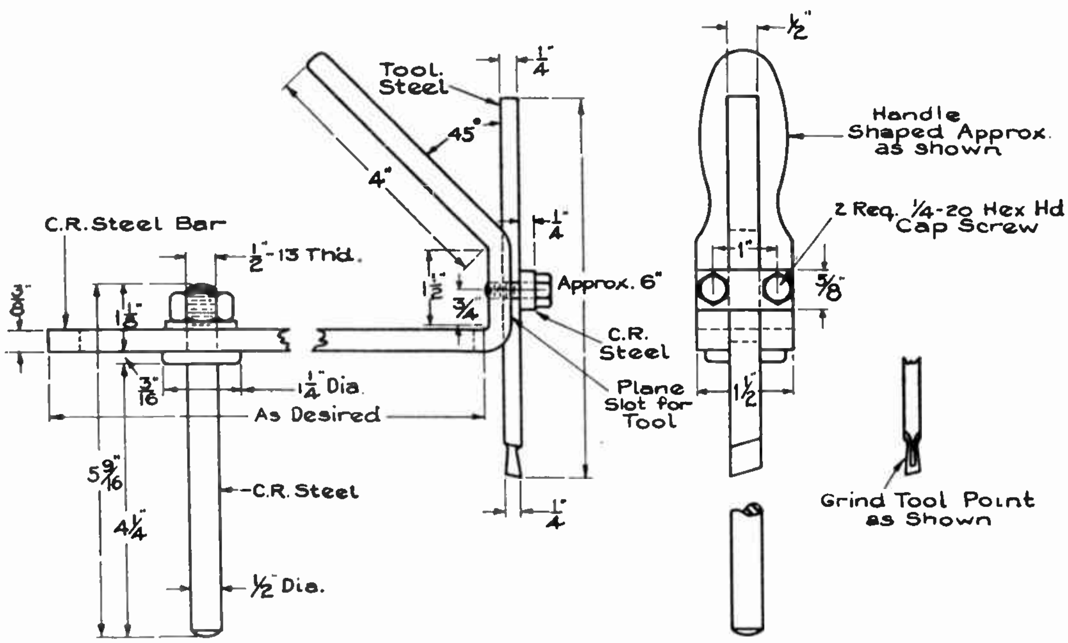


Fig. 110. An Inexpensive Tool Which May be Constructed for the Purpose of Drilling Circular Holes in Slate and Marble

in Fig. 110, may be made for the purpose of cutting round holes.

A square hole may be made by first drilling the four corners of the square and then sawing from hole to hole until the square is completed.

Irregular holes may be made by first laying off the shape of the hole on the panel, and then drilling holes along the mark. Each hole, of course, must intersect the previous one. When the hole has been made, the rough edge should be filed smooth.

Spare Parts

To insure continuity of service, the customer should order spare or renewal parts before he actually needs them. The manufacturer will gladly submit a recommended list, from which these can be ordered for convenient delivery. These spare parts should be properly tagged and placed in safe, but convenient, locations, where they can be found instantly in perfect condition when needed. Fuses, indicating lamps, arcing contacts, and parts subject to wear or burning are suggested as the spare parts which should be kept on hand.

Temporary Equipment

When it becomes necessary to connect part of a switchboard for operation, before the rest of it has arrived, it is usually the best practice to install temporary equipment somewhat away from the permanent board so that the final installation can be undertaken without handicap or danger from the temporary equipment. By a little planning, this changing over at the completion of the board will necessitate very little interruption in service.

To Determine Polarity of Low-potential Direct-current Wires

The polarity of wires which are to be connected for certain purposes (e.g., battery charging) should be definitely known before completing the circuit. This may be determined by connecting a voltmeter across the wires and closing the circuit. The voltmeter when connected should read up-scale. If this condition does not exist, the wires should be reversed. The voltmeter terminals are marked positive and negative and when connected correctly indicate the polarity of the connected wires.

If no voltmeter is available, the polarity of the wires can be determined by dipping the ends of the two wires in a glass of water in which a very small amount of common table salt, potash, or acid electrolyte has been dissolved. Keep the wires about one inch apart. When there is current flowing, gas bubbles will form on both wires, but the wire about which the greater amount of gas bubbles is being formed will be the negative side of the circuit (see Fig. 111).

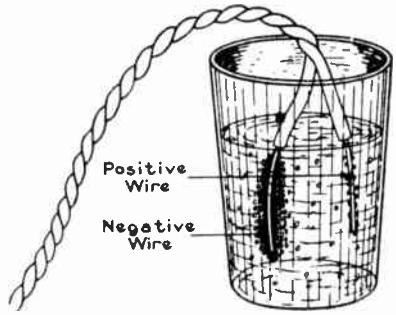


Fig. 111. Method of Checking Polarity of Low-voltage Circuit

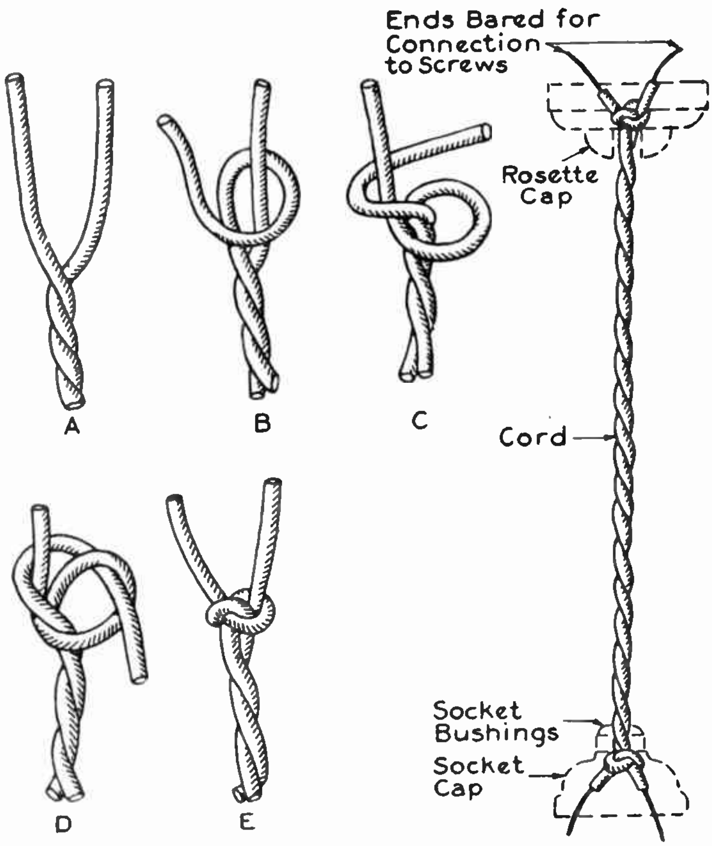


Fig. 112. Method of Tying Underwriters' Knot in Lamp Cord to Prevent Strain on Terminals of Sockets and Fixtures

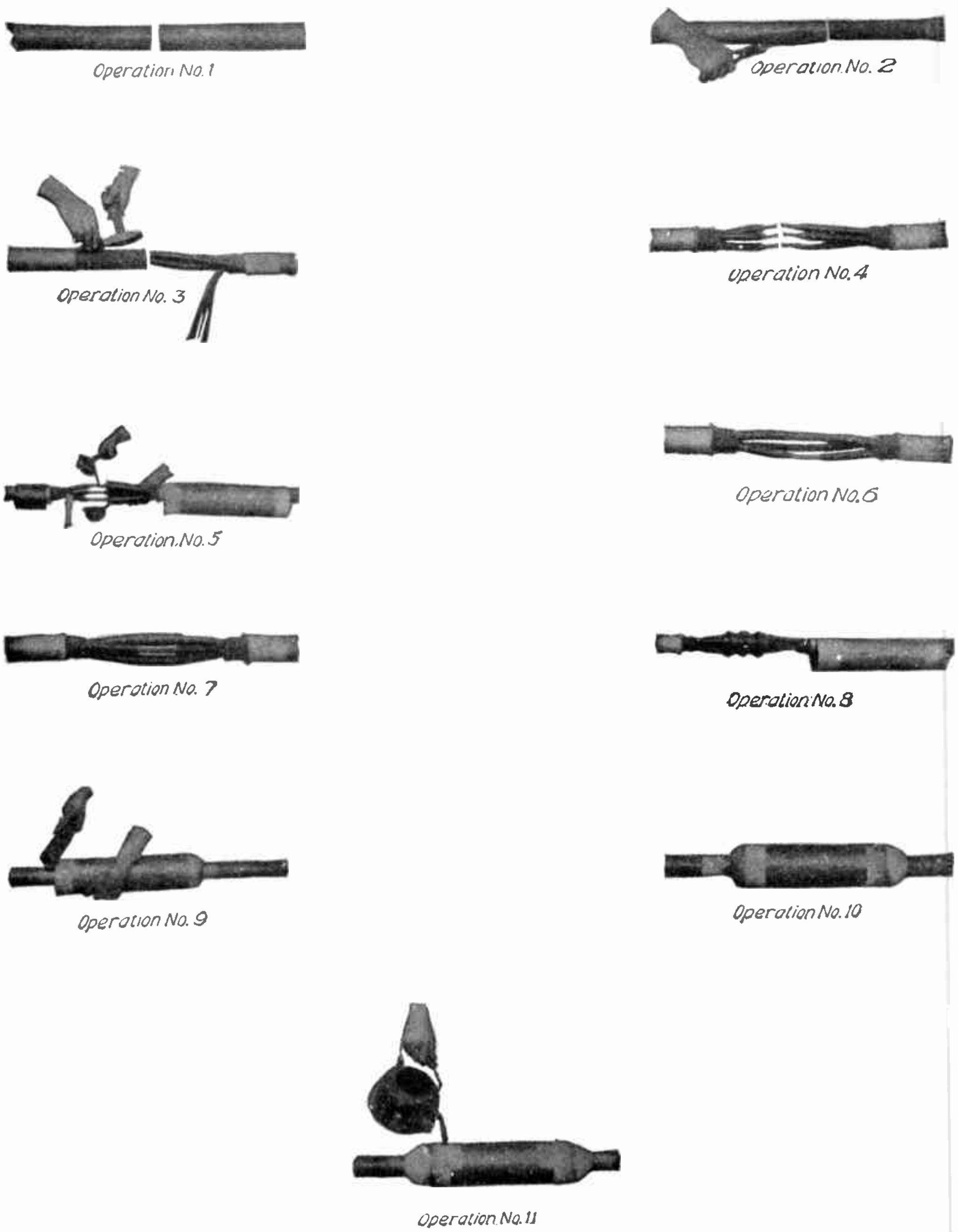


Fig. 113. Method of Splicing Cable

***How to Tie Underwriters' Knot in Lamp Cord**

Every wireman knows that it is necessary to tie the ends of lamp cord after it has been inserted in socket caps and other fixtures, in order to avoid the possibility of the wires being jerked loose from the terminals by a strong pull on the cord. Also, if the ends are tied there is less likelihood of the cord untwisting. Often, however, the knot at the ends is improperly tied, so that it is much less effective than it should be. The illustrations in Fig. 112 show how the Underwriters' knot, as it is called, should be tied when making installations.

Starting with the ends of the two conductors slightly separated, as at (A), the one at the right is looped loosely around the other, passing back of and in front of it, as shown in (B). The second, or left-hand, conductor is then bent to the left and looped (C) around the first, or right-hand, conductor and the end passed through the loop formed by the first conductor, as in (D). When the knot is tightened by holding the two ends and pulling on the cord, the knot will assume the shape shown in (E). The conductors can then be cut off to the desired length, the insulation skinned off, and the wires fastened under the terminal screws as usual.

A knot made in this way will not slip or twist and, as shown at the right, is large enough so that it can not, under any ordinary circumstances, be pulled through the opening in the fixture.

CABLE SPLICING

Method to be Followed in Jointing Three-conductor, High-tension, Varnished-cambric-insulated Cables Where the Working Voltage is Not Over 25,000 Volts

First: After the two cables to be joined have been trained around in the manhole and laid as nearly as possible in their proper position with their ends over-lapping, cut off the ends of each. Be sure that the ends are square, so that the two cables butt together. In handling, be careful not to give the cables any sharp bends. Mark with a knife the point where the lead jacket is to be removed on each cable. For about three inches back of where the jacket is to be removed, scrape the lead so as to give a clean surface for wiping. This is done before the lead jacket is removed, to prevent the lead chips from falling on and into the cable. The lead jacket can now be removed the required distance, care being taken not to cut the insulation. Bell out the lead as shown on page 88, using a blunt-nosed tool of hard wood or fiber, being careful not to cut the insulation. Remove the over-all belt of insulation to a point about one inch from the edge of the lead. Remove the jute fillers, cutting off at a point close to the end of the belt insulation (see operations 1, 2, and 3, as shown in Fig. 113).

Second: Strip the individual conductors of insulation the required distance from the end of each conductor so as to leave approximately ¼-inch space between the end of the insulation and the end of the copper connecting sleeve. Then pencil down the insulation on the single conductors for a distance equal to six times the thickness of the insulation on the conductors. On a cable with 6/32-inch insulation, this would make the length of the penciling approximately 1⅛ inch. It is important that the penciling be smooth and even. Tie the insulation down first with paraffined thread before starting to pencil, to prevent the tape from unwinding. Use a very sharp knife or special tool in penciling the insulation, and be careful not to nick the conductors (see operation 4, Fig. 113).

Third: Slip the lead sleeve over one end of one of the cables. Before slipping on the lead sleeve, scrape both ends to give a clean, bright surface. Clean the exposed ends of the bare conductors by pouring a solution of resin and alcohol or stearin over the strands, and then pour hot solder over them so as to fill in between the strands solidly with the solder. The ends of the other cable to be jointed should be treated in the same manner. See that the stripped ends of both cables fit together nicely without twisting the conductors. The bare conductor should now be slipped into the copper connecting sleeves, the slot in the sleeve being on top; the two conductors in each sleeve butting together in the center of the sleeve. The sleeve should then be pinched together with heavy pliers so that it will grip the conductors. The conductors should then be soldered fast to the connecting sleeves by pouring hot solder over the joint until it is thoroughly heated and the solder runs freely through the slot into the strands of the cable. Before soldering, the tapered ends of the insulation should be wrapped tightly with dry cotton tape and tied into place to protect the insulation from scorching during the soldering. All lumps of solder which collect on the bottom of the sleeve should be carefully removed, and the sleeve left smooth and clean. This can best be done with a piece of cloth before the solder sets. After cooling, any sharp projections should be smoothed off with a file and sandpaper. The same operation applies to the other two conductors (see operation 5, Fig. 113).

Fourth: After all the conductors are soldered into the copper sleeves, the cotton tape over the tapered ends should be removed, and each joint taped with narrow strips of G-E splicing rubber to a diameter equal to that over the insulation on each conductor. Then tape over the rubber with sufficient varnished-cambric

*F. Krug in *Industrial Engineer*.

OPERATION NO. 1

OPERATION NO. 2

OPERATION NO. 3

OPERATION NO. 4

OPERATION NO. 5

OPERATION NO. 6

Fig. 114. Method of Assembling and Sealing End Bells

tape to give a total thickness of insulation equal to 1½ times the thickness of insulation on the single conductors. The length of the taping from the center of the joint to the end of the taping should be twenty-five times the thickness of insulation on the conductor, or, the total length of the taping on the conductor fifty times the thickness of the insulation on the individual conductors of the cable. This reinforced taping should taper out toward the ends as shown in Fig. 113. The rubber splicing tape and the varnished-cambric tape must be applied smoothly and tightly. This is the secret of making good joints. After the three conductors are insulated, as described, tape each single conductor with a band of varnished cambric, the thickness of the band equal to the thickness of insulation on the single conductors of the cable. The single conductors have this belt applied in order to separate them so that the filling compound can flow freely between the conductors (see operations 6, 7, and 8, Fig. 113).

Fifth: The three insulated conductors should now be taped together with two belts of varnished cambric, each approximately 1½ inches wide, the thickness of the belt being 1½ times the thickness of the belt on the cable. These two belts should be served with several wraps of treated linen twine to keep the varnished cambric from unwrapping (see operation 8, Fig. 113).

Sixth: Slip the lead sleeve into position and beat the ends down to fit over the cable. Then apply gummed paper about three inches wide on the cable and on the sleeve in order to confine the wiping solder at the proper point. Both ends of the sleeve should be soldered to the lead sheath of the cable with a wiped joint. After the sleeve is wiped into place, file out a round spot on the lead sleeve not quite through the lead on the gummed paper at each end of the sleeve. Then cut a "V" shaped hole in the center of each. The joint should then be filled with No. 227 compound heated to a temperature of about 275 deg. F. Tilt the joint so that the filling hole will be slightly above the level of the other hole. The compound should be poured through the filling hole until the joint is filled, and about one gallon of hot compound should be allowed to run through the joint in order to boil it out and remove any moisture which may be present, If there is still frothing of the compound after the one gallon is run through the joint, the pouring should be continued until the frothing ceases, as this frothing indicates moisture.

Seventh: After the joint has been thoroughly boiled out, it should be allowed to cool. After cooling, any shrinkage should be made up by the addition of more No. 227 compound. After the compound is set, close the vent end of the sleeve and solder shut. Then give the joint a final fill, close the filling hole, and solder shut. Be sure that the two holes are well soldered. Clean the gummed paper from the lead, and do not disturb the joint after this is done (see operations 9, 10, and 11, Fig. 113).

General: It is important that each operation be made in a neat and thoroughly workmanlike manner, all care being taken that the hands of the jointer are kept dry and that all material used in making the splice is kept in a dry place. No cable should be opened and left exposed to the weather.

METHOD OF ASSEMBLING AND SEALING END BELLS

First: Cut off the end of the cable square, then remove the lead jacket the required distance from the end of the cable, being careful not to cut the insulation (see operation 1, Fig. 114).

Second: Remove the over-all belt of insulation to a point about 1¾ inches from the end of the lead, being careful not to cut the insulation on the single conductors. Remove the jute fillers, cutting off close to the end of the belt insulation. Slip on the brass nut, and bell out the lead as shown in operation 2, Fig. 114. Use a blunt-nosed tool of hard wood or fiber, being careful not to injure the insulation. The lead should be belled out so that it fits inside the brass nut.

For a two-conductor oval cable, the lead must be belled out to form a circular flange so as to fit the flanges of the bell. More care is required in belling out a flat cable to avoid splitting the lead by working it out too fast. On the long diameter of the cable it is necessary to file off part of the lead flange to make it circular.

Third: The brass bell should now be slipped over the end of the cable and the flanges on the bell and on the lead brought together. The loose brass nut should then be brought up into place and the nut on the bell screwed down, drawing the two flanges tightly together (see operation 3, Fig. 114).

Fourth: The wooden cap can now be slipped over the single conductors (see operation 4, Fig. 114) and then over the mica sleeves (see operation 5, Fig. 114,). About one-half the length of the mica sleeve should project through the cap.

Fifth: The bell should now be filled with No. 227 compound at a temperature of 275 to 300 deg. F. (see operation 6, Fig. 114). After cooling, any shrinkage should be made up by the addition of more No. 227 compound.

Sixth: Where the cable to which the bell is being attached has paper insulation, it is necessary to seal the insulation in the bell.

This may be done by using the long type of end-bell (see Fig. 115) connection on single-conductor cables with rubber or varnished-cambric insulation having the joint inside the bell. As an alternative, the short bell (see Fig. 116) can be used by removing the paper from the single conductors where they come out through the top of the bell and then taping the bare conductors with varnished cambric. The paper should be removed for a distance of about three inches below the top of the bell. If the single conductor extends for a considerable distance from the top of the bell, single-conductor cables with varnished-cambric insulation can be connected to the three conductors, outside of the bell, and then taped up with varnished cambric where the paper has been removed and over the joint.

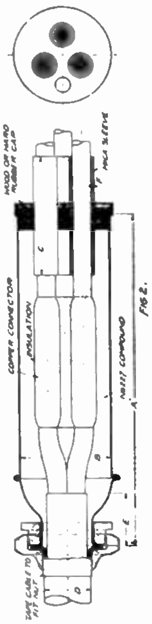


Fig. 115. Outline of Long End Bell

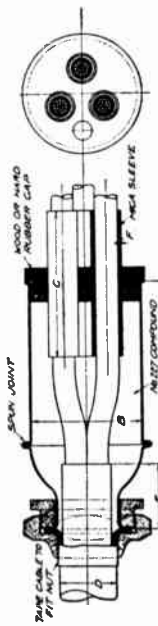


Fig. 116. Outline of Short End Bell

Removing No. 280 Slushing Compound

The use of No. 280 compound for protecting finished metallic surfaces in shipment has been standardized by the General Electric Company.

The compound can be removed readily by using commercial benzol and kerosene in the proportions of one to one. If benzol cannot be obtained, use volatile coal tar solvent or coal naphtha. Most of the paint-removers contain benzol and will cut No. 280 compound. They are, however, considerably more expensive than the benzol and kerosene. Acetone will also cut the compound.

In using any of these solvents great care must be taken to avoid fire, as they are very volatile and the gas is explosive.

REMOVABLE-TRUCK SWITCHBOARDS

Removable-truck switchboards consist of one or more self-contained units which are mounted side by side and connected mechanically and electrically to form a complete switchboard. For shipment, each unit is left as fully assembled as is practicable, so that the work of installation will be minimized.

Each unit consists of a housing and a truck, or a housing with a superstructure bolted on top and a truck unit (see Fig. 117). The housing and superstructure of each unit are so arranged that all apparatus which requires little or no attention and inspection, such as buses, disconnecting switches, etc., is mounted therein. The truck unit is arranged for mounting all apparatus which requires attention and inspection, such as oil circuit breakers, operating mechanisms, instruments, and meters. It is customary to mount all instrument transformers on the truck unit, but where large potential transformers with fuses are used, they are mounted in the superstructure. In such cases, provision is made so that the fuses are accessible by opening the superstructure doors.

Housing

The housing is a cubicle which is made of one-eighth-inch sheet steel shaped and welded together to form a compartment for the truck and a compartment for the buses (see Fig. 118). These two compartments are separated by a removable barrier. Openings in the barrier permit the passage of the primary disconnecting devices. A movable shutter, which is actuated by the movement of the truck, is mounted in front of the barrier. The shutter is also provided with openings for the primary disconnecting devices. When the truck is withdrawn from the housing, the shutter covers the openings in the barrier, making the live parts of the bus compartment inaccessible. As the truck is inserted, it moves the shutter so that the openings in both the shutter and the barrier coincide, thus permitting the truck-mounted disconnecting devices to enter the disconnecting devices in the bus compartment. The movement of the shutter is controlled by two arms which are connected from the top of the shutter to the upper front part of the housing. The truck rolls in under these two arms, thereby raising the shutter. When the truck is rolled out the shutter is lowered.

When no superstructure is used, the housing or truck compartment is ventilated by two openings in the roof, which are covered by a screen. On each side of the truck compartment and just above the floor plate, are the housing guide angles which guide the truck into its proper place in the housing. These angles are adjusted at the factory so that their vertical faces are at right angles to the front of the housing, and at a distance from the center line of the housing as shown in the following tabulation. The center line of the housing is marked on the front flange of the floor plate.

DIMENSIONS IN INCHES

Standard Housing Widths	Truck Distance from Center Line of Panel to Outer Edge of Guide Bar	Housing Distance from Center Line of Housing to Face of Angle
20	$7\frac{15}{16}$	8
28	$11\frac{15}{16}$	12
32	$13\frac{15}{16}$	14
36	$15\frac{15}{16}$	16
44	$19\frac{15}{16}$	20
48	$21\frac{15}{16}$	22

Superstructure

The superstructure is a cubicle made of $\frac{1}{8}$-in. sheet steel shaped and welded together. This element has doors on the front, back, and top. The front doors consist of two leaves, except for the 20-in. unit. These leaves are fastened by latches which are arranged to be operated by a switch-hook. The rear doors, which also consist of two leaves except for the 20-in. unit, are fastened by a hand catch which can be padlocked in its closed position. The top door is not fastened by a catch, but means are provided for padlocking it. The truck compartment ventilation is cared for by running rectangular vent tubes through the superstructure. The tops of these vent tubes are covered with a screen.

Primary Disconnecting Devices

The housing, or stationary, members of the primary disconnecting devices are fixed, while the truck, or movable, members are flexible (see Fig. 119). This flexibility is obtained by having each finger contact floating between certain limits and actuated by compression springs. This construction makes this member self-aligning. The capacity of each primary disconnect is governed by the number of finger contacts. The bus compartment houses and supports the stationary members of the primary disconnecting devices, buses, connection bars, and incoming or outgoing leads. The supports for housing discon-

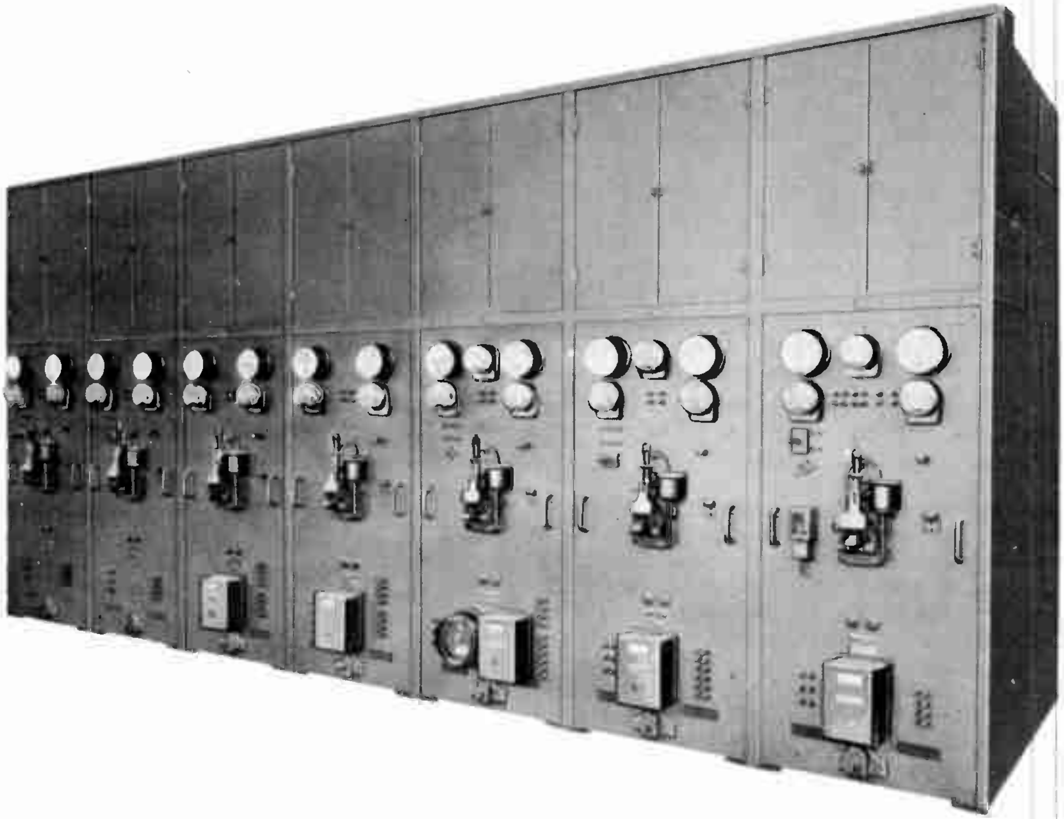


Fig. 117. Typical Removable-truck Switchboard with Superstructure

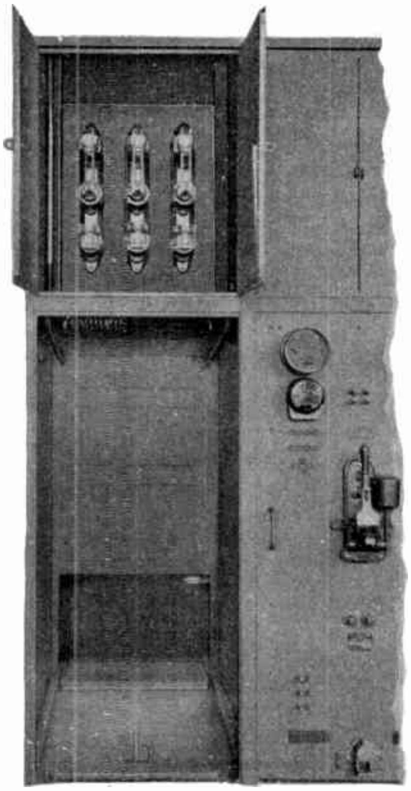


Fig. 118. Interior of a Removable-truck Switchboard Showing the Compartment for the Buses and the Compartment for the Truck

necting devices are bolted solidly in place, no adjustment being necessary after leaving the factory. The buses are mounted back of the disconnecting devices on the same insulated supports.

Secondary Disconnecting Devices

Secondary disconnecting devices are used to disconnect all secondary or control leads entering or leaving the truck, such as the leads to instruments, meters, relays, etc., when mounted on the truck and required to function with remotely mounted apparatus.

The secondary disconnecting device is of the sliding contact type (see Fig. 121). It functions when the truck is in the operating position and when the truck is withdrawn to a position wherein the primary disconnecting devices are properly separated electrically. This device consists of groups of contact units, any number of which can be assembled together to take care of specific requirements.

The fixed contact elements are reversible so that a continuous contact surface can be obtained or a contact at both the operating and testing positions of the truck.

The movable contact unit consists of a pivoted-finger arrangement which is actuated by a compression spring and operated between certain limits to take care of all vertical variations. Lateral variations are overcome by floating the finger-contact assembly crosswise with a travel great enough for any crosswise variation.

The fixed member of the secondary disconnecting device is mounted well to the front and under the top sheet of the housing. The movable member is mounted on a support across the top of the truck. The fixed member of the secondary disconnecting device is located and adjusted crosswise to the center line of the housing.

Truck and Panel

The truck is of heavy, riveted, angle-iron construction capable of supporting the oil circuit breaker, disconnecting devices, instrument transformers, and other auxiliary devices. The panel is of 0.156-in. stretcher-levelled sheet steel, rigidly attached to the truck frame. Drop-forged handles are attached to provide an easy means of handling. Openings are provided in the lower part of the panel to permit ventilation of the interior of the truck. These openings are protected by a screen fastened to the back of the panel. The wheels are of drop-forged steel with roller bearings. The axles are eccentrically related to the mounting by which they are secured to the truck frame. This eccentricity provides a means for levelling the truck and is locked in place when the adjustment is complete.

Floor

It is important that the portion of the station floor on which the housings are to be mounted and for a space at least 5 ft. 6 in. in front of the housings, should be perfectly level in all directions. Means must be provided for securing the housings to the floor, and a suggested method for doing this is shown in Fig. 120. Any other method may be used as long as the condition of a level floor is obtained.

If sleepers as shown in Fig. 120, or their equivalent are used, they must be set flush with the level floor.

Special care should be taken that the sleepers are set level with respect to each other and that the ½-in.–13 holes for the anchor bolts are in alignment and located as on floor plan drawings furnished with each particular installation.

Fig. 119. Construction of the Primary Disconnecting Device

It is recommended that the levelling of the floor and sleepers be accomplished by an instrument rather than by the ordinary spirit level and straight edge.

Anchor bolt holes should be located with reference to the center lines of the housings.

Anchor bolt holes in the floor angles can be kept clean by inserting bolts in them before grouting-in the floor. These bolts will also provide a reasonable clearance for the final anchor bolts.

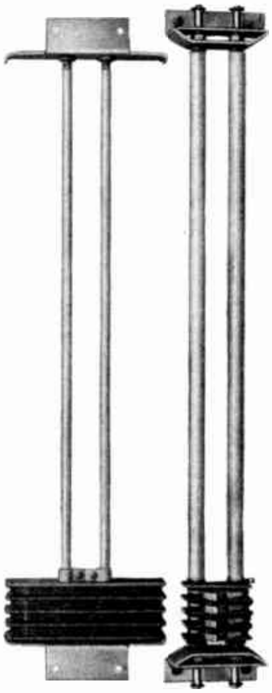


Fig. 121. Construction of Secondary Disconnecting Devices

When housings are to be mounted against a wall, ample space should be allowed from the wall to avoid installation difficulties.

Installation

After the trucks and housings have been uncrated they should be thoroughly inspected. All units are carefully tested at the factory for proper functioning and for interchangeability.

All electrical connections should be inspected and tightened. On the truck all connection bar joints are left untaped for inspecting and tightening the connection bolts. After all joints are made, they should be taped with varnished cambric for insulation with ½ lap according to the following table, and then covered with linen tape to hold the insulating tape in place. As a finish over the linen tape, G-E No. 480 gray insulating paint should be applied. Sufficient tape is furnished with each switchboard.

In order to facilitate handling where crane facilities are available, lifting slings, as shown in Fig. 122 and 123, are furnished for the housings and for the trucks.

To install the housings, locate them in their respective places as shown on the drawing and align them so that their front faces are exactly flush and spaced in reference to their center lines as indicated by mark on the front apron of the floor plate of each housing. After aligning, each unit is to be bolted securely to the sleeper angles by ½-in.–13 by 1¼-in. anchor bolts.

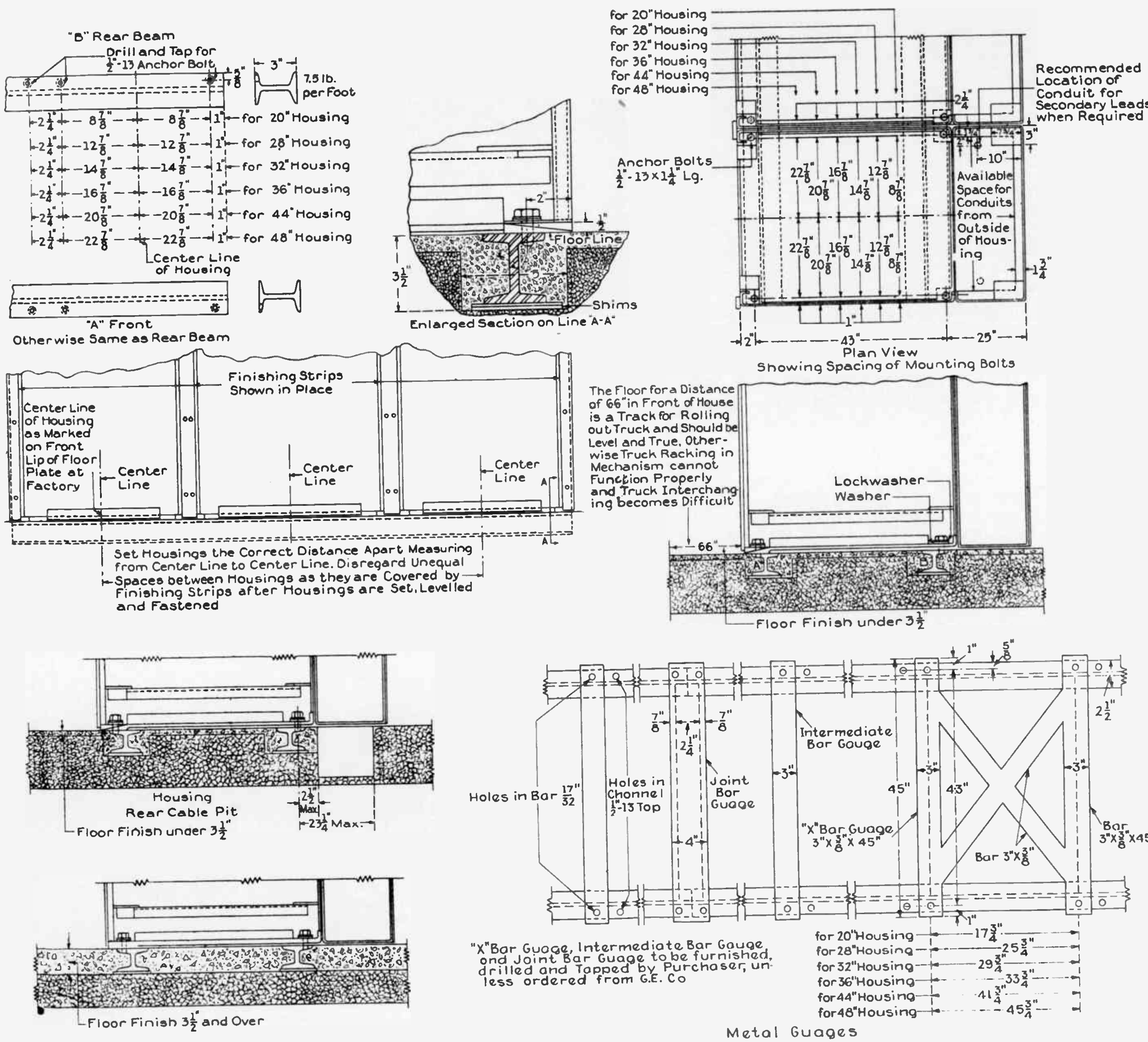
After the housings have been located and anchored, the finish strips should be fastened in place with No. 10–30 flat-head screws and large washers. The front top finish strip is to be placed first. On a housing without superstructure with the trucks in place, the clearance between the finish strip and the tops of the truck panels should be uniform throughout the board. On a superstructure unit, the clearance between the front top finish strip and the superstructure

VOLTS		Layer of 0.012 in. thick varnish cambric
Above	Up to and Including	
0	750*	3
750	1000	4
1000	3000	4
3000	4000	5
4000	5000	6
5000	6200	7
6200	7600	8
7600	8800	9
8800	10000	10
10000	11600	11
11600	13400	12
13400	15400	13

* None except for service in cement plants and similar places.

doors should be uniform throughout the board. The intermediate vertical finish strips are to be placed equidistant between the adjacent truck panels and abutting the top finish strip. When a superstructure is used, these vertical finish strips will fit tightly between the adjacent horizontal finish strips at the joint between the housings and the superstructures. The end vertical and horizontal strips covering the joints between the housings and superstructures are left in place during shipment. If they have been disturbed during shipment, they can be easily readjusted to their proper position. The strips on the top and in the rear of the units should be placed last. These strips are used to cover up the openings between the units. When a housing is mounted with its back against the wall, the rear strips are omitted.

It is necessary to assemble intermediate compound barriers between the housings. These



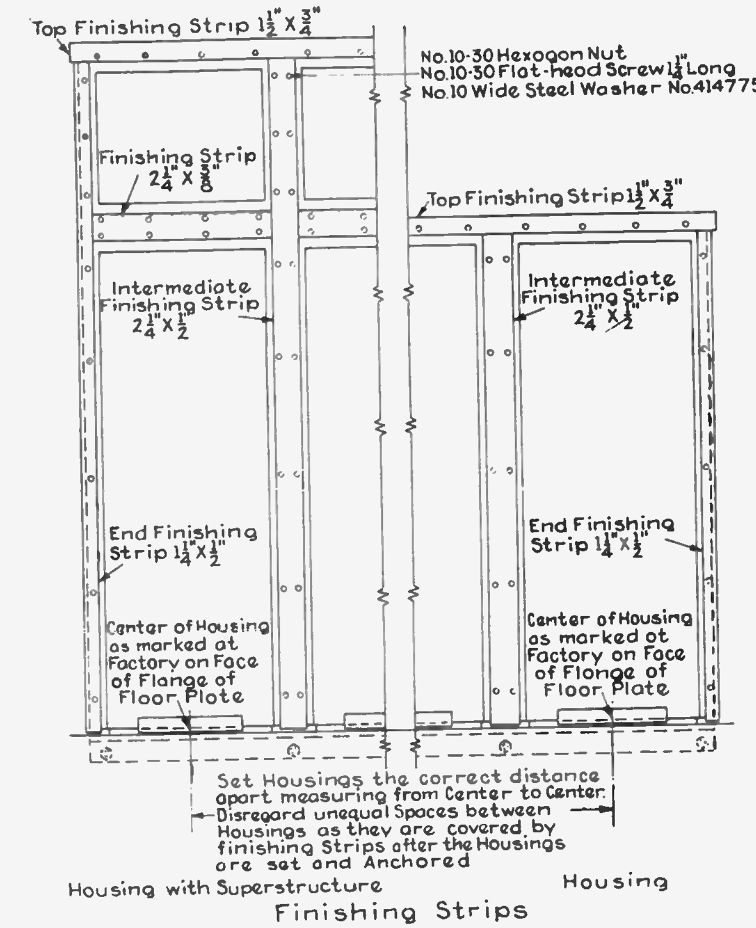


Fig. 120. Floor Construction for Truck Switchboards

FLOOR PREPARATION—3-inch "I" beams, 7.5 pounds per foot, are recommended as sleepers on which truck housings are installed. A trough, 5 inches wide, and 3½ inches deep from the finished floor line, is required for shimming and grouting the "I" beams as shown. These sleepers should be drilled and tapped for ½ in.-13 housing anchor bolts located as shown on floor plan prepared for each switchboard. It is important that these sleepers be straight and level for their full length, at the correct spacing, and that the flanges of both beams be parallel with each other. In order to insure this condition, it is recommended that ties be bolted between the sleepers at various intervals and the lower flange of the beam be shimmed to the proper height (see Metal Gauges). In this way, the proper spacing will be obtained. It is also recommended that squaring and leveling be accomplished by means of an instrument rather than by a level and square.

Care should be exercised, when grouting the beams and placing the finished floor, that the top flanges of the sleepers do not extend above the finished floor line, as this may cause improper operation of the racking device. To provide clearance for final anchor bolts, temporary bolts should be inserted while grouting.

ERECTION—Arrange the housing on the prepared sleepers as shown on the arrangement drawing. The housing should be lined up exactly flush face, keeping each house center-to-center as marked on the front lip of the housing, disregarding the space between units. Housings must not be pulled out of square to meet uneven sleepers.

METAL GAUGES—(See Fig. of Metal Gauges.)—Three types of metal gauges are recommended—an "X" bar gauge, an intermediate bar gauge, and a joint bar gauge. The "X" bar gauge should be placed at one end unless the switchboard is over 20 feet in length, in which case one should be used at each end. This "X" bar gauge squares the back sleeper with the front sleeper so that the anchor bolt holes are in their proper places. The joint bar should be used at the joints in the sleepers, and the intermediate bar at points between, to space properly the back and front sleepers and keep them parallel. These gauges also hold the steel sleepers in position so that shimming to a level position is made easy.

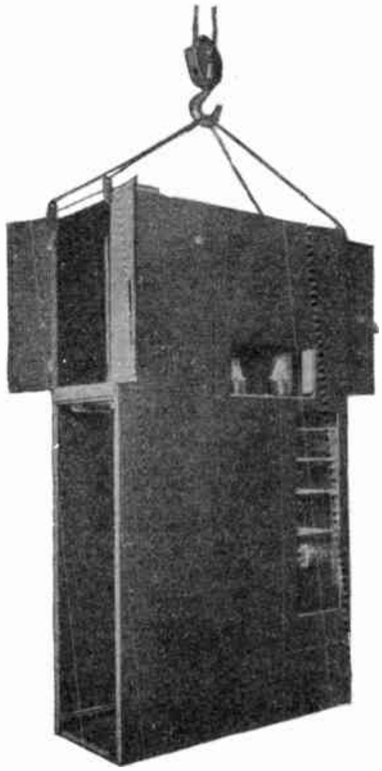


Fig. 122. Lifting Slings and Method of Transporting Housing

intermediate barriers are bolted fast to the main compound barrier of the housing when shipped. It is necessary that the barriers be placed between the housings to insure proper insulation between bus phases.

Previous to the installation of the buses, remove the shutter between the truck and bus compartment of each unit. The shutter can be removed by first removing the bolts on the back end of the rocker arms that actuate the shutter and then removing the six screws that hold the shutter in place. Holes are left in the front member of the shutter to give access to four of these screws. Then remove the end covers from the housings of each end unit. To do this, it is necessary for one man to enter the housing, release the cover catch, and then force the cover outward so that a man outside may lift it from the housing. Work should not be attempted on the buses unless the automatic shutter has been removed. When buses are to be mounted in the superstructure, the covers of this part of each unit must be removed.

To install the buses, first loosen the bus clamps of each disconnecting device and push the bars through as shown in Fig. 124. Make certain that the contact surfaces on the busbars are smooth and clean so as to obtain the maximum available contact surface. Poor contact causes heating and unsatisfactory operation. Guide the buses through the clamps from one housing to the next. When the buses have been inserted, clamp them in position and replace the end covers.

The ground bus should be inserted through the small rectangular opening in the sides of the bus compartment and securely clamped to its bracket in the housing.

The incoming and outgoing connections should be made in accordance with drawings which are furnished for each equipment.

Cables entering from the bottom can be located at any convenient position under the bus compartment by keeping the edge of the conduit at least 1¾ in. away from the outside dimensions of the back, and 3 in. from either side of the housing.

Secondary control leads can be brought up through this same space under the bus compartment through conduit to the metal box containing the terminal board.

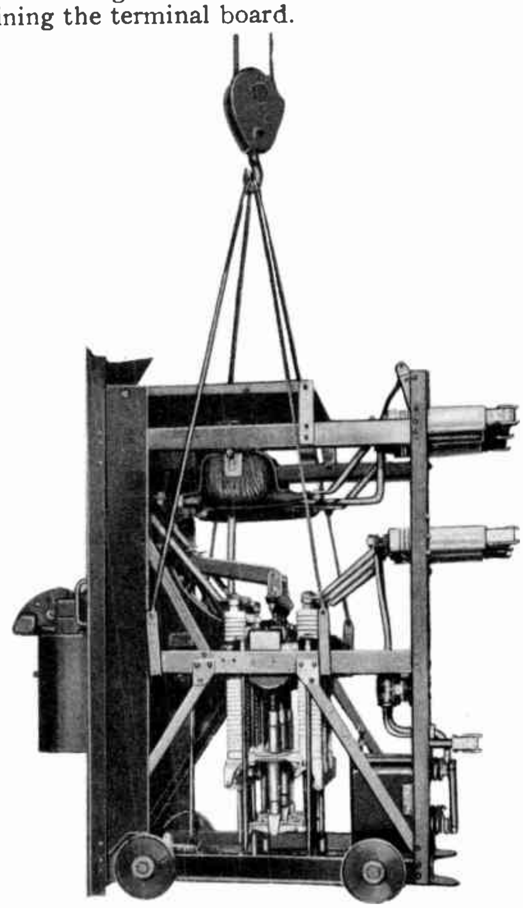


Fig. 123. Removable-truck Panel Unit, Showing Method of Lifting Truck by Means of a Crane and Cable Sling Attachment

The housings having been permanently located and the buses and shutters installed, the trucks may now be inserted in their respective housings. Proceed as follows:

1. Move the truck to a point approximately in front of its housing. Trucks may be carried by means of a crane and sling attachment as shown in Fig. 123. Another method of moving the trucks is by means of the transfer device (see Fig. 125).

Fig. 124. Method of Assembling Busbars

2. Align the first truck to be installed in front of its housing using the transfer device for moving.
3. Detach the transfer device and insert the cranking handle into the racking device and turn the handle counter-clockwise until the rack is fully extended (see Fig. 128).
4. Detach the cranking handle and push the truck in as shown in Fig. 126 until the hook on the end of the rack has engaged in the housing floor catch (see Fig. 128B).
5. Insert the cranking handle and turn it clockwise to draw the truck into the final (full in) position (see Fig. 127 and 128A).

ADJUSTMENTS

Truck

The truck is in adjustment when the panel is at right angles frontwise and crosswise to the plane of the bottom of the wheels, and the bottom of the panel ⅜ in. above this plane. The wheels are adjustable vertically by means of an eccentric hub arrangement.

Wheels

It is the practice to adjust the wheels and lock the hubs at the factory. In case readjustment is necessary, turning the eccentric hub will raise or lower the wheels to the proper adjustment. A heavy lock washer and keyed washer, whose purpose is to keep the hub from turning, are placed under the nut which holds the hub. After the wheel is in proper adjustment, the edge of the keyed washer is driven in a hole provided in the sill angle. If for any reason a wheel has to be removed or disturbed, a new lock washer and a new keyed washer should be provided.

Guiding-in Bars

Guiding-in bars, located on the side sill angles of the truck, pilot the truck into position as it is rolled into the housing. These bars are adjusted and tack-welded in position at the factory. This adjustment is such that the outer edges of these bars are at right angles to the panel and at a distance from the panel center line as specified in the tabulation on page 93.

Shutters

The rollers for operating the shutter are located at the top of the rear angles of the truck. They are adjusted in their proper position and their supports tack-welded at the factory. This adjustment is such that when the truck is in its full "in" position, the rollers will raise the shutter to such position that the openings in the movable member will coincide with the openings in the fixed member.

PRIMARY DISCONNECTING DEVICES

The truck members of the disconnecting devices are clamped solidly to an adjustable spider which is bolted on the rear angles of the truck. The spider is adjusted so that the contacts of the disconnecting devices are in their proper relation to the floor line and to the center line of the panel. All trucks with like equipment and similar

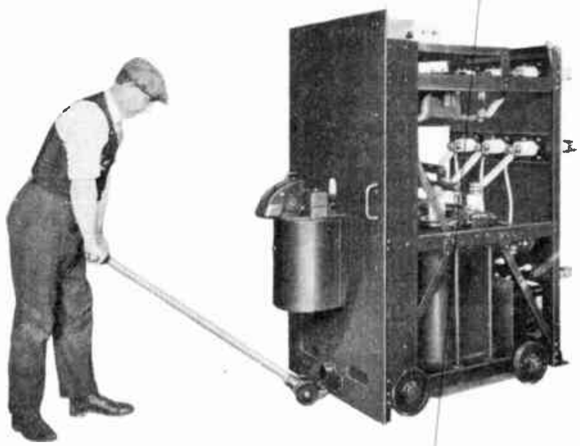


Fig. 125. Method of Using Transfer Device to Transport Removable-truck Panel Unit

arrangement of both primary and secondary disconnecting devices are interchangeable.

Secondary Disconnecting Devices

The truck member of the secondary disconnecting device is mounted on the top of the truck just back of the panel. It is located and adjusted to the panel center line.

Racking Device

The racking device, Fig. 128, is located at the bottom and just back of the panel. This device consists of a worm and rack with certain attachments to perform the operations required. It is operated by a crank inserted through the escutcheon which supports the rack mechanism. This mechanism must swing freely from its support in the escutcheon. It is removable by disengaging three pins, two of which hold the mechanism to the escutcheon, and one which connects it to the trip rod. The end of the worm rack is provided with a lug or hook which engages a catch welded on the floor plate of the housing.

1. The racking device is provided with an adjustable screw (9) so that an adjustment may be made if necessary to raise the end of the rack (hook) to allow the rack, when fully extended, to clear the upturned lip in the front of the housing floor by $\frac{1}{16}$ in.

Before the truck is inserted in the housing the first time, it is important that a check be made of the adjustment of the hook in the rack as mentioned above. If an adjustment is necessary, it may be secured by the lock nut (10) on the adjustable screw provided for that purpose (see Fig. 128 C).

Fig. 126. Method of Inserting Truck to the Position Where the Cranking Handle Must be Used

Interlock Mechanism

The racking device is connected to the breaker mechanism by an adjustable trip rod which controls the operation of the breaker in relation to the position of the truck in the housing.

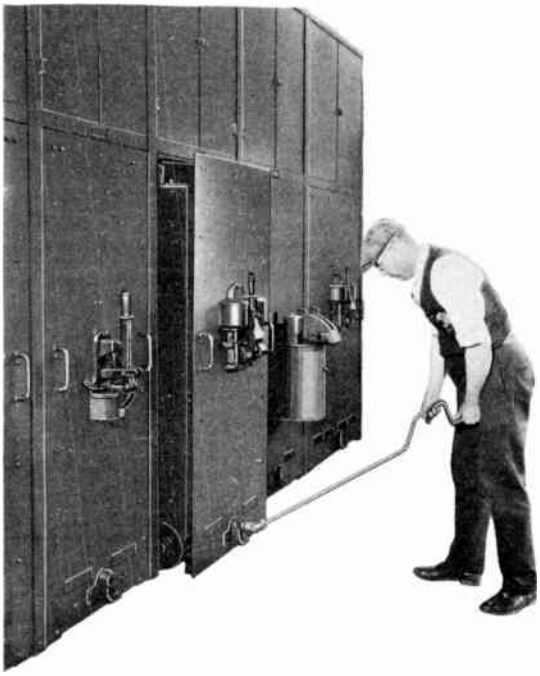
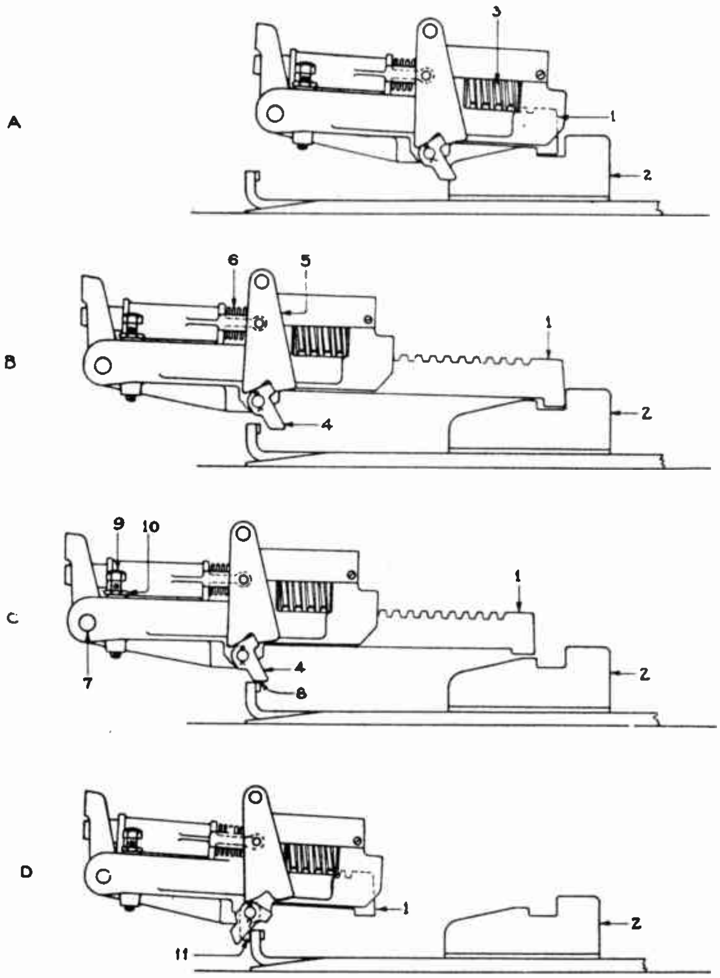


Fig. 127. Method of Inserting Truck with the Cranking Handle

This rod is in adjustment when the following sequence of operations can be performed. With the rack fully extended and the truck advanced into the housing until the hook on the rack has engaged the floor catch, the breaker can be opened and closed at will. With the truck still in this position and the breaker closed, one or two clockwise revolutions of the racking-in crank will trip the breaker if it is closed, when attempting to rack the truck toward the full "in" position. With the truck in its full "in" position and the breaker closed, the truck can be racked outward not more than $\frac{1}{4}$ in. before the breaker will trip. Counter-clockwise operation of the racking-in crank is necessary to withdraw the truck. The breaker cannot be closed when the truck is between the test position and the full "in" position.

The adjustment of the trip rod which controls a cam or interlock is done at the factory. The interlock functions so as to permit the sequence of operations mentioned above, but if for any reason it should be necessary to readjust this interlock, proceed as follows:



The full-in position of the racking device is obtained by pushing the truck into the housing with the rack fully extended until the hook on the rack (1) engages the floor catch (2) as shown at B; then insert the cranking handle and turn it clockwise. This action revolves the worm (3) on the rack (1) and, by reason of the rack-and-floor-catch engagement, draws the truck into the housing to the position shown here. It may be necessary to readjust the height of the rack mechanism to clear the front lip of the housing. This is accomplished by loosening the locking nut (10) and turning the bolt (9).

To remove the truck from the housing, insert the cranking device through the escutcheon on the front of the panel and turn the crank with a counter-clockwise motion. The truck will roll forward until the main disconnecting devices have parted and the pawl (4) rides over the upturned lip of the housing. This disengages the rack (1) from the cutout (2) in the housing, and the truck may then be pulled out by means of the handles on the front.

View C shows the racking device in position with the pawl (4) passing over the upturned lip of the housing.

After the truck has been withdrawn from the housing, the rack will remain in the position shown at B. If it is necessary to provide clearance in the truck for removal of oil tanks, the rack may be withdrawn into the device as shown at A by a clockwise motion of the cranking device. This action so sets the center pawl (11) that it interferes with the upturned lip of the housing when an attempt is made to run the truck in the housing. It is, therefore, necessary at all times to have the rack fully extended as shown at B before the truck can be inserted in its compartment. This feature is present because it is desirable to place the truck in the full "in" position with a steady and uniform motion by means of the cranking device rather than by pushing the truck in the housing with undue force.

The secondary disconnecting devices make contact in the test position when the truck is racked out to a point where the stenciled line on the right side of the truck reading "Test Position" lines up with the front of the vertical finishing strip.

Fig. 128. Positions of Racking Device During Operation of Removing Truck from Housing

Adjust the nut over the trip-rod support so as to change slightly the position of the cam or interlock. Then try the sequence of operations mentioned above. Continue the adjustment until all these conditions are obtained. When the adjustment is completed, secure it with the lock nut which is provided for that purpose.

Care

The truck should be pushed into its housing without undue force, to avoid excessive jar on the instruments.

The contact surfaces of both the primary and secondary disconnecting devices should at all times be kept clean and well lubricated with petrolatum. The racking device, rollers, and wheels should be kept lubricated with a good quality of grease, and free from grit and dirt.

If the barrier and shutter between the truck and bus compartment in any housing have to be removed for inspection, repairs, or cleaning, the equipment should be rendered electrically dead and the buses properly grounded to make the switchboard absolutely safe to be exposed and worked upon. This also applies to the superstructures. Lock facilities are provided for the top and rear doors of the superstructure and these should be kept padlocked when the unit is in service.

Means for padlocking the racking device of the trucks are also provided so that the operating handle cannot be inserted when the padlock is in place. This is also true when it is necessary to lock the truck in its operating or in its disconnected position.

On the FKR-35 and FKR-132A breaker units the oil tanks can be removed entirely from the truck with the truck on the floor.

When larger breakers are used, the oil tanks may be removed by lowering the tanks to the floor and an overhead hoist employed to lift the truck clear of the tanks. A pit may also be used to advantage by lowering the tanks into the pit, thus permitting repairs to, or inspection of the contacts. In removing the oil tanks, the arm of the racking device may be racked out of the way, but it must be again extended before the truck is inserted in the housing.

If the front of the panels should be accidentally marred during or after installation, the finish may be restored by spraying it with one coat of black Egyptian lacquer made by the Egyptian Lacquer Co. Before spraying, it may be necessary to clean the surface of the panel with carbon tetrachloride to remove grease or dirt and to sandpaper it lightly to smooth the surface. The spraying operation is done with a spray gun. Paper masks should be used to protect the nameplates, instruments, meters, relays, etc.

When ordering replacement parts, give the rating, panel number, requisition, summary number, etc., as stamped on the nameplate of the unit.

Instructions for apparatus mounted on the truck are supplied with the shipment of each equipment. Refer to these instructions for information as to the individual devices.

Additional copies of these Instructions will be mailed on request.

PUBLICITY MATTER

Publicity matter, issued by the General Electric Company on switchgear, is classified as descriptive, instructive, and supply part information.

Descriptive matter is issued in the form of Descriptive Bulletins, Folders, Sheets, and Booklets. The publications illustrate and describe the device or apparatus, and also explain outstanding features and available sizes.

Instructions are made in book form, cards, and folders, depending upon the importance of apparatus to which they apply, so that a purchaser may have the necessary information for installing, operating, and maintaining a purchased equipment. They should be used as a general guide by attendants, construction men, etc., whenever repair, adjustment, or inspection is to be made.

Supply part information consists of Part Bulletins, Sheets, and Photographs. They should be used by those interested when supply parts are needed, in as much as they readily assist in identifying parts and give the catalog number by which such parts are known. By the use of catalog reference when orders are placed, the least delay is encountered in shipment.

It is recommended, for stations that are equipped with General Electric apparatus, that a complete file be maintained of all publications pertaining to the installed equipment.

Copies of any publication available will be mailed immediately upon request. When requesting installation instructions, it is well to give the complete nameplate identification of the device. Requests for publicity matter should be made to the Distribution Section of the General Electric Company, Publicity Department, Schenectady, New York.

Miscellaneous Formulae

I
Current for 1 Kv-a.

Voltage	1-φ or d-c.	2 φ	3 φ
110	9.09	4.55	5.25
125	8.00	4.00	4.62
220	4.55	2.27	2.63
240	4.17	2.08	2.40
250	4.00	2.00	2.31
275	3.64	1.82	2.10
300	3.33	1.67	1.92
370	2.70	1.35	1.56
440	2.27	1.14	1.31
480	2.08	1.04	1.20
500	2.00	1.00	1.15
550	1.82	.909	1.05
575	1.74	.869	1.00
600	1.67	.833	.962
650	1.54	.769	.888
750	1.33	.666	.770
1,100	.909	.455	.525
1,150	.869	.434	.502
1,200	.833	.417	.481
2,080	.481	.240	.277
2,200	.455	.227	.263
2,300	.435	.217	.250
2,400	.417	.208	.240
3,300	.303	.152	.175
3,500	.286	.143	.165
4,000	.250	.125	.144
4,150	.241	.121	.139
5,500	.182	.0909	.105
6,600	.152	.0758	.0875
11,000	.0909	.0455	.0525
12,000	.0833	.0417	.0481
13,000	.0769	.0385	.0444
13,200	.0758	.0379	.0437
16,500	.0606	.0303	.0350
22,000	.0455	.0227	.0263
33,000	.0303	.0152	.0175
35,000	.0286	.0143	.0165
40,000	.0250	.0125	.0144
44,000	.0227	.0114	.0131
55,000	.0182	.00909	.0105
60,000	.0167	.00833	.00962
66,000	.0152	.00758	.00875
70,000	.0143	.00714	.00825
80,000	.0125	.00625	.00722
100,000	.01000	.00500	.00577
110,000	.00909	.00455	.00525
135,000	.00741	.00370	.00428
140,000	.00714	.00357	.00412
180,000	.00555	.00278	.00321

II
Usual Efficiencies of Machines

Ind. Motors, 85% p.f. 88% eff. (Varies with speed. Check each case.)
*Syn. Motors, 92% eff. and 90% Power-factor
Syn. Conv.—(above 200-kw.) 95% eff. 99% p-f.
Trans. 98% eff. Trans. and Conv. Combined 92%
D-c. Motors up to 10 hp. 83% eff.
11 to 35 hp. 85% eff.
36 to 75 hp. 88% eff.
76 to 1000 hp. 90% eff.
over 1000 hp. 92–93% eff.

*Rating covers input.

III

$$\text{Induction Motor kv-a.} = \frac{\text{hp.} \times 746}{1000 \times \text{eff.} \times \text{Power-factor}}$$

$= 1.0 \times$ hp. for 88% eff. and 85% Power-factor

IV

Synchronous Converter Potential Ratios. (Full Load)

2 φ and 6φ Diametrical	600 volts—74% of d-c. 250 volts—74% of d-c. 125 volts—74% of d-c.
3 φ and 6φ Y or Δ	600 volts—64% of d-c. 150 volts—64% of d-c. 125 volts—64% of d-c.

V

Rating of Circuits and Instruments
(N = Normal Load)

	"Max." Rated Mach. and Feeder	Overload Guarantees	
Running Load'	N Continuously	125% N. For 2 hr.	150% N. For 2 hr.
Lever Switch, Circ. Breaker, Oil Circ. Breaker	100% N.	125% N.	150% N. or Special
D-c. Ammeter Shunt	Same as Ammeter Scale except for special conditions above 2000 Amp.		
D-c. Ammeter Scale	Between 110 and 150% N.	150% N. Min.	180% N. Min.
A-c. Ammeter Scale	Between 110 and 150% N.	137% N. Min.	165% N. Min.

GENERAL ELECTRIC COMPANY

Sales Offices—Address nearest Office

Akron, Ohio	159 South Main Street
Amarillo, Tex.	806 South Grant Street
Atlanta, Ga.	187 Spring Street, Northwest
Baltimore, Md.	39 West Lexington Street
Binghamton, N. Y.	19 Chenango Street
Birmingham, Ala.	2031 First Avenue, North
Bluefield, W. Va.	307 Federal Street
Boston, Mass.	140 Federal Street
Buffalo, N. Y.	39 East Genesee Street
Butte, Mont	20 West Granite Street
Canton, Ohio	700 Tuscarawas Street, West
Charleston, W. Va.	304 Capitol Street
Charlotte, N. C.	200 South Tryon Street
Chattanooga, Tenn.	536 Market Street
Chicago, Ill.	230 South Clark Street
Cincinnati, Ohio	215 West Third Street
Cleveland, Ohio	925 Euclid Avenue
Columbus, Ohio	17 South High Street
Dallas, Tex.	1801 North Lamar Street
Davenport, Iowa	511 Pershing Avenue
Dayton, Ohio	25 North Main Street
Denver, Colo.	650 Seventeenth Street
Des Moines, Iowa	418 West Sixth Avenue
Detroit, Mich.	700 Antoinette Street
Duluth, Minn.	14 West Superior Street
El Paso, Tex.	109 North Oregon Street
Erie, Pa.	10 East Twelfth Street
Fort Wayne, Ind.	1635 Broadway
Fort Worth, Tex.	410 West Seventh Street
Grand Rapids, Mich.	148 Monroe Avenue, Northwest
Hartford, Conn.	18 Asylum Street
Houston, Tex.	1016 Walker Avenue
Indianapolis, Ind.	110 North Illinois Street
Jackson, Mich.	212 Michigan Avenue, West
Jacksonville, Fla.	11 East Forsyth Street
Kansas City, Mo.	1004 Baltimore Avenue
Knoxville, Tenn.	602 South Gay Street
Los Angeles, Calif.	5201 Santa Fe Avenue
Louisville, Ky.	455 South Fourth Street
Memphis, Tenn.	8 North Third Street
Miami, Fla.	25 Southeast Second Avenue
Milwaukee, Wis.	940 West St. Paul Avenue
Minneapolis, Minn.	107 South Fifth Street
Nashville, Tenn.	234 Third Avenue, North
Newark, N. J.	20 Washington Place
New Haven, Conn.	129 Church Street
New Orleans, La.	837 Gravier Street
New York, N. Y.	120 Broadway
Niagara Falls, N. Y.	201 Falls Street
Oklahoma City, Okla.	15 North Robinson Street
Omaha, Nebr.	409 South Seventeenth Street
Philadelphia, Pa.	1405 Locust Street
Phoenix, Ariz.	11 West Jefferson Street
Pine Bluff, Ark.	501 Main Street
Pittsburgh, Pa.	535 Smithfield Street
Portland, Oreg.	329 Alder Street
Providence, R. I.	76 Westminster Street
Richmond, Va.	700 East Franklin Street
Roanoke, Va.	202 South Jefferson Street
Rochester, N. Y.	89 East Avenue
St. Louis, Mo.	112 North Fourth Street
Salt Lake City, Utah	200 South Main Street
San Antonio, Tex.	201 Villita Street
San Francisco, Calif.	235 Montgomery Street
Schenectady, N. Y.	1 River Road
Seattle, Wash.	821 Second Avenue
Shreveport, La.	513 Marshall Street
Spokane, Wash.	421 Riverside Avenue
Springfield, Ill.	504 East Monroe Street
Springfield, Mass.	1387 Main Street
Syracuse, N. Y.	113 South Salina Street
Tacoma, Wash.	1019 Pacific Avenue
Tampa, Fla.	604 Ella Mae Street
Terre Haute, Ind.	701 Wabash Avenue
Toledo, Ohio	405 Madison Avenue
Trenton, N. J.	143 East State Street
Tulsa, Okla.	409 South Boston Street
Utica, N. Y.	258 Genesee Street
Washington, D. C.	800 Fifteenth Street, Northwest
Waterbury, Conn.	195 Grand Street
Wheeling, W. Va.	40 Fourteenth Street
Worcester, Mass.	340 Main Street
Youngstown, Ohio	16 Central Square

Canada: Canadian General Electric Company, Ltd., Toronto — Hawaii: W. A. Ramsay, Ltd., Honolulu

Motor Dealers and Lamp Agencies in all large cities and towns

SERVICE SHOPS

Atlanta, Ga.	496 Glenn Street, Southwest
Buffalo, N. Y.	318 Urban Street
Chicago, Ill.	509 East Illinois Street
Cincinnati, Ohio	215 West Third Street
Cleveland, Ohio	1133 East 152nd Street
Dallas, Tex.	1801 North Lamar Street
Detroit, Mich.	700 Antoinette Street
Kansas City, Mo.	819 East Nineteenth Street
Los Angeles, Calif.	5203 Santa Fe Avenue
Milwaukee, Wis.	940 West St. Paul Avenue
Minneapolis, Minn.	410 Third Avenue, North
New York, N. Y.	416 West Thirteenth Street
Philadelphia, Pa.	429 North Seventh Street
Pittsburgh, Pa.	16 Terminal Way
St. Louis, Mo.	1009 Spruce Street
Salt Lake City, Utah	360 West Second South Street
San Francisco, Calif.	340 First Street
Seattle, Wash.	1508 Fourth Avenue, South

Special service divisions are also maintained at the following works of the Company: Erie, Pa.; Ft. Wayne, Ind.; Oakland, Calif; Pittsfield, Mass.; Schenectady, N. Y.; and West Lynn, Mass—River Works and West Lynn Works.

BROADCASTING STATIONS

WGY, Schenectady, N. Y.	KOA, Denver, Colo.	KGO, Oakland, Calif.
Short Wave Stations	W2XAD—Schenectady	W2XAF—Schenectady

INTERNATIONAL GENERAL ELECTRIC COMPANY, INC.

Executive Offices: 120 Broadway, New York City — **SCHENECTADY, N. Y.** — Cable Address: "Ingenetric New York"

FOREIGN OFFICES, ASSOCIATED COMPANIES, AND AGENTS

ARGENTINA: General Electric, S.A., Buenos Aires, Cordoba, Rosario de Santa Fe, Tucuman, and Mendoza

AUSTRALIA: Australian General Electric Company, Ltd., Sydney, Melbourne, Adelaide, Brisbane, Newcastle, Queensland, Rockhampton, Maffra, Colac, Townsville, Canberra, Albury, and Lismore

BELGIUM AND COLONIES: Societe d'Electricite et de Mecanique (Procedes Thomson-Houston & Carels) Societe Anonyme, Brussels, Belgium

BRAZIL: General Electric, S.A., Rio de Janeiro, Sao Paulo, Bahia, Porto Alegre, Bello Horizonte, Juiz de Fora, Belem, Curityba, Santos, and Recife

CENTRAL AMERICA: International General Electric Co., Inc., Panama City, Panama; Guatemala City, Guatemala; New Orleans, La.

CHILE: International Machinery Company, Santiago, Antofagasta and Valparaiso. Nitrate Agencies, Ltd., Iquique

CHINA: Andersen, Meyer & Company, Ltd., Shanghai; China General Edison Company, Shanghai

COLOMBIA: International General Electric, S.A., Barranquilla, Bogota, Medellin, and Cali

CUBA: General Electric Company of Cuba, Havana, and Santiago de Cuba

ECUADOR: Guayaquil Agencies Co., Guayaquil

EGYPT: British Thomson-Houston Company, Ltd., Cairo

FRANCE AND COLONIES: Compagnie Francaise Thomson-Houston, Paris; International General Electric Co., Inc., Paris; Compagnie Des Lampes, Paris

GERMANY: H. B. Peirce, Representative, General Electric Co., Berlin

GREAT BRITAIN AND IRELAND: International General Electric Co., Inc., British Thomson-Houston Co., Ltd., London, W.C.2; British Thomson-Houston Co., Ltd., Rugby

GREECE AND COLONIES: Compagnie Francaise Thomson-Houston, Paris, France

HOLLAND: Mijnssen & Co., Amsterdam

INDIA: International General Electric Company, Inc., Calcutta, Bombay and Bangalore

ITALY AND COLONIES: Compagnia Generale Di Elettricita, Milan

JAPAN: Shibaura Engineering Works, Tokyo; Tokyo Electric Company, Ltd., Kawasaki, Kanagawa-Ken; International General Electric Co., Inc., Tokyo

JAVA: International General Electric Co., Inc., Soerabaia

MEXICO: General Electric, S.A., City of Mexico, Guadalajara, Monterrey, Vera Cruz and El Paso, Texas

NEWFOUNDLAND: International General Electric Co., Inc., St. Johns

NEW ZEALAND: National Electrical and Engineering Company, Ltd., Auckland, Dunedin, Christchurch and Wellington

PARAGUAY: General Electric, S.A., Buenos Aires, Argentina

PERU: International Machinery Co., Lima

PHILIPPINE ISLANDS: Pacific Commercial Company, Manila; International General Electric Co., Inc., Manila

PORTO RICO: International General Electric Company of Porto Rico, San Juan

PORTUGAL AND COLONIES: Sociedade Iberica de Construcoes Electricas Lda., Lisbon

SOUTH AFRICA: South African General Electric Company, Ltd., Johannesburg, Capetown, Durban, and Port Elizabeth

SPAIN AND COLONIES: Sociedad Iberica de Construcciones Electricas, Madrid, Barcelona, Bilbao, Valladolid, and Sevilla

SWITZERLAND: Trolliet Freres, Geneva

URUGUAY: International General Electric, S.A., Montevideo

VENEZUELA: International General Electric, S.A., Caracas and Maracaibo

Nov., 1930 (3m)