# Westinghouse
# Switchboards

Installation

Operation

Maintenance

INSTRUCTION BOOK

Westinghouse Electric Corporation

East Pittsburgh Works

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# FOREWORD

Many years in designing and manufacturing switching equipment have developed organized experience from which the highest results are obtainable. This experience has equipped Westinghouse Design and Manufacturing Departments to produce switchgear, which will yield the utmost in successful performance and satisfaction to the purchaser.

No matter how excellent the equipment may be, unless it is first properly installed and then given proper care after installation, operating results will, very probably, be disappointing.

Because it is of mutual interest and advantage to the purchaser and the manufacturer, that satisfactory operation should initially and permanently result, we urgently request you to study and carry out the instructions contained in this book.

If further information or more precise instructions are desired concerning any particular phase of the subject covered in this book, it will be furnished on request.

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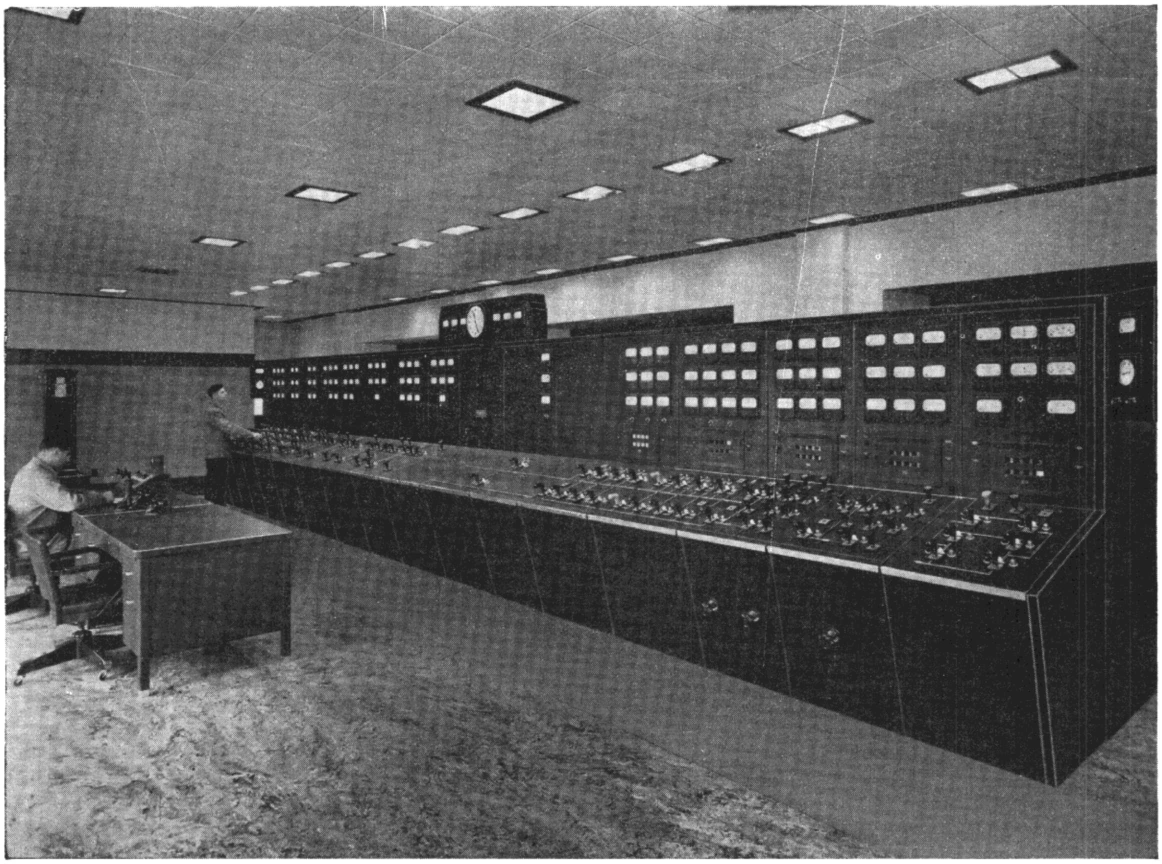


Control Desk for Generator, Transformer, Feeder and Station Auxiliary Circuits. Miniature Bus Indicates Main Power Circuits.

# Westinghouse

# Switchboards

## Installation - Operation - Maintenance

### Location of Equipment

**Assistance From the Company In Selecting Location**—The switching equipment in the modern power plant or substation is generally not a self-contained device, many pieces of apparatus being necessarily located some distance from the switchboard proper. The Company can usually render the Purchaser assistance in selecting the most suitable location for the equipment if drawings or sketches of the station are sent to the Works when placing the order. Obviously a better or more suitable switching equipment can be produced if the designer has complete information regarding the available space and general conditions pertaining to its ultimate location. Many details can, without affecting cost, be adapted to meet local conditions.

**Personal Safety**—In selecting the location of switching equipment, first consideration must always be given to personal safety. Continuity of service demands regular inspection, cleaning and repair with minimum equipment out of service. Ample space and elevation, or enclosure of live parts where possible, are the best safeguards. Aisles should always be of liberal width and particularly so if used when operating disconnecting switches and when inspecting and adjusting other equipment. Mats of good quality rubber or other insulating material should be placed in front of the switchboard and in the aisles as a further protection to the operating and maintenance personnel.

**Safety Codes and Local Regulations**—The Purchaser should familiarize himself with the regulations of the National Electric Code, the National Electrical Safety Code and any State or Municipal rules that may apply. Where local rules affect its design, the Purchaser must call the Company's attention to these when ordering the switchboard.

**Atmospheric Conditions** — Switching equipment designed for indoor installation must not be exposed to excessive moisture such as driving rain or condensation. It must be stored and installed in a dry place which is free from corrosive fumes and abrasive dust. Any contemplated deviation from these rules should be referred to the Company for advice. In locating the switchboard, precaution should also be taken to guard against the possibility of strong drafts carrying the arc from air circuit breakers to ground.

**Future Additions**—If future expansion is probable, provision should be made for the necessary space so that additional equipment can be installed with minimum change in the original installation and interference to service and with the maximum factor of personal safety.

### Shipping and Handling Facilities

**Advantages of Complete Factory Built Switchgear**—The advantages resulting from the use of complete factory built and tested switchgear are now well recognized. With all possible assembly and testing done at the factory where superior facilities for both are available, installation work is reduced to a minimum. This results in considerable saving in both time and expense to the Purchaser. Economies can be effected in the installation of even the simplest multi-panel switchboard if it can be moved into and handled as a unit at Purchaser's plant.

**Shipping Facilities, Purchaser's Handling Facilities and Size of Openings in Station Building**—These are generally the features that limit the shipping unit size of complete factory built equipment. The Purchaser should, therefore, give careful consideration in his building design, to the size of openings through which the equipment is to be moved and the maximum weight that can be handled. Since these matters have considerable bearing on the design of the switchgear equipment, complete information regarding them should be included in Purchaser's order.

### Drawings and Diagrams

**General**—The size and complexity of a switchboard generally determine the number of drawings that have to be made for its manufacture and installation. Usually front and rear view assembly drawings and a wiring diagram are all that are required for the simpler equipments. For more complicated ones, single line and schematic diagrams are necessary in addition to these. Structure drawings, station and conduit layouts and others that may be required are also made if called for in the contract. For an installation where a Purchaser makes his own structure assembly, standard outline drawings of the equipment to be mounted in it are provided for his use in making the design.

When a drawing is made by the company, a number is assigned and printed in the lower right hand corner. The original drawing is known as Sub. No. 1. If it is subsequently altered, the changes are briefly outlined and a new sub number added in the margin at one side. Both drawing and sub numbers should be specified in any correspondence regarding a drawing.

**Assembly Drawings**—The front and rear view assembly drawings show the ocation of the equipment on the switchboard. Similarly, structure drawings show the location of the equipment apart from the switchboard. If there is sufficient space, a "Bill of Material" in tabular form is printed on the drawing with the view. Otherwise it is put on a separate drawing, the number of which is listed with any other associated drawing and diagram numbers under the caption "Engineering Department Reference" which appears on all such drawings.

Item numbers are listed in the left hand column of the Bill of Material. They refer to and are for the identification of corresponding numbers appearing on the various views. Numbers from 1 to 200 represent material shown on the front view, 201 to 500 material on the rear view and numbers from 501 and up, material apart from the switchboard.

A description of the material, style or shop order (S.O.) numbers, drawing references and other information are also given in the Bill of Material. Much of this is only for use at the Works in building the equipment. A study of the description of material will, however, be of assistance in erecting the equipment, and the style and shop order references should be used when ordering renewal parts.

**Diagrams**—Diagrams in their various forms are the keys to switchgear installations. Standard symbols, as adopted by the American Standards Association, are used in their preparation. These symbols are shown in Figs. 1 and 2. Fig. 3 shows typical symbols for contactors, relays, instruments and meters.

**Single Line Diagram**—A single line diagram, as illustrated in Fig. 4, is of great value, especially for a large or more complicated installation, since it depicts the essential features in a simple manner. On it are shown the main power circuits together with the switching devices and the equipment to be controlled. Instrument transformers and their connected loads are also shown in their respective locations.

**Schematic Diagram**—A schematic diagram, as implied by the name, shows in the simplest possible manner the connections for the devices that constitute the switching equipment. Such a diagram, when made for a specific installation, assists the Purchaser in familiarizing himself with the scheme of control. It should, therefore, be carefully studied for that purpose. Fig. 5 shows a typical schematic diagram

A description of the control for the feeder oil circuit breaker as shown in Fig. 5, is given in the following paragraphs to assist in the general understanding of schematic diagrams.

When the circuit breaker is to be closed, the control switch handle is turned to the "CLOSE" position. This completes the circuit from bus P through control switch contact CS.C, control relay operating coil S-1 O, one pole of KN.S to bus N. This causes the control relay to operate and complete the circuit through the circuit breaker closing coil. This circuit is from bus P through one pole of KN.S, contact S-1, breaker closing coil C and the other pole of KN.S to bus N. The circuit breaker then closes and latches in. Auxiliary contact BKR.aa in the circuit of relay coil S-1 R, closes when the breaker mechanism operates and resets the control relay, causing contact S-1 to open. When the circuit breaker closes, an auxiliary contact completes the circuit through the indicating lamp R. This can be traced from bus P through lamp R, contact BKR., one pole of KN.S to bus N.

The circuit breaker is tripped manually by turning the control switch handle to "TRIP". This completes the circuit from bus P through control switch contact CS.T, circuit breaker trip coil T, two auxiliary contacts BKR. in series, one pole of KN.S to bus N When the circuit breaker opens, this circuit is immediately interrupted by the contacts BKR. Lamp G indicates the open position of the circuit breaker. Its circuit is from bus P through one pole of KN.S, contact BKR., lamp G and control switch contact CS.OCT to bus N.

In case the type CO overcurrent relays operate, their contacts O.C.REL. close and complete the tripping circuit in the same manner as described for manual tripping. Automatic tripping of the circuit breaker by means of the overcurrent relays starts the bell alarm to ring. This circuit is from bus P through one pole of KN.S, contact BKR., contact CS.SC to bell bus B and thence through the bell to bus N. Turning the control switch handle to "TRIP" opens contact CS. SC and silences the bell alarm.

**Wiring Diagram**—A switchboard wiring diagram is always made regardless of any others that might be required. It is used at the factory in wiring the switchboard and by the Purchaser when completing his external connections prior to putting the equipment into service. Fig. 6 shows a typical wiring diagram for a four panel switchboard and Fig. 6A its associated structure diagram.

Wiring diagrams show the connections on the panels as viewed from the rear and, although not drawn to scale, can be used to determine the arrangement of conduits. The various devices are shown in their relative locations on the panels, standard conventional symbols being used both for these and the equipment apart from the switchboard. The main power circuits are shown by heavy lines, exciter and field circuits by medium heavy lines and the smaller wiring by light lines. Dot dash lines outline the panel sections.

As shown in Fig. 6, wires terminate in circles below the panels. This is the conventional manner of grouping wires which connect to apparatus apart from the switchboard. Those at the bottom of panel No. 1 are designated by C1a-S1, C1b-S1, C1c-S1, etc. In the combination C1a-S1, the letters C, S and numerals 1 indicate that the wire group which it designates extends from switchboard panel No. 1 to structure section No. 1. The letter "a" designates the individual group. When the contract includes a conduit layout, the wires going to equipment apart from the switchboard are grouped to conform to the conduit arrangement.

**Forwarding Drawings for Purchaser**—Copies of drawings and diagrams specified in the contract are sent out as soon as possible after receipt of the order. If the contract calls for Purchaser's approval of these, they should be returned promptly with either an approval notation thereon or marked to show the changes required.

If, during the course of design, manufacture and test, it is found necessary to make changes, new prints of the revised drawings are forwarded. A com-

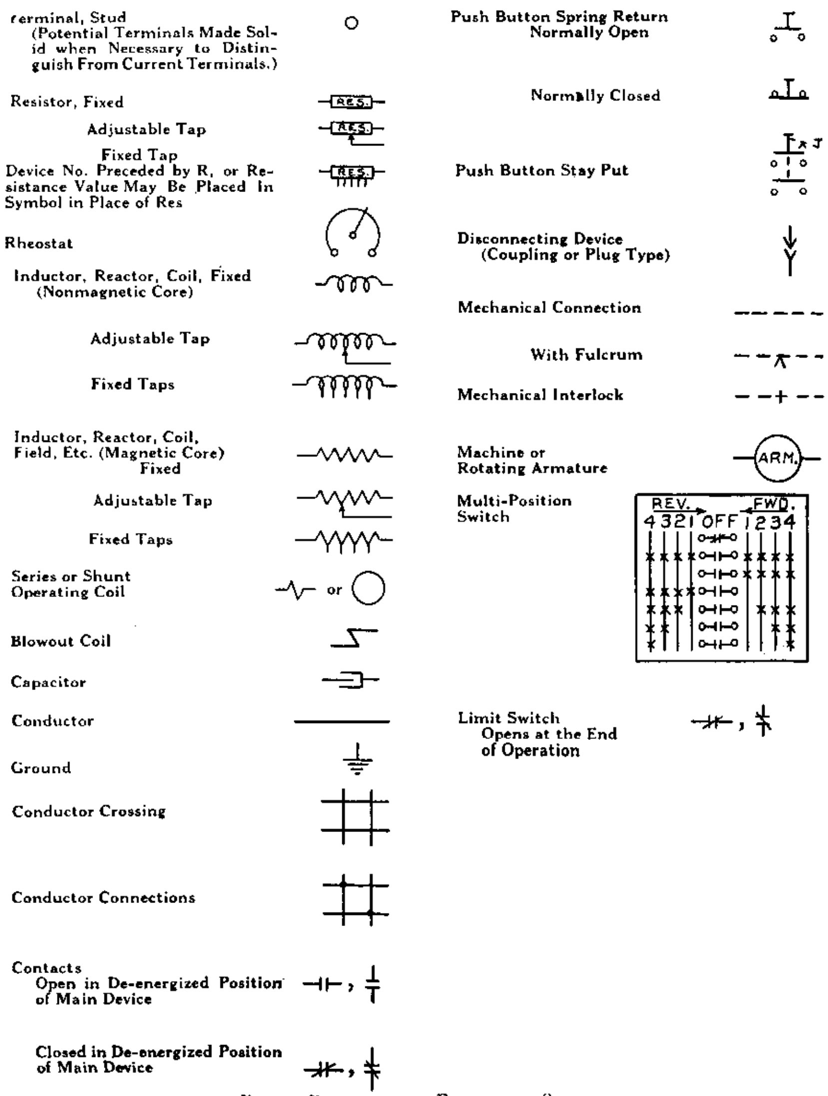



FIG. 1—FUNDAMENTAL ELECTRICAL SYMBOLS

plete set of drawings is also included with the shipment of equipment. When the Purchaser receives a drawing having a new sub number, he should destroy the superseded one immediately since serious trouble may result from the use of an obsolete copy.

## Factory Assembly

Except in rare instances required by unusual conditions, switchboards are assembled at the factory, with all devices mounted, and the panels completely wired. Buses and connections are fabricated and put in place to check their correctness. After the assembly has been completed, the equipment is thoroughly inspected and tested.

## Packing and Shipping

**Minimum Disassembly At The Factory**—In order to facilitate Purchaser's installation work, only those parts are disassembled which because of their size or for some other reason, cannot be shipped in place. The panels are shipped singly or in units of two or more, depending on shipping and Purchaser's handling facilities. When panels for a multipanel switchboard are shipped singly or in small units, their numbers are marked on the outside of the crate to facilitate selection for reassembly in the field.

Shipping completely assembled multi-panel switchboards is becoming more general. As shown in Fig. 7, the switchboard is provided with a lifting angle and crated for shipment with the panels in the vertical position. This method is recommended wherever possible.

**Shipment Notice**—The shipment notice, which is mailed from the factory at the time the equipment is shipped, lists the apparatus and gives other information which will be of assistance to the Purchaser when he receives the material.

A shipment number, and other essential information, is given at the top of each sheet of the shipment notice. This number will be the same for all material shipped at the same time from one of our works. A subsequent shipment from the same works or a shipment from another works will have a different shipment number. The numbers of the boxes, crates, etc. are given in the left-hand column of the shipment notice and their contents listed in one of the other columns.

The material is listed and described in sufficient detail to be readily identified, shop order and drawing numbers being given where necessary. Apparatus mounted on panels is not listed separately. However, a device that has to be removed for shipment either is marked or has a tag affixed, giving its drawing and item number. It is also listed and described on the shipment list.

**Drawings And Other Literature Shipped With Equipment**—A complete set of switchboard drawings and diagrams, a copy of this instruction book and any other literature that might apply, are packed in one of the boxes. Their numbers are given on the shipment notice with instructions to open the box containing them first. It is especially urged that this box be opened immediately on its receipt and that all drawings and other literature be placed in the hands of the person responsible for the erection of the equipment.

## Handling and Unpacking

**Precautions Necessary**—Switchboards usually have instruments, meters, relays and other delicate devices mounted thereon which might be damaged if subjected to shocks. Also panels and bases of insulating material are often drilled for supporting heavy metal parts and are thereby weakened too much to withstand rough handling. Associated equipment such as disconnecting switches, bus supports, etc., have porcelain parts which might be broken if handled carelessly. It is, therefore, imperative that all equipment be handled with the utmost care.

Unpacking also requires special attention. When opening instructions are stenciled on boxes or crates, they should be carefully followed. The use of heavy sledge hammers or crowbars and the complete demolishing of crates or boxes, might result in broken apparatus which would require considerable time to replace. Boxes and crates

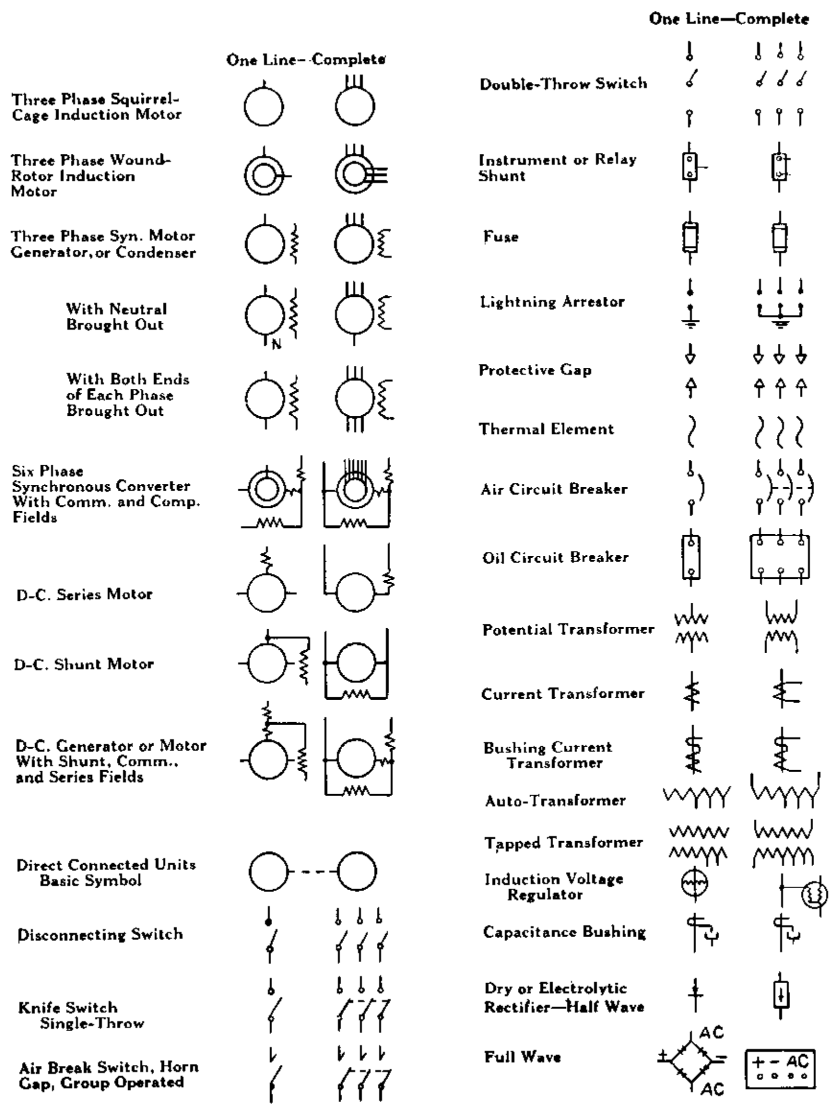



Fig. 2—Fundamental Electrical Symbols.

when unpacked, can often be used as storage receptacles or the lumber in them used for making storage bins.

When unpacking, the excelsior should not be destroyed until all the material listed on the shipment notice has been accounted for, otherwise some small piece of equipment might be lost. Identification tags should not be removed from the different pieces of apparatus until the equipment is completely installed.

**Checking Shipment**—When unloading a shipment, the numbers on the boxes and crates should be checked against the package numbers on the shipment notice. Also as the various boxes are unpacked, their contents should be compared with the list of material.

**Shortage Claims**—If any shortage is discovered, claim should be made promptly after receipt of shipment, otherwise it will not be considered. The letter making the claim should be directed to the sales office of the Company through which the order was placed. It should give the Company's general order number, the Purchaser's order number and its date, the consignee, the shipment and package numbers and the name of the missing device as given on the shipment notice.

**Breakage Claims**—Present all claims for breakage to the carrier, as the Company is not responsible for damage to apparatus after delivery of it to the carrier. If notified of such claims, however, the Company will gladly lend assistance to secure adjustment.

**Return of Material**—Do not return apparatus for credit or exchange without first obtaining written approval and shipping instructions from the sales office through which the order was placed Notification of such shipment, with a copy of the shipping receipt must be sent to the sales office. To obtain credit, shipment must bear the name and address of the sender.

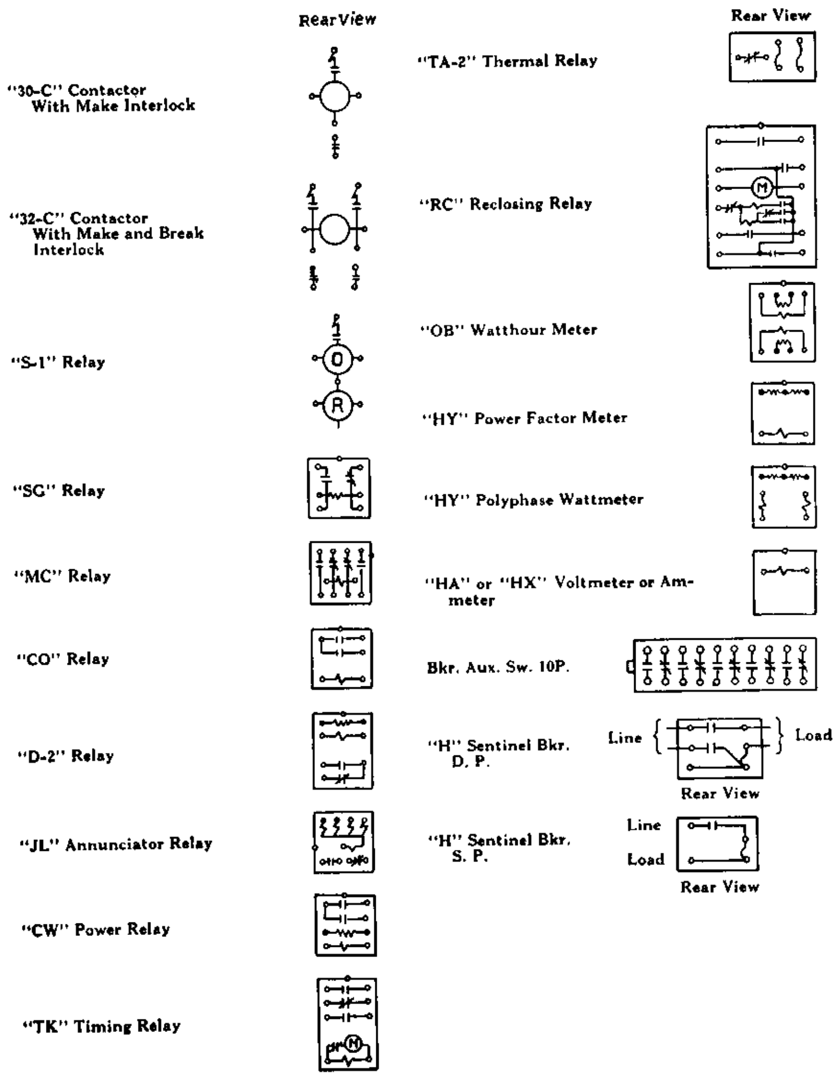



FIG. 3—TYPICAL SYMBOLS FOR CONTACTORS, RELAYS, INSTRUMENTS, AND METERS SHOWING SIMPLIFIED INTERNAL CONNECTIONS.

## Protection and Storage of Equipment

**General**—Protection against loss of equipment is an important precaution. Trouble and delay will be avoided by having good storage facilities arranged so that the apparatus will be accessible only to authorized persons and so that it can be quickly located when required in the erection program.

Switchboard equipment, regardless of whether it is to be installed immediately or stored for a while before being erected, should be kept in a dry, clean place. Conditions such as dampness caused by rain or change in temperature, cement dust, etc., should be carefully guarded against. Covering the equipment with tarpaulin is frequently necessary both during storage and erection. The longer the period of storage, the greater must be the care taken for protection of the equipment.

Crated apparatus which is not to be erected immediately will store much better if left crated. It should, however, be inspected to make sure that no damage has been incurred during transit.

Storage batteries should be given special attention as soon as they are received. They should be unpacked immediately, their condition checked and charged if necessary. They should never be allowed to stand uncharged. Refer to the section on Storage Batteries for information regarding their installation.

**Recording Location Of Equipment**—When storing, the location of the different crates and boxes should be marked on the shipment notice. Boxes or other packages containing castings and similar details not requiring protection can be unpacked. The material with their identification tags attached should be placed in numbered bins which can be made from the shipping cases. The bin numbers should be marked on the shipment notice so that the equipment can be quickly located during erection.

Details such as bolts, nuts, etc., are usually shipped in cloth bags attached to which are tags listing their contents. This makes it unnecessary to empty the bags until the material in them is required for assembly.

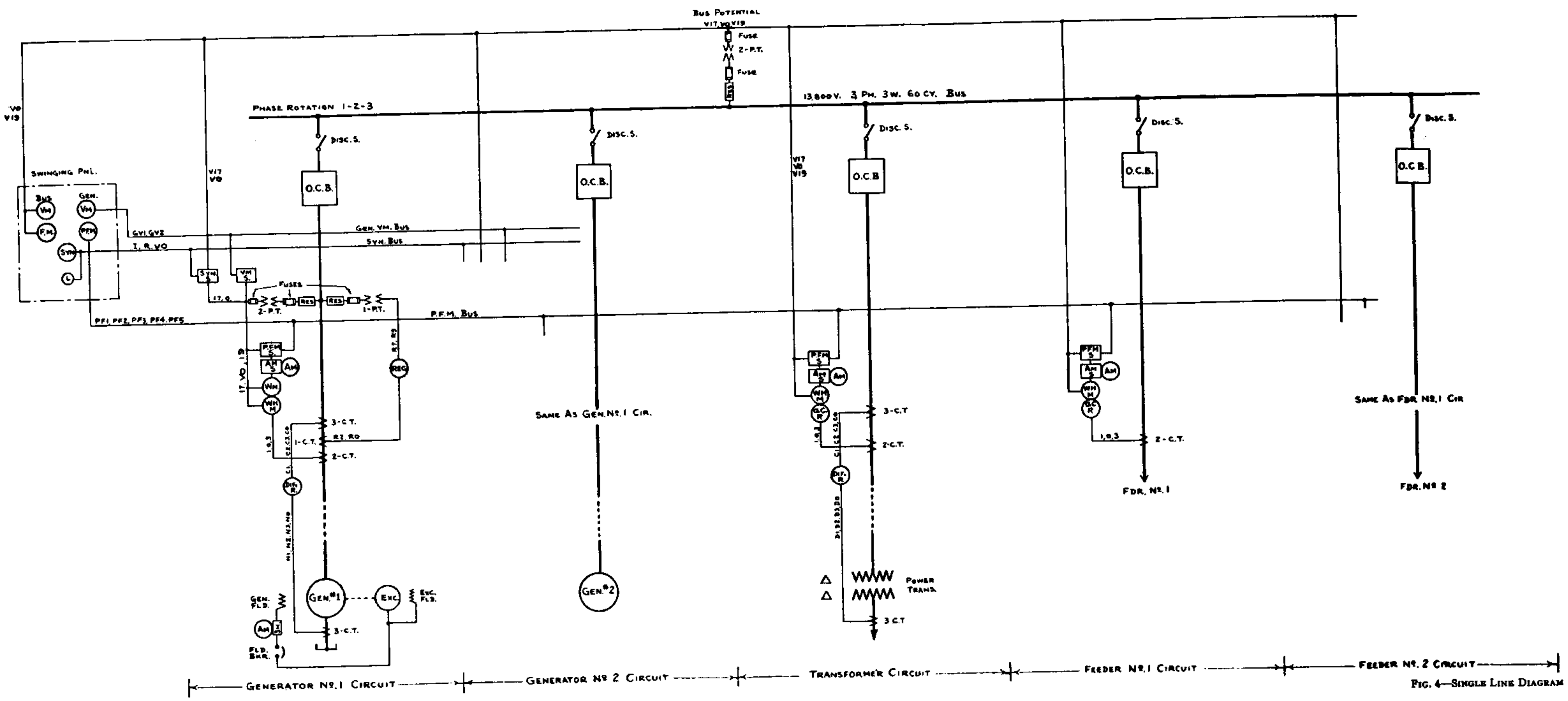



Fig. 4—Single Line Diagram

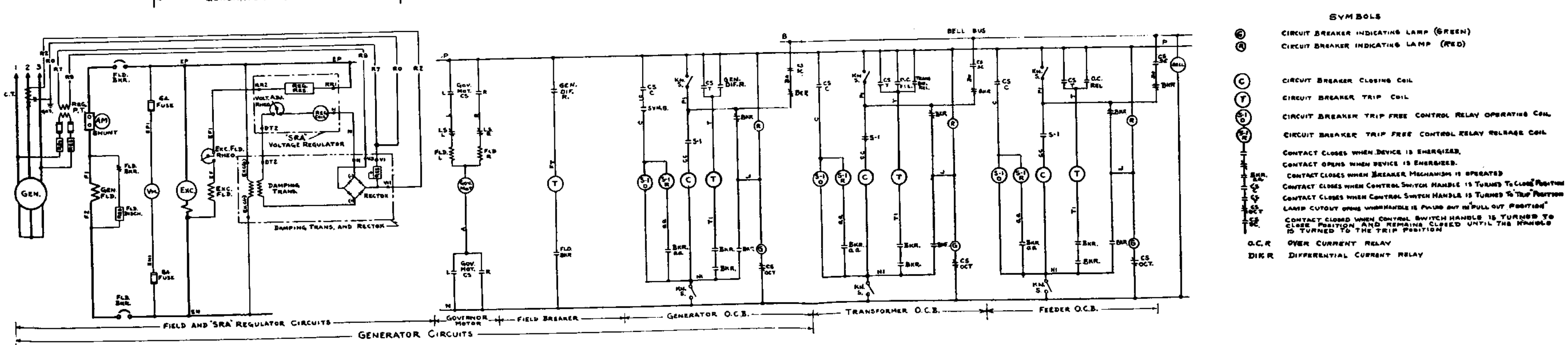



Fig. 5—Schematic Diagram

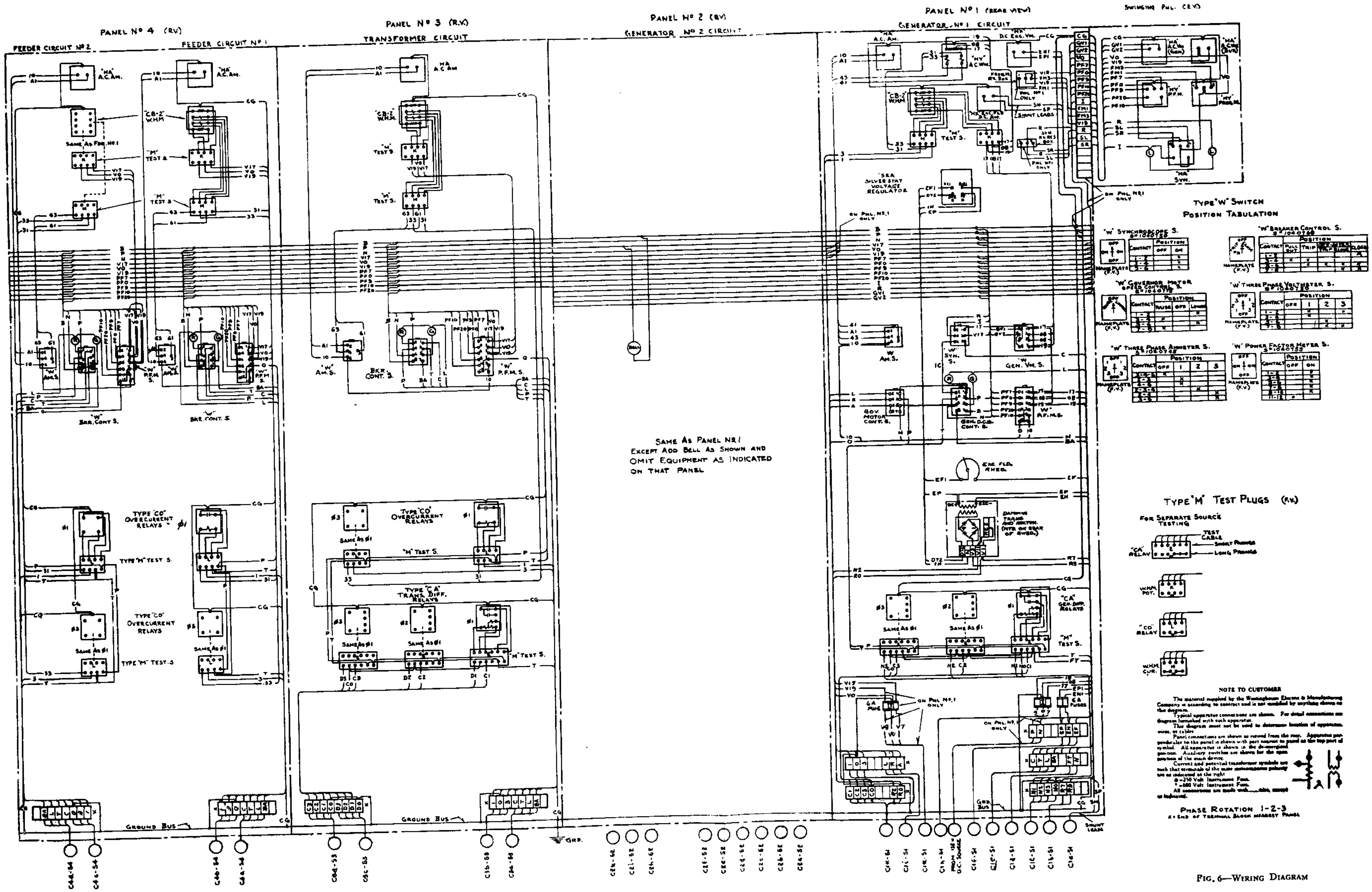



Fig. 6—Wiring Diagram

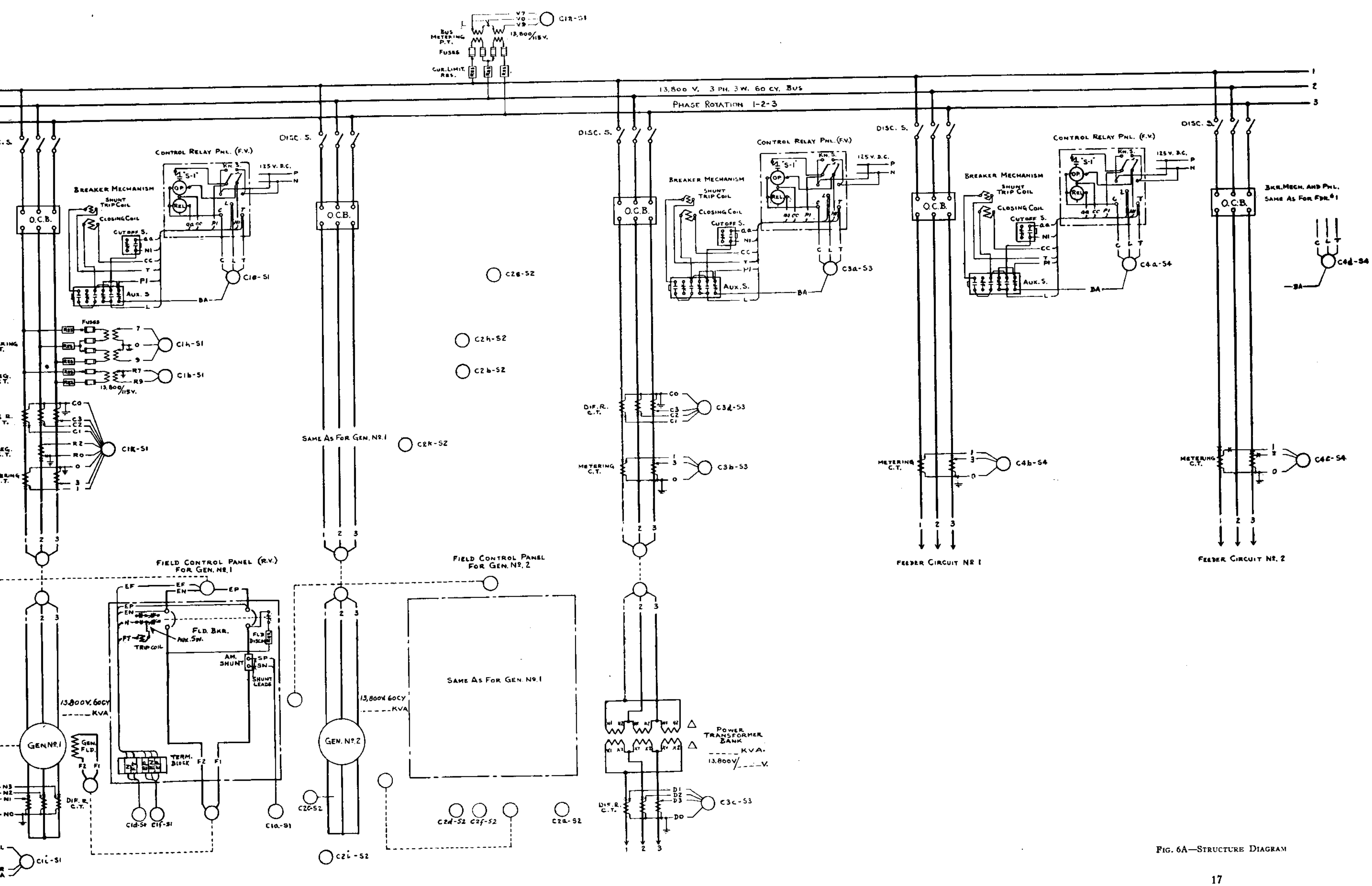



Fig. 6A—Structure Diagram

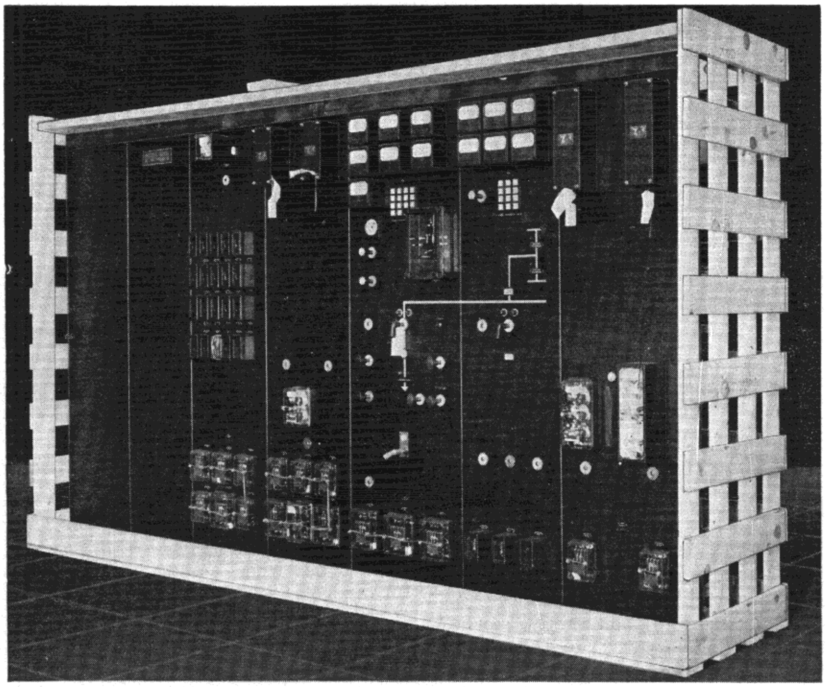


Fig. 7—Seven Panel Switchboard Partially Crated for Shipment.

**Card File For Large Installations**—For large installations, the shipment notice may be too bulky for quick and frequent reference. In such cases the material, when being unpacked, can be listed on small cards as shown in Fig. 8. The cards, when filed numerically by Westinghouse drawing and item numbers, provide a convenient reference for the location of the material during the construction period and a record of its withdrawal for erection purposes.

## Apparatus Instruction Books and Cards

Instruction books or cards are usually shipped with the principal pieces of apparatus such as instruments, meters, relays, circuit breakers, etc. When unpacking the equipment, these instructions should be detached and placed in the hands of the person in charge of erection. **No attempt should be made to install or adjust any device until the instructions applying to it have been carefully read and are thoroughly understood.**

Drawing No............................

Item No...............................

Description ............................

Shipment Notice No....................

Location—Bin No......................

Number of Pieces.......................

Drawn Out By..........Date...........

......................................

......................................

Fig. 8—Recommended Card Form for Recording Location and Withdrawal of Material

## Erection of Switchboard

**General**—Switchboards are erected at the factory on true and level bed plates to insure correct alignment. Purchaser should prepare his foundation with care, duplicating factory conditions as closely as possible. Time spent in assuring an accurate and level base will be amply repaid in labor saved during actual erection of the switchboard.

**Bases**—Channel iron bases having a depth of 6 inches, a flange width of 1.92 inches and weighing eight pounds per foot are supplied for all steel panel switchboards. They are also supplied for switchboards comprising asbestos or slate panels which have sub sections except those for railway or other grounded system installations operating at 600 volts or above. For these, the switchboard is usually insulated from ground by mounting it on a wooden sill which is usually furnished by the Purchaser.

The channel iron base has tapped holes for bolting steel panels or the frames for slab panels to it. In addition to these, it has two other holes—one $\frac{13}{16}$ and the other $1\frac{1}{4}$ inches—at each panel position. The former are for the holding down bolts and the latter for pouring in the grout.

The method of placing the holding down bolts in the floor will depend on the construction of the latter. For a new installation with a concrete floor, good results will be obtained by locating $\frac{5}{8}$ x 6 inch bolts at the proper places before the concrete is poured. Large washers should be placed above their heads to secure greater bearing surface. The bolts should extend not less than three inches above the floor level for receiving the channel base, washers and nuts. Inserts or expansion sleeves can be placed in the floor if this seems preferable or it may be possible to use through bolts.

Before erecting the panels, the channel base should be placed on the floor, leveled and bolted down as illustrated in Fig. 9. It should also be grouted in either before or after the panels have been erected. If done beforehand, all bolts must be in place in the channel before grouting. If this precaution is not observed, the grout will interfere with their being placed later.

After the channel base has been bolted down, its ends should be plugged with a mixture of fairly dry mortar, then dammed with boards or bricks as shown in Fig. 10. Grout consisting of one part cement and one part sand mixed with enough water so that it will flow smoothly, should be poured into the grout hole. Sufficient grout should be poured so that it will be slightly above the surface of the channel to provide for settling.

After the channel base has been grouted in, go over its surface lightly with a rough file to remove high spots and other matter which might interfere with the proper alignment of panels.

Wooden sills, when used, should be placed in the proper position on the floor, leveled and bolted down. When locating the holding down bolts, precaution must be taken so that they will not ground the switchboard frame. When erecting the panels, their frames are fastened to the sill with lag screws.

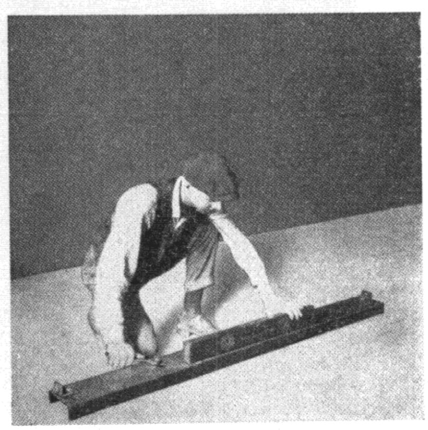


Fig. 9—Channel Iron Base Should be Leveled and Bolted to the Floor.

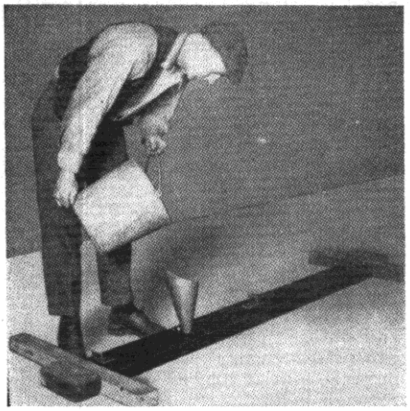


Fig. 10—After the Base Has Been Leveled and Bolted Down, the Ends of the Channel Should be Closed as Shown and Grout Poured Through the Large Hole Note that the Corner Angles Should not be Removed Until the Grout has Set.

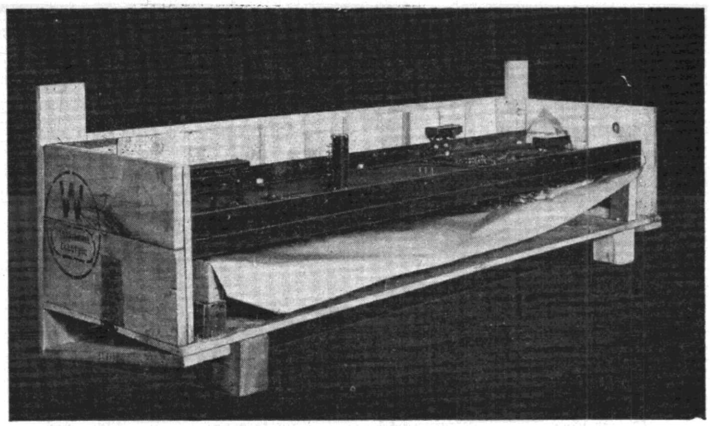


Fig. 12—When Unpacking, the Crate Should be Turned on Edge as Shown. Sufficient Boards have been Removed to Permit Handling the Panel.

**Wall Braces**—1¼ inch pipe is generally used for bracing the switchboard to the wall in its rear as shown in Fig. 11. The method of anchoring the braces depends on the construction of the wall. Heavy panel equipment requires solid fastenings. Through bolts, expansion bolts or lag screws can be used.

A temporary arrangement of wall braces may be more convenient until at least some of the panels are lined up and plumbed. Following this, the top iron—when supplied—can be put in place and finally the permanent wall braces.

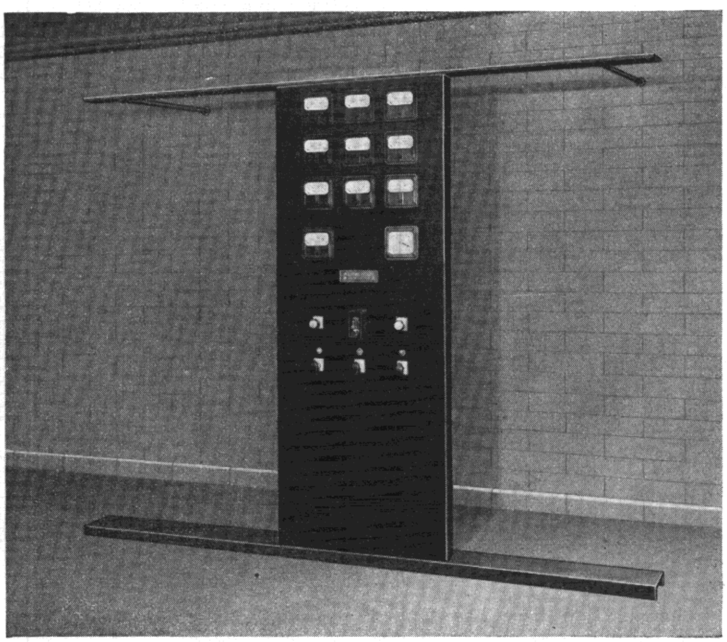


Fig. 11—Correct Method of Assembly, Aligning and Bracing Switchboard Panels. Note that Middle Panel Has Been Placed in Position First.

**Uncrating Panels**—After the switchboard base is in position and provision made for wall bracing, the panels which should still be in their crates, can now be moved, as required, to the place of their installation.

Crates for slate panels have extension feet as shown in Fig. 12, so that the panels will ride on edge during transit. They are not necessary on crates for steel or asbestos panels. When unpacking slate panels, the crates should be set on edge with one side resting on blocks as shown. The wing braces for the extension feet are first removed, then the boards of the crate until it is possible to lift out the panel.

Note that all panels, regardless of their type, when shipped individually for final erection in a multipanel switchboard, should be uncrated with the rear up as shown in Fig. 12 to safeguard the apparatus on the front and facilitate handling the panel.

**Middle Panel Erected First**—Regardless of the type of panel or frame construction, the best results in aligning will be obtained by first placing the middle panel in position as shown in Fig. 11 and assembling toward either end. This results in the distribution of any slight inequalities toward each end. A panel can be identified while still packed by referring to its number which is marked on the outside of the crate. Since this corresponds to the number given on the assembly drawing, its position in the switchboard can be quickly determined.

**Steel Panels Or Slab Panels On Angle Or Formed Channel Iron Frame**—A switchboard comprising steel panels or slab panels on angle or formed channel iron frame, can be erected more easily than one with pipe frame, since the panel and its frame is taken as a unit from its shipping crate, set in position and bolted to the base and adjacent panel.

**Panels On Pipe Frame**—Multi-slab panels for pipe frame mounting are usually shipped completely assembled. Although this necessitates furnishing extra pipe uprights which are used solely for shipping purposes, it permits complete wiring of the panels at the factory and greatly simplifies Purchaser's installation work. The following instructions and Fig. 13 should be followed when assembling switchboards mounted on this type of frame:

(1) Uncrate and place the middle panel—designated as No. 8—in position as shown in View A.

(2) Remove one pipe upright and its mounting brackets from panel No. 8 as shown in View B.

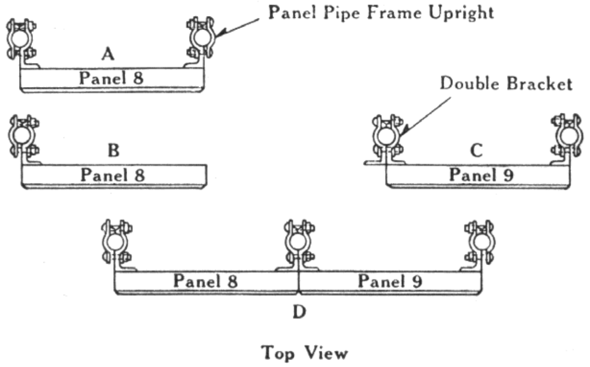



FIG. 13—METHOD OF ERECTING PIPE-FRAME SWITCHBOARD.

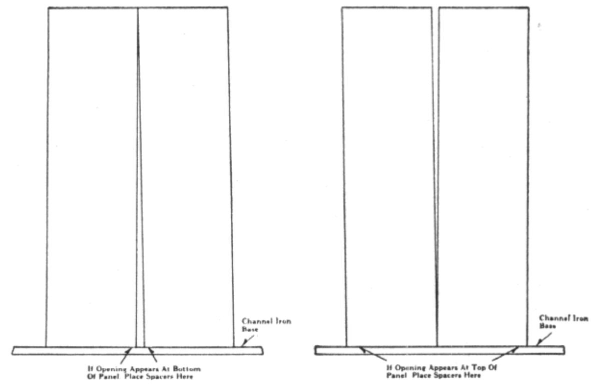



FIG. 14—METHOD OF ALIGNING PANELS.

(3) Uncrate panel No. 9 and convert the single brackets on its left hand upright to double brackets as shown in View C, using the single brackets taken from panel No. 8.

(4) Move panel No. 9 to its position as shown in View D. Bolt panel No. 8 to its right hand frame, making sure that the fuller board washers are in place between the rear of the slabs and the brackets.

(5) Continue this procedure progressively on either side of the erected panels until they have all been placed in position.

**Alignment Of Panels**—If, when erecting panels, it is found that large spaces appear between edges of adjacent panels, either at the top or bottom, they should be raised and spacers inserted between their bottom edges and the channel iron base as illustrated in Fig. 14. In order to secure a close fit, it may sometimes be necessary to cut the edges of two adjacent slab panels with a hack saw blade inserted between them.

**Multipanel And Duplex Switchboards Shipped As Complete Units**—Installation of these equipments is comparatively simple. As shown in Fig. 7, they are crated for shipment with the panels in the vertical position. On arrival at the place of installation, the switchboard should be uncrated, placed in the proper location and plumbed. If the floor on which it is to be installed is level, no difficulty will be experienced in doing the latter. If not, shims will have to be used to secure proper alignment. Following this, the channel base should be bolted down and grouted in.

## Control Desks

**General**—Modern Westinghouse control desks are made from ⅛ inch thick stretcher leveled sheet steel. They are built in sections and assembled in desired combinations on channel iron bases. The equipment is mounted on the desk which is then completely wired and tested. The construction is such that the trim can be removed from either end and sections added without disturbing apparatus already installed.

As shown in Fig. 18, they are designed for mounting over a pit or opening in the control room floor. This method of installation is strongly recommended since it facilitates making connections and inspecting the wiring.

Each section has a horizontal wiring trough so arranged that when all are in place, a continuous run is provided for the control and instrument buses. Terminal blocks are located in the various sections for making connections to these buses and to the cables coming from separately mounted apparatus.

**Shipment**—Control desks are crated for shipment in the vertical position and wherever possible, as complete assemblies. If the latter is not feasible, they are disassembled and the various sections crated and shipped individually or in groups of two or three as conditions permit.

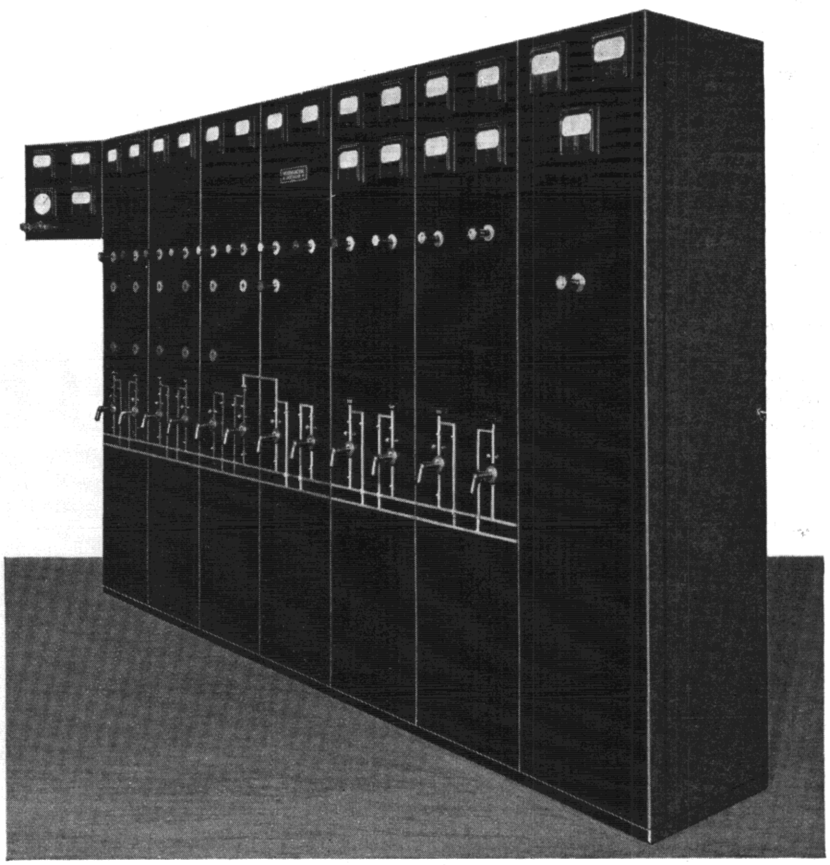


FIG. 15—FRONT VIEW OF DUPLEX SWITCHBOARD.

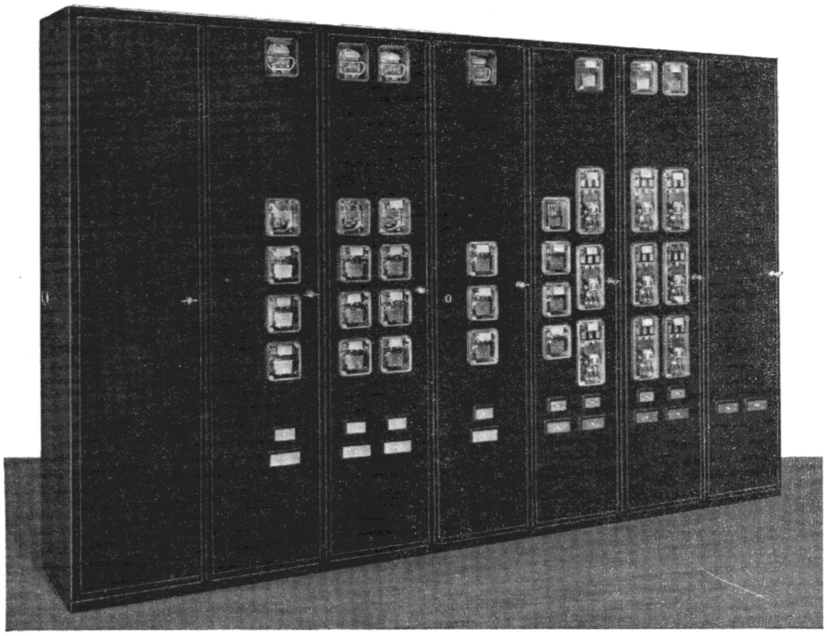


Fig. 16—Rear View of Duplex Switchboard Shown in Fig. 15.

## Hinged Instrument Panels and Brackets

Instruments such as voltmeters, the synchroscope, etc. whose use is common to a number of panels or sections of a board, are usually mounted on a formed steel panel, hinged at one end, as shown in Fig. 19. Connections between the instrument panel and the adjacent main panel are made through a terminal block. The hinged panel is provided with a rear cover to prevent contact with live studs and to improve appearance. When a duplex switchboard or control desk is equipped with a hinged panel, the interconnecting wires are cabled and taken through a bushed hole in the side of the adjacent section.

Regardless of whether the main board is shipped assembled or in units, the hinged instrument panel is usually detached and packed separately. When reassembling the equipment, the instrument panel should be unpacked after its adjacent stationary panel has been erected, and fastened in place by inserting the pins in the supporting hinges. Connections should then be made to the terminal block on the main panel and the instrument panel set at the angle which gives the operator the best visibility, using the adjustable stop provided for that purpose.

**Unpacking And Installation**—The procedure to be followed in unpacking and installing a control desk is essentially the same as that for a vertical steel panel switchboard. The foundation should be carefully prepared in advance and, if the desk has been shipped disassembled, the channel iron base placed on the floor, bolted down and grouted in either at the time or after the equipment has been installed.

The crated desk sections should then be moved to the place of installation in the order required for erection, and unpacked. When doing this, care should be exercised that the equipment is neither damaged nor the desk finish marred. Remove sufficient boards from the crate so that the section can be lifted out by means of the lifting angles bolted to the top of the desk section. These should be discarded after they have served their purpose.

The middle section should be erected first, and then the others, working progressively toward each end. After a section has been placed it should be bolted to the channel base and adjacent section. When all sections are in place, the control and instrument bus wires should be pulled in the wiring trough and connections made between these busses and the terminal blocks in accordance with the wiring diagram.

If the transportation and handling facilities permit shipment of the desk as a completely assembled unit, installation work is greatly simplified. Except for completing the external connections, it is only necessary to set the desk in place on the floor, fasten it down with the bolts which should be placed beforehand for that purpose and grout in the channel iron base.

## Precaution Necessary When Swinging Hinged Panels

The rears of duplex switchboards and certain types of control desks are generally equipped with hinged panels on which are mounted meters and relays. When swinging these panels, it is extremely important that it be done slowly and without jar to prevent damage to the meters and relays or false operation of the latter.

## Secondary Wiring

**General**—Since the secondary wiring is the vital part of a switchboard or control desk, it must be given special attention in the factory, during installation and after the equipment has been placed in service. The wiring is carefully inspected and tested to insure its leaving the factory correctly wired.

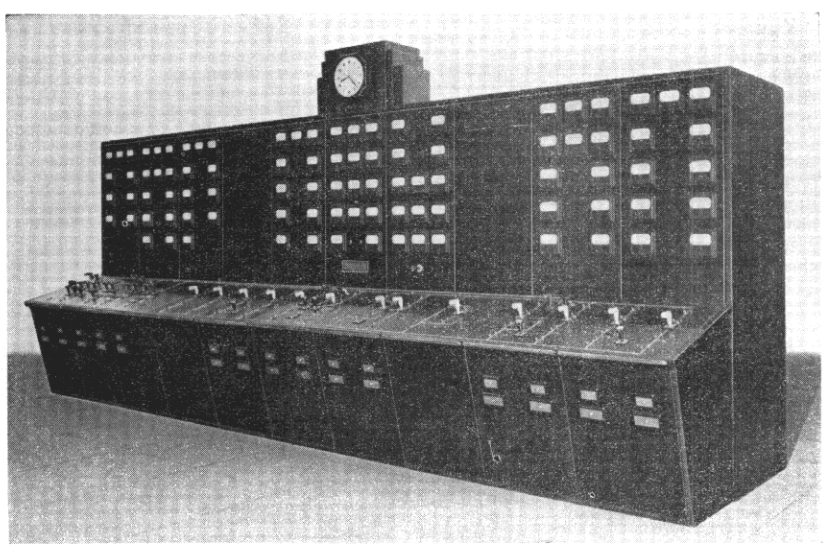


Fig. 17—Ten Section Type D-5-S Control Desk for Supervision and Control of a Terminal Substation.

With few exceptions, switchboards and control desks are wired with solid wire having flame proof covering, No. 12 and No. 18 being used for conventional and miniature equipments respectively. Flexible cable is used in making connections between the terminal blocks on hinged panels and the adjacent ones on the housing. Also wire having a higher current rating—usually for connections to apparatus apart from the switch board or for control buses—is sometimes required. Where this condition exists, the size of wire to be used is given on the wiring diagram. The diagram should, therefore, be carefully examined for such exceptions and wire of the proper characteristics installed where necessary.

**Ammeter Shunt Leads**—In most cases d-c. ammeters are mounted close to their shunts and standard No. 12 wire used for their interconnections, since commercial accuracies can be obtained under these conditions. When required, special long leads are furnished for connections to shunts located apart from the switchboard and the ammeters specially calibrated for use with these leads. If when installing, there is any excess length, it should be neatly rolled and supported apart from the panel. Under no condition should they be shortened unless the ammeter is recalibrated.

**Steel Panel Wiring**—As illustrated in Fig. 20, the vertical wiring is run in the channel shaped sides of Westinghouse steel switchboard panels and control desk sections. The wires are easy to place, accessible, and panels wired in this manner, present a neat appearance. Also, changes can be readily made when desired.

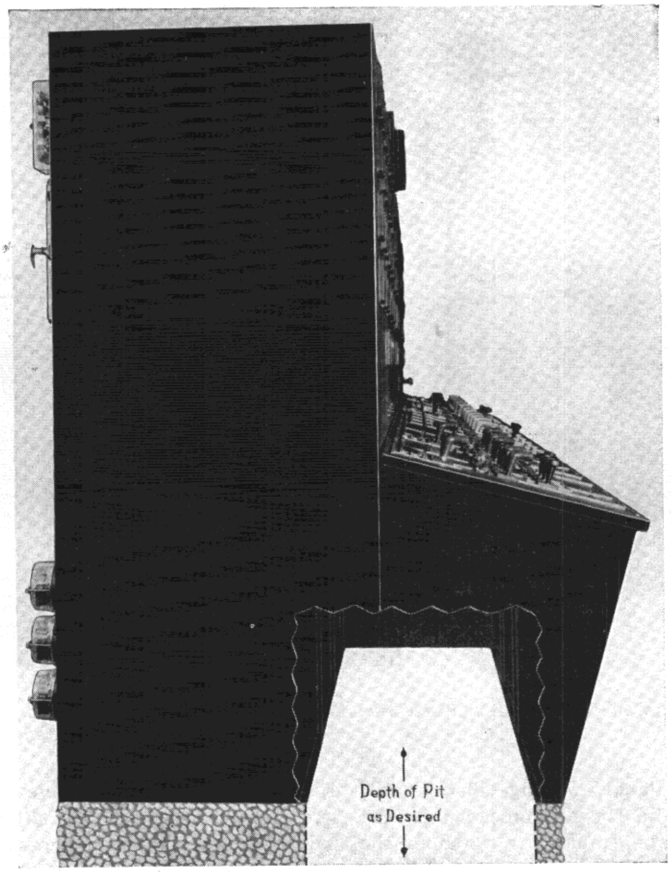



FIG. 18—END VIEW OF TYPE D-5-S CONTROL DESK ILLUSTRATING METHOD OF INSTALLATION OVER PIT.

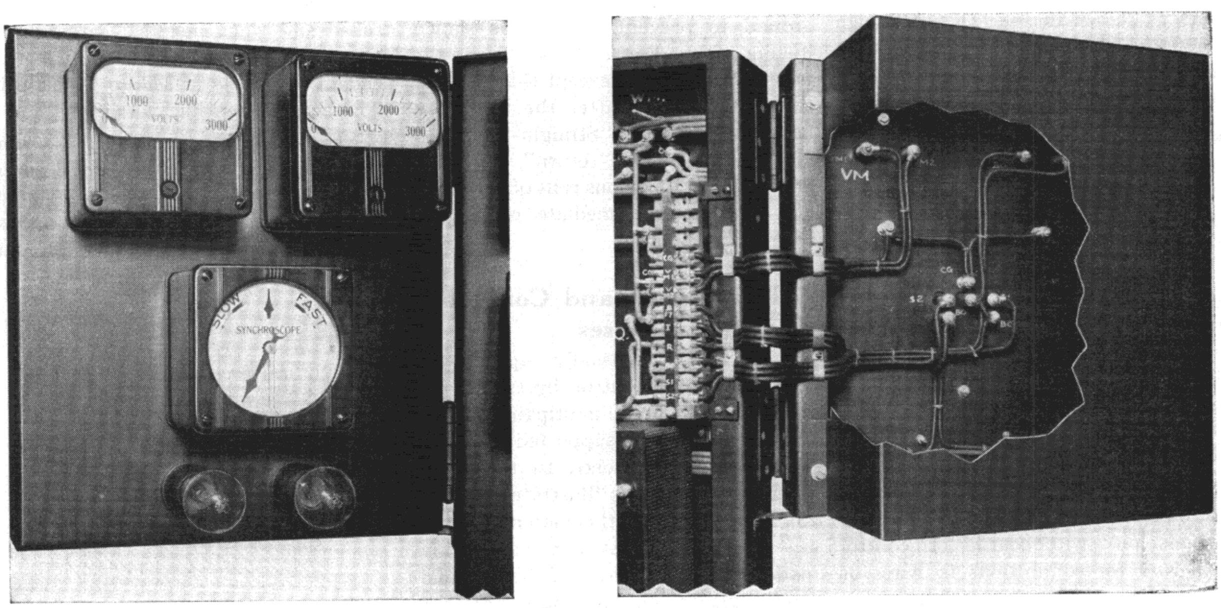



FIG. 19—HINGED STEEL INSTRUMENT PANEL.

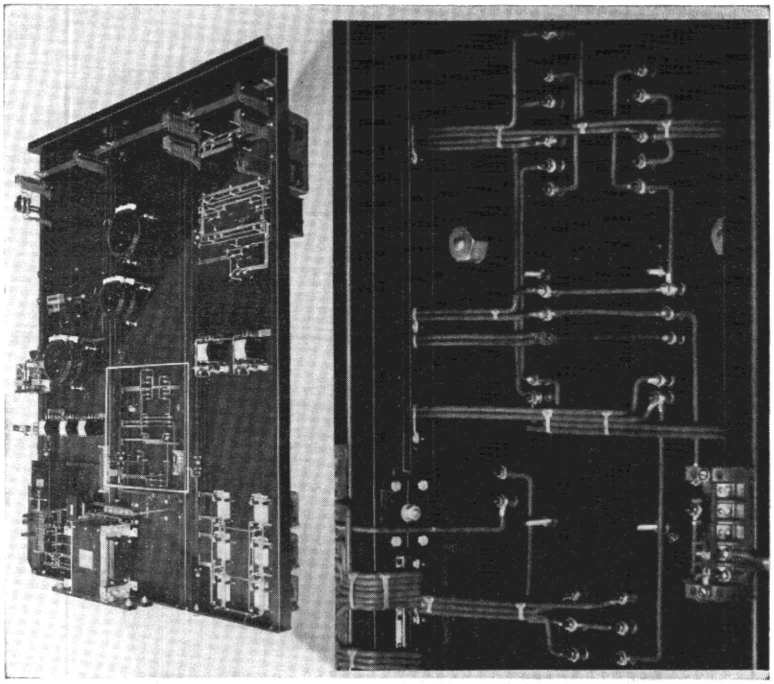


FIG. 20—REAR OF STEEL PANEL SWITCHBOARD SHOWING METHOD OF WIRING.

**Slab Panel Wiring**—Slab panel mounted on the recommended formed channel iron frames are wired in the same manner as steel panels. When mounted on angle or pipe frames they are wired in either of two ways—flat wiring or bracket wiring. The method used depends on the number of wires to be placed and the space available. In the former, wires are laid flat against the panel and held in place by metal cleats as shown in Fig. 21. Although this figure shows eight wires, smaller cleats are used for a lesser number.

Bracket wiring is used where a large number of wires have to be placed in a limited space. As shown in Fig. 22, wires are located in a plane perpendicular to the rear of the panel and held securely in place by metal cleats bolted to L brackets. This figure shows sixteen wires supported on one bracket. Occasionally wire groups are double decked on both sides of the supporting bracket when space is limited, although this is avoided when possible since the inner wires are not readily accessible.

**Terminal Blocks**—Moldarta terminal blocks as shown in Fig. 23 are mounted where necessary for making interconnections on switchboards or control desks and for connections to wires or cables going to apparatus apart from them. They are available in four sizes—4, 5, 8, and 12 point—and have marking strips on which wire designations are painted as given on the diagram.

**Wire Terminal Clamps**—Tinned brass terminal clamps are provided on all terminal blocks and on other devices where necessary. When making installation connections with solid wire, the insulation should first be removed, the wire bent into a hook shape, placed in the terminal and the skirts bent around to prevent fraying, as shown in Fig. 24. For stranded wire, the method is the same except that the end should be twisted after the insulation has been removed. "Straight-through", "right-angle" and "return" terminals are used for continuous runs of wire with one or more intermediate connecting points.

## Instrument and Control Buses

Brass tubing is usually supplied for instrument and control buses on the rear of Westinghouse multipanel switchboards. They are supported by insulated brackets attached to the panel flanges or frames as illustrated in Fig. 25. Buses made of this material do not sag and connections can be quickly made to them by means of the terminal screws placed on the buses at the factory for that purpose.

The bus is left in place when an equipment is shipped completely assembled. For a switchboard that has been shipped disassembled, the bus should be mounted in its proper location after all the panels have been erected and connections made in accordance with the wiring diagram.

When desired, buses can be insulated with cambric or other insulating tape. It is also possible to use micarta tubing for insulating the sections between the panel wiring connection points, these usually being made near the bus supports. If tubing is used, it has to be placed on the bus when the latter is being assembled on its supporting brackets and before connecting the panel wiring to it.

The buses have to be spliced where the length exceeds fourteen feet and when additions are made to existing equipment. Connecting bars are provided for this purpose where necessary. In applying these, the inside of the bus and outside of the bar should be tinned and then soldered together, as illustrated in Fig. 26.

Standard No. 12 wire is generally used for instrument and control buses in control desks. This is placed in the wiring trough and connections made to it through terminal blocks as previously explained.

## Miniature Bus

Miniature bus is occasionally supplied on switchboards and almost invariably on control desks. It represents the power equipment and circuits controlled and when installed with miniature disconnecting switches, the attendant can make a set up which will show actual operating conditions.

Extruded metal is generally used for miniature bus, although the circuits are sometimes represented by painted lines. In either case, different finishes or colors are used to represent different voltages.

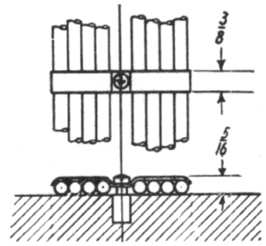



FIG. 21—FLAT WIRING.

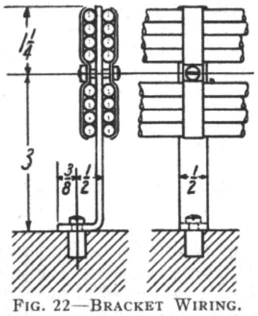



FIG. 22—BRACKET WIRING.

The bus is put on the panels at the factory and will not ordinarily require attention if the equipment is carefully erected on level bases. Extruded bus, when used, is terminated at the panel radius or bevel to eliminate possibility of bending or marring during the unpacking and erection period. Jumper pieces are provided for slipping over the bus at the panel intersections and should be put in place after the equipment has been reassembled.

## Card Holders and Nameplates

Westinghouse switchboards and control desks are equipped with card holders or nameplates for circuit identification if called for in the contract. The former are generally supplied with the simpler equipments. When a switchboard having card holders is ready to be put into service, cards with appropriate legends printed or typed thereon, should be inserted in the holders and pyralin or other transparent material placed in front of the cards to keep them clean.

Black anodized aluminum name plates are generally supplied where something other than card holders is desired. When cut through the hard black film, the white metal is exposed, giving an excellent and permanent contrast to the black surface. If, for some reason, the circuit identification data is not available before the equipment is shipped, to permit factory engraving, it will be necessary for the purchaser to have the

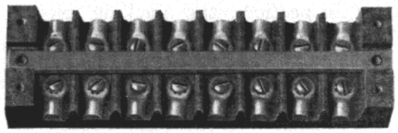


FIG. 23—EIGHT POINT TERMINAL BLOCK.

plates engraved locally when the equipment is being put into service.

Switchboards and control desks have identification nameplates on the rear of each panel or section. In addition to other information, these give the panel position and shop order number which should be given in any correspondence requesting information or ordering renewal parts.

## Erection and Maintenance of Auxiliary Apparatus

**Instruments, Meters And Relays**—Except in unusual instances, switchboards and control desks are shipped with instruments, meters and relays mounted in place. Regardless of how shipped, all instruction books, leaflets, or cards which are sent with the devices

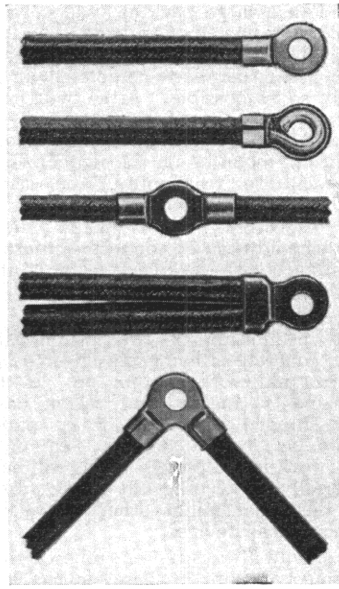


FIG. 24—"END," "STRAIGHT-THROUGH," "RIGHT ANGLE" AND "RETURN" TERMINALS.

should be carefully read before working with them.

Whether the devices are shipped mounted or unmounted, their mechanisms are blocked to prevent movement of parts that might otherwise be damaged in transit. When installing, the instruments, meters and relays should first be inspected for possible damage and then the blocking removed.

When the devices are removed from the panels at the factory for separate shipment, they and their associated resistors or reactors—if any—are packed in small cartons and a number of these

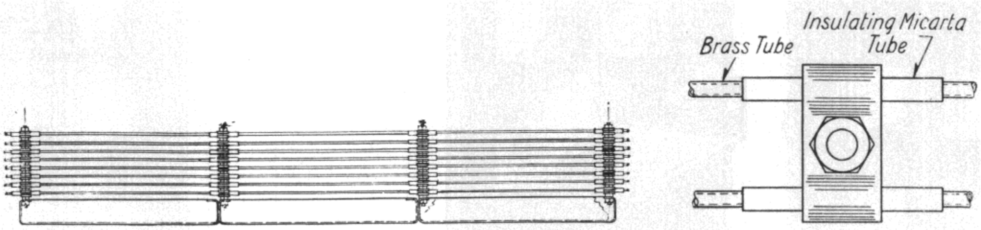



FIG. 25—TUBE BUS MOUNTED ON STEEL PANEL SWITCHBOARD AND DETAIL VIEW OF MOUNTING BRACKET.

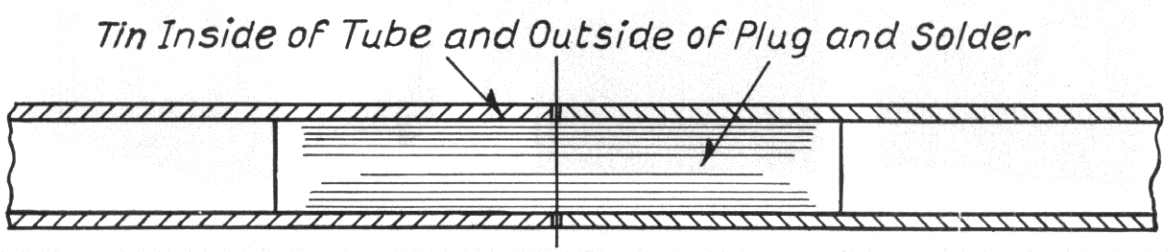



FIG. 26—METHOD OF SPLICING BUS WHEN LONG RUNS ARE REQUIRED.

placed in a large packing case. They should not be removed from their individual cartons until all construction work has either been completed or as nearly so as possible. After being unpacked, they should be inspected for possible damage and if in satisfactory condition, mounted on the switchboard. To facilitate reassembly, the serial numbers of the devices are painted at their respective positions on the panels. They should then be connected in exact accordance with the wiring diagram and the blocking removed.

Occasionally it will be necessary to start installation of the switchboard while concrete is being placed or other construction work is going on. If the instruments, meters and relays have been shipped in place, heavy paper should be wrapped around them until such work is completed. This will help materially in keeping out gritty, abrasive dust that might otherwise be injurious to the devices.

It should always be remembered that the mechanisms of these devices are delicate and that careful handling is required at all times. They should never be jarred or struck in an attempt to free a moving element since a cracked jewel or ruined pivot might result. Sticking is an indication that friction or misalignment is present and this must be properly corrected to prevent further trouble. Adjustments and repairs should be made only by skilled persons familiar with the equipment.

**Voltage Regulators**—Voltage regulators, of which there are several types, require the same care in handling as other instruments. Instructions are available for each type and a copy of those which apply are either shipped with the equipment or mailed separately. They should be referred to for detail information on installation, operation and maintenance. After the regulator is in place on the switchboard, no work should be done or adjustments made on it until the regulator instructions have been read.

The voltage regulator is usually shipped in place on its panel. After the switchboard has been erected, the regulator cover should be removed and the regulator carefully inspected to make sure that no parts have been loosened or damage incurred during shipment. After inspection, the packing pieces, cord, etc. should be removed.

For those installations where the regulator is shipped separately for ultimate mounting on the switchboard by the Purchaser, no attempt should be made to put it in place until the switchboard panels have been erected. When this work has been completed, the regulator should be unpacked, placed on the switchboard and connections completed in accordance with the wiring diagram. The cover should then be removed, the regulator inspected and packing material taken out.

Voltage regulators are equipped with cases which provide effective protection under ordinary conditions. The case should always be in place and closed except when servicing or adjusting the regulator. If construction work has to be done in the switchboard room with the regulator mounted on its panel, it should be covered with heavy paper or otherwise protected as conditions require.

**Knife Switches**—All knife switches are mounted on their panels and the contacts "ground in" at the factory. They should be inspected by the Purchaser before being put into service to make sure that they have not been bent or distorted when the panels were being unpacked and erected.

Frequent operation of switches is recommended in order to maintain their efficiency since the contact surfaces oxidize quickly when they are not operated. Occasionally, it may be necessary to re-contact switches which have been in operation for a long period or because of some accident, the jaws may have been forced out of alignment. The methods used are shown in Figs. 27 to 32 inclusive.

In case it is necessary to "grind in" the contacts of a switch, vaseline mixed with pumice or scouring powder should be applied to the blade and jaw. The switch should then be operated a sufficient number of times to secure the contact surface desired. Following this, the grinding mixture should be removed and the contact surfaces covered with a thin coat of pure vaseline before putting the switch into service. Emery dust or other hard abrasives should not be used for "grinding in" a switch since the copper will start cutting and the contact surface will be destroyed.

If the jaws of a switch become annealed due to overheating, poor contact will result and they should be replaced immediately with new ones. Annealed jaws may be detected by tapping them with an insulated object when the blade is open. If the jaw rings when tapped, it is not annealed. If a dull, dead sound results, the jaw is annealed.

If a switch should become galled by cause of friction between the copper surfaces, smooth up the contact surfaces and tin either the hinge jaw or

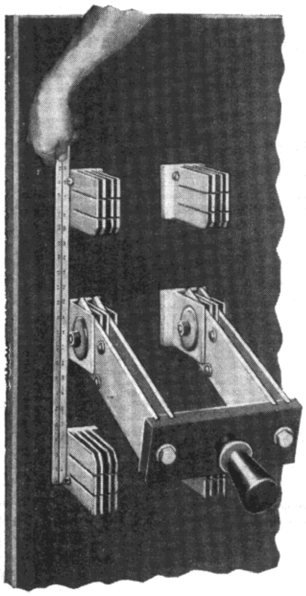


Fig. 27—The Outside Blades of the Hinge and Break Jaws Should First be Checked to See that They are in Line. A Steel Scale Can be Used for this Purpose, First Making Sure the Switch is "Dead."

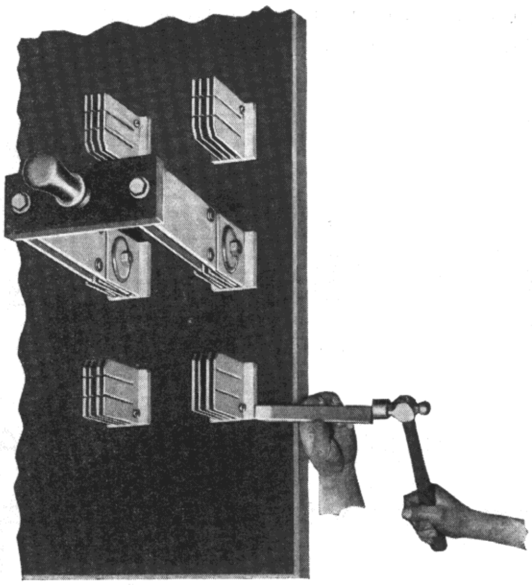


Fig. 28—If the Hinge and Break Jaws are not in Line, They Should be Tapped into Position by Using a Fibre Bar and Machinist Hammer as Shown.

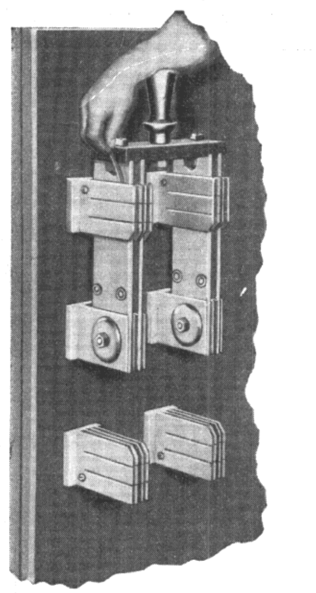


Fig. 29—A One and One Half Thousandth Feeler Gauge is Used to Check the Contact Between Blades and Jaw.

blade. The tinned surface seems to act as a bearing and has eliminated such trouble in many instances.

Plain break knife switches are ordinarily not intended for opening a loaded circuit. Precaution should, therefore, be taken to see that the circuit breaker or starting device in series with the switch is opened first. Knife switches with quick-break attachments can be used for opening loaded circuits up to their normal current rating.

**Type AB "De-ion" Circuit Breakers**—These breakers perform three separate duties when connected in a circuit; mechanical operation of opening and closing, efficient transmittal of current under normal conditions and interruption of the circuit on overload. Conventional switchboard assemblies involving these breakers—see Figs. 33 and 34—are shipped with them in place and all possible connections completed. In the switchboard shown in these figures, the type AB breakers are mounted behind removable steel panels which are held in place by screws at the top and bottom. When their moulded covers have been taken off, the breakers can be disconnected with a socket wrench and removed from the front without disturbing the bus copper or cables. This can be done with the circuit alive if necessary.

In the equipment shown in Fig. 35, the type AB "De-ion" circuit breakers are mounted in frames which can be readily moved into and out of their cells, the units being equipped with roller bearings to facilitate their movement. There are two main positions for the breaker unit within the cell: (1) "CONNECTED" position and (2) "DISCONNECT" position. In the former, the main and auxiliary contacts of the removable unit are in full engagement with their associated stationary ones. Only the auxiliary contacts are in engagement when the breaker unit is in the "DISCONNECT" position. Space is also available in these constructions for a third position of the circuit breaker at the front of the cell in which neither the main nor auxiliary contacts are in engagement. Detachable covers for the fronts of the cells close the openings whether the breakers are in or out of them.

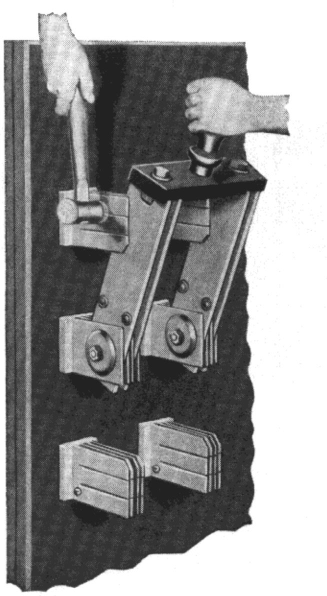


Fig. 30—If There is an Outward Bow in the Jaws, the Switch Blade is Pulled as Far as Possible and the Jaw Straightened by Striking Lightly with a Rawhide Mallet.

Switchgear equipment of this type is shipped with the breaker units removed from their respective cells. To facilitate reassembly, each cell has a number painted on it and the same number is painted on both the breaker unit and the cell cover.

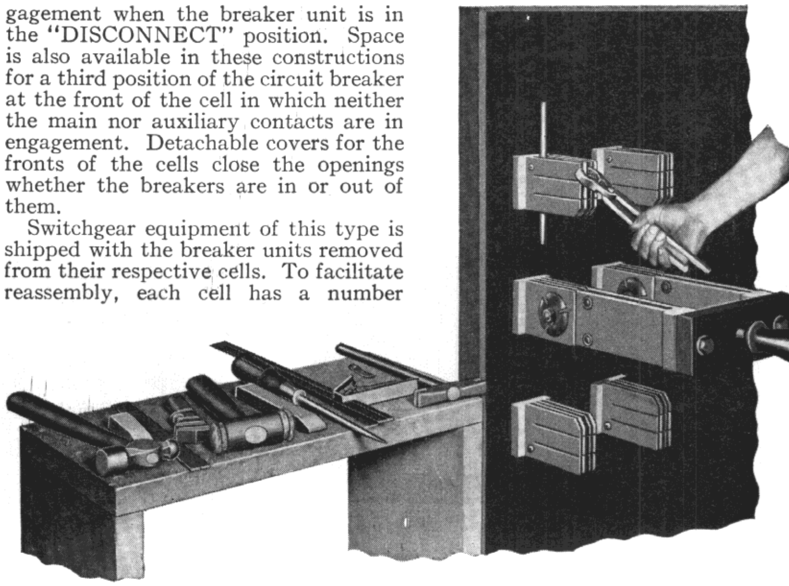


Fig. 31—An Inward Bow in the Jaws Can be Straightened by Inserting a Round Pin Between Them and Squeezing the Ends of the Jaws Together with a Pair of Pliers having Protected Fibre Ends. Note the Tools Used in the Different Operations.

After unpacking a breaker unit, the roller mechanisms on the sides of the frame should be inspected to make sure that they are in good order and free of any foreign mattter that might have gotten on them from the packing. The breaker unit can then be lifted into place at the cell entrance and moved into the "DISCONNECT" position. While here, the breaker should be operated to check its mechanical performance and in the case of a motor operated breaker, to prove the control and indicating circuits. If everything is satisfactory, it can then be advanced to the "CONNECTED" position with the levering device which is provided for this purpose and which should always be used when moving a breaker unit into or out of this position.

Type AB breakers require practically no attention or maintenance. The trip units, after adjustment at the factory, are guarded against unintentional change of calibration by soldering the calibration screws in position. A cover is then put on and sealed. Changes are not likely to be required but if necessary, the complete trip unit should be exchanged for one having the calibration desired. When installing a new trip unit, care must be exercised to see that all screws are tight. If this precaution is not taken, excessive heating may result.

If some part of a breaker operates at too high a temperature, look for a loose or otherwise defective contact between the hot part and its associated current-carrying parts. A loose or oxidized screw or nut at the front or rear of the breaker may account for the heating. A main contact temperature higher than would be permissible for copper brush contacts is not necessarily harmful in type AB circuit breakers since these parts are solid and are made of materials that do not form non-conducting oxides at temperatures that might be detrimental to copper contacts.

**Air Circuit Breakers**—Air circuit breakers are mounted on their panels or bases and thoroughly tested at the factory by experienced workmen. If reasonable care has been exercised in shipment, unpacking and erection of such a switchboard, little initial attention will be required other than to make sure that all packing has been removed and that no parts have been loosened or broken because of rough handling. The breakers do, however, require periodic inspection and servicing, the frequency depending on operating conditions. This should be done in accordance with the breaker instruction book.

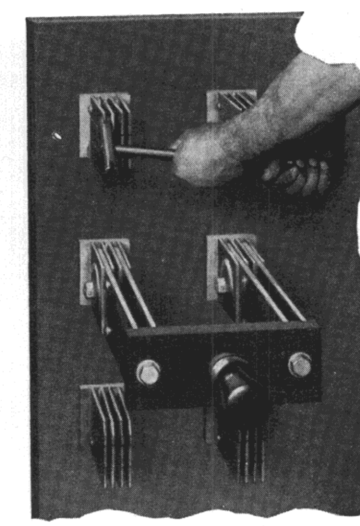


Fig. 32—Jaw Blades that are not Parallel Should be Twisted into Position as Shown.

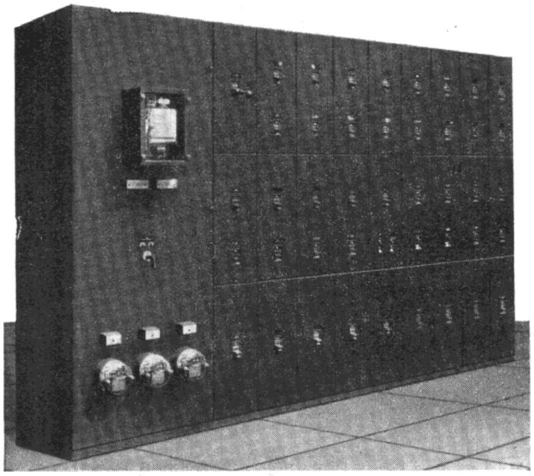


Fig. 33—Dead-Front Distribution Switchboard with Draw Out Main Breaker and Type AB Branch Breakers.

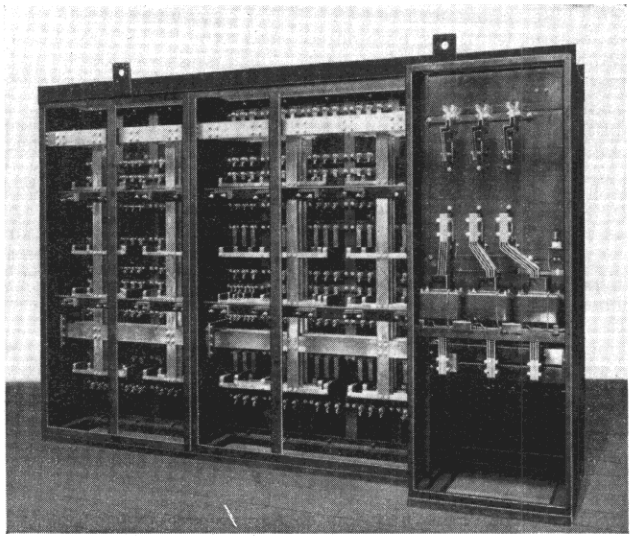


Fig. 34—Rear View of Dead-Front Distribution Switchboard Shown in Fig. 33.

The same will also be true of those switchboard constructions in which the breakers are mounted on fixed bases in the rear. The fronts of the breakers are accessible through openings in the panels which are normally closed by hinged covers.

Air circuit breakers are used in the assembly shown in Fig. 36. They are mounted in frames and placed in cells equipped with hinged front covers, in the same general manner as previously described for type AB "De-ion" breakers. Figs. 37 and 38 are front and rear views respectively of an individual breaker unit.

A rail extension is furnished for attaching to the front of the open cell when a breaker is to be placed therein. The breaker unit, after being unpacked and examined to make sure that it is in good condition, should be lifted on to the rail extension—a chain hoist will be required for the large units—and then rolled by hand into the "DISCONNECT" position. After checking the operation while in this position, it can be advanced to the "CONNECTED" position by the levering device provided for that purpose. This should always be used when moving the breaker into or out of this position.

Barriers must be used with multipole air circuit breakers on circuits over 250 volts d-c. and 480 volts a-c. and sometimes for all voltages over 125 when the poles are placed closer than standard spacing. When required, these will be supplied and shipped in place if their size permits. If too large, they will be removed from the switchboard and packed separately. In such cases, it will be necessary to reassemble them when the switchboard is being erected.

When installing a switchboard on which there are front of board open type air circuit breakers, care must be taken to see that the arcing contacts of the breaker are at least two feet from metal beams or other grounded parts. If conditions are such that this distance can not be maintained, asbestos barriers should

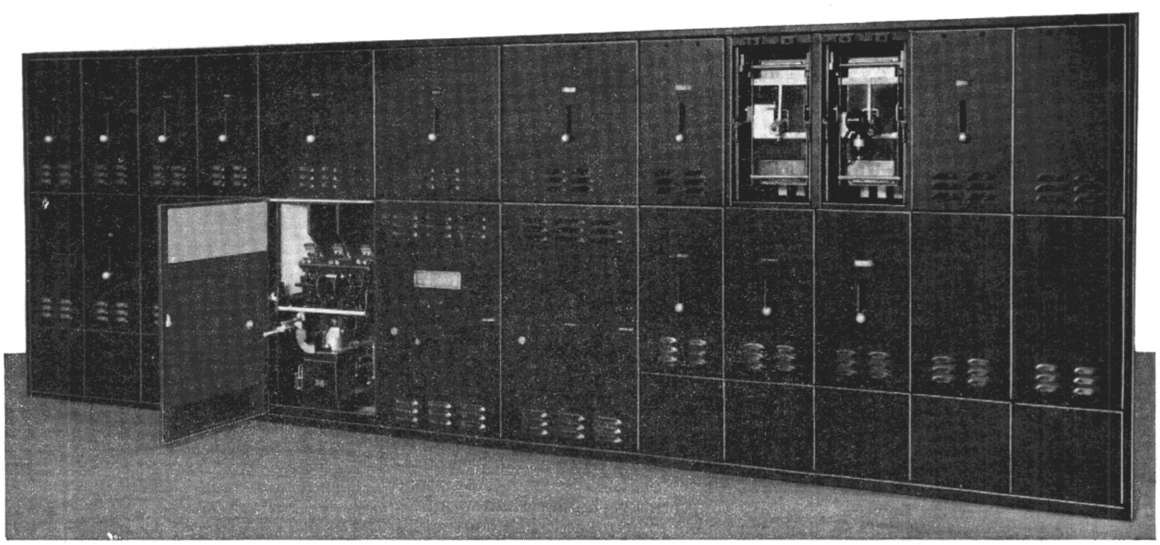


Fig. 35—Front View of Draw-Out Type Metal-Enclosed Air Circuit Breaker Switchgear Assembly.

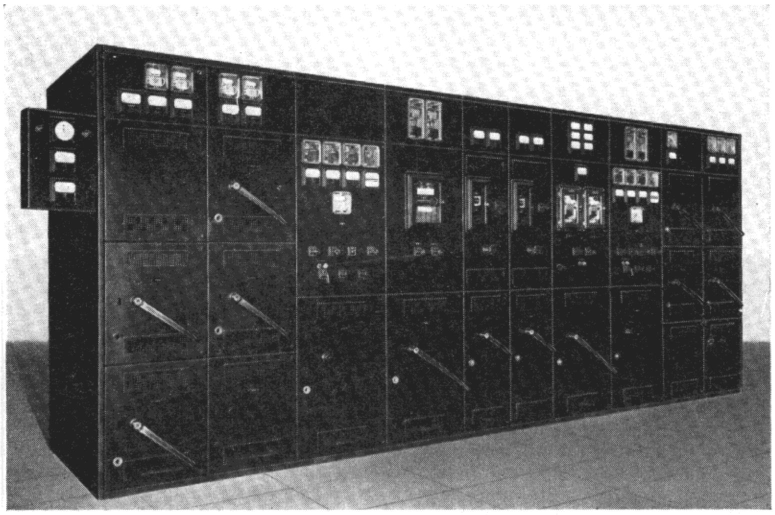


Fig. 36—Front View of Metal Enclosed Switchgear Assembly Housing Draw-Out Type Air Circuit Breakers.

be used to prevent the arc from going to ground when the breaker opens on overload or fault currents. Barriers are provided in the constructions using back of board and draw-out breakers to guard against this condition.

Although the air circuit breaker instruction book should be referred to for detail maintenance information, a few general facts are given here. Copper oxide or sulphide which forms readily on copper contacts in air is a very poor conductor. Consequently, unless a circuit breaker is operated at least once a day, the main copper contacts should be carefully cleaned and polished monthly with fine sandpaper in order to prevent overheating. One which normally carries only a small percentage of its rated current, does not require such frequent attention.

In contrast to copper oxide, silver oxide or sulphide is a comparatively good conductor so that circuit breakers having silver, silver alloy or silver plated main contacts do not require the removal of oxide. As a matter of fact, sand paper should never be applied to silver plated contacts since the useful silver plating would thereby be removed.

While it is true that after the main brush contacts have been properly adjusted, they will remain so indefinitely, occasional inspections should be made to see that all adjusting screws are tight. If any of these screws are found loose, the brush should be carefully examined to make sure that the adjustment has not shifted.

Excessive deposits of dust and dirt in the operating parts of a circuit breaker invariably cause binding of shafts, triggers rollers and pins as well as the operating levers. Care should, therefore, be taken to see that they are kept clean. This is particularly true where the equipment has been installed before the building construction work has been completed. In such instances, the entire structure should be completely covered by a tarpaulin to prevent plaster and like material from falling on the breakers.

Undue heating of an air circuit breaker may result from unfavorable conditions entirely apart from it. Common among these are insufficient lead capacity, poor contact pressure on the adjacent connections or defective cable joints. It is, therefore, essential that not only the breaker itself be inspected periodically but also the adjacent connections to make sure that they too are in good order.

**Oil Circuit Breakers**—Oil circuit breakers can be divided into two general classes: direct control and remote control. The former can be either panel or panel frame mounted and the latter, either manually or electrically operated.

According to the standards of the National Electrical Manufacturers' Association, oil circuit breakers may be mounted on the back of panels on circuits of grounded or ungrounded systems having line voltages up to and including 5000 volts between lines. Also panel or panel frame mounted breakers shall be limited to 2000 amperes, continuous rating, 5000 Kv-a. interrupting rating and below. Although manually or electrically operated remote control breakers are often used where the current, voltage and interrupting ratings are within the specified limits, they should be used where they are exceeded.

Regardless of the form of mounting or method of operation, all oil circuit breakers are completely assembled with their operating mechanisms and aux-

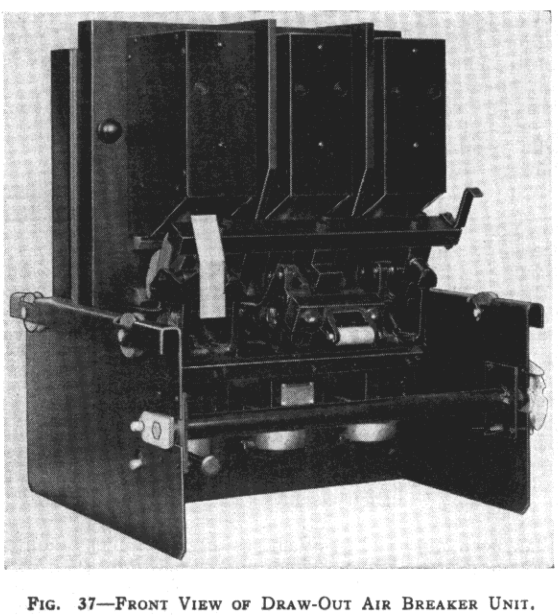


Fig. 37—Front View of Draw-Out Air Breaker Unit.

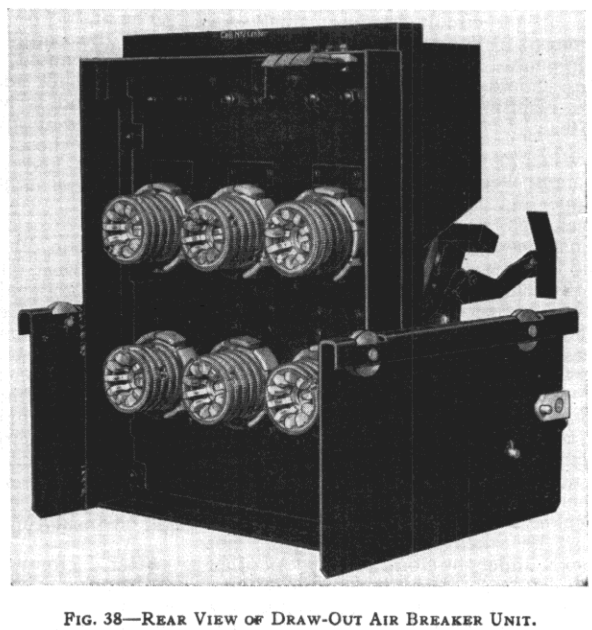


Fig. 38—Rear View of Draw-Out Air Breaker Unit.

iliaries and thoroughly tested before being shipped from the factory. Direct control breakers are usually shipped completely assembled on their panels. The only exception is where a large breaker is mounted on a slate panel which might break in shipment because of strains imposed on it by the circuit breaker. The coverplates of all manually operated remote control breakers are shipped in place on the switchboard.

It is impossible to give complete rules here for the installation of each type of oil circuit breaker. The instructions sent with the equipment should be carefully studied and followed in order to secure the best results. However, a few general instructions which should be considered in connection with their installation and maintenance, are given in the following:

Oil circuit breakers should be located in a clean, dry place free from the destructive action of acids, alkalies or gases, and where good ventilation can be secured They should be readily accessible for cleaning and inspection. Sufficient space must be provided for easy removal of the oil tanks.

Care should be used in unpacking so that the insulators and small mechanical parts will not be damaged or broken. The packing material should be removed and a careful inspection made to make sure that no damage has been incurred during shipment and that all the details are in good operating condition.

The bushings must not be allowed to strike against the panel, framework or other objects when breakers are being placed. Bushings are often broken, cracked or loosened in their supports by unnecessary jars due to careless handling. Where heavy bushings have to be mounted in position by the Purchaser, a rope sling will be found convenient for handling them.

Care must be exercised when remounting an oil circuit breaker which was removed from a slate panel for separate shipment. The supporting bolts and nuts should not be overtightened since the resulting strain might crack the slate.

When mounting a remote mechanically controlled breaker unit on a wall or supporting frame work, it should be leveled as accurately as possible. After it has been put in place, the coverplate and breaker unit should be connected with bell cranks and operating rods. Three-quarter inch pipe—extra strong for light and double extra strong for heavy breakers—is used for the latter. Any length of pipe exceeding twelve feet should have an intermediate support. The operating rods should all be in tension when closing the breaker to secure the best results. This, however, is not always possible. In applications where the operating rod next to the breaker must be in compression, care must be taken that this rod does not buckle under the closing effort. All other rods can be arranged to close the breaker under tension. In some breakers the toggle lever can be reversed so that the operating rods will all be in tension. To make these changes, consult the instruction book for the particular breaker.

If a frame mounted oil circuit breaker has been shipped assembled in its framework, it will only be necessary to correctly locate and fasten the frame in position on its foundation. The foundation bolts should be left loose to permit the frame to be properly plumbed and leveled by inserting shims under the floor flanges of the frame if necessary. After this has been done, the bolts should be tightened, securely fastening the circuit breaker frame to its foundation.

Since the proper alignment of links, pins, etc. of the operating mechanism is essential to the satisfactory operation of a circuit breaker, these should be carefully checked and the detail instructions followed explicity when installing the equipment. A breaker mechanism should not be operated until it has been thoroughly inspected. An electrically operated breaker should be slowly operated by hand before it is operated electrically. The operation should be observed to see that it is smooth throughout the closing and opening of the breaker, that no binding occurs and that there is no excessive play between parts. Before attempting to bend or force parts together, the instructions should be referred to, to see if they have been followed. Considerable time and trouble can be saved by avoiding too hasty action.

The larger types of oil circuit breakers are provided with vents or mufflers to relieve internal pressure built up within the breaker during short circuit interruption and also to vent inflammable gases and retain the oil. They are equipped with a top outlet for installations where it is desired to pipe the exhaust upward into a common header for conducting the gases from the structure.

The frame of an oil circuit breaker should be permanently grounded. A good, permanent, low resistance ground is essential for adequate protection. A poor ground is worse than no ground at all since it gives a false feeling of safety to those working around the equipment and also might result in ultimate loss of life or damage to the apparatus.

Before the oil circuit breaker tanks are filled with oil, all accessories such as gauges and valves must be in place and oil tight. Generally these will require no attention since the equipment is shipped with them in place. If leaks should develop, they can usually be stopped by filling the threads with shellac or Westinghouse No. 672 cement. After making sure that the tanks are free from debris and moisture, they should be filled with oil of the proper grade as described in detail in the Section on Insulating Oil.

After a circuit breaker has been put into service it must have regular, systematic inspection and care. The following require specific attention:

(1) Disconnect the breaker and its operating mechanism from the power and control circuits before inspecting or repairing.

(2) Make sure that the frame is well grounded.

(3) Keep the mechanism clear.

(4) Inspect the operating mechanism periodically to make sure that all parts work smoothly.

(5) See that the bolts, nuts, washers, cotter pins and all connections are in place and tight.

(6) Examine the contacts frequently, making sure that they are aligned and that contact surfaces bear with firm, uniform pressure. Replace badly pitted contacts before they are burned away sufficiently to cause damage to other parts of the apparatus.

(7) Inspect the bushing supports as the vibration incident to the operation of the breaker may cause the bushings to move slightly and result in misalignment of the contacts.

(8) Clean the bushings at regular intervals where abnormal conditions prevail, such as salt deposits, cement dust or acid fumes, to avoid flashovers as a result of the accumulation of foreign substances on their surfaces.

(9) See that the proper dielectric strength of the oil is maintained and that it is kept at the proper level, adding new oil as may be required to replace that lost by evaporation or other causes.

(10) Filter the oil after successive openings under short circuit if it shows signs of carbonization, or if the dielectric strength is lowered because of dirt or suspended matter therein. Carbonization is indicated by a black, flaky precipitate which floats in the oil when disturbed. Test the oil before replacing it in the tank.

(11) Where the service is severe, change or filter the oil every six months or oftener.

(12) Do not allow moisture to come in contact with the oil when filtering.

(13) Remove all oil once a year and thoroughly clean the tanks and other parts.

**Control And Instrument Switches**—Conventional switchboards and control desks are equipped with type W control and instrument switches. The former are for operating the remote electrically controlled devices and the latter for connecting the various instruments to their circuits.

Fig. 39 shows three switches mounted on a panel and illustrates their dial plates and handles. The pistol grip and notched handles are standard for control

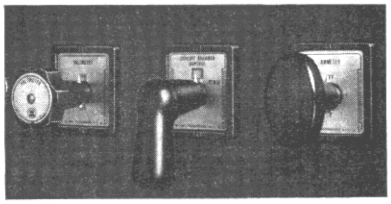


Fig. 39—Type W Control and Instrument Switches.

and instrument switches respectively. However, any of the switches can be provided with a pistol grip, notched or oval handle.

Sheet micarta side plates slide in grooves in the top and bottom of the switch, snapping snugly into the closed position. These keep out dirt and provide easy access for inspection of the contacts.

Type W circuit breaker control switches, as illustrated in Fig. 40, have a mechanical indicating device which indicates the last manual operation of the

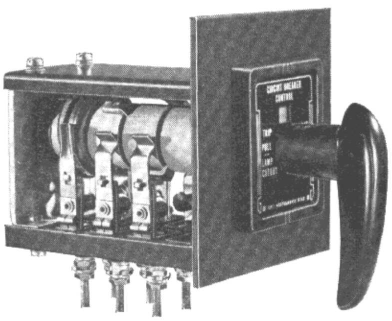


Fig. 40—Type W Circuit Breaker Control Switch with Side Plates Removed.

switch. After tripping the breaker, the switch handle can be pulled out while in the "TRIP" position and latched into place, thus opening both the trip and indicating lamp circuits. This feature not only reduces the load on the control battery but also provides means for differentiating between automatic and manual operation of circuit breakers since the only green lamps lighted on the switchboard will be those which indicate automatic operation and therefore require the operator's attention.

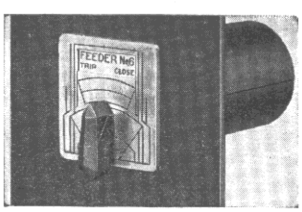


Fig. 41—Front View of Minatrol.

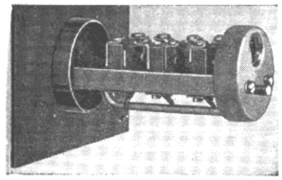


Fig. 42—Rear View of Minatrol with Cover Removed.

Most type W instrument switches have removable keys. These keys besides being labeled, are so constructed that they can be inserted only in the proper switch and can be withdrawn only when the switch is in the off position. This precludes the possibility of trouble when several independent circuits are connected to the same instrument through similar switches. If only one key is used, only one switch can be operated at a time. A key from any dissimilar switch can not be inserted.

In order to economize space, miniature control switchboards and desks are equipped with Minatrols—see Figs. 41 and 42—rather than type W switches. This is a compact control or synchronizing switch having smaller dimensions than the conventional ones. Type W switches are equipped with Minatrol face plates and handles where other forms of instrument switches are required for matching Minatrols in a switchboard assembly.

Since all control and instrument switches are mounted and wired at the factory, they require very little attention when the switching equipment is being installed. Before being put in service, the covers should be removed and the

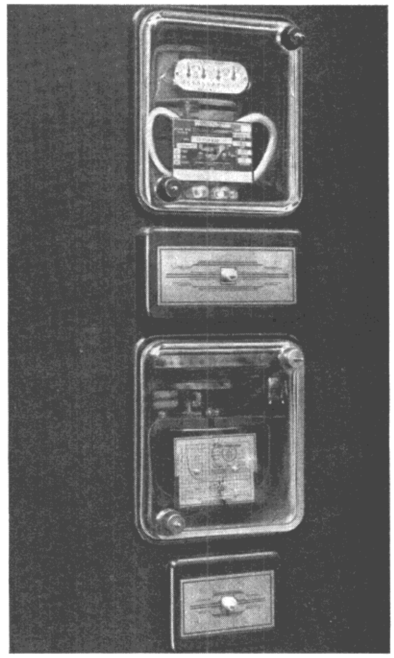


Fig. 43—Type M Test Switches Mounted on Panel.

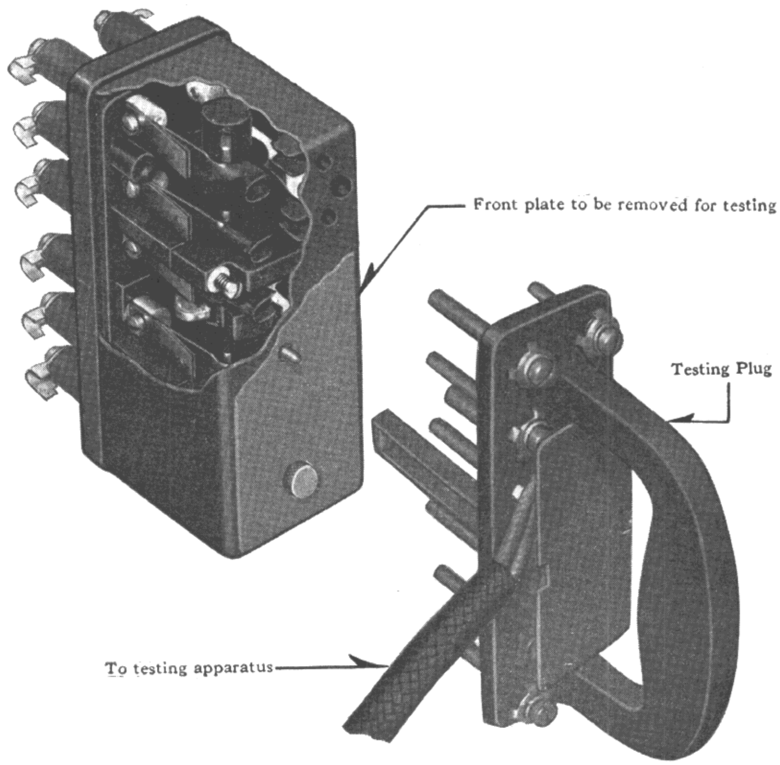



Fig. 44—Type M Test Switch and Plug for Separate Source Testing.

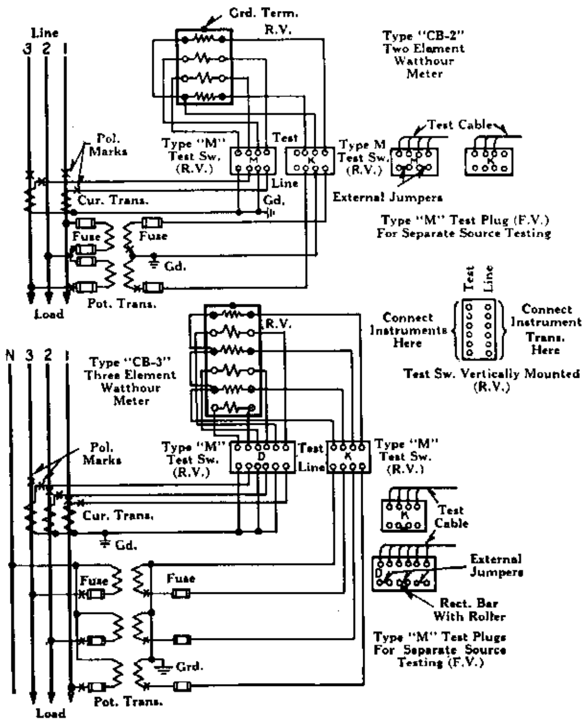



Fig. 45—Connections for Testing and Calibrating Type CB-2 and Type CB-3 Watthour Meters with Type M Test Switches and "Separate Source" Test Plugs.

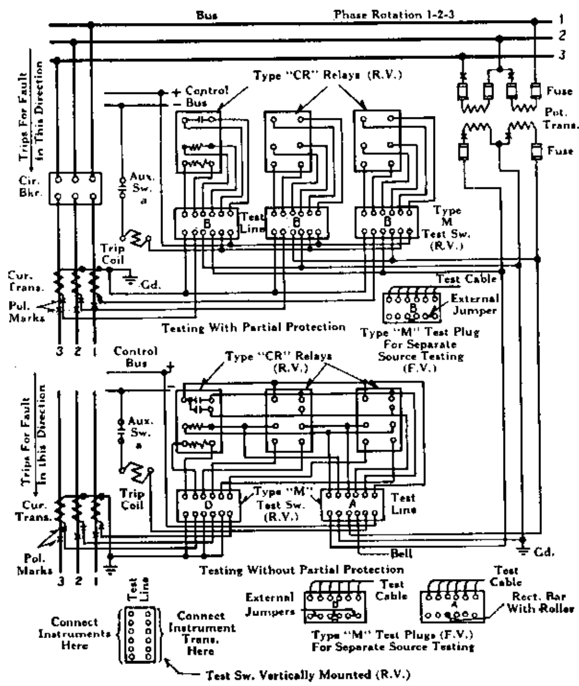



Fig. 47—Connections for Type CR Relays with Type M Test Switches and "Separate Source" Test Plugs.

interior of the switches inspected to see that no packing or other material has gotten inside the case and that all fingers are making contact.

When in service, the switches should be operated with a positive motion. Care should be exercised that instrument switches are moved from one stop position to the next when taking readings. They should not be left at an intermediate point. The switch covers should be removed occasionally, and the contacts inspected to make sure that they are in good order.

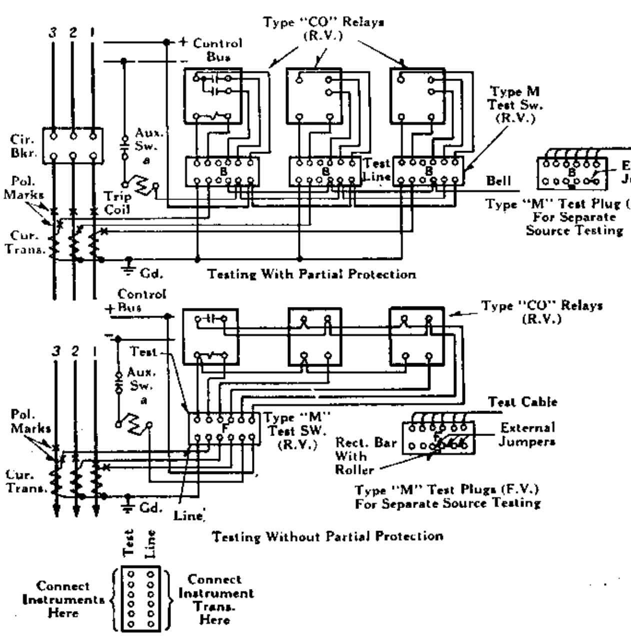



Fig. 46—Connections for Testing Type CO Relays with Type M Test Switches and "Separate Source" Test Plugs.

**Lamp Indicators**—Lamp indicators are connected in the control circuit of electrically-operated circuit breakers to indicate whether the breaker is opened or closed. They are also used to indicate the condition or position of various electrically-operated devices and the continuity of control circuits. The indicators are provided with glass caps of different colors as required for their service.

There are two types of Westinghouse lamp indicators; the standard indicator and the Minalite. The former is an assembly consisting of an 18 volt candelabra screw base lamp and resistor. The ohmic value of the latter depends on the voltage of the circuit on which they are to be applied, units being available for 25, 50, 125 and 250 volt service. The standard indicators are used in switchboard assemblies with type W control switches and for all general applications.

The Minalite is a small size switchboard lamp indicator developed especially for miniature steel switchboards. They are regularly used with Minatrols and other applications where a small indicator is required. The usual Minalite assembly includes a 55 volt slide base bulb and suitable resistor for the service voltage involved. However, designs are available for control circuits of 12.5 to 250 volts with a series resistor or on control circuits of 12.5 to 50 volts without a resistor.

Since lamp indicators are mounted on the switchboard and completely wired at the factory, they require no attention when the equipment is received

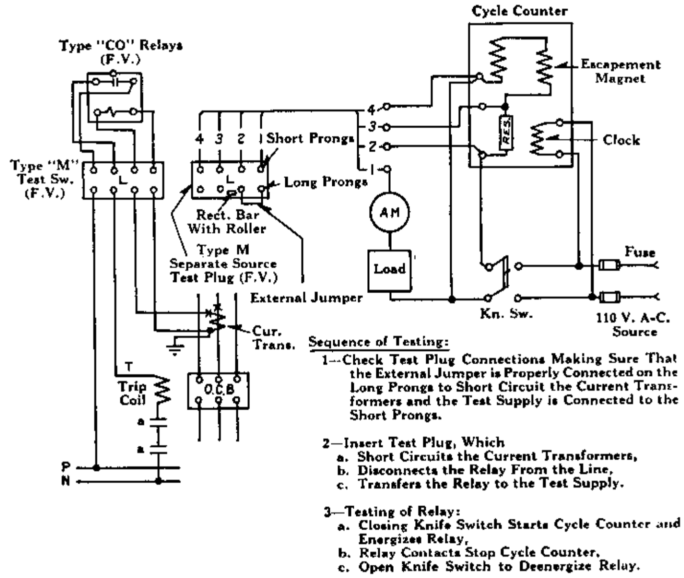



FIG. 48—TYPICAL TESTING CONNECTIONS FOR TYPE CO RELAY USING TYPE "M" TEST SWITCH AND "SEPARATE SOURCE" TEST PLUG.

other than to make sure that they have not been damaged during shipment and that the lamps are making good contact.

The bulbs will have to be replaced at the end of their useful lives. This can be done by first unscrewing the glass cap and then the bulb if it is a standard indicator or pulling the bulb out if it is a Minalite. The lamp extractor furnished with the equipment should be used when changing the lamp in the latter. No special precaution is necessary when replacing bulbs in the standard indicators since the type used is common for all applications. This is not the case with Minalites and it is, therefore, extremely important that replacements be made with lamps which have the same characteristics as those shipped with the switchboard.

**Test Switches**—Switchboards and control desks are equipped with type M test switches, as illustrated in Figs. 43 and 44, when called for in the contract. These are modern devices for multi-circuit testing of instruments, meters and relays by any conventional system. They are furnished with four or six independent single-pole circuits which can be used for current, potential or trip circuits. Figs. 45, 46 and 47 show typical connections.

The use of these test switches eliminates the hazard of accidentally tripping the circuit interrupting device when making test connections since no wiring changes are made on the board. Instruments and meters can be checked and calibrated against portable standards connected in series with the instrument or meter being tested under service conditions or by means of a phantom load.

Relays can be tested without removing protection from any phase except the one undergoing test. When required, spare relays can be substituted while the test is being made. Relays are generally tested by the use of a phantom load or loading transformer and cycle counter.

Two types of plugs—one for "SEPARATE SOURCE" testing and the other for "SERIES" testing—are available for type M test switches. The former provides for short circuiting the current transformer secondaries and "break before make" action for cutting in separate sources of energy. The "SERIES" test plug is used where a calibrating instrument or meter is to be connected in series with the equipment to be tested. It provides "make before break" transfer of current transformer circuits. "SEPARATE SOURCE" test plugs are regularly furnished with switchboard and control desk assemblies unless it is definitely known that the series method of testing is to be used.

The two types of plugs can be readily identified by either referring to the label on the plug, or examining the plug contacts or prongs. Those for the "SEPARATE SOURCE" test plug are of unequal length, and for the "SERIES" test plug, the same length. Extreme care must be used to see that the type of plug being used is suitable for the test scheme since a separate source plug cannot be used for the series method or vice versa.

Both types of plugs have a keyed guide and an operating arm so that they can be inserted only in the proper position. The operating arm is slotted and carries on its end a roller which engages the actuating cam on the rotor of the test switch. Multi-conductor cable connected to the terminals on the handle side should be used between the plug and the test equipment.

Any number of circuits can be tested in rapid succession since one plug can be connected and checked for all devices of a particular type which are to be tested. Once the proper connections are made to the plug, the tester simply plugs in, takes readings and proceeds to the next circuit.

The switches are mounted and wired at the factory and require no attention when the equipment is being installed. The plugs are shipped with the required jumper connections, separate plugs being supplied for each testing combination. The switches and their associated plugs are identified by letters A, B, C, etc. on the wiring diagram. Both the switches and plugs have these designating letters painted on them to facilitate identification by the tester.

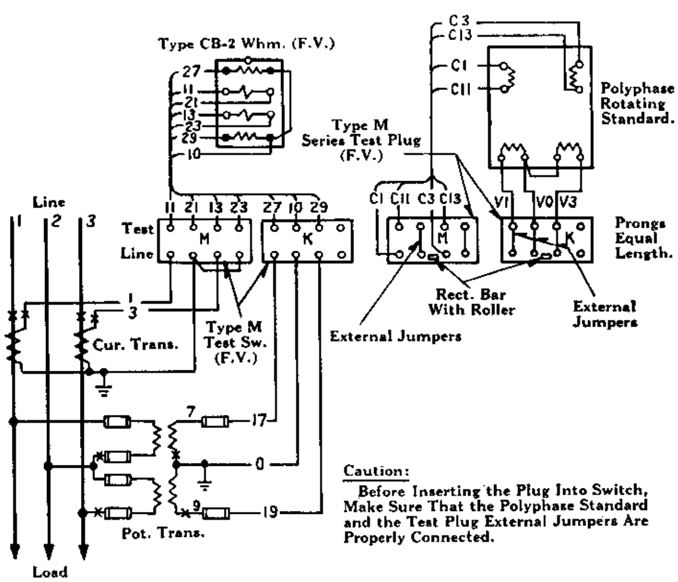



FIG. 49—TYPICAL TESTING CONNECTIONS FOR TYPE CB-2 WATTHOUR METER USING TYPE M TEST SWITCHES AND "SERIES" TEST PLUGS.

After the connections between the plug and testing equipment have been completed, the coverplate should be removed from the test switch, first unscrewing the thumb nut which holds it in place. The plug can then be inserted for the test.

Assuming that a "SEPARATE SOURCE" test plug is being used—see Fig. 48 for typical connections—its contacts, during the first part of their travel, short circuit the current transformers connected to the equipment being tested. As the plug continues its travel, the plug roller engages the actuating cam and turns the rotor. This opens, through the switch, the normal circuits of the equipment being tested. When the complete "in" position is reached, the test contacts of the plug engage the switch contacts connected to the equipment to be tested. Note that the plug should be all the way in for the test, there being no intermediate or inoperative point. In withdrawing the plug, the roller hooks the actuating cam on the opposite side and returns the rotor and circuits to the normal closed or operating position.

The operation when using a "SERIES" test plug—see Fig. 49—although generally the same, differs in that the contacts operate to insert the test equipment in the current transformer circuits before breaking the normal or operating circuits.

On completion of the test, the test switch covers should be put in place and fastened with the thumb screws.

**Field Rheostats**—Field rheostats for generators, motors, etc. are either mounted on the switchboard or apart from it, depending on their size and the available space. Even when mounted apart from it, provision is usually made for their operation at the switchboard either by means of an operating handwheel, cable and sprocket in case they are manually operated or a control switch if motor operated. There are a number of types of rheostat mountings and operating mechanisms available, but all are similar in principle of assembly and operation. Figs. 50 and 51 show an operating mechanism for two remote mounted rheostats and Fig. 52, a combination tetrapod and remote control mechanism.

When of Westinghouse manufacture, it is the usual practice to ship the operating mechanisms and the rheostats—if their size permits—completely assembled on the switchboard panels. This is sometimes impossible since this material is normally included as a part of the machine order and is not always available when the switching equipment is being assembled. However, the panels are always drilled for the rheostat mechanisms except where equipment of other manufacturers is being used and drilling information is not available. Field assembly when required, should be done in accordance with the instructions shipped with the rheostat equipment.

Rheostats can be located in any convenient place where they will have sufficient ventilation and will not transmit heat to other apparatus. Fig. 53 shows a number of typical methods of mounting rheostats apart from panels. Rheostats so mounted are operated by means of a flexible cable which should be run through ⅛" pipe. This pipe is not furnished as a part of the mounting because each installation differs in length of run, number of turns, degree of angles, etc.

The pipe should be smooth inside with ends reamed to prevent abrasion of the cable and should run from the drum housing on the panel to a point not less than 24 inches from the rheostat sprocket. Bends for all angles up to 90° can be made with a radius not less than six inches. If the rheostat and handwheel are considerable distance apart, requiring many bends in the pipe, roller elbows which can be furnished on special order, should be used at each turn instead of bending the pipe. This will eliminate friction between the ceble and pipe with resultant ease in operation.

Westinghouse remote control rheostat operating equipment includes 40 feet of flexible cable, 31 links of sprocket chain and two turnbuckles in addition to the mechanism for mounting on the switchboard panel. When the operating mechanism has been mounted, the midpoint of the cable should be fastened to the drum with the screw and washer provided for that purpose. After wrapping two turns around the drum to fill the groove, the loose ends should be threaded through the pipe and attached to the turnbuckles which should then be fastened to the chain at the rheostat sprocket. The turnbuckles are furnished for making final adjustment and to keep the chain and cable tight. Care must be taken to see that the pointer on the handwheel and the position of the rheostat arm are in agreement and that the rheostat operates properly over its entire range.

Rheostats should be carefully inspected before putting them in service to make sure that no damage has been incurred during shipment and that stationary and moving contacts are clean and making good contact. The mechanism of a motor operated rheostat should be inspected and then operated by hand before attempting to operate it electrically. All rheostat equipment should be inspected at regular intervals when in service to make sure that the contacts and operating mechanisms are in good condition.

**Field Discharge Resistors**—Switching equipments for synchronous a-c. machines generally include provision for disconnecting the fields of the machines which they control. Sometimes this provision is also included in equipments controlling d-c. generators. Discharge resistors must always be used when field circuits are opened.

Except for synchronous motors, it is Westinghouse practice to supply field

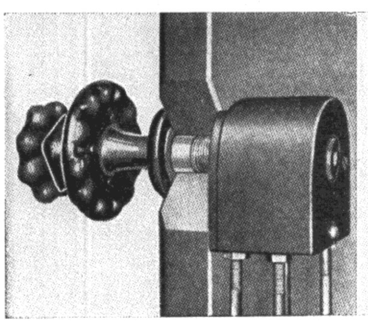


Fig. 50—Double Handwheel Remote Control Rheostat Operating Mechanism with Cover On.

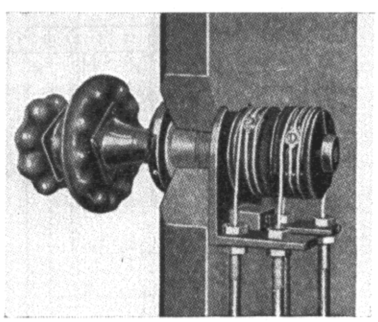


Fig. 51—Double Handwheel Remote Control Rheostat Operating Mechanism with Cover Off.

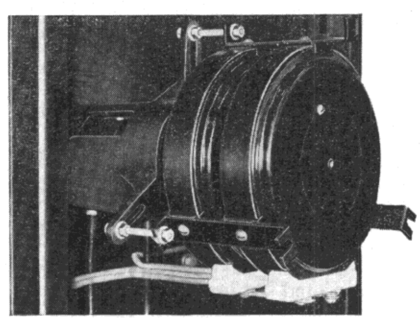
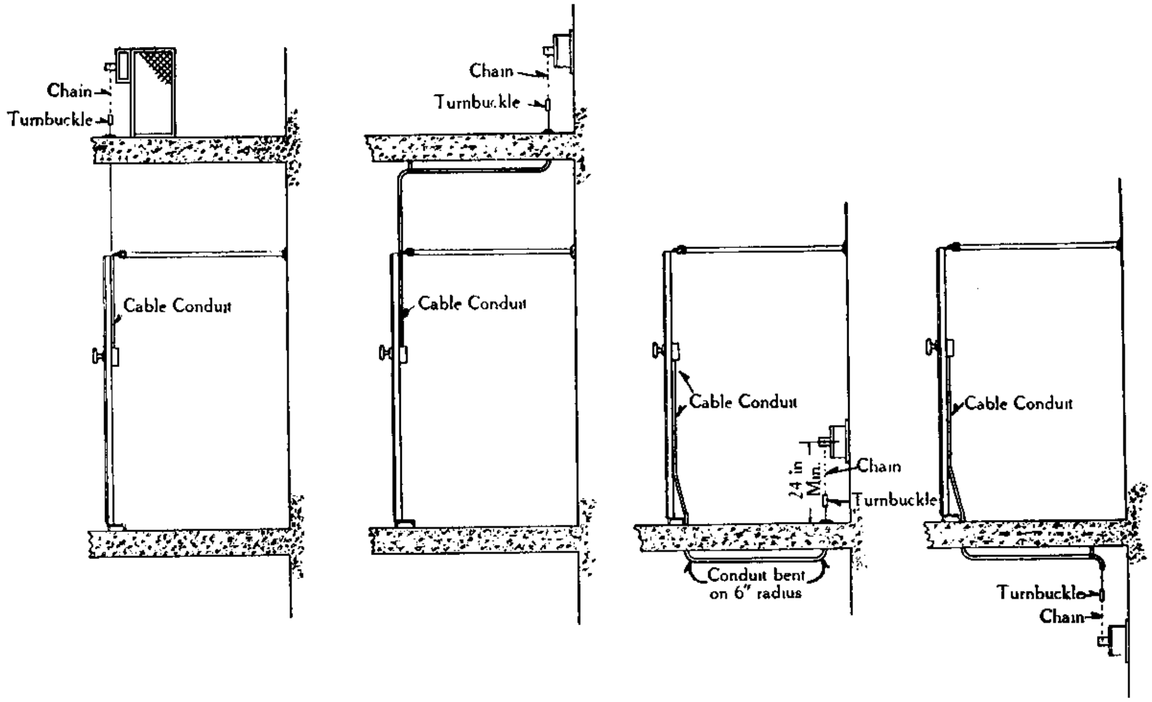


Fig. 52—Combination Tetrapod and Remote Control Mechanism.

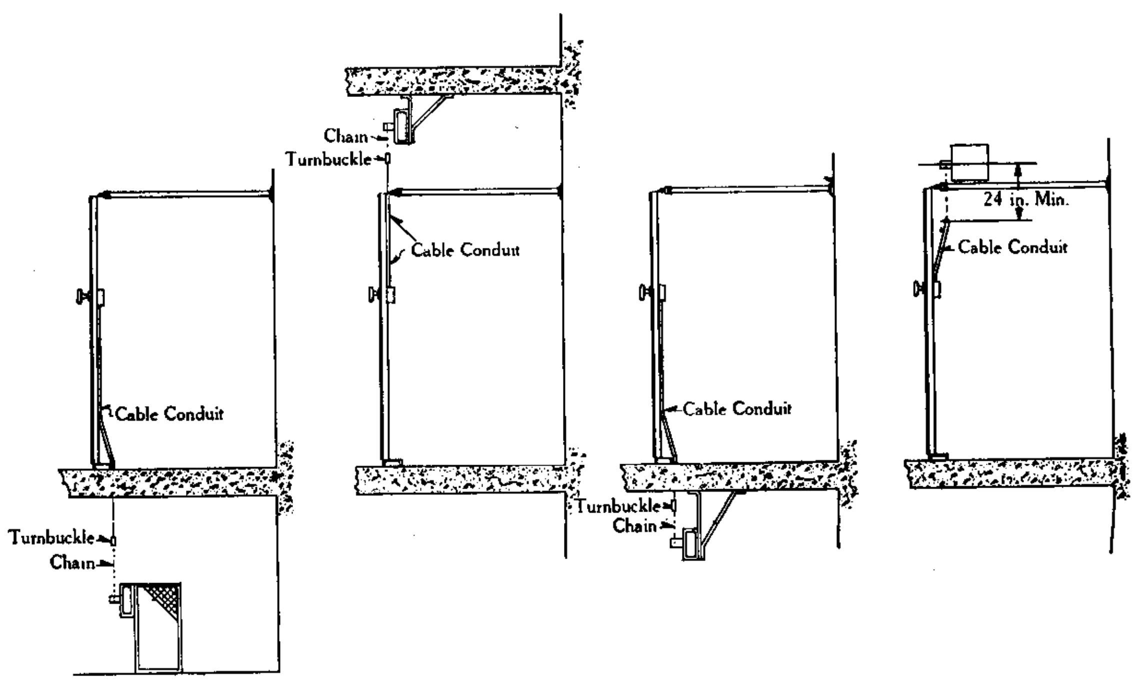



Rheostat on Floor Above Switchboard

Rheostat on Wall Above Switchboard

Rheostat on Wall in Rear of Switchboard

Rheostat on Wall Below Switchboard




Rheostat on Floor Below Switchboard

Rheostat on Ceiling Above Switchboard

Rheostat on Ceiling of Floor Below Switchboard

Rheostat on Wall Brace Above Switchboard

FIG. 53—TYPICAL METHODS OF MOUNTING RHEOSTATS APART FROM PANELS.

discharge resistors when required, as a part of the machine equipment. The resistors for synchronous motors are included in the switching equipment since the type to be used depends on the scheme of control. Occasional exceptions to this will be those instances where the field discharge resistor is included with the motor because of a Purchaser's specific request.

The field discharge resistor when included with the switching equipment, will be mounted on the panel near its associated field switch or circuit breaker and connections made to it if the design permits of this. If not, it will be shipped separately for mounting and wiring at the place of installation. Where possible, this same procedure will be followed in applying resistors which are supplied as a part of Westinghouse machine equipment. When shipped apart from the switchboard, it will be necessary to put them in place and complete the connections. Once installed, they require no further attention.

**Resistors For Instruments And Other Apparatus**—These are shipped in place on the switchboard whenever possible. If any field assembly has to be done, care must be exercised that the serial numbers of the resistors are the same as those of the equipment with which they are used and that they are connected exactly as shown on the wiring diagram.

**Ammeter Shunts**—Shunts are used in conjunction with ammeters for measurement of large direct currents where it is not practical to carry the full current of the circuit through the instrument. They are shipped in place on the switchboard except when because of their size or for some other reason, it is inadvisable to do so. When shipped separately, it will only be necessary to bolt them in place and connect the shunt leads. Care should be taken to avoid buckling or damaging the leaves on the manganin as this may affect the calibration of the shunt.

**Instrument Transformers** — Instrument transformers are used for two reasons: first, to provide protection from contact with high voltage circuits, and second, to permit the use of instruments and other devices with a reasonable amount of insulation and a reasonable current carrying capacity. Their function is to deliver to the devices connected to them, a current and voltage which is always proportional to the primary current and voltage and which does not exceed a safe potential above ground. The secondaries of standard potential and current transformers are designed for 115 volts and 5 amperes respectively. Transformers having special ratings are sometimes required and are supplied when necessary.

Both potential and current transformers may be one of several types depending on whether they are for indoor or outdoor service, the voltage of the installation and particularly with current transformers, the current carrying capacity and degree of accuracy required.

Since they require very little attention after they have been installed, instrument transformers for the higher voltage installations—above 7500 volts—should be located in compartments or mounted overhead in structures where there will be no danger of an attendant coming in contact with them. Those for use in lower voltage installations are mounted either on brackets attached to the switchboard or in the structure behind it. They are shipped in place in the switchgear assembly whenever possible. Where this is not feasible, they will have to be mounted and connected in the field.

The secondary circuits of both potential and current transformers should be grounded as a precaution against danger from the high voltage in case the insulation should break down because of lightning or other abnormal stresses. In polyphase groups, any point of the secondary can be grounded but it is preferable to use a neutral point or a common wire between two transformers. The wiring diagram furnished with the equipment shows the required grounding.

The secondary circuit of a current transformer should never be opened while the primary is carrying current. If it is necessary to disconnect instruments, meters, etc., the secondary should first be short circuited. If the secondary circuit is opened, a difference of potential is developed between terminals. The voltage may be high enough to endanger the life of a workman or cause a break down of the transformer insulation. In addition to this, the magnetic condition of the transformer core may be permanently changed, impairing the accuracy of the transformer.

When connecting instrument transformers, it is necessary to know the relative instantaneous direction of currents in the leads. For this reason, one primary and one secondary lead of the transformer are provided with a white polarity marker. The relation of the marked leads is such that the instantaneous direction of the current in them is the same; that is, toward the transformer in the marked primary lead and from the transformer in the marked secondary lead, or vice versa. The arrows in Fig. 54 show the relative instantaneous direction of currents in instrument transformers.

The high voltage and low voltage leads issue from opposite ends or sides of potential transformers and the letters H.V. and L.V., indicating the voltage of the windings, are marked on the transformers adjacent to the leads. Care must be taken to connect the high voltage leads to the line, as a dangerous voltage will be produced if the windings are reversed.

It is practically impossible to protect a potential transformer against overload with primary fuses, for the reason that any fuse wire small enough and long enough to open the transformer circuit with certainty during an overload would be mechanically too frail to be handled. It is, however, desirable to protect them against secondary short circuits and internal faults. This can be done with either type BA or type BAP fuses. Current limiting resistors should be used in series with the fuses when the short circuit capacity of the station or power source exceeds the interrupting capacity of the fuses. When the short circuit capacity of the system is unknown, it is recommended that resistors be used when the connected capacity is in ex-

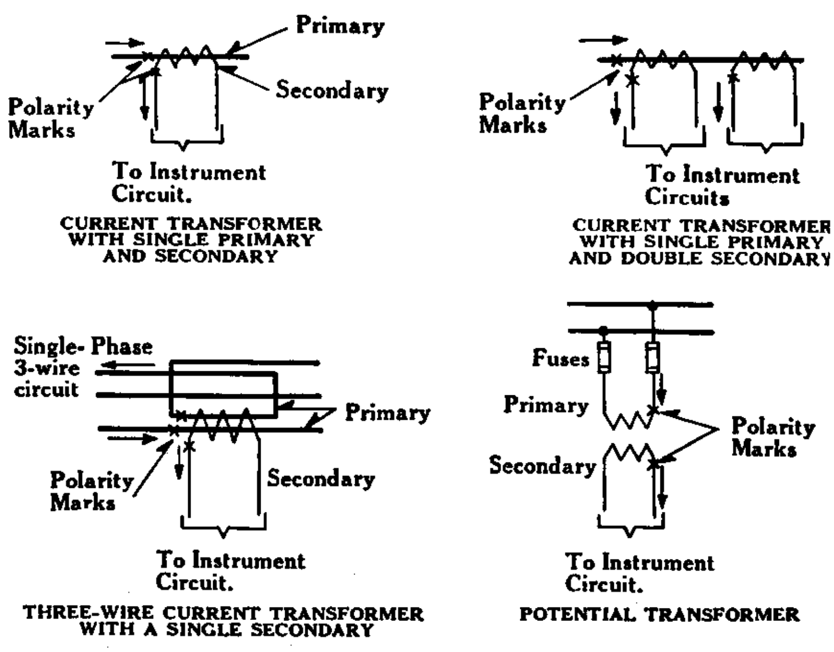



Fig. 54—Symbols for Current and Potential Transformers. The Small Arrows Indicate Relative Instantaneous Direction of Current in the Primary and Secondary Leads.

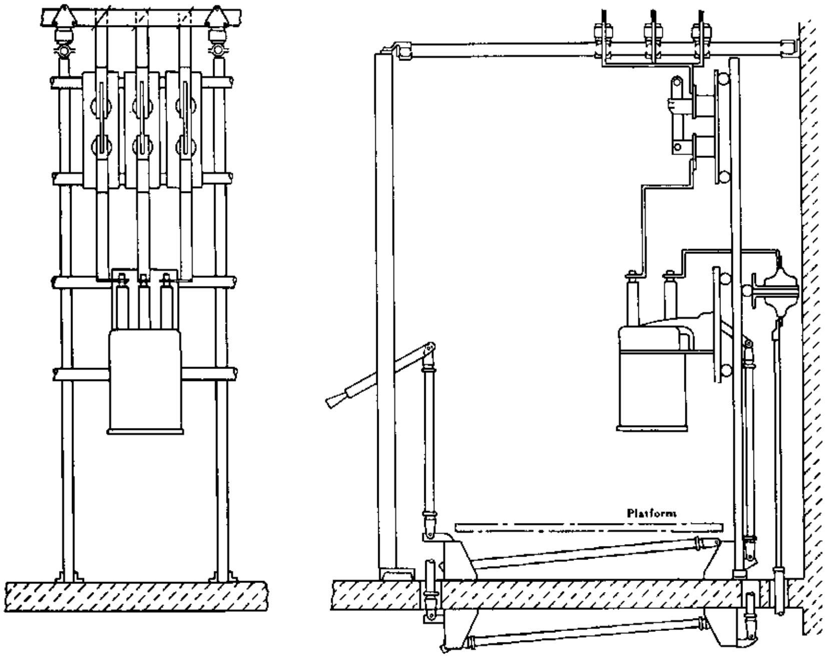



Fig. 55—Typical Arrangement of a Single Bus System Using a Manually Operated Oil Circuit Breaker with Disconnecting Switches Between Bus and Breaker. Platform Recommended When Bell Cranks are Mounted Above Floor.

cess of 2000 kv-a. The resistors limit the short circuit current to a value which the fuses can interrupt. In normal operation, the resistors carry only the very small primary current of the transformers and the resulting drop in voltage is inappreciable.

**Disconnecting Switches**—Disconnecting switches are used primarily for isolating apparatus from the circuit for purposes of inspection and maintenance. They may be single-pole hook stick operated, either in single or double-throw form, or as a double-throw selector switch and in three-pole, single throw, remote control form. Selector type disconnecting switches permit the transfer without interrupting the circuit. Remote control switches are usually group operated and may be either manually or motor operated.

Disconnecting switches should be located at such a height or be guarded so that it will not be possible for any person to accidentally come in contact with them. The arrangement should, however, allow for easy manipulation without requiring hook sticks of excessive length. They should be located so that gravity will tend to open them, carefully lined up and rigidly supported. Excessive strains imposed by connecting leads should be carried by auxiliary supports.

All disconnecting switch jaws and blades are aligned on their bases at the factory. If the switch base is bolted to an uneven wall or surface, it may deflect, causing misalignment of the jaw and blade. It is frequently necessary to use washers or spacers when mounting them on uneven surfaces in order to obtain proper alignment.

Disconnecting switches, unless specially designed, are not intended to be opened under load and extreme care should be used to guard against this possibility. Unless there is some form of interlock between the disconnecting switches and their associated circuit breaker, it is often desirable to place warning signs in prominent positions to emphasize this.

The instructions given for maintenance of knife switches also apply to disconnecting switches. They should be operated from time to time to prevent excessive oxidization of their contacts. Misalignment should be corrected in the manner outlined for knife switches.

**Hook Sticks**—A hook stick is supplied with switching equipment requiring one. A definite, dry, clean place should be provided for keeping it. Before using a hook stick, it should be inspected to see that it is perfectly clean. If it is provided with a grounding clamp and chain, make sure that the chain is well grounded. Rubber gloves should be worn when using hook sticks.

**Bus and Cable Supports**—The proper selection of bus supports to withstand short-circuit stresses is a matter of extreme importance. While a great many articles have been written on the subject, they have not considered many of the important factors. The methods of calculations outlined in the National Electrical Manufacturers Association's "Power Switchboard Standards—Publication No. 37-39" have been carefully checked and will give accurate results. This publication should be referred to for detailed information on this subject. The Company should also be consulted freely in connection with actual problems.

Westinghouse bus and cable supports are available for all applications and are supplied when called for in the contract. They are carefully inspected and tested before being shipped from the factory. When received in the field they should be unpacked and inspected to make sure that they have not been damaged in shipment. Obviously, careful handling will be necessary when unpacking and placing them in their ultimate location. They should be cleaned both before and after being put in service. The frequency of the latter will depend on the atmospheric conditions where they are installed.

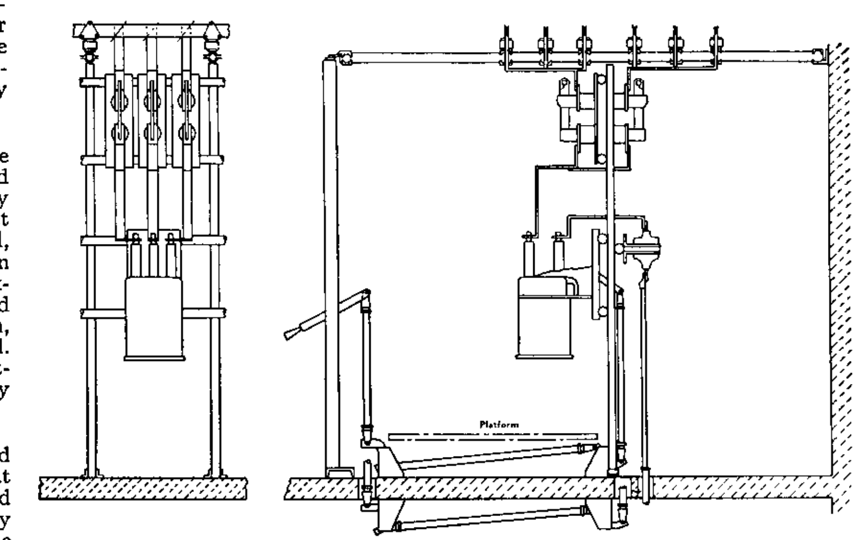



Fig. 56—Double Bus System with Disconnecting Switches Between Buses and Breaker Platform Recommended When Bell Cranks are Mounted Above Floor.

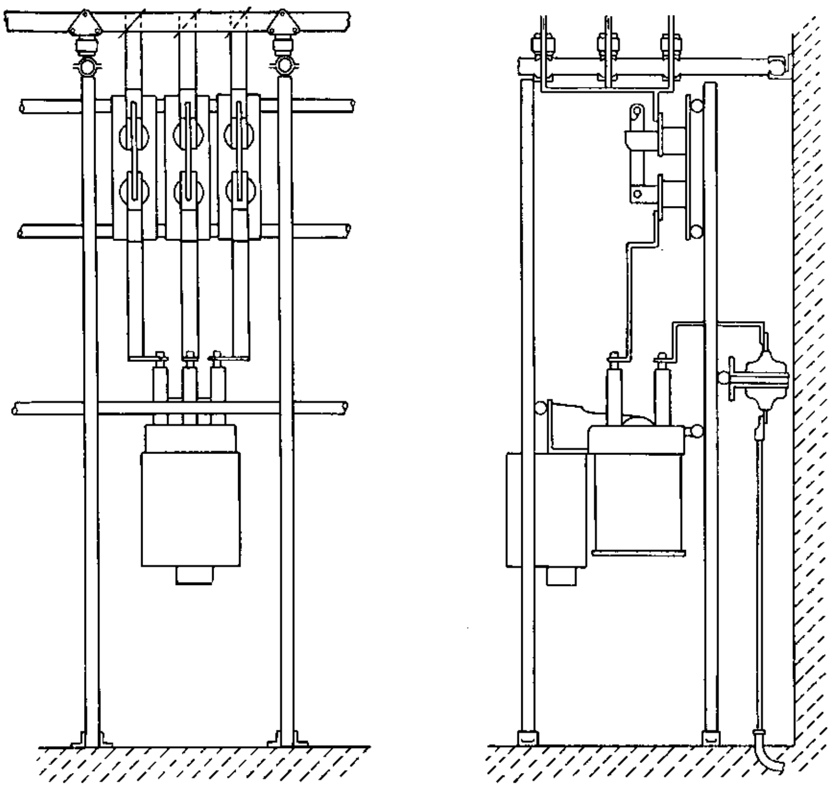


FIG. 57—SINGLE BUS SYSTEM USING AN ELECTRICALLY OPERATED OIL CIRCUIT BREAKER WITH DISCONNECTING SWITCHES BETWEEN BUS AND BREAKER.

## Structures

**General**—Oil circuit breakers, instrument transformers, etc., when not mounted on the back of the switchboard, are generally located in a structure either in its rear or on a different floor level. The structure may be of pipe or structural steel shapes.

The structure location with reference to the panels on which the operating handles of manually operated circuit breakers are located, should be such that the length of the operating rods, number of bell cranks and unsupported pipes will be a minimum.

Structures should be designed so that when assembled, there will be no chance for any movement incident to the operation of the oil circuit breakers. Such movement might transfer stresses to the adjacent connections and disarrange adjustments between the breaker and operating handle on the panel.

In heavy capacity installations, care must be taken that the supporting structure does not form a complete magnetic circuit around heavy current carrying conductors.

Structures are not fabricated and assembled at the factory unless specifically called for in the contract. When not assembled, the framework and circuit breaker supports, wire, rods, tubes and bars for connections, buses and similar material requiring assembly and fitting during installation, will not be fabricated at the factory, but will be furnished in bulk, in commercial lengths, with fittings necessary for complete assembly.

**Pipe Frame Structures**—Steel pipe has long been recognized as a convenient material for structural work, particularly in connection with both indoor and outdoor electrical installations.

Pipe is light compared to its strength, has a symmetrical cross section which resists bending equally well in any direction and can be cut easily and rapidly with inexpensive tools by inexperienced workmen. In addition to this it is available in a well graded series of sizes and can be obtained anywhere in convenient lengths with either black or galvanized finish. For these reasons, most of the structures are made of 1¼″ pipe clamped together with threadless fittings. Figs. 55, 56 and 57 show typical pipe structures mounting oil circuit breakers, disconnecting switches and current transformers.

Westinghouse fittings as illustrated in Fig. 58 are used in pipe structure assemblies. They are fully described and style numbers are listed in Catalog Section 37-400, a copy of which will be furnished on request. The line of fittings is unusually complete and flexible, it being possible to make a large variety of typical structures with the use of only seven different types of fittings. They are made of the highest grade of malleable iron commercially obtainable. These fittings use yokes and carriage bolts for clamping so that a considerable area of contact with the pipe is secured. As the fittings are bolted up they yield slightly due to the malleable characteristics of the metal until they fit the pipe perfectly.

The square shank under the head of the carriage bolt fits into the square hole in the fitting. Since this prevents the bolt from turning, the assembly is readily accomplished with a single wrench. Hexagonal nuts are used for further convenience in assembly.

The fittings are furnished with either a black-gloss baked finish for indoor use, or galvanized for use in outdoor installations. All carriage bolts for both indoor and outdoor fittings are hot dipped galvanized.

Although designed primarily for electrical installations Westinghouse pipe fittings are by no means so restricted in their application. They will be found economical and convenient for the construction of racks, railings, frames, fences, etc.

Pipe structures which have been erected at the factory are generally disassembled for shipment. They can, however, be forwarded with all material in place when transportation and handling facilities permit. When shipped disassembled, the various parts of the structure have identification numbers corresponding to the item numbers in the bill of material on the assembly drawing. The equipment should be reassembled in accordance with the drawings which apply. The structure members should be put in place first and securely fastened with the fittings, making sure that they are accurately plumbed and leveled. Following this, the bus supports, disconnecting switches, circuit breakers, etc. can be mounted in their proper locations.

Pipe plugs as shown in Fig. 60 are furnished with all pipe structures. They should be inserted in the ends of the pipe to improve the general appearance and in the case of outdoor structures, to prevent collection of moisture in the pipes. A few blows on the face of the plug with a machinist's hammer is all that is necessary to drive them into place.

**Steel Structures**—Structures made from standard steel shapes which are cut to size and welded in the desired combinations, are frequently used. They can be built in sections for shipment in units as necessitated by transportation and handling facilities. Being completely factory built and tested, the installation time and cost are greatly reduced. The equipment shown in Figs. 64 and 64-A was shipped and installed completely assembled.

**Wall Mounted Equipment** — Sometimes the oil circuit breakers and disconnecting switches are mounted on the wall behind the switchboard, the buses being supported on the wall braces. Where the walls are of concrete, extreme care must be used in placing the anchor bolts or they will not register with the mounting bolt holes of the apparatus. If they do not fit, it is necessary to file the mounting bolt holes.

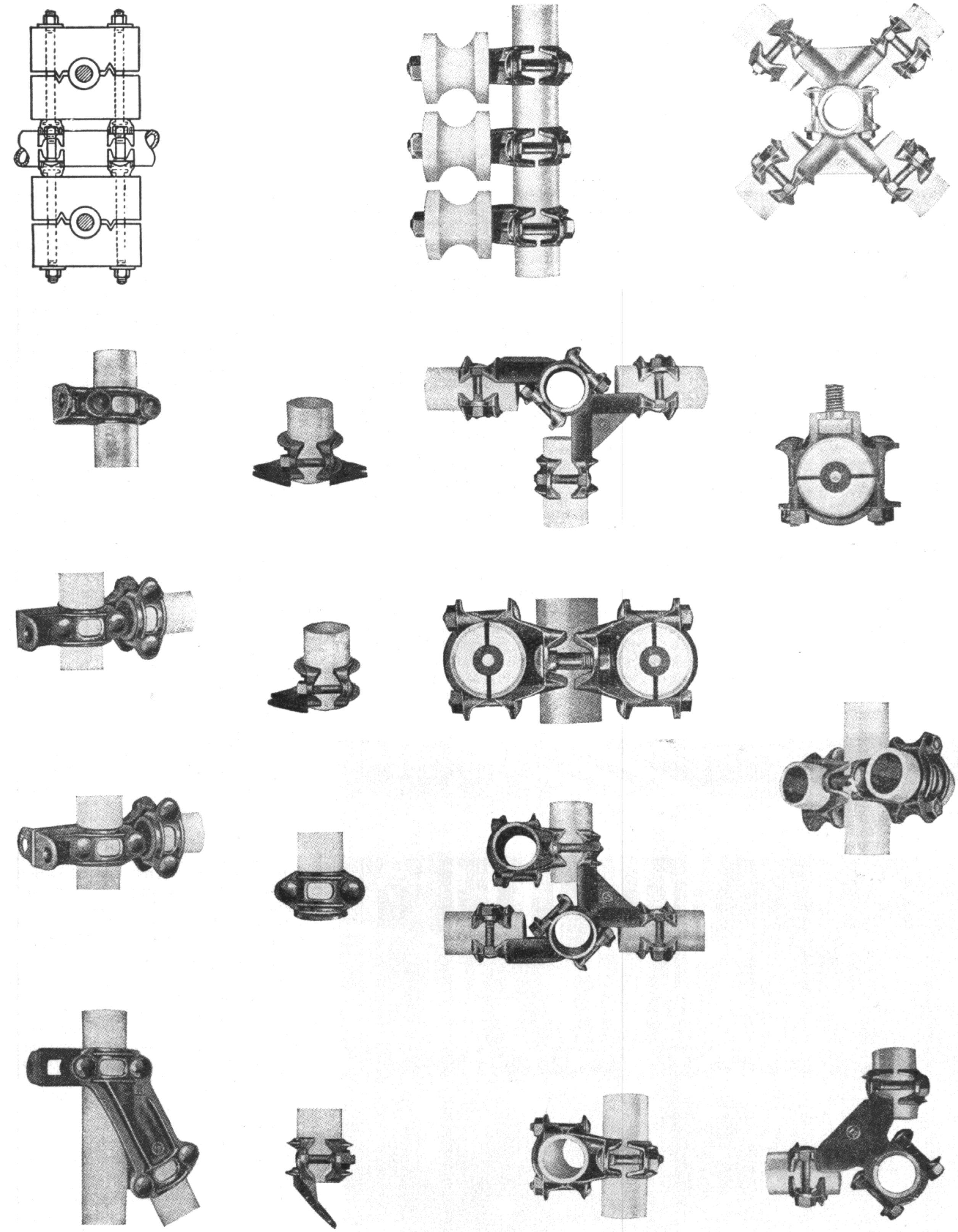


Fig. 58—Typical Westinghouse Threadless Pipe Fittings, etc. A Complete Line of These Fittings with Style Numbers will be Found in the Westinghouse Catalog.

To eliminate this trouble, the Westinghouse Company has designed an insert—See Figs. 61, 62 and 63—which permits moving the apparatus mounting bolt to any desired position in a ⅝ inch radius. They are available for use with either ⅜, ½ or ⅝ inch machine bolts.

The use of these adjustable inserts will save both time and money in any installation where equipment has to be bolted to concrete walls or floors. Tests have proven that their holding power is as great as the strength of the bolts.

The construction of the insert is shown in Fig. 63. The housing has been designed so as to obtain the maximum holding power when imbedded in concrete. The rotatable bolt carrier may be turned to any desired position. A slot in the top permits any bolt adjustment within a ⅝ inch radius. Washer B is also slotted, making it possible to fasten apparatus with small bases or feet to the insert. The retaining spring holds the rotatable bolt carrier in position while the insert is being bolted to the concrete form or when fastening apparatus to the imbedded insert. As will be noted in Fig. 61, both the housing and the rotatable bolt carrier are provided with teeth which prevent any change in position while in engagement.

Fig. 63 shows the insert fastened to the concrete form with the nut in the rotatable bolt carrier. This method of securing the insert to the form is recommended because the threads of the bolt are often damaged when the stud protrudes through the nut on the outside of the form. After the form has been taken down, the nut may be removed from the insert and the head of the bolt placed in the rotatable bolt carrier with stud protuding outward for supporting apparatus. Holes are provided in the base of the insert as shown in Fig. 62, for applications where it may be desirable or even necessary to nail them in place before the concrete is poured.

## Grillework

Grillework is frequently placed at the rear of a switchboard to prevent access to the equipment by unauthorized persons and also to improve its appearance. Doors with locks provide access to the enclosed area for inspection and maintenance. Screening high-voltage live parts, such as oil circuit breakers and their connections along aisles and runways, is also an added precaution to the safety of the operators.

When included in the contract, grillework is fabricated and assembled at the factory, being made up in sections that can be handled conveniently. It is always shipped disassembled. After the associated switching equipment has been completely erected, the grillework should be unpacked and assembled in accordance with the drawings, fastening the sections in place with the clamps and bolts provided for that purpose.

## Conduit

**General**—When the station is being designed, care should be taken to see that a sufficient number of conduits of the proper size are provided for both the main and secondary connections. It is also well to make provision so that any reasonable repairs or changes can be made in the wiring without jeopardizing the continuity of service.

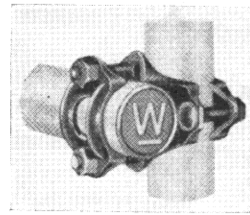


Fig. 60—Westinghouse Pipe Plug Driven in End of Pipe.

If the secondary and control leads do not run beyond the switchboard room, they frequently come to the switchboard overhead. Otherwise the best practice is to embed the conduits in the floor, terminating them about two or three inches above the finished floor and as close to the terminal blocks as possible. Although steel conduit is recommended for all leads between the switchboard and other equipment, tile or fibre can be used if necessary or desirable.

Control lead should not be placed in the same conduit with secondary leads from instrument transformers. When steel conduit is used, all wires on a single phase or polyphase circuit should be run in the same conduit. Where this is not possible, a non-metallic conduit should be used.

All steel conduits whether carrying primary or secondary cables, should be grounded.

**Conduit Size**—The inside diameter of the conduit should be at least 30 per cent larger than the outside diameter of the cable to be used in it. Uniformity of size, even if larger than necessary is an advantage in appearance as well as economy in purchasing the material.

Table A gives the number of wires or cables that can be installed in various sizes of conduits. It applies to complete conduit systems and not to short sections of conduit used for protecting exposed wiring from mechanical injury.

**Bending Conduit**—Sharp bends in conduit must be avoided and such bends as are necessary must be so made that the conduit will not be injured. The radius of the curve of the inner edge of any field bend should not be less than six times the internal diameter of the conduit. The number of bends between outlets should not be more than the equivalent of four quarter bends, including those at the outlets. Conduit elbows are recommended for all conduits which are too large to bend satisfactorily.

There are many different types of conduit benders on the market. The type to be used in any installation should be determined by the size and amount of conduit to be installed. If a small amount is involved, a simple bender can be purchased or one made as shown

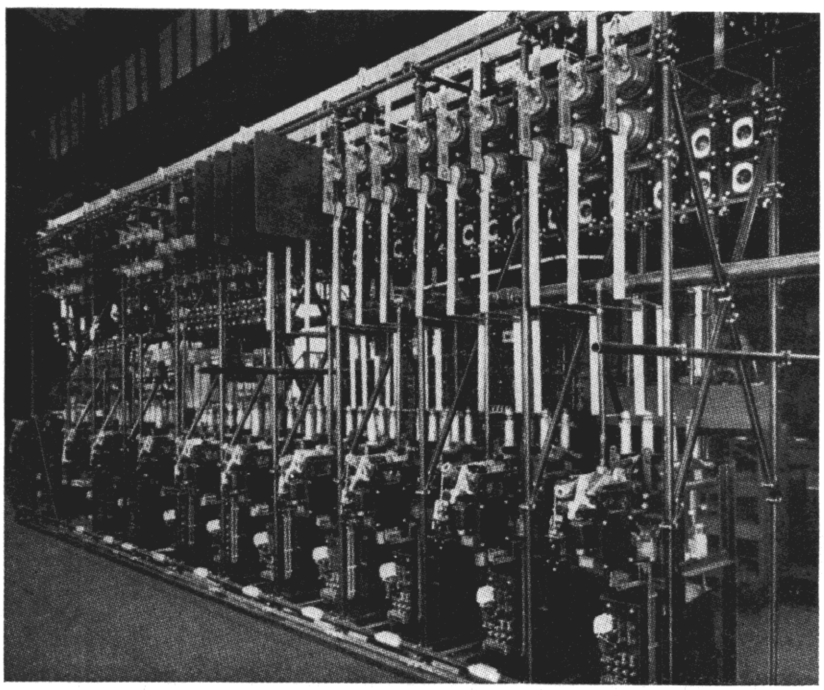


Fig. 59—Pipe Structure Mounting Electrically Operated Oil Circuit Breakers, Disconnecting Switches, Instrument Transformers, Etc.

**Table A—Conduit Sizes for Wires and Cables in Two-Wire and Three-Wire Systems**

| Size of Conductor B.&S.Gage | Number of Conductors in One Conduit — Minimum Size of Conduit in Inches: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| No. 18 | ½ | ½ | ½ | ½ | ½ | ½ | ½ | ½ | ¾ |
| 16 | ½ | ½ | ½ | ½ | ½ | ½ | ¾ | ¾ | ¾ |
| 14 | ½ | ½ | ½ | ½ | ¾ | ¾ | ¾ | 1 | 1 |
| 12 | ½ | ½ | ½ | ¾ | ¾ | 1 | 1 | 1 | 1¼ |
| 10 | ½ | ¾ | ¾ | ¾ | 1 | 1 | 1¼ | 1¼ | 1¼ |
| 8 | ½ | ¾ | 1 | 1 | 1¼ | 1¼ | 1¼ | 1¼ | 1½ |
| 6 | ½ | 1 | 1¼ | 1¼ | 1½ | 1½ | 2 | 2 | 2 |
| 5 | ¾ | 1¼ | 1¼ | 1¼ | 1½ | 2 | 2 | 2 | 2 |
| 4 | ¾ | 1¼ | 1¼ | 1½ | 2 | 2 | 2 | 2 | 2½ |
| 3 | ¾ | 1¼ | 1¼ | 1½ | 2 | 2 | 2 | 2½ | 2½ |
| 2 | ¾ | 1¼ | 1½ | 1½ | 2 | 2 | 2½ | 2½ | 2½ |
| 1 | ¾ | 1½ | 1½ | 2 | 2 | 2½ | 2½ | 3 | 3 |
| 0 | 1 | 1½ | 2 | 2 | 2½ | 2½ | 3 | 3 | 3 |
| 00 | 1 | 2 | 2 | 2½ | 2½ | 3 | 3 | 3 | 3½ |
| 000 | 1 | 2 | 2 | 2½ | 3 | 3 | 3 | 3½ | 3½ |
| 0000 | 1¼ | 2 | 2½ | 2½ | 3 | 3 | 3½ | 3½ | 4 |
| 200000 CM | 1¼ | 2 | 2½ | 2½ | 3 | 3 | 3½ | 3½ | 4 |
| 225000 | 1¼ | 2½ | 2½ | 3 | 3 | 3½ | ... | ... | ... |
| 250000 | 1¼ | 2½ | 2½ | 3 | 3 | 3½ | ... | ... | ... |
| 300000 | 1¼ | 2½ | 3 | 3 | 3½ | 3½ | ... | ... | ... |
| 350000 | 1¼ | 2½ | 3 | 3½ | 3½ | 4 | ... | ... | ... |
| 400000 | 1¼ | 3 | 3 | 3½ | 4 | 4 | ... | ... | ... |
| 450000 | 1½ | 3 | 3 | 3½ | 4 | 4½ | ... | ... | ... |
| 500000 | 1½ | 3 | 3 | 3½ | 4 | 4½ | ... | ... | ... |
| 550000 | 1½ | 3 | 3½ | 4 | 4½ | 5 | ... | ... | ... |
| 600000 | 2 | 3 | 3½ | 4 | 4½ | 5 | ... | ... | ... |
| 650000 | 2 | 3½ | 3½ | 4 | ... | ... | ... | ... | ... |
| 700000 | 2 | 3½ | 3½ | 4½ | ... | ... | ... | ... | ... |
| 750000 | 2 | 3½ | 3½ | 4½ | ... | ... | ... | ... | ... |
| 800000 | 2 | 3½ | 4 | 4½ | ... | ... | ... | ... | ... |
| 850000 | 2 | 3½ | 4 | 4½ | ... | ... | ... | ... | ... |
| 900000 | 2 | 3½ | 4 | 4½ | ... | ... | ... | ... | ... |
| 950000 | 2 | 4 | 4 | 5 | ... | ... | ... | ... | ... |
| 1000000 | 2 | 4 | 4 | 5 | ... | ... | ... | ... | ... |
| 1100000 | 2½ | 4 | 4½ | 6 | ... | ... | ... | ... | ... |
| 1200000 | 2½ | 4½ | 4½ | 6 | ... | ... | ... | ... | ... |
| 1250000 | 2½ | 4½ | 4½ | 6 | ... | ... | ... | ... | ... |
| 1300000 | 2½ | 4½ | 5 | 6 | ... | ... | ... | ... | ... |
| 1400000 | 2½ | 4½ | 5 | 6 | ... | ... | ... | ... | ... |
| 1500000 | 2½ | 4½ | 5 | 6 | ... | ... | ... | ... | ... |
| 1600000 | 2½ | 5 | 5 | 6 | ... | ... | ... | ... | ... |
| 1700000 | 3 | 5 | 5 | 6 | ... | ... | ... | ... | ... |
| 1750000 | 3 | 5 | 5 | 6 | ... | ... | ... | ... | ... |
| 1800000 | 3 | 5 | 6 | 6 | ... | ... | ... | ... | ... |
| 1900000 | 3 | 5 | 6 | ... | ... | ... | ... | ... | ... |
| 2000000 | 3 | 5 | 6 | ... | ... | ... | ... | ... | ... |

**NOTE: The above is from Table 2, 1937 N.E.C.**

in Fig. 66 which illustrates the "hickey" method of bending conduit. The "hickey" is made of a piece of 1¼" pipe approximately four feet long, with a pipe tee screwed on one end. The conduit to be bent is laid on the floor and the tee slid to the point of bending and slightly pulled and then readjusted. This pulling and readjusting should be continued until the conduit has been bent to the desired angle. Extreme care should be used to see that readjustments are made long and often enough to prevent the conduit from buckling.

**Installing Conduit**—The ends of all conduit should be reamed before joining the sections together. This will minimize the possibility of cutting the cable insulation. Conduit unions should be used where required, rather than "running" threads. Bushings should be used at all outlets. Conduit fittings can often be used to advantage on the ends of conduit adjacent to machines, circuit breakers, etc. The open ends of all conduits should be plugged or capped as soon as the conduits are in place and they should remain so until the cables are to be installed.

When placing conduit which is to be imbedded in concrete, pipe compound or white lead should be used on the threaded joints to insure a water tight connection. Provision should also be made for drainage to carry off any water that might accumulate because of condensation or accidents.

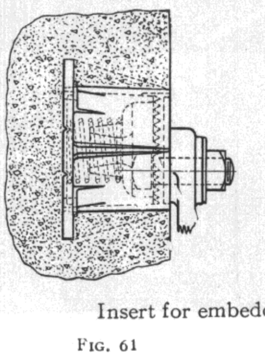
Fig. 67 is a construction view of a power station showing the conduits just before the concrete floor was poured. Note particularly the templates that are used for holding the conduits in position.

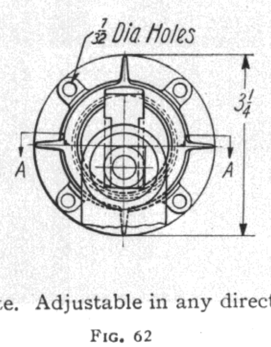
Conduits that are not embedded in concrete should be rigidly supported to withstand the strain incident to pulling in the cable.

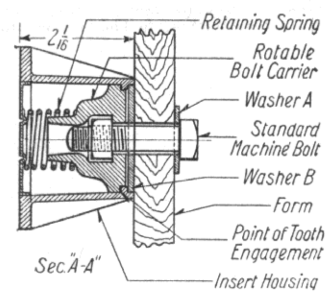
When the secondary and control leads are to be run from the top of a panel to a structure located directly in its rear, they should be placed in steel conduits supported at proper intervals along the wall braces.

**Terminating Conduit at Rear of Switchboard Panels**—Figs. 68, 69 and 70 show typical arrangements for terminating incoming instruments and control cables and their conduits at the bottom of the switchboard. While a different type of panel frame construction is shown in each figure, either conduit arrangement can be used with any type of switchboard. By referring to the figures it will be noted that the terminal blocks are mounted perpendicular to the plane of the panel. This arrangement provides the maximum amount of free space directly behind the panel and allows full access to its rear.

A neat arrangement is to embed the conduits in the floor and have them all terminate uniformly near the terminal blocks as illustrated in Fig. 68. This elbow should be embedded, allowing two or three inches of the straight part of the conduit to be exposed. This can be easily done in thick floors, but when they are thin, a coping with a curb angle as shown, may have to be used.





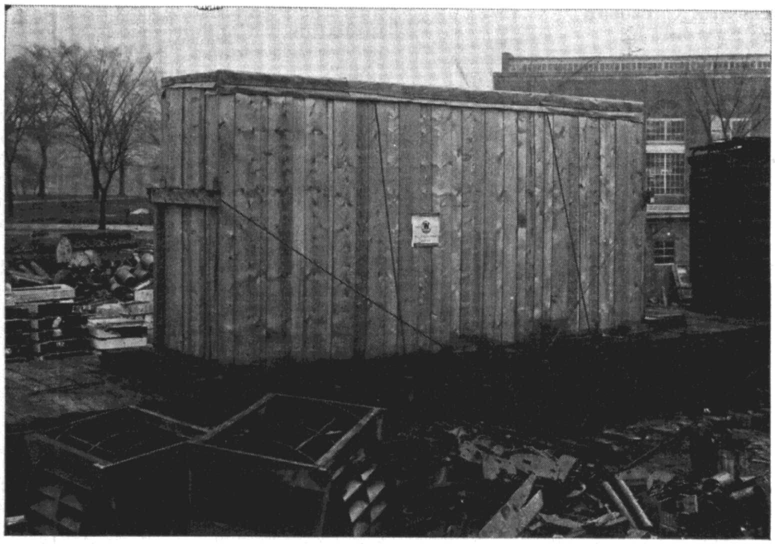




Insert for embedding in concrete. Adjustable in any direction within a ⅝ inch radius.

Fig. 61

Fig. 62

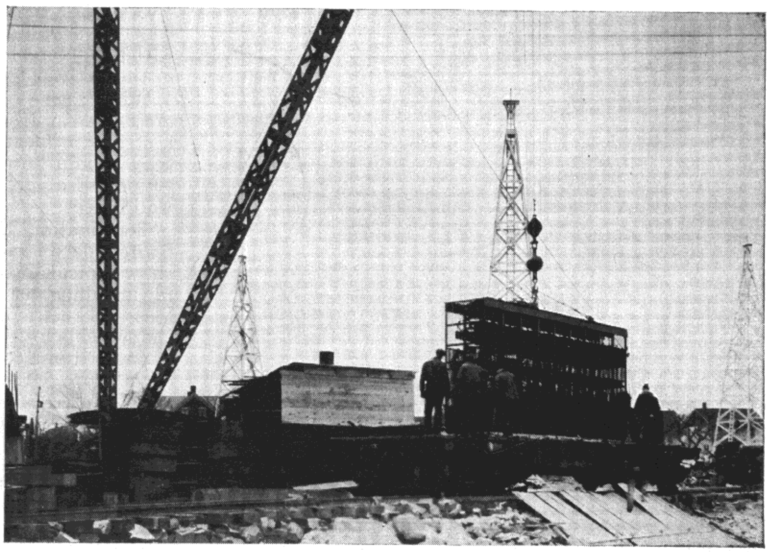
Fig. 63



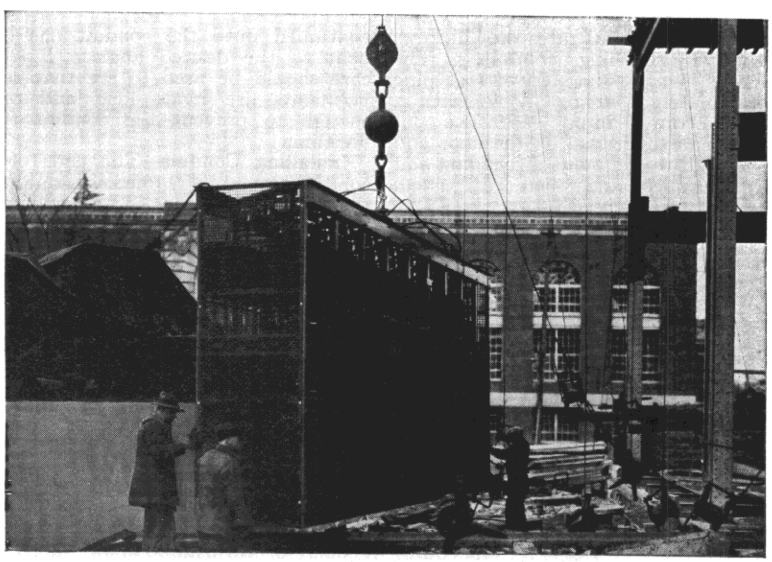
The accompanying illustrations show how easily and quickly Westinghouse factory-assembled switching equipment can be installed. In this particular installation only one and one-half hours were required to remove a completely assembled and tested switchgear structure from a flat car to its final position in the generating station.

Like all Westinghouse factory-assembled switching equipment of this nature, the nine-cell, arc-welded structure shown

Factory-Assembled Structure Housed and Fastened to Flat Car as Received by The Customer



Structure Being Hooked on to The Yard Crane

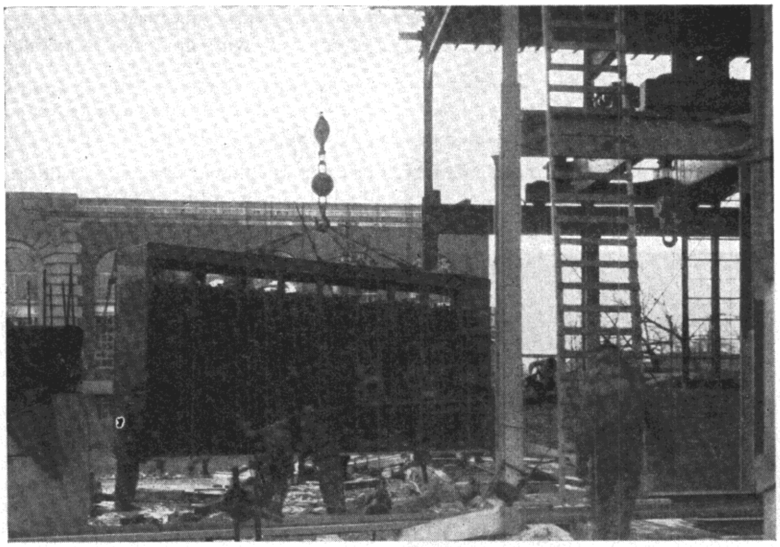


View of Structure Being Swung Into Position for Attaching to The Station Crane

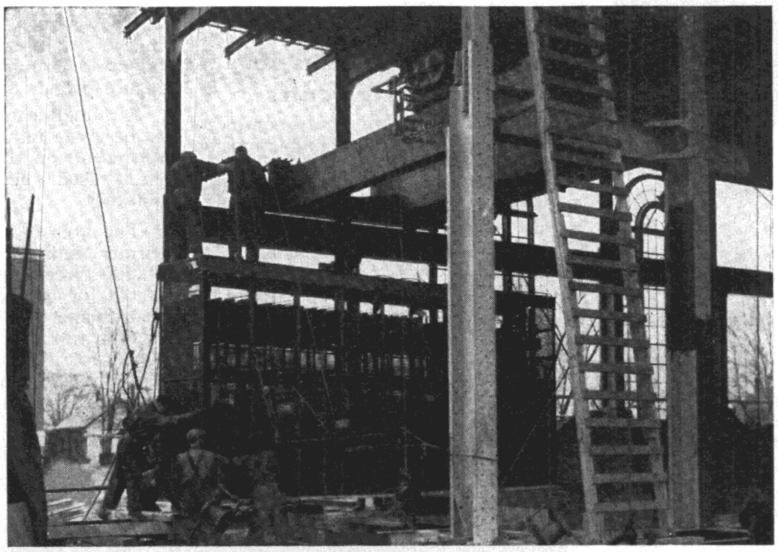
Fig. 64

was shipped with circuit-breaker, switch, and bus connections made. Exterior connections, that is, connections from the generator unit to the structure were the only ones made at the point of installation.

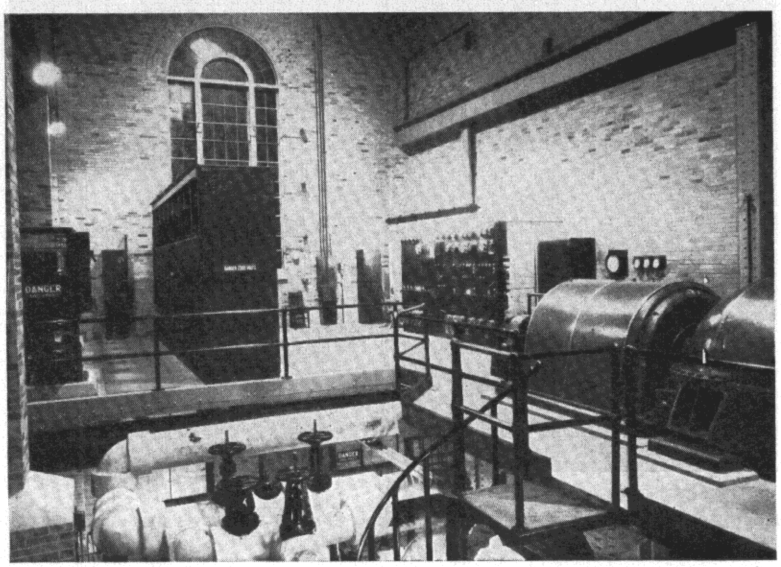
These modern structures entirely eliminate the costs of labor and material in building concrete or other classes of cell structures which were formally required.



Swinging The Structure Into Place Just Before Hooking It on to The Station Crane



Structure Being Transferred From The Yard to The Station Crane



Interior of Generating Station Showing The Structure in Its Final Position

FIG. 64A.

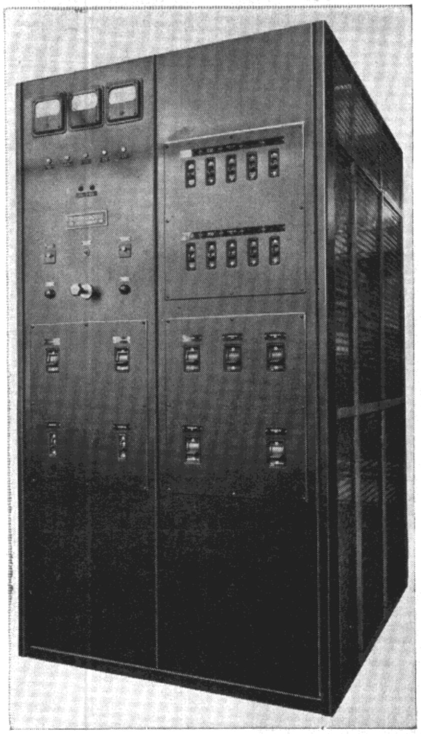


Fig. 65—Switchboard with Grille Enclosure at Rear.

Another method is to have the conduits terminate in a trench just back of the switchboard sill as shown in Fig. 69. The trench should be of suitable depth, provided with a drain and have a curb around it to prevent the entrance of debris. The trench is covered with a series of plates. Short fixed sections with bushed holes through which the cables are brought to the switchboard, are located adjacent to the terminal blocks. Wider ones with a handhole to facilitate removal, are placed between the fixed sections. This method of terminating conduits permits crossing the leads in the trench instead of at the rear of the panels as is sometimes found necessary, thus making a neater installation.

Fig. 70 shows a method of terminating conduits which are not embedded in the floor. They are brought up through an opening in the floor behind the switchboard and which extends along its entire length. The opening is covered with metal plates similar to those described in the foregoing paragraph, the conduit ends extending through holes in the stationary sections. For installations like this, placing of the conduit should be started at the switchboard end. This permits drilling the stationary plates in a more uniform manner, thus insuring a neater appearing job when completed.

**Pulling Cable Through Conduit**—Even though the conduits have been plugged or capped as instructed in the foregoing, they should be cleaned out before any wire or cable is pulled in. This can be done by blowing compressed air through them—if this is available—and if not, by pulling a cloth through. The work of pulling the cable will be materially lessened if talc or soapstone powder is blown into the conduit or dusted on the cable beforehand. Under no circumstances should oil or grease be used except on lead covered cable.

When pulling in wire and cable, a flexible steel ribbon commonly called a "fish wire" or "snake" is first run through the conduit. If the cable to be pulled is not too heavy, it may be attached directly to the "fish wire" and pulled in. Where the run is long and heavy cable is to be installed, the "fish wire" should be followed by a heavier wire or rope.

A cable grip is recommended for attaching the wire or cable to be pulled in by the "fish wire" or rope. If one is not available, the conductor can be fastened directly to the wire or rope and the junction taped to prevent it from catching in the conduit.

## Wires and Cables for Auxiliary Circuits

**General**—Coded multi-conductor cable is recommended for connections between the switchboard and the instrument transformers, circuit breaker operating mechanisms, etc., when the number of wires in each group is fairly uniform throughout the installation. The use of this greatly facilitates installation work since the different wires in the cable can be readily recognized by their individual color. Single wires are generally used for connections where interlocking is required in the circuits for the electrically operated devices which makes

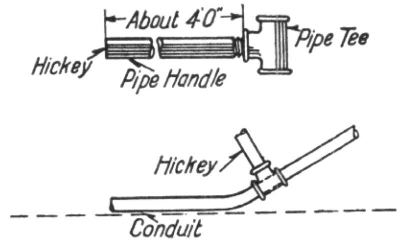



Fig. 66—Conduit Bender.

it impossible to take all the wires from the switchboard directly to the devices controlled.

**Size of Conductors**—The size of the conductors will depend on their length and the current to be carried. When selecting wire or cable for instrument transformers the losses in the conductor should be calculated and a check made to insure that the combination of instrument load and conductor losses do not exceed the capacity of the transformer. Also, it is quite important that the drop in the circuit controlling an electrically operated circuit breaker be checked to insure proper operation.

Although each installation will have to be given individual consideration, information on the following can be generally used where lengths do not exceed 500 feet.

The area of cable for current transformer connections should be at least 19,500 circular mills for long runs and 10,000 for very short ones. For potential transformer circuits they should be 10,000 and 6,000 circular mills respectively for long and short runs.

For small solenoid operated circuit breakers, the closing coil leads should be

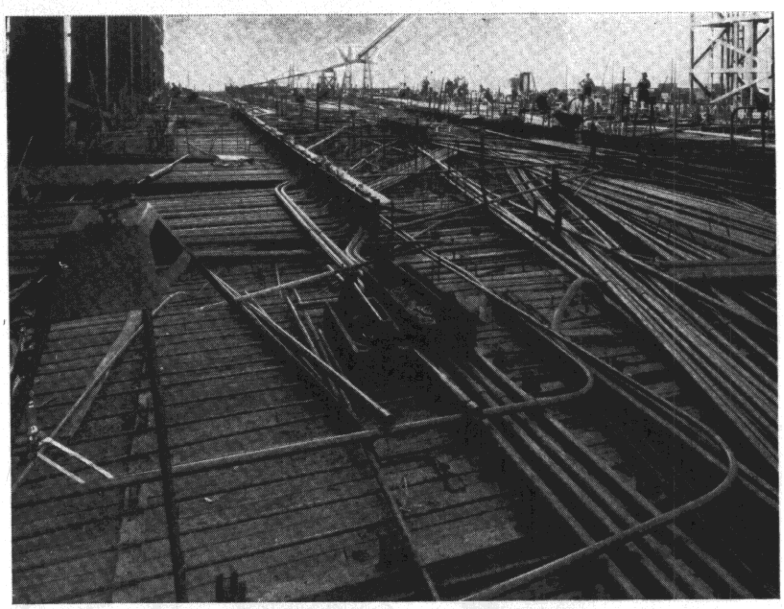


Fig. 67—Construction View of Power Station Showing Conduits before Concrete Floor was Poured.

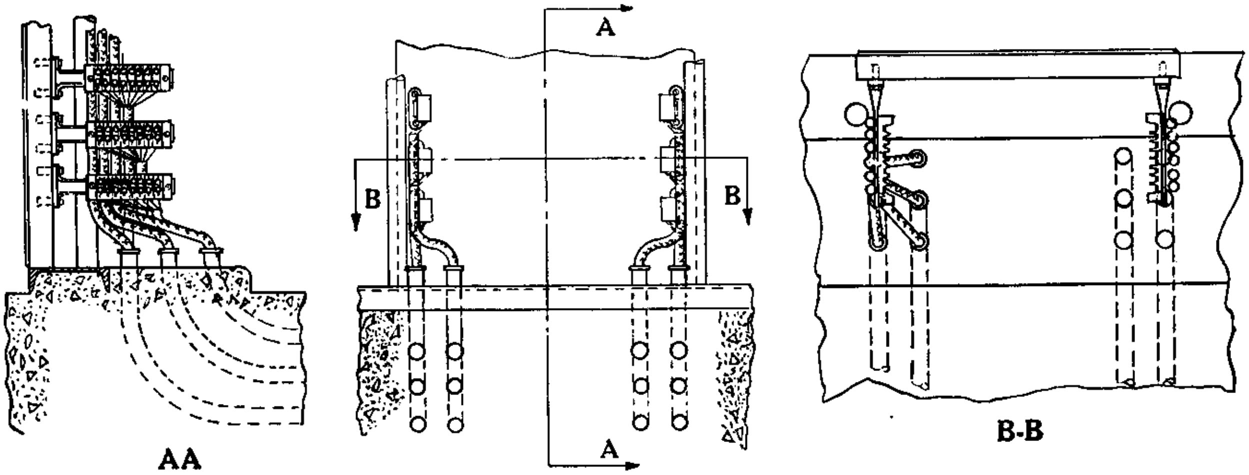



FIG. 68—METHOD OF TERMINATING CONDUITS ENTIRELY EMBEDDED IN CONCRETE EXCEPTING THE ELBOW ENDS WHICH EXTEND A FEW INCHES ABOVE FLOOR. SWITCHBOARD MOUNTED ON PIPE FRAME.

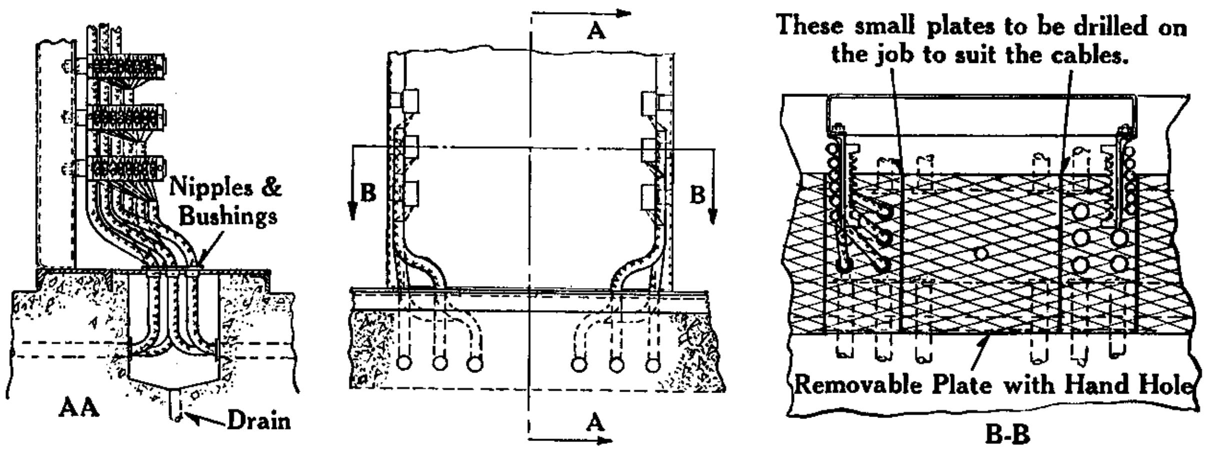



FIG. 69—CONDUITS TERMINATING IN A TRENCH. CABLES ARE BROUGHT TO THE SWITCHBOARD THROUGH BUSHED HOLES IN THE TRENCH COVER PLATES. STEEL PANEL SWITCHBOARD.

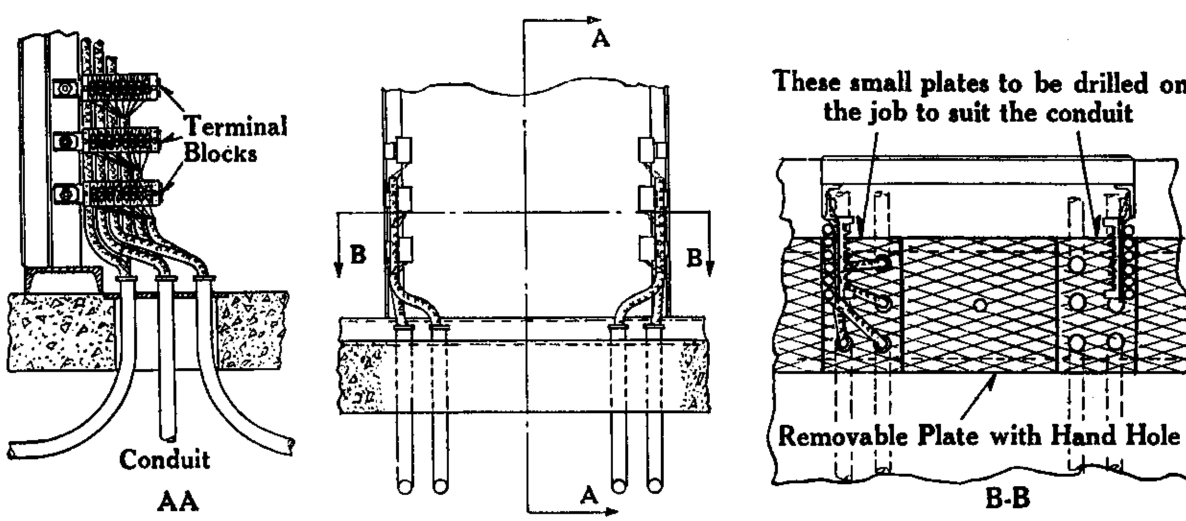



FIG. 70—ARRANGEMENT FOR TERMINATING CONDUITS WHICH COME TO SWITCHBOARD THROUGH OPENING IN THE FLOOR. CONDUIT ENDS SUPPORTED IN PLACE BY STATIONARY IRON PLATES. SWITCHBOARD MOUNTED ON ANGLE IRON FRAME.

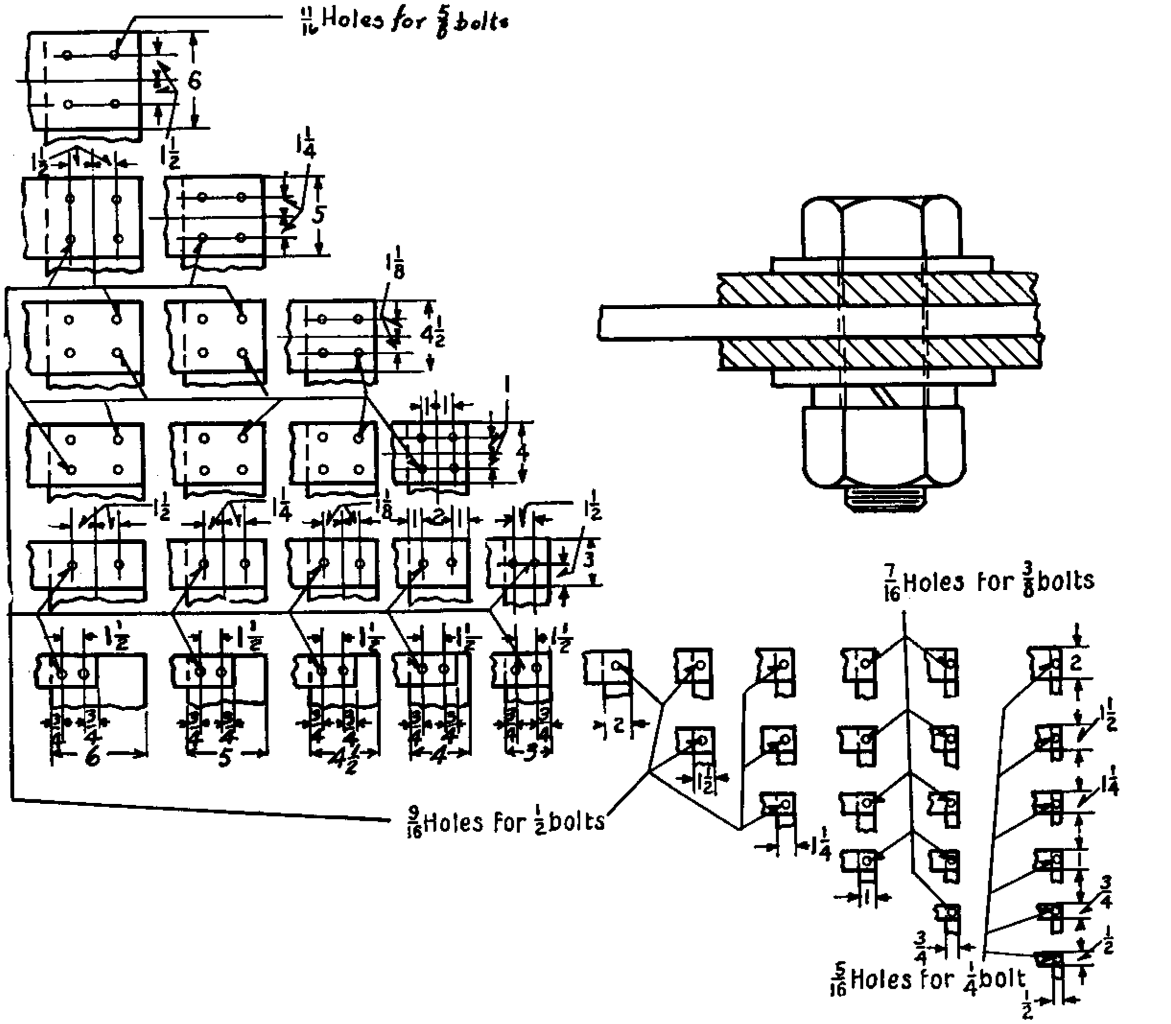



FIG. 71—RECOMMENDED SPACINGS AND BOLT DIAMETERS FOR COPPER BAR JOINTS. A PALNUT OR OTHER LOCKING DEVICE MAY BE USED IN PLACE OF LOCK WASHER SHOWN.

approximately 19,500 circular mills and the trip coil and indicator leads 6,000 circular mills. Heavier closing coil leads should be used for larger breakers.

Control cable for governor motors, electrically operated rheostats and similar equipment should have an area of 10,000 circular mills when the runs are long and 6,000 when they are short.

If solid wire is to be used rather than cable, Nos. 8, 10 and 12 wires can be used respectively where the 19,500, 10,000 and 6,000 circular mill cables are recommended in the foregoing.

**Insulation**—Wire and cable for instrument and control circuits in the conventional installations should be insulated for 600 volt service. Where something different is required, it should be selected in accordance with individual instructions applying to the equipment.

The outside covering will depend on local conditions. If they are to be installed in a dry place, braid covered cable will be satisfactory. If moisture is present, the cable will either require a lead sheath or a weatherproof covering.

## Buses and Connections for Power Circuits

**General**—The selection of material for buses and their connections depends on a number of factors such as current to be carried, voltage and frequency of the installation, atmospheric conditions, etc. Regardless of the material used, it is essential that the buses be well supported and that all connections be made in accordance with the best practice for the particular material involved.

Installations involving high currents—particularly alternating current—require special consideration. Problems involving currents higher than those considered in the following should be referred to the Company for specific recommendations.

All connections which are removed from the rear of panels for shipping purposes are stenciled or painted with a number. The same number is painted on the panel near the point of connection to facilitate reassembly in the field.

**Wire or Rod**—Bare copper wire or rod is used quite extensively in the very simple equipments and also in the more extensive ones where this material is particularly suitable for the conditions involved. It can be bent in the desired shapes with comparative ease and when fitted to the terminals on circuit breakers, switches and other devices, makes a very neat and satisfactory installation.

Table B gives the current carrying capacities of bare copper rod having diameters from ½ to 1½ inches. These values are based on 30°C. temperature rise above 20°C. ambient.

**Table B—Current Carrying Capacities of Bare Copper Rod**

| Diameter in Inches | D-C. | 25 Cycle | 60 Cycle |
|---|---|---|---|
| ½ | 340 | 330 | 325 |
| ⅝ | 480 | 440 | 420 |
| ¾ | 600 | 580 | 550 |
| ⅞ | 760 | 720 | 670 |
| 1 | 920 | 860 | 800 |
| 1⅛ | 1080 | 1000 | 950 |
| 1¼ | 1250 | 1170 | 1100 |
| 1⅜ | 1450 | 1330 | 1250 |
| 1½ | 1600 | 1500 | 1400 |

**Copper Bar**—This material is the one most commonly used for buses and their connections in switching equipment. When equipment is received that has been completely factory built, it is only necessary to put such pieces in place that had to be removed for shipment. If buses and connections have to be fabricated in the field, the instructions given in the following paragraphs should be observed.

Copper bar should not be bent at an angle which will result in breaking the fibre of the material. When making flat bends the radius should not be less than the thickness of the bar. Edgewise bends should not be attempted unless special tools for this purpose are available. Copper may be twisted, however, but it should be annealed beforehand. To anneal copper, first heat to a dull red, then dip immediately in water. After bending, the dark stains resulting from the annealing process may be removed by rubbing with fine emery cloth.

Before placing copper bar in the slots of laminated switch or circuit breaker studs, the laminations should be examined to make sure that they are clean, smooth and parallel. When more than one bar is used for connection to equipment having round studs, spacers should be used between bars to obtain ventilating space. Using thin nuts on the studs instead of spacers may cause excessive heating unless they are properly "set-up".

The factors which affect the contact resistance of a copper bar joint are the preparation of the surface of the joint and the pressure with which the contact surfaces of the joint are forced together. To insure a satisfactory joint, the bar, if rough or distorted, should be laid on a smooth surface and the contact area flattened by hammering with a raw-hide mallet. If it is particularly rough, filing may be necessary. The contact surfaces of the bars should then be well cleaned with emery cloth, wiped free of emery dust and given a coat of vaseline or boiled linseed oil. The vaselined or oiled surfaces should be rubbed slightly with fine emery cloth to remove any trace of oxidization and then clamped or bolted together without the vaseline or oil being removed. Surfaces prepared in this manner have little chance to oxidize, since the pressure at the joint due to

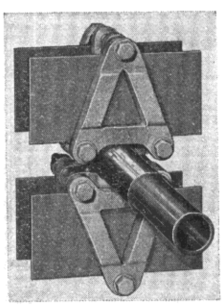


Fig. 72—Modified Hollow Square Bus Support.

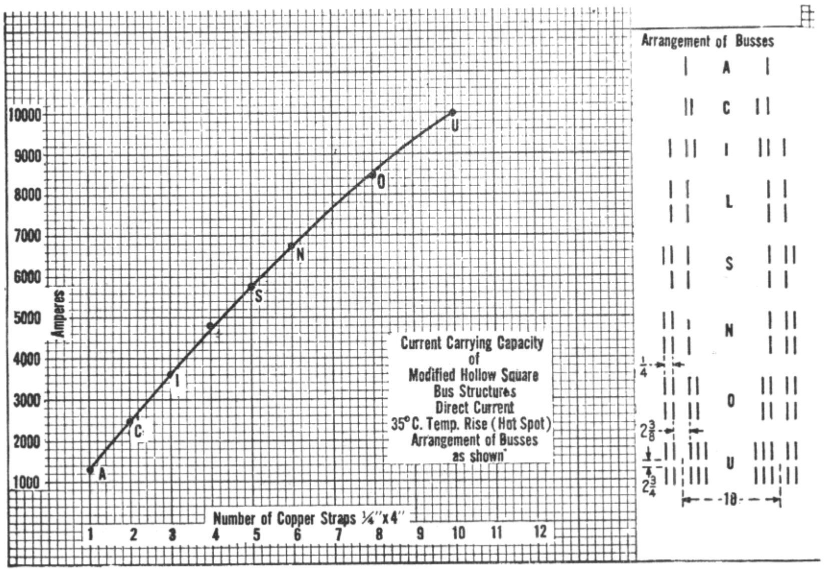



Fig. 73—Current Carrying Capacity of Copper Bar—Direct Current.

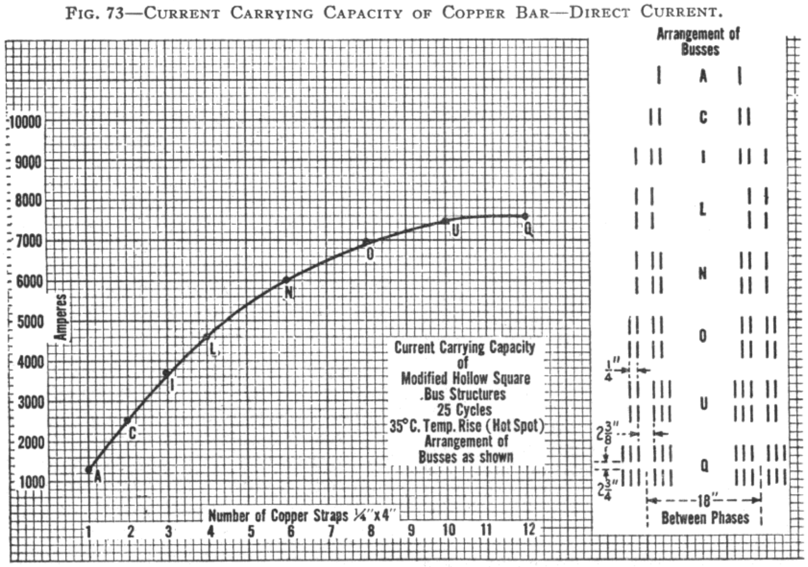



Fig. 74—Current Carrying Capacity of Copper Bar—25 Cycles.

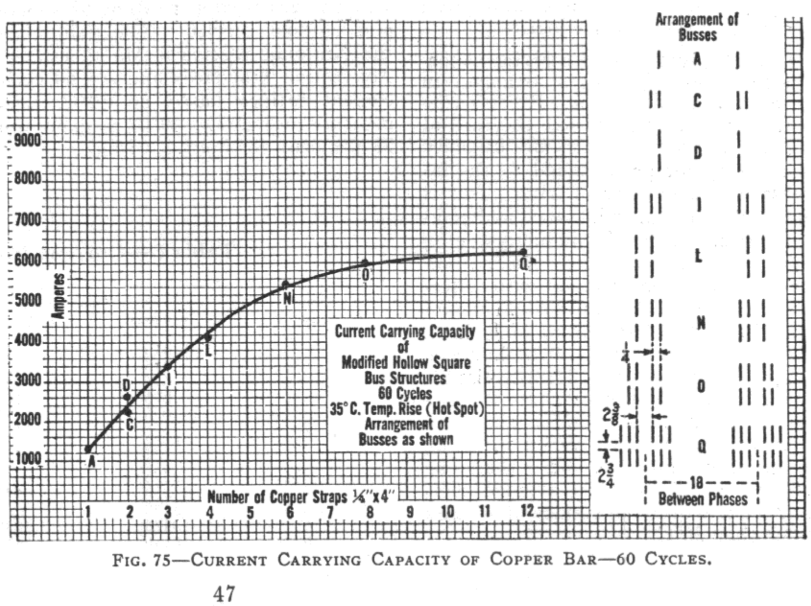



Fig. 75—Current Carrying Capacity of Copper Bar—60 Cycles.

**Table C—Capacities for Copper Bar In The Conventional Bus Arrangement**

| Size in Inches | No. of Bars | Ampere Capacity — 60 Cycle A-C. | 25 Cycle A-C. | Direct Current |
|---|---|---|---|---|
| 3 x ¼ | 1 | 1000 | 1050 | 1050 |
| 3 x ¼ | 2 | 1650 | 1680 | 1800 |
| 3 x ¼ | 3 | 1800 | 1880 | 2400 |
| 3 x ¼ | 4 | 2100 | 2250 | 3000 |
| 4 x ¼ | 1 | 1350 | 1375 | 1375 |
| 4 x ¼ | 2 | 2250 | 2300 | 2400 |
| 4 x ¼ | 3 | 2500 | 2610 | 3200 |
| 4 x ¼ | 4 | 3000 | 3200 | 4000 |
| 5 x ¼ | 1 | 1620 | 1650 | 1650 |
| 5 x ¼ | 2 | 2700 | 2760 | 2900 |
| 5 x ¼ | 3 | 3000 | 3040 | 3800 |
| 5 x ¼ | 4 | 3600 | 3860 | 4700 |
| 6 x ¼ | 1 | 1890 | 1920 | 1920 |
| 6 x ¼ | 2 | 3050 | 3120 | 3300 |
| 6 x ¼ | 3 | 3500 | 3660 | 4300 |
| 6 x ¼ | 4 | 4150 | 4450 | 5200 |

the bolting or clamping will force the vaseline or oil from between the straps to form a seal around the coated area. Excellent results have also been obtained by tinning the contact areas before they are clamped together.

When "setting-up" the connections, particular attention must be paid to the pressure between the contact surfaces. The connections must be securely bolted or clamped, since the conductivity of the joint is proportional to the applied pressure rather than to its area. Factory made joints are usually bolted whereas clamps are frequently used for those which have to be made in the field. If it is desired to bolt instead of clamp the joints when fabricating connections in the field, the dimensions in Fig. 71 are recommended.

After the copper connections have been placed and securely clamped, they may, if desired, be cleaned and given a coat of transparent lacquer.

Table C gives current carrying capacities for copper bus bars arranged in the conventional manner. By referring to it, it will be noted that the rate of increase of current carrying capacity in a bus is not proportional to the increase in the number of bars. This is due to the mutual inductance and physical arrangement of conductors, etc., which must be taken into consideration particularly when dealing with alternating current. The data given is based on an individual bar spacing of ¼ inch. The a-c. values apply to both single and polyphase systems. The permissible maximum or "hot spot" temperature rise has been fixed at 35°C. above an ambient value of 40°C. When operating at this limit, buses of more than one lamination will have an average temperature rise over the surface of all bars of less than 30°C.

The nearer the bus arrangement approaches a hollow square, the more efficient it will be. Fig. 72 shows a modified hollow square bus support which is suitable for 4000 volts maximum service. Their design is very flexible and assemblies can be secured for supporting from one to twelve bars. Figs. 73, 74 and 75 give current carrying capacities for various bar assemblies mounted in these supports.

**Copper Tubing**—This material is quite generally used for bus bars and connections particularly in high voltage or current installations. Iron pipe size, hard drawn tubing is used to obtain the required rigidity. Generally standard tubing will be satisfactory although extra heavy can be used where additional strength is required.

Table D gives the current ratings of various sizes of copper tubing for indoor and outdoor service. The values are the National Electrical Manufacturer's Association Standards and are 60 cycle current ratings based on 30°C. temperature rise above 40°C. ambient for 98 per cent conductivity copper.

## Cables for Power Circuits

**Selection of Cable**—When selecting cables for connections to machines, transformers, etc., consideration must be given to such factors as voltage, current, frequency, temperature and the prevalence of water, moisture, oil, acids or corrosive gases. The temperature limit of the insulation should never be exceeded. Particular care must be exercised when cables are to be installed in conduit or unusually warm places.

Table E gives the allowable current carrying capacities of insulated copper wire and cable as adopted by the National Board of Fire Underwriters for interior conductors. It is considered inadvisable to list here current ratings other than these due to the number of variable factors that enter into the selection of suitable cable. Specific recommendations will be furnished if desired. When requesting this, all pertinent information regarding the cable installation should be submitted to us.

For three phase leads where the current is small, one three conductor cable is preferable to three single ones. Since it is not practical to manufacture three conductor cables larger than 500,000 circular mils, single conductor cables are recommended for higher capacities.

Particular attention must be paid to the arrangement of cables when being used in parallel. Since all three phases of an alternating current circuit must be run in the same steel conduit, three cables should be run in one and three in another if two leads per phase are used, and a single conduit is too small to accommodate all six. When a number of cables are used and they are bunched, the inner ones will be unable to dissipate the required amount of heat and excessive temperatures will result. Lead covered or weatherproof cable must be used where moisture is present.

**Bending Cable**—To prevent weakening of the cable insulation, sharp turns, corners and edges should be avoided where possible. The radius of bends 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 bends may be five times the outside diameter of the cable. The minimum radius that should be used in bending solid insulated wire is six times its overall diameter.

**Table D—Current Ratings of Copper Tubing**

| Size in Inches | Ampere Capacity — Indoor Standard | Indoor Extra Heavy | Outdoor Standard | Outdoor Extra Heavy |
|---|---|---|---|---|
| ½ | 410 | 460 | 550 | 620 |
| ¾ | 515 | 575 | 680 | 770 |
| 1 | 675 | 750 | 860 | 1010 |
| 1¼ | 875 | 1000 | 1130 | 1270 |
| 1½ | 1025 | 1150 | 1285 | 1460 |
| 2 | 1300 | 1500 | 1585 | 1850 |
| 2½ | 1700 | 1975 | 2010 | 2390 |
| 3 | 2175 | 2475 | 2560 | 3000 |
| 3½ | 2525 | 2875 | 3040 | 3410 |
| 4 | 2850 | 3225 | 3400 | 3880 |
| 4½ | 3100 | 3675 | 3700 | 4300 |
| 5 | 3425 | 4300 | 4100 | 5000 |
| 6 | 4150 | 5100 | 4750 | 5850 |

**Table E—Allowable Current Carrying Capacities of Insulated Wire and Cable for Interior Conductors**

| Size AWG | Dia. of Solid Wire In Mils. | Area in Circular Mils. | Ohms Per 1000 Ft. at 77°F. | Column A Rubber Ins. (Amperes) | Column B Var. Cam. Ins. (Amperes) | Column C Other Ins. (Amperes) |
|---|---|---|---|---|---|---|
| 22 | 25.4 | 642 | 16.46 | .. | .. | .. |
| 20 | 31.9 | 1,022 | 10.35 | .. | .. | .. |
| 18 | 40.3 | 1,624 | 6.510 | 3 | .. | 6 |
| 16 | 50.8 | 2,583 | 4.094 | 6 | .. | 10 |
| 14 | 64.1 | 4,107 | 2.575 | 15 | 18 | 20 |
| 12 | 80.8 | 6,530 | 1.619 | 20 | 25 | 30 |
| 10 | 101.9 | 10,380 | 1.018 | 25 | 30 | 35 |
| 8 | 128.5 | 16,510 | .6405 | 35 | 40 | 50 |
| 6 | 162.0 | 26,250 | .4028 | 50 | 60 | 70 |
| 5 | 181.9 | 33,100 | .3195 | 55 | 65 | 80 |
| 4 | 204.3 | 41,740 | .2533 | 70 | 85 | 90 |
| 3 | 229.4 | 52,630 | .2009 | 80 | 95 | 100 |
| 2 | 257.6 | 66,370 | .1593 | 90 | 110 | 125 |
| 1 | 289.3 | 83,690 | .1264 | 100 | 120 | 150 |
| 0 | 325.0 | 105,500 | .1002 | 125 | 150 | 200 |
| 00 | 364.8 | 133,100 | .07947 | 150 | 180 | 225 |
| 000 | 409.6 | 167,800 | .06302 | 175 | 210 | 275 |
| 0000 | 460.0 | 211,600 | .04998 | 225 | 270 | 325 |
| | | 250,000 | .0431 | 250 | 300 | 350 |
| | | 300,000 | .0360 | 275 | 330 | 400 |
| | | 350,000 | .0308 | 300 | 360 | 450 |
| | | 400,000 | .0270 | 325 | 390 | 500 |
| | | 500,000 | .0216 | 400 | 480 | 600 |
| | | 600,000 | .0180 | 450 | 540 | 680 |
| | | 700,000 | .0154 | 500 | 600 | 760 |
| | | 750,000 | .0144 | 525 | 630 | 800 |
| | | 800,000 | .0135 | 550 | 660 | 840 |
| | | 900,000 | .0120 | 600 | 720 | 920 |
| | | 1,000,000 | .0108 | 650 | 780 | 1,000 |
| | | 1,100,000 | .00981 | 690 | 830 | 1,080 |
| | | 1,200,000 | .00899 | 730 | 880 | 1,150 |
| | | 1,300,000 | .00830 | 770 | 920 | 1,220 |
| | | 1,400,000 | .00770 | 810 | 970 | 1,290 |
| | | 1,500,000 | .00719 | 850 | 1,020 | 1,360 |
| | | 1,600,000 | .00674 | 890 | 1,070 | 1,430 |
| | | 1,700,000 | .00634 | 930 | 1,120 | 1,490 |
| | | 1,800,000 | .00599 | 970 | 1,160 | 1,550 |
| | | 1,900,000 | .00568 | 1,010 | 1,210 | 1,610 |
| | | 2,000,000 | .00539 | 1,050 | 1,260 | 1,670 |

1 Mil=0.001 inch.

If it is necessary to make bends which might be injurious, the insulation should be removed and the bend reinsulated after the cable has been installed. It is advisable to taper the original cable insulation for several inches on each side of the bend in order that the cable will present a neat appearance when the new insulation is added.

**Soldering Cable**—When soldering cable into a terminal, it is first necessary to tin the inside if the manufacturer—Westinghouse terminals are already coated—has not done this. See that the inside of the terminal is clean. Coat this surface lightly with a good soldering flux. Hold the terminal over a solder pot with pliers and, using the ladle, slowly pour it full of the hot metal. Spill the solder back into the pot and repeat a few times until the inside surface is completely tinned. Very large terminals can be held upright on the floor or a bench, heated with torches and gradually filled with solder which melts and tins the surface. An ordinary large monkey wrench can be tightened on to a large tube terminal, using pliers on the thumb nut, and makes a good clamp to hold the terminal upright.

The end of the cable should be cut off to remove any distorted strands. The insulation should then be cut off squarely far enough back to let the cable go to the bottom of the hole in the terminal. The cable end should now be coated with flux and held in a solder pot or slowly lowered in the terminal which is partly filled with solder and kept heated with torches. It will probably be necessary to surround the insulation near the terminal with moist rags or protect it with tape to prevent burning. When the cable is tinned, it is ready to be soldered into the terminal.

Be sure no water is in the terminal or is dropped into the molten solder as it may explode causing serious burns to anyone nearby.

Heat the terminal and fill one quarter of it with solder. Slowly push the cable end into it, still applying heat so that the solder remains molten. The excess solder will run out over the end of the terminal. Remove the heat and wipe off the outside. Allow the terminal to cool being sure the joint is not moved till the solder sets. Large terminals can be cooled with wet rags. Clean the terminal. If the insulation tends to fray, it should be corded or taped and varnished to give a finished appearance.

Westinghouse tube terminals are coated on the inside with flux. If torches are used on the terminals, be sure the flux is not burned off before the solder is applied or a good tinning job cannot be obtained. Finely stranded cable should be tied with fine wire before being tinned to hold the strands in place. With some types of braid it is advisable to cord the insulation or protect it with asbestos tape during the soldering operation and then replace this with new wrapping if the insulation frays when it is removed.

**Cable Terminals**—Cable terminals (potheads) are recommended for terminating all cables in circuits operating above 600 volts, especially for outdoor service. They serve the double purpose of adequately protecting the ends of the cables from mechanical injury or entrance of moisture, and of providing convenient means for disconnecting the aerial lines from the cable, as occasion requires.

Terminals are available with different types of cable entrances, namely, wiped joint for lead covered cables; stuffing box for all non-metallic cables or lead covered cables where a wiped joint cannot be conveniently made; and conduit connected for terminals mounted directly on the conduits carrying the cables.

Lead covered cable should not be unsealed until it is ready to be connected as its exposed end will absorb moisture.

**Supporting Cable**—When cables are not run in conduit, suitable supports must be provided to keep them in position. Where installed in long vertical runs, they should be supported every ten feet. If the conductor is very heavy, supports should be used which clamp the bare cable, the insulation to be removed at the point of support for this purpose. This will eliminate the possibility of the conductor slipping through the insulation. When supporting cable in this manner, the insulators will have to be suitable for the circuit voltage.

**Grounding Metal Sheath Cable**—The metal sheaths of cables carrying polyphase currents should be grounded at several places. Lead or bronze sheath single conductor cables carrying alternating current must have their sheaths grounded at one point only, preferably in the middle, and the cable sheath must be insulated from the support at all other points. This prevents induced sheath currents. If the continuity of the sheath is broken, the individual sections must each be grounded at one point.

**Cable Insulation and Personal Safety**—Treat all circuits as if they were alive unless it is positively known that they are dead. **DO NOT TRUST INSULATION AS IT IS OFTEN INSUFFICIENT EXCEPT AS A PROTECTION AGAINST ACCIDENTAL CONTACT.**

## Tightening Connections

When installing equipment, it should always be remembered that the conductivity of a bolted or clamped joint is proportional to the pressure applied at the joint. All connections should, therefore, be carefully inspected and tightened before the equipment is placed in service. Failure to observe this precaution will result in trouble.

## Insulating Connections

**Where Required**—No bare connections above 750 volts should be allowed in the switchboard room, or where connections are accessible from the aisles. Connections for 11,000 volts and above are usually so far out of reach as to be harmless, and so well protected by space as to preclude the necessity for wrapped insulation.

Insulation is also recommended for all connections and terminal lugs for circuits below 750 volts in which enclosed switches or oil circuit breakers are used. While a knife switch with bare live parts is in itself a caution notice, a device such as a circuit breaker 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.

Insulation cannot be applied at the factory since it should be continuous over all joints and terminals. Most types of these have to be left exposed for inspection and tightening by the Purchaser before being placed in service. In these cases, the insulation must, therefore, be applied at the time of installation in Purchaser's plant and is considered a part of the installation material. Since insulation may have a tendency to increase the temperature rise of a conductor, the purchaser should not insulate connections designed to be left bare without first consulting the Company.

**Methods and Materials Used**—The most common method is to cover the parts to be insulat ed with tape. When the joints are not symmetrical, the work may be greatly simplified and the appearance of the finished job improved if the uneven surfaces are filled in with conducting paste over which the tape may be more easily applied.

The conductor should be wrapped with half-lapped layers of .010 inch varnished cambric tape (Westinghouse Catalog No. 1266 Tan Treated Cloth) applying the number of layers required for the voltage range as given in Table F. Apply a coat of insulating varnish (Westinghouse Catalog No. 311 Varnish) between layers. Cover the cambric with one layer of .007 inch cotton tape and wrap the ends with cord to keep them in place. Finish with two coats of black insulating varnish (Westinghouse Catalog No. 414 Varnish).

Westinghouse tan treated cloth No 1266, one inch wide, .010 inch thick, is carried in stock in 36 yard rolls and is, therefore, available for quick shipment. It is made from high grade materials and is cut on just the angle and with the right amount of tack needed to assure a good, smooth, uniformly taped job.

Good results can also be secured by covering the buses and connections with tubing, angles or channels, made of Micarta. Round tubing can be used to advantage in covering bare wire or rod, whereas rectangular tubing, angles and channels can be used for covering copper bar. Where bends occur in the conductors, short lengths of these materials can be used on the straight runs and the bends or elbows insulated with tape.

## Ground Connections

**General**—A good and reliable ground connection is necessary for every switchboard installation. It should be of sufficient capacity to take care of any abnormal conditions that might occur on the system, and should be independent of the grounds for lightning arresters and other apparatus.

**Instrument Cases, Switchboard Frames and Associated Structures**—The established regulations for all a-c. switchboards, regardless of the service voltage, are that the cases of instruments, meters and relays, frames and associated structures be grounded.

All d-c. switchboards having one side connected directly to ground, for example a railway switchboard, should have cases, frames and associated structures insulated from ground. In general, they should be grounded for other d-c. switchboards.

In mixed switchboards, for example one having both a-c. and railway panels, a literal interpretation of the safety code requires that the a-c. panel frames and associated structures be grounded and d-c. panel frames and associated structure be insulated. It will, however, often be preferable to insulate the entire panel framing of a mixed board even though the associated a-c. structure is grounded. Such cases should, however, always be checked to make sure that the arrangement selected is in accordance with local requirements.

It should always be remembered that when panel frames are grounded, the cases of the instruments, meters and relays should be grounded and vice versa.

All multi-section control desks are provided with a ground bus. Also, multi-panel switchboards have them when they are required. It is bolted directly to the rear flanges of steel panels as shown in Fig. 20. Brackets are used to support the ground bus for switchboard assemblies having pipe or angle iron frame. When erecting the equipment in the field, care must be taken to see that good electrical contact is made between this bus and the panel or desk frame. The secondary wiring ground connections must also be made to it as shown in the wiring diagram. Ground connections for single panels are made directly to the frame.

**Instrument Transformer Secondaries, Oil Circuit Breaker Frames, Conduit and Cable Sheaths**—These should be grounded in accordance with information given with the installation instructions for this equipment.

**Temporary Grounds**—Work on current carrying parts should not be undertaken until these parts have been disconnected from the system and connected to the ground bus. Provision should, therefore, be made by the Purchaser for connecting flexible ground leads so as to reach every part of the switching equipment.

## Method of Determining Phase Rotation

**General**—When connecting two systems together it is essential that their phase rotations are the same. Also in connecting power factor meters, reactive factor meters, reverse power relays, etc., it is necessary to see that the phase rotation is in accordance with that indicated on the wiring diagram.

This cannot be checked from the direction of rotation of the equipment itself since the physical direction of rotation of any given piece of apparatus is not necessarily the same as the direction of the phase rotation.

In the case of a power factor meter or reactive factor meter, this can readily be checked by following the directions given on the instruction cards for these instruments and this will serve as a check on the balance of the apparatus.

**Lamps and Inductive Load**—Another method of determining phase rotation is by means of two lamps and an inductive

**Table F—Cambric Tape Required for Different Voltages and Shapes of Conductors**

| Voltage Range | *Number of Half-Lapped Layers | Amount of 1-inch Cambric Tape in Yds. per Lineal Foot of Conductor: Rod ½" | Rod 1" | Bar ¼" x 2" | Bar ¼" x 4" |
|---|---|---|---|---|---|
| 0—1,000 | 3 | 3.52 | 6.6 | 9.5 | 17.5 |
| 1,001—2,000 | 4 | 4.78 | 9.0 | 12.9 | 23.5 |
| 2,001—3,000 | 4 | 4.78 | 9.0 | 12.9 | 23.5 |
| 3,001—4,000 | 5 | 6.17 | 11.4 | 16.4 | 29.7 |
| 4,001—5,000 | 6 | 7.65 | 13.9 | 19.9 | 36.0 |
| 5,001—6,200 | 7 | 9.25 | 16.5 | 23.6 | 42.3 |
| 6,201—7,600 | 8 | 10.1 | 19.2 | 27.4 | 48.8 |
| 7,601—8,800 | 9 | 12.7 | 22.1 | 31.3 | 55.3 |
| 8,801—10,000 | 10 | 14.5 | 24.8 | 35.3 | 62.0 |
| 10,001—11,600 | 11 | 16.4 | 27.9 | 39.4 | 68.8 |
| 11,601—13,400 | 12 | 18.4 | 30.8 | 43.7 | 75.7 |
| 13,401—15,400 | 13 | 20.5 | 34.0 | 48.0 | 82.7 |
| 15,401—17,400 | 14 | 22.6 | 37.1 | 52.5 | 89.8 |
| 17,401—19,400 | 15 | 24.9 | 40.0 | 57.0 | 97.0 |
| 19,401—21,200 | 16 | 27.2 | 43.8 | .... | .... |
| 21,201—23,200 | 17 | 29.6 | 47.2 | .... | .... |
| 23,201—25,000 | 18 | 32.1 | 50.8 | .... | .... |
| 25,001—26,800 | 19 | 34.7 | 54.5 | .... | .... |
| 26,801—28,000 | 20 | 37.2 | 58.0 | .... | .... |
| 28,001—30,400 | 22 | 42.9 | 65.6 | .... | .... |
| 30,401—32,800 | 24 | 48.8 | 73.7 | .... | .... |
| 32,801—35,200 | 26 | 55.0 | 82.0 | .... | .... |
| 35,201—37,600 | 28 | 61.6 | 90.6 | .... | .... |
| 37,601—40,000 | 30 | 68.5 | 99.5 | .... | .... |

*Each half-lapped layer equals two thicknesses of tape. As an example for the 1001—2000 voltage range, 4 half-lapped layers are required. This is equal to 8 thicknesses of tape.

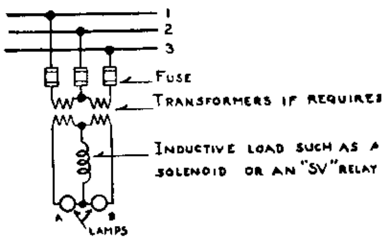



Fig. 76—Method of Determining Phase Rotation Using Lamps and Inductive Load.

load connected as shown in Fig. 76. When so connected, one of the lamps will be brighter than the other. If lamp A is brighter than lamp B, phase rotation is counter clockwise, i.e., 1-2-3. Conversely, if lamp B is brighter than lamp A, phase rotation is clockwise i.e., 3-2-1.

On special order the Company can supply complete equipment of lamps and reactance mounted in a compact and convenient portable form for checking phase rotation.

**Three-Phase Motors**—When making connections to starting taps for induction motors and self-starting synchronous motors or converters, it is often difficult to check the relative phase rotation on the starting and running positions. This is, however, of the utmost importance since it is obvious that if with the switch in the starting position, tendency to rotate is in one direction and the opposite when the switch is thrown to the running position, the apparatus would probably be seriously damaged when operation was attempted.

Phase rotation can be checked in this case by the lamp and inductance method as previously described, or it may be more convenient to use a small three-phase motor connected to the running side of the switch as shown in Fig. 77. If the motor rotates in the same direction when the switch is thrown to the running position that it did when the switch was in the starting position, it is evident that the connections are consistent.

## Checking and Testing Connections

**Installation Tests**—After the switching equipment together with the apparatus which it is to control has been installed and all interconnections made, it should be given a final check and test before being put into service. This is necessary to insure that the equipment has been correctly installed and that all connections are complete. Extreme care must be exercised to prevent the equipment to be controlled from being connected to the system while the preliminary tests are being conducted. If disconnecting switches are not available, the line leads should be disconnected to accomplish this.

**Testing Equipment Required**—The testing equipment required will depend entirely on the type of installation. Portable voltmeters—both a-c. and d-c.—with a wide range of scales will usually be required. If the equipment to be put into service is quite extensive and complicated, both a-c. and d-c. ammeters should be available in case unexpected trouble develops.

Some simple portable device for ringing or lighting out circuits should be included in the testing equipment. A magneto is used for the former. A convenient method for the latter is to add a solid contact point to the "lens end" of a flashlight. At some other convenient place on the flash light add a binding post. The battery and lamp should be connected in series between the contact point and the binding post. One end of a flexible wire, four or five feet in length, can be attached to the binding post and the other end provided with a spring clip for quickly attaching to the point to be tested. Touching the contact point at the other end of the circuit whose continuity is being checked should complete the circuit through the lamp. The lamp lighting will indicate that the circuit is intact.

**Checking Connections on the Switchboard and To Devices Apart From It**—Although the inspection and tests given the switching equipment at the factory insures that all the connections on the switchboard are correct and in good order when it leaves there, they should be examined to make sure that they have not been loosened or damaged during shipment or installation. All bolted connections and joints should be tightened to insure good contact.

After installation, the connections to the equipment apart from the switchboard such as instrument transformers, circuit breaker operating mechanisms, auxiliary switches, etc., should either be rung or lighted out to make sure that they are also correct. The extent to which this will have to be done depends on the thoroughness of the installation work. There must, however, be definite assurance that all connections are correct before an attempt is made to operate the equipment.

**Checking Operation**—In order to show up any errors in the installation, the different parts should be tried out by putting current through them at reduced voltage. This procedure should be continued progressively until all parts have been proved. Any incorrect operations during this trial period should be carefully noted and steps taken to remedy them.

**Care of Covers for Instruments, Meters, Relays and Other Devices During Test**—The covers for instruments, meters, relays and other devices which have to be removed during the course of installation and test should be carefully stored when removed from their normal positions. Since these are made either partly or entirely of glass, they may be broken if not properly protected. If something, such as the end of the working day, temporarily stops the test work, all covers should be put in place to keep dust and dirt from collecting on the vital parts of the equipment.

### Record Drawings

As soon as the switchboard has been installed and put into operation, the drawings supplied with the equipment should be gone over and notations made on them of any deviation made during the installation, such as changes in the order of panels, distance to wall, direction of cables, electrical connections, etc. A set of these should be returned to the Company so that the tracings can be changed for permanent record. Obviously, this is necessary in order that there will be no confusion in handling future orders for changes or extensions.

## General Operating, Inspection and Maintenance Suggestions

**Operating**—When starting up a station, a careful check should be made to see that all switches and circuit breakers are open and that all parts are in good operating condition. Prominently marking the names or numbers of the circuits on the operative devices, will often avoid confusion, especially when the station is started for the first time, and will be of considerable help to new operators.

The premises, particularly the switchboard room, should be kept clean. Compressed air or a hand bellows very often answers for cleaning the switchboard, especially the rear. The fronts of the panels can be cleaned in accordance with the instructions in the section on Refinishing, Cleaning and Repairing Switchboard Panels.

**Inspection and Maintenance**—In order to obtain satisfactory operation from switching equipment, it must have proper inspection and maintenance. The inspection must be done systematically and at regular intervals by experienced men and should cover all the devices and connections. Obviously, when making these inspections, extreme care must be exercised and that no cir-

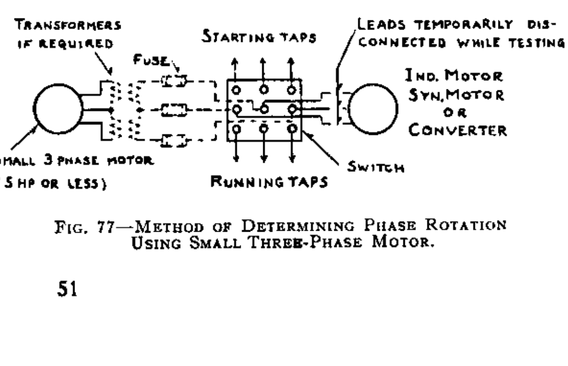



Fig. 77—Method of Determining Phase Rotation Using Small Three-Phase Motor.

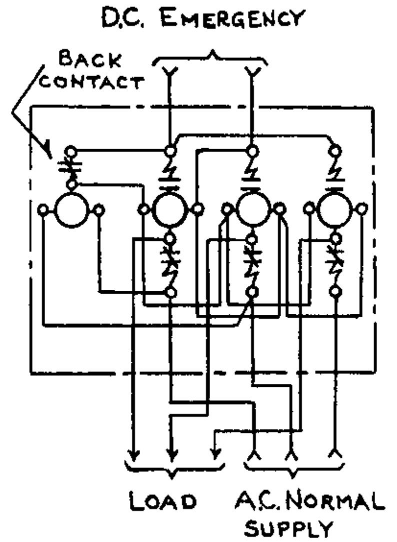



FIG. 78—DIAGRAM OF AUTOMATIC THROW OVER SWITCH. ALL CONTACTS ARE SHOWN FOR DE-ENERGIZED CONDITION OF COILS.

cuits are shorted or grounded and that the inspector experiences no personal harm. Any defect which is discovered should be corrected immediately.

Prints of all drawings and copies of all instruction books, cards, and leaflets should be readily available so that in case of trouble, the maintenance man can refer to them for such detail information as may be required to correct the situation.

**Frequency of Inspection**—The size and nature of the installation will determine to a large extent how often the equipment should be inspected. The thoroughness and care with which the inspector does his work may make frequent inspection unnecessary, while on the other hand, hasty and haphazard inspection will eventually result in trouble even if made once a week. Inspectors should, therefore, be thoroughly instructed and experienced in both the function and the adjustment of the various devices and should have a uniform method of making the inspection. Good results can very often be obtained by furnishing the inspectors with detail lists covering points which have to be checked and reported on at stated intervals.

**Equipment Which is Not Put Into Service Immediately After Installation**—Occasionally, switching equipment is not put into service until several weeks after the installation work has been completed. In such instances, it is extremely important that the equipment be maintained in good condition, so that no difficulty will be experienced when operation is started.

## Renewal Parts

In order to insure continuity of service, renewal parts should be ordered before they are actually needed. To facilitate ordering these, a recommended list of renewal parts will be furnished on request. This list, in addition to style numbers, will give the number of pieces that should be carried in stock based on the number of devices in service.

Renewal parts should be kept in perfect condition and where they can be instantly found when needed. A systematic record should be kept of the number on hand and additional parts reordered when the available stock is reduced to an established minimum.

## Illumination of Switchboard

Both the front and rear of the switchboard should be amply illuminated by the station lighting system. It is suggested that this include some emergency circuits so that the switchboard room cannot be put in darkness under any abnormal condition.

In stations having storage batteries, this can be accomplished most easily by use of automatic throw-over switches, which, on failure of the normal line circuit, throw a number of lights on to the battery. Fig. 78 is a diagram of connections of such a switch. The company has a number of standard designs of throw-over switches which can be furnished on order.

## Storage Batteries

**General**—It is not intended to give here information relative to selection, unpacking, installing and maintaining the battery since the battery manufacturer's instructions are very specific and should be carefully followed. It should be noted, however, that when the station is being laid out, a definite place should be provided for the battery. A few general suggestions are given which should be followed in selecting and preparing a location for it.

**Battery Room**—For the sealed jar type of cell, a separate battery room is not essential. The open type cell, however, should be installed in a separate room which is both well lighted and well ventilated. If the location is such that direct sunlight will fall on the cells, the windows should be coated with an opalescent paint. If natural illumination is not possible, the room should be well provided with electric lights. The battery should be located so that all cells are readily accessible for adding water necessary to replace loss from evaporation.

The room should be dry and with a temperature as near 70° F. as practical. High temperatures (above 80° F.) should be avoided, insofar as possible. Low temperatures reduce the battery capacity, but are not harmful. **SINCE THE GASSES GIVEN OFF DURING CHARGING FORM AN EXPLOSIVE MIXTURE, AN EXPOSED FLAME SHOULD NEVER BE BROUGHT NEAR THE BATTERY.**

There should be as little exposed piping and iron work in the battery room as possible, particularly near the floor. At the floor level and for the first four or five feet, it is especially necessary that the iron work be protected with asphaltum paint. If radiators or coils are present, they should be located as high as possible from the floor and protected with asphaltum paint also. On ceilings and walls above the top level of the cells, a good white lead, linseed-oil paint should be used. The white walls and ceiling will materially assist in illumination of the room.

## Electrical Clearances

Tables G and H give minimum electrical clearances used in the design of Westinghouse switching equipment. Values for striking and creeping distances are given in Table G both for systems rated up to 150 Kv-a. and also for those above this. All secondary connections from instrument transformers are classified as less than 150 Kv-a. capacity. The values apply to connections and bare parts mounted on switchboards but do not apply to individual pieces of apparatus.

Where one side of a circuit is permanently grounded, the clearance class for parts of opposite polarity should be used. For voltages above 3500, all live parts should be supported on insulating pillars.

Clearances in Table G do not apply within the proximity of an electric arc. Where arcs are likely to occur, non-combustible barriers should be used for voltages above 250 volts d-c. or 480 volts a-c.

Voltage limits for panel materials are:

Slate up to 750 volts.

Marble up to 2500 volts.

Micarta and ebony asbestos up to 3500 volts.

Voltage classes up to 69,000 volts are maximum allowable. Voltages above 69,000 are nominal and a variation of plus or minus 5% may be allowed without changing the values given.

## Insulating Oil

**General**—The insulating oil furnished by the Company has been developed after many years of research work in cooperation with the oil refiners. In response to requests from customers for a reduction in the number of grades of insulating oil used in electrical apparatus, the Universal Wemco C oil has been developed which is particularly well adapted for all Westinghouse oil insulated apparatus such as oil circuit breakers, transformers, induction feeder regulators, etc.

The insulating oil is just as much a part of the apparatus in which it is used as any of the other materials which are built into the apparatus. In order to insure the performance guaranteed for the apparatus, only the insulating oil furnished by the Company should be used.

As all oil is subject to deterioration in service even under the most favorable conditions, it is essential to provide for periodic inspection and test, and to purify the oil whenever it is necessary in order to maintain it in good condition.

The more handling which an insulating oil receives, the greater the opportunity for contamination unless adequate precautions are taken.

A few general instructions are given in the following relative to the care of insulating oil. See Instruction Book 5336—Westinghouse Insulating Oil for Electrical Apparatus—for complete instructions for storing, handling, inspecting, testing and purifying of insulating oil.

**Shipment**—Universal Wemco C oil is shipped in tank cars, drums and cans. The modern tank cars are usually lagged to prevent rapid fluctuations in temperature during transit and thus reduce the amount of expansion and contraction of oil. Changes in the volume of the oil due to temperature variations tend to cause breathing in of moist air resulting in condensation of moisture inside the tank and lowering of the dielectric strength of the oil.

The drums are provided with screw bungs having gaskets to prevent admission of water. The oil and the drums are both heated above room temperature while the drums are being filled, and the bungs are tightened immediately after filling. After cooling to normal temperature, the bungs are again tightened.

When filling cans, they, as well as the oil, are heated above room temperature and are hermetically sealed immediately after filling.

**Storage**—It is possible for bungs to become loosened by change in temperature or rough handling in transit. As soon as a drum of oil has been unloaded the bung should be examined and tightened if it is loose.

It is very desirable that oil in drums be stored in a closed room. Outdoor storage of oil is always hazardous and should be avoided if at all possible. If it is necessary to store it out of doors, protection against direct precipitation of rain or snow should be provided. Drums stored out of doors should be placed on timbers so as to be clear of the ground. They should always be placed on their sides and never turned up on end. The bungs should be turned at an angle of about 45 degrees from the top. It is recommended that the drums be covered with tarpaulin.

Cans containing oil must not be exposed to the weather. They should not be unsealed before the oil is actually needed. It is not necessary to make dielectric tests on oil in sealed cans.

Screw caps are provided on the cans, for use where the contents are only partially used after the hermetic seal is broken, to prevent contamination with moisture or dirt.

**Placing Oil in Service**—The most careful precaution must be taken to insure absolute dryness and cleanness of the apparatus before filling it with oil, and to prevent the entrance of water and dirt during the transfer of the oil to the apparatus.

When putting a new circuit breaker or transformer into service, see that the tank is free from moisture and foreign material. When carbonized or sludged oil is removed from a circuit breaker or transformer in service, thoroughly clean the interior of the apparatus so that the new oil will not be contaminated. This may be done by flushing with clean insulating oil and wiping with clean dry lint-free cotton cloths. Cotton waste is undesirable for this on account of the lint which may be introduced into the oil.

All vessels used for transferring the oil should be carefully inspected to see that they are absolutely dry and free from dirt.

**Table G—Minimum Clearance in Inches Between Live Parts or Bare Conductors**

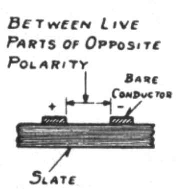
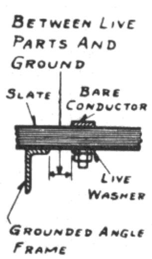
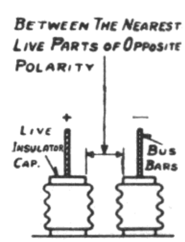
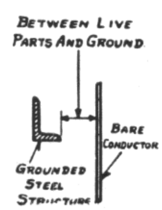
| Creeping Distances on Surfaces | | Voltage Class | Striking Distances Through Air | |
|---|---|---|---|---|
|   |   | For Intermediate Voltages, Use the Distance Given for the Next Higher Voltage Class |   |   |
| Indoor Application on Circuits Connected to Systems up to 150 Kv-a. Capacity or Wiring Connected to the Secondary of Instrument Transformers | | | | |
| 3/8 | 1/4 | Up to 50 | 1/4 | 1/8 |
| 1/2 | 3/8 | 125 | 3/8 | 1/4 |
| 5/8 | 1/2 | 250 | 3/8 | 1/4 |
| 1 | 3/4 | 600 | 1/2 | 3/8 |
| 1 1/4 | 1 1/4 | 750 | 3/4 | 3/4 |
| 1 3/4 | 1 3/4 | 1500 | 1 1/4 | 1 1/4 |
| Indoor Application on Circuits Connected to Systems Above 150 Kv-a. Capacity | | | | |
| 1 | 1/2 | 125 | 1/2 | 3/8 |
| 1 1/4 | 5/8 | 250 | 3/4 | 3/8 |
| 2 | 1 | 600 | 1 | 1/2 |
| 2 1/8 | 1 1/4 | 750 | 1 1/4 | 3/4 |
| 2 1/2 | 1 3/4 | 1500 | 1 3/4 | 1 1/4 |
| 3 | 2 1/2 | 2500 | 2 1/2 | 2 |
| 3 1/2 | 3 | 3500 | 3 | 2 1/2 |

**Table H—Minimum Clearances in Inches Between Live Parts or Bare Conductors in Air**

For Rigid Conductors Only when Supported Clear of Surface.
For Flexible Conductors Increase Clearances Given by Twice the Maximum Sag.
Small Spacings may be used for Standard Apparatus When all Parts are Shaped to Minimize Electrostatic Stresses.

| Indoor | | Voltage Class | Outdoor | |
|---|---|---|---|---|
| (See Fig. 79) Phase to Phase X | (See Fig. 79) To Ground Y | For Intermediate Voltages, it is Advisable to Use the Distance Given for the Next Higher Voltage Class | (See Fig. 79) Phase to Phase X* | (See Fig. 79) To Ground Y* |
| | | Up to 3,500 | 6 | 6 |
| 3½ | 2½ | 5,000 | 6 | 6 |
| 4 | 3¼ | 7,500 | 6 | 6 |
| 7 | 5½ | 15,000 | 12 | 9 |
| 11 | 8½ | 23,000 | 17 | 13 |
| 16 | 12 | 34,500 | 24 | 18 |
| .. | .. | 46,000 | 32 | 23 |
| .. | .. | 69,000 | 44 | 32 |
| .. | .. | 92,000 | 55 | 40 |
| .. | .. | 115,000 | 67 | 50 |
| .. | .. | 138,000 | 81 | 59 |
| .. | .. | 161,000 | 94 | 68 |
| .. | .. | 196,000 | 111 | 82 |
| .. | .. | 230,000 | 130 | 95 |

* All dimensions are minimum. More clearance than shown may be necessary to meet local conditions.

The preparation and filling of outdoor apparatus should preferably be done on a clear, dry day. If this is not possible, protection against water must be provided.

Rubber hose must not be used in handling oil. Always use metal hose. Oil can easily become contaminated from the sulphur in rubber and should not be allowed to come in contact with it.

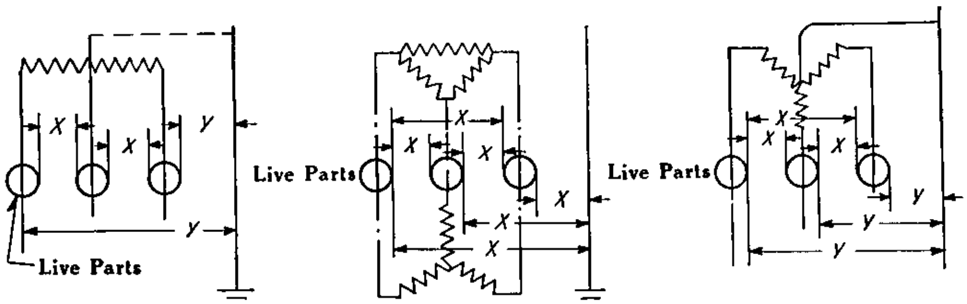
**Temperature Of Oil**—A drum of cold oil when taken into a warm room will "sweat", and the resulting moisture on the surface may mix with the oil as it flows from the drum. Before breaking the seal the drum should, therefore, be allowed to stand long enough to reach room temperature, which may require eight hours, or even longer under extreme temperature conditions.

**Straining Oil**—Although the drums and tank cars are thoroughly washed and dried at the refinery before filling, a certain amount of scale is sometimes loosened from the inside in transit. Therefore, oil which has not been filtered should be strained through two or more thicknesses of muslin, or other closely woven cotton cloth which has been thoroughly washed and dried to remove the sizing. The cloth may be stretched across a large size funnel and should be renewed as often as necessary.

**Inspecting and Testing**—The oil should be sampled and tested before being transferred to the apparatus and again before the apparatus is put into service. Complete information for doing this is given in I.B. 5336.

Periodic inspection and tests should be made so that the oil can be renewed when necessary. The frequency of these will depend on the service to which the apparatus is subjected. Circuit breakers which are called upon to open the circuit frequently under heavy loads require much more frequent inspection and purification of the oil than those subjected to lighter duty.

It is recommended that operators prepare a schedule for inspection based on the operating conditions. Reference to the station log, together with the record of dielectric tests of the oil should determine the frequency of inspection and test. The period between successive inspections should never be longer than six months. When the dielectric strength




Single Ph. or Quarter Ph. with Neutral Grounded or Ungrounded.

Three Ph. Delta or Star Connected Ungrounded.

Three-Phase Star Connected Grounded Neutral

Fig. 79

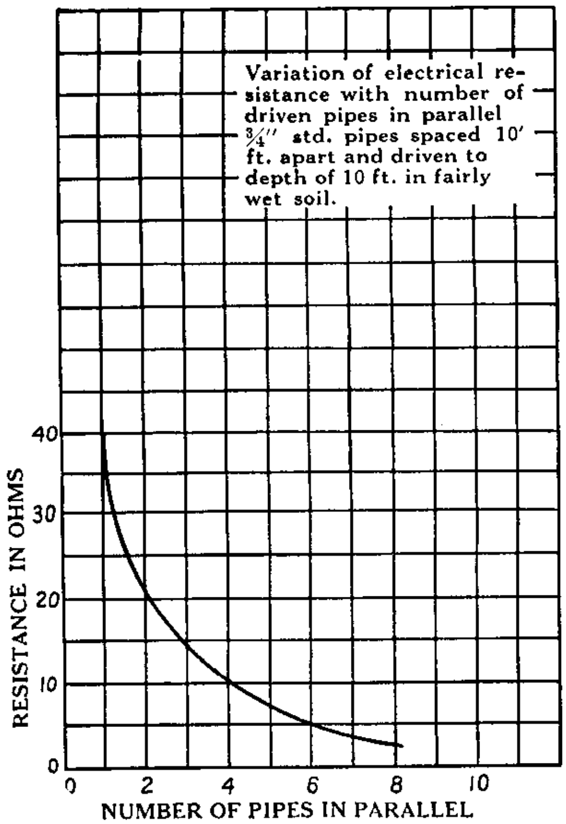



FIG. 80—VARIATION OF ELECTRICAL RESISTANCE WITH DRIVEN PIPES USED IN PARALLEL.

of the oil drops to 20 Kv., in the standard dielectric test the oil should be looked upon with suspicion and in no case should it be allowed to drop below 18 Kv.

**Oil Testing Service**—Many users of oil circuit breakers and transformers do not have the necessary equipment for testing insulating oil. Although the Company manufactures a special test ing device for this purpose, an oil testing service has been established for those who do not care to buy the testing equipment. Information regarding this service is given in I.B. 5336 and can also be secured from the nearest Westinghouse Sales Office.

**Extinguishing Oil Fires**—While the Universal Wemco C oil furnished with circuit breakers and transformers will not take fire unless brought to a very high temperature, it should be remembered that under abnormal conditions such a temperature can be reached, so that proper precaution against fire should be taken.

Suitable means should always be provided for drawing off oil from storage tanks and extinguishing fire. The best way to extinguish burning oil is to smother the flames so that the supply of fresh air is cut off. Chemical fire extinguishers may be used but under no circumstances should water be poured on the fire.

## Insulation Tests

Most operators have standing instructions for the periodic testing of insulation either by high voltage or megger. Such tests are recommended so that possible failures may be anticipated. Particular care should be taken to have a separate test made upon any spare equipment which is not in service at the time the regular test is made as it is exceedingly important that this is also maintained in the best condition.

It is recommended that these tests be made every three months where possible. The room temperature and humidity of the atmosphere should be noted and subsequent tests should be made under approximately the same conditions. It is also advisable to p ot a curve of insulation resistance as measured by the megger over a period of years to determine how the insulation is holding up.

It is strongly recommended that a megger test be made, as well as a high voltage test, and that the megger test always be made before the voltage test is applied. No definite rules can be given here for the passing requirements of the megger test as these will vary with the extent, and design of the bus structure, and the number of insulators involved. This emphasizes the value of a year to year chart of insulation resistance so that abnormal readings can be recognized.

Voltage tests for switchgear devices such as breakers, instrument transformers, disconnecting switches, etc., are now listed (or in preparation) for low frequency and impulse voltage flash over values. The latter are based on a standard test wave form and values are listed by the American Standards Association and others, such as the A.I.E.E. and N.E.M.A. High potential tests at 60 cycle are determined from the impulse value and do not have a fixed ratio to the voltage class of the apparatus.

The tabulation of the voltage tests is not yet complete so that it will be necessary to consult up-to-date catalogs for information. Apparatus connected to the same circuit should have the same approximate impulse voltage rating. Application is made according to catalog recommendations. The question of exposure to surge voltage should be given consideration. Where such potentials may occur, gaps or lightning arresters are necessary. Apparatus for unexposed circuits can all be coordinated to the same test voltage, and, in some cases, lower values than for exposed circuits are allowed. Flash overs practically never occur so gaps or arresters are not necessary. In general the more valuable and more difficult to repair apparatus should be at least equal or slightly higher in impulse strength than the other devices.

Periodic field tests on breakers and structures should be made at lower voltages than in the factory. A-c. voltages not exceeding 75 per cent of the published value for one minute should be used and similar tests for the same time interval should be made on transformers but at 65 per cent of the published value.

The A.S.A. Test Code includes some instructions on di-electric tests in the field. These should be referred to for further information.

It is advisable to measure 60 cycle testing voltage by a sphere gap before applying it to apparatus. This insures that the insulation will not be damaged by too high potentials.

Impulse field testing at reduced gap settings, while desirable, is not practical because of the special apparatus required.

Mounted and wired switchboard apparatus is tested at 1500 volts between live parts and ground and between separate circuits regardless of the voltage of the circuit. Equipment such as low voltage annunciators, clocks, telephone circuits and the like, should not be tested at this potential. Supervisory control and telephone apparatus in general can stand 500 volts to ground and between circuits.

## Method of Making Grounds

**Water Systems**—Water piping systems afford by far the best grounding systems obtainable and should be used for grounding purposes where possible. Due to their great extent, water systems have a very low resistance usually only a fraction of an ohm. Furthermore, they are of a very permanent nature and connections to them are generally easy to install and inspect.

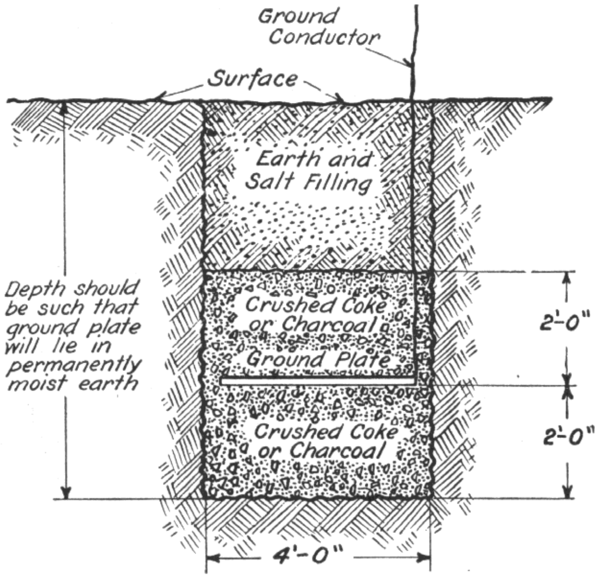



Fig. 81—Method of Making Ground Connections.

Water systems have such a comparatively low ground resistance that where they are in proximity to pipe or plate grounds it has been found that a difference of potential will exist between the two during ground fault conditions, which may constitute a hazard to life unless they are connected together. An additional hazard may also exist when ground current resulting from a fault foreign to the station returns to a piping system which is isolated from the station ground. For safety considerations, therefore, water pipes when adjacent to equipment to be grounded should always form an integral part of the grounding system. Since there is no danger to water pipes of electrolysis by stray alternating-current, the permission to ground to water system should not be difficult to obtain especially in view of the great advantage to the public in the protection of life and the slight disadvantage if any to the water utilities. In making connections to water piping systems it is, of course, advisable to ascertain if the piping is large enough and if the material used in the pipe joints has a low enough resistance and sufficient thermal capacity to carry the maximum possible ground fault currents. Care should also be exercised to electrically connect all parts of the piping system liable to be physically disconnected and to shunt the pipe system where necessary around meters and shut-off stop-cock in order to keep the connection with the underground piping system continuous.

**Pipe Grounds**—In out of the way places where water piping systems are not available it is generally necessary to resort to artificial grounds such as pipe or plate grounds. The present tendency seems to be away from the use of plate grounds and toward the greater use of pipe grounds due principally to the fact that in most cases the same results can be obtained with driven pipes at a much less expense than with plates. Although a single pipe ground has a higher resistance than a single plate ground, a pipe ground resistance of almost any desired value can be obtained by multiple grounding; that is, by connecting numerous pipes in parallel. In this way a ground of a given resistance can be obtained more economically with pipes than with the use of plates, and in addition the multiple pipe ground will have the advantage of providing a well distributed ground which is a very important requirement. Fig. 80 shows the variation in resistance when pipes are used in parallel.

In general ¾-inch pipe is sufficient and should be driven approximately ten feet—not less than six—in moist soil and in all cases should be below the frost line. Where pipes must be driven to greater depth in order to reach the proper soil conditions a 1, 1¼ or 1½-inch may be preferable in order to stand the strain incident to driving.

Galvanized pipe may be used, provided it has a clean surface, presents no grease, paint or other insulating coating. An arrow-pointed pipe tip will expedite driving of the pipe.

As about 90% of the resistance of a pipe ground falls within a radius of six to ten feet around the pipe the best results will be obtained by using a spacing of at least six feet; each pipe is in this manner kept out of the dense current field of the other and a minimum resistance is obtained for the group of pipes as a whole.

The electrical conductance of any soil is by means of the electrolytes formed by moisture combining with the soluble acids, alkalies and salts and where they are lacking their artificial introduction will show excellent results. The periodic introduction of copper sulphate crystals and water in the ends of ground pipes usually gives excellent results. It will not deteriorate the ground-pipes. Where any artificial treatment is used it should be renewed periodically.

**Plate Grounds**—In those cases where pipes cannot be driven and the soil conditions are not of the best, plate grounds may be desirable. One method of making a good plate ground is to dig a hole four feet square until permanently damp earth is reached. See Fig. 81. Cover the bottom of the hole with charcoal about pea size, over this lay ten square feet of tinned copper plate. Solder and rivet the copper ground wire securely across the entire length of the ground plate, cover the ground plate with two feet of crushed coke or charcoal, then fill the hole with earth with plenty of common salt sprinkled in it, using running water to settle. The size of ground wire or cable should be of sufficient current carrying capacity to prevent fusing. Special care is necessary in power stations where the generator neutral points are grounded to have the ground cable of sufficient capacity to carry the current which may flow in case of short circuits or grounds on the system.

**Strip Grounds**—Strip grounds are also very satisfactory where the soil conditions are poor. The strip should be buried in a straight line. This will give the greatest distribution and the most effective ground connections. From the data available on strip grounds it is apparent that after a depth of three feet has been reached, there will not be a further marked decrease of resistance with increasing depth.

**Inspecting and Testing Grounds**—To obtain continuous and reliable service from grounding systems requires a systematic routine inspection and the measurement of the electrical resistance of ground electrodes and all connections comprising the system.

The usual practice is to make these tests at intervals of one year. This can be considered as a satisfactory interval.

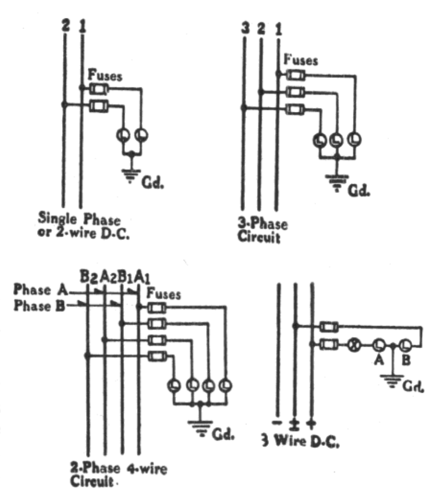



Fig. 82—Diagrams of Ground Detector Equipment Using Lamps. (X) Represents Lamp on Rear of Panel.

since serious deterioration by corrosion—except where chemicals or coke are used—cannot be expected in a single year. The possibility of mechanical injury, however, exists at all times, and visual inspections should be made at shorter intervals in order that any defects which may exist can be corrected at once.

## Ground Detecting Equipment

**When Required**—It is usually necessary to have some sort of ground detecting equipment for any ungrounded system. Direct current railway or mining switchboards, where one side is grounded, three phase, four-wire systems with the neutral grounded or other similar systems with a grounded connection, do not need any ground detector devices. Any ground on a bus or connection not intentionally grounded would, of course, result in a short circuit and the tripping of breakers or blowing of fuses will give all necessary indication.

**Equipment Used**—The standard practice is to use lamps or voltmeters on voltages up to and including 300 volts. This equipment can also be used on voltages up to and including 750 volts provided they are connected to ground through push buttons or ground detector switches. Static ground detectors are used on higher voltages.

The simplest method for low-voltage two-wire systems is to connect two lamps of the system voltage in series across the two wires with a ground connection between the two lamps as shown in Fig. 82. A ground on one side will short circuit and darken the lamp on that side. The same general scheme is used for multi-phase systems.

On a three-wire, direct-current system with ungrounded neutral, three lamps can be connected in series between one outside wire and the neutral, with a ground between the lamp connected to the neutral and the two other lamps. See Fig. 82. The voltage rating of each lamp should be the same as the line-to-neutral voltage. With no ground on the system, each lamp will have one third of the line to neutral voltage impressed on it. With a ground on the outside line to which the ground detector lamps are not connected, all lamps will burn at full brilliancy. If the line to which the two lamps are connected is grounded, the two lamps will go out, and the single lamp will burn at full brilliancy. With a ground on the neutral, the single lamp will go out and the two other lamps will burn at half brilliancy.

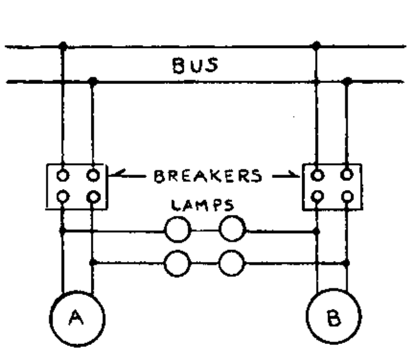



Fig. 83—Connections for Synchronizing Low Voltage Single-Phase Generators.

## Synchronizing

**General**—The fundamental condition necessary when synchronous apparatus is to be connected to a system already in operation is that the electromotive forces of the incoming machine and of the system to which it is connected shall be approximately the same at each instant. This requires that the frequencies be the same; that the two voltages be equal, as indicated by a voltmeter; and that the two voltages be in phase.

The elementary principle employed in determining when generators are at the same frequency and in phase is illustrated by Fig. 83 in which A and B represent two single-phase generators, the leads of which are connected to the bus-bars by the breakers and two series of incandescent lamps which are connected as shown. As the electromotive forces change from the condition of phase coincidence to that of phase opposition, the flow of current through the lamps varies from a minimum to a maximum.

When the electromotive forces of the two machines are exactly equal in phase, the current through the lamps is zero. As the difference in phase increases, the lamps light up and increase to a maximum brilliancy when corresponding phases are in exact opposition. From this condition the lamps will decrease in brilliancy until completely dark, indicating that the machines are again in phase. The rate of pulsation of the lamps depends upon the difference in frequency, i.e., upon the relative speed. It is usually necessary to place voltage transformers between the main circuits and the synchronizing circuits to reduce the voltage at the switchboard to safe limits, as shown in Fig. 84.

In order to determine whether the lamps will be bright or dark for a given synchronizing connection when the machines are in phase, disconnect the main leads of the first generator at the generator and close in the main breakers of both generators with full voltage on the second generator. Since both machine circuits are then connected to one machine, the lamp indication will be the same as when the main or paralleling breakers are open and both machines are in phase. If the lamps burn brightly and it is desired that they be dark for an indication of synchronism the connections of one of the voltage transformer primaries or one of the secondaries should be reversed. Dark lamps as an indication of synchronism are recommended. The lamps should be adapted for the highest voltage which they will receive, i.e., double the normal voltage.

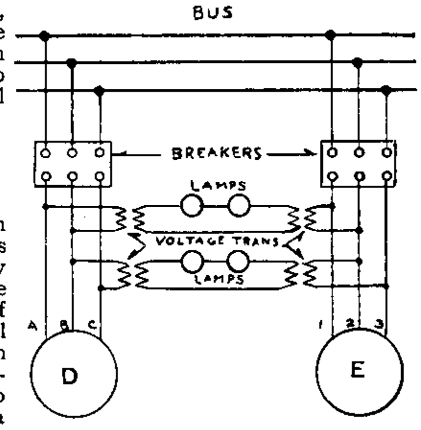



Fig. 84—Connections for Synchronizing Three-Phase Generators.

**Phasing-Out**—In the case of polyphase machines, it is not only necessary that one phase be in synchronism with one phase of another generator but the sequence of maximum values of voltage in the several phases must be the same. The "phase rotation" must therefore be checked before making permanent connections. The necessary connections for two three-phase generators are shown in Fig. 84.

Connect the generators temporarily to their breakers so that the phase of D will be in parallel with those of E. For example, connect phase A-B to 1-2; phase B-C to 2-3; and phase C-A to 3-1. Connect synchronizing apparatus in any two phases as phase 1-2, A-B and phase 2-3, B-C. Test out the synchronizing connections with machine D running at normal speed and voltage, the leads disconnected from E at the generator and the paralleling breaker closed. Having changed the synchronizing connections, if necessary, so that both sets of lamps will be the same when indicating synchronism, open the paralleling switches, reconnect the leads of machine E and bring it up to normal speed and voltage. Then observe the two sets of synchronizing lamps. If their pulsations come together, i.e., if both sets are dark and both are bright at the same time, the phase rotation of the two generators are the same and the connections are correct for paralleling the generators when the lamps are dark. If, however, the pulsations of the lamps alternate, i.e., if one is dark when the other is bright, reverse any two leads of one machine and test out the synchronizing connections again, changing them if necessary so that they are the same when indicating synchronism. The lamps will not be found to pulsate together and the generators may be thrown in parallel at the proper indication. Synchronizing apparatus in one phase only is sufficient for paralleling the generators after the first time.

The procedure in synchronizing a generator with an existing power system is the same, the phase rotation of the generator being changed, if necessary, to agree with that of the system.

The paralleling of two phase generators is accomplished in a similar manner. In case of incorrect phase rotation the two leads belonging to either phase must be reversed instead of any two leads.

**Synchroscope**—A synchroscope is an instrument that indicates the difference in phase between two electromotive forces at every instant. By its aid the operator can see whether the incoming machine is running fast or slow, what the difference in speed is and the exact instant when it is in synchronism. These conditions cannot be observed with certainty by the use of lamps alone and it is usual practice for large machines to have both synchroscope and lamps.

The synchroscope has a pointer which shows the phase angle between the incoming and running machines. This angle is always equal to the angle between the pointer and the vertical position marked on the dial of the instrument. When the frequencies of the two machines are equal the pointer stops at the same position on the scale, and when the machines are in phase the pointer coincides with the marker at the top of the scale.

In order to check the synchroscope connections, proceed in the same manner as previously described for determining whether lamps will be bright or dark for a given synchronizing connection. If the synchroscope pointer stops at the bottom, reverse the leads at the upper terminals. If it stops in the same position the connections to the upper terminals are made to the wrong phase.

Detailed instructions for synchronizing generators, frequency changers, and synchronous converters are given in the instruction books which are shipped with the machines.

## Refinishing, Cleaning and Repairing Switchboard Panels

**Refinishing and Cleaning**—Black marine finished slate, asbestos or steel panels can be refinished by spraying with lacquer. Approximately one quart of lacquer is required to cover ten square feet with two coats. Before applying this, the equipment on the panel should be covered to protect it from the lacquer.

Black marine finish may be removed from a panel by rubbing with a piece of waste which has been soaked in lacquer thinner. Panels can be cleaned by wiping with a chamois skin which has been immersed in luke warm water and wrung partially dry. They may also be cleaned by wiping with a cloth to which naphtha has been applied.

**Plugging Holes in Steel Panels**—If apparatus has been permanently removed from a steel panel, the exposed holes can be plugged by first making a steel plug of the same thickness as the panel material and slightly smaller than the hole to be filled. Next weld it in place, making sure that it is exactly flush with the face of the panel. File or grind and emery both the front and rear until it is perfectly smooth. A coat of shellac should then be applied to the plug and surrounding surface, followed with a coat of sprayed lacquer. After the lacquer has dried, it should be rubbed with 7/0 emery paper, then resprayed and rerubbed until a neatly finished surface is obtained.

**Plugging Holes in Slate or Asbestos Panels**—Holes in black marine finished slate or asbestos panels can be readily plugged with Westinghouse patching cement. When doing this, the first step is to remove any loose pieces of panel material and roughen up the inside of the hole with a file or emery cloth. Next heat the end of a stick of the cement and the spot to be plugged, with a gasoline torch. This is done by holding the flame on the cement with the latter in such a position that the flame is also directed onto the panel. When the end of the stick is softened enough to flow slightly, give the stick a shake to remove the outer layer, which is liable to be burned, and then apply the plastic cement to the hole which is to be plugged. Push the cement solidly into place with a steel rod or other suitable implement. When more cement is needed, the surface of that already applied should be reheated with the torch. Fill the hole from both sides of the panel and smooth with a putty knife. Final smoothing of the cement may be done with a coarse file before the work has cooled completely, or by rubbing with abrasive stone or emery cloth after it has cooled.

The part plugged and the immediate surrounding surface of the panel should then be sprayed with lacquer and rubbed down with very fine sand paper or emery cloth, allowing the lacquer to dry before rubbing down. This spraying with lacquer and rubbing down with emery cloth should be repeated until a satisfactory finish has been secured.

Wooden plugs may be used to help fill the hole. These plugs should be cut in such a manner so as to be an easy driving fit. When a plug is used, a $\frac{1}{8}$-inch space should be left at each end—both at the front and rear of the panel—so that the cement can be applied.

**Drilling Panels**—Occasionally, it is desired to add equipment to an existing switchboard for which no drilling was initially provided at the factory. When this is necessary, standard drills can be used for drilling steel and asbestos panels. Drills ranging in size from No. 7 to $\frac{9}{16}$ inch, when used for slate, have to be specially ground as shown in Fig. 85. The point should be ground the same as when used for iron except that the heel should be entirely ground off. Holes larger than this are drilled with a lead drill, then followed with a standard drill of the proper size.

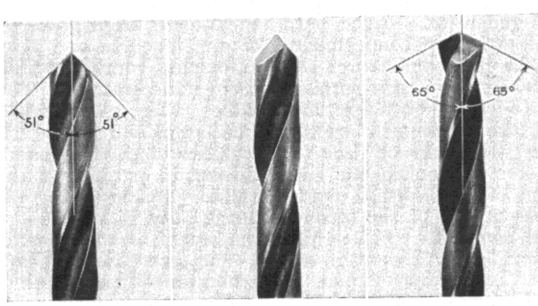


Fig. 85—Properly Ground Drill for Drilling Slate. Three Different Positions of the Same Drill Are Shown.

## Safety First Suggestions

All upturned or protruding nails should be withdrawn or clinched.

Loose nails, screws, bolts, etc., should not be left strewn promiscuously on any floor, scaffold, working platform or other places where persons walk.

Worn out or faulty tools should be promptly discarded.

All temporary openings in the floor should be railed off.

Ladders, temporary platforms and supports should be strong and safe so as to eliminate any possibility of collapse when loaded.

When men are working overhead, the location should be roped off and danger signs placed below.

Rope slings should be checked periodically to make sure that they are in good condition and care taken to see that they are not overloaded.

The links in lifting chains should be annealed frequently when subjected to long hard usage.

Loose clothing should not be worn when working around moving machinery.

Wiping with rags around current carrying parts—either dead or alive—may cause trouble and should not be permitted. Compressed air should be used for such cleaning. The nozzle of the air hose should be insulated and the air filtered.

Where any shock or explosion hazard exists, belts and rapidly moving parts of machines should be grounded to eliminate static electricity. No metal planks or metal belt lacings should be used in the presence of explosive gases or dusts.

Tanks, pipes or drums used in the storage, handling or use of flammable or explosive volatile liquids or oils should

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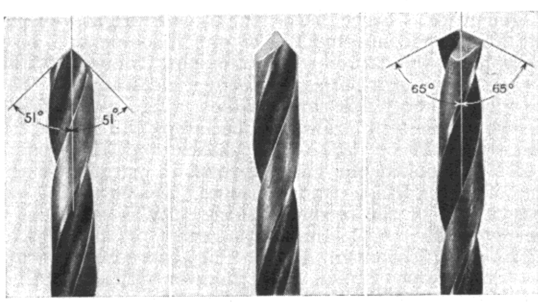
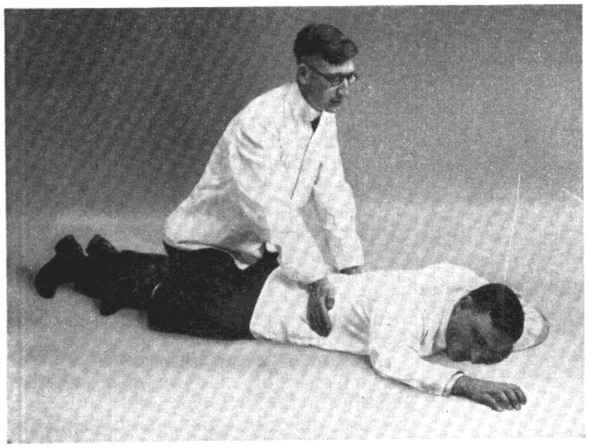
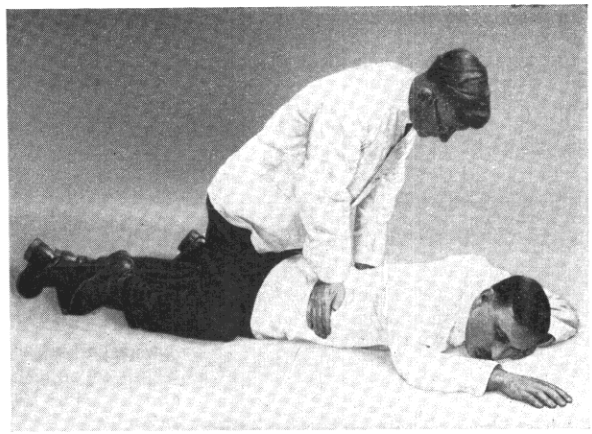



Fig. 85—Properly Ground Drill for Drilling Slate. Three Different Positions of the Same Drill Are Shown.



**FIRST POSITION**

Fig. 86—Place Hands on Victim's Sides with the Ball of the Thumb Resting on the Floating Ribs Well Away from the Spine



**SECOND POSITION**

Fig. 87—With Arms Held Rigid, Swing Your Shoulders Forward Bringing Your Weight to Bear Gradually and Evenly on the Patient Until you Count Three, Then Resume the Original Position as Shown on Fig. 86 while Counting Two. Repeating About Twelve Times a Minute. Victim Should Show Signs of Life in ½ Hour. Note Position of Victim with Head on Side Resting on Left Arm so that Tongue May Hang Out of Mouth

be properly grounded to carry off any static electricity that might be generated.

In case of fire, do not use liquid fire extinguishers until all circuits have been made dead.

Only heavy, reinforced cords should be used for portable lamps and tools. They should be kept well insulated and should be laid or strung so as not to cause a tripping or catching hazard.

Electricians working above ground should always wear safety belts. Rubber gloves should be worn when working on high voltage circuits. Such gloves should be tested daily to detect the presence of holes. Ground chains should be used when necessary.

Wherever possible, no work should be performed on electrical equipment until the current has been turned off. Switches, which have been opened for that purpose, should be locked or blocked open and a suitable warning device placed thereon.

All connections should be considered alive until the men expecting to work on them assure themselves personally that the circuits are dead, and every possible precaution should be taken to see that there is no chance of an operator energizing a circuit while men are working on it.

Only in extreme emergencies should men be permitted to work around live parts and then this work should be performed only by experienced persons. Every precaution should be taken to guard against possible accidents. Tools should be insulated, rubber gloves and mats should be provided, all of which should be tested frequently to insure that they are in good condition.

Many fatal accidents have occurred to persons working around low voltage circuits in which investigation has proven that such fatalities were due to the victims being in poor physical condition. It is, therefore, important to have the physical condition of all men working around live parts checked periodically.

## The Prone Pressure Method of Resuscitation

**General**—Many persons die from electric shock, drowning or asphyxiation from poisonous fumes when a few simple measures might have saved their lives. The victims are seldom killed outright and only need to have their breathing restored artificially.

The prone pressure method of resuscitation is exceedingly simple, easily and quickly learned, and involves the services of but one person and no mechanical apparatus. Employes who are apt to encounter emergencies where resuscitation will have to be resorted to, should be trained in accordance with the instructions outlined in the following. To be effective, the procedure must be carried out by a person who has had previous training.

**Artificial Respiration**—To properly understand artificial respiration, it is necessary to familiarize oneself with normal breathing. As we know, the lungs themselves have very little to do with our breathing. They are just two bags which hold the air that is taken into the body.

The diaphragm is a broad, fan shaped muscle which divides the trunk of the body into two compartments and is the real organ of breathing. In the lower compartment or abdomen are the stomach, intestines, etc.; in the upper, the heart and lungs. These organs in the abdomen are freely movable and are made use of in the Schaeffer prone pressure method of artifical respiration.

The diaphragm has an up-and-down motion like the piston in an engine. This motion is continuous unless something interferes, such as electrical shock, poison gas or apparent drowning, which temporarily paralyzes it, causing breathing to cease.

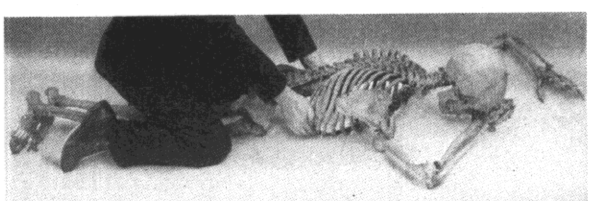


Fig. 88—Only Cover the Two Floating Ribs with the Hands as Shown When Giving the Schaeffer Method of Resuscitation.

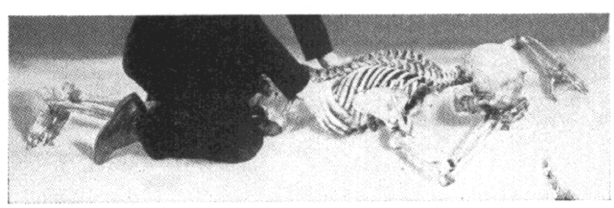


Fig. 89—Do Not Cover All Five Ribs with the Hands as Shown Above When Giving the Schaeffer Method of Resuscitation. See Fig. 88 for Correct Method.

In the prone pressure method, pressure is exerted on the body below the diaphragm, the stomach, intestines, etc., being forced up against it and it in turn forced against the lungs, squeezing them and causing the air to be expelled

Pressure is then released when these organs all drop back to their original position and air is again sucked into the lungs, causing them to refill.

**Method of Operation**—Start treatment immediately and as near the scene of the accident as possible.

The victim should be placed on his stomach, as shown in Fig. 86, with head resting sideways on one arm so that the tongue of its own weight drops out of the throat.

The operator should kneel, straddling the victim well below the waist facing toward the head; his hands on the victim's side, with the ball of the thumb resting on the floating ribs well away from the spine.

The operator should then swing forward with arms rigid, slowly bringing his weight to bear evenly on the patient until he counts three, as in Fig. 87. The original position should then be resumed as shown in Fig. 86 while counting two. Repeat the operation about twelve times a minute.

The fingers and the thumb should be parallel so that they will be on the floating ribs—two bottom ribs—only, as in Fig. 88. If the fingers are spread out, as in Fig. 89, about five ribs will be covered, thus in some degree defeating the purpose.

The treatment should be started immediately; every second is precious as a man can live only about three minutes without air. When help arrives, a doctor should be called. The victim usually shows signs of life within a half hour, but if not, the operation should be continued two hours or more, if necessary, or until stiffening of the body occurs.

When the patient begins breathing without aid, he should be placed on a stretcher, kept warm, and removed to the hospital or his home. Under no circumstance should he be allowed to walk. In all cases, he should be kept in bed for several hours and under observation for not less than 48. Gassed cases should be kept in bed two or three days if possible and be watched very closely for the first 12 hours. In case of relapse, the operation as indicated above should be repeated.

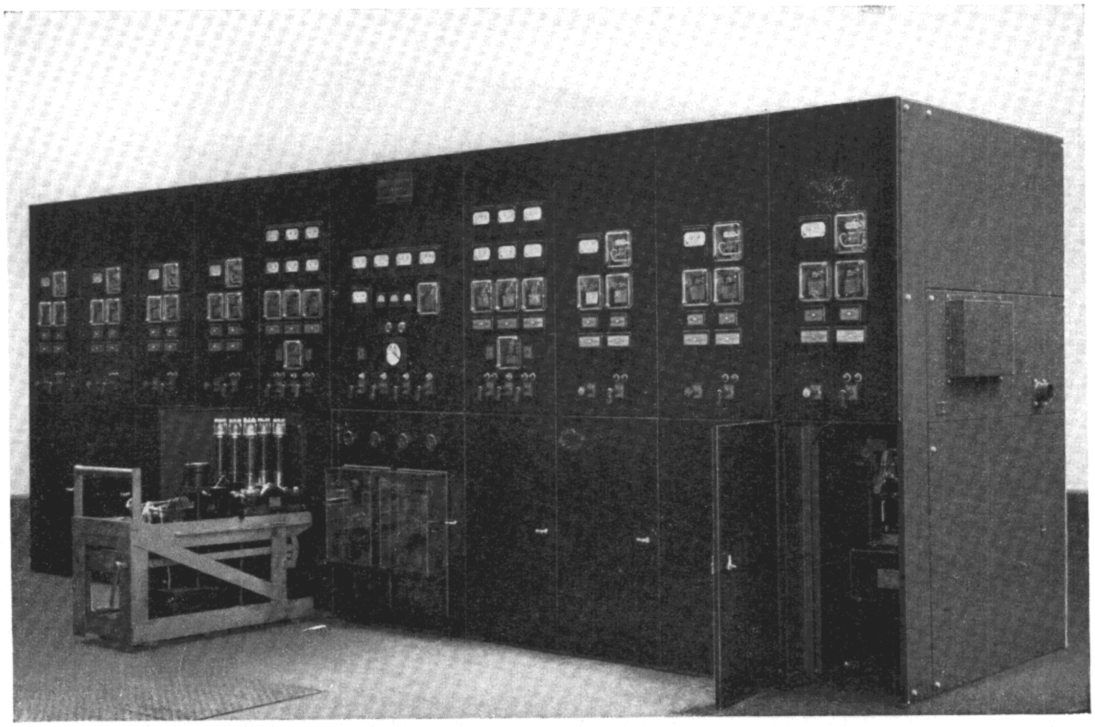


FIG. 90—TYPICAL METAL ENCLOSED STRUCTURE HAVING FRONT ENCLOSURE WITH FLUSH TYPE INSTRUMENTS, METERS AND RELAYS FOR GENERATOR AND FEEDER CIRCUITS. BREAKER AT THE RIGHT IS IN OPERATING POSITION.

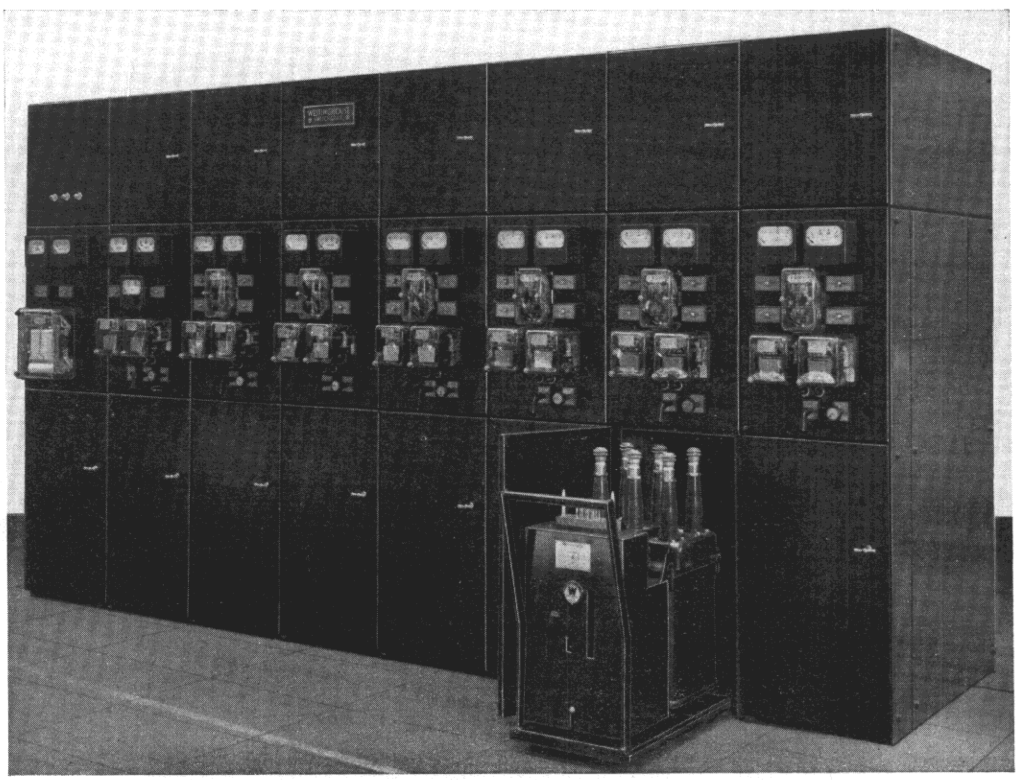


FIG. 91—METAL-ENCLOSED STRUCTURE EQUIPPED WITH PROJECTION TYPE INSTRUMENTS, METERS AND RELAYS FOR FEEDER CIRCUITS; SHOWS ONE BREAKER UNIT REMOVED FROM CELL FOR INSPECTION AND MAINTENANCE.

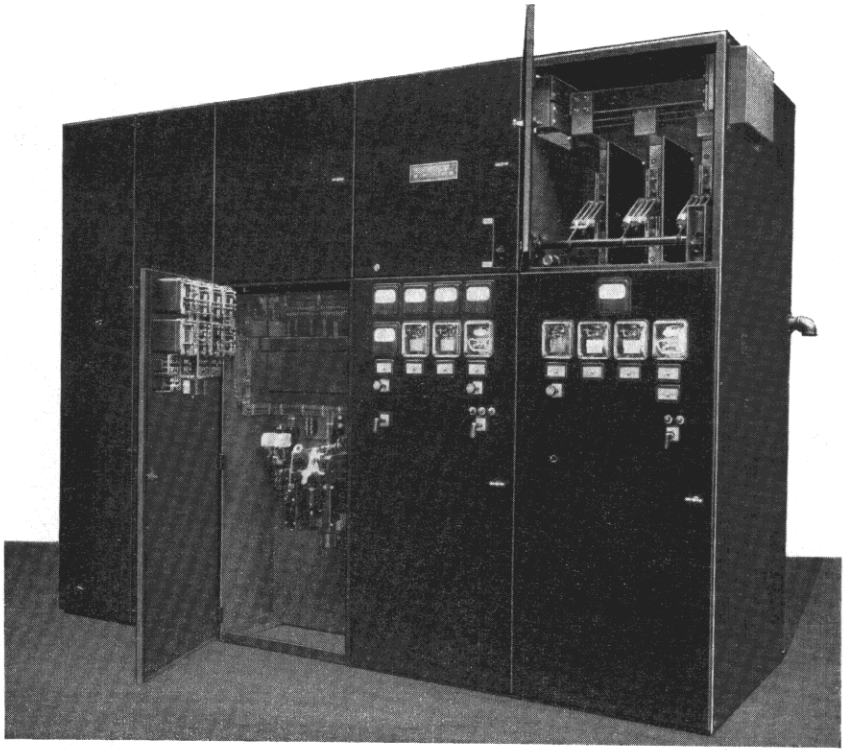


FIG. 92—TYPICAL CUBICLE STRUCTURE WITH INSTRUMENT PANEL AND SUPERSTRUCTURE. HINGED DOORS PROVIDE CONVENIENT ACCESS TO THE CIRCUIT BREAKER AND DISCONNECTING SWITCH COMPARTMENTS.

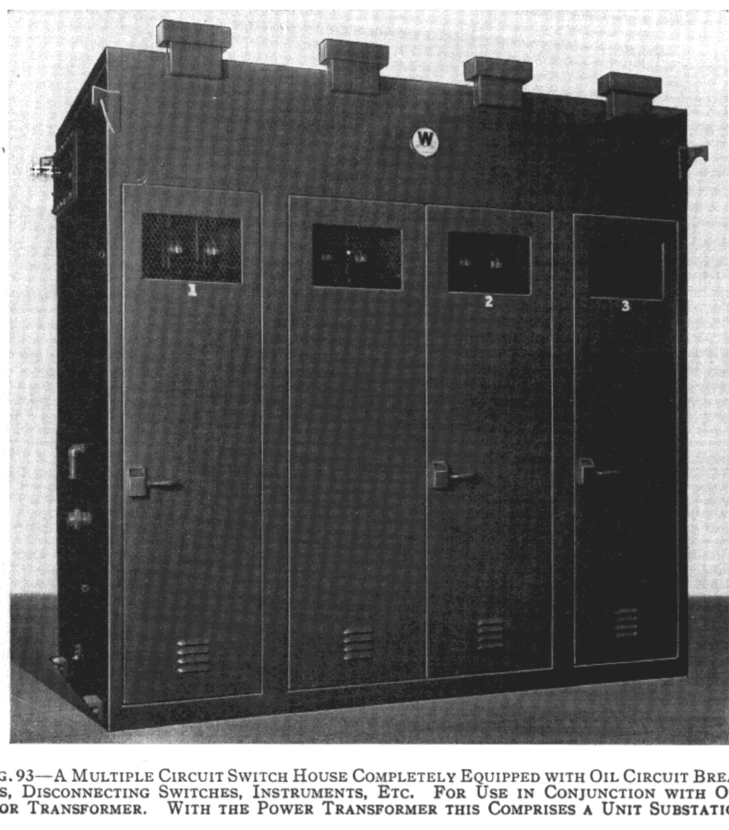


FIG. 93—A MULTIPLE CIRCUIT SWITCH HOUSE COMPLETELY EQUIPPED WITH OIL CIRCUIT BREAKERS, DISCONNECTING SWITCHES, INSTRUMENTS, ETC. FOR USE IN CONJUNCTION WITH OUTDOOR TRANSFORMER. WITH THE POWER TRANSFORMER THIS COMPRISES A UNIT SUBSTATION.

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