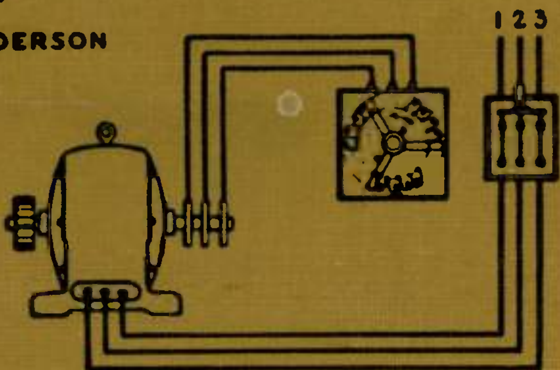
AUDELS

WIRING DIAGRAMS FOR LIGHT AND POWER

by

E·P·ANDERSON



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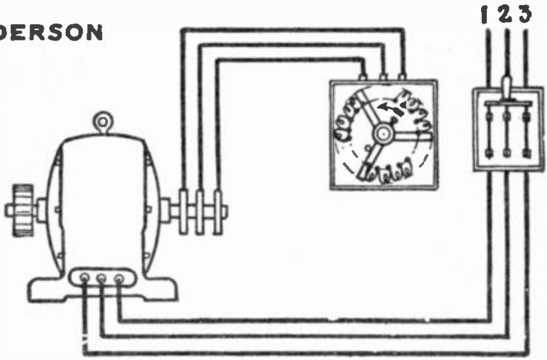

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AUDELS WIRING DIAGRAMS
FOR
LIGHT AND POWER

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Foreword—

THE importance of wiring diagrams of electrical machinery and associated relays and instruments are well known to all electrical workers and students of electricity.

In this book an attempt has been made to bring together a time-saving, well organized, ready reference group of popular connection diagrams, and while it is impossible to cover all possible power system arrangements and operating conditions, attention has been given to the conditions most often encountered in average practice.

Numerous illustrative diagram examples are given, especially in the parts dealing with power transformers and synchronizing connection of alternating current generators, due to the importance of this subject, whenever electric energy is generated and transmitted.

Because other symbols and methods of wiring may be possible in electrically equivalent circuits, great care should be observed when connecting electrical apparatus. The diagrams furnished by the manufacturer of equipment to be installed, should be followed in each individual case.

THE AUTHOR.

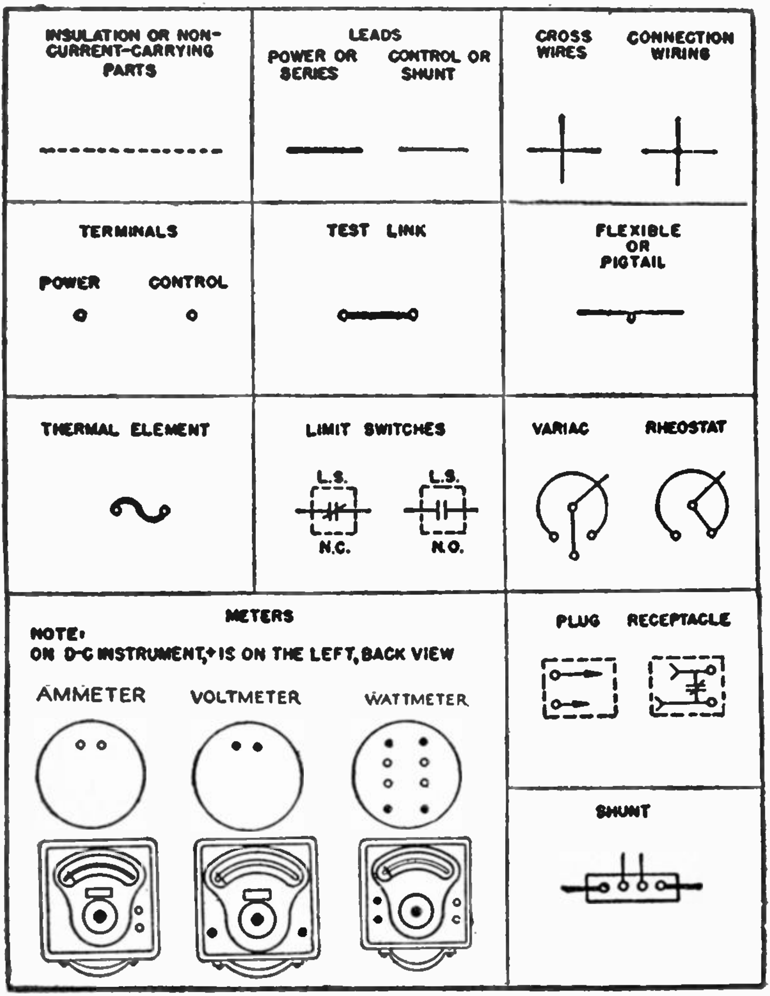
The successful operation of power systems depends upon knowledge of the concerted effects of many interconnected machines.

LIST OF SECTIONS

Note.—Each section consists of a related group of diagrams

WIRING SYMBOLS

WIRING SYMBOLS



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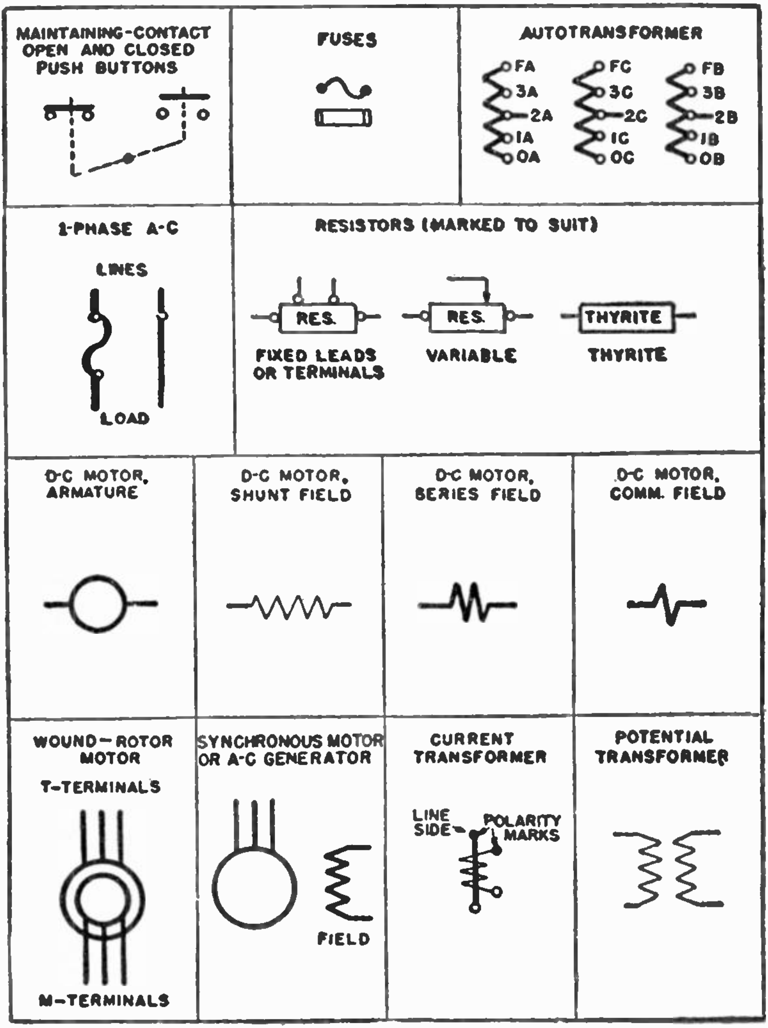

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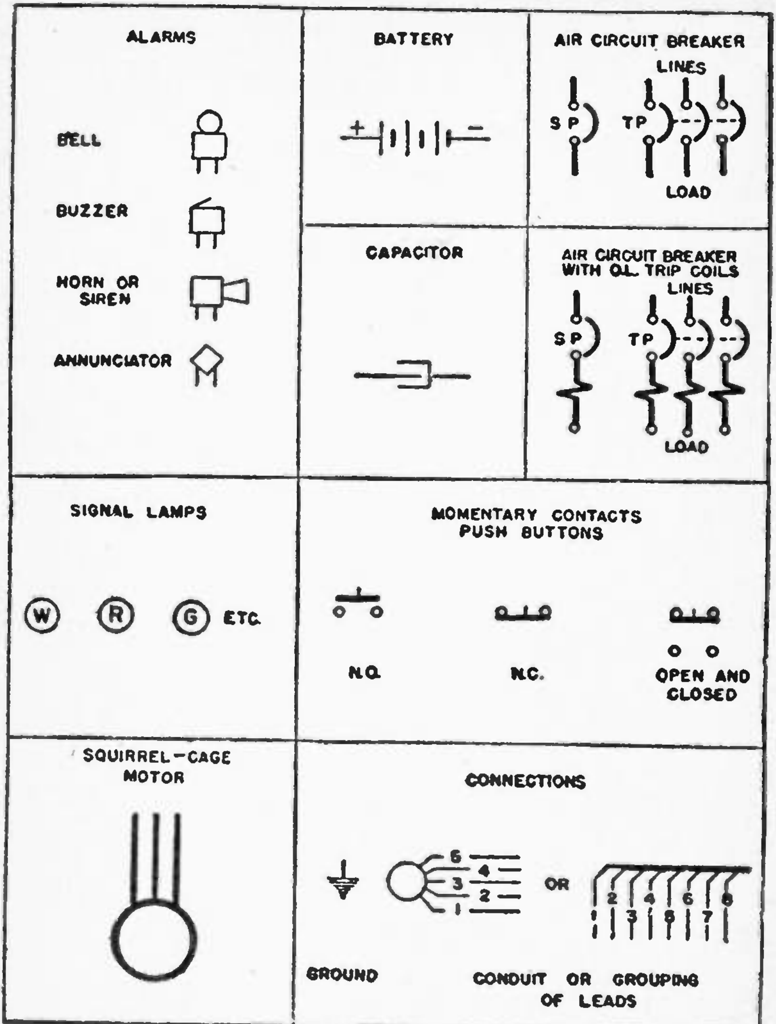

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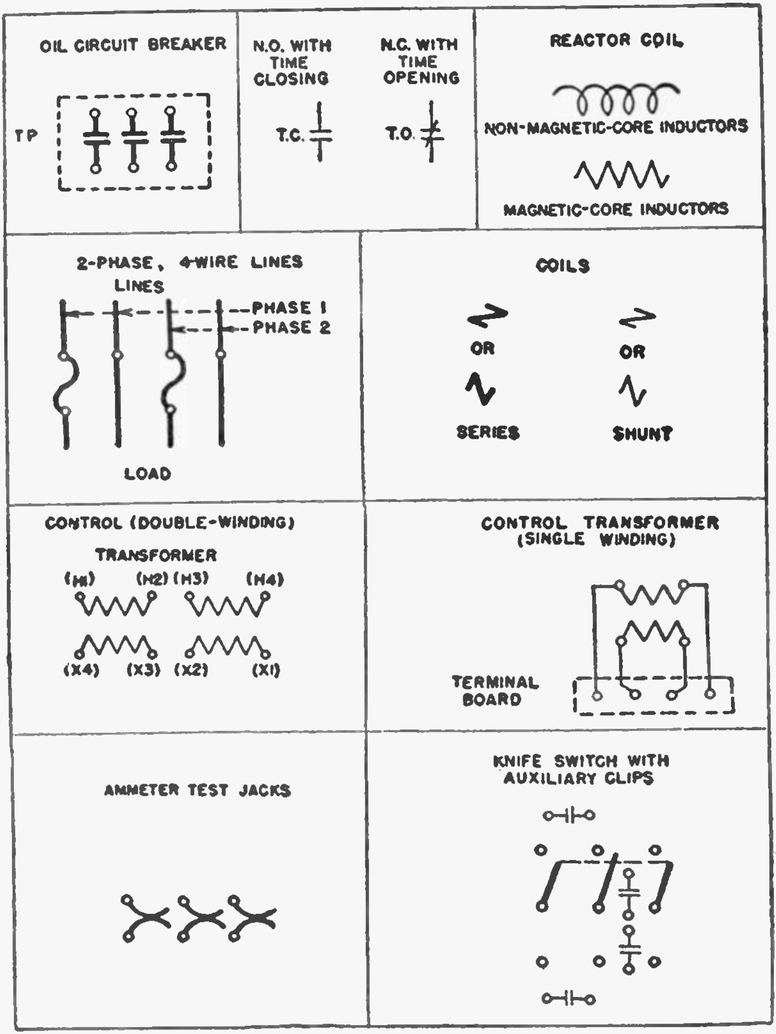

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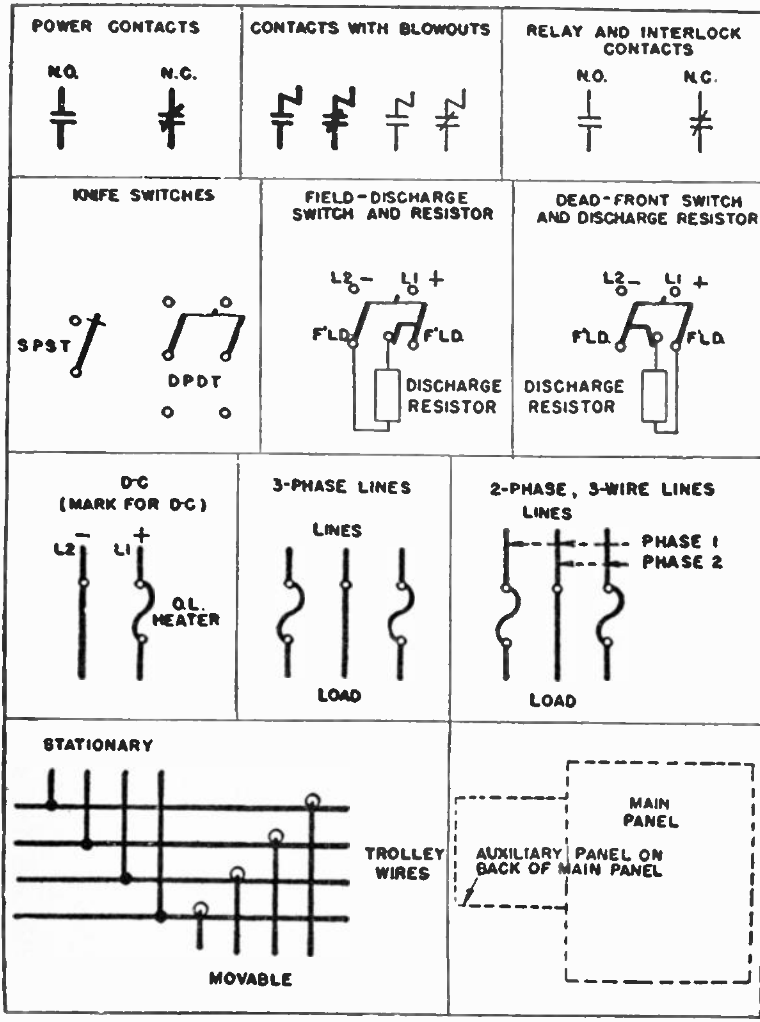
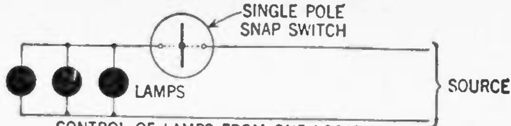


HOUSE WIRING BELLS AND ANNUNCIATOR CIRCUITS

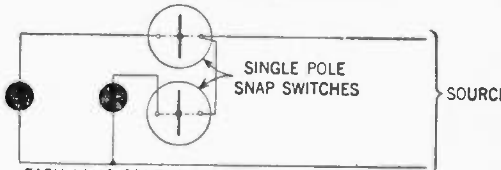
VARIOUS LAMP CONTROL SCHEMES

A



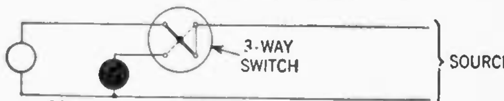
CONTROL OF LAMPS FROM ONE LOCATION

B



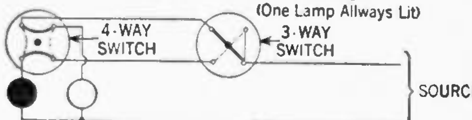
EACH LAMP CONTROLED FROM ITS OWN SWITCH

C



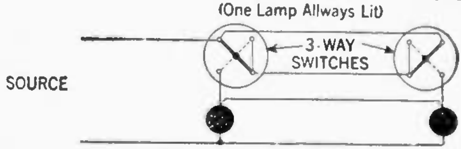
CONTROL OF LAMPS BY ONE 3-WAY SWITCH
(One Lamp Allways Lit)

D



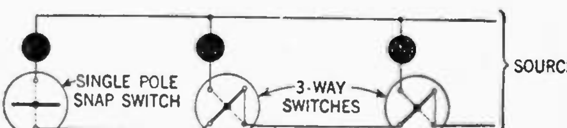
CONTROL OF LAMPS FROM 2 LOCATIONS
(One Lamp Allways Lit)

E



CONTROL OF LAMPS FROM 2 LOCATIONS

F



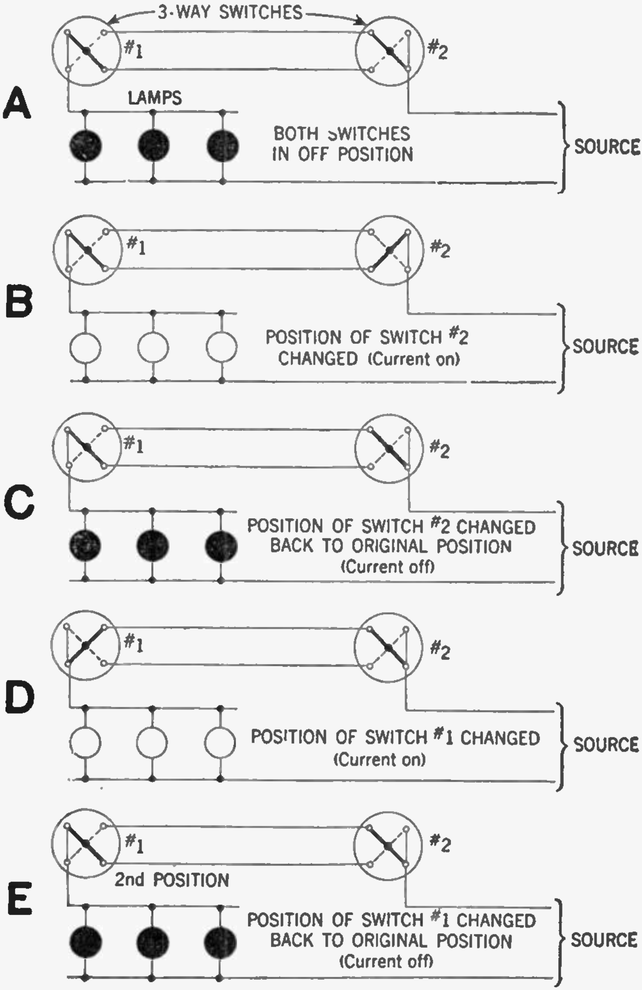
ARRANGEMENT WHEREBY A SWITCH WILL OPERATE
ITS OWN LIGHT FOR CERTAIN POSITIONS OF THE
TWO OTHER SWITCHES.

In the lamp control diagrams represented above, fig. A illustrates the connection when one single pole snap switch is used.

Fig. B shows how two lights (or two group of lights) can be controlled individually from a set of two single pole switches.

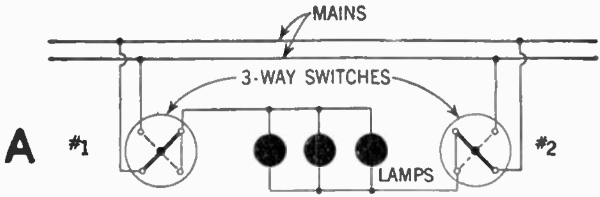
Figs. C to F illustrate a series of special types of lamp control used in, for example, test circuits, or in any location where particular control schemes are desirable.

LAMP CONTROL FROM 2-LOCATIONS

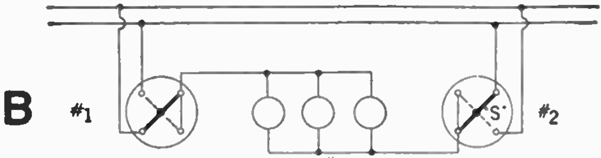


A convenient and often used method for control of a lamp or a group of lamps from two points by means of 3-way switches is shown in the diagrams. The lamps may be extinguished or lighted from either switch regardless of the position of the other. When both switches are in the positions shown in fig. A, the lamps are extinguished, and can be illuminated by the operation of switch No. 1 or 2. If as shown in diagram, No. 2 switch is operated the lamps will be illuminated, and can now be extinguished from either switch. A typical sequence of operation is shown diagramatically in figs. A to E.

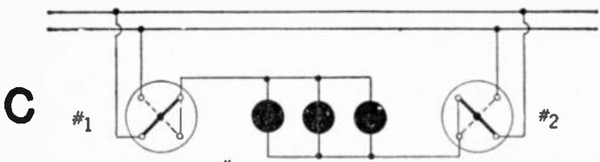
LAMP CONTROL FROM 2-LOCATIONS



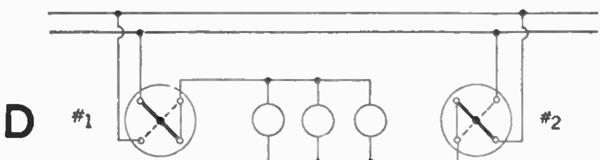
BOTH SWITCHES IN OFF POSITION



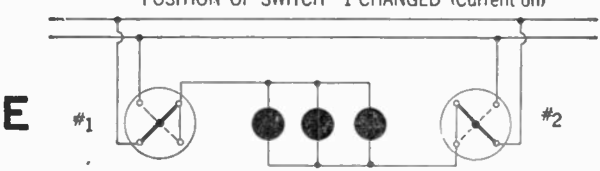
POSITION OF SWITCH #2 CHANGED (Current on)



POSITION OF SWITCH #2 CHANGED BACK TO ORIGINAL POSITION (Current off)



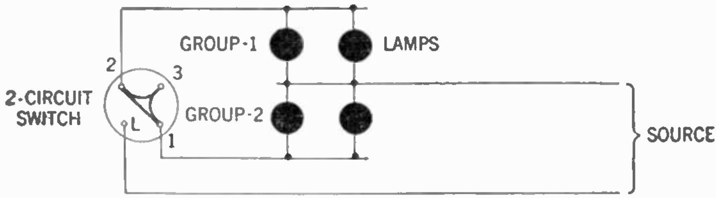
POSITION OF SWITCH #1 CHANGED (Current on)



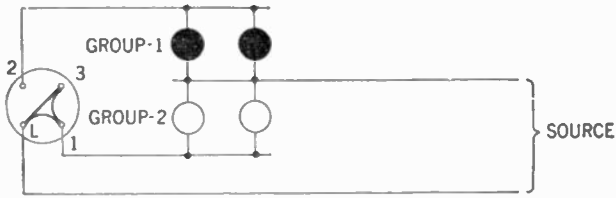
POSITION OF SWITCH #1 CHANGED BACK TO ORIGINAL POSITION
(Current off)

This connection provides an economical means of lamp control from two locations. Although not permissible under the National Electric Code it is shown only as an electrically possible circuit. As in the previous connections shown, both switches are in off position in fig. A, the lamps extinguished, and can be lit by operating either switch. If switch No. 2, fig. B. is operated to position "S" the lamps will be illuminated, and can be extinguished again from any one of the two switches. Figs. A to E inclusive shows the lamps lighted or extinguished, depending on position of switch No. 1, relative to the position of switch No. 2.

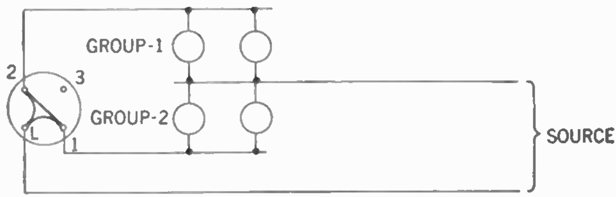
LAMP CONTROL FROM 2-CIRCUIT ELECTROLIER SWITCH



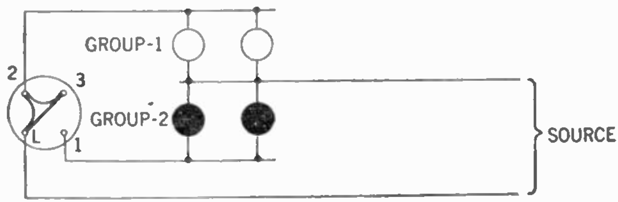
1st POSITION OF SWITCH



2nd POSITION OF SWITCH



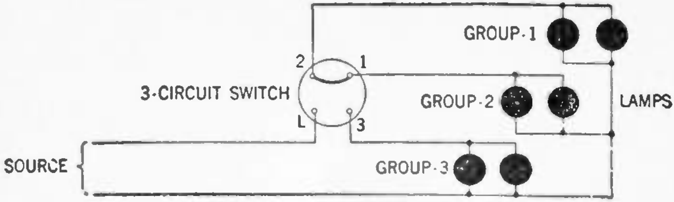
3rd POSITION OF SWITCH



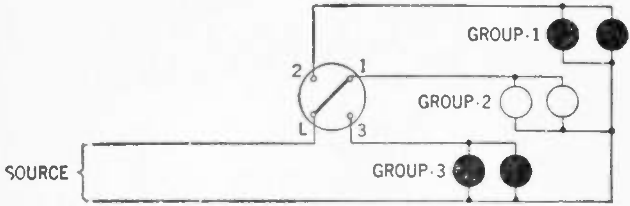
4th POSITION OF SWITCH

Large fixtures or electroliers are often wired so that lights can be controlled in two or more independent groups. As shown in the diagram the two groups of lamps are extinguished in the first position of the switch. When operating the switch to second position, group No. 2, will be illuminated. In the third position the maximum amount of brightness is obtained as both groups of lamps are illuminated, and finally in the fourth position, group No. 1 only is lit. This switch may not be considered as standard, it is only one of several arrangements.

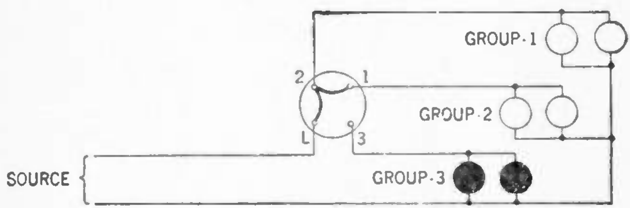
LAMP CONTROL FROM 3-CIRCUIT ELECTROLIER SWITCH



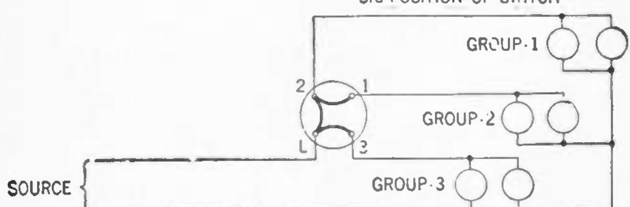
1st POSITION OF SWITCH



2nd POSITION OF SWITCH



3rd POSITION OF SWITCH

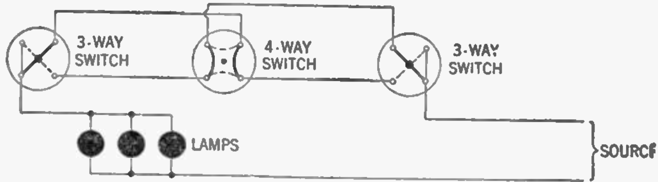


4th POSITION OF SWITCH

A 3-circuit electrolier switch from which three groups of lamps are controlled is shown above. The sequence of operation is depicted diagramatically and is principally the same as shown in the previous 2-circuit switch. In the 4th position maximum illumination is obtained, with all lamps lighted. The switch shown is typical only among a great variety of switches manufactured for electrolier or dome lamp control. The current carrying capacity of the switch as well as potential of the source to be connected should be considered for each individual application.

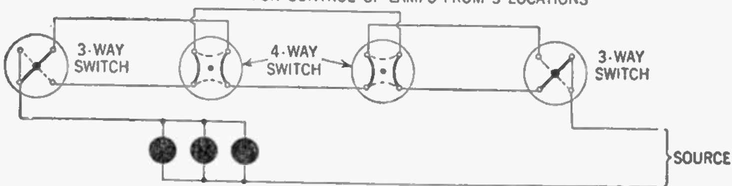
CONTROL OF LAMPS FROM MORE THAN ONE LOCATION BY MEANS OF 3 AND 4-WAY SWITCHES

A



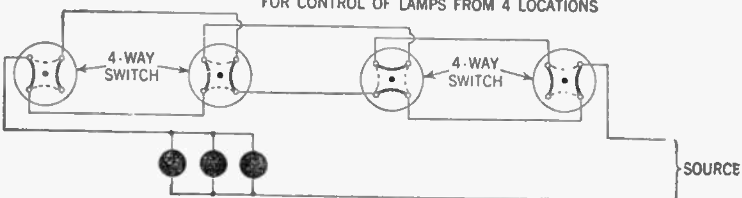
USE OF TWO 3-WAY AND ONE 4-WAY SWITCH
FOR CONTROL OF LAMPS FROM 3 LOCATIONS

B



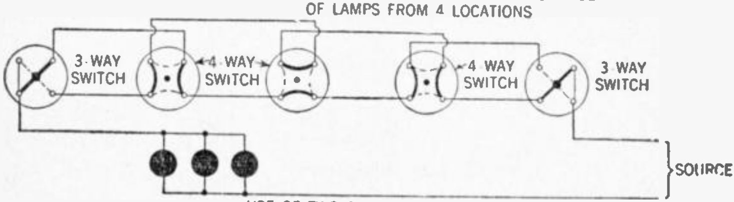
USE OF TWO 3-WAY AND TWO 4-WAY SWITCHES
FOR CONTROL OF LAMPS FROM 4 LOCATIONS

C



USE OF FOUR 4-WAY SWITCHES FOR CONTROL
OF LAMPS FROM 4 LOCATIONS

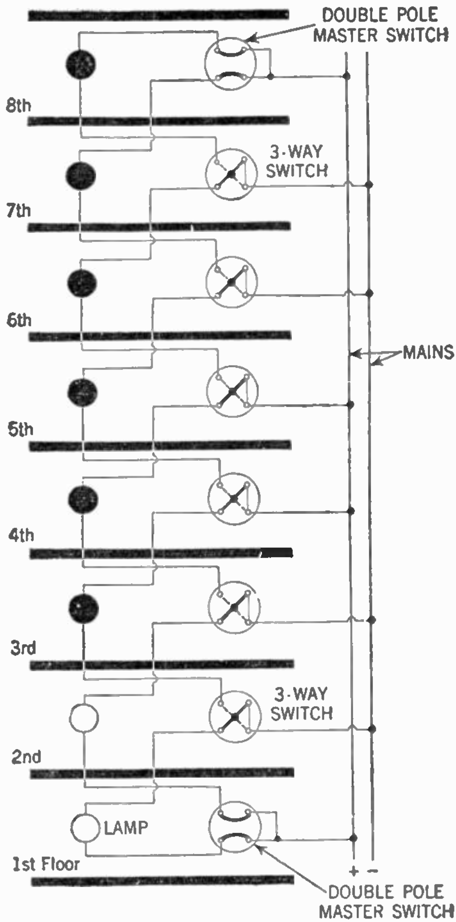
D



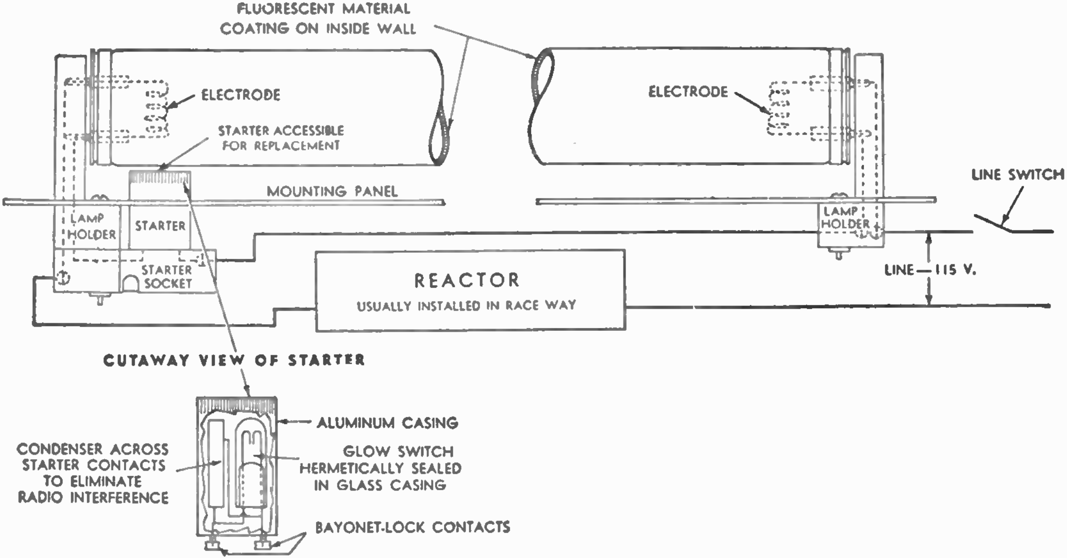
USE OF TWO 3-WAY AND THREE 4-WAY SWITCHES
FOR CONTROL OF LAMPS FROM 5 LOCATIONS

The series of connection diagrams shown in figs. A to D, illustrate the conventional methods of lamp control when using 3- and 4-way switches. With reference to fig. A, it is obvious that for any additional point of control desired a 4-way switch connected the same as the middle switch must be used. See figs. B to D.

STAIR-WAY LAMP CONTROL WIRING



As shown in circuit diagram the switches used in this type of light control consist of two double pole switches, inter-connected on the first and last floor, and one 3-way switch for each floor. The sequence of operation is as follows: Closing switch on the first floor lights lamp on first and second floor. Turning the switch on the second floor extinguishes the light on the first floor and lights the lamp on the third floor, etc. This operation is continued until the top floor is reached, in other words the switch on each floor should be turned in passing. It can be readily seen that this light control arrangement lends itself to operation of lamps irrespective of number of floors encountered.



Schematic Diagram of Typical Fluorescent Lamp Circuit. The necessary auxiliaries for any fluorescent lamp installation is (1) the ballast, and (2) the starter.

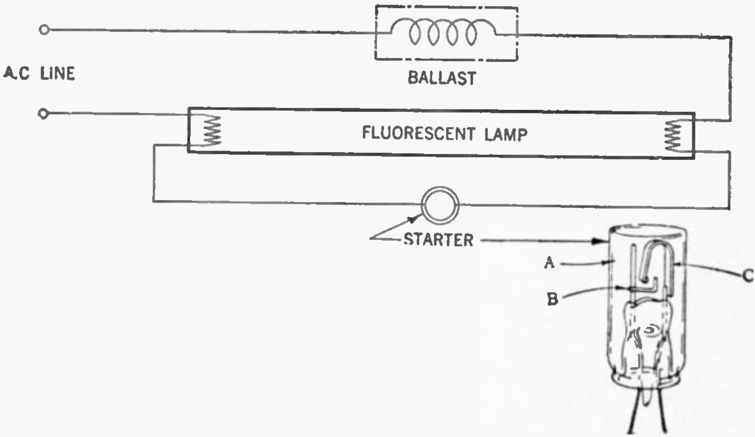
The ballast for operating lamps on 60 cycle A.C.consists of a small choke coil (reactor) wound on an iron core The ballast serves three important functions, namely:

1. It preheats the electrode to make available a large supply of free electrons.
2. It provides a surge of relatively large potential to start the arc between the electrodes.
3. It prevents the arc current to increase beyond the limit set for each size of lamp.

Ballasts. These may be designed for operation of a single lamp or as is more common, for two lamps mounted in a single fixture. Certain practical advantages are obtained from the choice of an electrical circuit which combines under one cover the equipment for the control of two lamps.

Chief among the advantages are improved power factor, decreased stroboscopic effect and reduced auxiliary losses. Each lamp is operated through a separate choke coil. A condenser is connected in series with one lamp and its choke coil to give a leading current. The leading and lagging current will combine with a resulting line power factor of very nearly 100%.

When connecting lamps, ballast and starter into an electric circuit, it is of the utmost importance to observe the manufacturers' diagram usually labeled on the ballast. This diagram should be followed in each instance for proper operation of the lamp or lamps. Also it should be clearly understood that each lamp size must have a ballast designed for its particular wattage, potential and frequency.

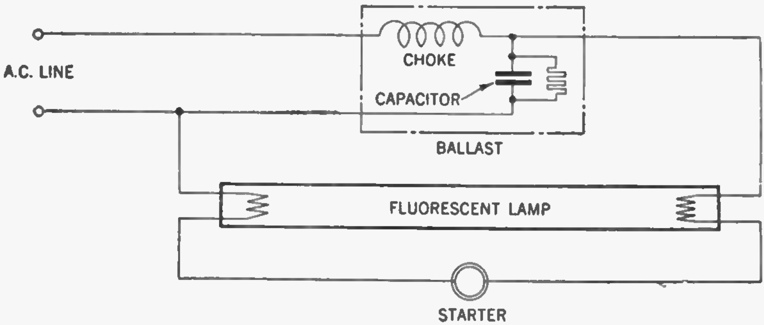


Wiring Diagram of Single Fluorescent Lamp. In the glow type starter **A**, represents glass bulb filled with inert gas; **B**, fixed electrode; **C**, bi-metal strip.

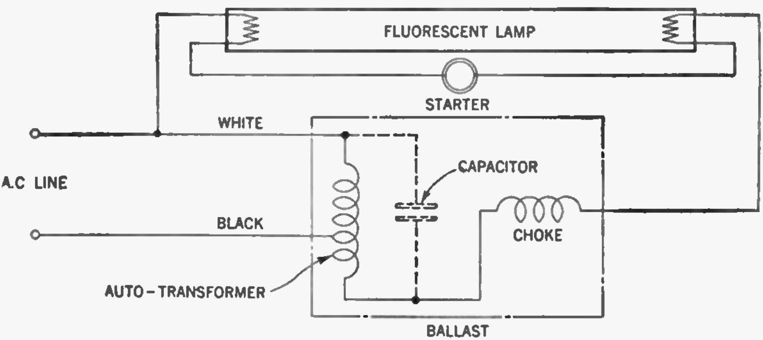
Starters. The starter is designed to act as a time delay switch which will connect the two filament type electrodes in each end of the lamp in series with the ballast during the short pre-heating period when the lamp is first turned on and then open the circuit to establish the arc. This pre-heating causes the emission of electrons from the cathodes and thus makes it possible for the arc to strike without the use of excessively high voltage.

Operation. The switch is enclosed in a small glass bulb and consists of two electrodes, one of which is made from a bi-metal strip in an inert gas such as neon or argon. These electrodes are separtaed under normal conditions but when closed form part of a series circuit through the lamp electrodes and the choke coil (ballast).

When voltage is applied a small current flows as a result of the glow discharge between two electrodes of the switch. Heating of the electrodes results, which by the expansion of the bi-metallic element, causes the electrodes to touch. This short circuiting of the switch stops the glow discharge but allows a substantial flow of current to pre-heat the lamp electrodes. There is enough residual heat in the switch to keep it closed for a short period of time for the electrode pre-heating. The glow being quenched, the bi-metal cools, the switch opens and the resultant high voltage surge starts normal lamp operation. If the lamp arc fails to strike, the cycle is repeated.

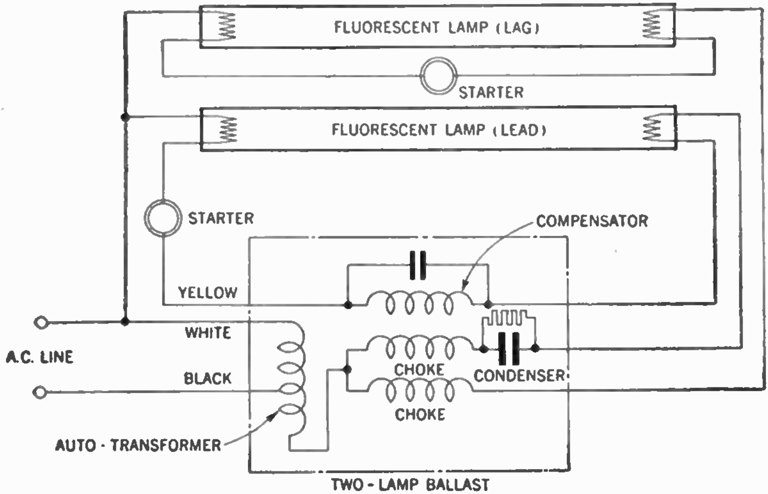


Wiring Diagram of Single Fluorescent Lamp with Capacitor for Improvement of Power Factor. For operation of the 13, 30, 40 and 100 watt lamps on 110-125 volt circuits, the ballast must include a transformer for stepping up the voltage.

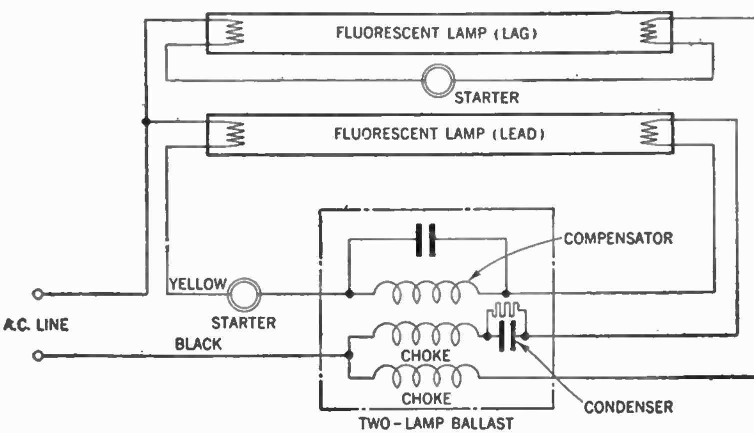


Wiring Diagram of Single Fluorescent Lamp with Power Factor Corrected Ballast and Auto-Transformer for Stepping Up the Voltage.

FLUORESCENT LAMP CIRCUITS

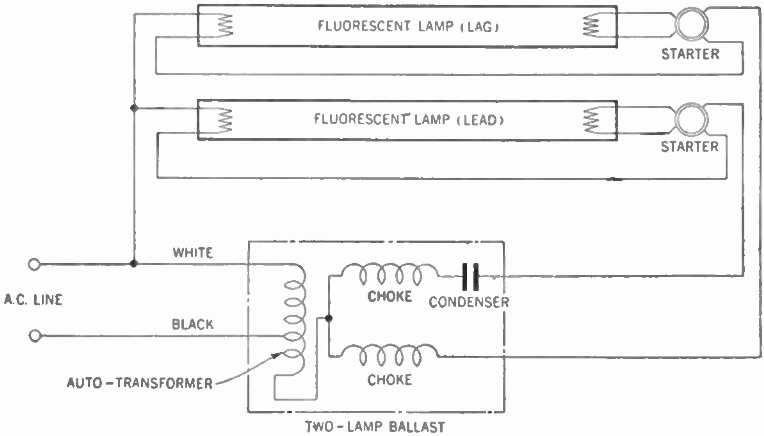


Wiring Diagram of Two-Lamp Ballast with Built in Starting Compensator and Auto-Transformer.

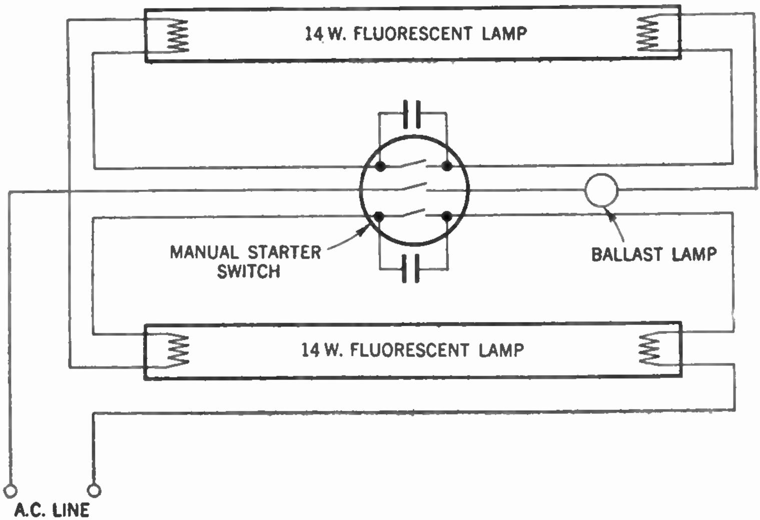


Wiring Diagram of Two-Lamp Ballast with Built-In Starting Compensator.

FLUORESCENT LAMP CIRCUITS

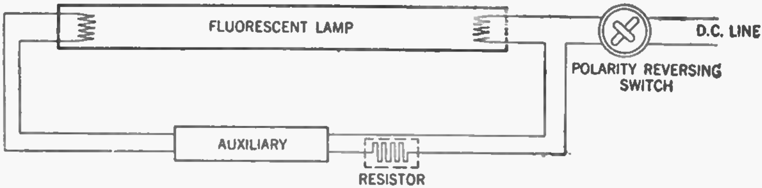


Wiring Diagram of Two-Lamp Ballast with Auto-Transformer and a Four-Contact Starter Socket for Each Lamp.



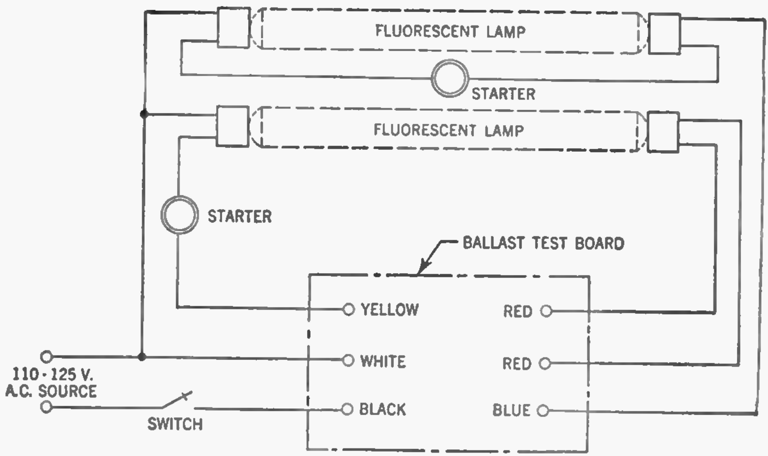
Wiring Diagram for Operating Two 14 Watt Fluorescent Lamps in Series with a Special Incandescent Ballast Lamp.

FLUORESCENT LAMP CIRCUITS



Wiring Diagram of Fluorescent Lamp for Operation on Direct Current. While the fluorescent lamp is basically an alternating current lamp, it is also used on direct current where alternating current is not available. Due to the lack of voltage peaks, where direct current is used, lamp starting is generally more difficult than on alternating current and special starting devices must be used. The thermal and manual starting switches in addition to a starting inductance is generally employed.

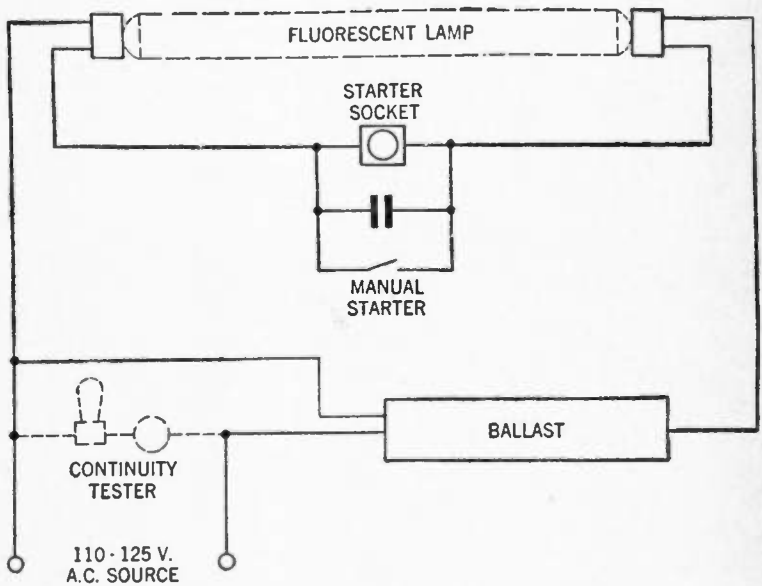
With fluorescent lamps, one end of the tube may become dim after operating a few hours on direct current. This is due to the bombardment of electrons in one direction only. By reversing the direction of current flow at certain intervals (once a day or more frequently if desired) by means of a special reversing switch, this end dimming may be eliminated.



Wiring Arrangement for Ballast Test Board. By means of a circuit of this type 40 watts two lamp ballasts for use on standard voltage may easily be tested.

FLUORESCENT LAMP CIRCUITS

This is simply a two-lamp circuit with binding posts left at the point where the ballast must be connected in order that quick connections may be made. By providing socket spacing necessary to receive lamps of other sizes, such a test board can be used to check ballasts of any size, provided care is taken to make the connections through the proper binding posts.

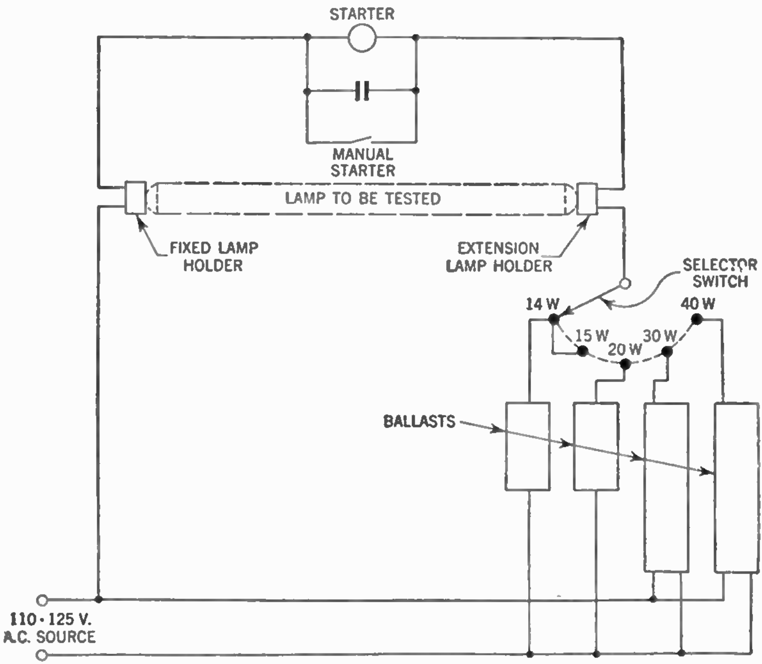


Wiring Diagram Illustrating a Simple Testing Board for Fluorescent Lamps. A test board of this type may be used for checking of 40 watt lamps, for example, with the lamp holders spaced to receive lamps of the proper size, and are provided with a starter socket and manual starter switch, properly connected to a suitable ballast. A filament continuity checker can also be included if desired. This consists of a fluorescent lamp socket, in series with an incandescent lamp of the 25 watt size or smaller.

A testing board of this type has been found helpful for checking of flourescent lamps and starters to see that they operate satisfactorily.

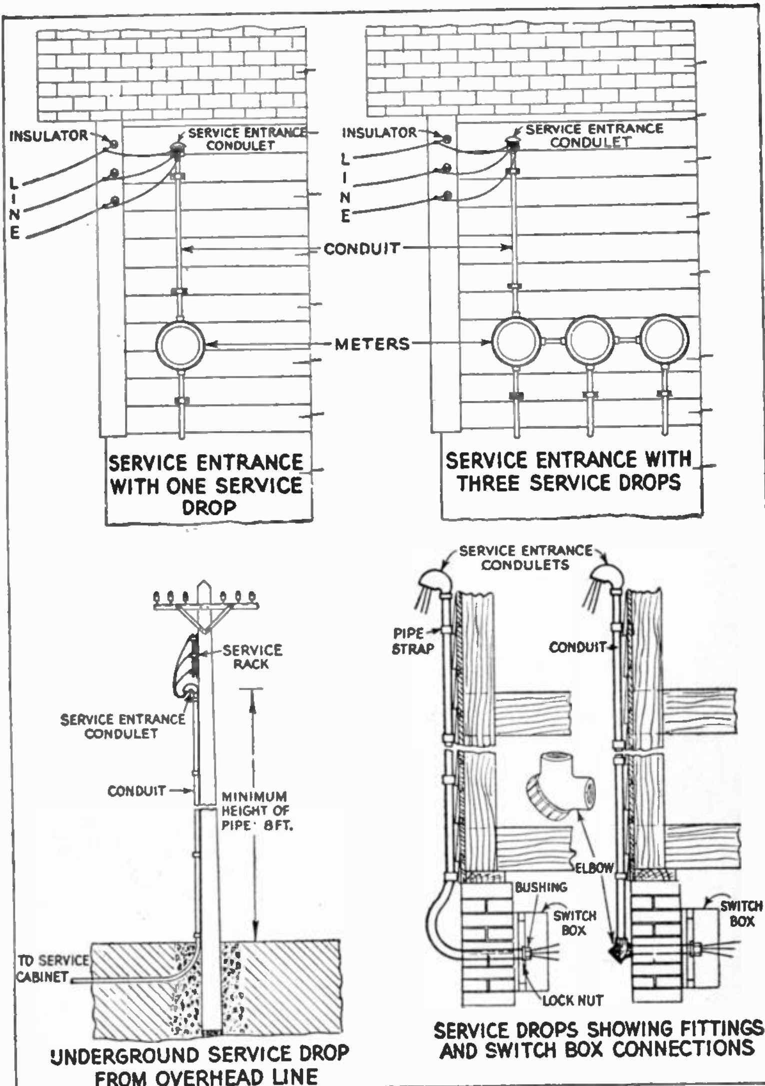
FLUORESCENT LAMP CIRCUITS

Lamp boards of this general type may also be made to check lamps of several different sizes by providing the necessary ballasts and lampholders properly spaced to receive the lamps, or one lamp socket mounted stationary and the other provided with pins so that it can be plugged into jacks located at the proper distance for taking lamps of various lengths.



Wiring Diagram of Portable Test Kit for Checking Fluorescent Lamps and Starters. By means of a circuit arrangement of this type various size lamps and starters may be tested directly on the job. All that is required is that the kit be large enough to hold the required ballasts, as connection to one end of the lamp is made by means of a lamp holder on the end of an extension cord. A selector switch must be included for making connections to the proper ballast.

VARIOUS METHODS OF INSTALLING SERVICE DROPS



SERVICE ENTRANCE WITH ONE SERVICE DROP

SERVICE ENTRANCE WITH THREE SERVICE DROPS

UNDERGROUND SERVICE DROP FROM OVERHEAD LINE

SERVICE DROPS SHOWING FITTINGS AND SWITCH BOX CONNECTIONS

TYPICAL METHOD OF GROUNDING FOR HOUSE WIRING SERVICE

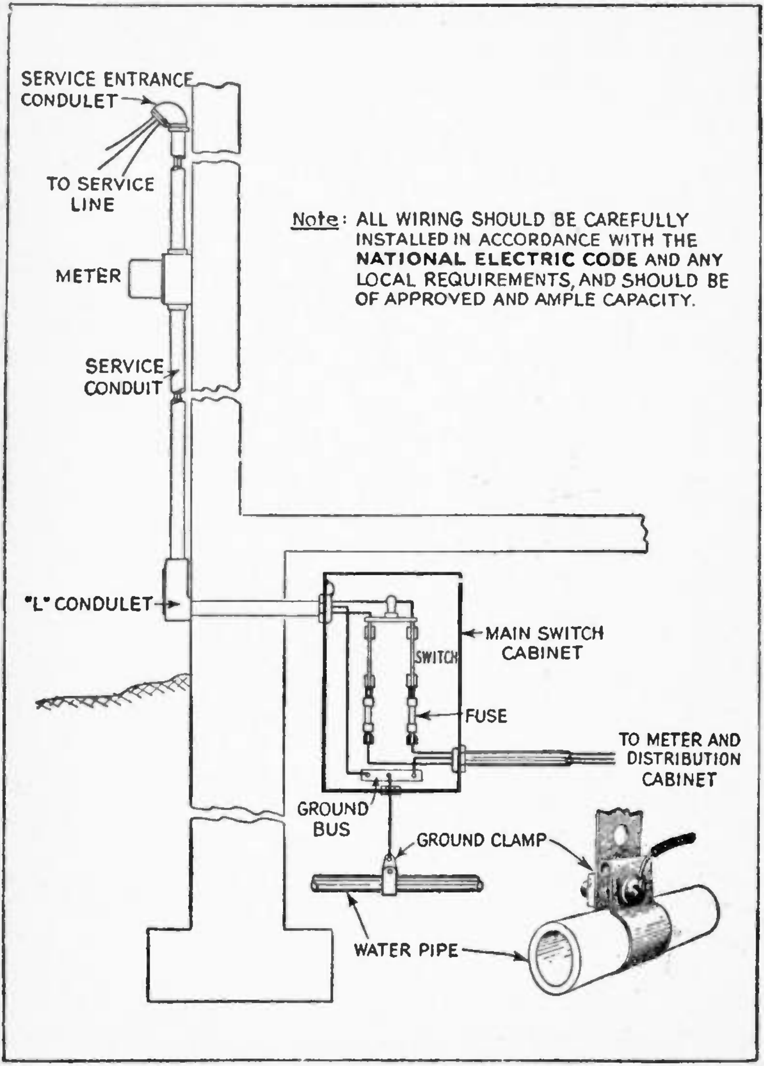
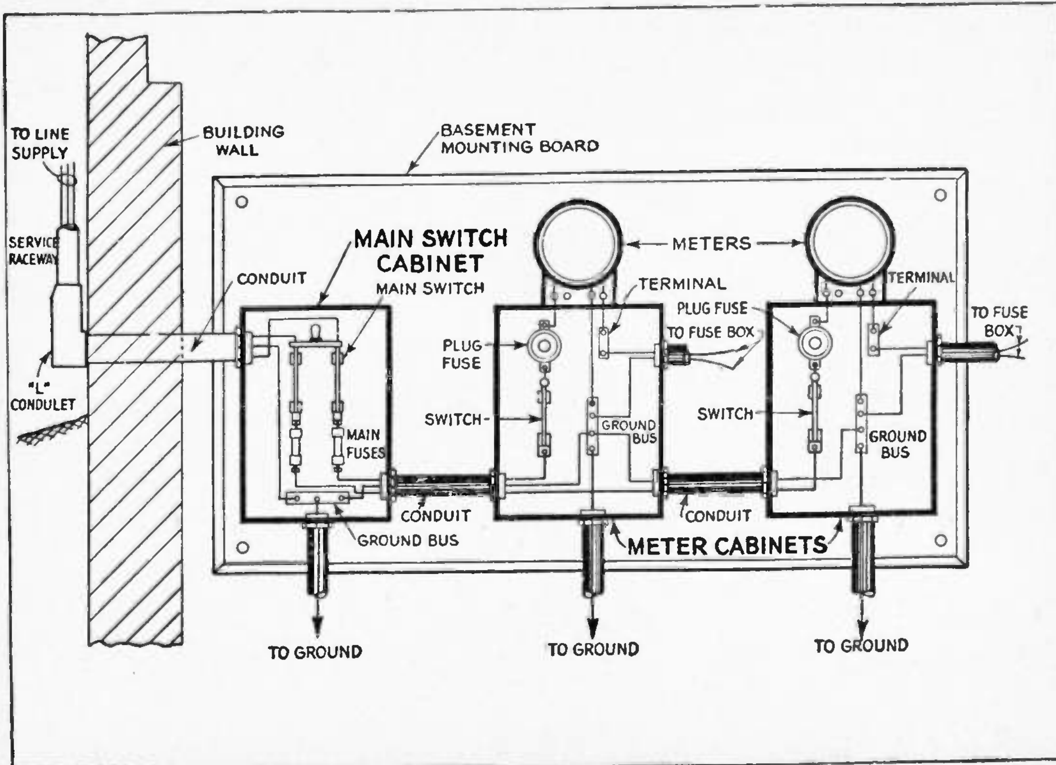
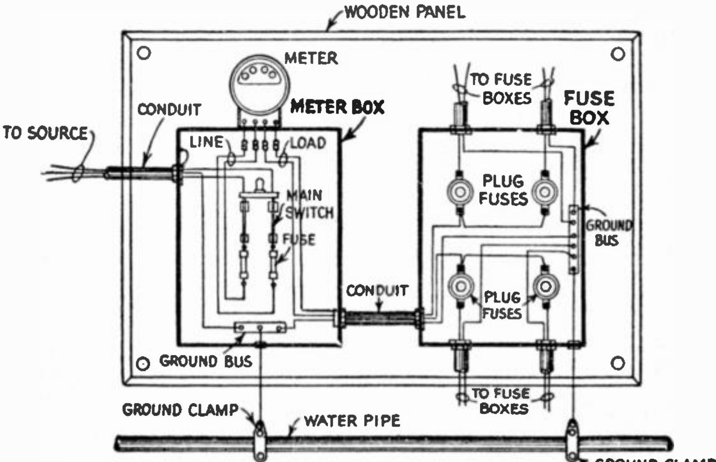


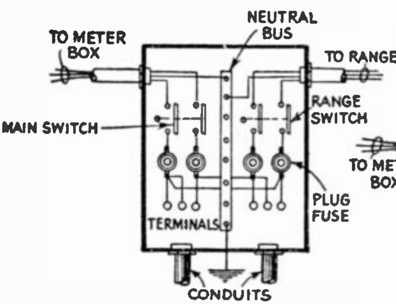
DIAGRAM OF CONNECTIONS FOR TYPICAL 2-METER SERVICE



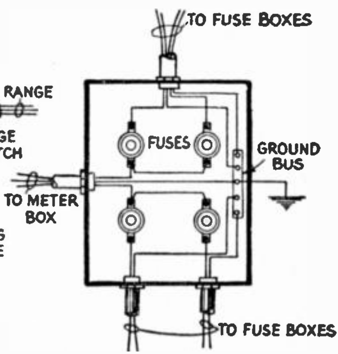
WIRING DIAGRAM OF THREE WIRE METER AND SERVICE BOXES



3-WIRE SERVICE CONNECTION

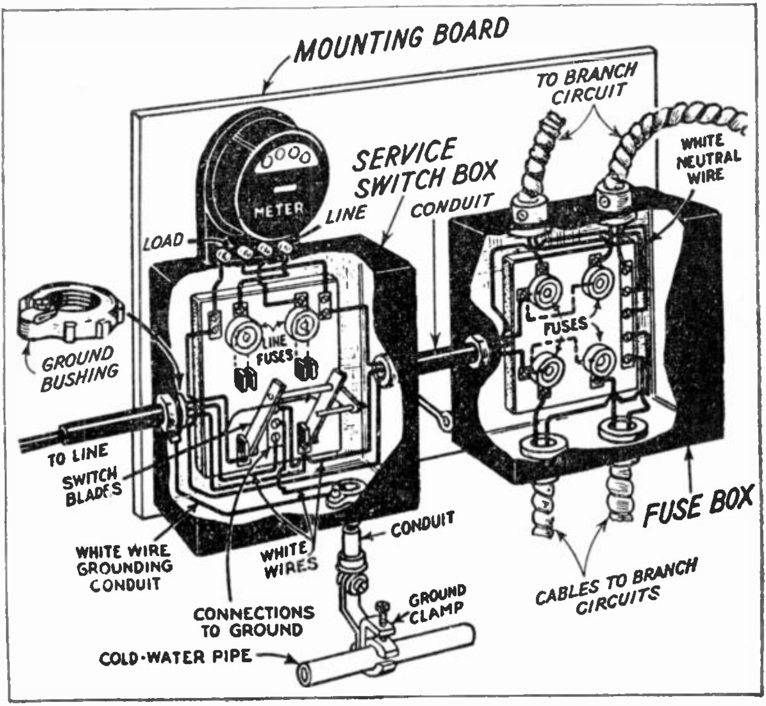


3-WIRE SERVICE SWITCH & FUSE BOX



3-WIRE FUSE-BOX

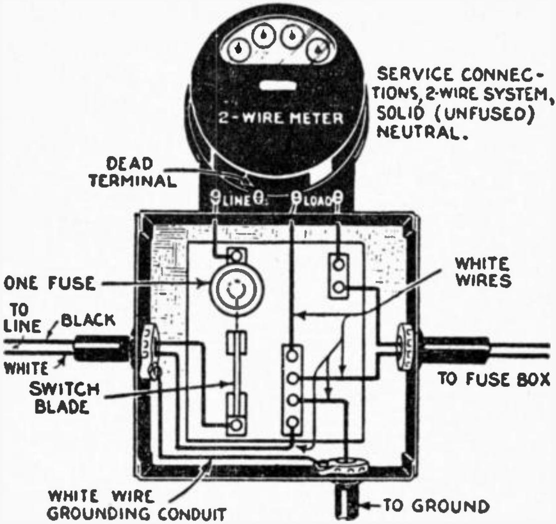
SERVICE CONNECTION FOR A THREE WIRE SYSTEM



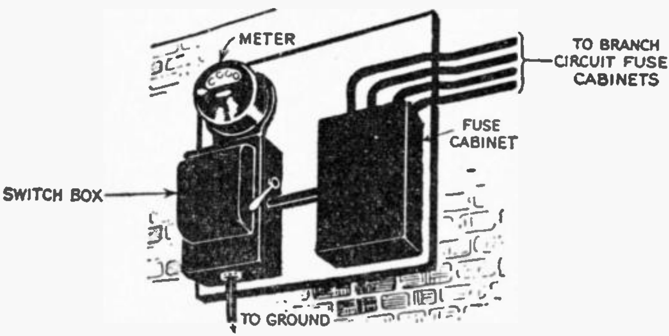
Installation Notes. It is important that all wiring be installed to conform with the requirements of the National Electric Code or any local requirements for safe electrical installation.

The first requirement for any installation is to determine the type and size of load (number of lamps, motors, heating elements, etc. required). When this is done it is a comparatively easy matter to compute the maximum wattage requirements, from which data the current is obtained from Ohm's law.

When the current load for each circuit is known, the size of fuses and wire for the main and branch circuits is determined from wiring tables. In most branch circuits where the maximum load does not exceed 15 amperes, No. 14 wire is used, although in some localities the branch circuit load is limited to 1200 watts (at 110 volts) and no branch circuit may include more than twelve outlets. Generally circuits supplying oil burners, washing machines, refrigerators, electric ranges, and any heating appliance exceeding 1000 watts, are wired on independent circuits, separate from the light circuits. In three wire systems it is required that the load be balanced or evenly distributed between the ground and the outside wires.

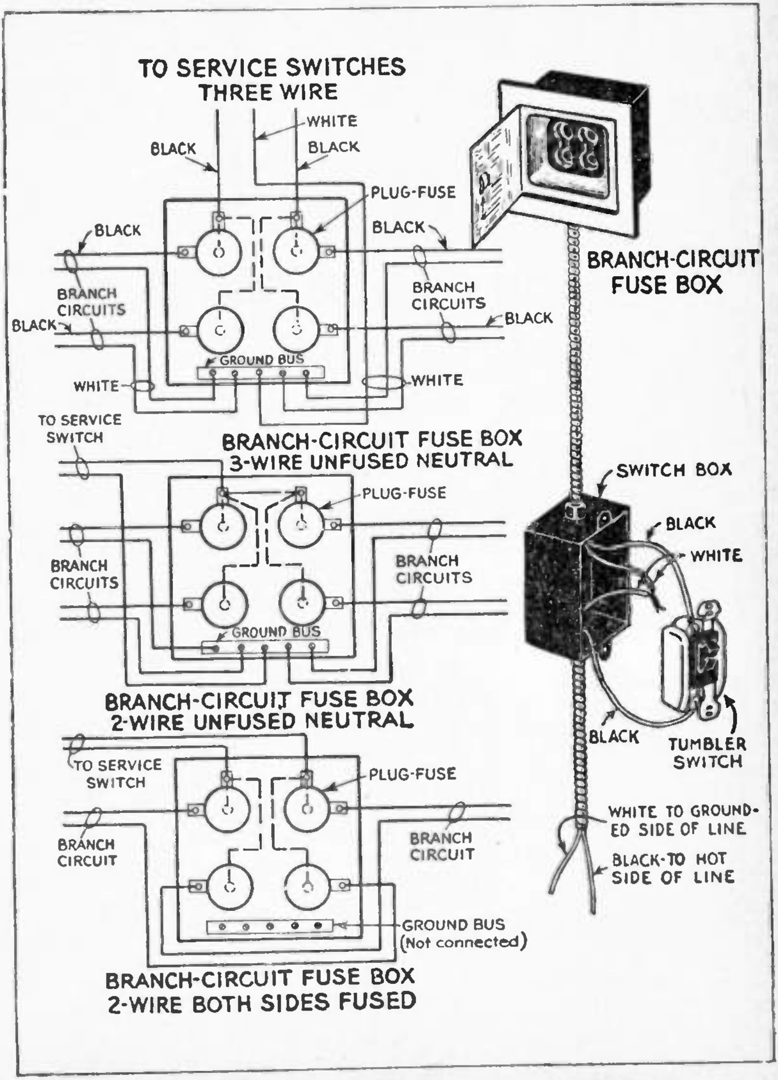


TYPICAL SERVICE METER BOX
(INTERIOR VIEW)



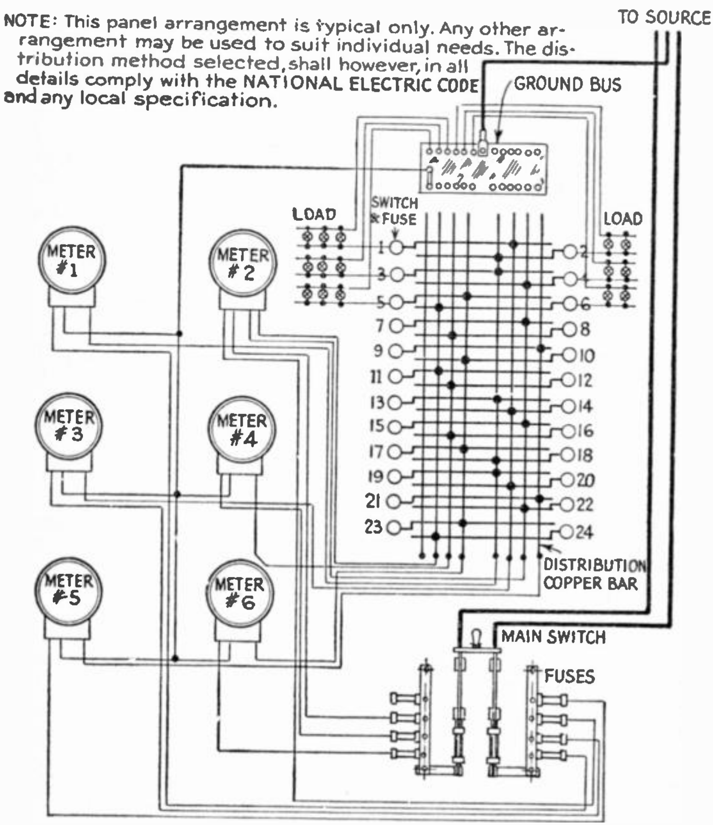
TYPICAL BASEMENT INSTALLATION
(EXTERIOR VIEW)

WIRING DIAGRAM OF VARIOUS BRANCH CIRCUIT FUSE BOXES



CONNECTION DIAGRAM OF A COMBINATION METER AND CONTROL PANELBOARD FOR APARTMENT-HOTEL

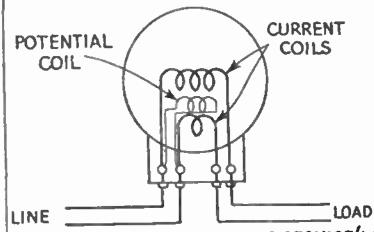
NOTE: This panel arrangement is typical only. Any other arrangement may be used to suit individual needs. The distribution method selected, shall however, in all details comply with the NATIONAL ELECTRIC CODE and any local specification.



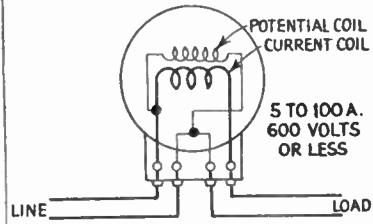
OPERATION: For the sake of clarity only six meters are shown one of which is a three wire meter.

Meter #1 measures energy cosumption in circuits #2, 3, 13, 18 and 19.
" 2 " " " " " 4, 6, 7, 11, 15, 22 and 24
" 3 " " " " " 1, 14 and 20
" 4 " " " " " 8, 12 and 16
" 5 " " " " " 9 and 21
" 6 " " " " " 5, 10, 17 and 23

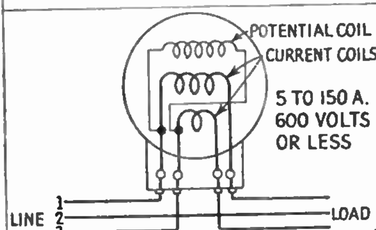
CONNECTION OF WATTHOUR-METERS (FRONT VIEWS)



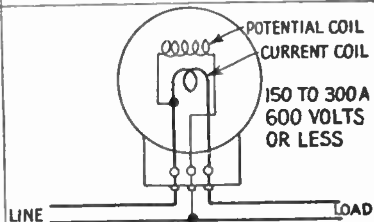
TYPICAL METER FOR HOUSE SERVICE(A.C.)



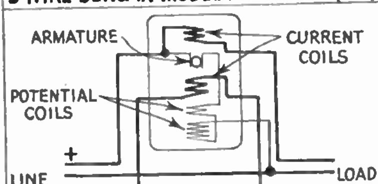
2-WIRE DUNCAN MODEL M-2 METER(A.C.)



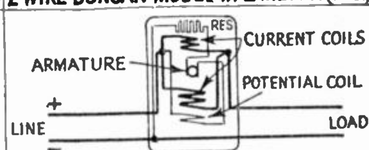
3-WIRE DUNCAN MODEL M-2 METER (A.C.)



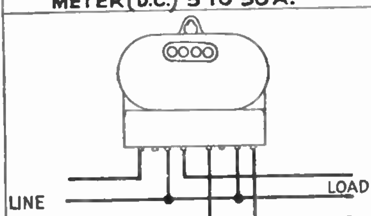
2-WIRE DUNCAN MODEL M-2 METER (A.C.)



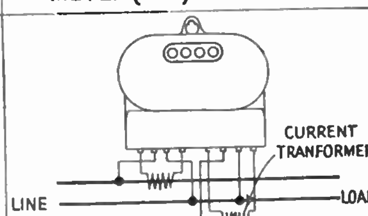
WESTINGHOUSE 3-WIRE MODEL CW-6 METER (D.C.) 5 TO 50 A.



WESTINGHOUSE 2-WIRE MODEL A METER (D.C.) 100 TO 450 A.

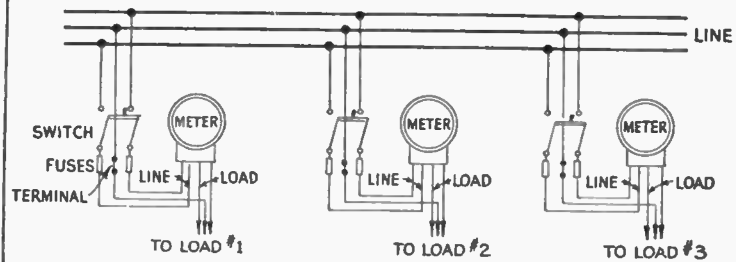


SANGAMO TWO AND THREE PHASE, THREE WIRE MODEL "H" METER (A.C.)

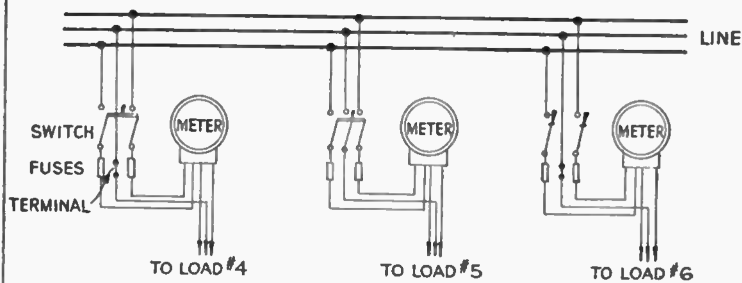


SANGAMO TWO AND THREE PHASE, THREE WIRE MODEL "H" METER WITH CURRENT TRANSFORMERS (A.C.)

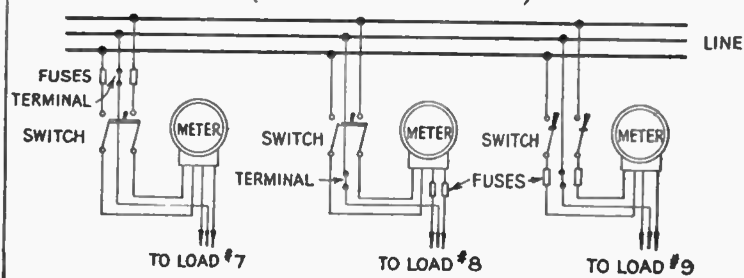
EXTERNAL CONNECTION DIAGRAMS OF WATTHOUR-METERS



CONNECTION SEQUENCE: SWITCH, FUSES, METER
(NOTE: NEUTRAL UNFUSED)

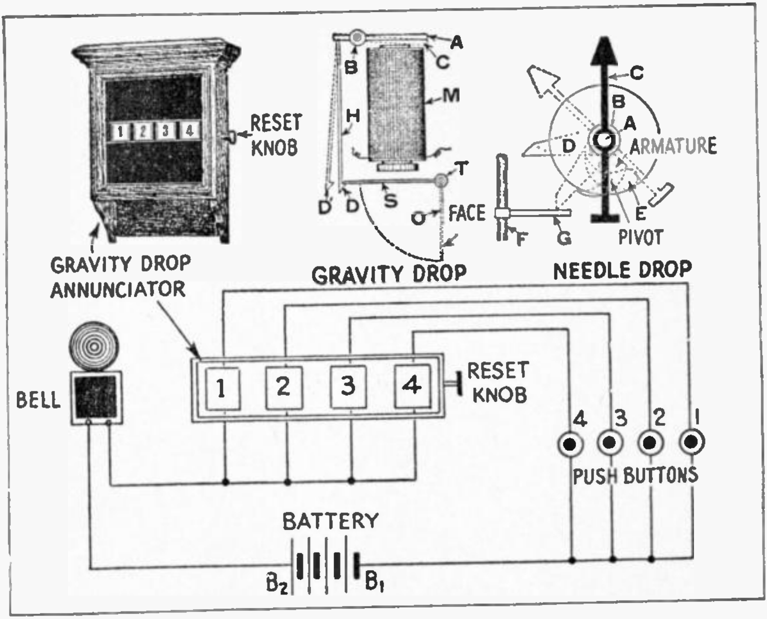


CONNECTION SEQUENCE: SWITCH, FUSES, METER
(NOTE: NEUTRAL UNFUSED)



CONNECTION SEQUENCE: FUSES, SWITCH, METER —SWITCH, METER, FUSES —SWITCH, FUSES, METER (NOTE: NEUTRAL UNFUSED)

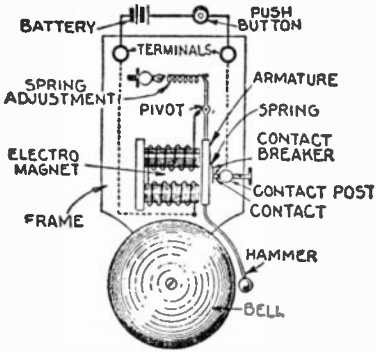
ANNUNCIATOR WIRING DIAGRAM



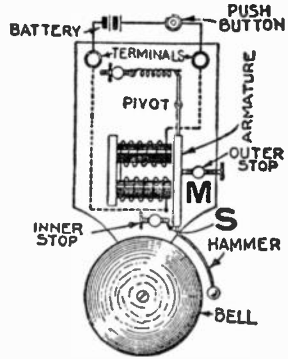
Gravity Drop Annunciator. When the circuit is completed by the operation of the push button, the current flows from B_1 of the battery through the coil of the electromagnet marked (M) in the detail sketch and energizes its core, and the latter attracts the armature A, pivoted at B. When the armature is moved to the position C, the claw D, is thrown to the position D_1 thereby releasing the shutter S, pivoted at T, allowing it to drop by gravity to position O, thus displaying the number marked upon its face.

Needle Drop Annunciator. In sending a current through the coil of the electromagnet, the armature E, turns on its pivot toward the magnet core A, thereby releasing the arm D, which in falling rotates the arrow to the position shown in the dotted lines. The arrow is reset bv pressing a button, which raises the rod F, carrying the arm G.

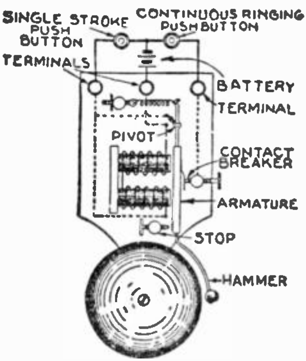
INTERNAL CONNECTION OF BELLS



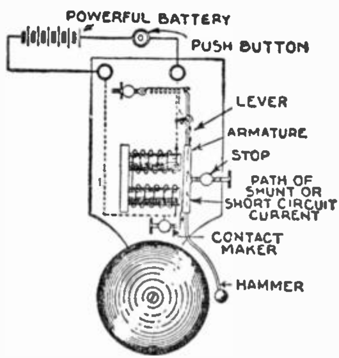
SERIES VIBRATING BELL



SINGLE STROKE BELL



COMBINATION VIBRATING AND SINGLE STROKE BELL

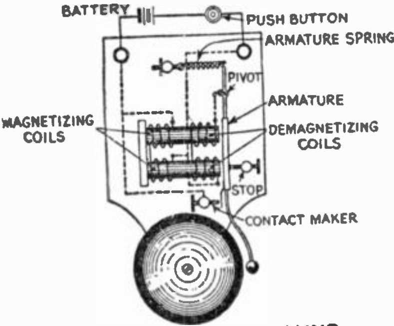


SHUNT-VIBRATING AND SINGLE STROKE BELL

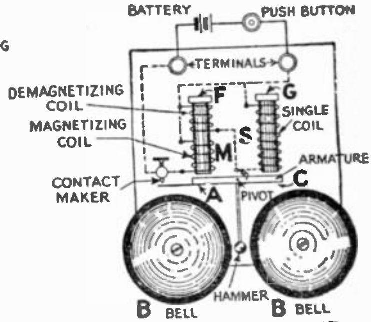
Operation of Series Vibrating Bell. When the push button is operated, the current energizes the magnet and attracts the armature causing the hammer to strike the bell, but before it reaches the end of the stroke, the contact breaker breaks the circuit and the hammer, influenced by the tension of the armature spring rapidly moves back to its initial position, thus completing the cycle.

Operation of Single Stroke Bell. When the push button is operated the current energizes the magnet and attracts the armature causing the hammer to strike the bell. The armature remains in the attracted position so long as the current flows through the magnet. When connection with the battery is broken, the hammer spring pulls the armature back against M. A stop S, averts the motion of the armature, momentum springing the lever and causing the hammer to strike the bell.

INTERNAL CONNECTION OF BELLS



DIFFERENTIALLY-WOUND VIBRATING BELL



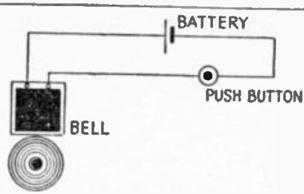
DIFFERENTIAL AND ALTERNATE BELL

Operation of Combination Vibrating and Single Stroke Bell. This bell is essentially a vibrating bell with the addition of a third terminal and a stop to prevent continued contact of the hammer with the bell when working single stroke.

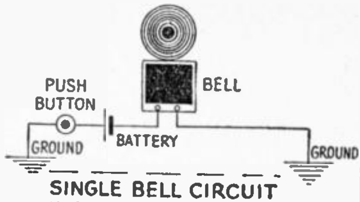
Operation of Shunt-vibrating and Single Stroke Bell. This is simply an ordinary shunt bell with a switch arranged so that the short circuit through the contact maker, armature and lever may be cut out, thus restricting the current to the magnet winding.

Operation of Differentially-wound Vibrating Bell. When the battery circuit is closed, current flows through the magnetizing winding and energizes the magnets which in turn attract the armature. The contact maker closes the circuit through the demagnetizing coils, which demagnetize the magnets. The armature spring pulls the armature back against the stop, while the contact maker breaks the circuit through the demagnetizing coils.

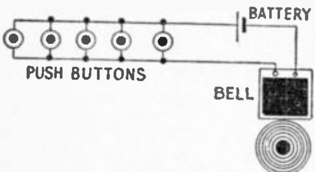
Operation of Differential and Alternate Bell. When the battery circuit is closed by means of the push button, current flows through the magnetizing winding M and energizes F, which attracts end A of the armature. The contact maker closes circuit through magnetizing coil, and the single coil S, of magnet G. After which the demagnetizing coil demagnetizes F, and as a result, magnet G attracts end of C, of the armature after which contact maker breaks the circuit through demagnetizing coil D, and single coil S, of magnet G, completing the operation cycle.



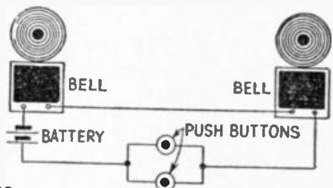
SINGLE BELL CIRCUIT



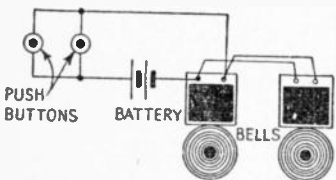
SINGLE BELL CIRCUIT WITH GROUND RETURN



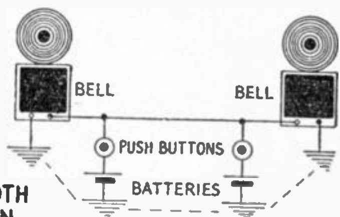
BELL CONNECTIONS, WIRED TO OPERATE FROM FIVE PUSH BUTTON STATIONS



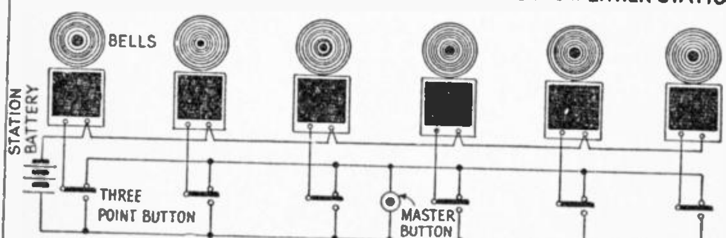
SERIES BELL CIRCUIT WILL OPERATE BOTH BELLS FROM EITHER PUSH BUTTON



SERIES BELL CIRCUIT TO OPERATE BOTH BELLS FROM EITHER PUSH BUTTON

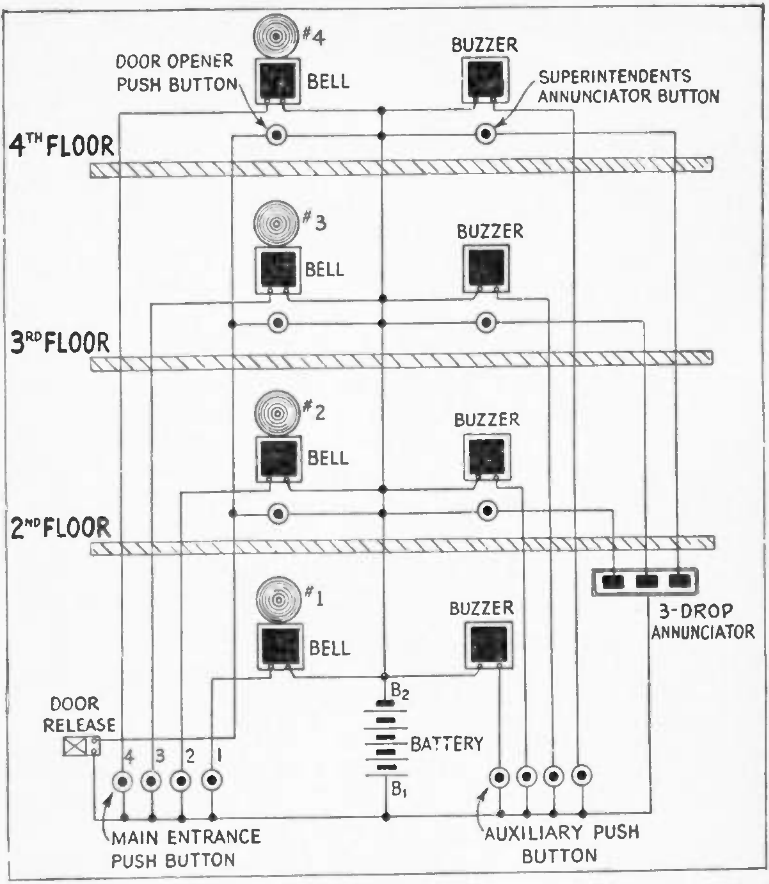


SERIES BELL CONNECTIONS TO OPERATE FROM EITHER STATION



SELECTIVE AND MASTER BUTTON SYSTEM. MASTER BUTTON WIRED TO RING ALL BELLS SIMULTANEOUSLY

WIRING DIAGRAM FOR BELLS IN APARTMENT BUILDING

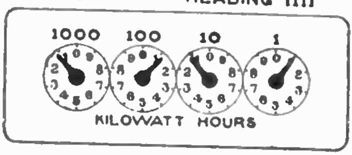


OPERATION. When for example, push button to apartment on 4th floor is operated, a circuit is completed from battery B_1 through bell #4 and to battery B_2 causing the bell to ring. Similarly when door opener push button on 4th floor is pressed, a circuit is formed from battery B_2 energizing the release coil, which opens the door. The auxiliary push buttons from the service entrance functions in a similar manner, notifying tenant by means of buzzer, the presence of service man.

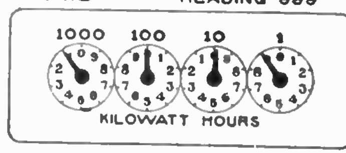
ELECTRIC METER READING

How to Read an Electric Meter. A consumer of electricity is billed for the amount of electrical energy in kilowatt-hours registered by the meter located on the premises at certain intervals of time—usually once a month. In order to facilitate the reading of meters, the front of the meter is usually equipped with four equally divided dials as shown in the figures below. It should be observed that each division on the **first right hand** dial represents one kilowatt-hour or unit. (One kilowatt-hour equals 1,000 watt-hours). Beginning with this dial read each dial to the left in succession, placing the figures in the same order as read; always make sure to take those figures which the dial finger actually has passed. If uncertain if the dial finger has actually passed a certain figure or not, note whether the next dial has passed its zero (0), remembering that no dial finger has completed a division until the dial finger next to the right has made a complete revolution.

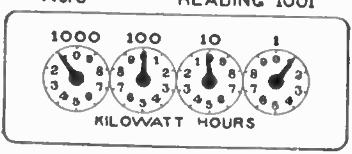
No. 1 READING 1111



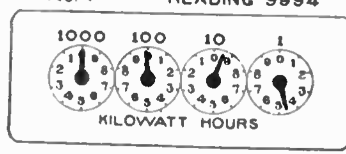
No. 2 READING 999



No. 3 READING 1001



No. 4 READING 9994

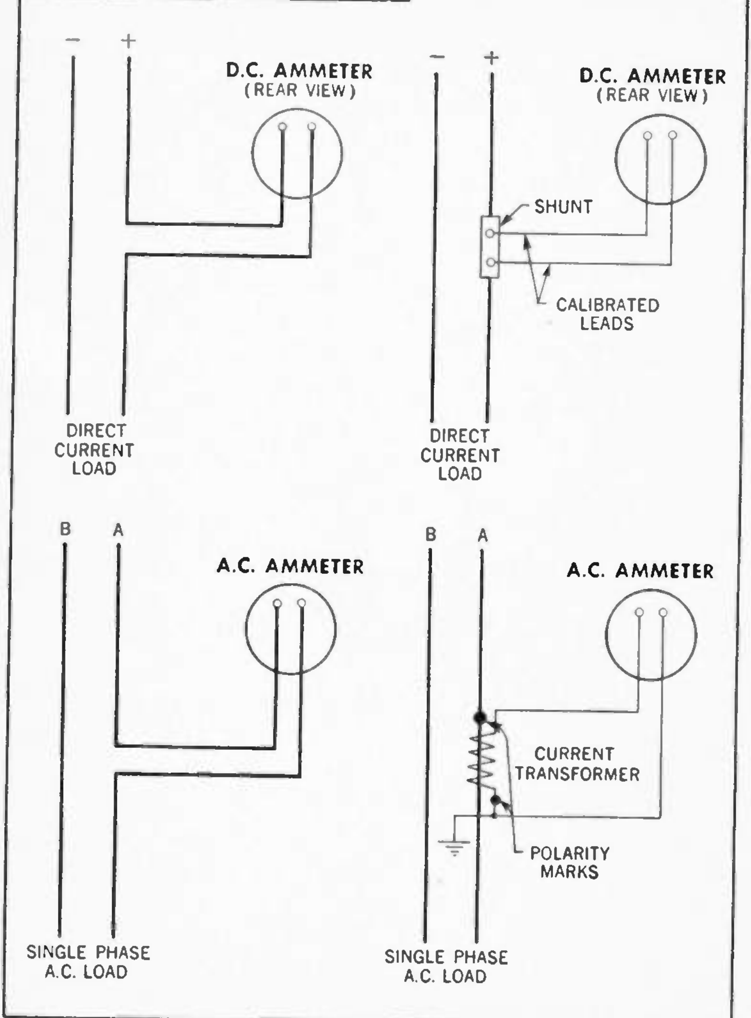


The relation between the speeds of all dial fingers is ten to one, i.e. one complete revolution of one dial hand indicates one division on the next dial to the left. If the above precautions be observed, it is a simple matter to read any meter. For example, the meter shown in example No. 1, indicated 0.1 (one-tenth) on the dial at the extreme right, the two next following indicate one each and finally the last dial also indicates one, making the total register reading 1111.1 or a registration of 1111.1 kilowatt hours.

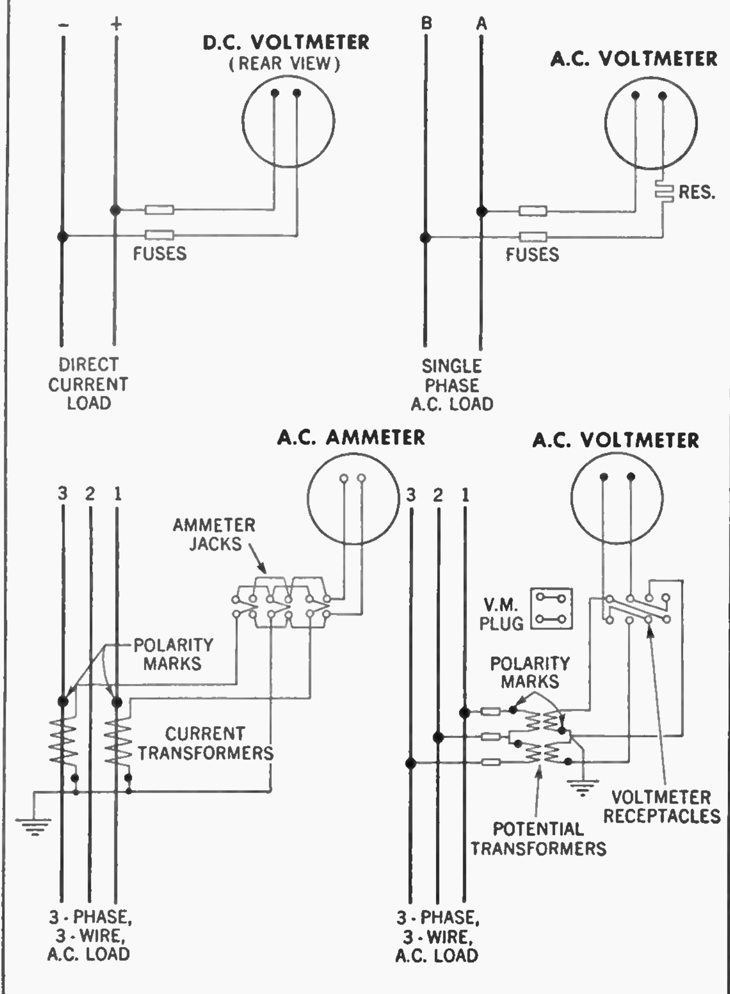
The reading example represented by Meter No. 2 in a similar manner, indicates 0.9 (nine-tenths) on the dial at the extreme right; the second dial finger rests on 0, but since the first rests only on 0.9 and has not as yet completed its revolution, it follows that the second dial finger also indicates 9. This 9 placed before 0.9 already obtained gives 9.9. The same is true about the third dial. The second dial finger at 9 has not as yet completed its revolution so the third has not completed its division; hence another 9 is obtained making 99.9. The same is true about dial four, thereby making the total registration 999.9 kilowatt-hours. The number of kilowatt-hours registered on meters Nos. 3 and 4 will similarly be obtained, being 1001 and 9994 respectively.

METERS
AND
CONNECTIONS

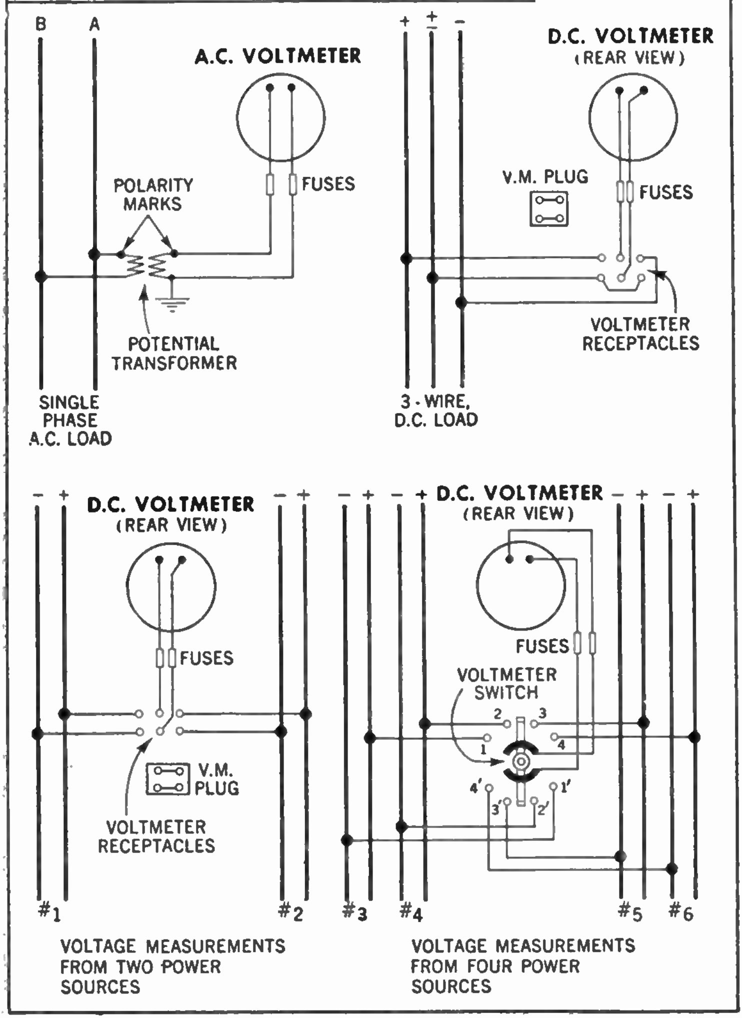
AMMETER CONNECTIONS



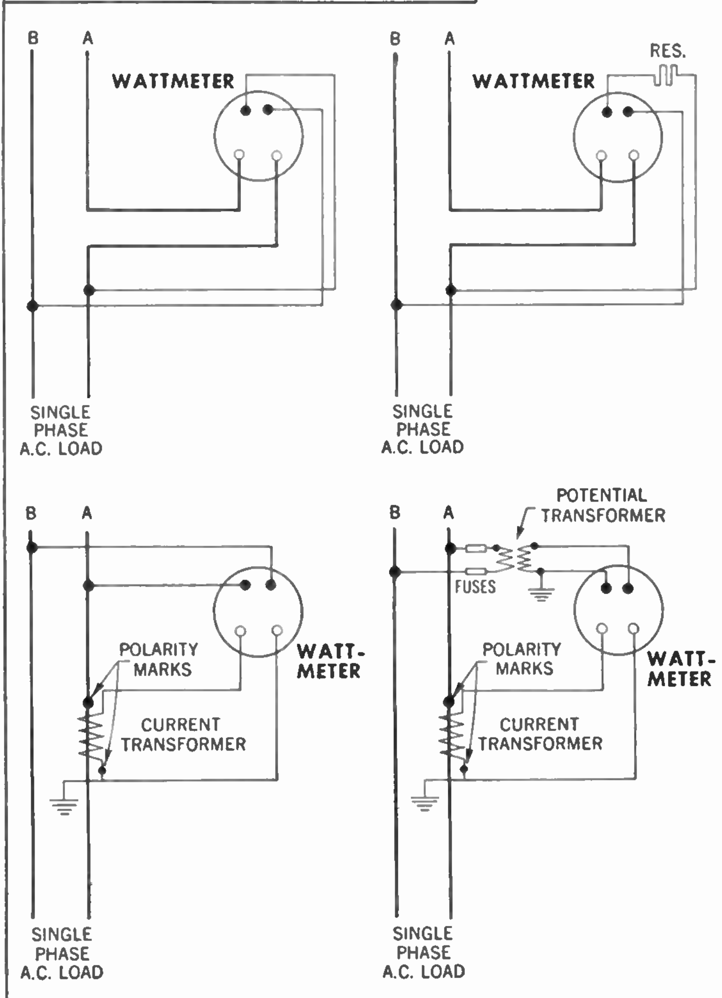
VOLTMETER AND AMMETER CONNECTIONS



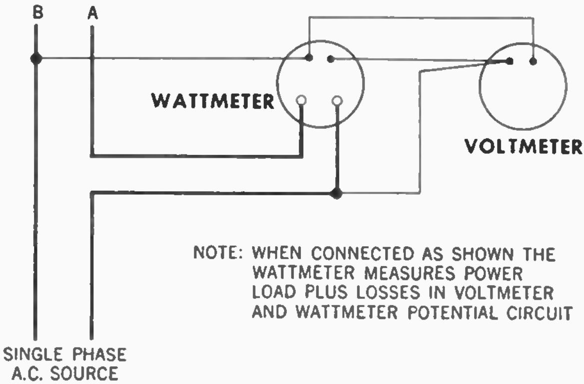
VOLTMETER CONNECTIONS FOR ALTERNATING AND DIRECT CURRENT



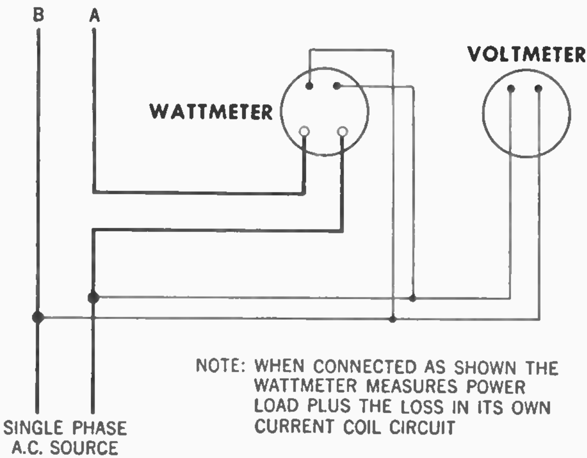
WATTMETER CONNECTIONS FOR SINGLE PHASE A.C. CIRCUITS



WATTMETER AND VOLTMETER CONNECTIONS IN SINGLE PHASE A.C. CIRCUITS

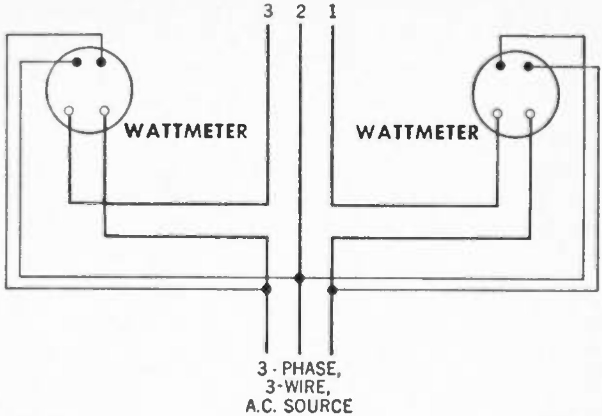


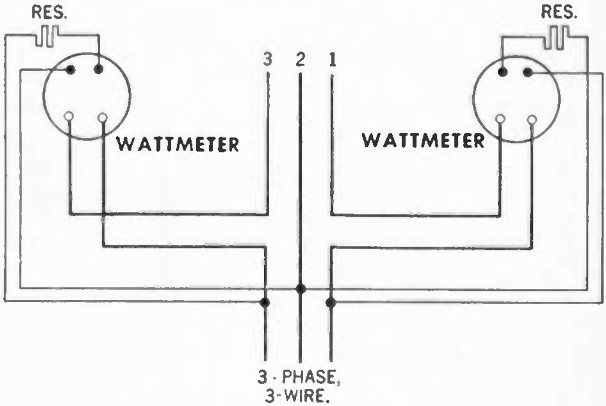
NOTE: WHEN CONNECTED AS SHOWN THE WATTMETER MEASURES POWER LOAD PLUS LOSSES IN VOLTMETER AND WATTMETER POTENTIAL CIRCUIT



NOTE: WHEN CONNECTED AS SHOWN THE WATTMETER MEASURES POWER LOAD PLUS THE LOSS IN ITS OWN CURRENT COIL CIRCUIT

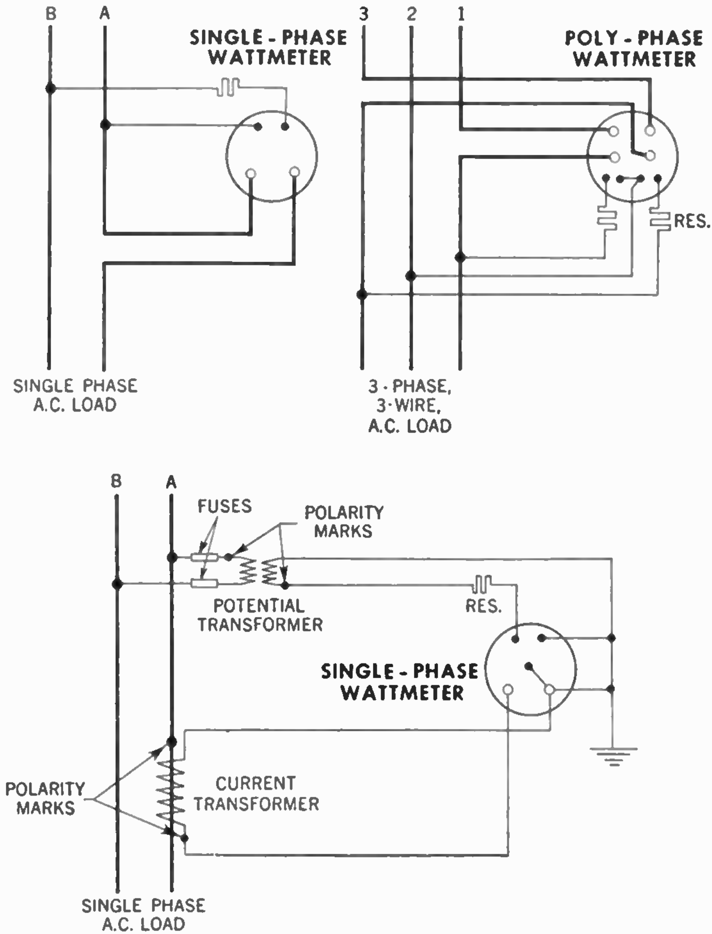
TWO WATTMETER CONNECTIONS FOR POWER MEASUREMENT



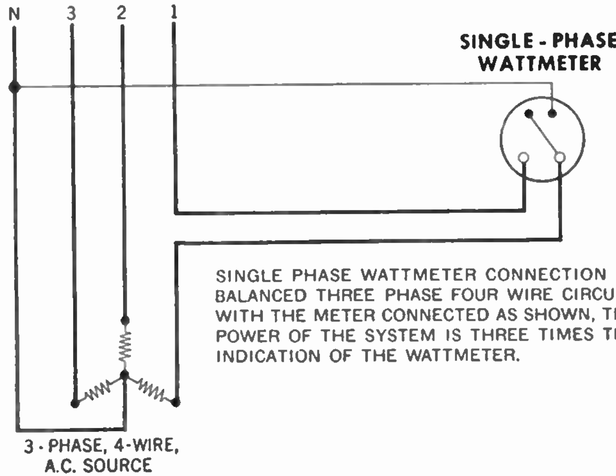


CONNECTIONS OF TWO WATTMETERS FOR MEASUREMENT OF POWER. WHEN CONNECTED AS ILLUSTRATED, THE TWO WATTMETERS WILL NOT INDICATE ALIKE EVEN IF THE LOAD BE BALANCED. ABOVE 50% POWER FACTOR, THE THREE PHASE POWER IS THE SUM OF THE TWO READINGS. BELOW 50% POWER FACTOR, IT IS NECESSARY TO REVERSE THE READING OF ONE WATTMETER (BY REVERSING ITS CURRENT LEADS) AND THEN TAKE THE DIFFERENCE BETWEEN THE READINGS OF THE TWO METERS.

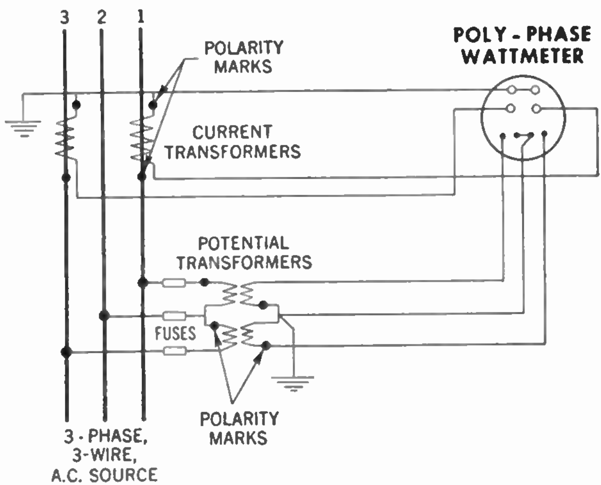
WATTMETER CONNECTIONS SINGLE AND POLY-PHASE



WATTMETER CONNECTIONS SINGLE AND POLY-PHASE



SINGLE PHASE WATTMETER CONNECTION IN BALANCED THREE PHASE FOUR WIRE CIRCUIT. WITH THE METER CONNECTED AS SHOWN, THE POWER OF THE SYSTEM IS THREE TIMES THE INDICATION OF THE WATTMETER.



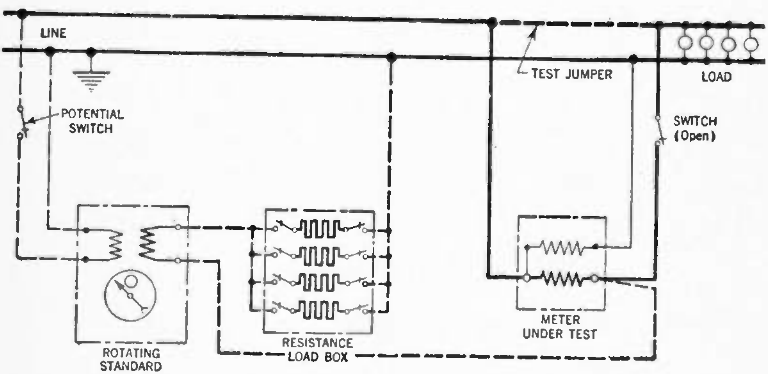
WATT-HOUR METER TEST

A watt-hour meter is used for measurement of electric energy. Principally it consists of an electric motor with associated windings so arranged that the mechanical torque produced indicates the electrical power.

One winding of the meter is usually connected in series with the load and the other across the circuit. The torque of such a motor will be proportional to the power and the total revolutions of the motor will be a measure of energy consumed by the load.

In addition a watt-hour meter is equipped with a register which records the revolutions of the meter shaft and a magnetic brake whose function it is to retard the revolutions of the motor.

Due to the inability of most meters to record the energy consumption correctly over a period of time, periodic test schedules are usually followed where each meter in service is compared with a **portable standard** meter, that is a meter in which the error has been reduced to a minimum.



Testing Circuit for a Two-Wire Meter, Using a Resistance Load.

The size of error permitted may vary in different parts of the Country but is usually around ±3 per cent of its rated load.

When setting up a meter for test the current coils of the two meters, that is, the Portable Standard and the **meter under test** are connected in series, whereas their potential coils are connected in parallel.

During the test period, the revolutions of the **standard** are compared with the meter under test for the same interval of time, allowance being made in the calculations for the disc constant of the two meters.

In cases where the load be unknown it may be determined by timing the standard with a stop watch and comparing the value of the watts from the expression,

$$\text{True watts} = \frac{3{,}600 \times \text{Revolutions} \times \text{Watt-hour Constant}}{\text{Time in seconds}} \tag{1}$$

With reference to the test circuits the rotating standard is operated by a potential switch, which stops and starts the standard, a reading of the standard is taken at the beginning and at the end of the test and the difference between these two readings gives the number of revolutions of the standard.

If no correction is to be applied to the rotating standard, the per cent accuracy of the watt-hour meter under test is obtained from equation,

$$\text{Per cent accuracy} = \frac{k_h \times r}{K_h \times R} \tag{2}$$

Where

r = revolutions of meter under test.
R = revolutions of rotating standard.
k_h = watt-hour constant of meter under test.
K_h = watt-hour constant of rotating standard.

The method shown may be facilitated by introducing an additional symbol, values for which may be given to the tester in tabular form. Thus, if R_o = the number of revolutions the rotating standard should make when the tested meter is correct, the number of revolutions of two watt-hour meters for a given load vary inversely as their disc constants, then

$$\frac{R_o}{r} = \frac{k_h}{K_h} \text{ or } R_o = \frac{k_h \times r}{K_h} \tag{3}$$

Subsituting R_o in the equation for per cent accuracy, we obtain

$$\% \text{ accuracy} = \frac{R_o \times 100}{r}$$

Example. In a certain test the rotating standard has a constant $K_h = 0.05$ and the watt-hour meter under test has a constant $k_h = 0.5$. If the number of revolutions of the meter under test, $r = 2$, determine the number of revolutions of the rotating standard.

Solution. Substituting values in formula (3) we obtain

$$R_o = \frac{k_h \times r}{K_h} = \frac{0.5 \times 2}{0.05} = 20. \quad \text{Ans.}$$

That is, for 2 revolutions of the meter under test, the standard should make 20 revolutions.

WATT-HOUR METER TEST

Example. Assume the rotating standard in the previous example actually made 20.24 revolutions, what is the accuracy of the watt-hour meter under test?

Solution.

$$\text{Per cent accuracy} = \frac{R_o \times 100}{r} = \frac{20 \times 100}{20.24} = 98.8\%. \quad \text{Ans.}$$

This actually means that the meter is 1.2% slow and should be speeded up slightly.

Example. In a test of a D.C. 15 amperes watt hour meter, the corrected average volt and ampere readings are 220 and 14.75, respectively. During the test interval 38 revolutions are counted in 53.5 seconds and the meter constant is 1.25. What is the percent accuracy of the meter at this load?

Solution. Average standard watts

$$W_1 = 14.75 \times 220 = 3{,}245$$

Inserting our values in equation (1) we obtain the average meter watts as

$$W = \frac{3{,}600 \times 38 \times 1.25}{53.5} = 3{,}196$$

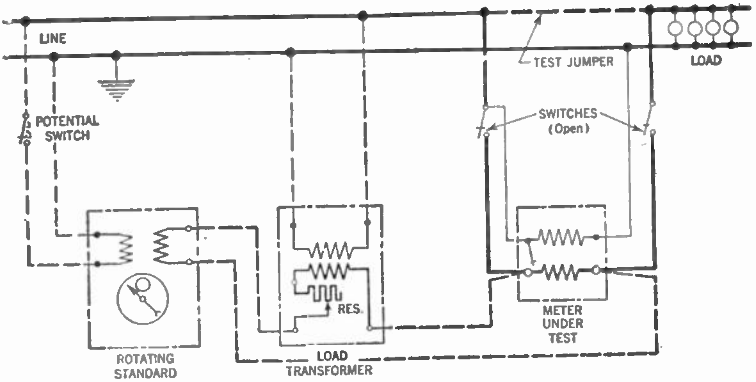
$$\text{Meter accuracy} = \frac{W}{W_1} = \frac{3{,}196}{3{,}245} = 0{,}985 \text{ or } 98.5\%. \quad \text{Ans.}$$

Other well known methods used in testing of watt-hour meters are: (1) **the indicating instrument method** and (2) **the stroboscopic method.** In the former, load is applied to the meter and watt-hours are measured by means of indicating instruments and timing devices such as stop watches or cronographs.

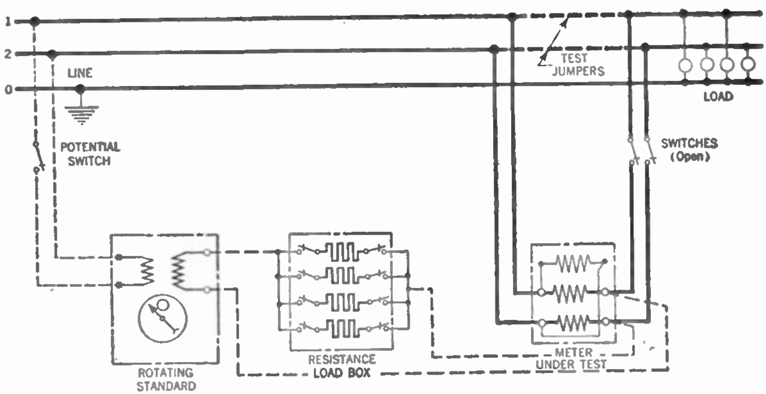
The ratio between the indicated or meter watt-hours and true watt-hours represent the accuracy of the meter under test, and is usually expressed in per cent.

The stroboscopic method involves the comparison of the speed of two similar discs, and utilizes a light source, a lens system, a photo-electric cell and amplifying equipment. This method of meter testing finds application in meter shops having a large number of meters to be tested. It is not limited to type of meter to be tested except that marking or slotting of the disc is necessary in order to obtain pulsating light.

WATT-HOUR METER TEST



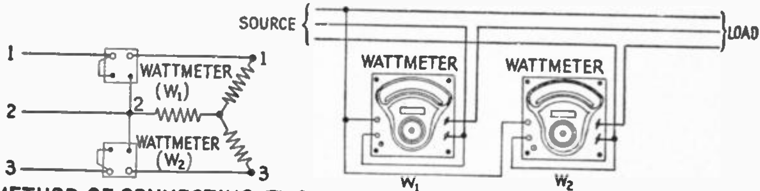
Testing Circuit for a Two-Wire Meter, Using a Loading Transformer. NOTE: Line side of meter may be left connected to service and potential jumper omitted. With such connections secondary of loading transformer and current coil of rotating standard will be at line potential.



Testing Circuit for a Three-Wire, Single Phase Meter, Using a Resistance Load on Line to Line Voltage.

POWER MEASUREMENT IN POLYPHASE SYSTEMS

Power Measurements with Two Watt-Meters: With reference to connection diagram, the current coils of the meters should be in two of the lines and each potential coil connected from that line in which its current coil is placed, to the third line. The algebraic sum of the connected watt-meter readings gives the total wattage. That is, if the power factor of the load be unity, each watt-meter will read one half the total power. If the power factor is 50%, one watt-meter will read zero and the other will read the total power. If the power factor is somewhere between 50% and 100%, one watt-meter will read more than the other, in which case the total power is found by adding the two watt-meter readings. If the power factor is below 50% one watt-meter will indicate backwards. The connection of the current or voltage coil of this meter should be reversed in order that a reading may be obtained. In this case the power taken by the circuit is determined by subtracting the reading of the watt-meter that reversed from the other watt-meter reading.

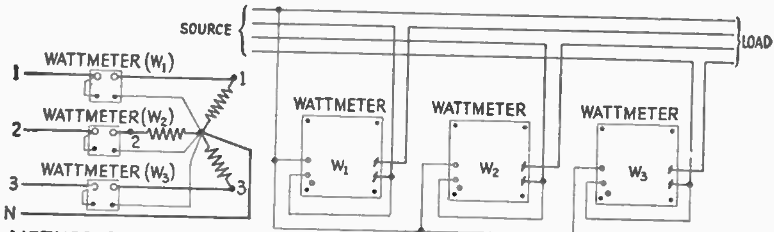


METHOD OF CONNECTING TWO WATTMETERS TO A POLYPHASE CIRCUIT

Power Factor Measurement. In a balanced **three phase** circuit, the power factor may be obtained from the readings of the two watt-meters, without measuring the voltage or the amount of current of any of the circuits, by applying the following formula.

$$\tan \phi = \frac{W_1 - W_2}{W_1 + W_2}\sqrt{3}$$

Where ϕ = angle of lag; W_1 = reading on watt-meter indicating the larger amount of power; W_2 = reading on watt-meter indicating the smaller amount of power

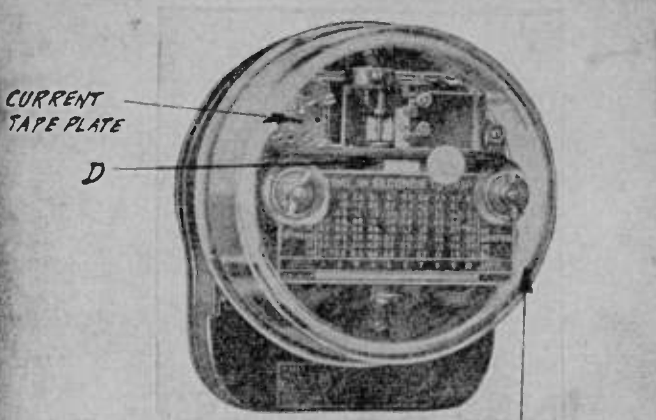


METHOD OF CONNECTING THREE WATTMETERS TO A POLYPHASE CIRCUIT

To measure the power in a three phase four wire system, three watt-meters should be used and connected as shown. The current coils should be connected in the three lines and each potential coil should be connected from the line in which the current coil is placed to the neutral line. In this case watt-meter (W_1) measures the power taken by phase 1 watt-meter (W_2) the power taken by phase 2, etc. and the total power is equal to the sum of the readings of the three meters.

RELAYS AND INSTRUMENT CONNECTIONS

OVERLOAD RELAY



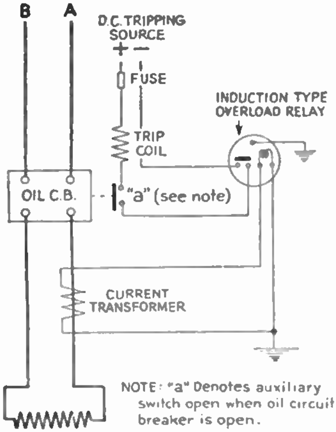
TIME LIMIT INDUCTION TYPE
OVERLOAD RELAY

OPERATION: In general the relay operates as follows: When an overcurrent exceeding the setting at which the relay is to operate occurs, the rotation of the disk "D", actuated by a "U" shaped driving magnet and retarded by a pair of permanent magnets, causes the contacts to close after an interval of time which depends upon the amount of current passing through the relay, and also predetermined by the setting of the time lever.

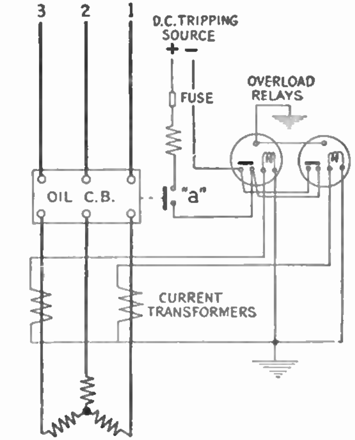
For typical wiring diagram; see the following page.

METHODS OF OVERLOAD PROTECTION WITH INDUCTION TYPE OVERLOAD RELAYS

SINGLE PHASE CIRCUIT

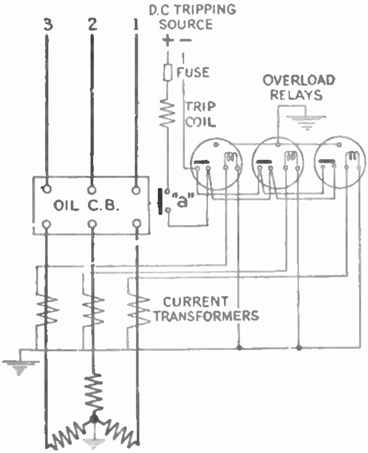


THREE PHASE, THREE WIRE CIRCUIT



THREE PHASE, THREE WIRE CIRCUIT

(NEUTRAL GROUNDED OR UNGROUNDED)



TWO PHASE, FOUR WIRE CIRCUIT

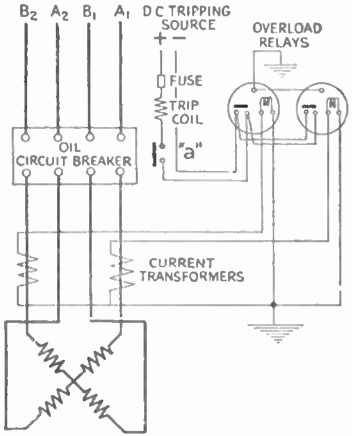
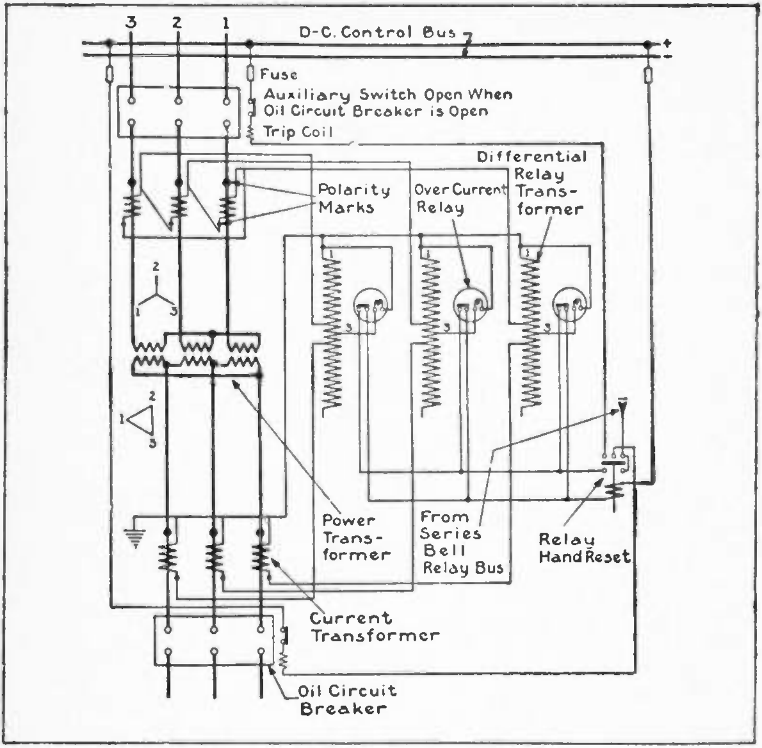


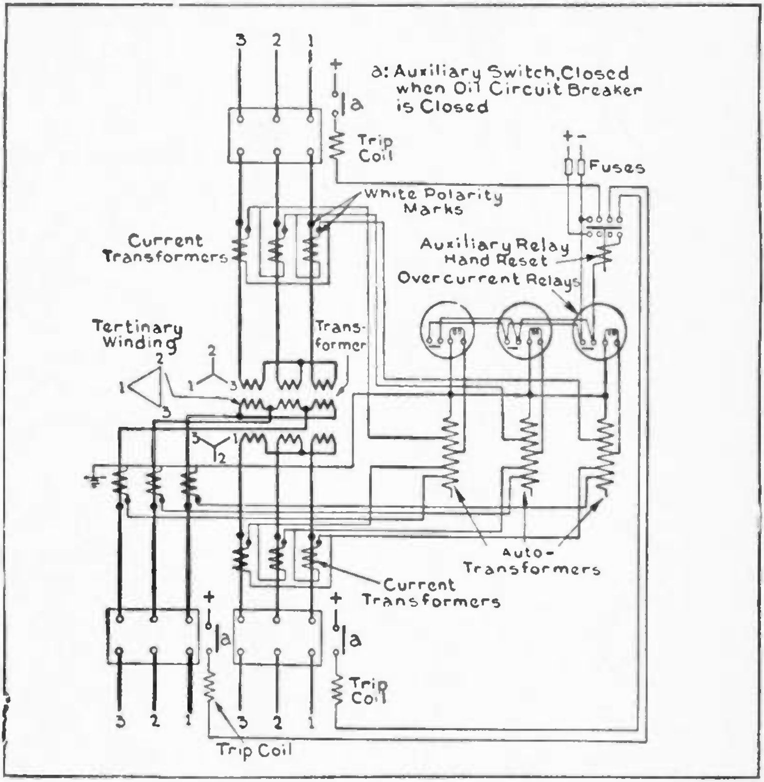
DIAGRAM OF CONNECTION FOR DIFFERENTIAL PROTECTION OF POWER TRANSFORMERS



Operation. Differential protective equipment is used with power transformers most frequently when two or more are operated in parallel. Thus, when this system of protection is utilized both automatic and simultaneous tripping of the high- and low-voltage breaker is obtained in case of internal breakdown in the transformers.

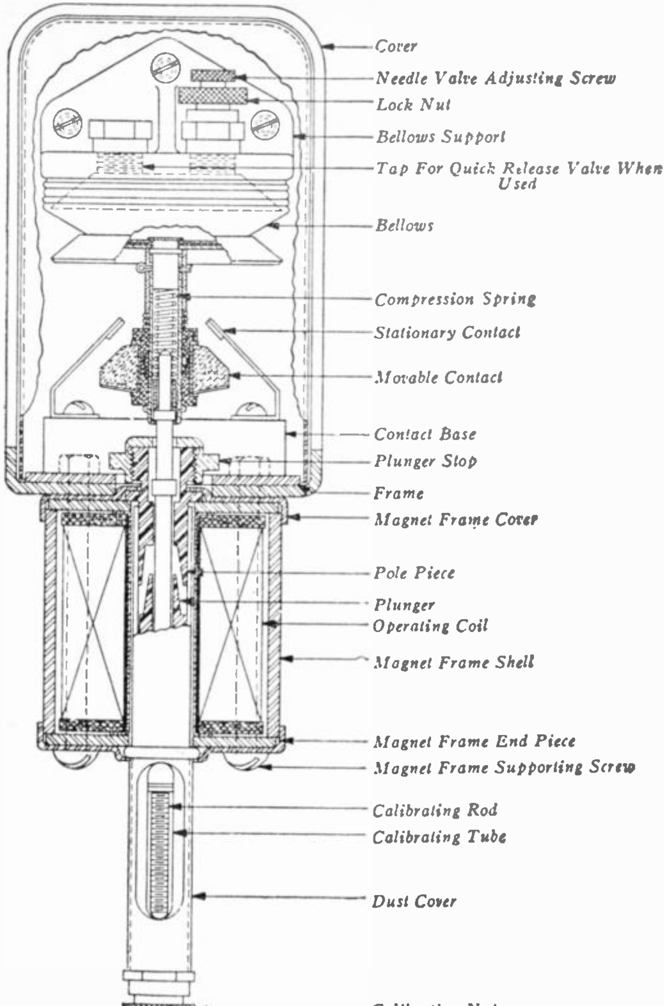
It is important that current transformers be selected of proper ratios to give equal secondary currents on the high- and low-voltage side. However, most frequently the ratio of transformation is such that this is difficult to obtain, in which case taps are resorted to, which may be changed from time to time. (For operation of relays see following page.)

CONNECTIONS FOR DIFFERENTIAL PROTECTION OF TRANSFORMER-BANK WITH A TERTIARY WINDING USING INDUCTION TYPE OVER CURRENT RELAYS



Operation. When due to internal faults in transformer windings the current through the overcurrent relays exceeds that for which the relays are set to operate, the relays close their contacts, in turn energizing the auxiliary relay coil resulting in a simultaneous tripping of the three circuit breakers.

OVERCURRENT RELAY



SECTIONAL VIEW OF PLUNGER TYPE OVERCURRENT RELAY

FOR APPLICATION AND CONNECTIONS, SEE FOLLOWING PAGES.

PLUNGER TYPE OVERLOAD RELAY

Operation Principles. When due to certain conditions in the circuit to be protected, the current exceeds the value at which the relay is set to operate, the plunger raises and carries up with it the movable cone contact, or it strikes against the center of the toggle mechanisms (depending upon the type of contacts in the relay) thus causing the contacts to function.

Generally, when a relay functions to open its contacts it is referred to as a **circuit-opening** type, and when it functions to close its contacts, it is referred to as the **circuit-closing** type. In this manner the function of the contacts of a relay is most frequently used as a means of identification, a relay being **circuit-closing** or **circuit-opening** or **circuit-opening** and **circuit-closing.**

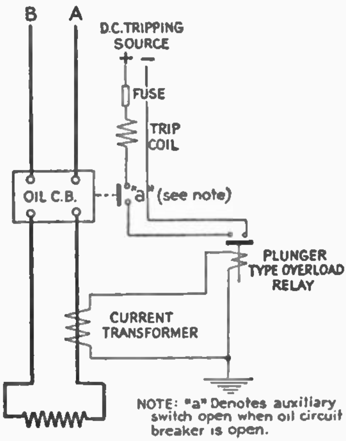
Timing Features. In regard to speed of operation a relay may be referred to as instantaneous or **time** delay. The word **instantaneous** conveying a general qualifying term applied to any relay indicating that no delayed action has been purposely introduced.

The time relays are similar in construction to the instantaneous type, except for the addition of an air bellows which limits the rate of travel of the relay plunger, and in this way introduces an interval of time to the opening or closing of the relay contacts.

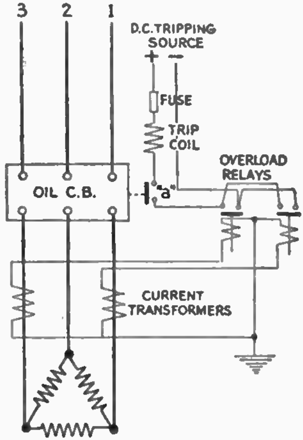
This time delay may be regulated to suit the special service desired, which is accomplished by means of a needle valve located in the head of the bellows as shown on page 58. This valve controls the rate of air flow from the bellows under various operating conditions.

METHODS OF OVERLOAD PROTECTION WITH PLUNGER TYPE CIRCUIT CLOSING RELAYS

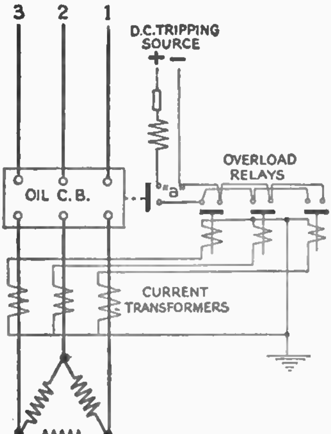
SINGLE PHASE CIRCUIT



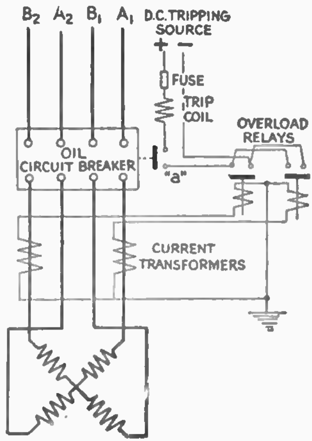
THREE PHASE, THREE WIRE CIRCUIT



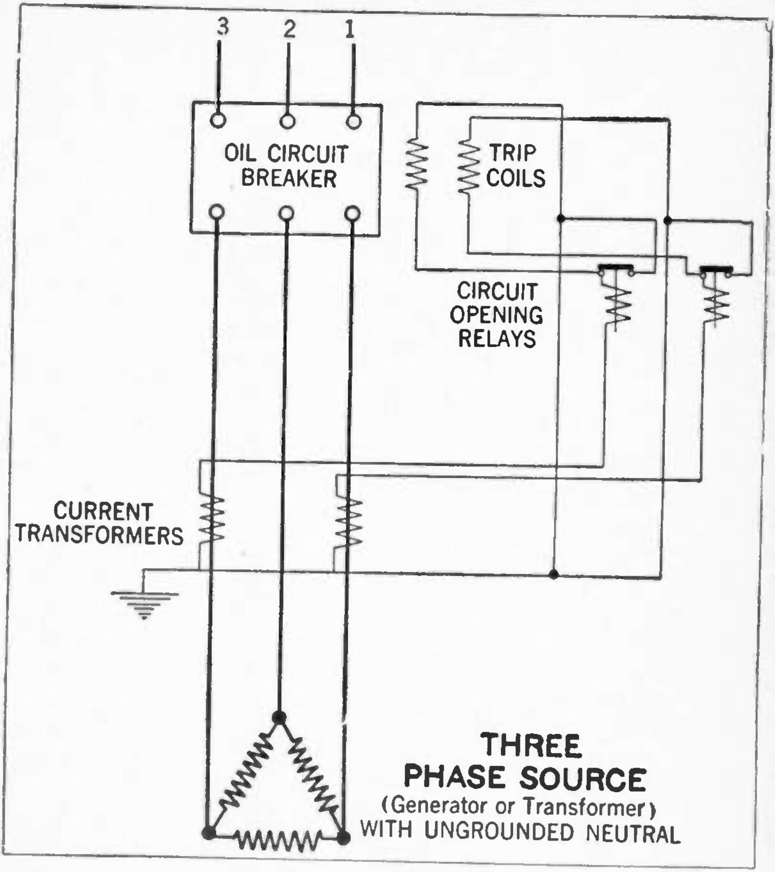
THREE PHASE, THREE WIRE CIRCUIT



TWO PHASE, FOUR WIRE CIRCUIT

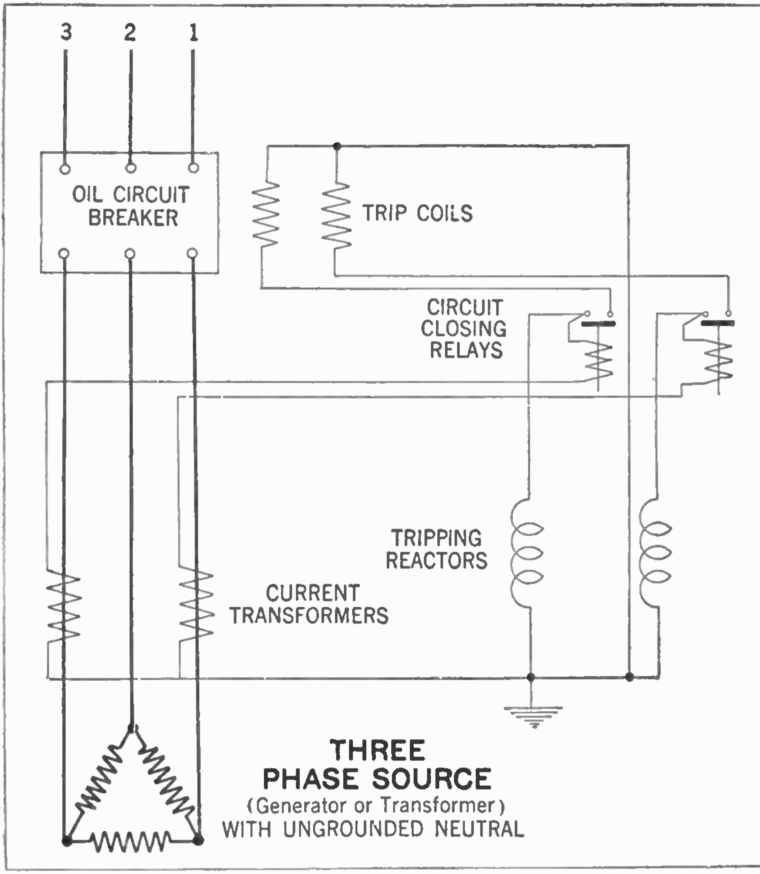


OVERLOAD PROTECTION WITH PLUNGER TYPE CIRCUIT OPENING RELAYS



OPERATION. In this circuit overload protection is accomplished by means of a set of current transformers, with its associated relays and trip coils. The relay contacts are normally closed. When the overload through the trip coils exceeds that for which the relays are set to operate, the contacts open, placing the trip coils in series with the relay coils, causing the trip coils to trip the oil circuit breaker.

OVERLOAD PROTECTION WITH PLUNGER TYPE CIRCUIT CLOSING RELAYS

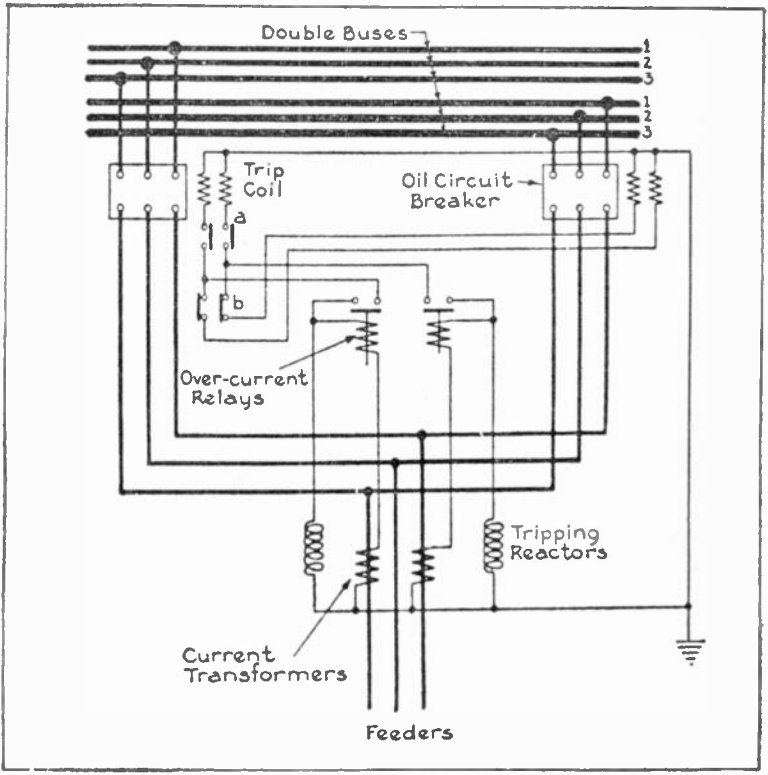


Operation. When tripping reactors are used as in over-current and other types of relays, instrument and meters should be connected from an extra set of current transformers.

Tripping reactors are frequently employed when a direct current or reliable alternating current is not available as a tripping source for the relays.

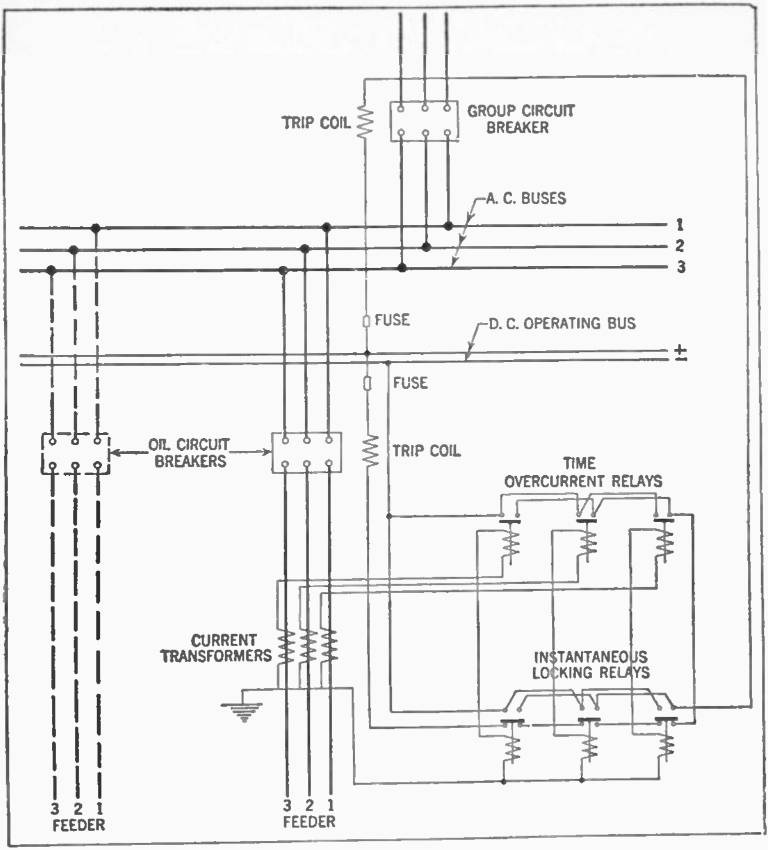
Normally the trip coil circuit is open and the reactor forms the closed circuit of the current transformer secondary. When the overload is of a sufficiently high value to cause operation of the relay, it closes the trip coil circuit in shunt with the reactor causing sufficient current to be passed through the coils to trip the breaker.

TRIPPING OF TWO OIL CIRCUIT BREAKERS USING TRIPPING REACTORS AND CIRCUIT CLOSING RELAYS



Note. Auxiliary switch "a" is open when oil circuit breaker is open, and auxiliary switch "b" is closed when the oil circuit breaker is open.

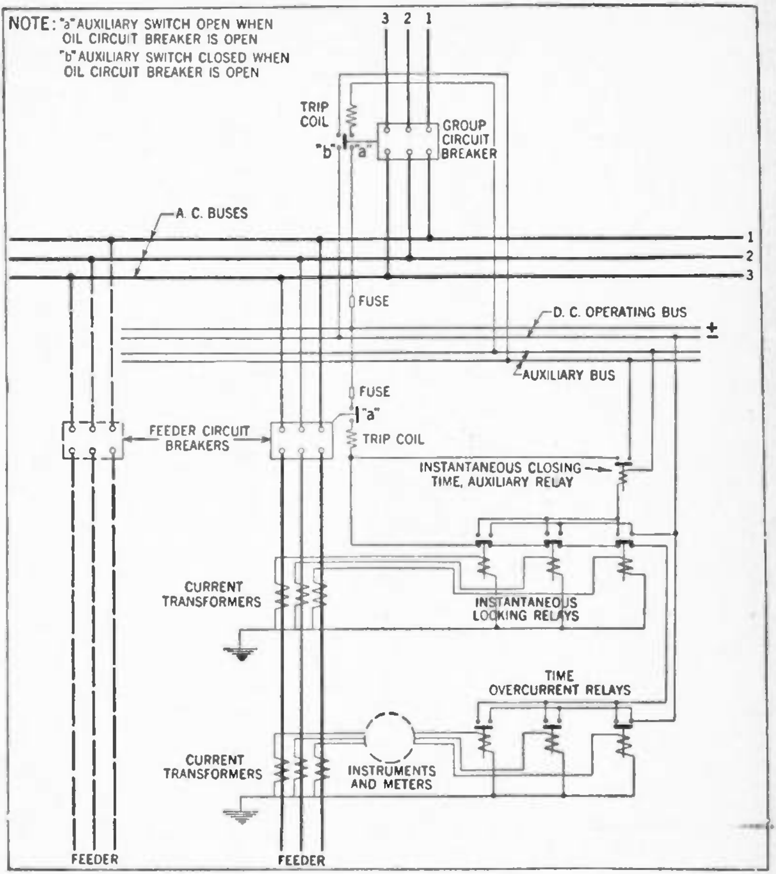
APPLICATION OF LOCKING RELAYS TO FEEDER CIRCUITS



OPERATION. In this system each feeder is equipped with a complement of time overload relays adjusted to trip the feeder breaker on simple over-current, and a set of instantaneous locking relays with high current coil setting, adjusted not to function as long as the primary current does not exceed the capacity of the feeder breaker, but to function instantaneously in case the current exceed this value.

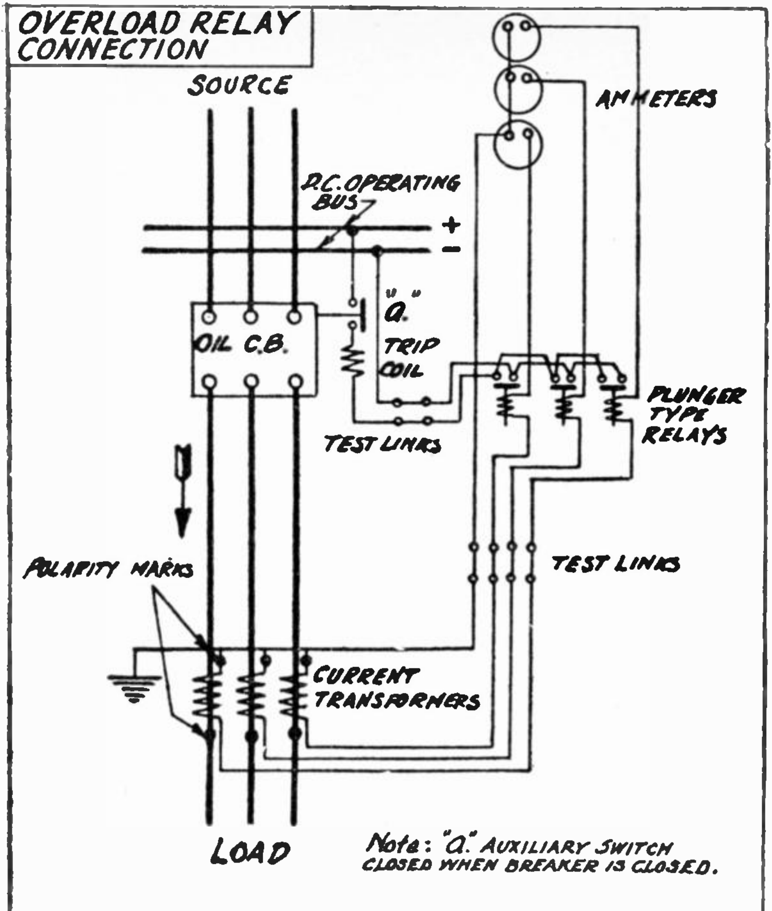
The operation of the locking relays opens the tripping circuit of the feeder breaker, thus locking the feeder breaker closed, and closes the tripping circuit of the heavy duty group circuit breaker.

APPLICATION OF LOCKING RELAYS TO FEEDER CIRCUITS



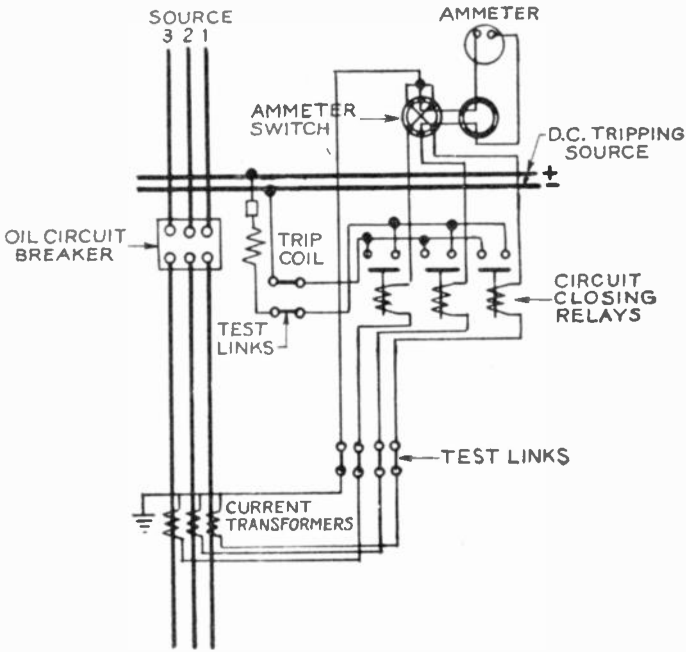
Operation. In this, as in the system shown on the previous page, the locking relays operate only upon excessive over-current in which case the locking relays close the feeder breaker and open the group breaker.

An additional relay equipped with a direct current coil is arranged to close instantaneously and reset itself (open) in a definite time, is used as an auxiliary relay to work in conjunction with a circuit closing auxiliary switch on the group breaker to open the feeder breaker after the group breaker has been opened.



OVERLOAD PROTECTION OF A.C. FEEDER SHOWING APPLICATION OF TEST LINKS, FACILITATING TESTING RELAYS AND METERS.

OVER CURRENT PROTECTION



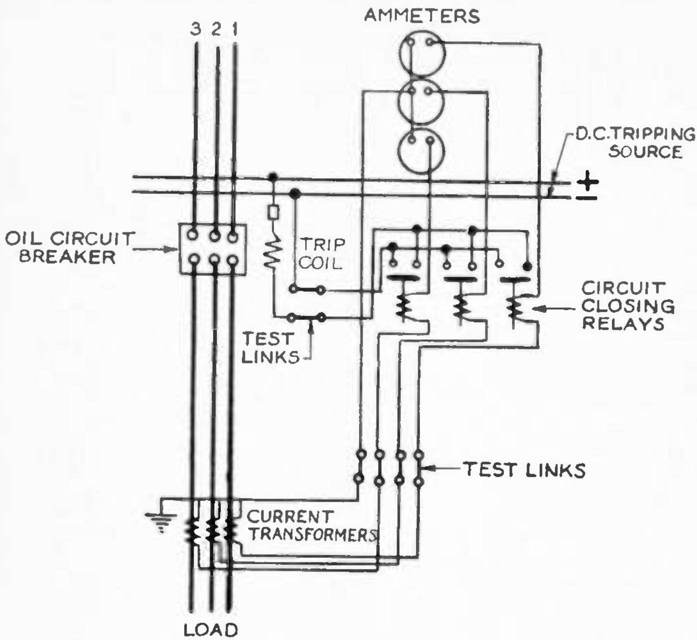
Overload protection on typical A.C. feeder circuit.

OPERATION: When current exceeds the setting of the relays, the relays will close their contacts energizing the trip coil, which trips the oil circuit breaker.

The test links shown are optional but will, if used, facilitate the testing and calibration of instruments.

The current in each phase is measured by means of ammeter and three way switch.

OVER CURRENT PROTECTION



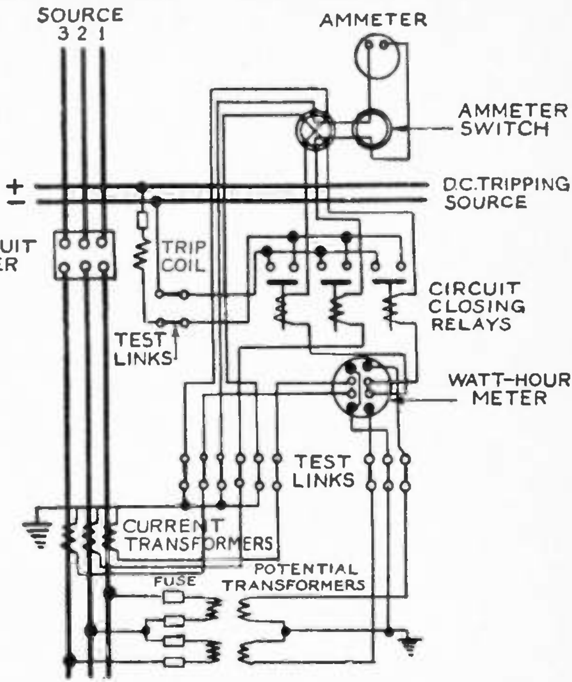
Overload protection on typical A.C. feeder.

OPERATION: When current exceeds the setting of the relays, the relays will close their contacts, energizing the trip coil which trips the oil circuit breaker.

The test links are optional but will, if used, facilitate testing or calibration of instruments.

The current in each phase is measured by individual ammeters.

OVER CURRENT PROTECTION



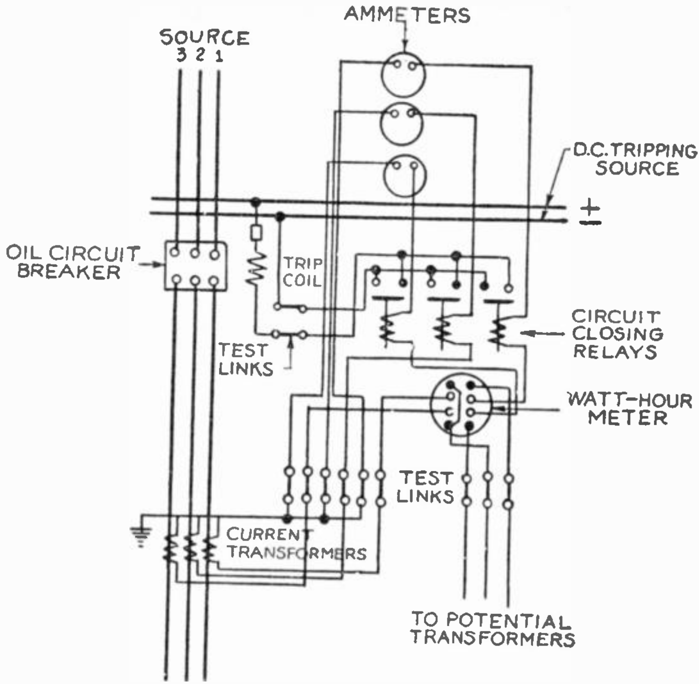
Overload protection on typical A.C. feeder.

OPERATION: When current exceed the setting of the relays, the relays will close their contacts, energizing the trip coil which trips out the oil circuit breaker.

The energy is measured by means of a watt-hour meter; and the current in each phase by ammeter and three way switch.

Test links shown are optional but will, if used, facilitate the testing of relays and instruments.

OVERLOAD PROTECTION

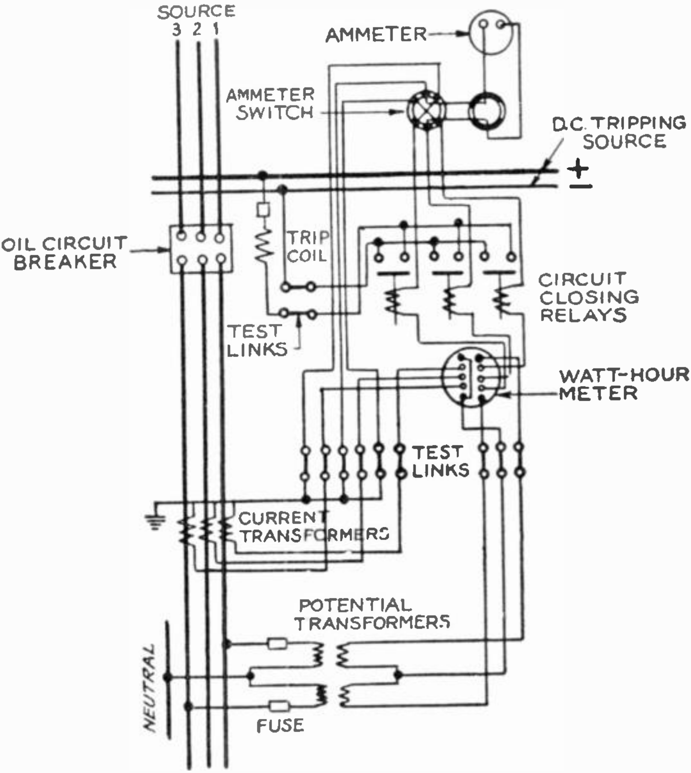


Overload protection on A.C. feeder.

<u>Operation</u>: When the current exceeds the setting of the relays, the relays will close their contacts, energizing the trip coil which trips out the breaker.

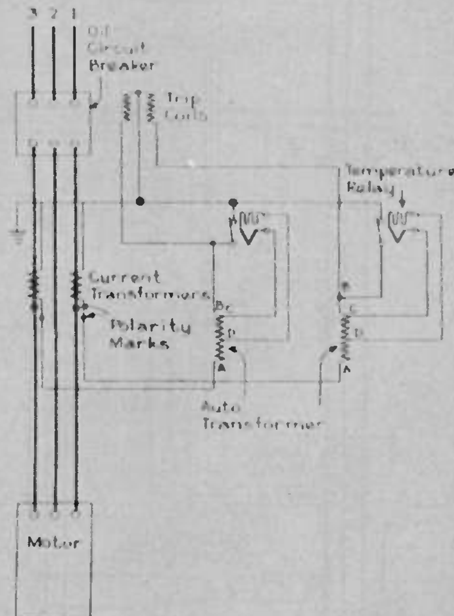
The energy is measured by means of a watt-hour meter, and the current in each phase by individual ammeters. Test links are optional but will, if used, facilitate the testing or calibration of relays and instruments.

OVER CURRENT PROTECTION



OPERATION: When current exceeds the setting of the relays, the relays will close their contacts energizing the trip coil, which trips out the oil circuit breaker.
The energy is measured by a watt-hour meter, and the current in each phase by ammeter and three way switch.
Test links are optional but will, if used, facilitate the testing and calibration of relays and instrument.

TEMPERATURE OVERCURRENT PROTECTION



Temperature overcurrent protection for synchronous motor using temperature relays.

OPERATION: When the overcurrent exceed the rating at which the relays is set to operate, the heating effect of the current passing through the relays will cause the relay contacts to close and energize the trip coils which trips the oil circuit breaker. The relays operating characteristics is usually inverse-time, in that the time to operate the relay varies inversely with the overcurrent applied.

GROUND DETECTOR AND CONNECTIONS

GROUND DETECTOR

On underground systems, A.C. as well as D.C., it is necessary to install some kind of equipment for detection or reading leakage to ground, in accord with the N.E.C.S. rules.

For low voltage two wire systems, the simplest method is to connect two lamps of the system voltage in series across the two wires, with the connection between the two lamps grounded.

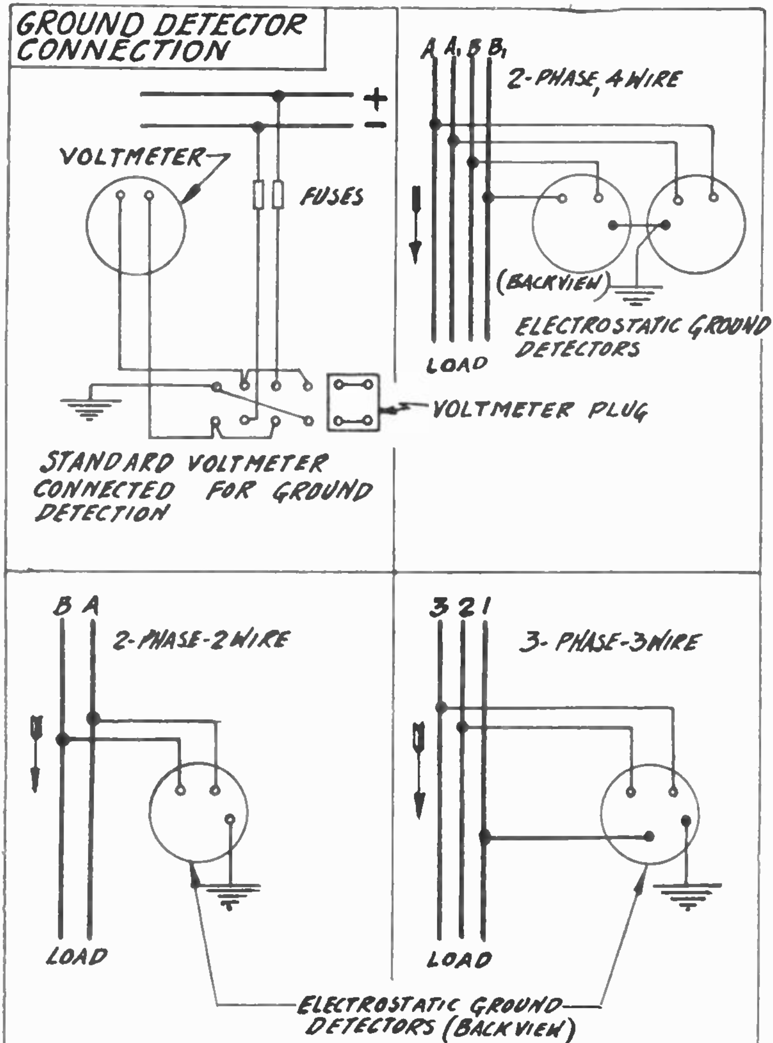
Ground on one side will obviously short circuit and darken the lamps on that side.

Above 300 volts, static or glover type of ground detectors are generally used; a typical instrument for ground detection is shown above, and standard connection for same are shown on the following pages as well as ground detection by voltmeter or lamp method.

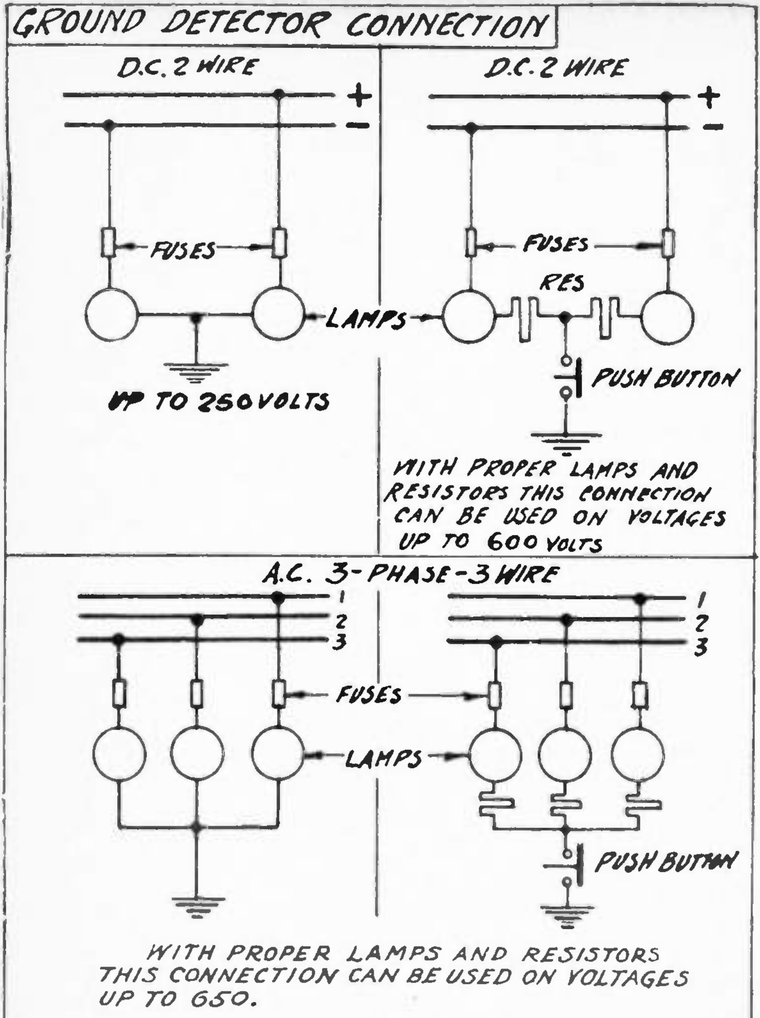
Before connecting ground detection instrument, compare operating voltage with that given on the meter; and in each case follow the manufacturers recommendation.

For example of ground detection diagram,

See the following pages.



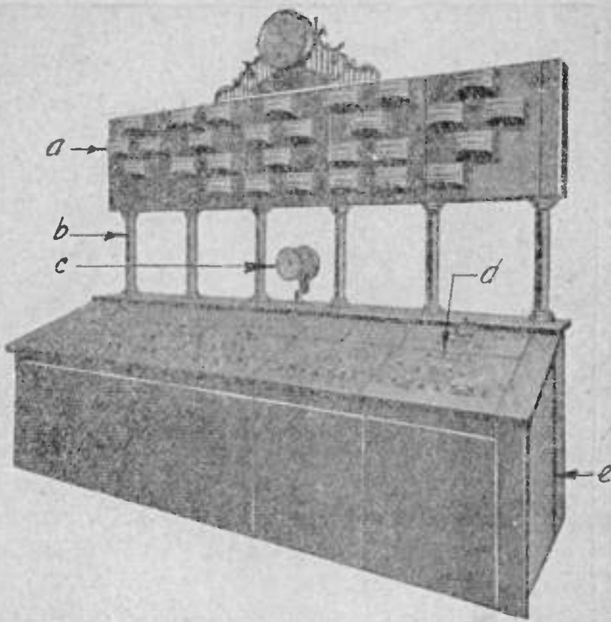
CONNECTION FOR GROUND DETECTION ON A.C. CIRCUITS, FOR VOLTAGES UP TO 3300.



CONNECTION OF GROUND DETECTOR LAMPS ON A.C. AND D.C. CIRCUITS.

SWITCHBOARD AND WIRING DIAGRAMS

BENCH TYPE SWITCHBOARD



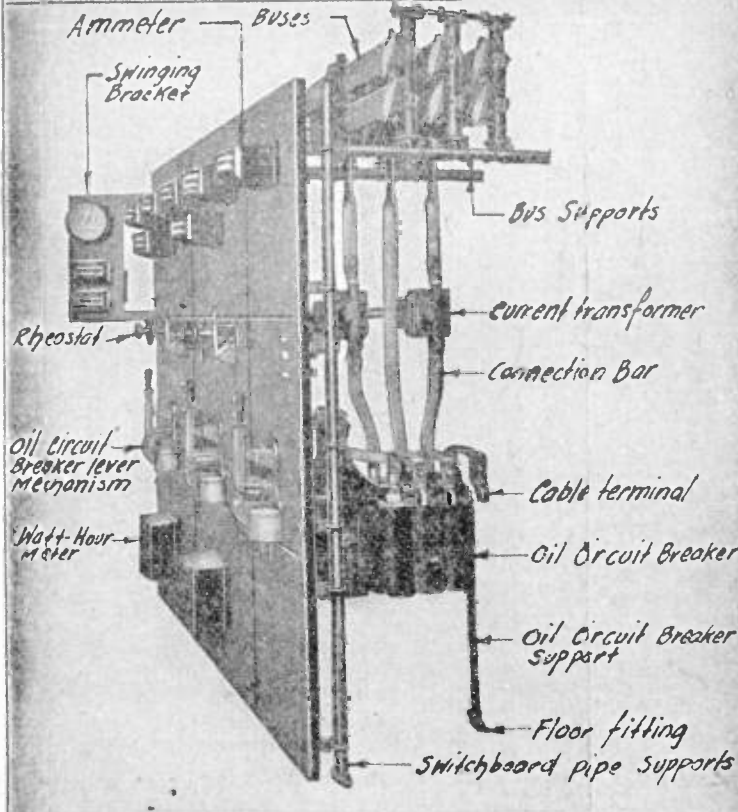
— BENCHTYPE SWITCHBOARD —

This type Switchboards are used primarily where the vertical board cannot be used on account of its limited space for mounting a required number of devices within a certain optical and operating range.

The Oil Circuit Breakers when using this type of switchboard are usually located and operated remotely from the switchboard itself; and all secondary wiring is laid in conduits leading to oil circuit breaker solenoids, current and potential transformers Etc.

a = Meter.
b = Panel support and wire conduit.
c = Synchronous indicator.
d = Control switch.
e = Wire grille.

SWITCHBOARD ARRANGEMENT

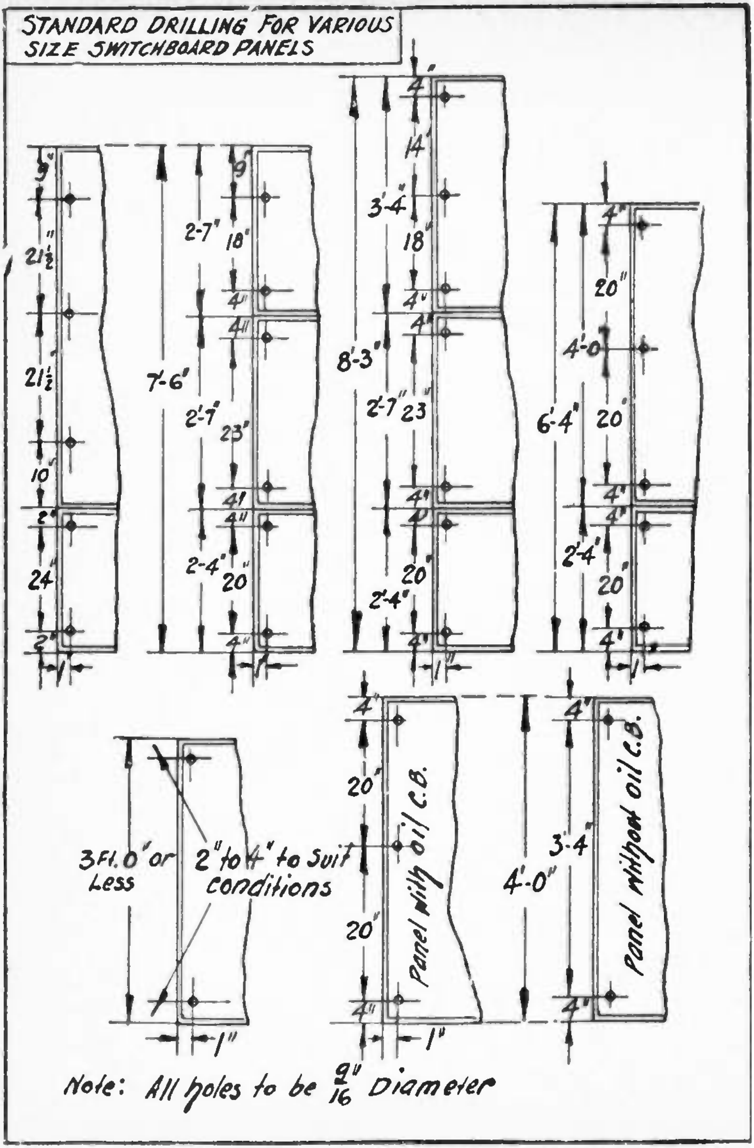


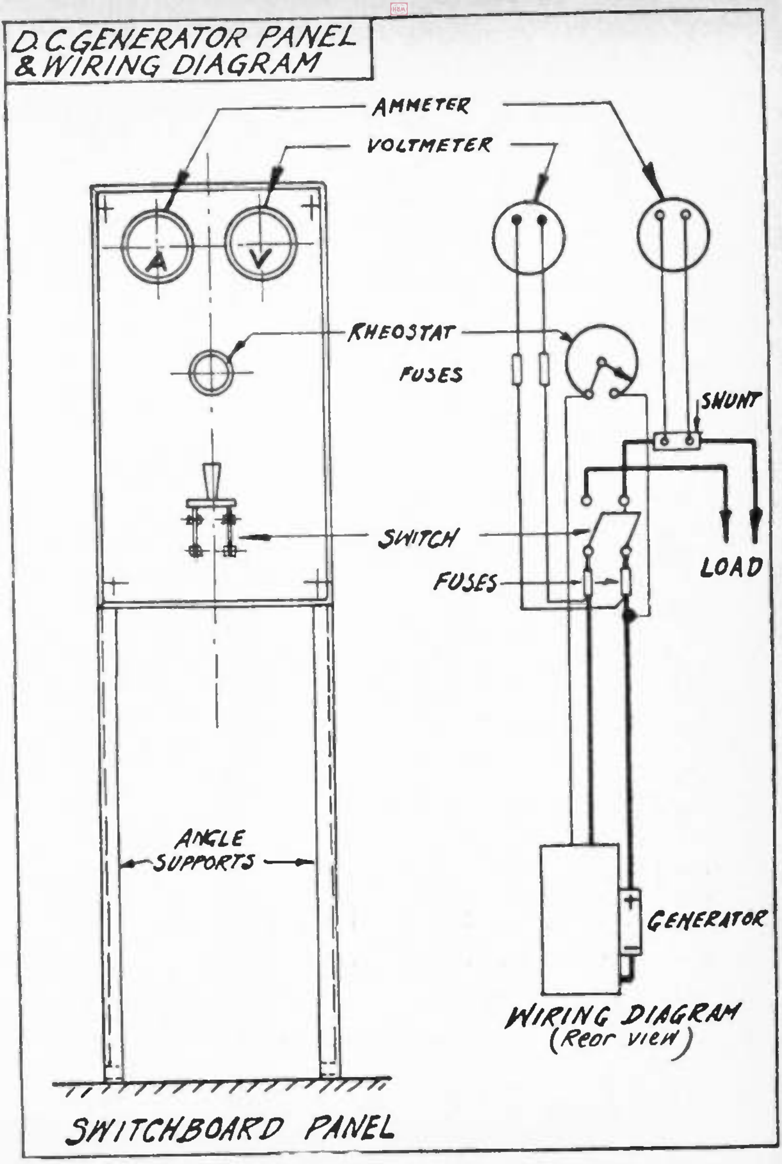
TYPICAL BACK-OF-BOARD CONNECTIONS

This switchboard shows a typical back of board arrangement with busses supported on pipes attached to the switchboard mounting pipes.

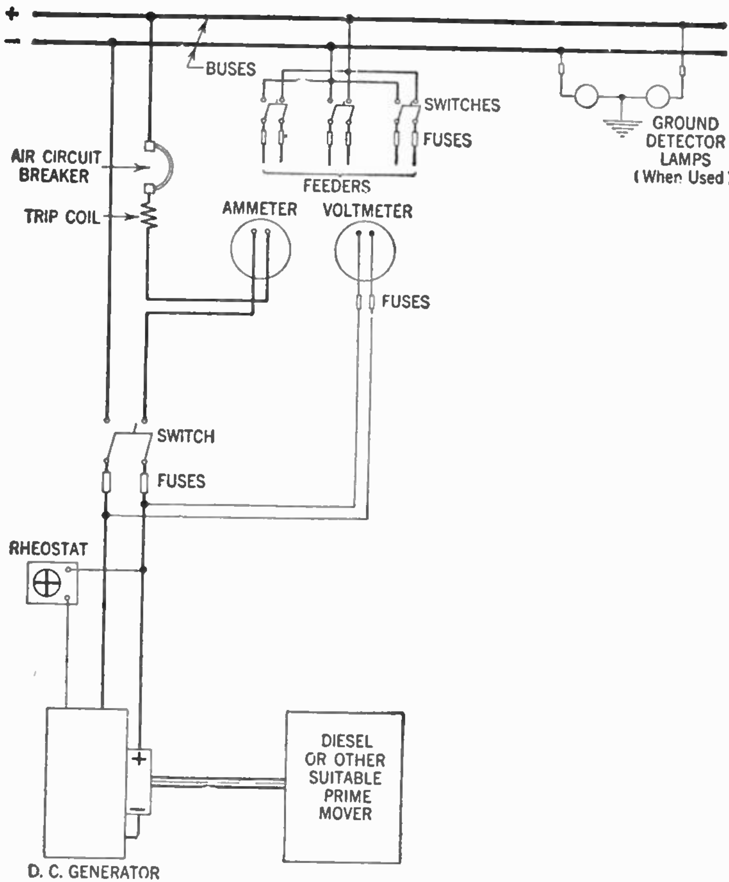
The bus supporting pipes also serve as wall Braces to support the switchboard proper.

The rheostats are controlled from front of board by means of concentric handles as shown.


STANDARD DRILLING FOR VARIOUS SIZE SWITCHBOARD PANELS
9"
21½"
21½
10"
2"
24"
2"
1
7-6"
2-7"
18"
9"
4"
4"
2'-7"
23"
4"
4"
2-4"
20"
4"
1
8'-3"
4"
14"
3'-4"
18"
4"
4"
2'-7"
23"
4"
4"
20"
2'-4"
4"
1"
6'-4"
4"
20"
4'-0
20"
4"
4"
2'-4"
20"
4"
1
3 Ft. 0" or Less
2" to 4" to Suit conditions
1"
4"
20"
20"
4"
1"
Panel with oil C.B.
4'-0"
4"
3'-4"
4"
Panel without oil C.B.
Note: All holes to be 9/16" Diameter

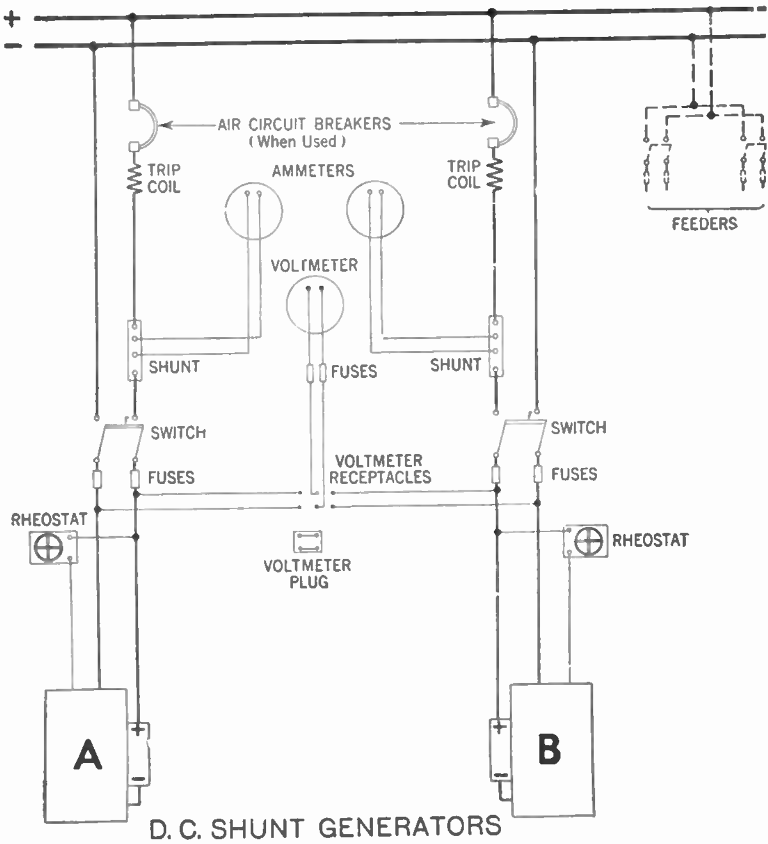

D.C. GENERATOR PANEL
& WIRING DIAGRAM
AMMETER
VOLTMETER
A
V
RHEOSTAT
FUSES
SHUNT
SWITCH
LOAD
FUSES
ANGLE
SUPPORTS
GENERATOR
WIRING DIAGRAM
(Rear view)
SWITCHBOARD PANEL

Direct Current Generator Connections

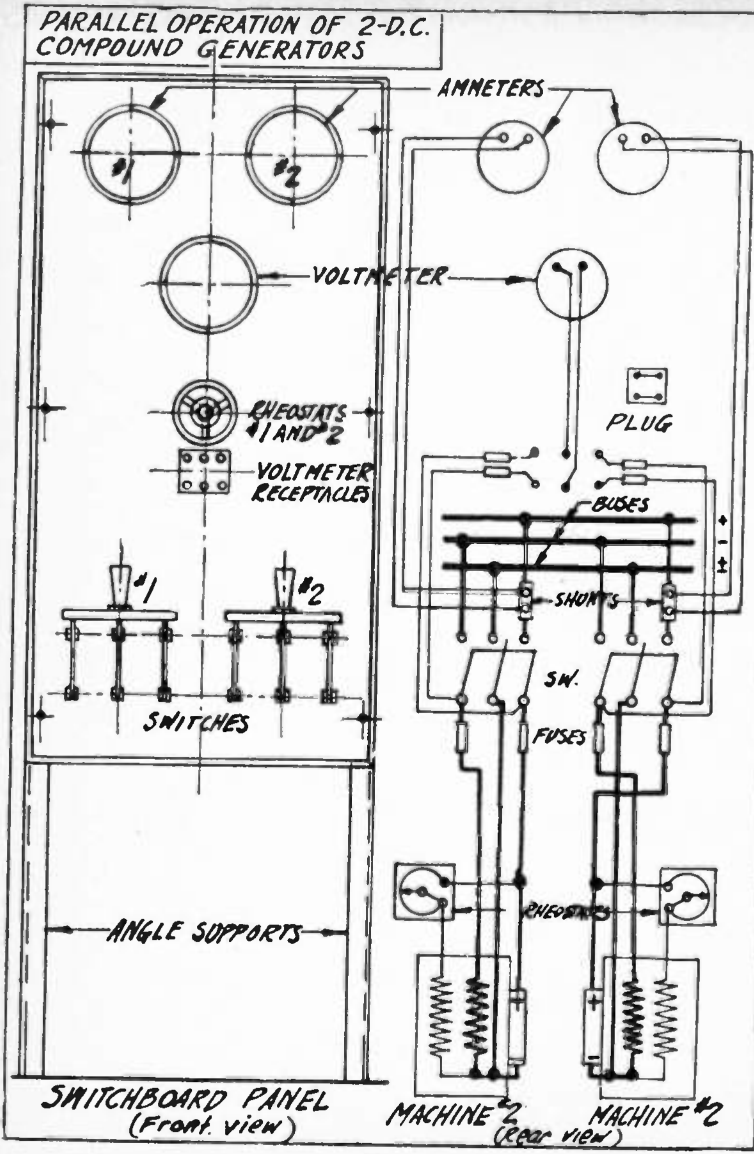


Connection of a shunt wound direct current generator. The connections are largely self-explanatory, the voltmeter being connected across the main leads at the generator side of the double-pole knife switch. This will enable the operator to read the voltage of the machine at all times, regardless of the position of the main switches. The current indicator (ammeter) is connected in series with the positive lead connecting the machine to the load. The purpose of the over-load coil on the circuit breaker is to prevent the current from reaching dangerous proportions, that is, when the current exceeds the calibrated settings of the coil. the breaker trips. disconnecting the generator from its load.

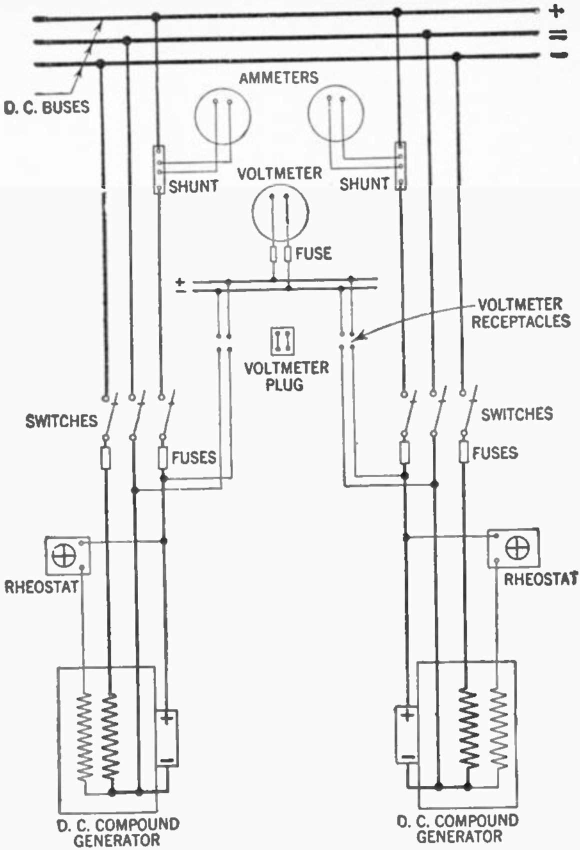
Connection for Parallel Operation of Two Shunt-Wound D.C. Generators



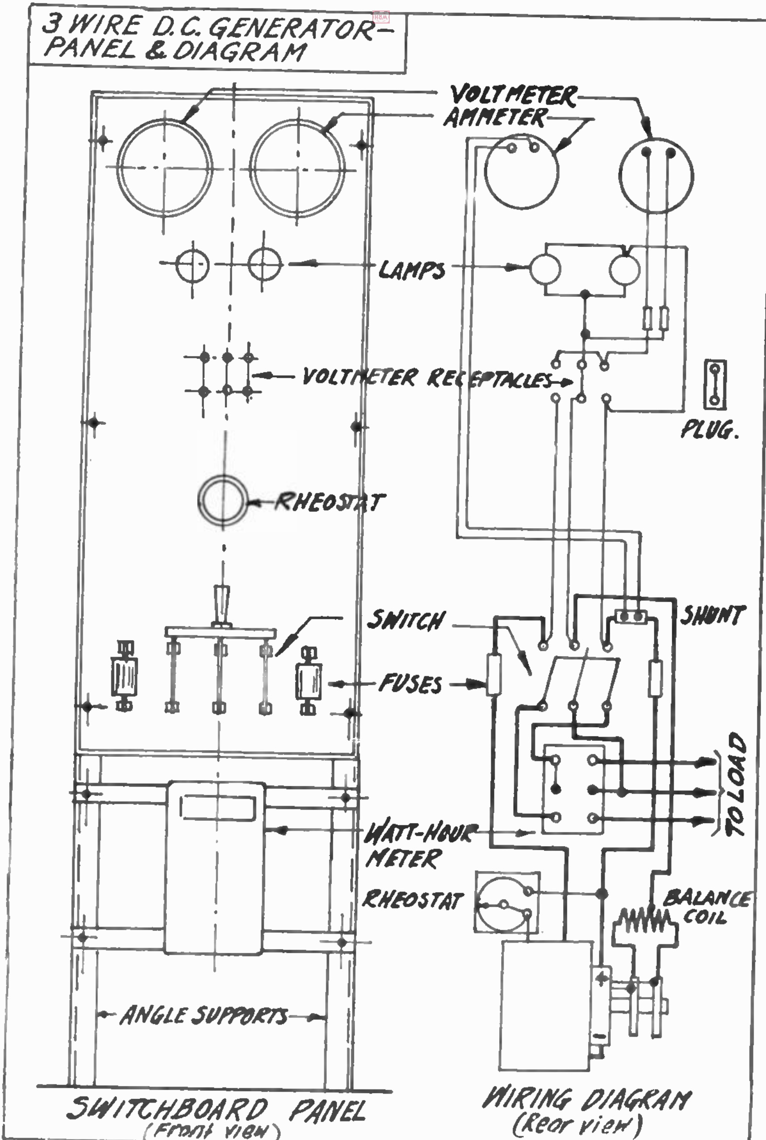
Detail connection diagram for parallel operation of two shunt-wound generators. It is customary to employ only one voltmeter with the addition of receptacles and a plug as shown. Sometimes a rotary switch arrangement is employed, in which case the receptacles and plug be omitted. The voltmeter may in either case be connected at will, to read the voltage across the terminals of any one of two or more generators. Occasionally voltage readings across the bus-bars (load) may be included in the voltmeter-switch arrangement. The method for operating the two generators in parallel are as follows: Assume that generator **B**, by means of its prime mover has been brought up to normal speed and is already connected to the bus-bars. Then with the switch and circuit breaker of **A** open, start the prime mover of **A**, and bring it up to speed. Now adjust the field rheostat of **A**, and note the voltmeter reading on this machine. Finally close the circuit breaker and switch of generator **A**.


PARALLEL OPERATION OF 2-D.C.
COMPOUND GENERATORS
AMMETERS
#1
#2
VOLTMETER
RHEOSTATS #1 AND #2
VOLTMETER RECEPTACLES
PLUG
BUSES
SHUNTS
SW.
FUSES
SWITCHES
ANGLE SUPPORTS
RHEOSTATS
SWITCHBOARD PANEL
(Front view)
MACHINE #2
MACHINE #2
(Rear view)

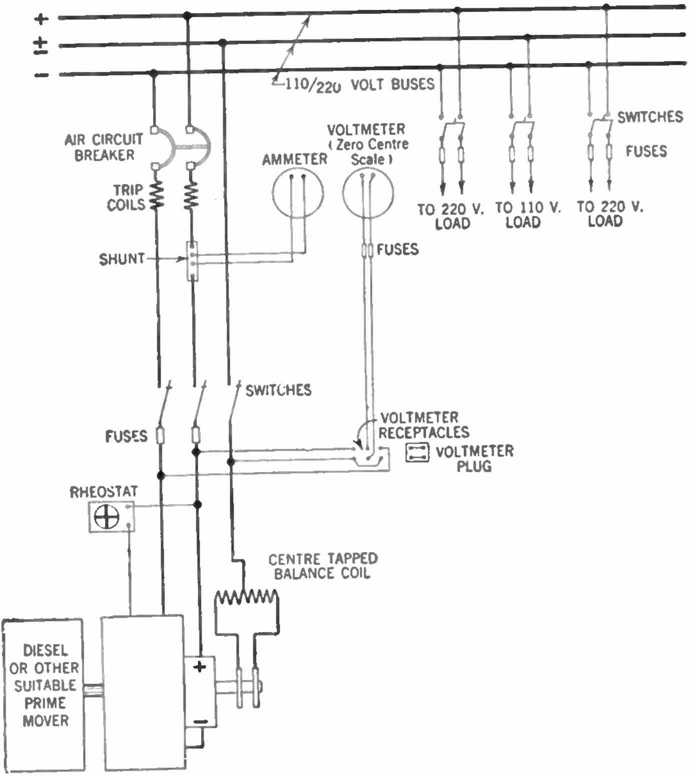
Connection for Parallel Operation of Two Compound-Wound D.C. Generators



Detail of connections for two compound generators in parallel. When two over-compounded generators are to be operated in parallel, it is necessary for a satisfactory division of loads, to parallel their respective series field. This is accomplished by connecting their negatives together as indicated, and this common connector is usually referred to as the *equalizer*. The instruments and switches shown are connected in the usual manner, which are similar to those used for connection of shunt generators in parallel, the only addition being the equalizer and connections thereto. It should, however, be noted, that the ammeter for each machine should be connected in the lead from the armature to the main bus, and not in the lead from the series field, because if the ammeter be placed in the latter it will read the series field current which may be quite different from the current supplied by the generator to the load connected to the buses.

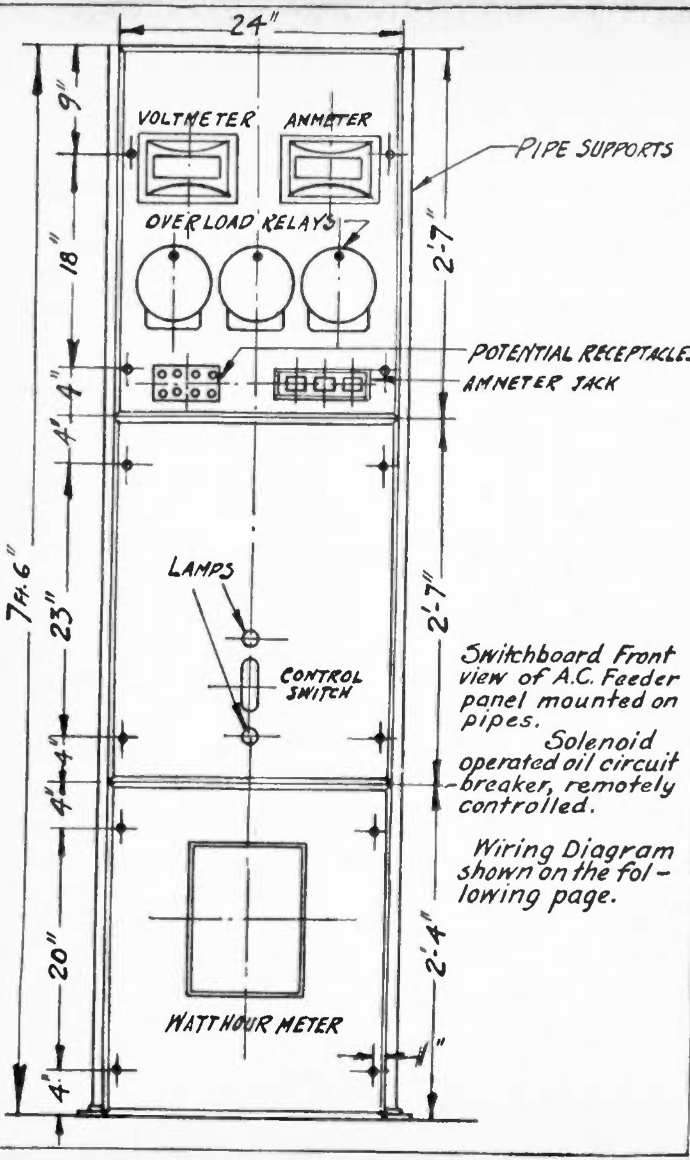

3 WIRE D.C. GENERATOR—
PANEL & DIAGRAM
VOLTMETER
AMMETER
LAMPS
VOLTMETER RECEPTACLES
PLUG.
RHEOSTAT
SWITCH
SHUNT
FUSES
TO LOAD
WATT-HOUR
METER
RHEOSTAT
BALANCE
COIL
ANGLE SUPPORTS
SWITCHBOARD PANEL
(Front view)
WIRING DIAGRAM
(Rear view)

Direct Current Three-Wire Generator



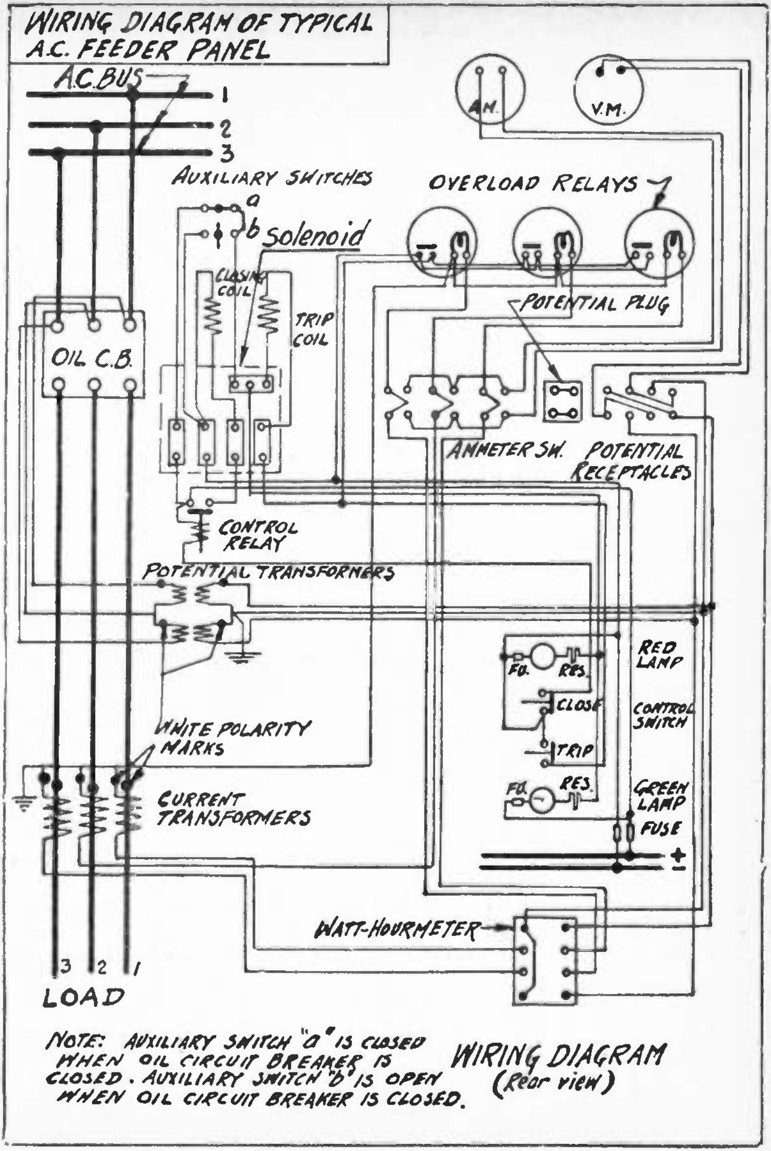
D. C. GENERATOR

The three-wire generator with external balance coil is often resorted to when it is desired to obtain a three-wire system with a minimum of rotating machinery. The third wire (sometimes misleadingly called *neutral*) is obtained as follows: To an ordinary generator designed to give a terminal voltage equal to that between the two main wires, are added two slip rings as shown; from these slip rings two leads are brought out and connected to armature points located 180 electrical degrees apart (this connection is not shown in the diagram). Collectors from the slip rings are connected from the two ends of the balance coil wound on an iron core, and the middle point of this coil is finally connected to the third wire. It should be observed that in a system of this kind it is necessary to balance the load between the two main wires and the wire leading from the balance coil as closely as possible. The amount of unbalance allowed for a properly designed system (usually specified by the manufacturers) should not exceed 10% approximately of the total current.

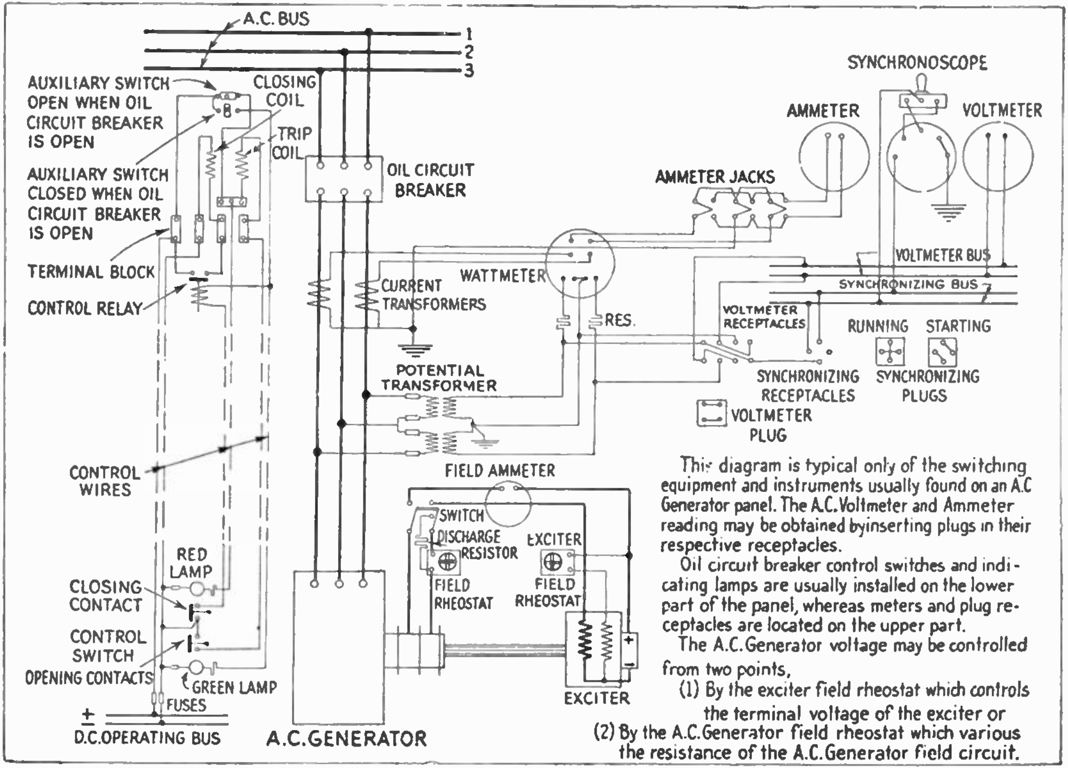


Switchboard Front view of A.C. Feeder panel mounted on pipes.
Solenoid operated oil circuit breaker, remotely controlled.

Wiring Diagram shown on the following page.


WIRING DIAGRAM OF TYPICAL A.C. FEEDER PANEL
A.C. BUS
1
2
3
AUXILIARY SWITCHES
a
b
Solenoid
OVERLOAD RELAYS
A.M.
V.M.
CLOSING COIL
TRIP COIL
OIL C.B.
POTENTIAL PLUG
AMMETER SW.
POTENTIAL RECEPTACLES
CONTROL RELAY
POTENTIAL TRANSFORMERS
RED LAMP
FU.
RES.
CLOSE
CONTROL SWITCH
TRIP
WHITE POLARITY MARKS
GREEN LAMP
FUSE
+
−
CURRENT TRANSFORMERS
WATT-HOURMETER
3
2
1
LOAD
NOTE: AUXILIARY SWITCH "a" IS CLOSED WHEN OIL CIRCUIT BREAKER IS CLOSED. AUXILIARY SWITCH "b" IS OPEN WHEN OIL CIRCUIT BREAKER IS CLOSED.
WIRING DIAGRAM
(Rear view)

WIRING DIAGRAM FOR TYPICAL A.C. GENERATOR



This diagram is typical only of the switching equipment and instruments usually found on an A.C Generator panel. The A.C. Voltmeter and Ammeter reading may be obtained byinserting plugs in their respective receptacles.

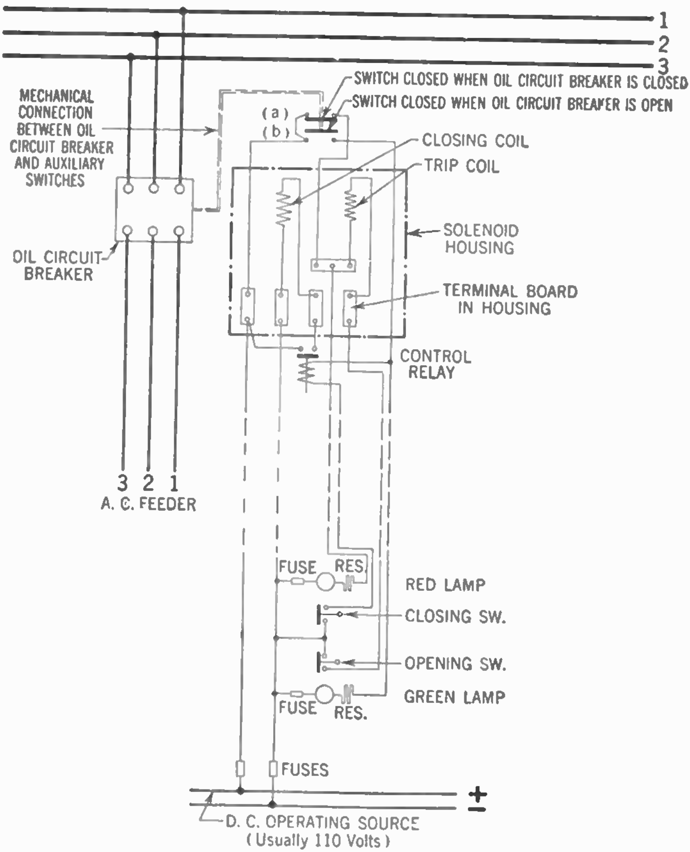
Oil circuit breaker control switches and indicating lamps are usually installed on the lower part of the panel, whereas meters and plug receptacles are located on the upper part.

The A.C. Generator voltage may be controlled from two points,

(1) By the exciter field rheostat which controls the terminal voltage of the exciter or

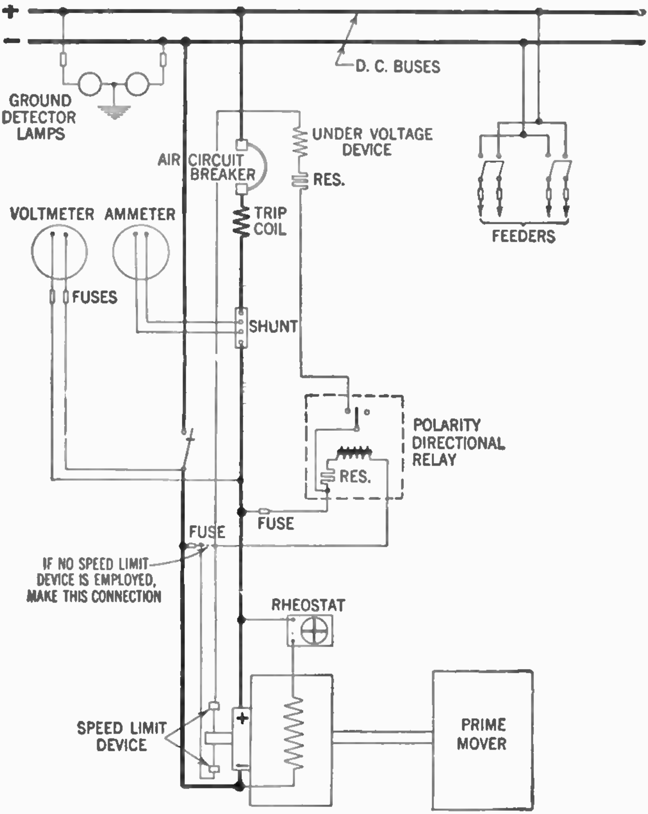
(2) By the A.C. Generator field rheostat which various the resistance of the A.C. Generator field circuit.

Connection for D.C. Operated Solenoid Used for Control of D.C. Oil Circuit Breaker



Typical connection diagram for a remote controlled oil circuit breaker. In this method of operation, it is necessary, however, that an unfailing supply of direct current be available. The operation of the breaker is accomplished as follows: Assume the breaker is open and the condition for its closing has been established. When the main breaker is open, auxiliary switch marked (b) is closed, and the green lamp on the instrument board is lighted. When the closing switch is operated, the coil of the control relay. Whose contacts are normally open, becomes energized and closes its contact which in turn actuates the closing coil (which is mechanically connected with the breaker contacts) closing the breaker. This closing of the breaker simultaneously reverses the position of the auxiliary switches, opening the previously closed switch marked (b) and closes switch marked (a), which in turn extinguishes the green lamp and lights the red. The breaker may be opened in a similar manner by operating the lower of the two switches on the control board.

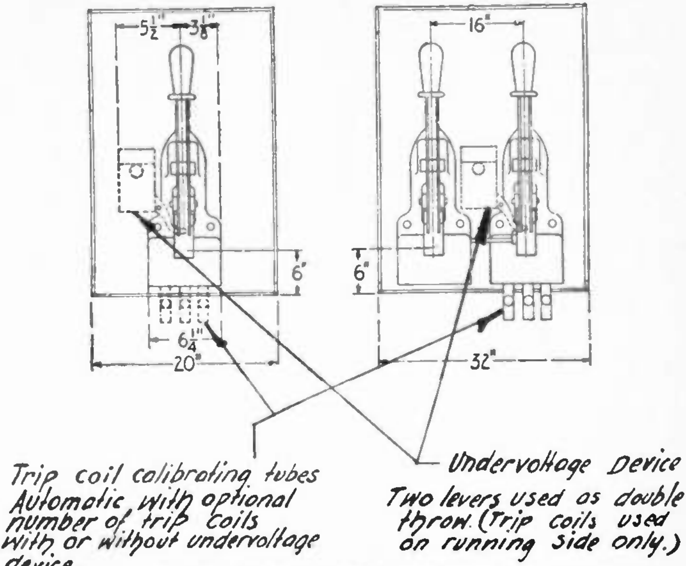
Electrolytic Generator with Polarity-Directional Protection



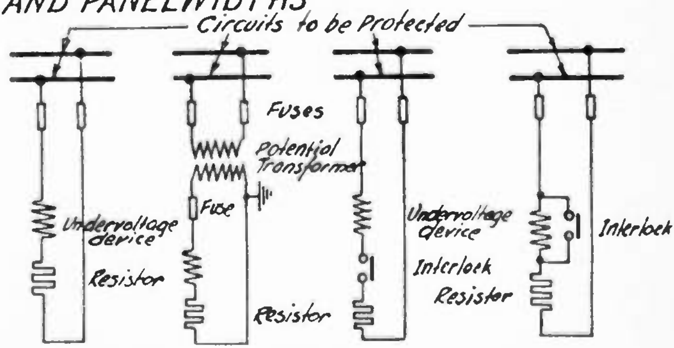
D. C. GENERATOR

Polarity directional protection such as that which may be used, where protection against sparks is of the utmost importance, for example, where hydrogen or other high explosive materials are manufactured. In such cases it is of the utmost importance that the polarity be not inverted, as the explosion resulting from such a condition might endanger both life and property. The polarity-directional relay consists essentially of a pair of stationary permanent magnets, a rotable soft iron armature pivoted within a stationary coil and a double throw set of contacts. The winding of the coil is of such direction that when potential is applied, connected with the proper polarity, the armature tends to rotate in a direction to keep the contacts closed to one side. A spring, in tension, tends to pull the armature back, open the closed contacts and close the contacts on the other side. When an invertion of the polarity occurs, the spring overcomes the action of the magnet which opens the circuit breaker.

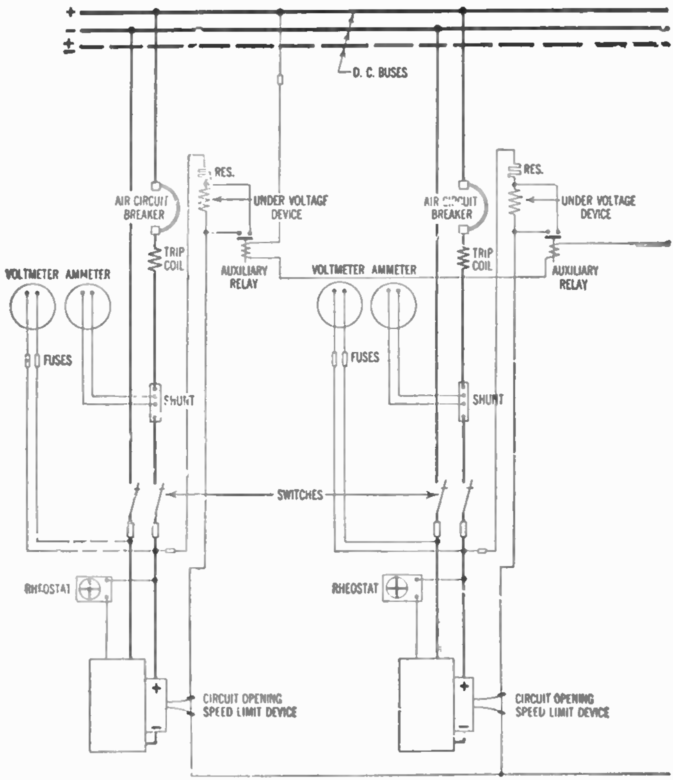
UNDERVOLTAGE DEVICE AND DIAGRAMS



OIL CIRCUIT BREAKER OPERATING LEVERS AND PANELWIDTHS

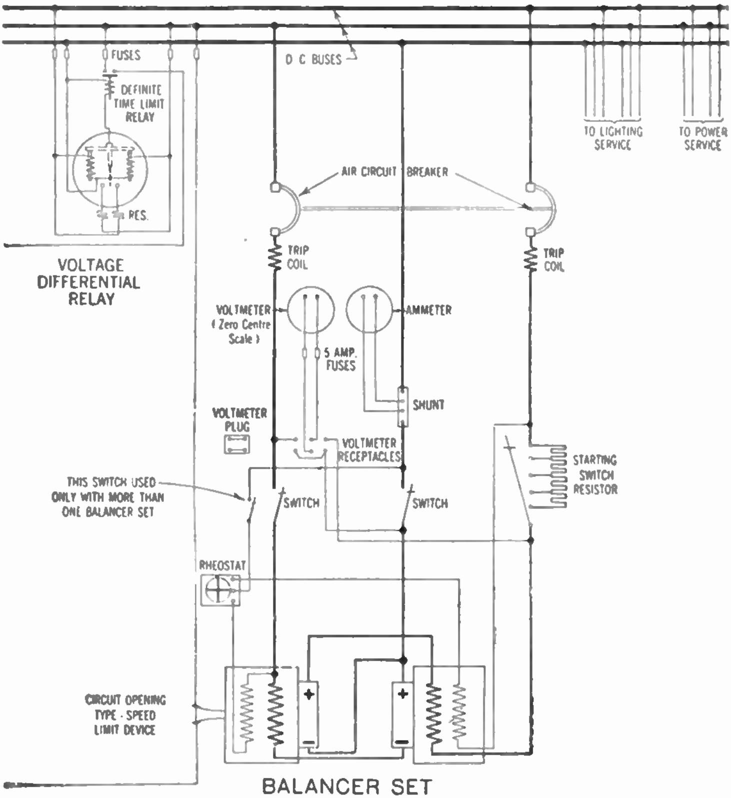


METHODS OF CONNECTIONS FOR UNDERVOLTAGE DEVICE ATTACHMENTS

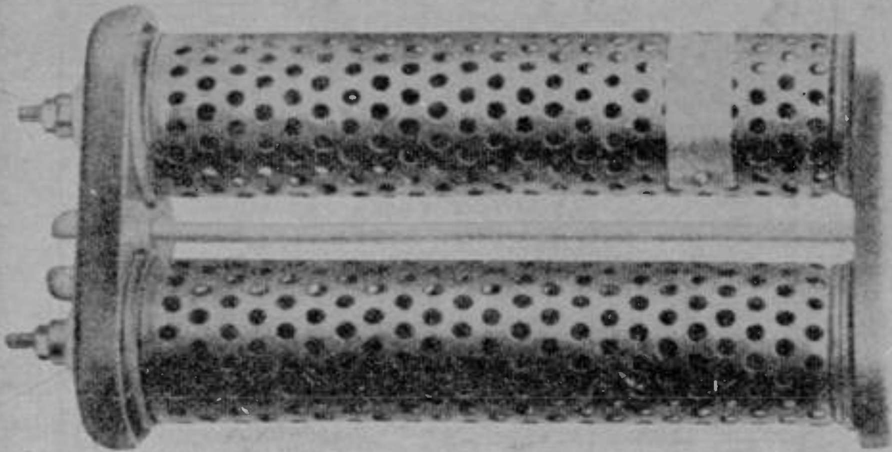


D. C. GENERATORS

Common method of obtaining three-wire service by means of a small motor-generator of identical size, usually identified as a balancer set. The additional wire or the so-called *neutral* is obtained and brought out from the common lead in the balancer set connecting the positive of one machine with the negative of the other. By the employment of a system of this kind, it is possible to establish better economy, in that the higher potential between the main generators, positive and negative leads can be utilized for power service. The amount of this saving in copper may best be understood by the fact that the weight of the conductors (and therefore the cost) required to transmit a given amount of power at a given efficiency is inversely proportional to the square of the line voltage. When establishing such a system, however, it is necessary to employ some protective scheme to guard against the unbalance of voltage in case the balancer set should become disconnected. The voltage differential relay shown, will protect against unbalanced voltage, and as this relay is practically instantaneous in action, and to protect against false operation, therefore, upon transitory disturbances, definite time limit relays are utilized in the contact circuits

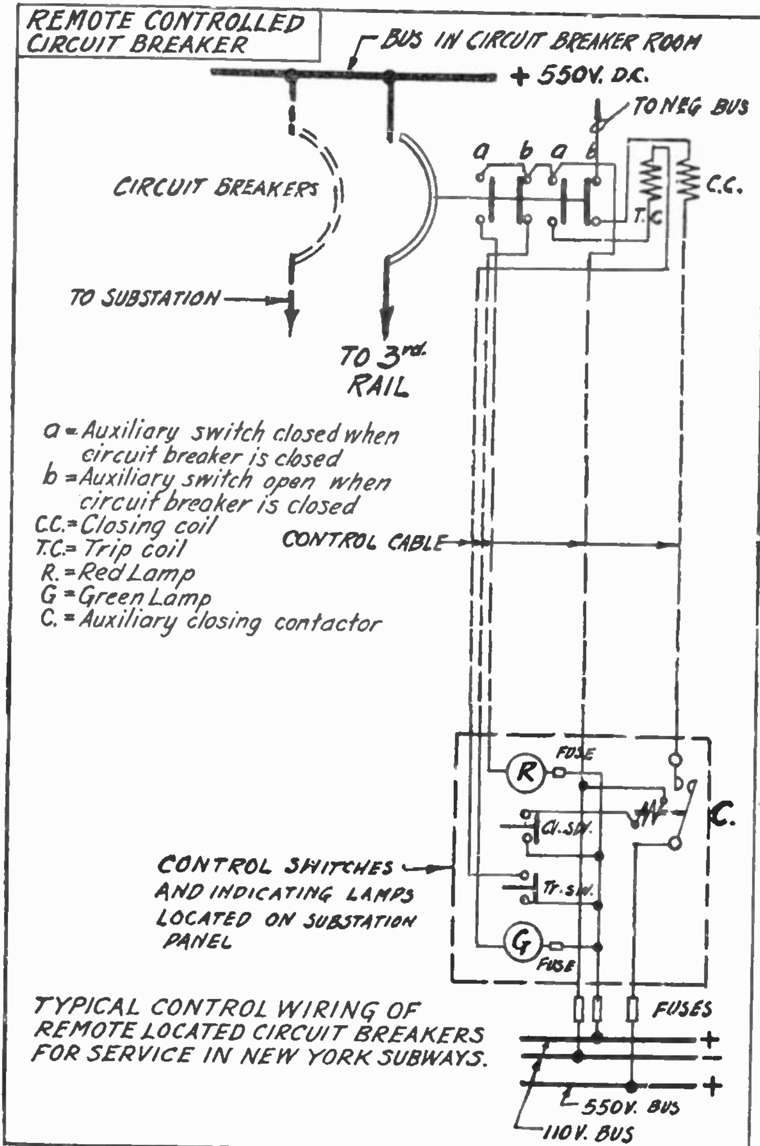


The voltage differential relay functions principally as follows: The relay consists essentially of a pair of solenoids of equal characteristics, and each with a plunger core connected to a balanced lever which actuates the contacts. One winding is connected across one circuit and the other winding across the other circuit of the two circuits to be differentially protected. As long as the voltages are equal, the balance lever is in equilibrium and the contacts remains open. When for any reason the voltage becomes unequal, the unequal pull of the two solenoids tends to close the contacts and when this difference in voltage reaches the value at which the relay is calibrated, the contacts close instantaneously energizing the definite time limit and auxiliary relays which in turn shorts the coil of undervoltage device on the circuit breakers, tripping the breakers and disconnects the generators from the buses.



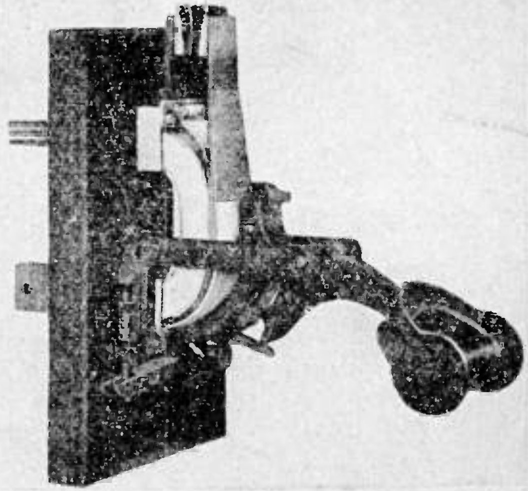
TYPICAL SWITCHBOARD RESISTANCE UNIT FOR BACK OF BOARD CONNECTIONS.

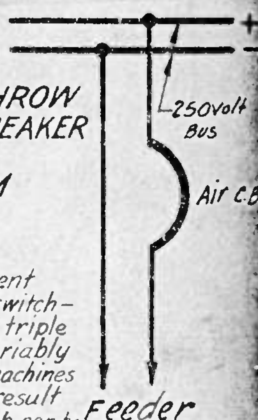
CIRCUIT BREAKER ARRANGEMENT AND DIAGRAMS



TYPICAL CONTROL WIRING OF REMOTE LOCATED CIRCUIT BREAKERS FOR SERVICE IN NEW YORK SUBWAYS.

AIR CIRCUIT BREAKER





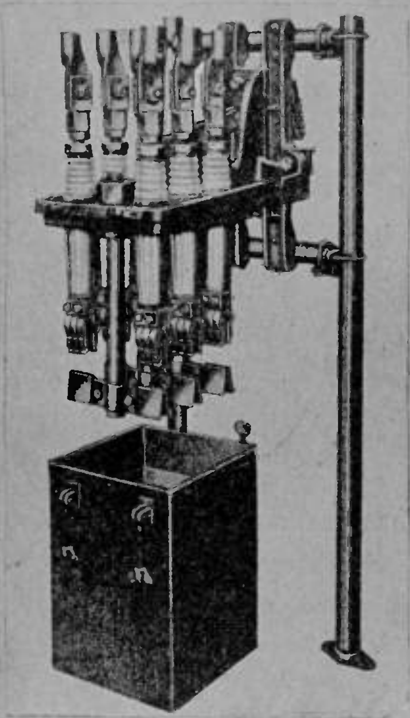
SINGLE POLE SINGLE THROW OVERLOAD AIR CIRCUIT BREAKER WITH WIRING DIAGRAM

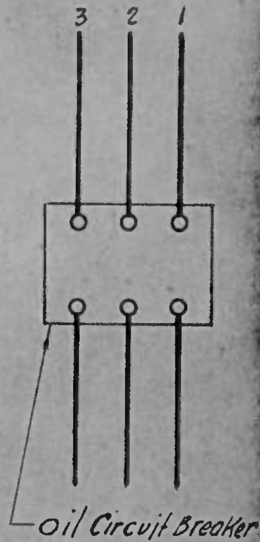
250 V. 2000 AMP.

Air circuit breakers are used as current interrupting devices for all direct current switchboards. They are made in single, double, and triple pole combinations. They are used almost invariably as automatic devices to prevent damage to machines or other electrical apparatus which might result from abnormal conditions in the circuit, which can be short-circuit or over-current, reverse current, under-voltage, unbalanced voltage in three wire systems, phase reversal etc. To obtain some form of protection it is necessary to use a relay in connection with the breaker.

For instruction pertaining to size, operation, installation and maintenance, inquire electrical manufacturer.

OIL CIRCUIT BREAKER





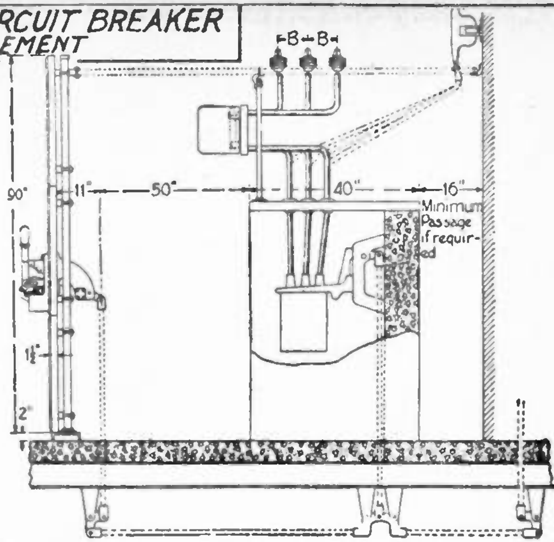
METHOD OF MOUNTING OIL CIRCUIT BREAKERS

There are four standard methods of mounting Oil Circuit Breakers: (1) On back of panel. (2) On panel frame. (3) On framework remote from panel. (4) In cells.

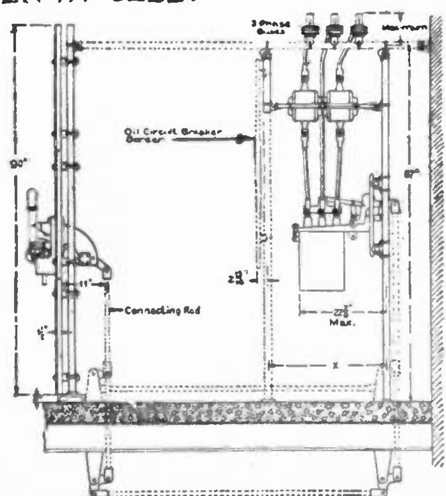
1. Back of panel mounting are used for small plant switchboard for circuits up to and including 2500 volts and up to 800 Amp. in capacity.
2. On panel frame up to and including 2500 volts and for any breakers above 800 amperes in capacity, but is not recommended when the greater number of breakers is 800 Amperes or above in capacity.
3. On framework remote from panel for circuits above 2500 volts and up to 6600 volts, and for double-thron breakers except in occasional cases where connections can be made satisfactorily on back of panel, or on panel frame. For large tank type breakers up to and including 73000 volts.
4. In cells for circuits above 6600 volts.

For various methods of oil circuit Breaker mounting, see the following pages.

OIL CIRCUIT BREAKER ARRANGEMENT

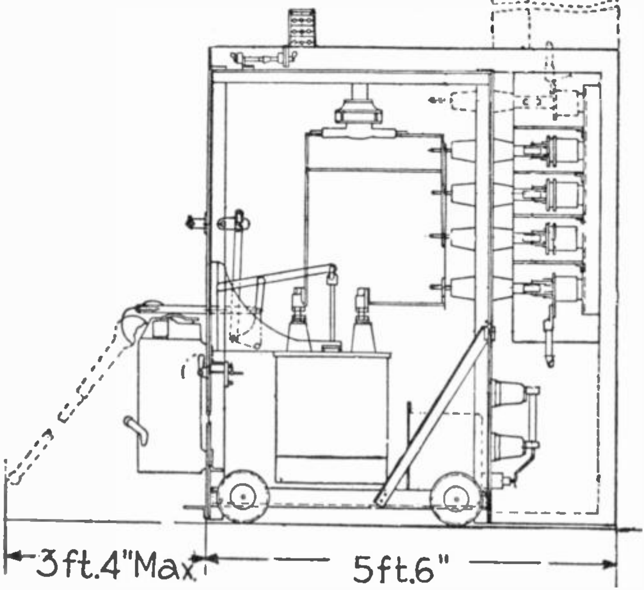


MANUALLY OPERATED, REMOTE CONTROLLED BREAKER IN CELL.



MANUALLY OPERATED, REMOTE CONTROLLED BREAKER ON FRAMEWORK.

TRUCK PANEL SWITCHBOARD



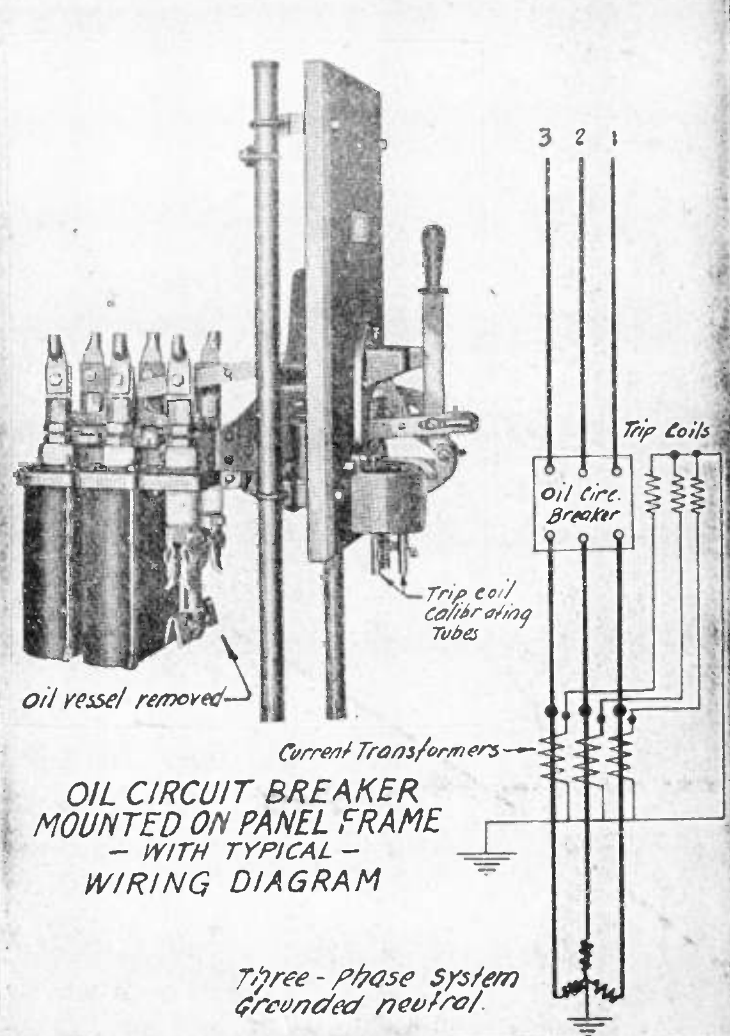
MOTOR OPERATED OIL CIRCUIT BREAKER MOUNTED ON SAFETY ENCLOSED REMOVABLE TRUCK TYPE PANEL (General Electric Co., Mfg.)

An aisle space of at least 7'-6" must be left in front of panel.

The typical truck type panel, as the term is generally applied, consists of two elements; the truck or removable element, and the housing or stationary element. The former carries the oil circuit breaker, instrument transformers, breaker operating mechanism instrument and meters, and movable disconnecting devices. The housing carries the bus bars, stationary disconnecting devices, cables, and the tracks for the removable element.

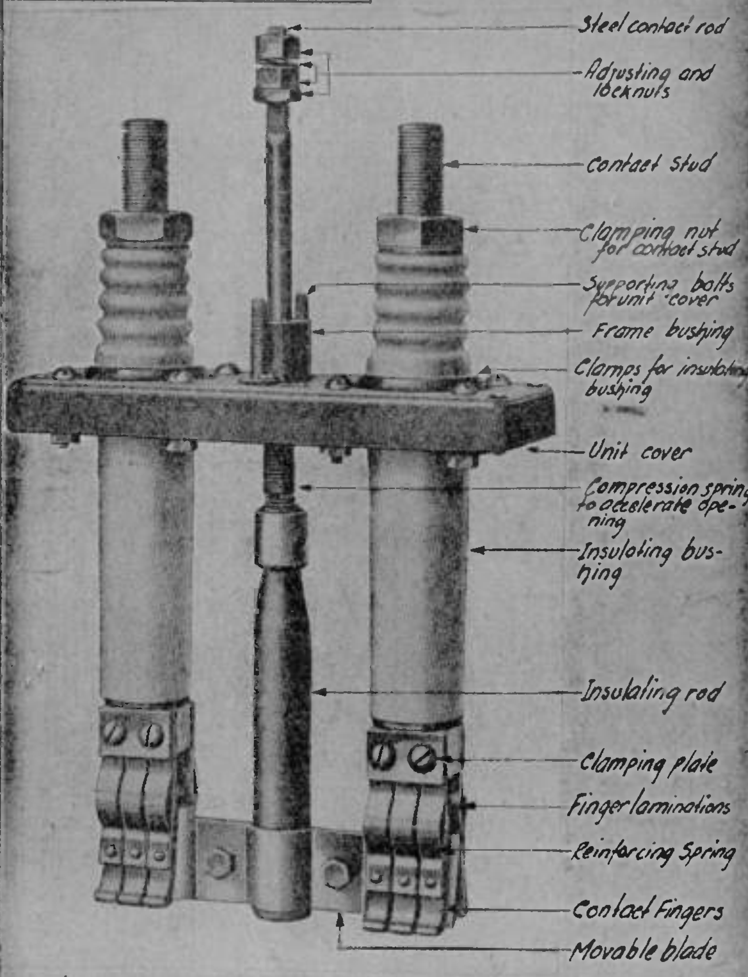
The principal features of this type switchboard are: Reliability and continuity of service, (incase of inspection or repairs a truck can be withdrawn and a spare put in its place) safety to the employees, facility of installation and maintenance, and economy in operation.

OIL CIRCUIT BREAKER AND DIAGRAM

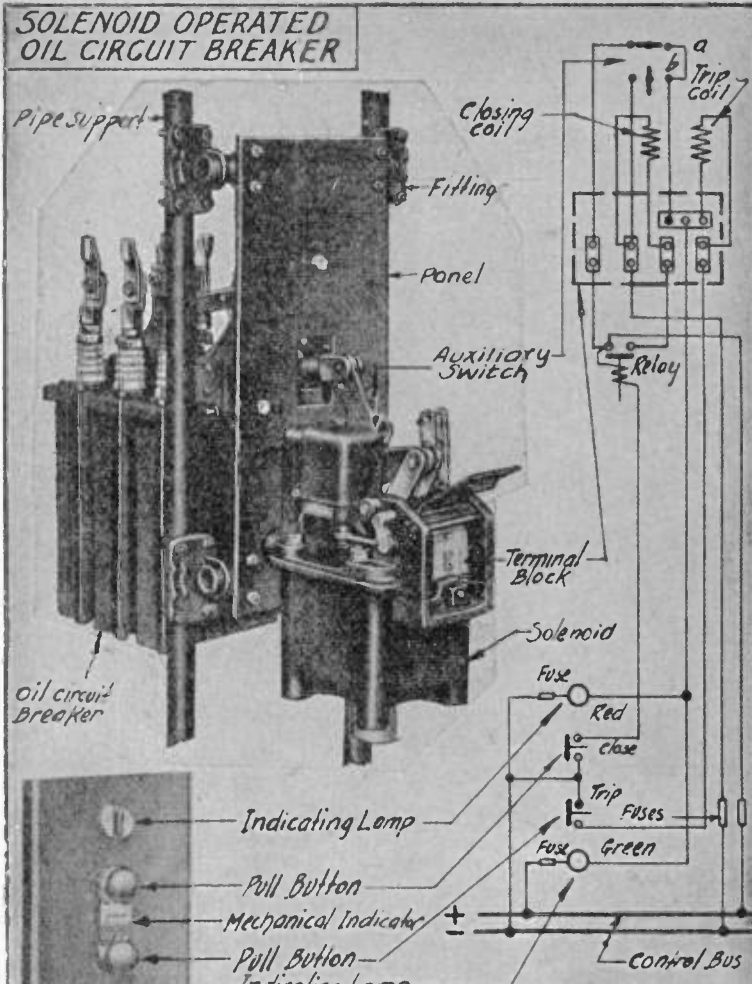


OIL CIRCUIT BREAKER MOUNTED ON PANEL FRAME
— WITH TYPICAL —
WIRING DIAGRAM

SINGLE POLE OIL CIRCUIT BREAKER UNIT



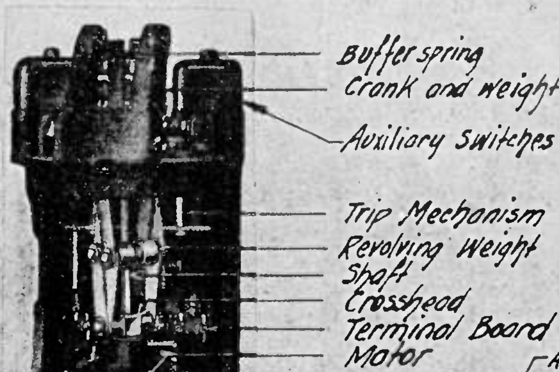
SINGLE POLE OIL CIRCUIT BREAKER UNIT WITH OIL VESSEL REMOVED (General Electric Mfg.)

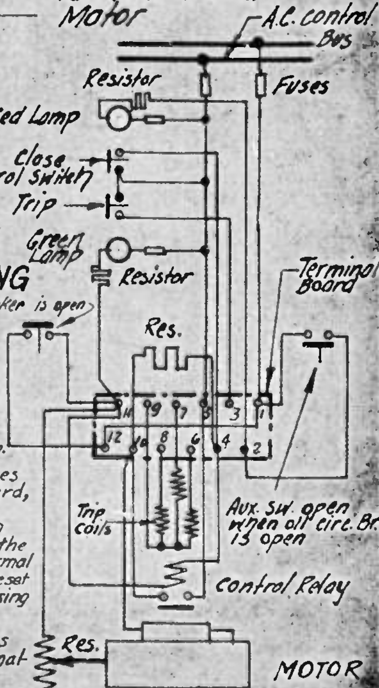


SOLENOID OPERATED OIL C.B.
—WITH—
WIRING DIAGRAM

NOTE: a = Auxiliary switch closed when oil circuit breaker is closed.
b = Auxiliary switch open when breaker is closed.

MOTOR MECHANISM FOR OIL CIRCUIT BREAKER





MOTOR MECHANISM FOR OIL CIRCUIT BREAKER OPERATION WITH WIRING DIAGRAM.

— OPERATION —

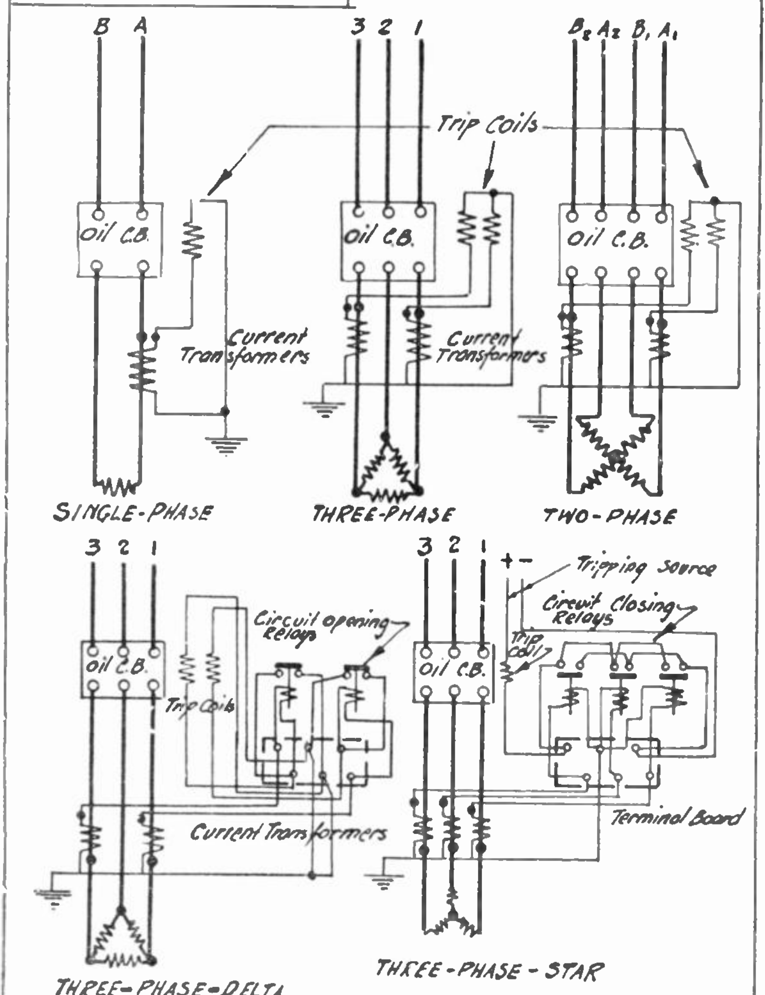
The breaker is closed by means of a pull button switch which completes the circuit of the control relay.

The control relay in turn energizes the motor of the mechanism, and seals itself to insure complete closing operation.

As the motor of the mechanism increases in speed the flyweights move outward, away from the driving shaft, and pull downward the toggle mechanism to close the breaker. This action raises the counterweight, which returns to its normal position after the breaker opens and reset the toggle mechanism for the next closing operation.

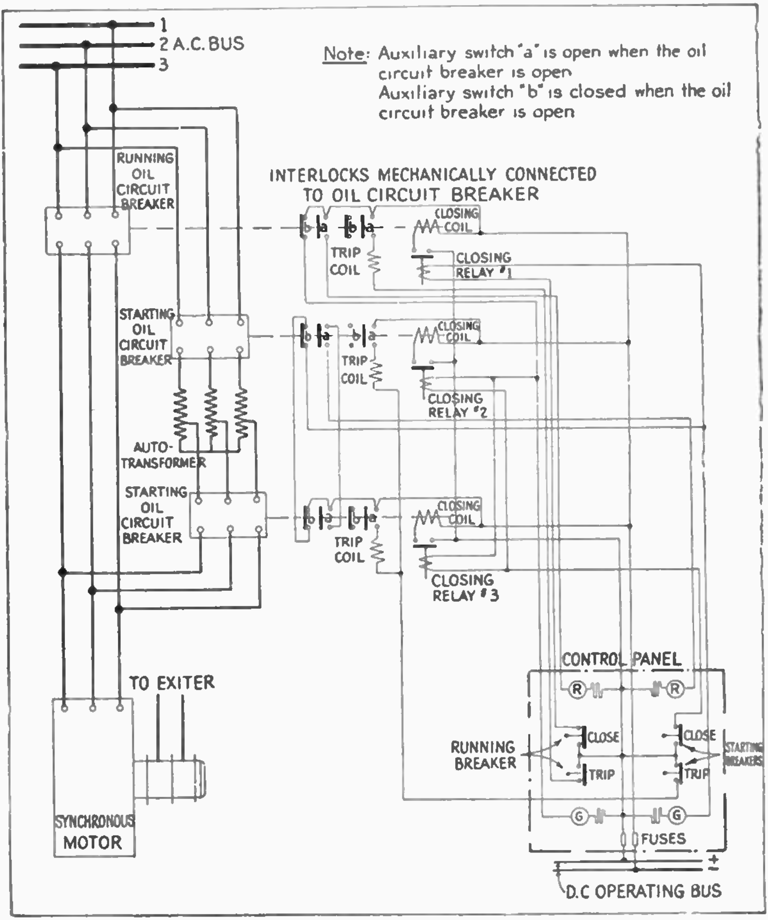
The circuit breaker at all times trips free from the mechanism, and is normally tripped by overload trip coils.

OIL CIRCUIT BREAKER WIRING



METHODS OF OIL CIRCUIT BREAKER WIRING WITH AND WITHOUT OVER-CURRENT RELAYS

OIL CIRCUIT BREAKERS AND CONTROL ARRANGEMENT FOR LARGE SYNCHRONOUS MOTOR



A.C. AND D.C. GENERATOR AND MOTOR DIAGRAMS

TERMINAL MARKINGS AND CONNECTIONS FOR DIRECT CURRENT MOTORS AND GENERATORS

Marking of Terminals. The purpose of applying markings to the terminals of electric power apparatus according to a standard is to aid in making up connections to other parts of the electric power system, and to avoid improper connection that may result in unsatisfactory operation or damage.

Location of Markings. The markings are placed on or directly adjacent to terminals to which connections must be made from outside circuits, or from auxiliary devices which must be disconnected in order to facilitate shipments from manufacturer.

Precautions. Although the system of terminal markings with letters and subscript numbers gives information, facilitating the connections of electrical machinery, there is the possibility of finding the terminals marked without system or according to some system other than standard (especially on old machinery or machinery of foreign manufacture). There is a further possibility that internal connections having been changed or that errors be made in markings. It is therefore advisable, before connection of apparatus to power supply systems, to make a check test for phase rotation, phase relation, polarity and equality of potential.

Subscript Numerals on Direct-Current Machinery Terminals. As applied to the terminals of direct-current windings of generators, motors and synchronous converters, the subscript numerals indicate the direction of current-flow in the windings. Thus, with standard direction of rotation and polarity, the current in all windings will be flowing from 1 to 2, or from a lower to a higher subnumber.

Direction of Rotation for D.C. Motors. Connections shown on the following pages will give the standard **counter-clockwise** rotation facing the end opposite the drive. To obtain the opposite direction, or **clockwise** rotation, the **armature or main field leads must be reversed.**

Direction of Rotation for D.C. Generators. The standard direction of rotation for D.C. generators is **clockwise** when facing the end of machine opposite drive, usually the commutator end of the machine. Direct current generators with connections properly made up for standard rotation (clockwise) will not function if driven counter-clockwise, as any small current delivered by the armature tends to demagnetize the fields and thus prevents the armature from delivering current. If conditions call for reversed rotation, connections should be made up with either the armature leads transposed or the field leads transposed.

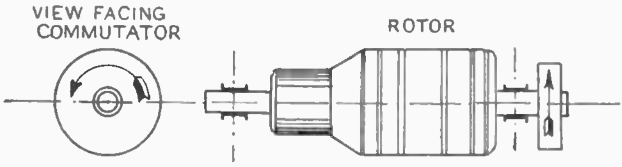
TERMINAL MARKINGS AND CONNECTIONS FOR DIRECT CURRENT MOTORS AND GENERATORS —continued

Motor Generators. Any direct current machine can be used either as a generator or as a motor. For desired direction of rotation, connection changes may be necessary and should be accomplished as previously described. The conventions for current flow in combination with the standardization of opposite directions of rotation for direct current generators, and direct current motors works out so that any direct current machine can be termed **generator** or **motor** without change in terminal markings. A direct-current motor or a direct current generator, by direct coupling constitutes a motor generator. With such coupling, direction of rotation of motor and generator are necessarily reversed when each is from the **end opposite the drive.** The standard clockwise rotation for direct current motors meets such coupling requirements without change in standard connections or rotation for either direct current machine.

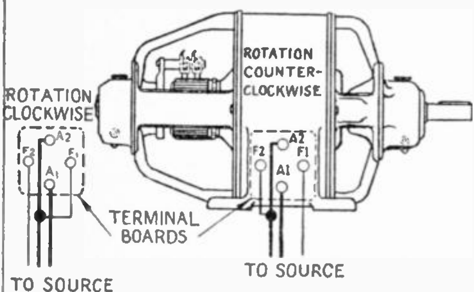
Coupling of A.C. and D.C. Motors and Generators. In the same manner as that already described for direct current motors and generators, a direct current motor may be coupled to an alternating current generator without changing from the standard in either individual machine. When, however, the coupling of an alternating current motor to a direct current generator becomes necessary, this coupling cannot be made without rotation other than standard for one of the two machines. Since the rotation of the alternating current machine is usually the more simply changed, it is general practice to operate a motor generator with clockwise rotation viewed from the generator end.

Example on How to Change Direction of Rotation in a D.C. Motor. When brushes are set for standard counter-clockwise rotation, it will be necessary to change assembly of brush holders for trailing operation. With reference to page 114 showing diagram and connections of a typical motor, proceed as follows: 1. Change connection as shown for clockwise rotation. 2. To change assembly of brush holders for trailing operation, first lock the armature in position of one brush on the commutator surface. Mark the brush holder stud of this brush X and studs of the opposite polarity Y. Raise all brushes in the holders, remove holders from the studs and reassemble them on the same studs in the reverse direction. Lower brush holders until the distance between the bodies and commutator surface is 3/32 in. then shift brush holder yoke until the nearest brush from either stud Y exactly fits over the space previously occupied by the brush X. The leads from the brush holder studs, one from the commutating fields and the other from the terminal board (lead A_1), should be interchanged in the studs. Erase paint mark on bearing housing and make a new mark to line up with the mark on the brush yoke.

TERMINAL MARKINGS AND CONNECTIONS FOR D.C. SHUNT-WOUND MOTOR



STANDARD DIRECTION OF ROTATION COUNTER-CLOCKWISE WHEN FACING COMMUTATOR END OF MOTOR



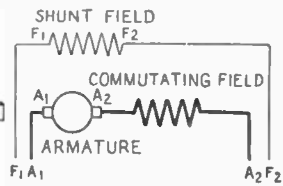


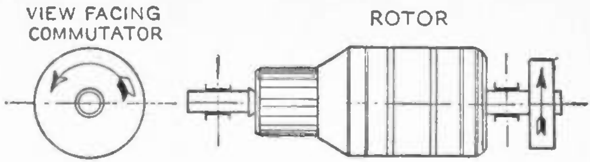
DIAGRAM OF CONNECTIONS

The above drawings represent a typical shunt-wound motor, with terminal connections for either the standard counter-clockwise rotation or clockwise rotation, which sometimes is utilized to facilitate the proper functioning of machinery to be operated.

All motor and control wiring should be carefully installed in accordance with the NATIONAL ELECTRIC CODE and any local requirements, and should be of ample capacity based on a maximum line voltage drop of 2 per cent at full load current.

Before operation, make sure that voltage on motor and control nameplates correspond with that of power supply.

TERMINAL MARKINGS AND CONNECTIONS FOR D.C. COMPOUND-WOUND MOTOR



STANDARD DIRECTION OF ROTATION COUNTER-CLOCKWISE WHEN FACING COMMUTATOR END OF MOTOR.

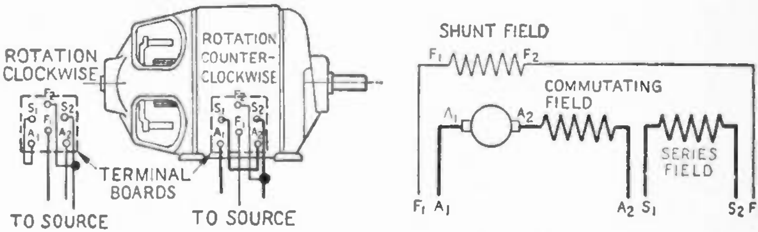


DIAGRAM OF CONNECTIONS

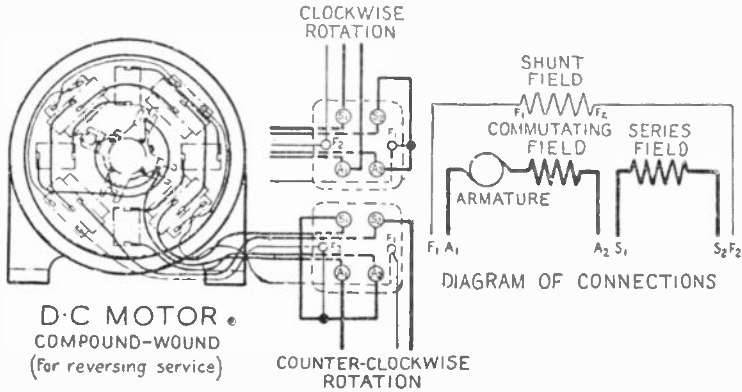
TYPICAL CONNECTION DIAGRAM FOR COMPOUND-WOUND MOTOR

<u>OPERATION OF MOTORS:</u> Before placing the motor in service for the first time the following precautions should be observed:

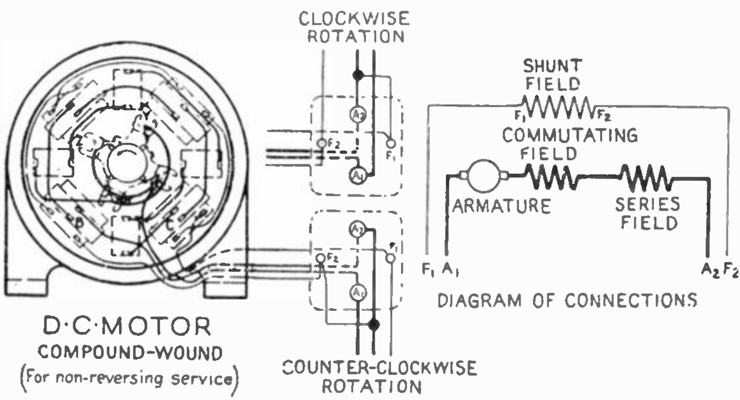
Dry out all moisture. If the motor has been exposed to moist atmosphere for a long time while in transit or storage (or has been idle for a long period after installation in moist atmosphere) it should always be dried out thoroughly before being placed in service. If possible, place the motor in an oven and bake at a temperature not exceeding 85°c.

Fair results can be obtained by enclosing the motor with canvas or other covering inserting some heating units or incandescent lamps to raise the temperature and leaving a hole at the top of the enclosure to permit the escape of moisture The motor may also be dried out by passing a current at low voltage (motor at rest) through the field windings that will raise the temperature not over 85°c. The heat should be raised gradually until the whole winding is of this uniform temperature.

TERMINAL MARKINGS AND CONNECTIONS FOR STANDARD AND CLOCKWISE ROTATION

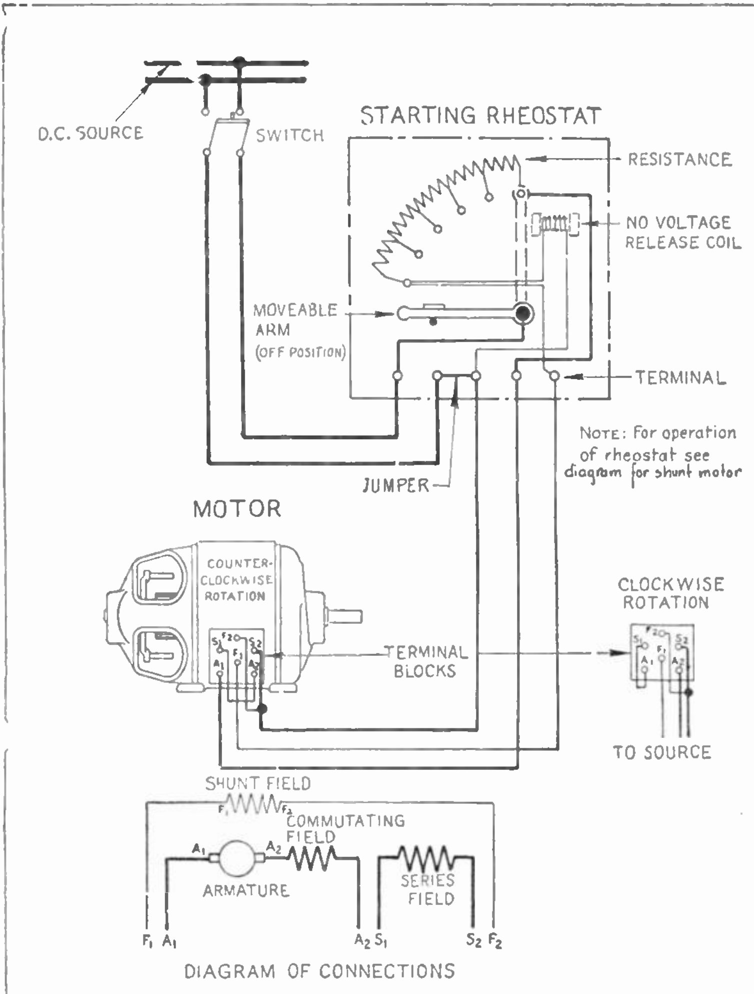


D·C MOTOR
COMPOUND-WOUND
(For reversing service)

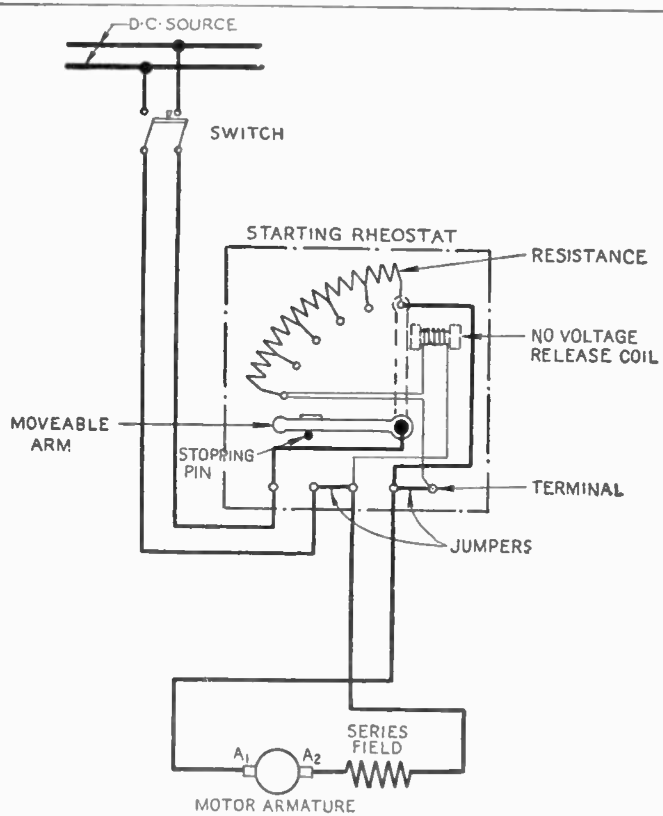


D·C·MOTOR
COMPOUND-WOUND
(For non-reversing service)

STARTING RHEOSTAT AND CONNECTION DIAGRAM FOR D.C. COMPOUND-WOUND MOTOR

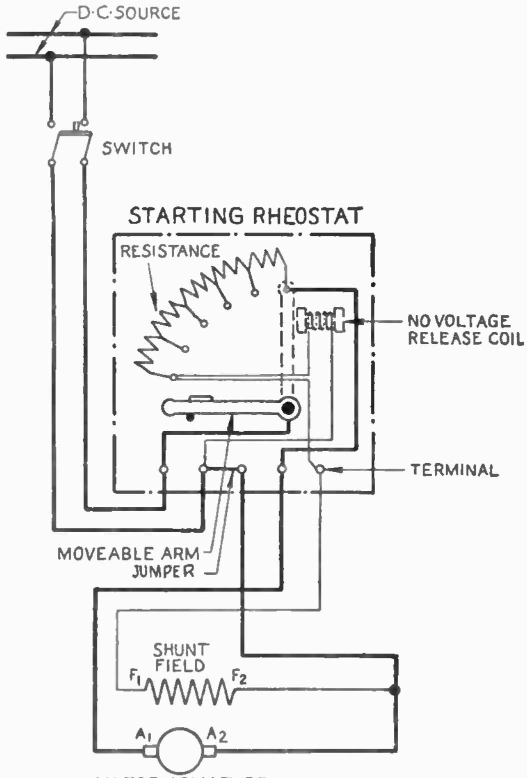


STARTING RHEOSTAT AND CONNECTION DIAGRAM FOR D.C. SERIES-WOUND MOTOR



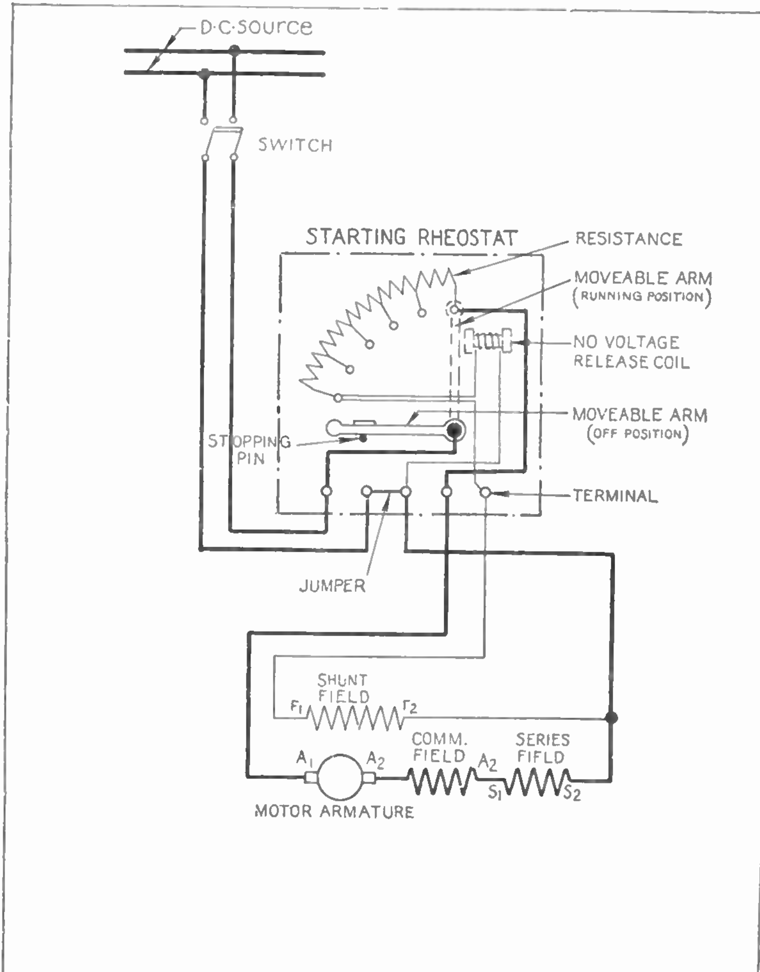
OPERATION: When field be interrupted due to an open connection or failure of source, the No Voltage release coil will automatically release the moveable arm, which by action of its spring (not shown in diagram) returns to its "Off" or starting position.

STARTING RHEOSTAT AND CONNECTION DIAGRAM FOR D.C. SHUNT-WOUND MOTOR



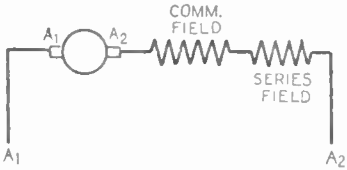
OPERATION: When voltage fails or shunt field be interrupted the No Voltage release coil will automatically release the moveable arm, which is returned to its starting position by action of holding spring (not shown in diagram). This method of starting will prevent accidental application of a heavy current thru the motor armature, causing fuses to blow, or serious damage to motor.

STARTING RHEOSTAT AND CONNECTION DIAGRAM FOR D.C. COMPOUND-WOUND MOTOR

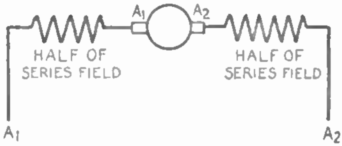


CONNECTION DIAGRAMS FOR D.C. SERIES-WOUND MOTORS

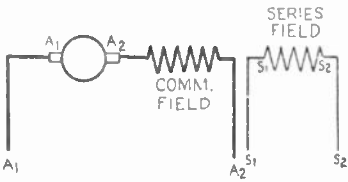
NON-REVERSING COMMUTATING POLE TYPE



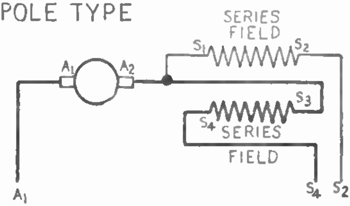
NON-REVERSING NON-COMMUTATING POLE TYPE



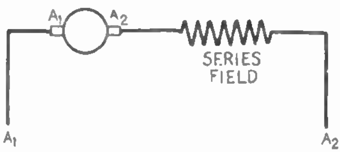
REVERSING COMMUTATING POLE TYPE



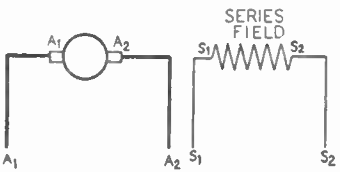
REVERSING NON-COMMUTATING POLE TYPE



NON-REVERSING NON-COMMUTATING POLE TYPE

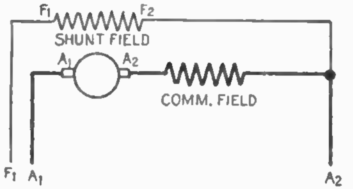


REVERSING NON-COMMUTATING POLE TYPE

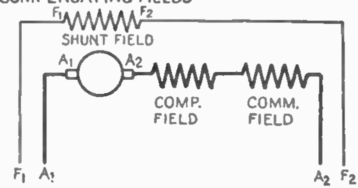


CONNECTION DIAGRAMS FOR D.C. SHUNT-WOUND MOTORS

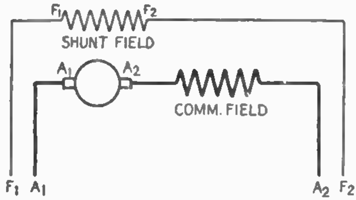
NON-REVERSING COMMUTATING POLE TYPE



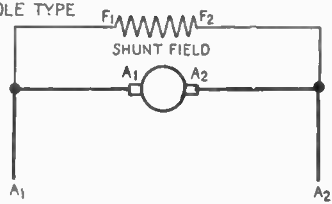
REVERSIBLE WITH COMMUTATING AND COMPENSATING FIELDS



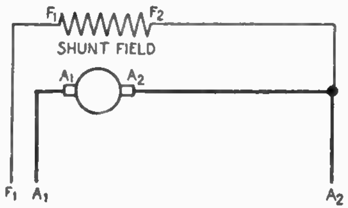
REVERSING COMMUTATING POLE TYPE



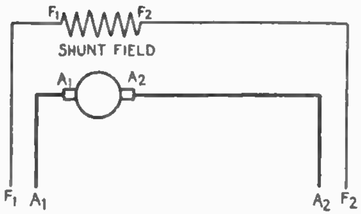
NON-REVERSING NON-COMMUTATING POLE TYPE



NON-REVERSING NON-COMMUTATING POLE TYPE

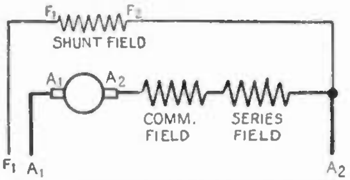


REVERSING NON-COMMUTATING POLE TYPE

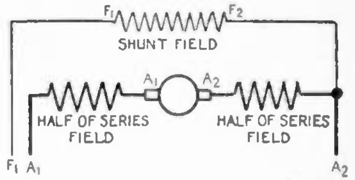


CONNECTION DIAGRAMS FOR D.C. COMPOUND-WOUND MOTORS

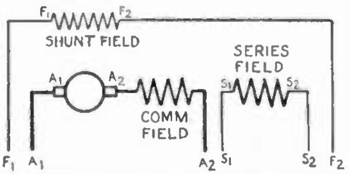
NON-REVERSING COMMUTATING POLE TYPE



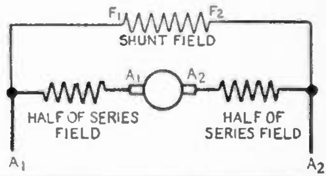
NON-REVERSING NON-COMMUTATING POLE TYPE



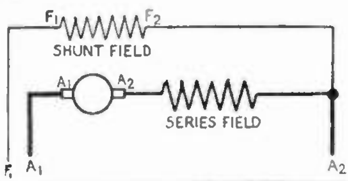
REVERSING COMMUTATING POLE TYPE



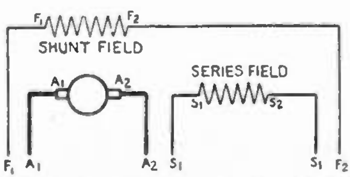
NON-REVERSING NON-COMMUTATING POLE TYPE



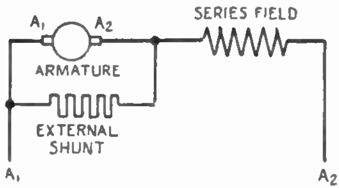
NON-REVERSING NON-COMMUTATING POLE TYPE

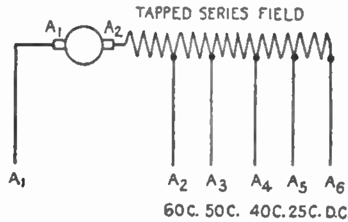


REVERSING NON-COMMUTATING POLE TYPE

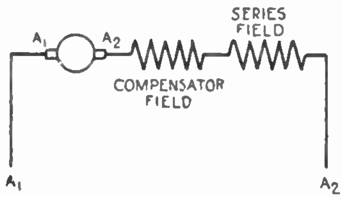


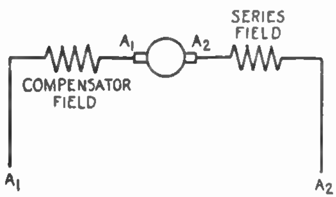
CONNECTION DIAGRAMS FOR UNIVERSAL TYPE MOTORS (A.C. OR D.C.)





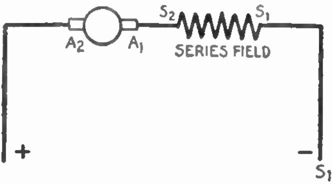
NOTE:-
TAPS MAY BE OMITTED OR OTHER TAPS BROUGHT OUT WHEN FREQUENCIES ARE DIFFERENT FROM THOSE SHOWN.



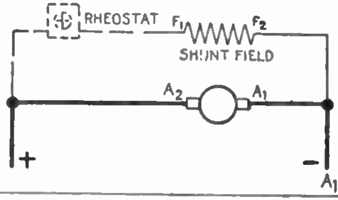


CONNECTION DIAGRAMS FOR D.C. GENERATORS (TWO-WIRE)

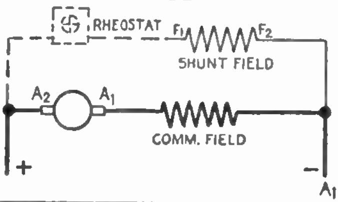
SERIES GENERATOR WITHOUT COMMUTATING POLES



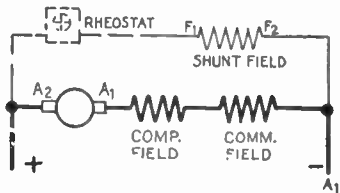
SHUNT GENERATOR WITHOUT COMMUTATING POLES



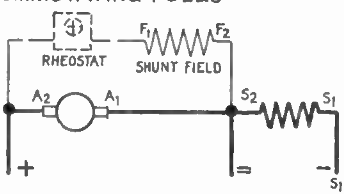
SHUNT GENERATOR WITH COMMUTATING POLES



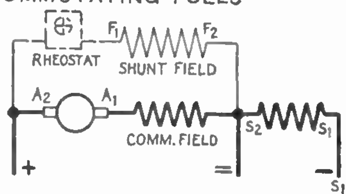
SHUNT GENERATOR WITH COMMUTATING AND COMPENSATING FIELDS



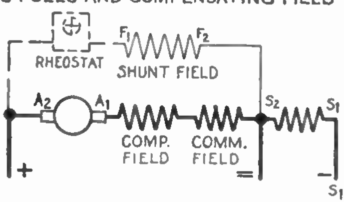
COMPOUND GENERATOR WITHOUT COMMUTATING POLES



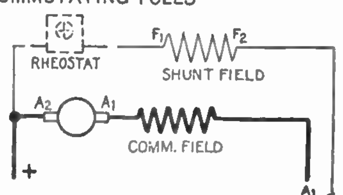
COMPOUND GENERATOR WITH COMMUTATING POLES



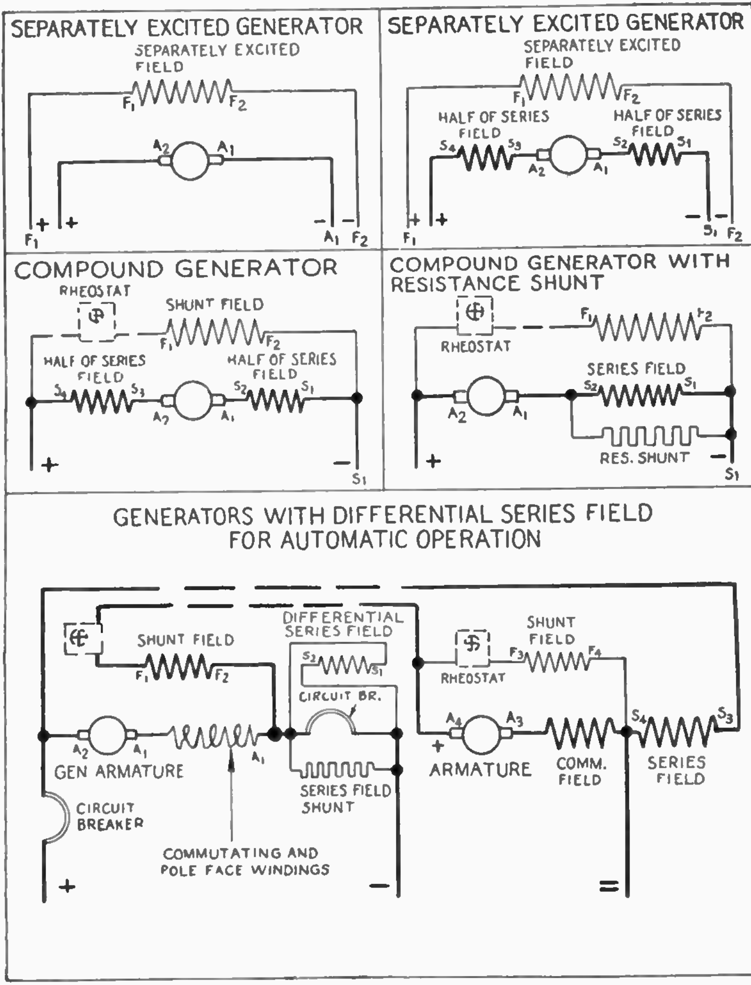
COMPOUND GENERATOR WITH COMMUTATING POLES AND COMPENSATING FIELD



SEPARATELY EXCITED GENERATOR WITH COMMUTATING POLES

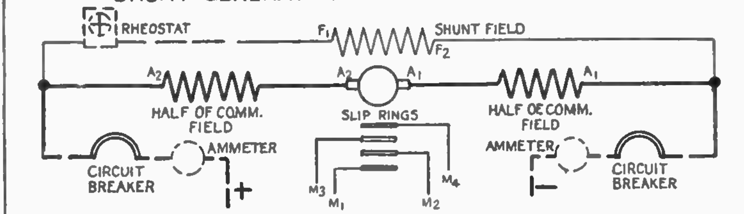


CONNECTION DIAGRAMS FOR D.C. GENERATORS (TWO-WIRE)

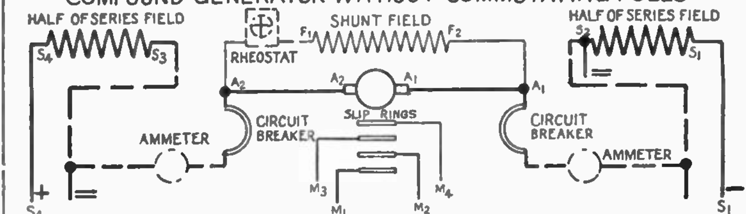


CONNECTION DIAGRAMS FOR D.C. GENERATORS (THREE-WIRE)

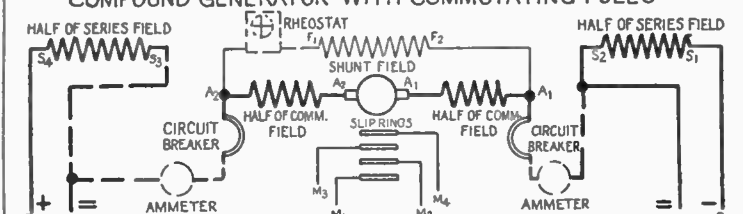
SHUNT GENERATOR WITH COMMUTATING POLES



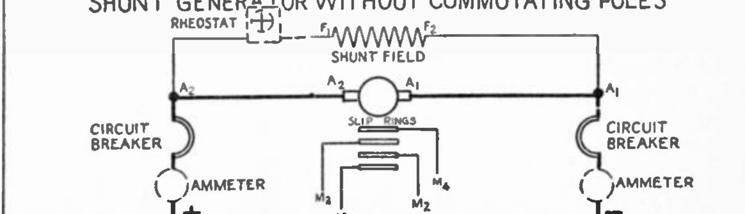
COMPOUND GENERATOR WITHOUT COMMUTATING POLES



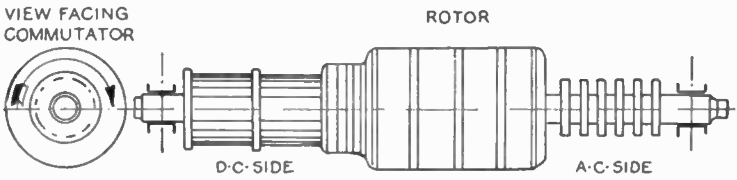
COMPOUND GENERATOR WITH COMMUTATING POLES



SHUNT GENERATOR WITHOUT COMMUTATING POLES

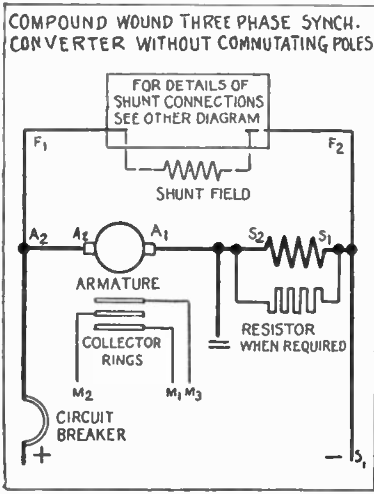


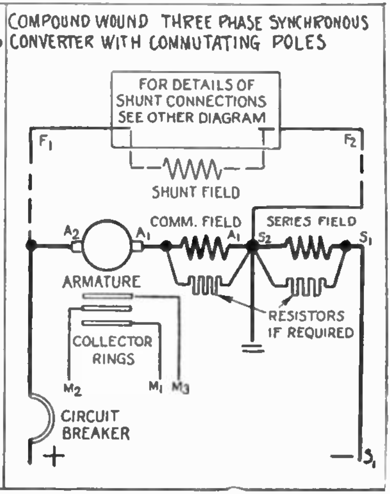
CONNECTION DIAGRAMS FOR SYNCHRONOUS CONVERTERS (TWO-WIRE)



Standard Direction of Rotation Clockwise When Facing the Direct Current or Commutator End of Converter

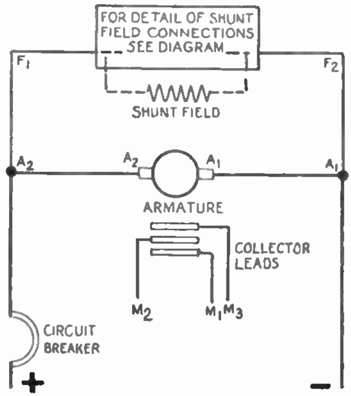
The above (standard) direction of rotation is obtained only if the terminal sub numerals 1, 2, 3 applied to the collector rings M_1, M_2, M_3 are connected to alternating current generator leads marked T_1, T_2 and T_3 respectively. Due to the great variety of **shunt field** connections, these diagrams are shown separately from the other connection diagrams. In some cases a shunt field connection diagram may be used with only one machine diagram, whereas in other cases a machine diagram may be used in combination with any of several shunt field diagrams.



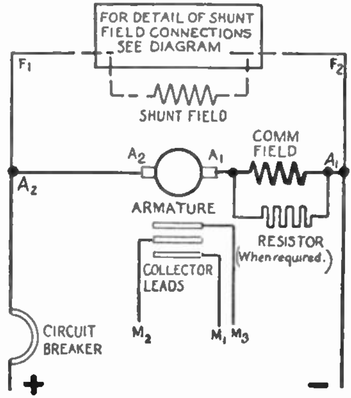


CONNECTION DIAGRAMS FOR SYNCHRONOUS CONVERTERS (TWO-WIRE)

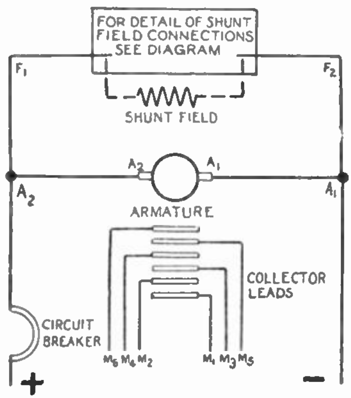
SHUNT-WOUND THREE-PHASE SYNCHRONOUS CONVERTER WITHOUT COMMUTATING POLES



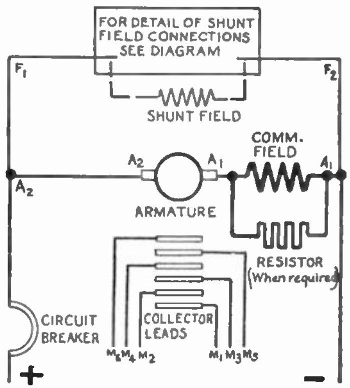
SHUNT-WOUND THREE-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES



SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITHOUT COMMUTATING POLES

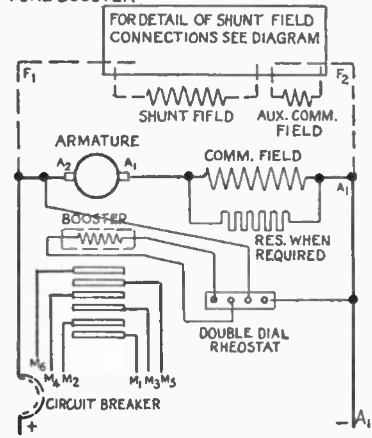


SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES

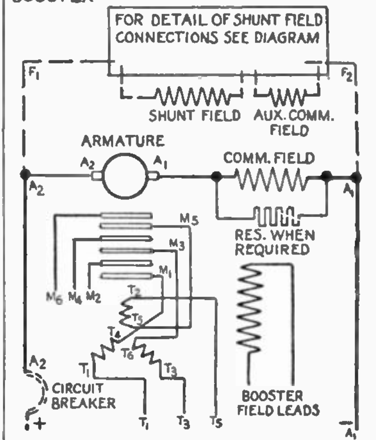


CONNECTION DIAGRAMS FOR SYNCHRONOUS CONVERTERS (TWO-WIRE)

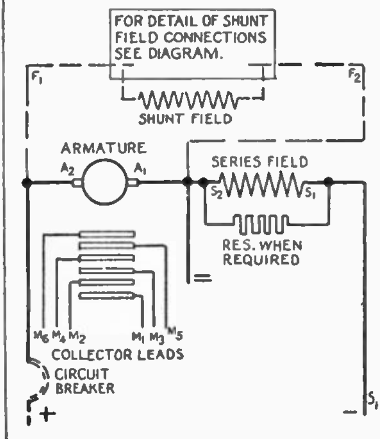
SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING FIELD, AUXILIARY COMMUTATING FIELD AND REVOLVING ARMATURE BOOSTER



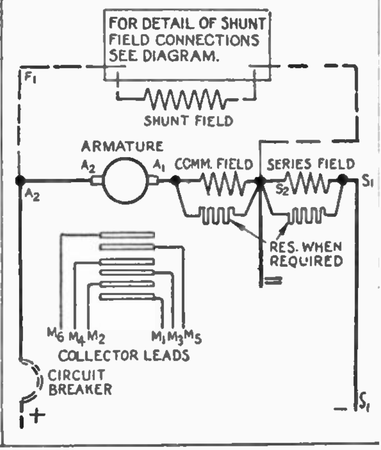
SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING FIELD, AUXILIARY COMMUTATING FIELD AND REVOLVING FIELD BOOSTER



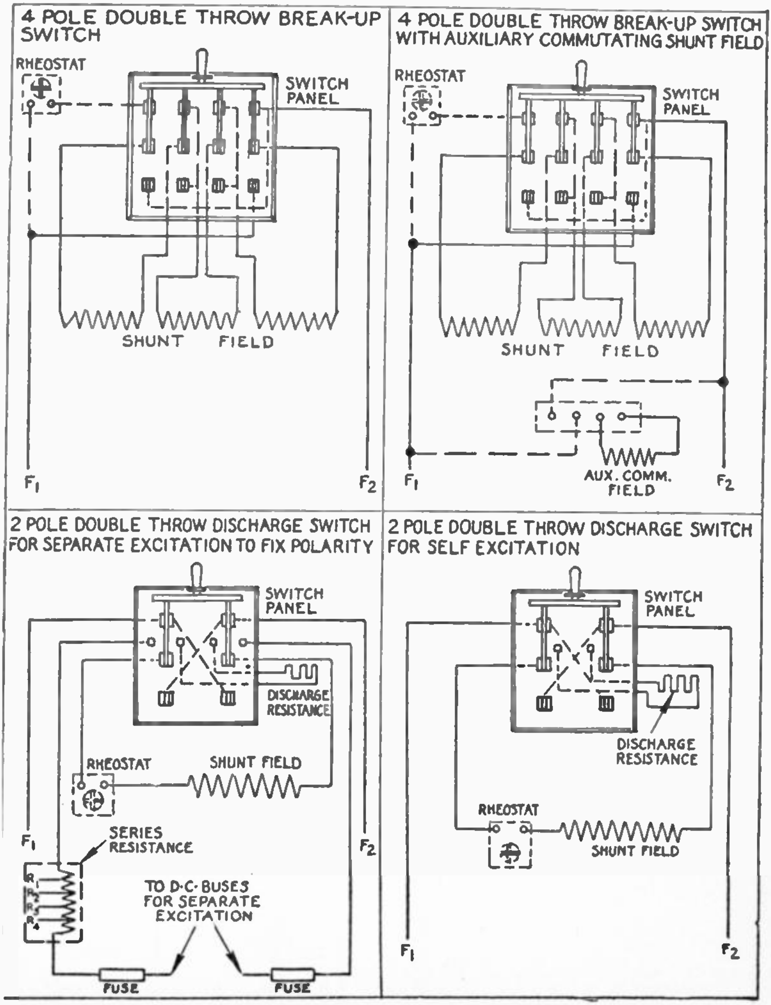
COMPOUND-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITHOUT COMMUTATING POLES



COMPOUND-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES



SHUNT FIELD CONNECTIONS FOR SYNCHRONOUS CONVERTERS



SYNCHRONOUS CONVERTER WIRING DIAGRAM

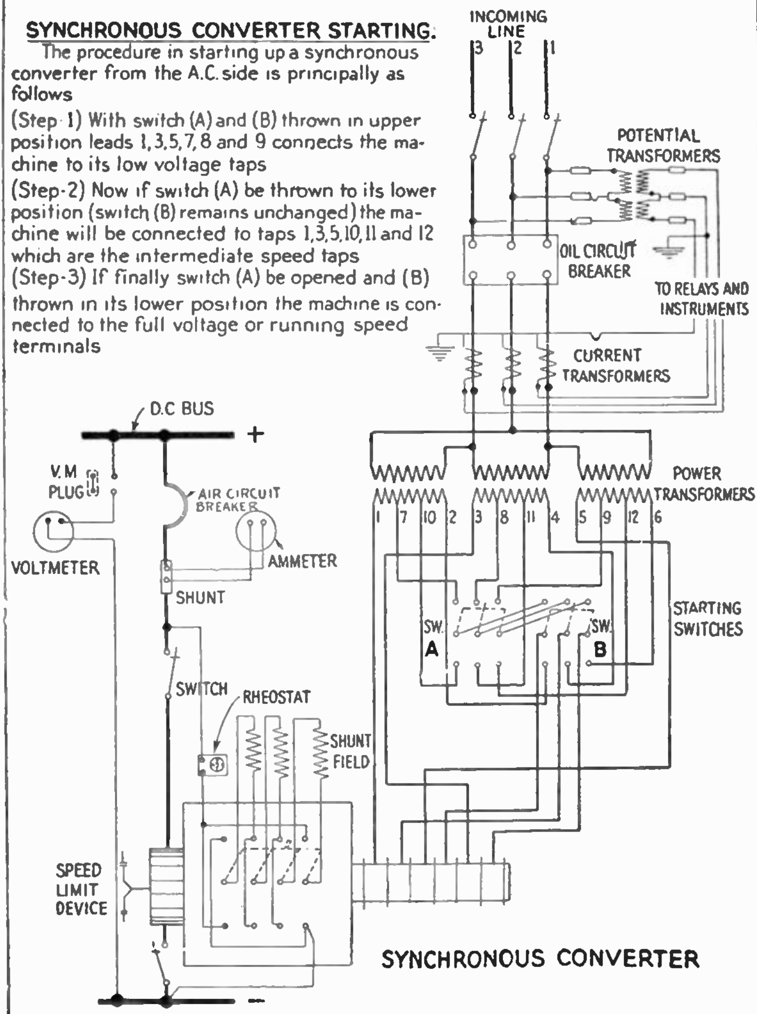
SYNCHRONOUS CONVERTER STARTING.

The procedure in starting up a synchronous converter from the A.C. side is principally as follows

(Step 1) With switch (A) and (B) thrown in upper position leads 1, 3, 5, 7, 8 and 9 connects the machine to its low voltage taps

(Step 2) Now if switch (A) be thrown to its lower position (switch (B) remains unchanged) the machine will be connected to taps 1, 3, 5, 10, 11 and 12 which are the intermediate speed taps

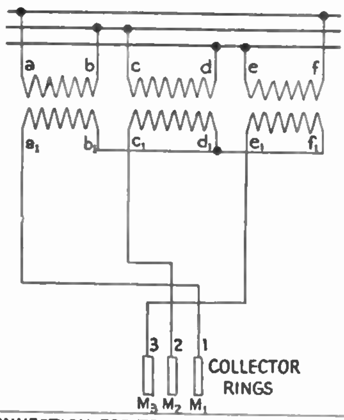
(Step 3) If finally switch (A) be opened and (B) thrown in its lower position the machine is connected to the full voltage or running speed terminals



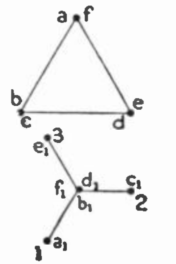
SYNCHRONOUS CONVERTER

TRANSFORMER CONNECTIONS AND VECTOR DIAGRAMS FOR SYNCHRONOUS CONVERTERS

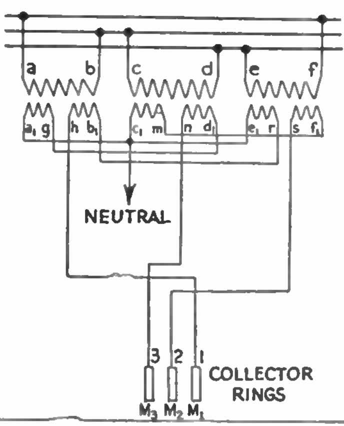
CONNECTION FOR TRANSFORMATION FROM DELTA TO Y



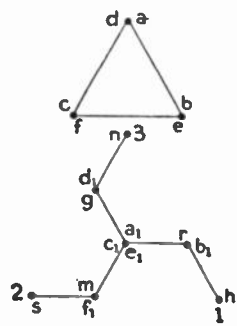
VECTOR DIAGRAM OF DELTA-Y CONNECTIONS



CONNECTION FOR TRANSFORMATION FROM DELTA TO ZIG ZAG OR DISTRIBUTED - Y

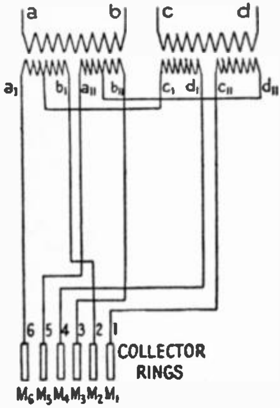


VECTOR DIAGRAM OF DELTA - DISTRIBUTED - Y CONNECTIONS

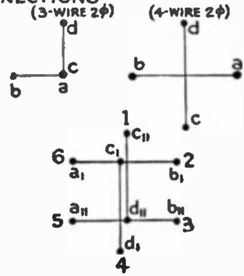


TRANSFORMER CONNECTIONS AND VECTOR DIAGRAMS FOR SYNCHRONOUS CONVERTERS

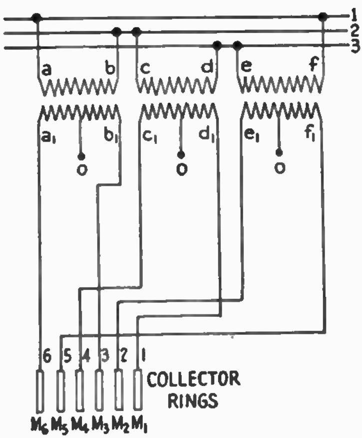
DOUBLE-T CONNECTION FOR TRANSFORMATION FROM TWO-PHASE TO SIX-PHASE.



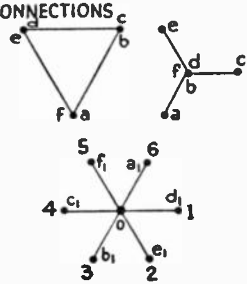
VECTOR DIAGRAM OF DOUBLE-T CONNECTIONS



DIAMETRICAL CONNECTION FOR TRANSFORMATION FROM 3-PHASE TO 6-PHASE

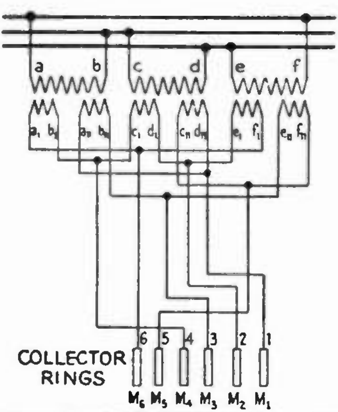


VECTOR DIAGRAM OF DIAMETRICAL CONNECTIONS

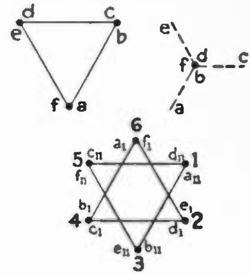


TRANSFORMER CONNECTIONS AND VECTOR DIAGRAMS FOR SYNCHRONOUS CONVERTERS

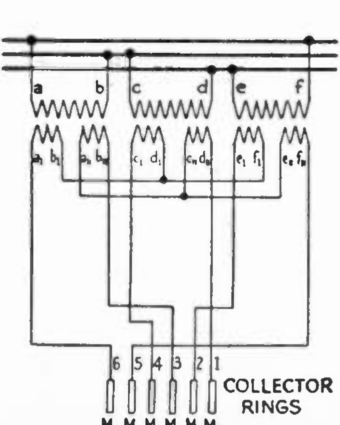
CONNECTIONS FOR TRANSFORMATION FROM DELTA TO DOUBLE-DELTA



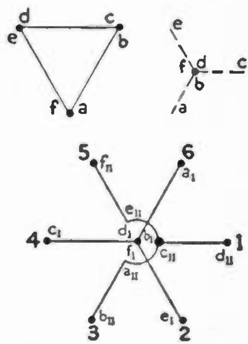
VECTOR DIAGRAM OF DELTA DOUBLE-DELTA CONNECTIONS

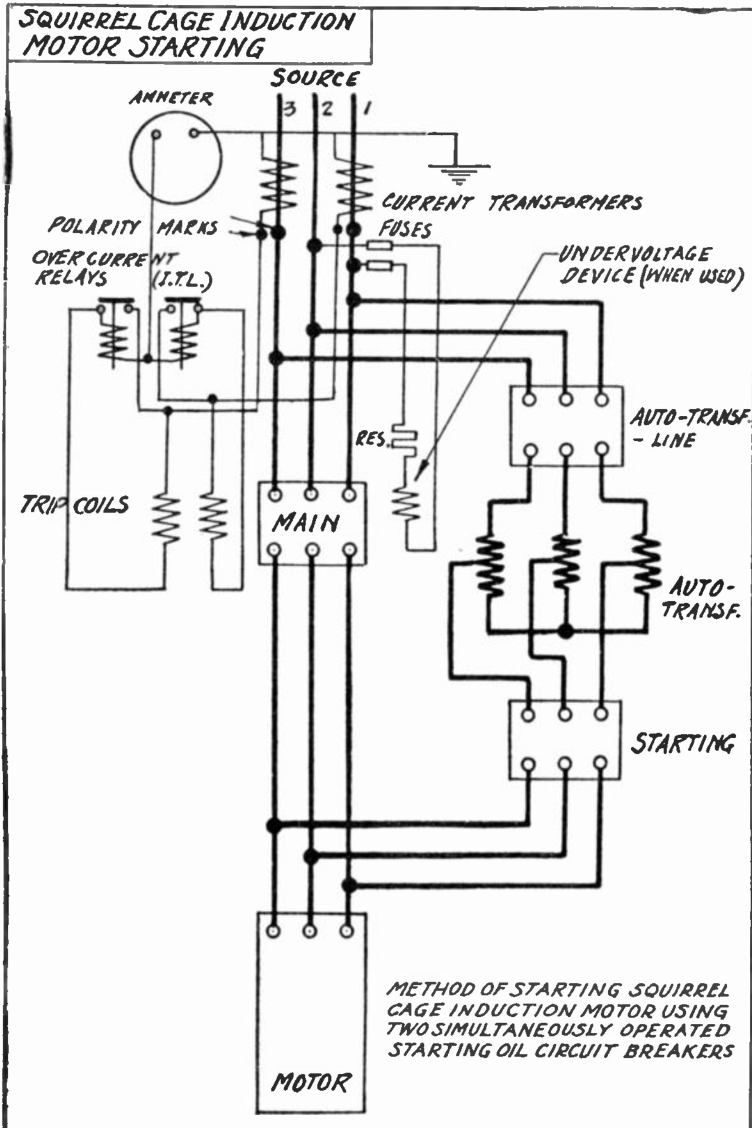


CONNECTIONS FOR TRANSFORMATION FROM DELTA TO DOUBLE-Y

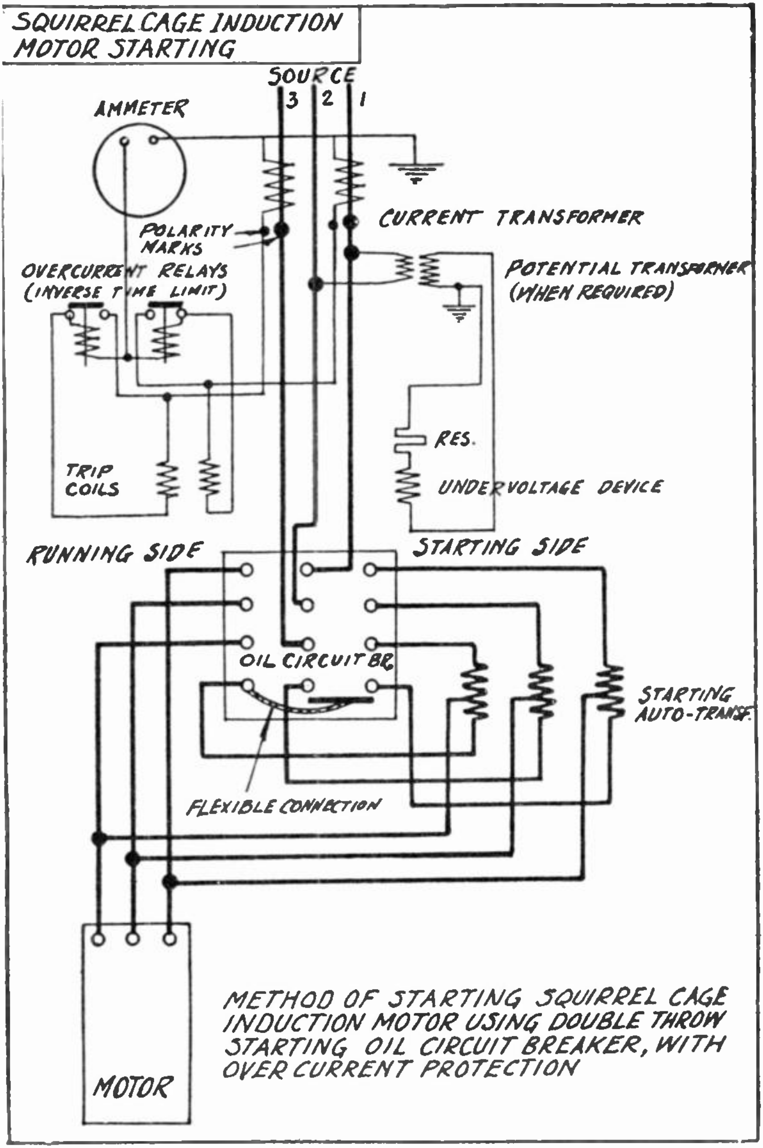


VECTOR DIAGRAM OF DELTA DOUBLE-Y CONNECTIONS

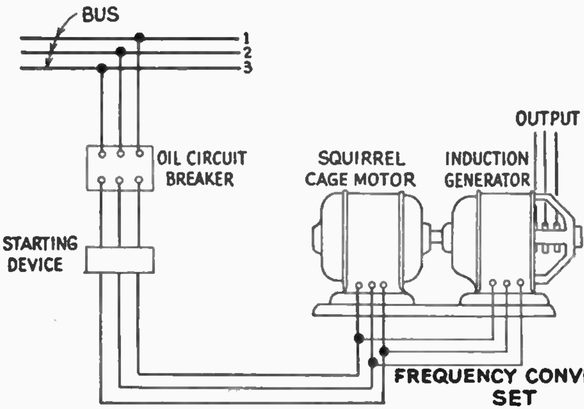




METHOD OF STARTING SQUIRREL CAGE INDUCTION MOTOR USING TWO SIMULTANEOUSLY OPERATED STARTING OIL CIRCUIT BREAKERS


SQUIRREL CAGE INDUCTION MOTOR STARTING
SOURCE
3
2
1
AMMETER
CURRENT TRANSFORMER
POLARITY MARKS
OVERCURRENT RELAYS (INVERSE TIME LIMIT)
POTENTIAL TRANSFORMER (WHEN REQUIRED)
RES.
TRIP COILS
UNDERVOLTAGE DEVICE
RUNNING SIDE
STARTING SIDE
OIL CIRCUIT BR.
STARTING AUTO-TRANSF.
FLEXIBLE CONNECTION
MOTOR
METHOD OF STARTING SQUIRREL CAGE INDUCTION MOTOR USING DOUBLE THROW STARTING OIL CIRCUIT BREAKER, WITH OVER CURRENT PROTECTION

FREQUENCY CONVERTER-SET AND RESISTANCE STARTER FOR WOUND-ROTOR INDUCTION MOTOR

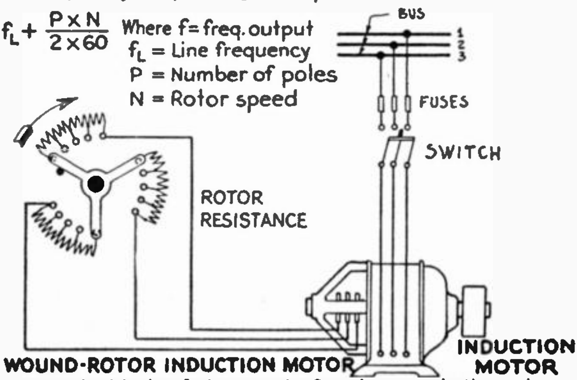


FREQUENCY CONVERTER SET

The induction generator is fundamentally a transformer. If the rotor be held stationary, the output frequency will be the same as that of the supply. When the generator be connected to run in a direction opposite to that of its rotating magnetic field the frequency and voltage will be greater in proportion to its speed. The frequency output may be expressed as follows:

$$f = f_L + \frac{P \times N}{2 \times 60}$$

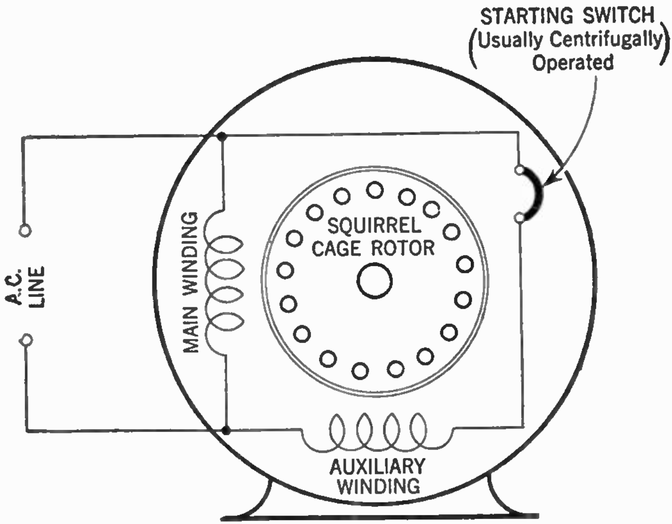
Where f = freq. output
f_L = Line frequency
P = Number of poles
N = Rotor speed



STARTER FOR WOUND-ROTOR INDUCTION MOTOR

The motor is started with the full amount of resistance in the rotor circuit, as the motor gains speed the rotor resistance is gradually cut out by moving the moveable arms as shown.

FRACTIONAL HORSEPOWER MOTOR DIAGRAMS

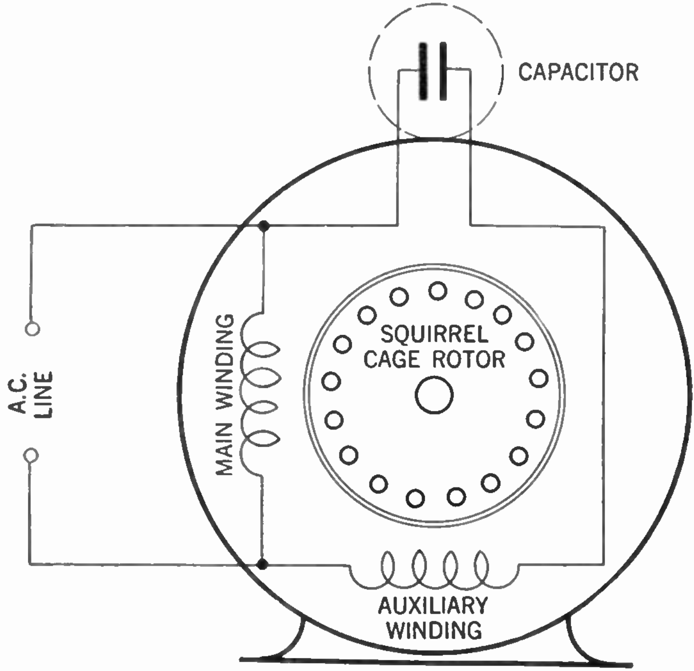


The Split-Phase Induction Motor. This motor type is commonly manufactured in fractional horsepower sizes. It is equipped with a squirrel-cage rotor for constant speed operation and has a starting winding of high resistance (commonly termed auxiliary winding), which is physically displaced in the stator from the main winding. This displacement produced by the relative electrical reistance values in the two windings, creates starting ability similar to that of a ployphase motor.

In series with the auxiliary winding is a starting switch (usually centrifugally operated) which opens the circuit when the motor has attained approximately 75 to 80 percent of synchronous speed.

The function of the starting switch is to prevent the motor from drawing excessive current from the line and also to protect the starting winding from damage due to heating. The motor may be started in either direction by reversing eithe the main or auxiliary winding.

Single-phase, split-phase motors are suitable for oil burners, blowers, busines machines, buffing machines, grinders, etc.

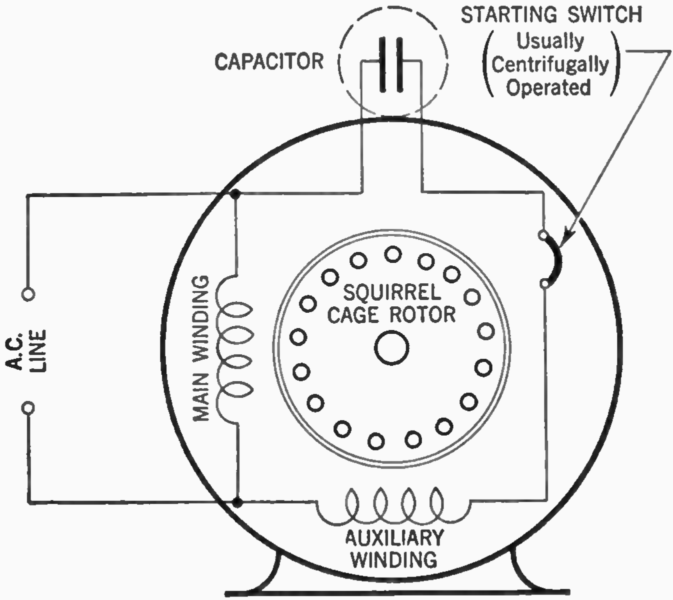


The Split-Phase, Permanently Connected Capacitor Motor. This type of split-phase motor, is commonly manufactured in fractional horsepower sizes.

In common with other types of split-phase motors, it is equipped with a squirrel-cage rotor and a main and auxiliary winding. A capacitor is permanently connected in series with the auxiliary winding, thus a motor of this type starts and runs with a fixed value of capacitance in series with the auxiliary winding.

The motor obtains its starting torque from a rotating magnetic field produced by the two stator windings physically displaced. The main winding is connected directly across the line, while the auxiliary or starting winding is connected to the line through the capacitor, giving an electrical phase displacement.

A motor of the permanent split-phase capacitor type is suitable for direct connected drives requiring low starting torque, such as fans, blowers, certain types of centrifugal pumps, etc.



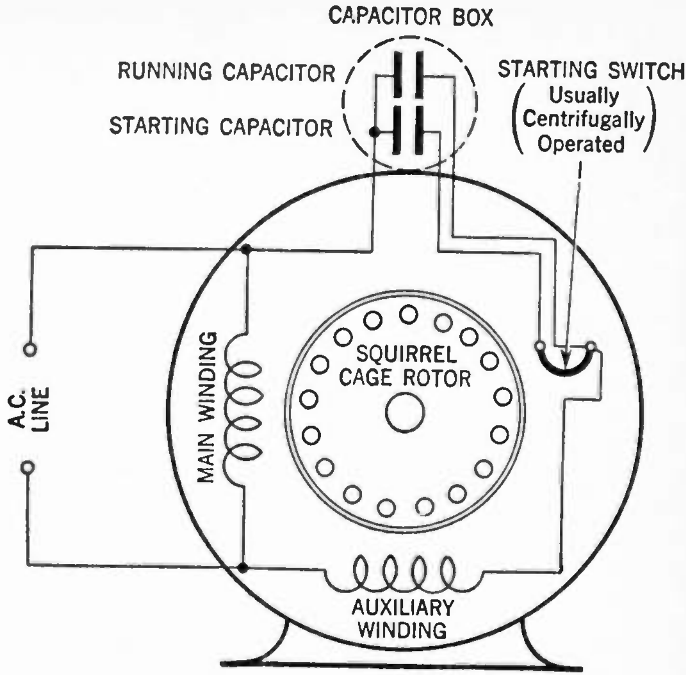
The Split-Phase, Capacitor-Start Motor. This fractional horsepower motor ma be defined as a form of split-phase motor having a capacitor connected in serie with the auxiliary winding.

The auxiliary circuit is opened by means of a centrifugally operated switc when the motor has attained a predetermined speed (usually approximately 7 to 80 per cent of synchronous speed).

A motor of this type is sometimes termed a capacitor-start, induction-run moto in contrast to the straight capacitor run type which is termed a capacitor-star capacitor-run motor.

The rotor is of the squirrel cage type as in other split-phase motors. The mai winding is connected directly across the line, while the auxiliary or startin winding is connected through a capacitor which may be connected into th circuit through a transformer with suitable designed windings and capacitor c such values that the two windings will be approximately 90 degrees apart.

This type of motor is particularly suited for such applications as air conditioning domestic and commercial refrigeration, belt driven fans, etc.



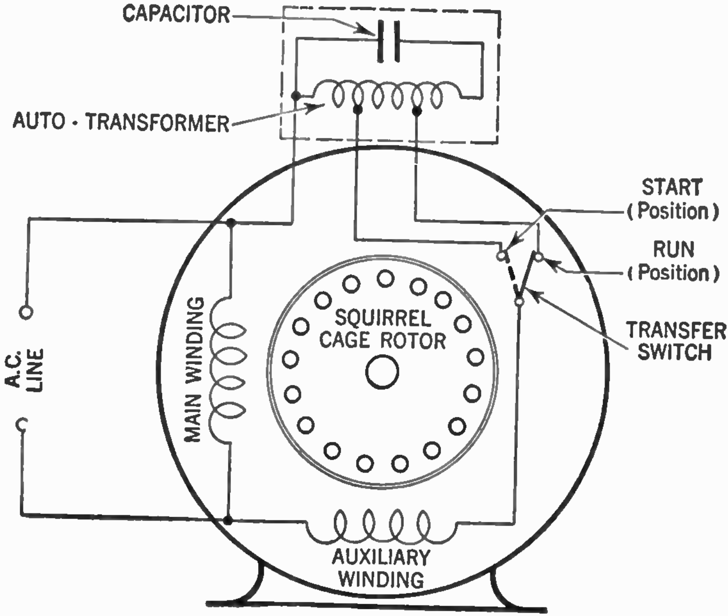
The Split-Phase, Capacitor-Run Motor. This type of motor, also termed two-value capacitor-motor has a running capacitor permanently connected in series with the auxiliary winding, the starting capacitor being in parallel with the running capacitor only during the starting period.

In operation the motor starts with the starting switch closed. After the motor has attained a speed of approximately 70 to 80 per cent of synchronous, the starting switch opens, thus disconnecting the starting capacitor.

The running capacitor is usually of the paper-spaced oil filled type, normally rated at 330 volt A.C. for continuous operation. They usually range from 3 to 16 micro-farads, depending upon the size of the motor.

The starting capacitor is generally of the electrolytic type and may range in sizes of from 80 to 300 micro-farads approximately, for 110 volt, 60 cycle motors.

This type of motor is designed for applications requiring high starting torque, such as compressors, loaded conveyors, reciprocating pumps, refrigeration compressors, stokers, etc.

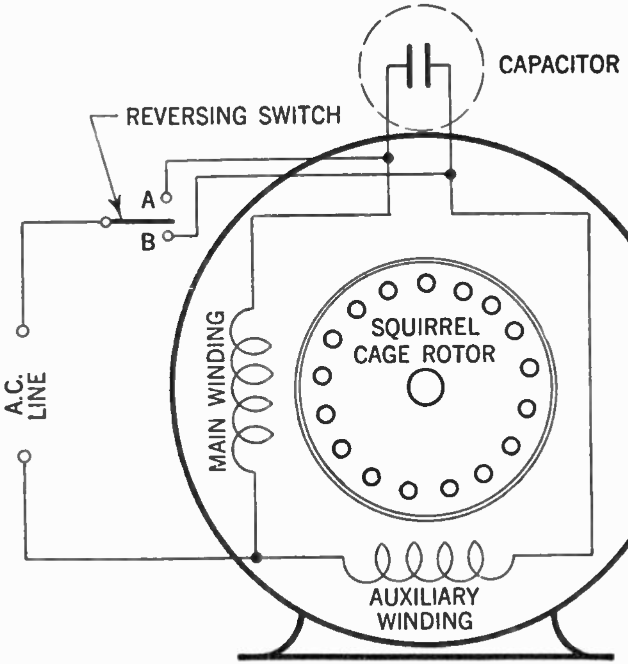


The Split-Phase Capacitor-Run Motor. Another type of two-value capacitor motor is using a capacitor transformer unit. The motor is of the split-phase squirrel cage type with the main and auxiliary winding physically displaced in the stator.

This type of motor employes a **transfer switch** which is equivalent to a single pole double throw switch, by means of which a high voltage is impressed across the capacitor during the starting period.

After the motor has attained a speed of 70 to 80 per cent of synchronous, the transfer switch operates to change the voltage taps on the transformer. The voltage impressed upon the capacitor by means of the transformer will be of a value of from 600 to 800 volts during the starting period and approximately 350 volts for continuous operation.

This type of motor is designed for applications requiring high starting torque such as compressors, loaded conveyors, reciprocating pumps, refrigeration compressors, stokers, etc.

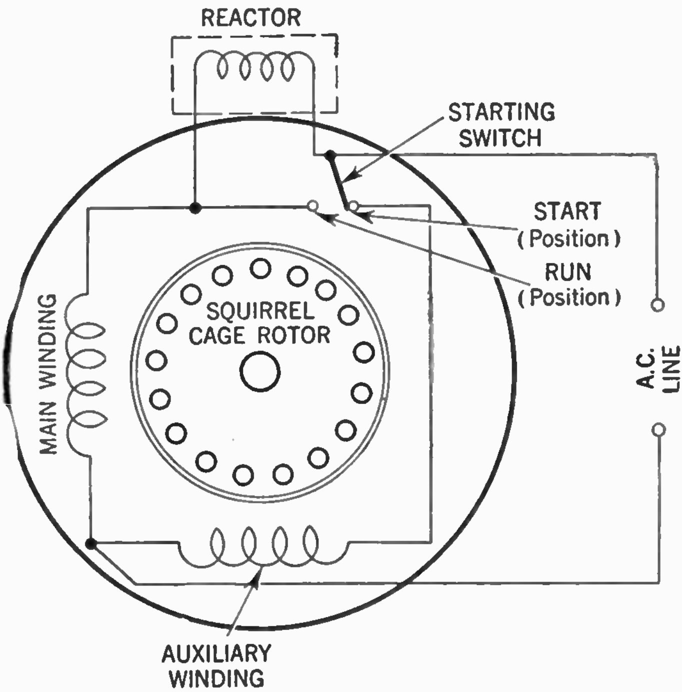


The Split-Phase, Capacitor-Run, Induction Motor (Reversible type). In applications where it is necessary to employ a reversible high-torque intermittently rated capacitor type, a motor connected as shown has found employment.

When the reversing switch is in the B position, the auxiliary winding becomes the main winding, and the main winding becomes the auxiliary winding. With the switch in the A position, both windings functions as shown in the diagram.

Since the direction of rotation in split-phase motors is always from the auxiliary winding toward the main winding, it follows that an interchange of the winding will also reverse the direction of rotation.

From the foregoing it follows that with motor connections arranged in this manner, the main and auxiliary windings in the motor must be identical both as to size of wire and number of effective turns.

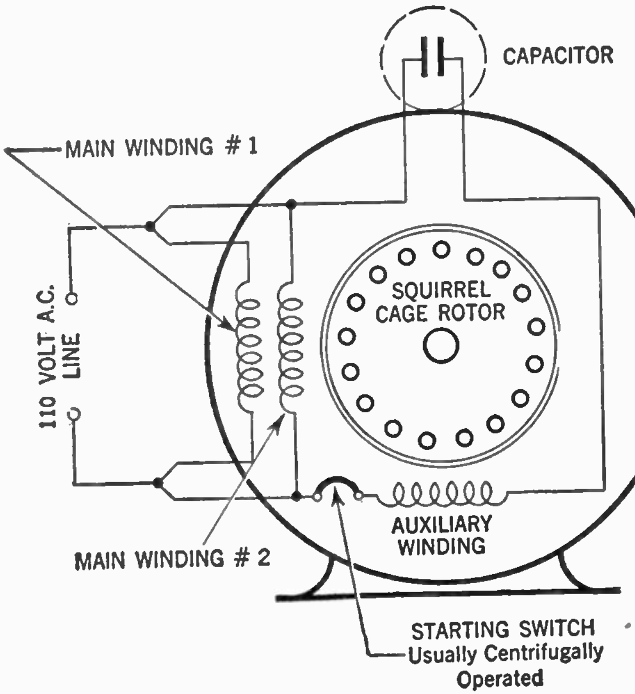


The Reactor-Start, Split-Phase, Induction Motor. This type in common with other types of split-phase motors is equipped with an auxiliary winding, displaced in magnetic position from, and connected in parallel with the main winding.

The function of the reactor is to reduce the starting current and increase the current lag in the main winding. At approximately 75 per cent of synchronous speed the starting switch operates to shunt out the reactor, disconnecting the auxiliary winding from the circuit.

The starting switch must be of such construction so as to be equal to a single pole double throw switch.

This is a constant speed motor and lends itself best for such applications as light running machines such as fans, small blowers, business machines, grinders, etc.



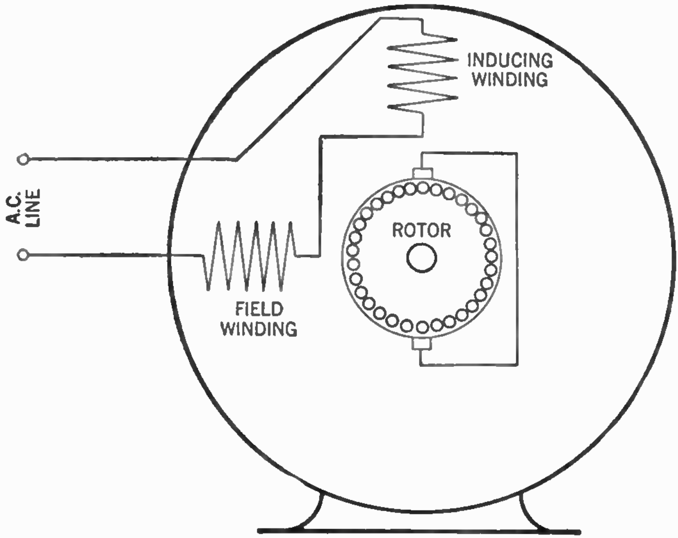
The Split-Phase, Single Value Capacitor Motor (Dual-Voltage Type). A motor of this type differs from the conventional type of capacitor motor in that it has two identical main windings arranged for either series or parallel connections.

With the main windings connected in parallel the line voltage is usually 220 volts, whereas when the main windings are connected in series a fine voltage of 110 volts is usualty employed.

The starting switch and operating characteristics of the motor do not differ from single-value capacitor-start motors previously described.

In common with other types of split phase motors, the auxiliary winding is a separate winding displaced in space from the main winding 90 degrees. Also in series with the auxiliary winding is the usual centrifugal switch and starting capacitor.

A winding arrangement of this type gives only half as much starting torque on 110 volts as on a 220 volts winding.



The Repulsion Motor. By definition a repulsion motor is a single phase motor which has a stator winding arranged for connection to the source of power and a rotor winding connected to a commutator. Brushes and commutators are short-circuited and are so placed that the magnetic axis of the rotor winding is inclined to the magnetic axis of the stator winding.

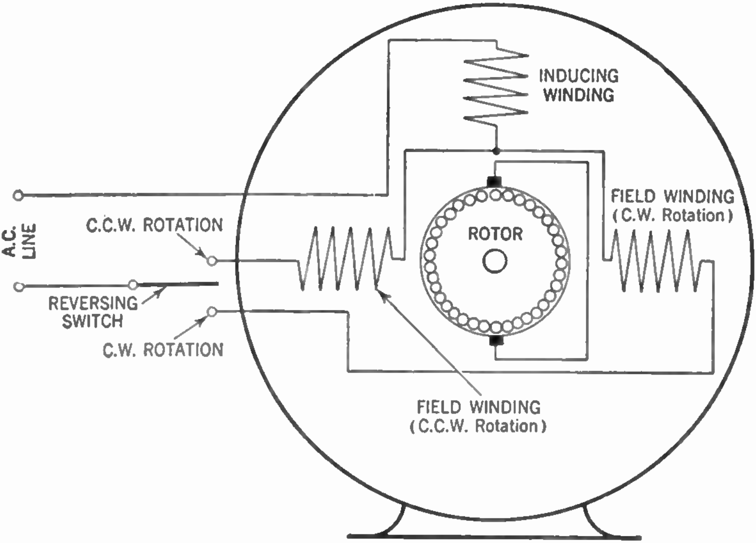
It has a varying speed characteristic, a high starting torque and moderate starting current.

Due to its low power factor except at high speeds, it is often modified into the **compensated repulsion motor**, which has another set of brushes placed midway between the short-circuited set and this added set is connected in series with the stator winding.

The Repulsion-Start Induction Motor. By definition a repulsion-start induction motor is a single phase motor having the same windings as a repulsion motor, but at a predetermined speed the rotor winding is short- circuited or otherwise connected to give the equivalent of a squirrel cage winding. This type of motor starts as a repulsion motor, but operates as an induction motor with constant-speed characteristics.

It has a single-phase distributed field winding with the axis of the brushes dis placed from the axis of the field winding. The armature has an insulated winding.

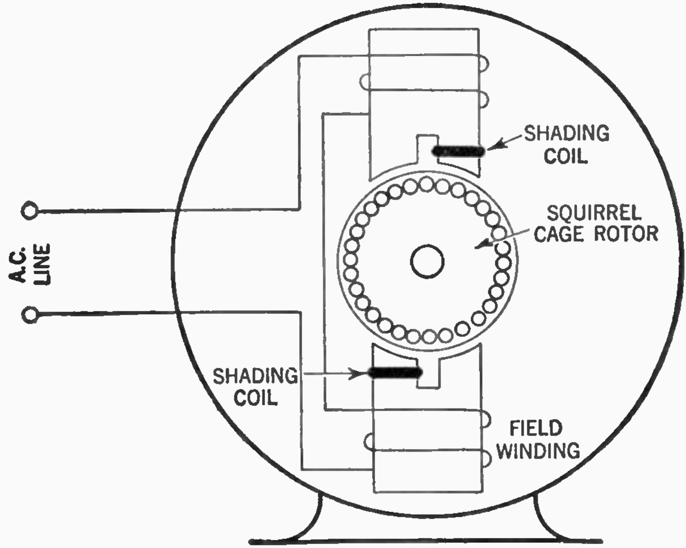
The current induced in the armature is carried by the brushes and commutator resulting in high starting torque. When nearly synchronous speed is attained the commutator is short-circuited so that the armature is then similar in its functions to a squirrel cage armature.



The Repulsion-Start, Induction Motor (Reversible Type). In certain applications, it is necessary to reverse the direction of rotation. A motor of this type has two stator windings displaced as indicated. Reversal of the motor can be accomplished by interchanging the field winding connections.

Thus, for example, with the switch in the upper position, the motor will rotate in a counter-clockwise direction, whereas if the switch be in the lower position the motor will run in the opposite direction, or clock-wise.

The Shaded-Pole Motor. By definition a shaded-pole motor is a single phase induction motor provided with an auxiliary short-circuited winding or windings displaced in magnetic position from the main winding.



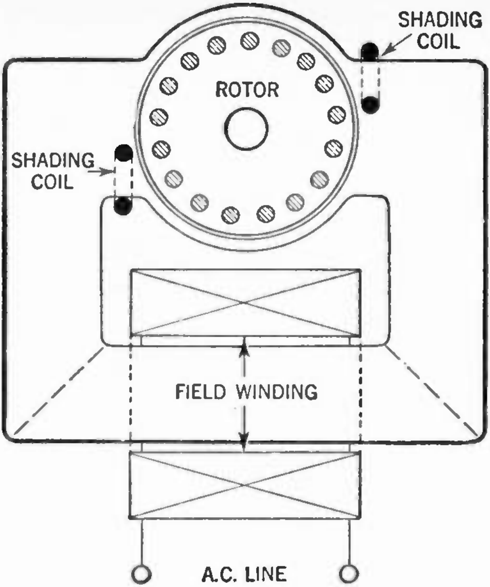
Although there are a number of different construction methods employed principally the motor operates as follows: The shading coil (from which th motor has derived its name) consists of low resistance copper links embedde in one side of each stator pole, and are used to provide the necessary startin torque. When the current increases in the main coils a current is induced in th shading coils that opposes the magnetic field building up in part of the pol pieces they surround.

When the main coil current decreases, that in the shading coil also decreases until the pole pieces are uniformly magnetized. As the main coil current and th pole piece magnetic flux continue to decrease, current in the shading coils re verses and tends to maintain the flux in part of the pole pieces.

When the main coil current drops to zero, current still flows in the shading coil to give the magnetic effect which causes the coils to produce a rotating mag netic field which makes the motor self starting.

This motor is used largely where the power requirements are small, such as i electric clocks, instruments, toys, hair dryers, small fans, etc. It is simple in con struction and low in cost and is in addition very rugged and reliable.

The Shaded-Pole Motor (Skeleton Type). This type of motor is built for ap plications where the power requirements are very small. The field circuit wit



its winding, is built around the conventional squirrel cage rotor and consists or punchings that are stacked alternately to form overlapping joints, in the same manner that small transformer cores are assembled.

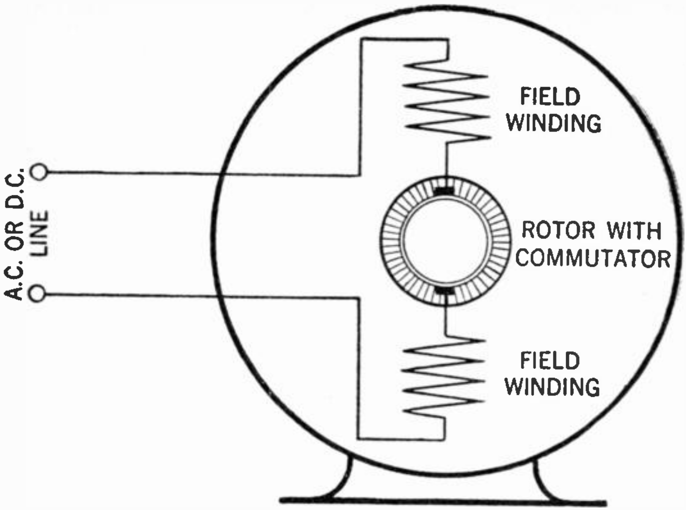
Motors of this class will operate only on alternating current; they are simple in construction, low in cost and extremely rugged and reliable. Their principal limitations are, however, low efficiency and a low starting and running torque.

A shaded pole motor is not reversible, unless shading coils are provided on each side of the pole, and means for opening one and closing the other coil are provided.

The inherently high slip of a shaded pole motor makes it convenient to obtain speed variation on a fan load, for example, by reducing the impressed voltage.

The Universal Type Motor. The universal motor is designed for operation on either alternating or direct current. It is of the series-wound type, that is, it is provided with a field winding on the stator which is connected in series with a commutating winding on the rotor.

Universal motors are commonly manufactured in fractional horse-power sizes and are because of their use on either A.C. or D.C. currents, preferred, particularly in areas where power companies supply both types of current.



Full-load speeds generally range from 5,000 to 10,000 r.p.m. with no-load speeds from 12,000 to 18,000 r.p.m. Typical applications are portable tools, office appliances, electric cleaners, kitchen appliances, sewing machines, etc.

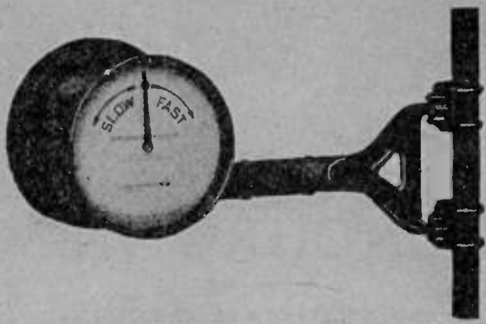
The speed of universal motors can be adjusted by connecting a resistance of proper value in series with the motor. Advantages of this speed control method is obvious, in such applications as motor operated sewing machines, where it is necessary to operate the motor over a large range of speed.

In such applications adjustable resistances are used and the speed varied at will of the operator. Universal motors may be either compensated or uncompensated, the latter type being used for the higher speeds and lower ratings only.

Universal Motor Connection Method. As previously noted, speed regulation is commonly accomplished by means of a variable resistance in series with the motor. Speed reversal in a universal type motor is usually obtained by an interchange of the brush-holder leads, having the armature connected off neutral. In the split-series, three-wire reversible type universal motor, one stator coil is used to obtain one direction and the other stator coil to obtain the other direction of rotation, only one stator coil being in the circuit at a time. The only requirement being that the armature connections be on neutral in order to obtain satisfactory operation in both directions of rotation.

SYNCHRONISM INDICATOR AND WIRING DIAGRAMS

GENERAL METHOD OF SYNCHRONIZING



— SYNCHRONISM INDICATOR —

PARALLEL OPERATION OF SYNCHRONOUS GENERATORS

Before Generator #2 can be connected in parallel with Generator #1, the following conditions must be obtained:

(1) Both machines must have the same frequency and wave form.

(2) Their terminal voltages must be equal.

(3) Their sequence of Maximum potential values must be the same.

When synchronizing proceed as follows:

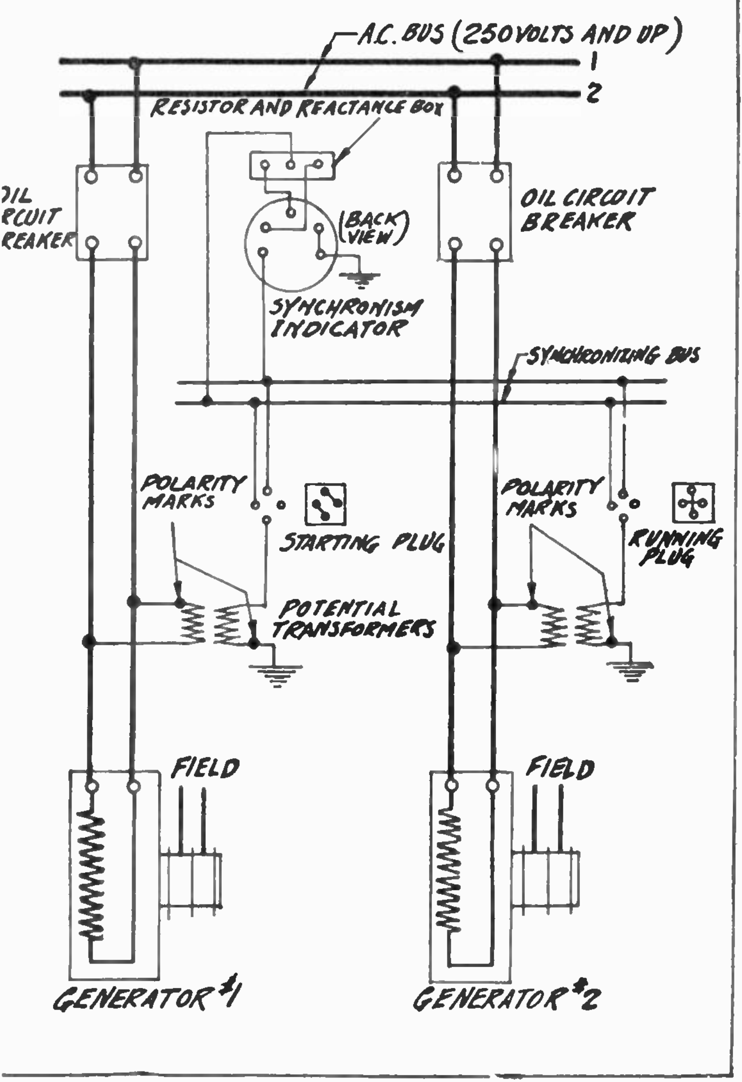
I. LAMP SYNCHRONIZING : Machine #1 is running and supplying the load and its oil circuit breaker is closed, the running plug is inserted. Bring machine #2 up to voltage by Slowly increasing the speed of its prime mover, as the speed of mach. #2 increases insert the starting plug, when now the machines are running at nearly the same speed, the synchronizing lamps light up then go out, light up again etc. If the machines are in steps with lamps out or lamps in, (Depending on if light or dark lamp connections are used) wait until they go out for a few seconds then close the oil circuit breaker on machine #2 and the machines are now in parallel.

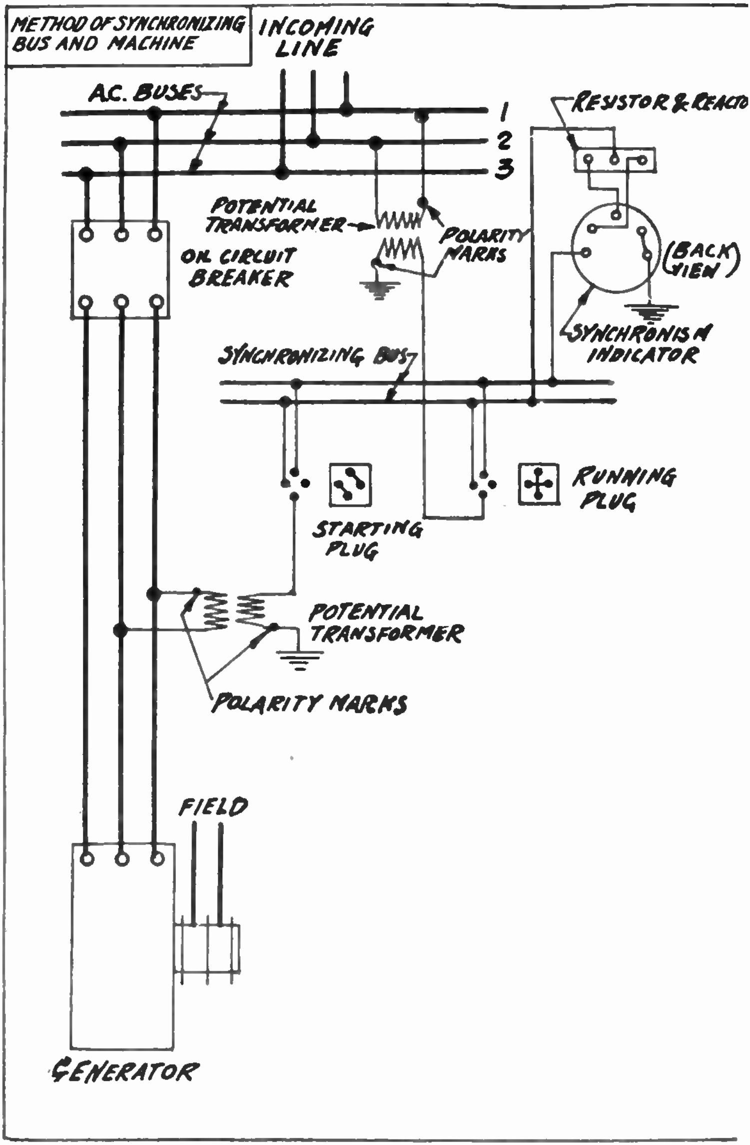
II. INDICATOR SYNCHRONIZING

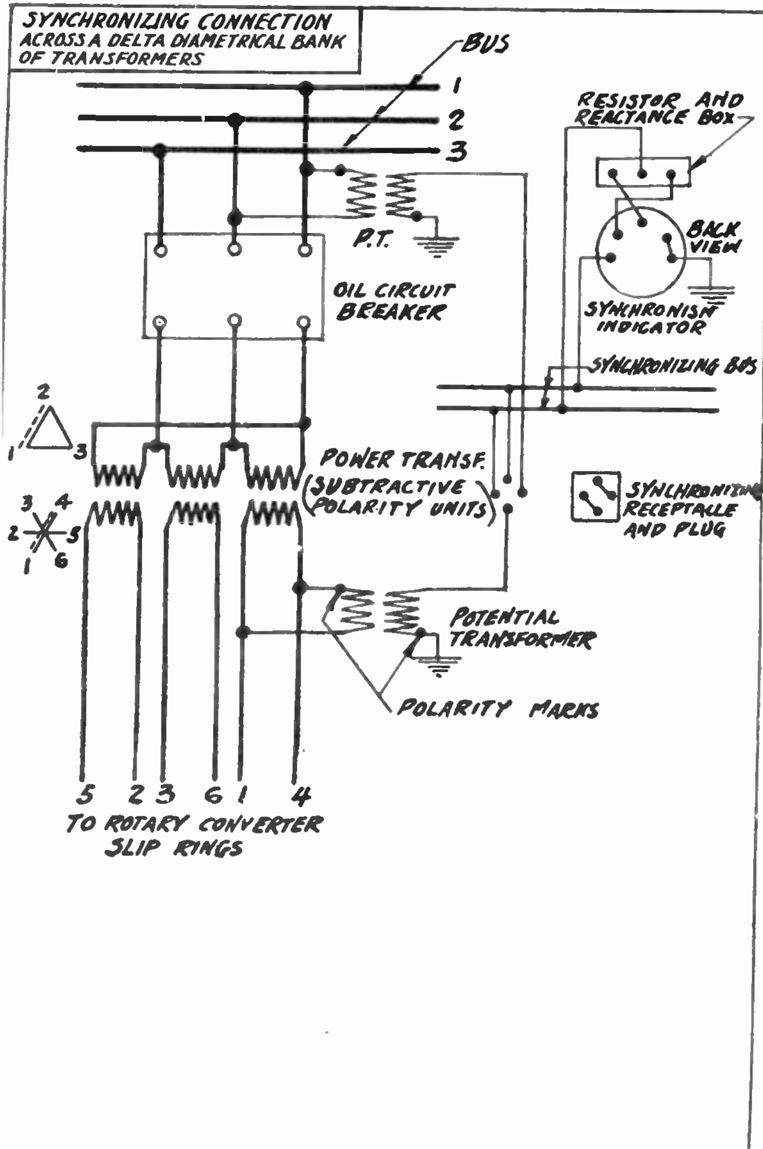
Proceed same as before: The rotary motion of the pointer on the indicator indicates whether the Generator to be synchronized is running to slow or to fast. When the pointer remains stationary in the vertical position the two machines are in synchronism and the oil circuit breaker can be closed.

After paralleling the two machines adjust the mechanical power input and the generated e.m.f. until each machine supplies its share of the total load, and the power factor of each machine is the same and equal to that of the total load.

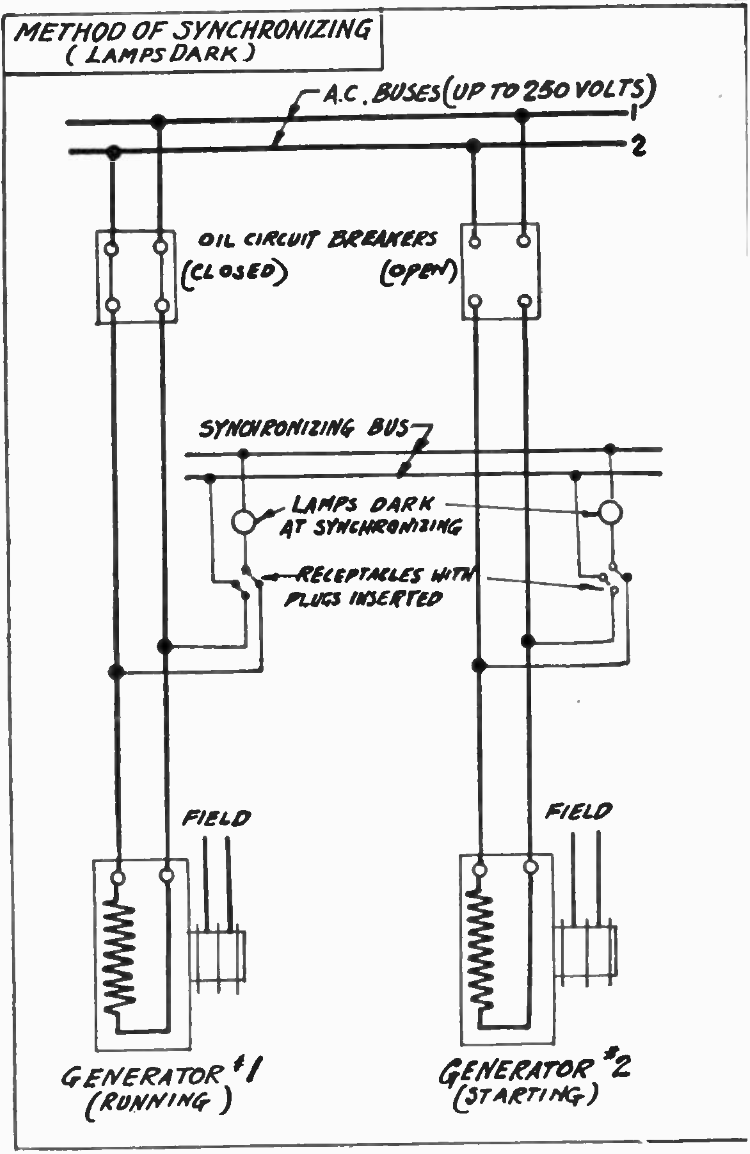
METHOD OF SYNCHRONIZING
2-A.C. GENERATORS

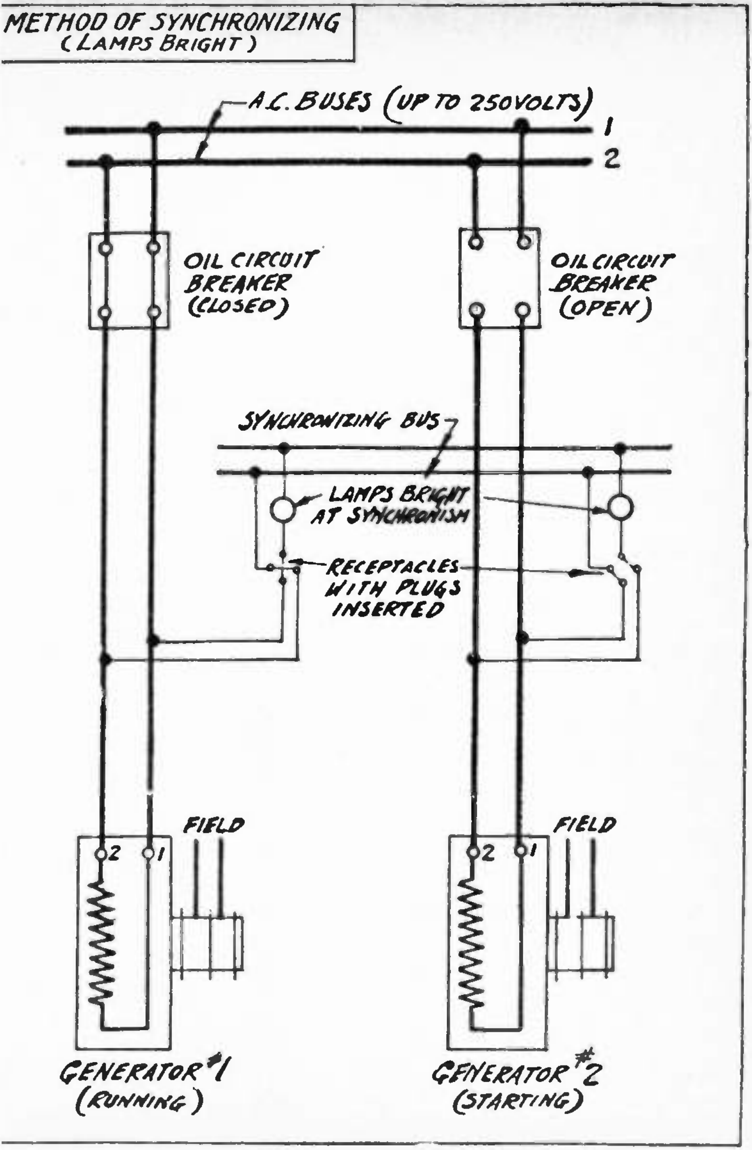



METHOD OF SYNCHRONIZING BUS AND MACHINE
INCOMING LINE
A.C. BUSES
1
2
3
RESISTOR & REACTO
POTENTIAL TRANSFORMER
POLARITY MARKS
OIL CIRCUIT BREAKER
(BACK VIEW)
SYNCHRONISM INDICATOR
SYNCHRONIZING BUS
STARTING PLUG
RUNNING PLUG
POTENTIAL TRANSFORMER
POLARITY MARKS
FIELD
GENERATOR

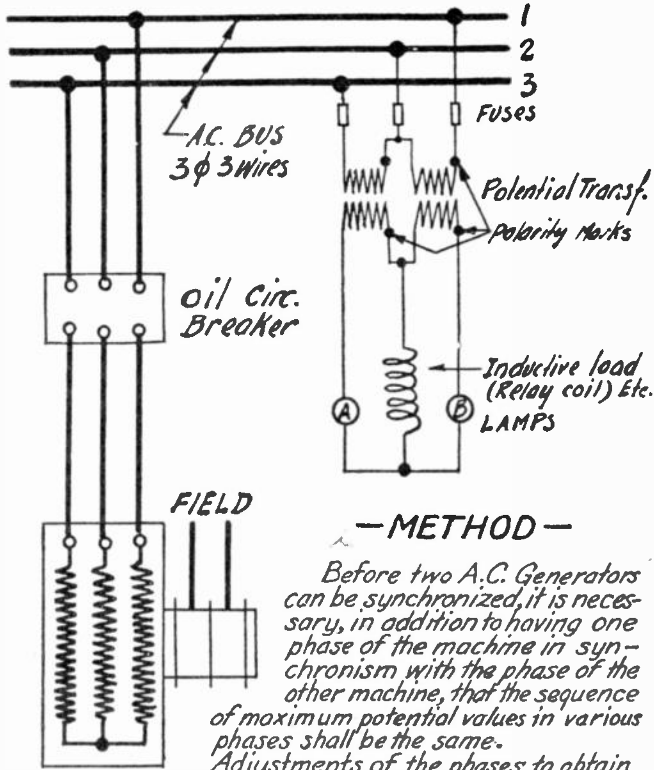


SYNCHRONIZING CONNECTION ACROSS A DELTA DIAMETRICAL BANK OF TRANSFORMERS
BUS
1
2
3
P.T.
OIL CIRCUIT BREAKER
RESISTOR AND REACTANCE BOX
BACK VIEW
SYNCHRONISM INDICATOR
SYNCHRONIZING BUS
POWER TRANSF. (SUBTRACTIVE POLARITY UNITS)
SYNCHRONIZING RECEPTACLE AND PLUG
POTENTIAL TRANSFORMER
POLARITY MARKS
5 2 3 6 1 4
TO ROTARY CONVERTER SLIP RINGS


METHOD OF SYNCHRONIZING
(LAMPS DARK)
A.C. BUSES (UP TO 250 VOLTS)
1
2
OIL CIRCUIT BREAKERS
(CLOSED)
(OPEN)
SYNCHRONIZING BUS
LAMPS DARK
AT SYNCHRONIZING
RECEPTACLES WITH
PLUGS INSERTED
FIELD
FIELD
GENERATOR #1
(RUNNING)
GENERATOR #2
(STARTING)


METHOD OF SYNCHRONIZING
(LAMPS BRIGHT)
A.C. BUSES (UP TO 250 VOLTS)
1
2
OIL CIRCUIT BREAKER (CLOSED)
OIL CIRCUIT BREAKER (OPEN)
SYNCHRONIZING BUS
LAMPS BRIGHT AT SYNCHRONISM
RECEPTACLES WITH PLUGS INSERTED
FIELD
FIELD
2
1
2
1
GENERATOR #1 (RUNNING)
GENERATOR #2 (STARTING)

PHASE ROTATION TEST



A.C. Generator

—METHOD—

Before two A.C. Generators can be synchronized, it is necessary, in addition to having one phase of the machine in synchronism with the phase of the other machine, that the sequence of maximum potential values in various phases shall be the same.

Adjustments of the phases to obtain this sequence is known as "phase rotation test." To obtain the phase rotation of the machine, proceed as follows: Connect two lamps "A" & "B" and an inductive load as shown. One lamp will grow brighter than the other; and if that lamp should be the "B" lamp, the phase relation is clockwise or 1-2-3. If on the other hand "A" should glow the brighter, the phase rotation is counterclockwise or 3-2-1.

The leads of the machine may be transposed after a check to confirm with phase rotation of the other machine, or the Bus, as the case may be.

TRANSFORMER CONNECTIONS

CIRCUIT CONNECTIONS & DEFINITIONS OF VOLTAGE AND CURRENTS IN THREE-PHASE SYSTEMS.

In a three-phase system, (Transformer-circuit or apparatus) there are two voltages between which a sharp distinction must be made: The voltage

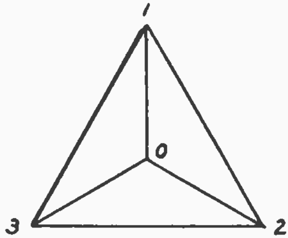


Fig. 1

between the phase conductors, and the voltage from phase conductor to neutral (or ground where the neutral is at ground potential).

In the usual diagrammatic representation as in fig. 1, these voltages are denoted as the delta-voltage and the star-voltage.

If then, 1, 2 and 3 are the three phase conductors of a three-phase circuit, 0 the neutral, (regardless of whether it actually exists as conductor or not) the DELTA-VOLTAGES 1-2, 2-3, 3-1 are variously called the, Line Voltage, Voltage Between Lines, Voltage Between Conductors, or simply the Three-phase Voltage or the voltage of the system; The STAR-VOLTAGES 0-1, 0-2, 0-3 are similarly called the Voltage To Ground, Voltage To Neutral, or Neutral Voltage, etc.

Delta-voltage = 1.73 times Star-voltage.

$$\text{Star-voltage} = \frac{\text{Delta-voltage}}{1.73}$$

Thus the delta-voltage is the higher one, the star voltage being a part only of the delta-voltage.

Similarly a distinction is made between the delta-current and the star-current in a three-phase system. The DELTA-CURRENT *is the current which flows from phase to phase: From 1 to 2, from 2 to 3, from 3 to 1.*

The STAR-CURRENT *is often simply denoted as the Current, Current Per Phase, Line Current is the Current flowing in the phase conductors in 1, or 2, or 3 and may be supposed to flow towards the neutral O.*

Star-current = 1.73 times delta-current

$$\text{Delta-current} = \frac{\text{Star-current}}{1.73}$$

When speaking of the Voltage and the Current or Line Voltage and Line Current of a three-phase system, without further qualifications, the Delta Voltage and the Star Current are understood.

In the conventional denotations, voltage and current in the three-phase system thus do not correspond to each other; and therefore are not in phase with each other on non-inductive load, but show a phase displacement of 30 degrees: the angle 0-1-2 in fig. 1.

TRANSFORMERS & CONNECTIONS

A transformer is defined as a form of stationary induction apparatus in which the primary and secondary windings are ordinarily insulated one from another. A transformer does not generate power, but merely changes the power from one voltage to another.

The three-phase transformer consists of three primary and three secondary windings, (see fig. 1) usually connected in star or delta respectively.

Single-phase transformers (see fig. 2), connected in star or delta are often preferable to three-phase transformers because of the fact that single-phase reverse units are less expensive; and also because damage to one single-phase transformer may be repaired, while another identical spare-transformer is inter-connected in the three-phase unit without loss of service.

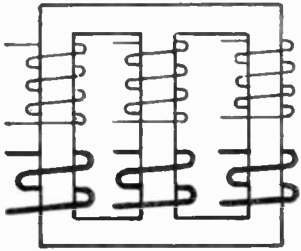


Fig. 1

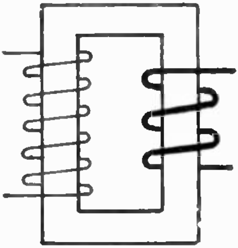


Fig. 2

When two sets of transformers are connected in parallel to the primary and secondary circuits of a three-phase system, any combination of delta and star may be used in each set except that, with one set of transformers connected in delta-star or star-delta, the other set may not be connected delta-delta or star-star.

For example of transformer connections,
See the following pages.

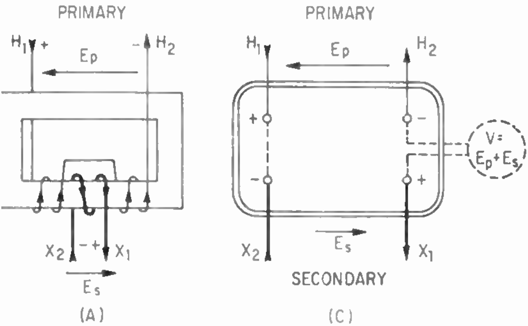


FIGURE 1 - ADDITIVE POLARITY

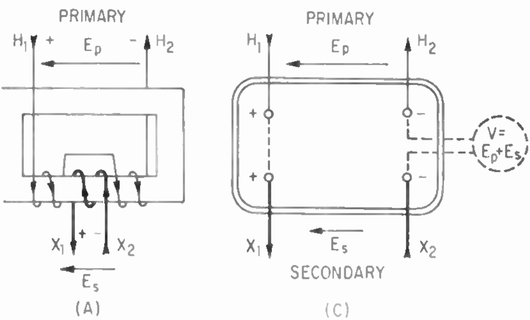
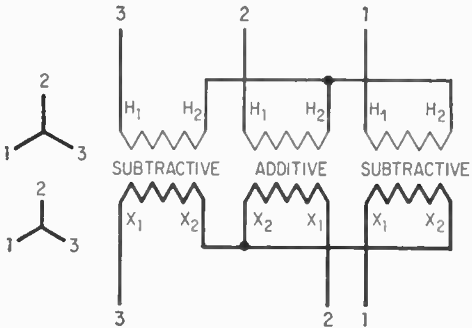


FIGURE 2 - SUBTRACTIVE POLARITY

'O TEST FOR POLARITY: WITH PRIMARY AND SECONDARY IN SERIES (ONE PRIMARY LEAD BEING ONNECTED TO THE ADJACENT SECONDARY LEAD) THE TRANSFORMER IS EXCITED FROM AN .C SOURCE ON EITHER SIDE AND THE VOLTAGES ACROSS THE HIGH-VOLTAGE WINDING AND LSO BETWEEN THE FREE PRIMARY AND SECONDARY TERMINALS ARE MEASURED. IF THE ATTER VOLTAGE IS FOUND TO BE LESS THAN THAT ACROSS THE HIGH-VOLTAGE WINDING, HE POLARITY IS SUBTRACTIVE, IF MORE IT IS ADDITIVE. IN TESTING FOR POLARITY A 'RACTION OF THE RATED VOLTAGE IS SUFFICIENT.

VECTOR AND WIRING DIAGRAM OF CONNECTIONS FOR INDICATING WATTMETER CONNECTED ACROSS A STAR-DELTA GROUP OF POWER TRANSFORMERS.



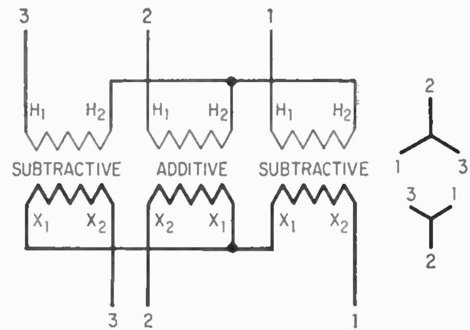


DIAGRAM SHOWING CONNECTIONS FOR STAR-STAR POWER TRANSFORMER GROUP TO OBTAIN ADDITIVE OR SUBTRACTIVE LINE POLARITY.

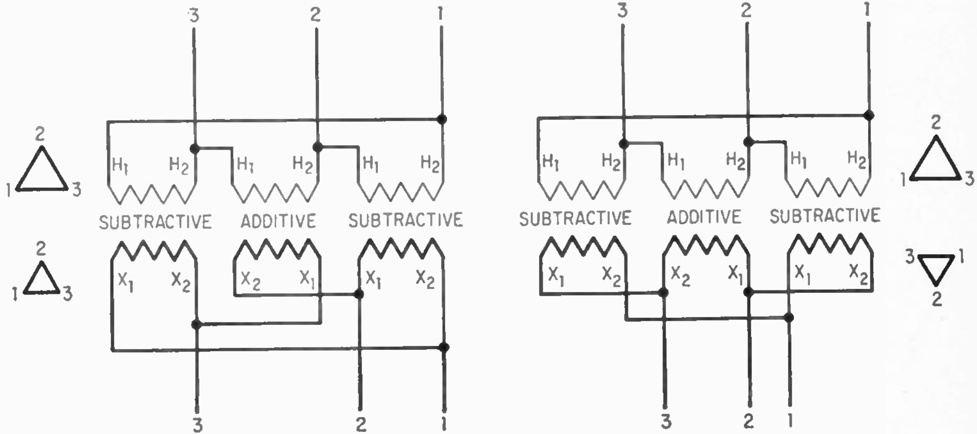
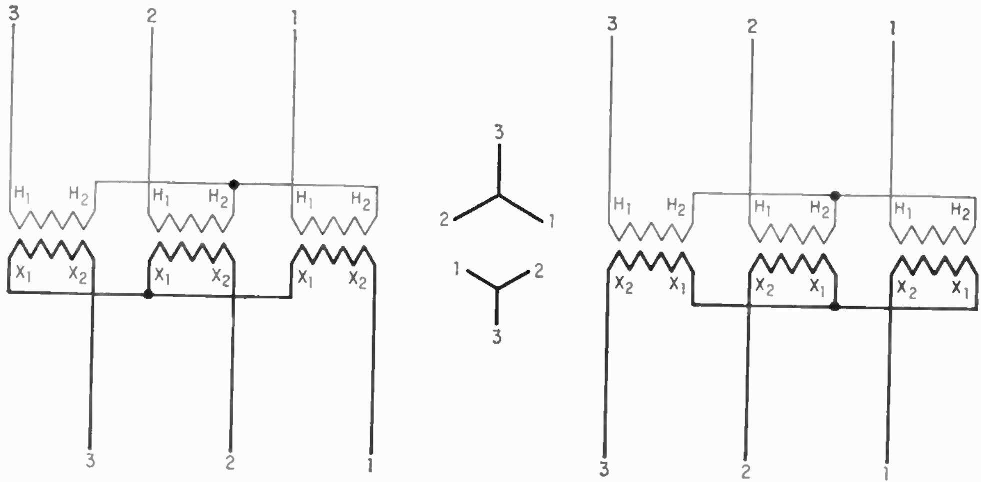


DIAGRAM SHOWING CONNECTIONS FOR DELTA-DELTA POWER TRANSFORMER GROUP TO OBTAIN ADDITIVE OR SUBTRACTIVE LINE POLARITY.



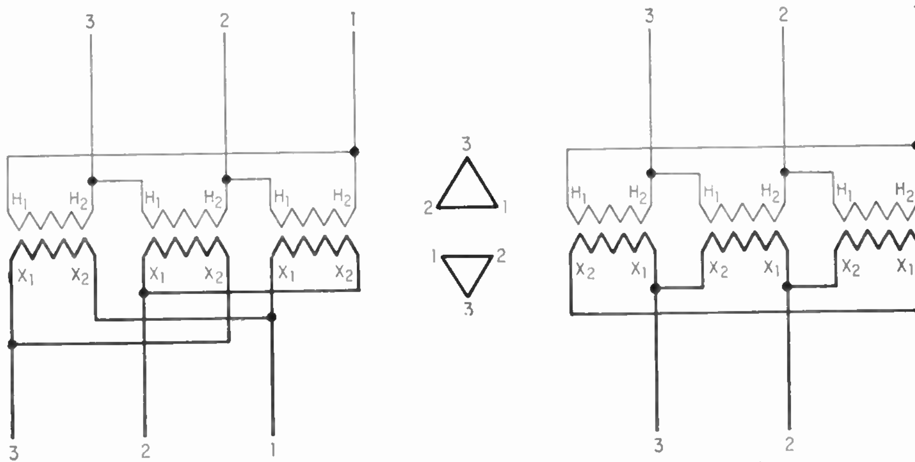
(A)

SUBTRACTIVE POLARITY UNITS

(B)

ADDITIVE POLARITY UNITS

VECTOR AND WIRING DIAGRAM SHOWING CONNECTIONS FOR OBTAINING ADDITIVE LINE POLARITY WITH TRANSFORMER UNITS OF EITHER ADDITIVE OR SUBTRACTIVE POLARITY IN STAR-STAR GROUPS.



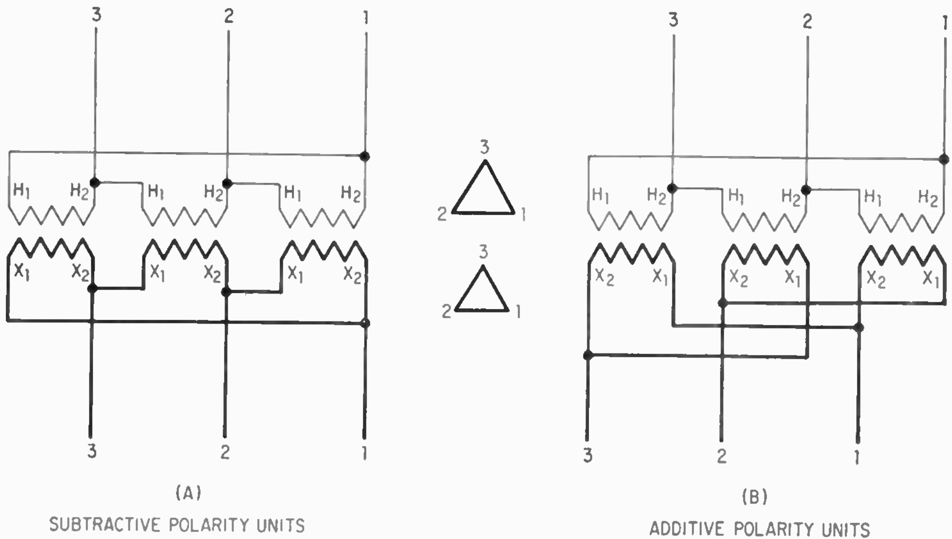
(A)

SUBTRACTIVE POLARITY UNITS

(B)

ADDITIVE POLARITY UNITS

VECTOR AND WIRING DIAGRAM SHOWING CONNECTIONS FOR OBTAINING ADDITIVE LINE POLARITY WITH TRANSFORMER UNITS OF EITHER ADDITIVE OR SUBTRACTIVE POLARITY IN DELTA-DELTA GROUPS.



VECTOR AND WIRING DIAGRAM SHOWING CONNECTIONS FOR OBTAINING SUBTRACTIVE LINE POLARITY WITH TRANSFORMER UNITS OF EITHER ADDITIVE OR SUBTRACTIVE POLARITY IN DELTA-DELTA GROUPS.

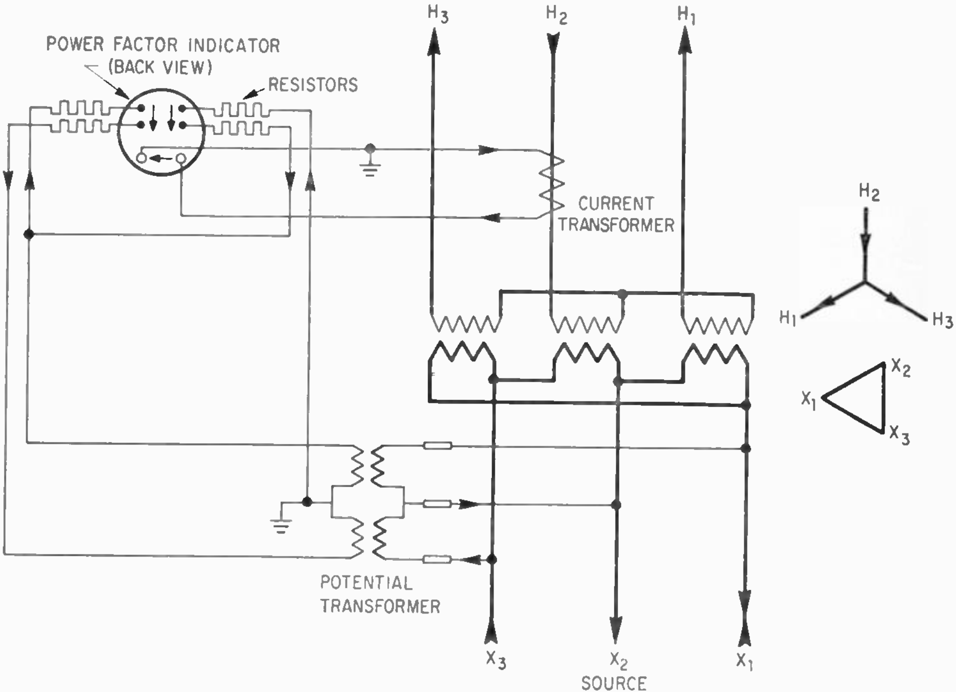
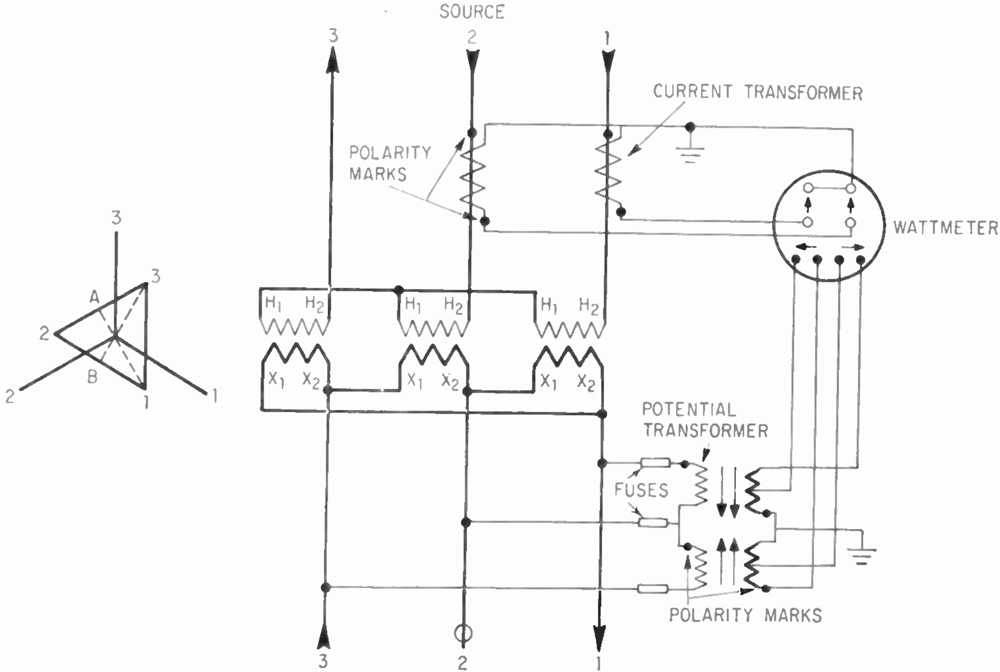
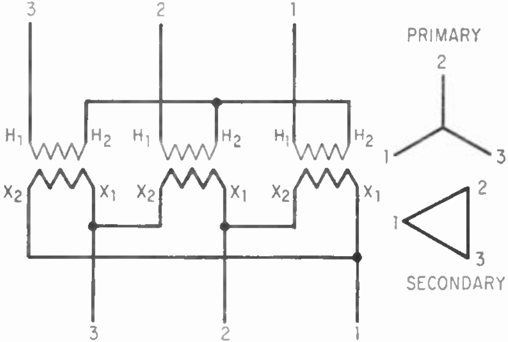


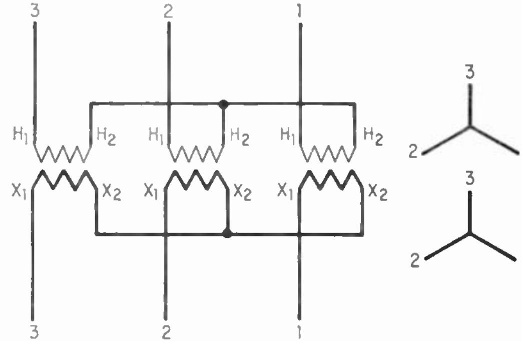
DIAGRAM OF CONNECTIONS FOR TYPICAL POWER FACTOR INDICATOR CONNECTED ACROSS A STAR-DELTA TRANSFORMER BANK.



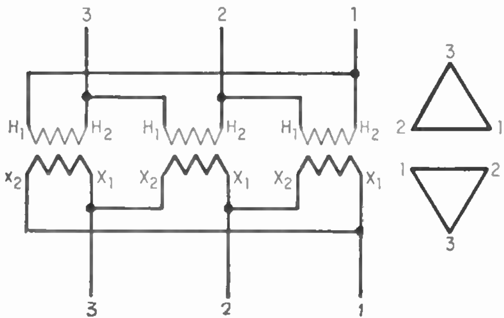
VECTOR AND WIRING DIAGRAM OF CONNECTIONS FOR INDICATING WATTMETER CONNECTED ACROSS A STAR-DELTA GROUP OF POWER TRANSFORMERS.



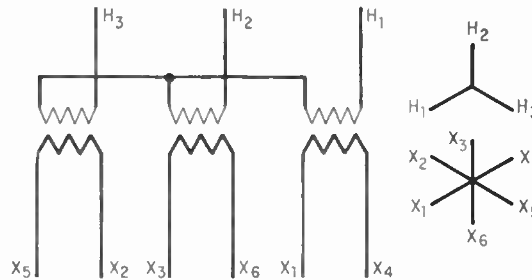
CONNECTIONS OF STAR-DELTA TRANSFORMER BANK, WITH ADDITIVE POLARITY UNITS.



CONNECTIONS OF STAR-STAR TRANSFORMER BANK, WITH SUBTRACTIVE POLARITY UNITS.

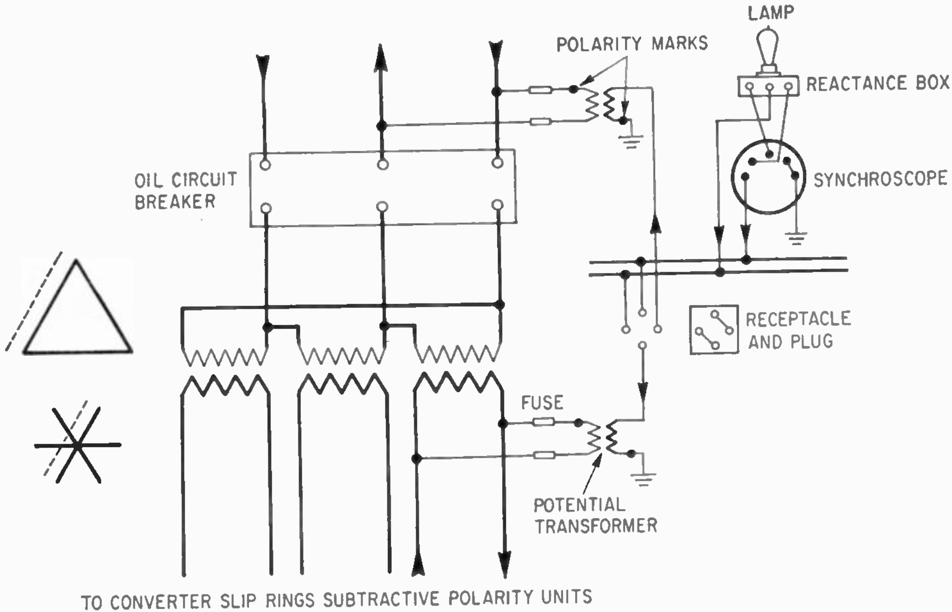


CONNECTIONS OF DELTA-DELTA TRANSFORMER BANK WITH ADDITIVE POLARITY UNITS.

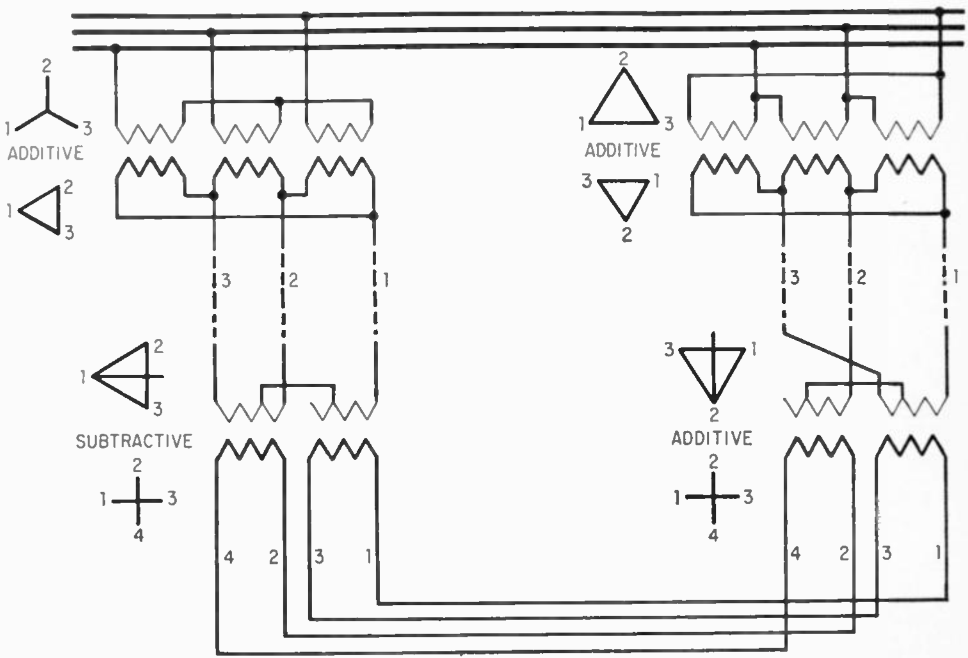


TO ROTARY CONVERTER SLIP RINGS

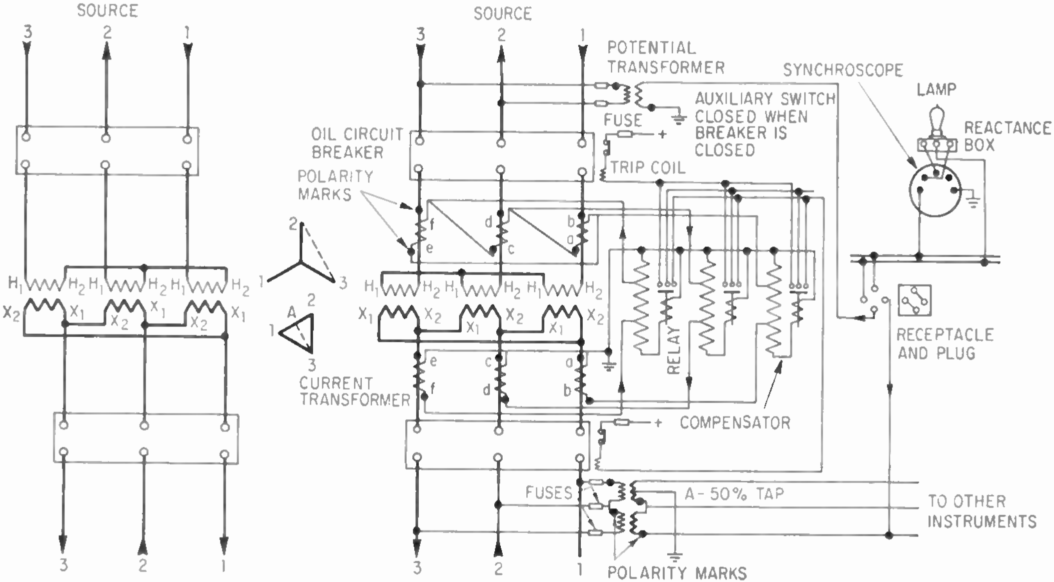
CONNECTION OF STAR-DIAMETRICAL TRANSFORMER BANK FOR ROTARY CONVERTER SERVICE.



VECTOR AND WIRING DIAGRAM SHOWING SYNCHRONIZING CONNECTIONS ACROSS A DELTA-DIAMETRICAL BANK OF TRANSFORMERS CONSISTING OF SUBTRACTIVE POLARITY UNITS.



VECTOR AND WIRING DIAGRAM SHOWING THREE PHASE VOLTAGES CARRIED ACROSS VARIOUS TRANSFORMER GROUP FORMS RESULTING IN IN-PHASE VOLTAGES ON THE QUARTER PHASE SYSTEM.

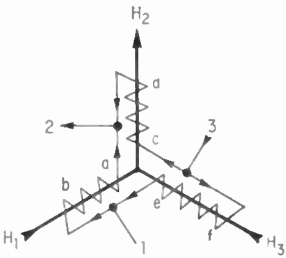


ADDITIVE POLARITY UNITS

SUBTRACTIVE POLARITY UNITS

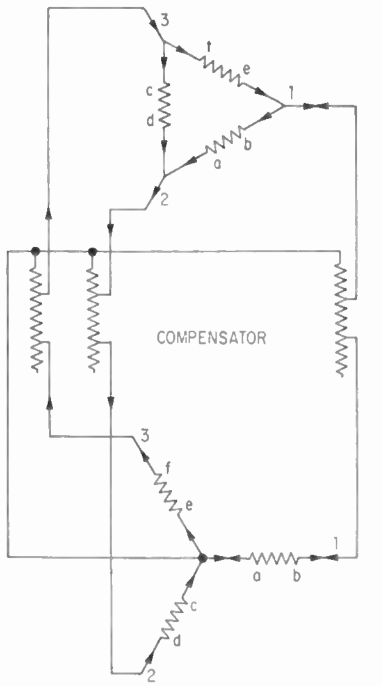
SECONDARY CONNECTIONS
SIMILAR TO THOSE SHOWN
FOR SUBTRACTIVE POLARITY

VECTOR AND WIRING DIAGRAM SHOWING CONNECTIONS FOR DIFFERENTIAL PROTECTION AND SYNCHRONIZING ACROSS A STAR-DELTA TRANSFORMER BANK.

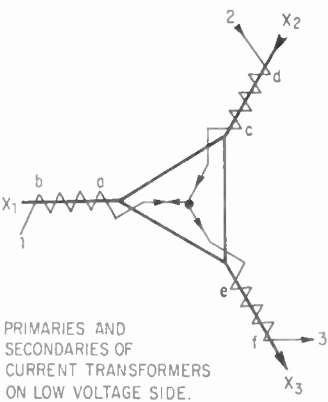


PRIMARIES AND SECONDARIES OF CURRENT TRANSFORMERS ON HIGH VOLTAGE SIDE

PHASE POSITION AND DIRECTION OF CURRENTS IN SECONDARIES ON HIGH VOLTAGE SIDE (8.66 AMPERES)

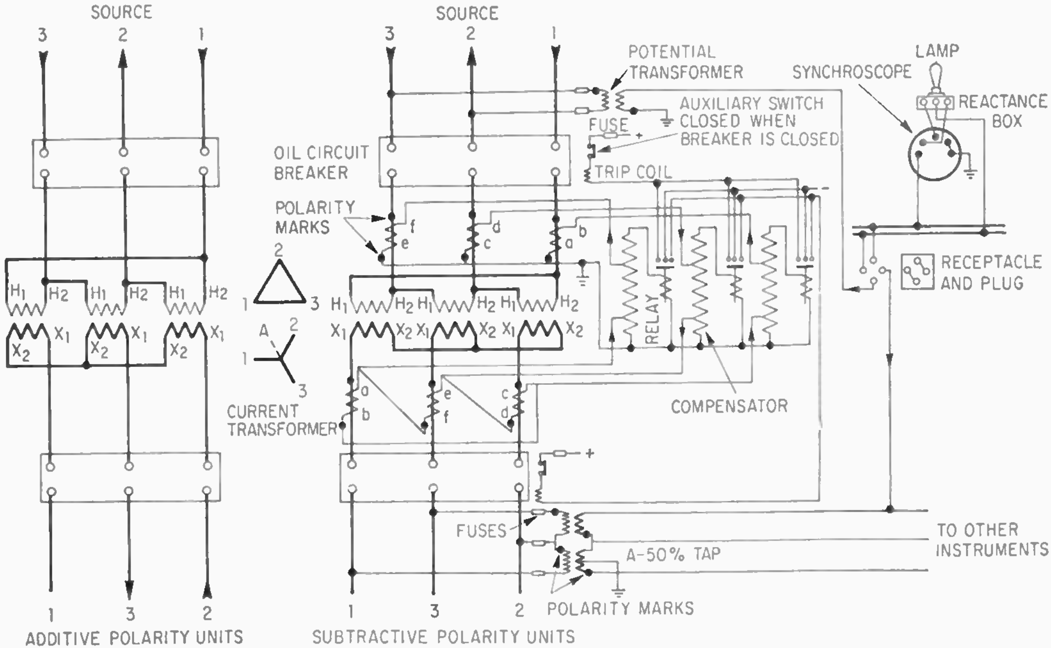


PHASE POSITION AND DIRECTION OF CURRENTS IN SECONDARIES ON LOW VOLTAGE SIDE (5.00 AMPERES)



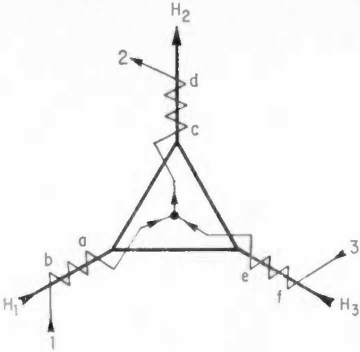
PRIMARIES AND SECONDARIES OF CURRENT TRANSFORMERS ON LOW VOLTAGE SIDE.

VECTOR DIAGRAM REPRESENTING CURRENT RELATIONS AT A GIVEN INSTANT IN CURRENT TRANSFORMERS ARRANGED FOR DIFFERENTIAL PROTECTION WITH POWER TRANSFORMERS CONNECTED IN STAR-DELTA. See opposite page.

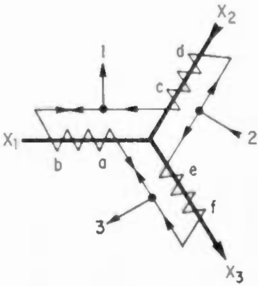


SECONDARY CONNECTIONS SIMILAR TO THOSE SHOWN FOR SUBTRACTIVE POLARITY

VECTOR AND WIRING DIAGRAM SHOWING TYPICAL CONNECTIONS FOR DIFFERENTIAL PROTECTION AND SYNCHRONIZING ACROSS A DELTA-STAR TRANSFORMER BANK.

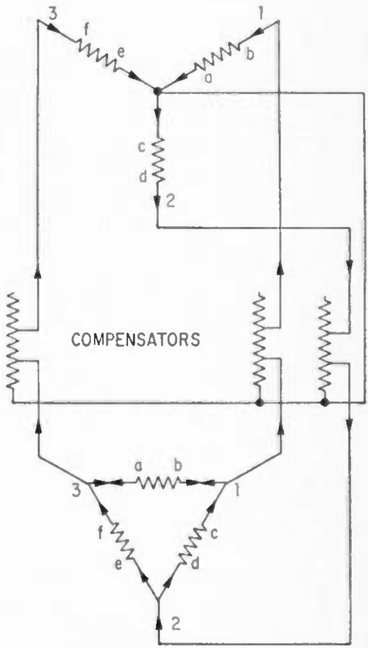


PRIMARIES AND SECONDARIES OF CURRENT TRANSFORMERS ON HIGH VOLTAGE SIDE.



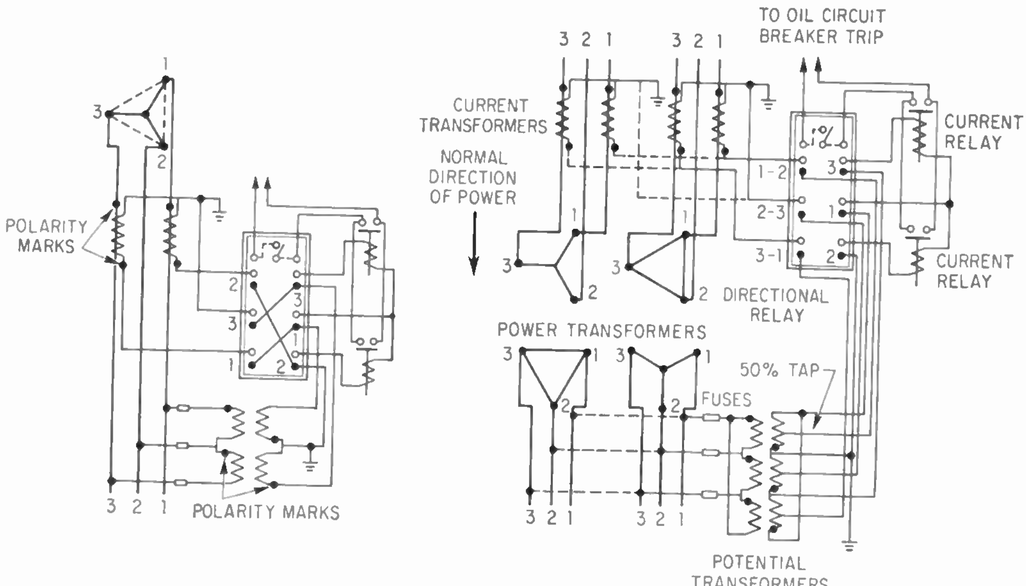
PRIMARIES AND SECONDARIES OF CURRENT TRANSFORMERS ON LOW VOLTAGE SIDE.

PHASE POSITION AND DIRECTION OF CURRENTS IN SECONDARIES ON HIGH VOLTAGE SIDE. (5.00 AMPERES)



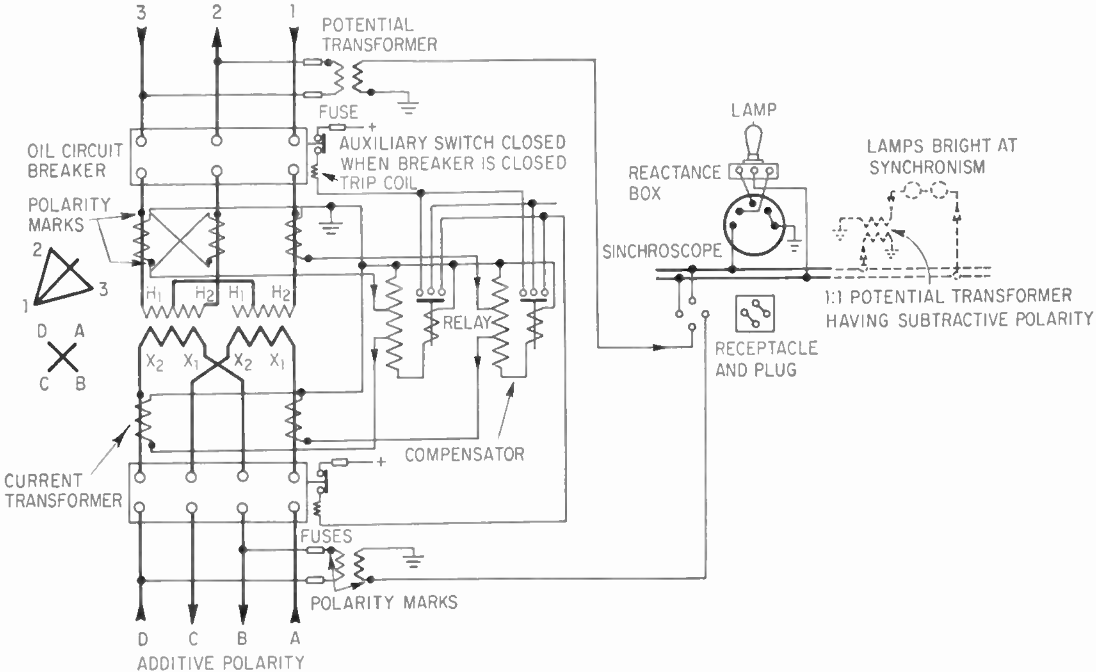
PHASE POSITION AND DIRECTION OF CURRENTS IN SECONDARIES ON LOW VOLTAGE SIDE. (8.66 AMPERES)

VECTOR DIAGRAM REPRESENTING CURRENT RELATIONS AT A GIVEN INSTANT IN CURRENT TRANSFORMERS ARRANGED FOR DIFFERENTIAL PROTECTION WITH POWER TRANSFORMERS CONNECTED IN DELTA-STAR. See opposite page.

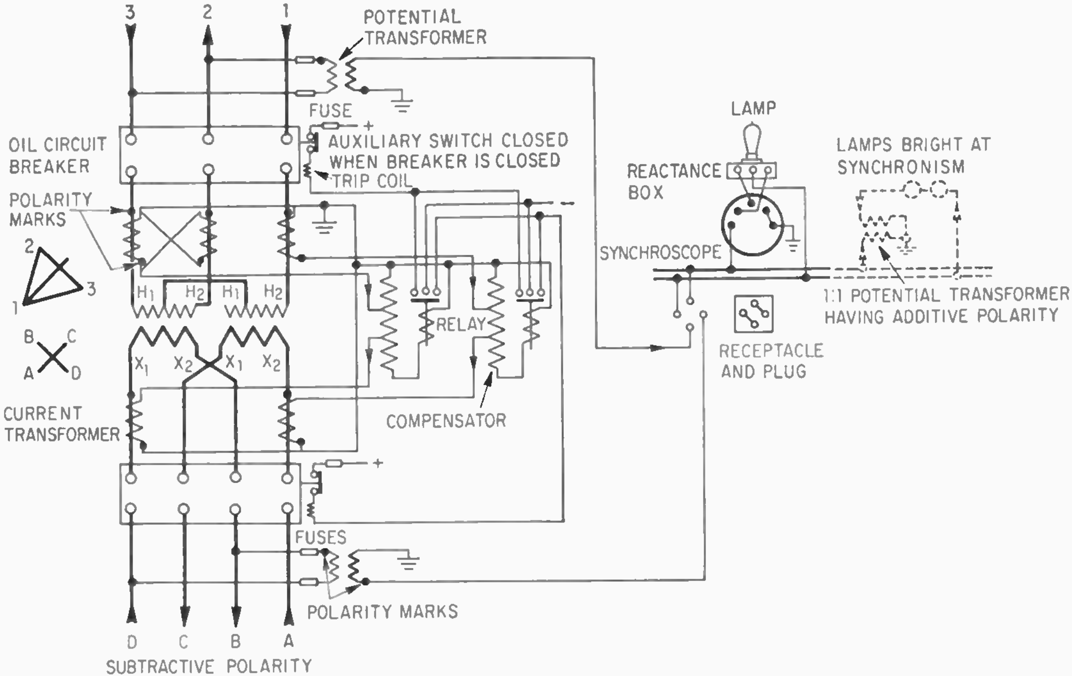


PHASE ROTATION 1-2-3

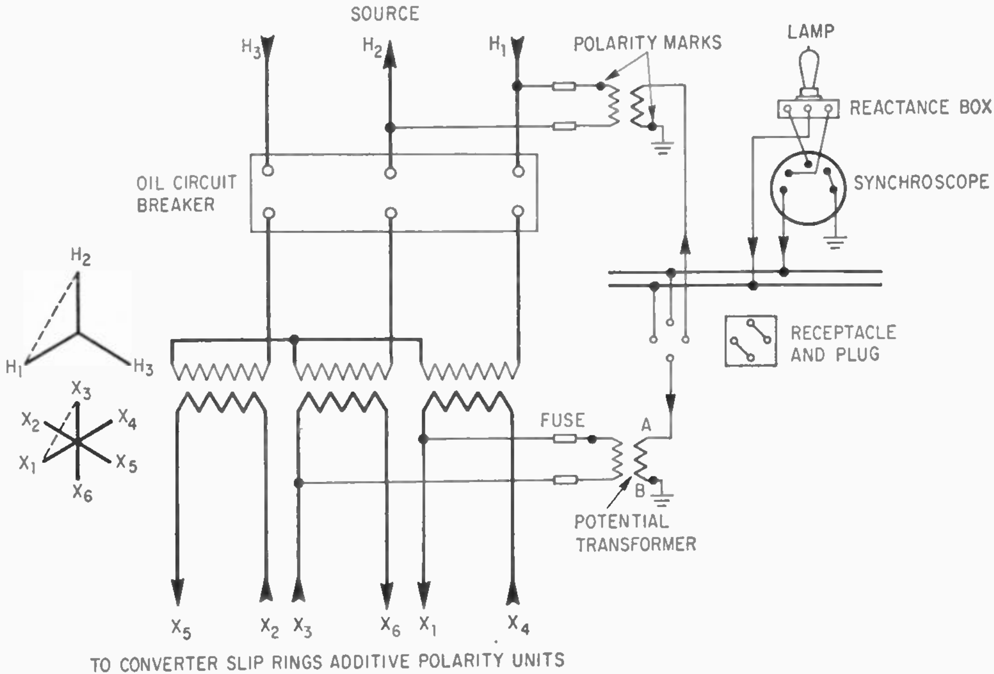
VECTOR AND WIRING DIAGRAM SHOWING LOW DIFFERENTIAL RELAY MAY BE CONNECTED ACROSS A STAR-DELTA OR DELTA-STAR GROUP OF POWER TRANSFORMERS.



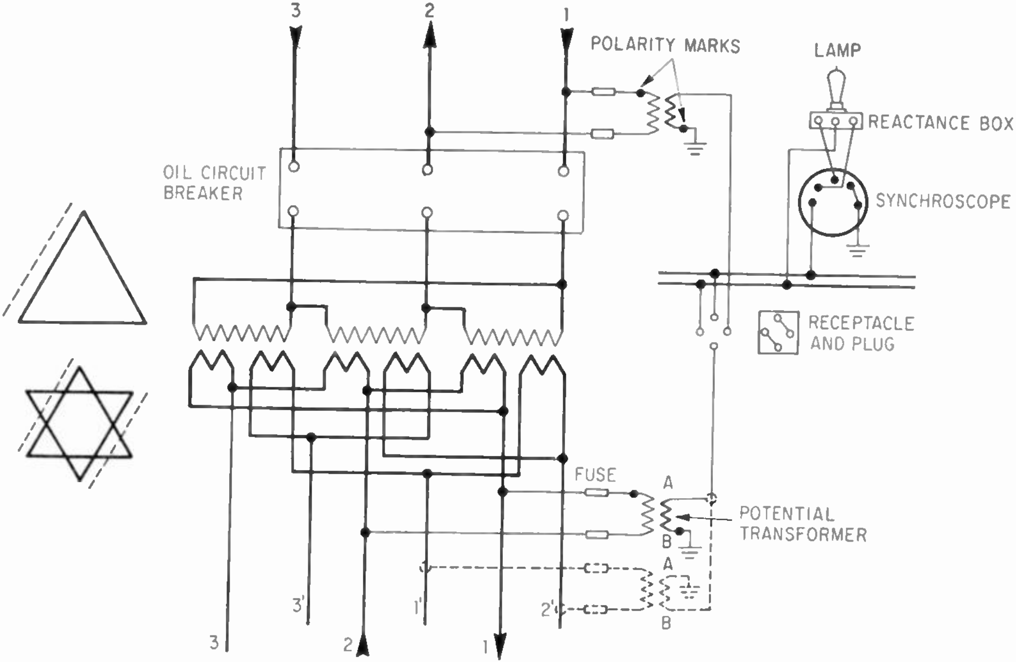
VECTOR AND WIRING DIAGRAM CONNECTIONS FOR DIFFERENTIAL PROTECTION AND SYNCHRONIZING ACROSS A SCOTT-CONNECTED BANK OF ADDITIVE POLARITY TRANSFORMERS.



VECTOR AND WIRING DIAGRAM OF CONNECTIONS FOR DIFFERENTIAL PROTECTION AND SYNCHRONIZING ACROSS A SCOTT-CONNECTED BANK OF SUBTRACTIVE POLARITY TRANSFORMERS.

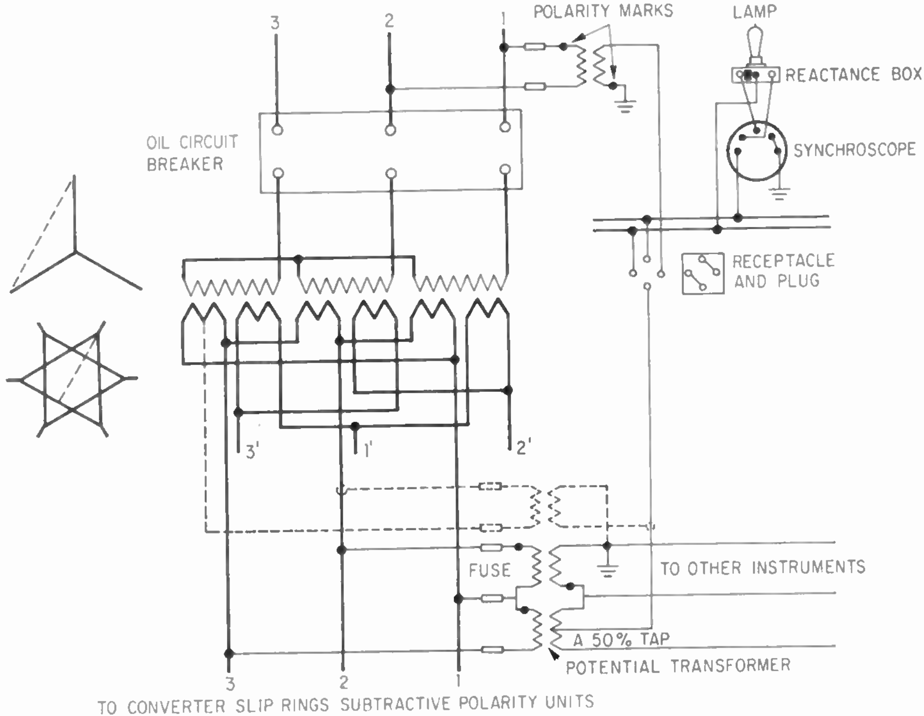


VECTOR AND WIRING DIAGRAM SHOWING SYNCHRONIZING CONNECTIONS ACROSS A STAR-DIAMETRICAL BANK OF TRANSFORMERS CONSISTING OF ADDITIVE POLARITY UNITS.

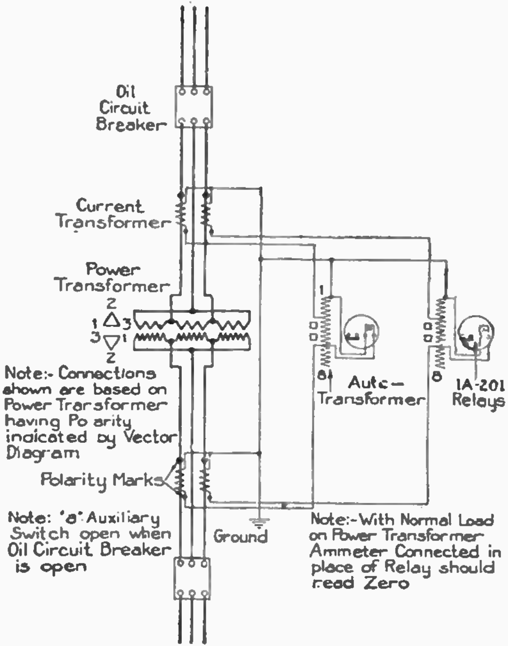


TO CONVERTER SLIP RINGS SUBTRACTIVE POLARITY UNITS

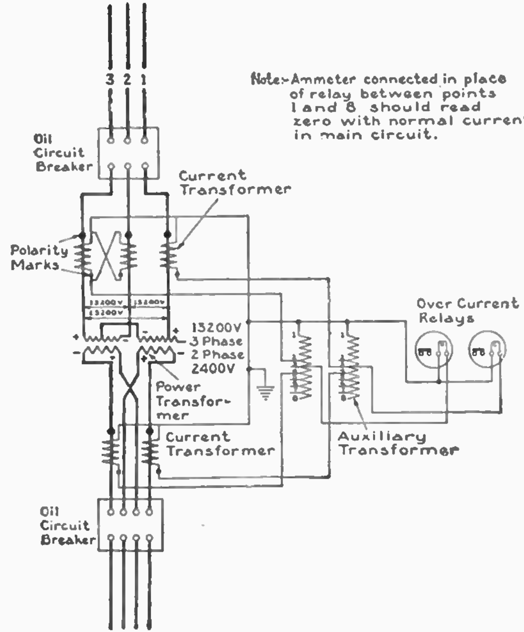
VECTOR AND WIRING DIAGRAM SHOWING SYNCHRONIZING CONNECTIONS ACROSS A DELTA-DOUBLE DELTA BANK OF TRANSFORMERS CONSISTING OF SUBTRACTIVE POLARITY UNITS.



VECTOR AND WIRING DIAGRAM SHOWING SYNCHRONIZING CONNECTIONS ACROSS A STAR-DOUBLE DELTA BANK OF TRANSFORMERS CONSISTING OF SUBTRACTIVE POLARITY UNITS.



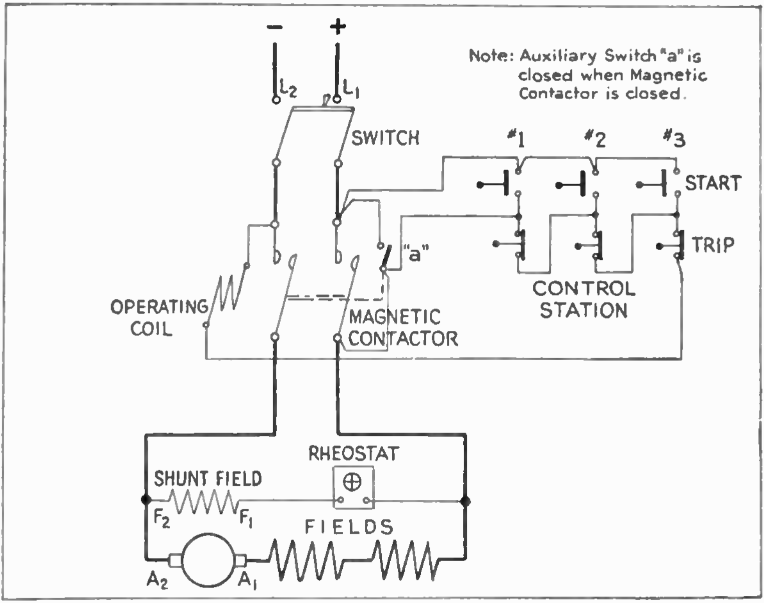
Current-Differential Protection of Power Transformer, Connected Delta-Delta



Current-Differential Protection of Power Transformer, Three-Phase to Two-Phase

INDUSTRIAL CONTROL WIRING OF D.C. MOTORS

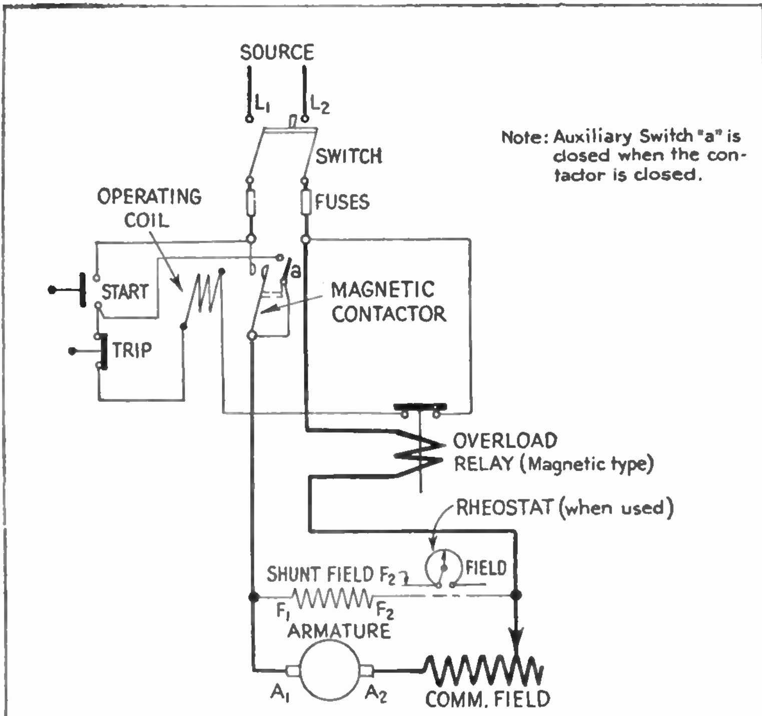
D.C. MOTOR STARTER WITH MAGNETIC CONTACTOR AND THREE CONTROL STATIONS



Motor Control by Means of Magnetic Contactor. The above diagram will facilitate the understanding of the advantage connected with the usage of a magnetic contactor, especially when it is desired to operate the motor from any one of several places, as for example in operation of a conveyor. The line magnetic contactors have a large following for the following reasons: (a) If the motor is to be operated at frequent intervals, less physical effort will be exerted to operate the push button than that required to close a heavy breaker; (b) A number of control stations may be arranged to operate the motor from several locations, thus saving time and providing for a more economical operation, especially since the control wiring consists of small inexpensive wire.

Operation. When the starting button is operated a circuit is formed through the operating coil causing the contactor to close its contact. The magnetic contactor does not open after the finger is removed from the starting button, because a new circuit is accomplished through auxiliary switch "A" by means of which the operating coil is energized. To stop the motor the trip button is operated. This action de-energizes the operating coil causing the contactor to open and disconnects the motor from its source.

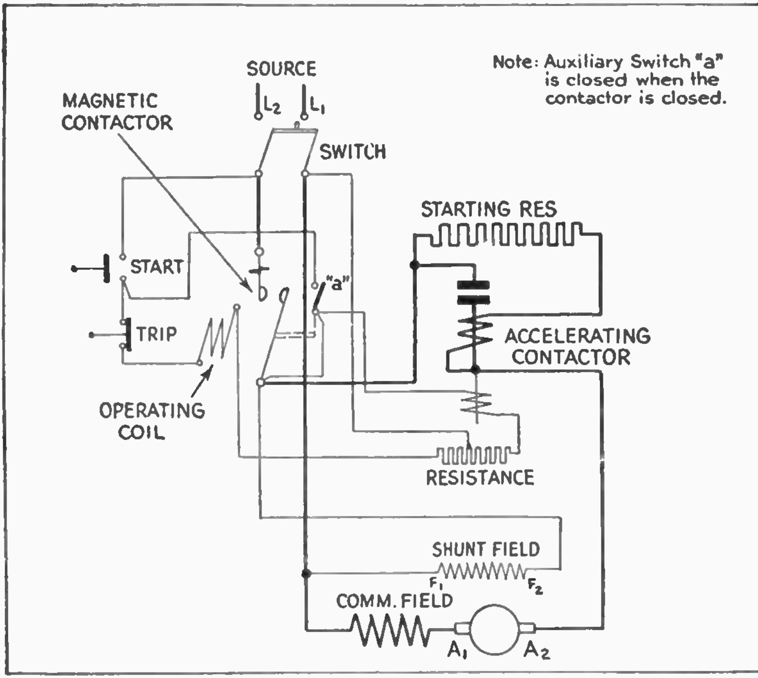
D.C. MOTOR STARTER WITH MAGNETIC CONTACTOR AND OVERLOAD RELAY



Operation. When the starting button is operated a circuit is formed through the operating coil causing the contactor to close its contact. The magnetic contactor does not open after the finger is removed from the starting button, because a new circuit is accomplished through auxiliary switch "A" by means of which the operating coil is energized.

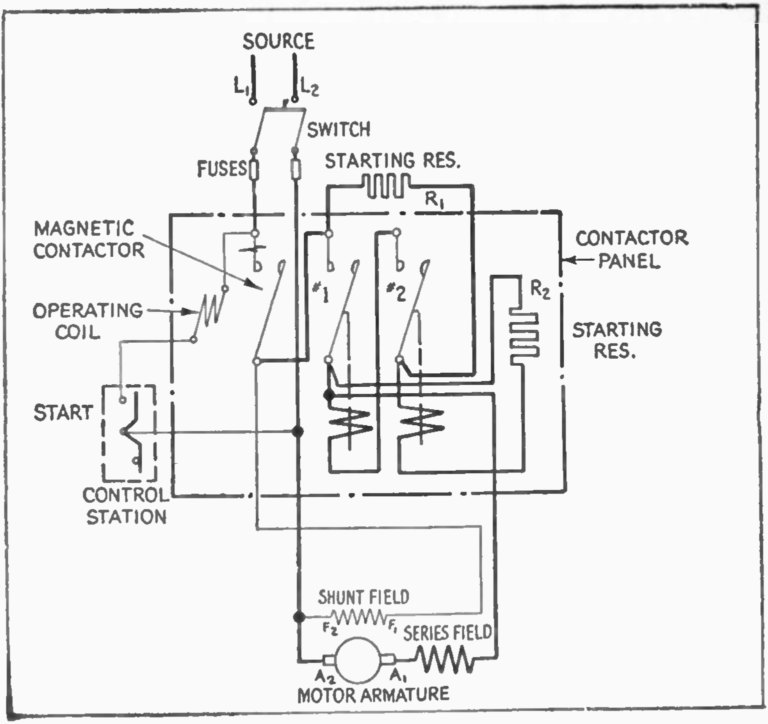
To stop the motor the trip button is operated. This action de-energizes the operating coil causing the contactor to open and disconnects the motor from its source. The overload relay is set to operate at a certain overload depending upon the particular operating conditions but should in no case be caused to operate on the motor starting current.

D.C. COUNTER E.M.F. STARTER WITH TWO CONTACTORS



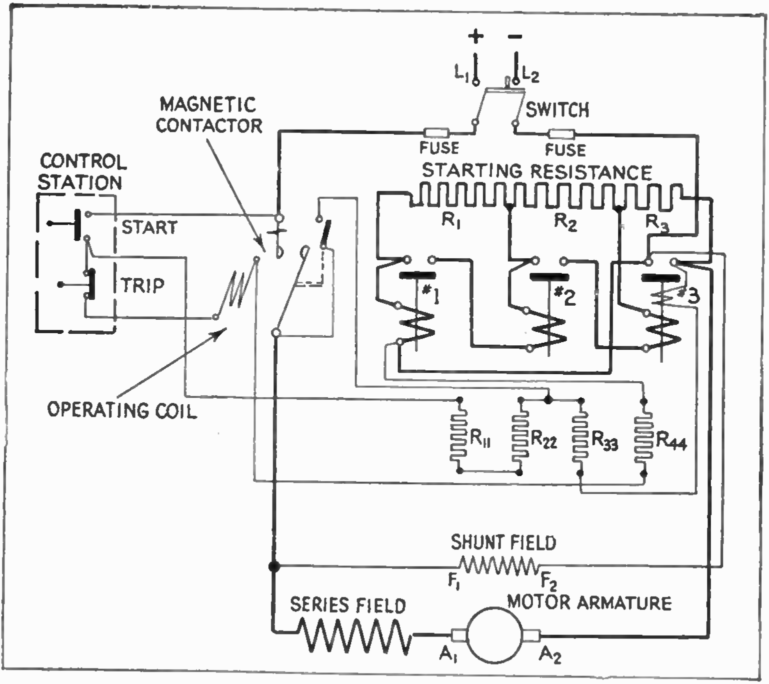
Operation. With reference to the diagram, this starter functions as follows When the starting button is pressed the operating coil is energized through a resistance closing the magnetic contactor. After the finger has been removed from the starting button the lower section of the accelerating contactor is placed in series with the magnetic contactor operating coil. This reduces the power required to hold the magnetic contactor closed and the magnetizing action of the lower accelerating contactor coil aids the upper section of the coil closing this contactor when the armature voltage has reached a predetermined value. The motor is disconnected from its course by means of operation of the trip button which de-energizes the operating coil causing the magnetic contactor to open

D.C. MOTOR STARTER WITH SERIES LOCKOUT CONTACTORS



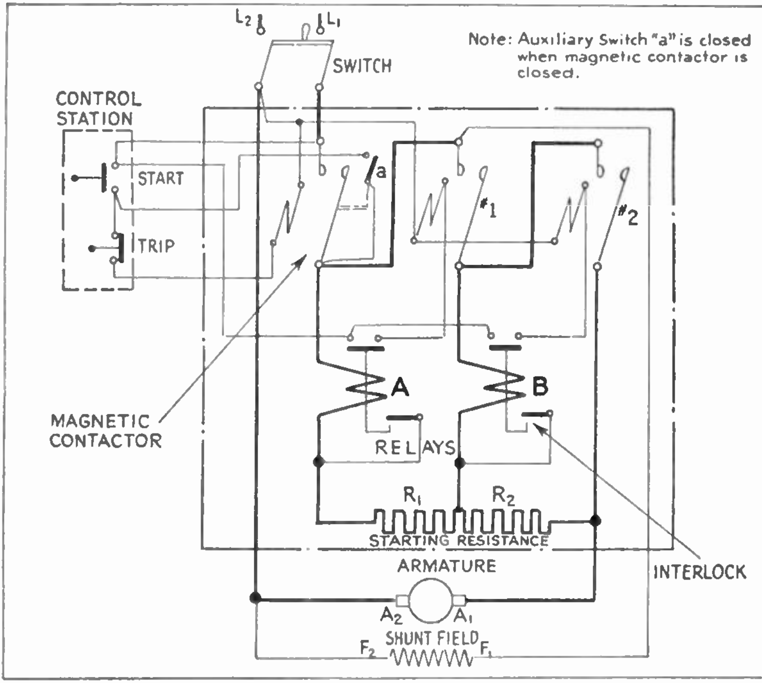
Operation. Closing the starting button the magnetic contactor closes, connecting the motor to the line through all the series resistances. Contactor #2 closes its contacts as soon as the current has reached the value at which the contactor is set to operate. This shunts out R_2 and cuts in coil of contactor #1 in the circuit. As the accelerating process of the motor continues the current decreases and contactor #1 closes connecting the motor directly across the line.

D.C. MOTOR STARTING BY MEANS OF SERIES CONTACTORS



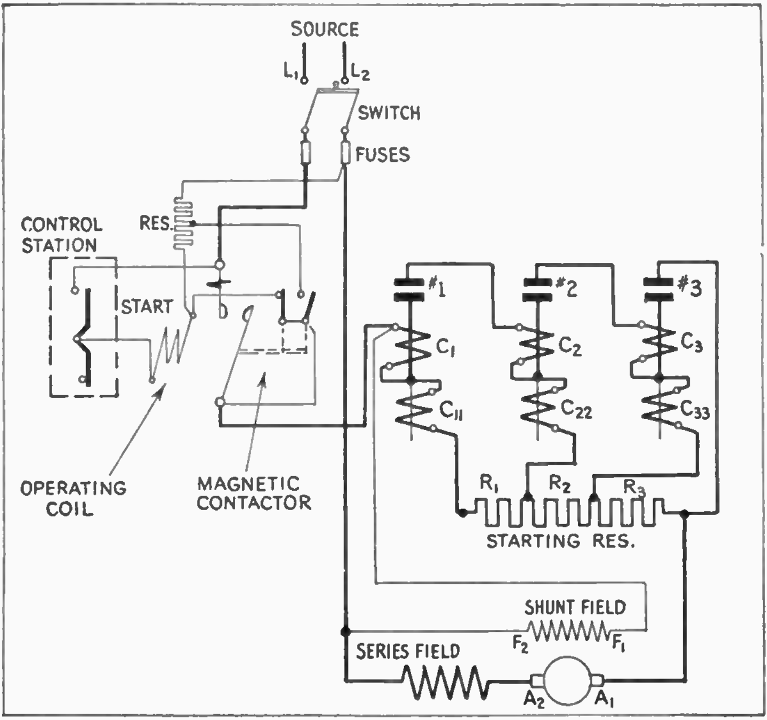
Operation. After the magnetic switch is closed and the starting button is released, R_{11} and R_{22} is connected in series with the closing coil. At the closing of the magnetic contactor, the shunt field is connected directly across the line and current passes from L_1 through the series field, armature, the whole starting resistance and the coil of contactor #1 to L_2. Contactor #1 will close when the current reaches a value corresponding to its setting. With the closing of this contactor R_1 is shunted out and the current flows through the series field, armature, R_3, R_2 and the coils of contactors #2 and #1 to L_2. The decrease in current due to the closing of contactor will cause contactor #2 to be locked out. Contactor #2 closes as soon as the current has reached a value to which it is set. This action again shunts out R_2 and coil of contactor #3 is brought into the circuit. Contactor #3 closes when its current setting has been reached, shunting out R_3, finally connecting the motor across its supply source. In this starting method, contactors #1 and #2 drop out while contactor #3 is held closed by the holding coil shown at the top of the contactor.

D.C. MOTOR STARTER EMPLOYING SERIES RELAYS



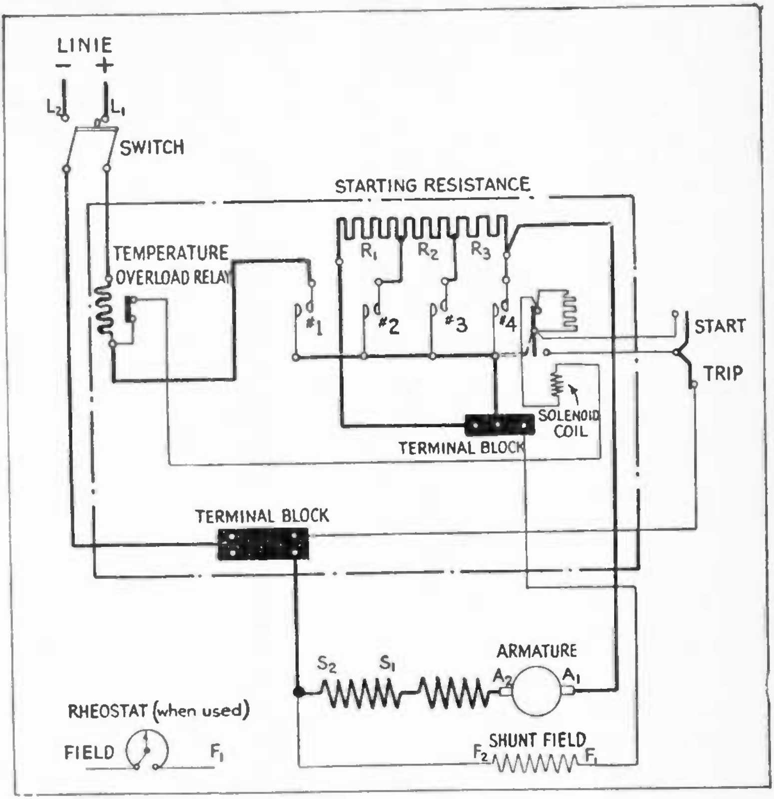
Operation. In this method of motor starting, an interlock type of relay is provided for each step of starting resistance. The relay contacts are normally held closed by gravity, although the magnetic force produced by the coil holds it open until the current has reached a set value. The starting method is as follows: The magnetic switch is closed in the usual manner causing the current to flow from L_1 through relay coil A, resistances R_1, R_2, motor armature to L_2. When the starting current reaches the value for which relay A is set, its contacts closes, which in turn causes contactor #1 to close. This action shunts out relay A and R_1 and provides a path for the current through R_2, relay coil B, and contactor #1. This operation is repeated until all the contactors are closed at which time the relay coils are shunted out and the motor is connected directly across the line.

D.C. STARTER WITH CURRENT LIMITING CONTACTORS



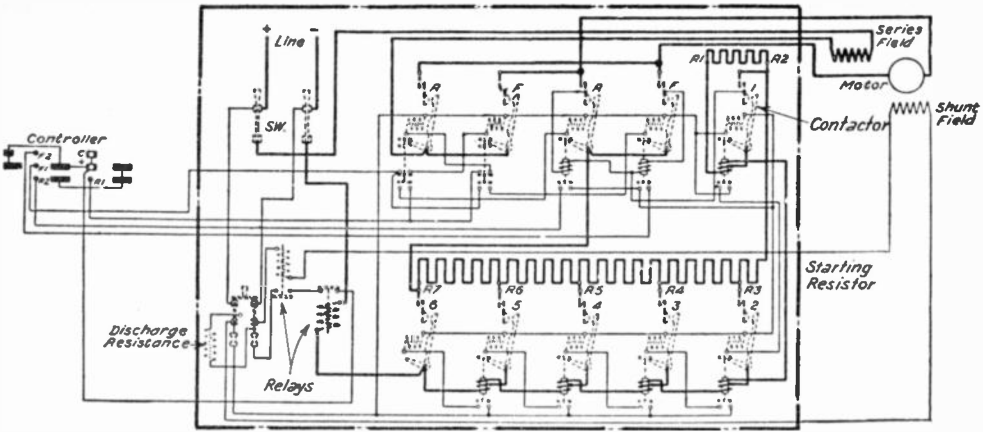
Operation. When the starting button is closed energizing the operating coil the magnetic contactor closes. The starting current flows from L_2 through the series field, armature, starting resistance, contactor coils C_1 and C_{11} to L_1. The shunt field is connected directly across the line. After the current through contactor #1 has reached the contactors setting value, this contactor closes its contact, shunting out coils C_1, C_{11} and R_1. This operation provides a current path through C_{22}, C_2 via contactor #1 and its coil C_1. After the current through contactor #2 has reached the contactors setting value, this contactor closes, and so the process is repeated until all the contactors are being closed, at which time the motor is connected directly across the line.

D.C. COMPOUND-WOUND MOTOR WITH SERIES RESISTANCE STARTER



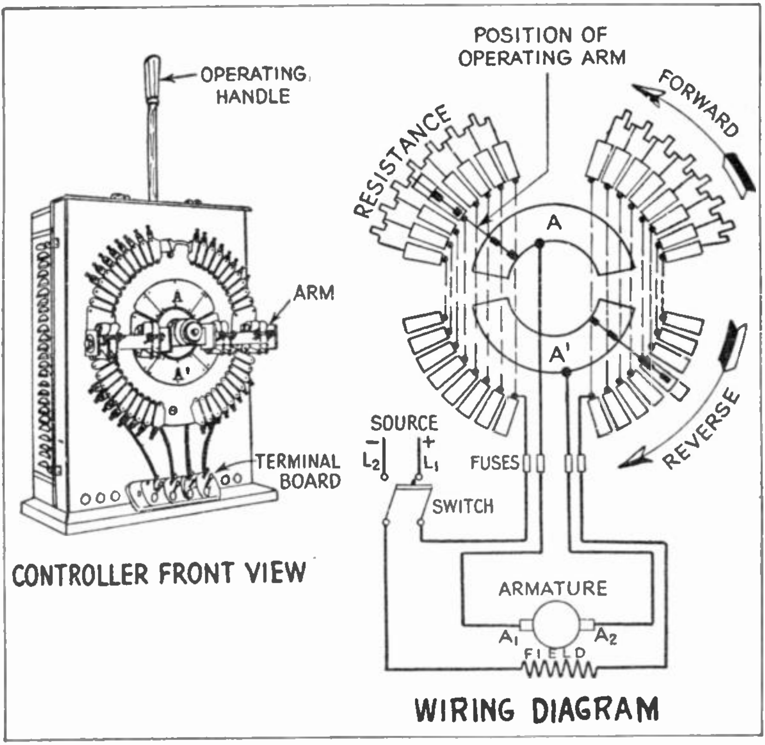
Operation. When the starting button is pressed, contactor #1 closes, connecting the entire starting resistance in series with the motor. After a predetermined interval of time, contactor #2 is engaged shunting out resistance R_1 In a similar mcnner each one of the contactors will serve to cut out the resistance preceding it until the entire resistance has been shunted out and the motor is connected across the line at normal voltage. The overload relay serves to protect the motor against over-current and may be set to operate to suit individual operating conditions. When the over-current exceeds the setting value of the relay the relay contacts opens, de-energizing the solenoid coil which trips the contactors, disconnecting the motor from its supply source.

D.C. COMPOUND-WOUND MOTOR CONTROL FOR STEEL MILL, MAIN ROLL DRIVE



Operation. Direct current motors for motor-driven reversing mills, are used only on low voltage circuits usually not exceeding 250 volts, consequently remote control is easily secured and contactors can be used with entire satisfaction for closing, opening and reversing the armature circuit and for cutting out resistance. In addition to the disconnecting switches shown, a combined shunt field and control switch is supplied which renders it impossible to open the shunt field without at the same time disconnecting the armature from the line. An overload relay and shunt field relay afford protection respectively in case of overloads or accidental opening of the shunt field. Current limit relays insure uniform acceleration, while no-voltage protection is secured automatically since the contactors are actuated by line potential.

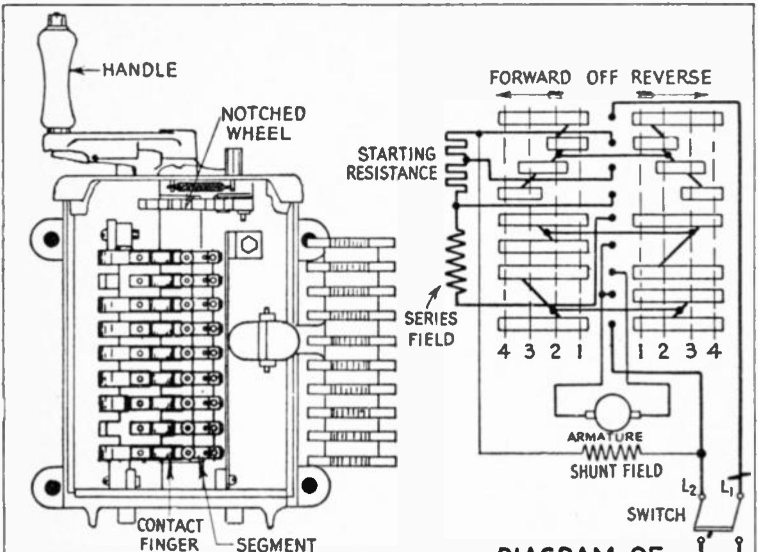
WIRING DIAGRAM AND FRONT VIEW OF TYPICAL FACE PLATE CONTROLLER



Operation. As shown in the illustrations the segments are installed in a circle on the face of the controller. Connections from these segments to the collector plates (designated A and A_1) are established by means of two arms which by a movement in either direction changes the resistance in the circuit to be operated, as indicated in the wiring diagram. Thus when the handle is moved in a **forward direction** sections of the starting resistance are cut out in steps, causing the armature to increase its speed.

When on the other hand the arm is moved in a **reversed direction,** the current becomes reversed in the armature (only) which causes the motor to rotate in the opposite direction. Finally when the arm is in the **off position,** the arm rests on two insulating plates in which case the operating handle is the vertical position.

WIRING DIAGRAM AND INSIDE VIEW OF TYPICAL DRUM CONTROLLER

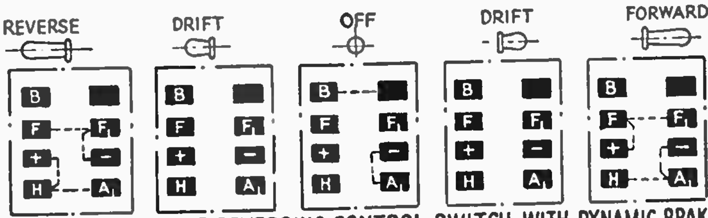


INSIDE VIEW OF DRUM CONTROLLER

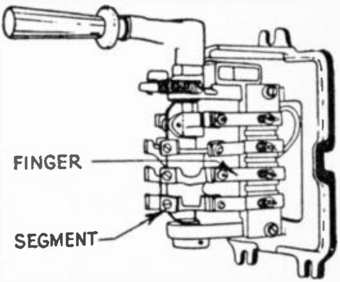
DIAGRAM OF CONNECTIONS

Operation of Controller. The drum controller consists generally of a drum cylinder insulated from its central shaft to which the operating handle is attached. To facilitate the operation, copper segments are attached to the drum. These segments are connected to and insulated from one another as shown in the diagram of connections. A series of stationary fingers are arranged to contact with the segments. These fingers are insulated from one another but interconnected to the starting resistance and the motor circuit. The drum assembly has a notched wheel keyed to the central shaft, the function of which is to indicate to the operator when complete contacts are made. With reference to the diagram, when the controller is moved forward one notch, the fingers are in position 1. The current then flows from L_1 through all the series resistance to L_2, and the motor starts rotating. When the handle is moved further the resistance is gradually being cut out of the armature circuit and inserted in the field circuit. Finally, when the handle is turned to notch 4, all the resistance has been transferred from the armature to the field circuit, and the motor is running at full speed.

REVERSING CONTROLLER FOR D.C. MOTOR

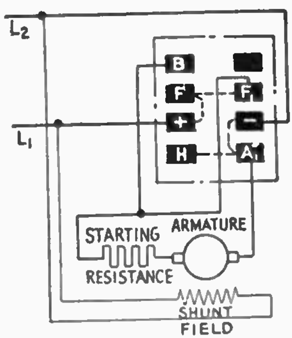


VARIOUS POSITION OF REVERSING CONTROL SWITCH WITH DYNAMIC BRAKE



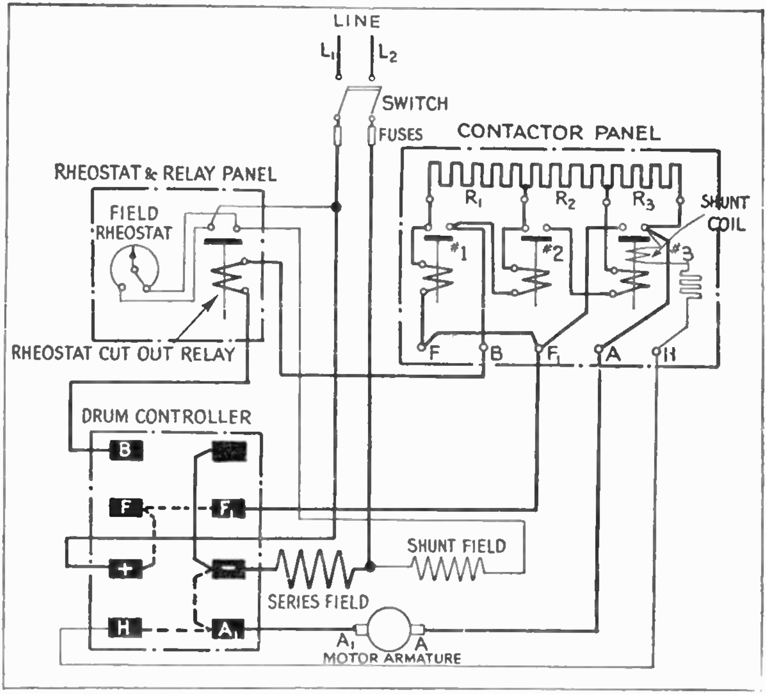
REVERSING CONTROL SWITCH WITH DYNAMIC BRAKE

Operation. In some industrial processes a combination of dynamic breaking and reversing is required. A common type of switch for this requirement is shown, together with a sequence in which the contacts are made. With reference to diagrams, L_1 and L_2 are connected to the positive and negative terminals. When the handle is in the **reverse** position, H and A_1 are positive, while F and F_1 are **negative.** If the handle be turned to **forward** position F, F_1 and H, A_1 exchange polarities. Suppose that the motor armature be connected between A_1 and F_1, the current through it and hence the direction of rotation will be reversed as the handle is turned from reverse to forward. Therefore this switch is fundamentally a reversing switch and may hence be utilized in connection with any starter.



WIRING DIAGRAM

WIRING DIAGRAM OF REVERSING AND DYNAMIC BREAKING CONTROLLER FOR D.C. MOTOR



Operation. As indicated in the diagram the shunt field is connected directly across the line through the rheostat when the switch is in a closed position. With reference to the diagram of the drum controller wiring, with the main switch in the **forward** position the line circuit is from L_1 to F_1, through all the starting resistance, motor armature to the negative terminal and L_2. Contractors #1, #2 and #3 close their contacts in sequence as the armature current decreases, which connects the motor directly across its supply source.

Dynamic Breaking. This is effected by turning the handle of the control switch from the **forward** to the **off** position. Segments in the control switch connects A_1 and B together, placing sections R_2 and R_3 of the starting resistance across the armature. This circuit provides dynamic breaking action causing the motor to slow down rapidly. As the motor slows down the generation voltage diminishes and the current through the resistance decreases as a consequence, tending to reduce the breaking torque.

INDUSTRIAL CONTROL WIRING OF A.C. MOTORS

MOTOR CONTROL METHODS

The Functions of Motor Control. The elementary functions of any motor control are **starting, stopping** and **reversing** the motor. These functions however, are only a few of the many contributions which the control renders to efficient operation of modern electric drives. Among the common functions of motor control required in motor installations are:

1. **Motor Starting.** This includes the basic function of starting and stopping the motor, including protection from overload and under-voltage when required
2. **Motor Starting and Reversing.** This includes the basic function of starting the motor where the direction of rotation of the motor is changed at will of the operator.
3. **Motor Starting and Speed Regulation.** Basic function of starting and stopping the motor involving speed regulation or adjustment of motor speed as by rheostat control.
4. **Motor Starting Reversing and Speed Regulation.** Basic function of starting, stopping or reversing the motor involving speed regulation as by rheostat control.
5. **Motor Starting and Speed Selection.** Basic functions of starting and stopping the motor, involving selection of one of several basic speeds as by pole changing.
6. **Motor Starting, Reversing and Speed Selection.** Basic functions of starting, stopping and reversing, including selection of one of several basic speeds.

With respect to the general construction and method of starting and control required in motor installations as:

7. **Across the Line Starter.** This consists of a line switch (with protection as may be required) for connecting the motor directly across the supply line. This method of starting is also referred to as "full voltage starting".
8. **Starting Rheostat.** Also referred to as the **face-panel** type. This is a type of rheostat whose stationary contacts are mounted upon the face of an insulating panel whose surface is a plane, the contacts being arranged in the form of an arc (or arcs) of a circle and the moveable contact (or contacts) being mounted upon a pivoted switch arm (or arms).
9. **Primary Resistor Starter.** A starter which provides reduced voltage to the primary of the motor by inserting resistance in the primary circuit during acceleration. The device includes the necessary switching mechanism, which may be manually or magnetically operated.
10. **Secondary Resistor Starter.** A starter which reduces the primary starting current by inserting resistance in the secondary circuit usually the rotor of a wound rotor motor during acceleration. The device includes the

necessary switching mechanism, which may be manually or magnetically operated.

11. **Compensator or Autotransformer Starter.** A starter which provides for reduced voltage starting by means of a compensator or auto-transformer from which a predetermined fractional part of the winding is tapped off to produce voltage reduction to suit the particular starting load. The device includes the necessary switching mechanism to switch from the tap to full voltage and also to open the circuit of the compensator winding.

12. **Star-Delta Starter.** A star-delta starter is one which is applicable for starting of motors which have their windings arranged for full rated operation, with windings connected in delta, and arranged for starting at reduced voltage with windings connected in star.

13. **Magnetic Controller.** One wherein the main circuits are made and broken by magnetically operated switches controlled by a master switch located either within the controller or at any desired distance from the main controller.

With respect to the operation of the control circuit, magnetic controllers may be sub-divided as follows:

14. **Non-Automatic.** Where the operator is responsible for all control functions of starting, stopping and accelerating the motor.

15. **Semi-Automatic.** Where the rate of acceleration after starting by the operator, is dependent upon accelerating contactors, which are adjusted to function under pre-determined conditions of currents, voltages and time.

16. **Full-Automatic.** Where all basic functions including starting or stopping of the motor, are performed without the necessity of manual direction in any degree after being initially energized.

With respect to their type for operating magnetic controllers, the sub-classification of master switches may be made as follows:

17. **Drum Switch.** In general for non-automatic types of controllers.

18. **Push Button.** In general for semi-automatic types of controllers.

19. **Automatic Switch.** Operated by float, pressure, etc., for full automatic controllers.

20. **Emergency Run Feature.** Provides a means for temporarily rendering the overload device inoperative during an emergency.

With respect to the proximity of the master switch, magnetic controllers may be sub-classified as follows:

21. **Distant Motor Control.** Where the master switch is mounted apart from the main control panel.

MOTOR CONTROL METHODS

22. **Local Motor Control.** Where the master switch may be combined with the main control panel.

The service classification of control resistors with reference to the duty period are:

23. **Continuous Rating.** Where the load is required to be carried for an unlimited period.

24. **Periodic Rating.** Where the load can be carried for alternate periods of load and rest.

25. **Standard Periodic Rating.** Where the starting and intermittent duty may be standardized as light, heavy, or extra heavy starting, or intermittent duty classifications.

The kind of protection to be provided where required may be termed as:

26. **Low or Under-Voltage Protection.** Operates to cause and maintain the interruption of the main power or reduction or failure of voltage.

27. **Low or Under-Voltage Release.** Operates to cause the interruption of power upon reduction or failure of voltage, but not to maintain the interruption of power upon return of voltage.

28. **Overload Protection.** Operates to protect against escessive current to cause and maintain the interruption of current not in excess of six times the rated motor current.

29. **Short-circuit Protection.** Where the overload protection does not provide for short-circuit protection such short-circuit protection shall be provided as by fuses.

30. **Single-Phase Protection or Indication.** Where required, shall indicate and protect the personnel and equipment upon the failure of any part of the circuit which would cause an open phase.

MOTOR PROTECTIVE DEVICES

The function of motor protective devices are to protect the motor against certain abnormal conditions, such as:

1. Overloads.
2. Short-circuits.
3. Under-voltage, etc.

This includes devices which functions on the basis of temperature, voltage, frequency or time and causes the switching mechanism to operate when a predetermined set of conditions exist.

Overload Relays. These devices are of two general types, namely:

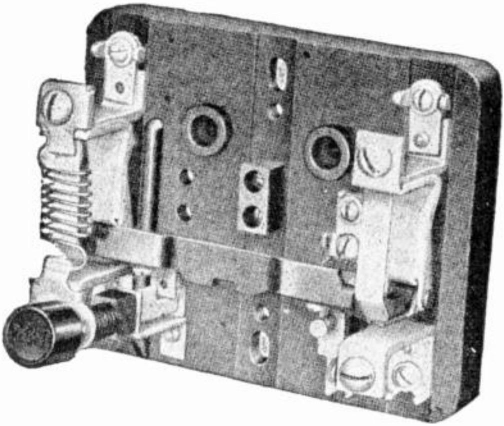
1. Thermal overload relay, and
2. Dash-pot overload relay.

Thermal and dash-pot overload relays are again divided into two types as:

1. Hand reset, and
2. Automatic reset.

As the name denotes, hand reset relays must be reset by hand after having tripped (usually by pressing a button projecting through the enclosing case) whereas the automatic reset type resets themselves automatically.

Thermal Overload Relay. The thermal overload relay consists of a heater coil which is connected directly to the line of the motor, and which heats up directly in the proportion of current flowing through it. Mounted adjacent to the heater is a strip of thermostatic metal anchored at one end, the other end being free to move. As the thermostatic metal is made up of two metals rolled together (each metal having a different expansion constant) the thermostatic strip will bend or warp when heated.



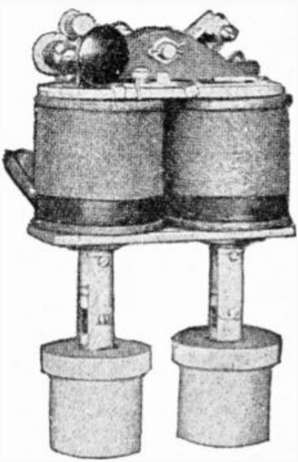
Illustrating a Two-Pole Temperature Overload Relay with Detachable Heater and Thermal Unit. NOTE: Heater removed from right hand unit to show thermostatic metal strip. (Courtesy General Electric Co.)

Because one end is solidly anchored, all of the movement occurs at the free end. When the metal is cold, its end position prevents a trigger (on which control circuit contacts are mounted) from tripping.

A relay of this type is quite accurate and its operating characteristics is well defined. It is possible to design a heater that will raise the temperature of the thermostatic strip at the same rate as the temperature in the motor with which it is being used, and so adjust the relay that it will trip the control contacts when the temperature of the motor has reached the allowable maximum.

Because some time is required to transmit the heat from the heater coil to the thermostatic strip, it is not affected by monentary current increases. This makes it possible to start the motor with an inrush of six to ten times normal current without tripping the relay.

Dash-pot Overload Relay. The dash-pot overload relay uses the mechanical retardation principle of a dashpot to retard the movement of a core in a magnetic field, produced by a solenoid coil in series with the motor leads. Such an arrangement is affected by the quality of the mechanical clearance between piston and cylinder wall, changes in viscosity of the dash-pot oil caused by temperature variations and other extraneous conditions tending to upset its accuracy.



Illustrating Typical Dash-Pot, Two-Element Magnetic Type Overload Relay with Oil Dash-Pots to Give Inverse Time Tripping Characteristics. (Courtesy General Electric Co.)

It is mainly because of its inaccuracy that this relay is at present being replaced by relays operating on the thermal principle.

MOTOR CONTROL METHODS

Under-Voltage Protection. Under-voltage or low-voltage protection as it is sometimes called is defined as: **The effect of a device operative on the reduction or failure of voltage, to cause and maintain the interruption of power to the main circuit.**

With reference to the diagram page 206, under-voltage protection is provided for in the following manner: Contactor **M**, handles the motor circuit. It contains a normally open contactor holding interlock **B**, which closes when the contactor is closed.

The two-button, push-button station consists of a normally open **start** contact **C** and a normally closed **stop** contact **D**. When contact is made momentarily at **C**, by pressing the start button, the contactor coil **M**, is energized and contactor **M** closes, which in turn closes the interlock circuit **B**. It will be noted that the interlock **B** parallels the start contact **C**. The contactor is, therefore, held in through the interlock circuit **B**, even after the start contact **C**, opens up when the finger is removed from the button.

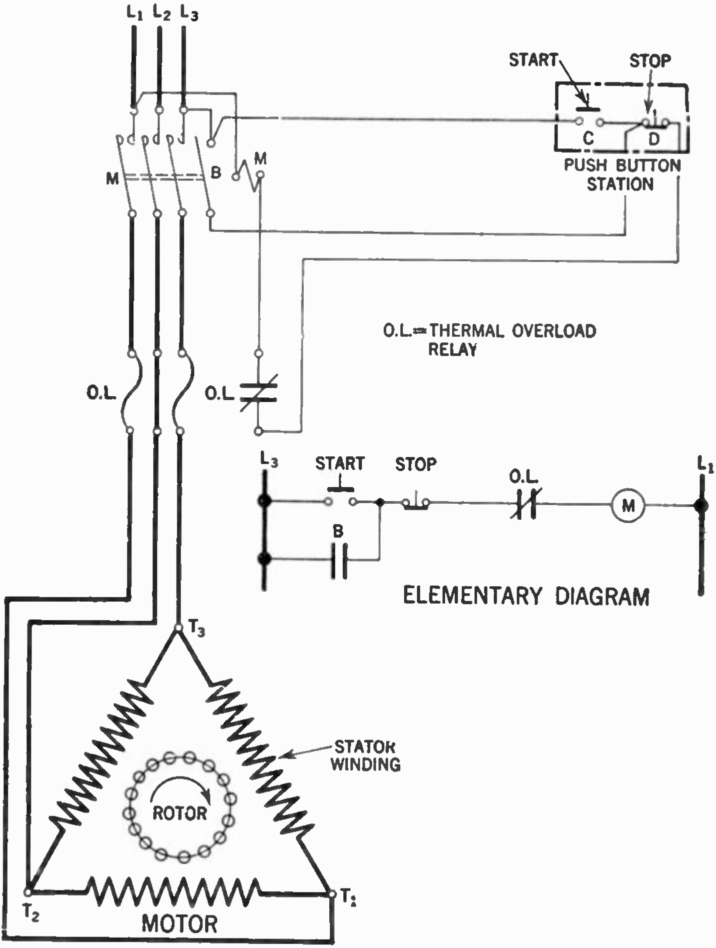
In the case of voltage failure, coil **M**, is de-energized and contactor **M** opens which in turn opens interlock circuit **B**. When voltage returns, the contactor will not close until the circuit is again established at **C**, by pushing the start button.

Under-Voltage Release. Under-voltage or low-voltage release is defined as: **The effect of a device operative on reduction or failure of voltage to cause the interruption of power to the main circuit, but not to prevent re-establishment of the main circuit on return of voltage.**

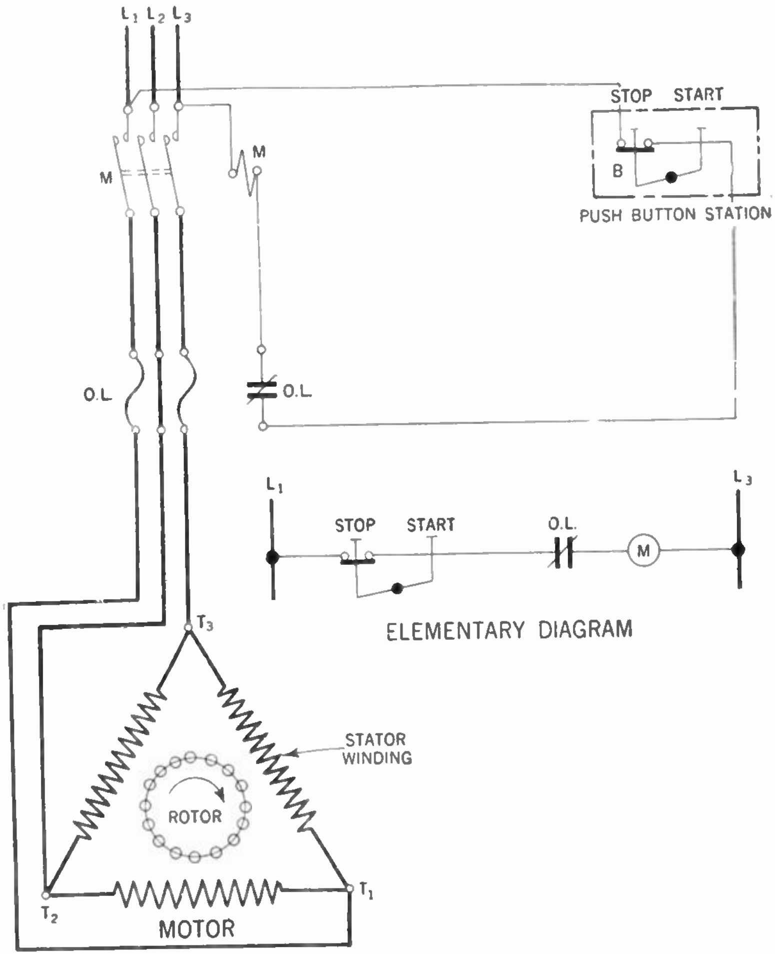
With reference to the diagram page 207, under-voltage release is provided for in the following manner: The control consists of a contactor **M**, for handling the motor circuit, and a maintained contact control switch **B**. Switch **B**, can be a knife switch, a float switch, a pressure switch or a maintained contact push-button station whose contacts close and remain closed regardless of the voltage on them.

To start the motor, the control switch **B**, is closed. This energizes the contactor coil **M**; the contactor **M**, closes and the motor is connected to the line. Now if voltage fails, the coil **M**, is de-energized and contactor **M**, opens. Nothing happens to contact **B**, as a result of the failure.

When this type of control is used on certain machines, such as saws, millers, etc. there is always danger if an operator returns to his machine and attempts to remove the saw or milling head, not realizing that the machine has stopped because of the momentary voltage failure. By providing under-voltage protection this hazard is eliminated, because the motor cannot restart when the power returns after a voltage failure, until the operator presses the start button.



Fundamental Wiring Diagram of Under-Voltage Protection as Employed on a Manually Operated Squirrel-Cage Induction Motor. It should be noted that any combination of control sequence for under-voltage protection can be obtained by applying these two fundamental rules: (1) Wire all stop buttons in series with the holding coil, with each other and with the electrical interlock. (2) Wire all start buttons in parallel with each other and with the interlock.



Fundamental Wiring Diagram Showing Method of Wiring to Obtain Under-Voltage Release. Under-voltage release allows the control to drop out if for any reason the power source voltage is inadequate, but when the voltage again reaches sufficient value the control will function automatically to connect the apparatus to the line through the proper starting sequence.

MOTOR CONTROL METHODS

Control Methods of Squirrel Cage Motors. Polyphase induction motors of the squirrel cage type may be started and controlled by several methods. They are:

1. Directly across the line.
2. By means of autotransformers.
3. By means of resistors or reactors in series with the stator winding.
4. By means of the star-delta method.

Starting Current-Torque Relationship. Before discussing the various methods which are available for reducing starting current and improving line-voltage conditions, it is important to have a thorough knowledge of the effects of reduced voltage starting on the motor, as well as on the power system.

Any method which reduces the starting current to the motor is accomplished by a reduction in starting torque. Therefore, it is essential to know something about the load torque characteristics in determining if a given current limitation can be met. In other words, there are boundary conditions in which the permissible current to be taken from the line would not provide the needed output torque at the motor shaft, necessary for the successful acceleration of its connected load. With all starting methods, the torque of a squirrel cage motor varies as the square of the applied voltage at the motor terminals.

Across the Line Method of Starting. This is generally the most economical method of starting, but is on account of the large starting current required, usually limited to motors up to 5 horse power. With this method of starting the motor is connected direct to full line voltage by means of a manually operated switch or a magnetic contactor.

Starting by Means of Autotransformer. In the case of the autotransformer type of starting the current taken from the line varies as the square of the voltage applied to the motor terminals, and it is convenient to remember that the torque and line currents are reduced at the same rate. Thus, an autotransformer starter, designed to apply 80% of the line voltage to the motor terminals, will produce 64% of the torque that would have been developed if the motor had been started on full voltage, and will, at the same time, draw 64% as much of the current from the line as would have been required for full-voltage starting.

Starting by Means of Resistors or Reactors. With resistor or reactor starting the starting current varies directly with the voltage at the motor terminals, because the resistor or reactor is in series with each line to the motor and must carry the same current that flows in each motor terminal.

It is evident therefore, that the resistor and reactor type of reduced voltage starting requires more line current in amperes per unit of torque in foot-pounds than does the autotransformer type.

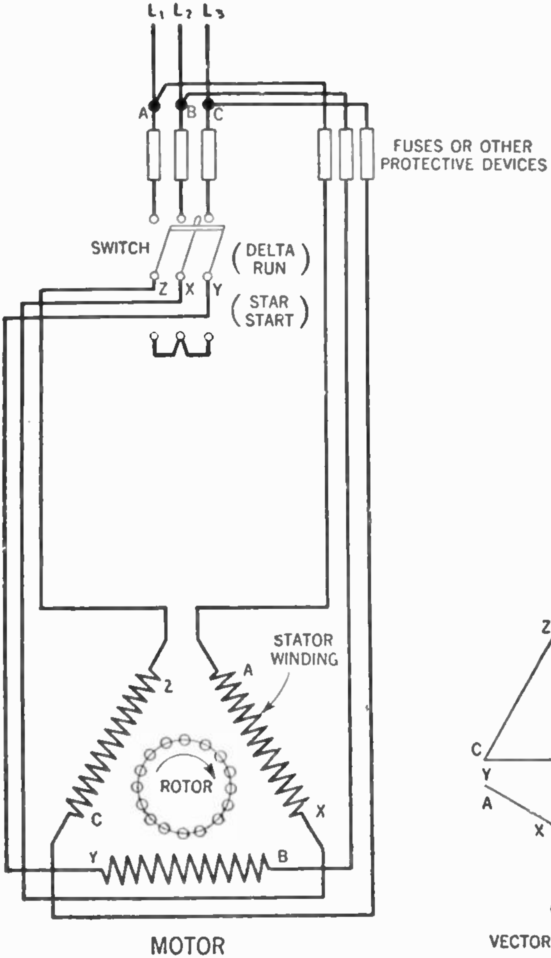
Thus, if a motor connected to a loaded centrifugal pump, for example, is started with 80% tap on the autotransformer the initial torque is 64%. If, on the other hand, the motor were started with a primary resistor, limiting the starting voltage to 65% of line voltage, the initial torque would only be 42.25%.

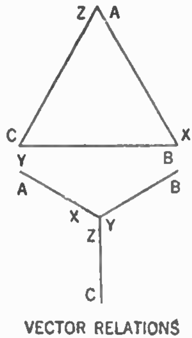
On some power systems, it is necessary to meet a restriction on the rate of current increase in starting. The rate of increase of current is determined to meet the conditions as they exist at that particular point on the system where the motor is started.

Starting By Means of the Star-Delta Method. Three phase induction motors of the squirrel cage type may occasionally be started by the star-delta method. This starting method is associated only with motors designed for their full power with the delta connected three phase winding. There must also be provided additional leads from the motor which when regrouped will result in a star arrangement of the three phase winding.

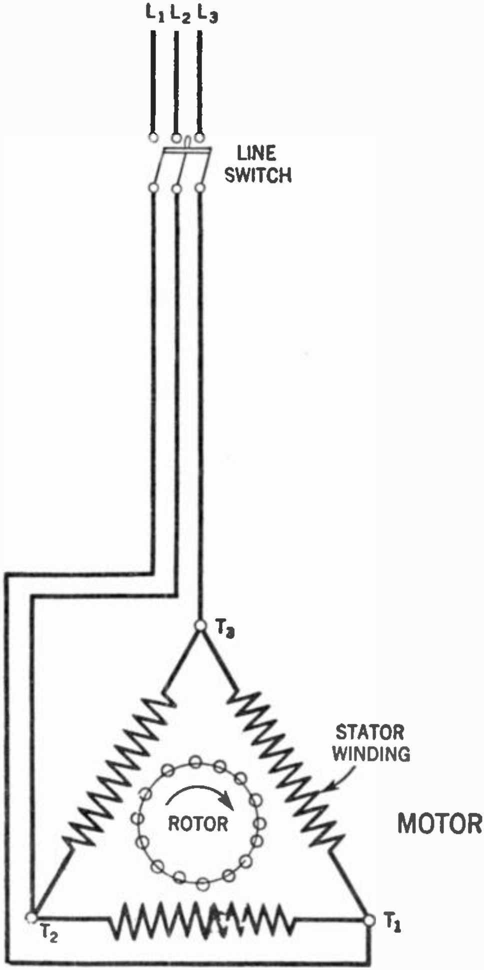
There will be six main leads required from the motor to accomplish the switch from start across the line (star-connection) to run across the line (delta-connection). The starting connection is always star, since the voltage is $1/\sqrt{3}$ or 57.8% of the delta or line voltage.

From the foregoing it follows that this type of reduced voltage starter (which is limited to 57.8% of line voltage at starting) can be employed only where the motor has a light starting load. In all other applications higher starting voltages are obtained with the resistor, reactors or autotransformers as previously outlined.

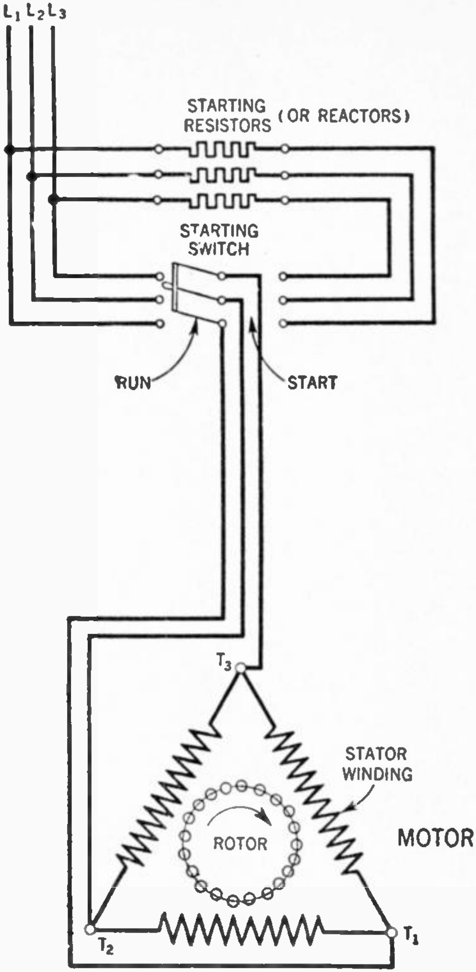




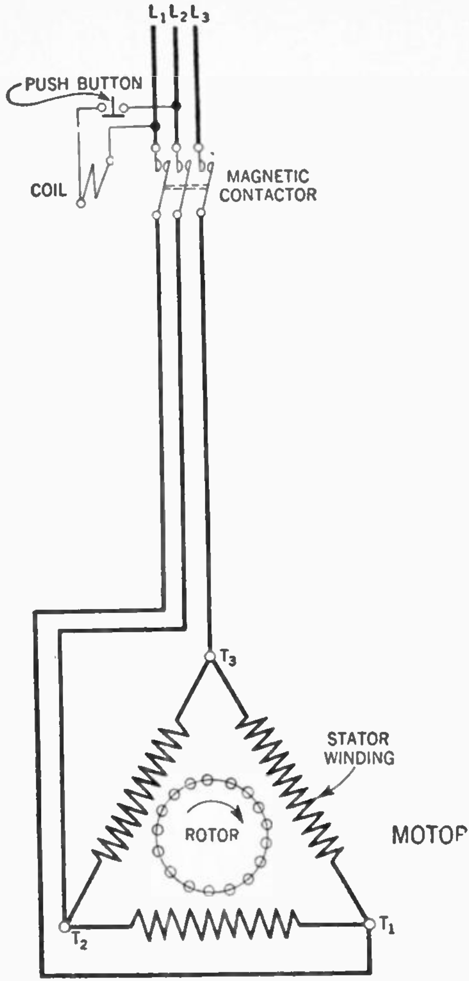
Illustrating Typical Connection Diagram when Star-Delta Method of Starting is Used for Squirrel-Cage Induction Motor. In the case of large motors that is motors rated above 5 h.p. a special oil switch controller is most commonly employed.



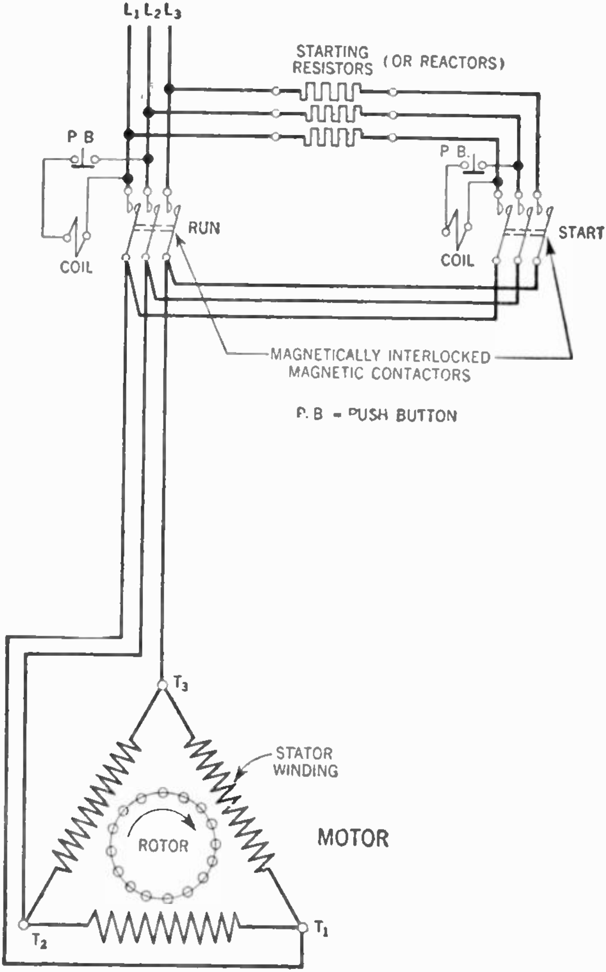
Fundamental Wiring Diagram of Typical Across the Line Non-Reversible, Single-Speed, Manually Operated Squirrel-Cage Induction Motor.



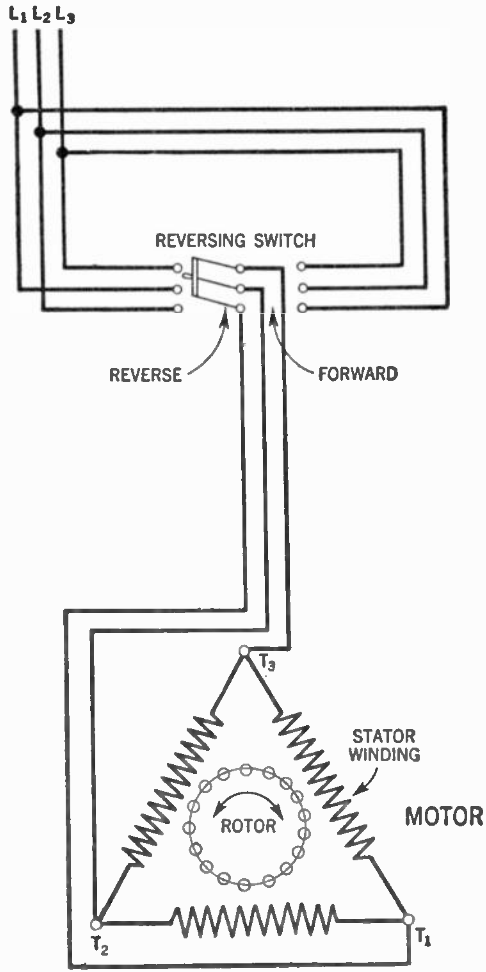
Fundamental Wiring Diagram of Typical Reduced Voltage, Non-Reversible, Single Speed, Manually Operated Squirrel-Cage Induction Motor.



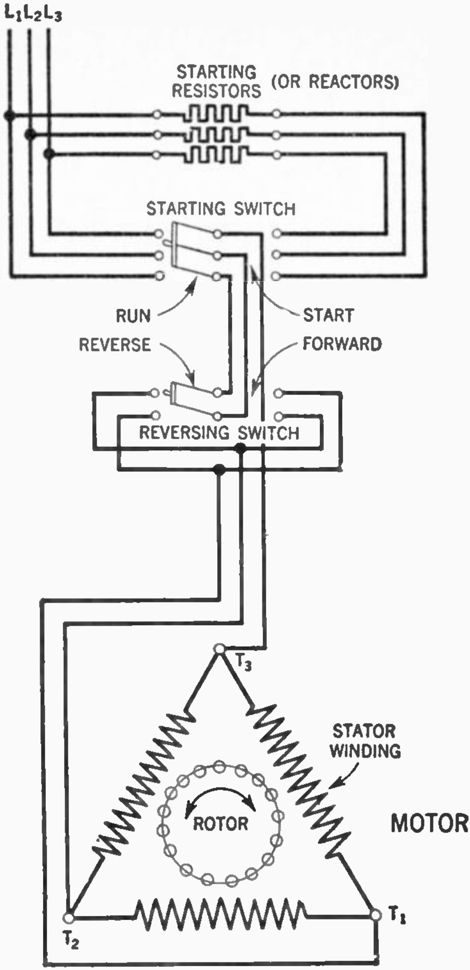
Fundamental Wiring Diagram of Typical Across the Line, Non-Reversible, Single Speed, Magnetically Operated Squirrel-Cage Induction Motor.



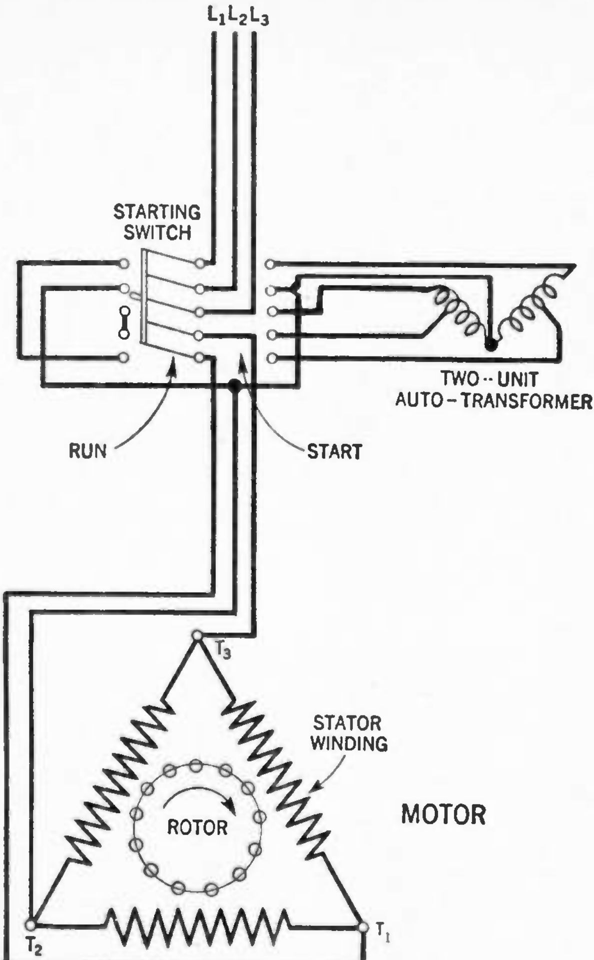
Fundamental Wiring Diagram of Typical Reduced Voltage, Non-Reversible, Single Speed, Magnetically Operated Squirrel-Cage Induction Motor.



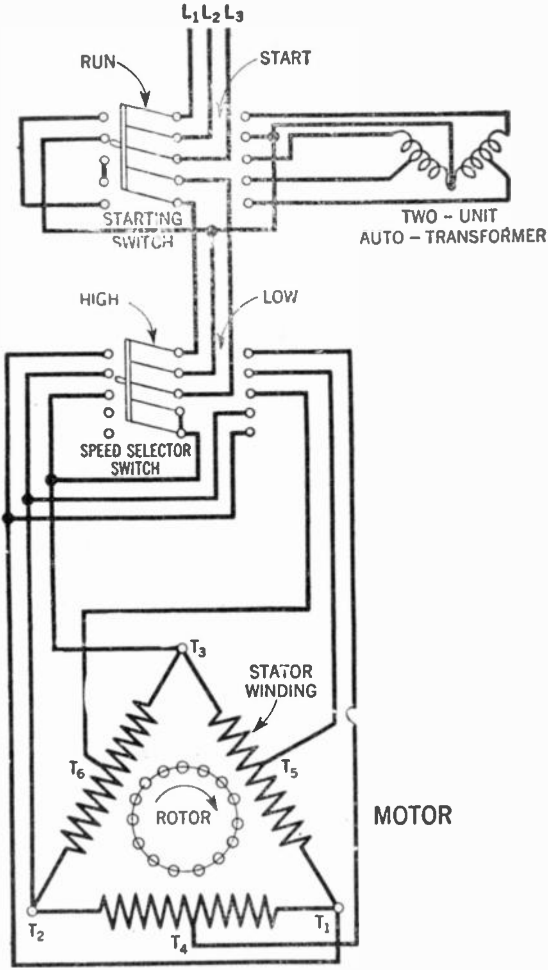
Fundamental Wiring Diagram of Typical Across the Line, Reversible, Single Speed, Manually Operated Squirrel-Cage Induction Motor.



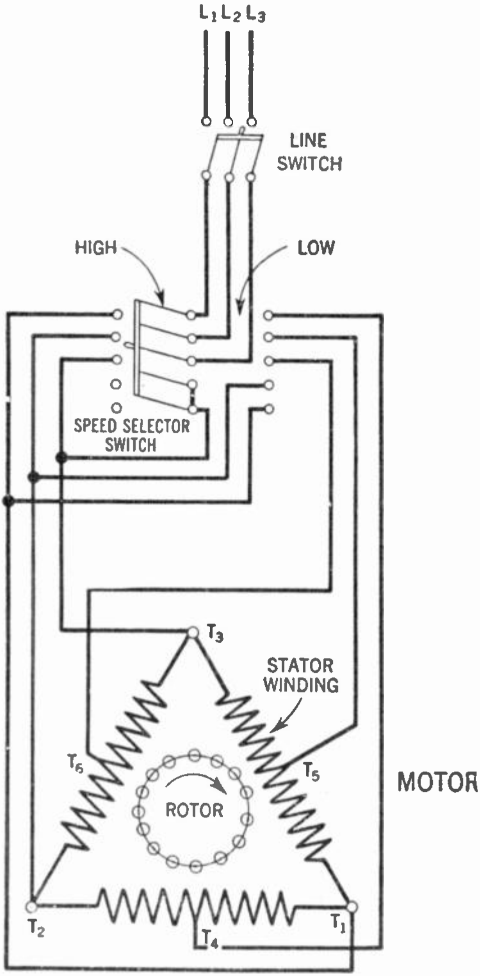
Fundamental Wiring Diagram of Typical Reduced Voltage, Reversible, Single Speed, Manually Operated Squirrel-Cage Induction Motor



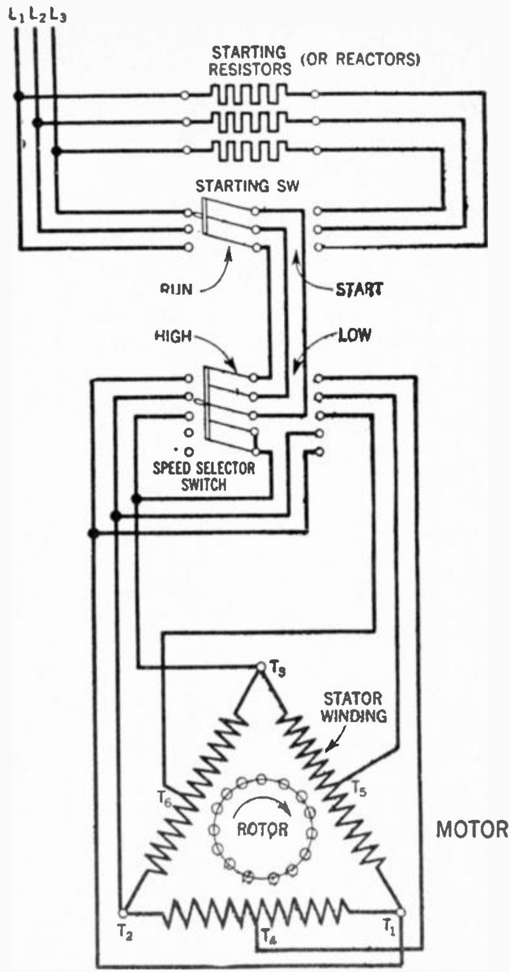
damental Wiring Diagram of Typical Reduced Voltage, Non-Reversible, le Speed, Manually Operated Squirrel-Cage Induction Motor.



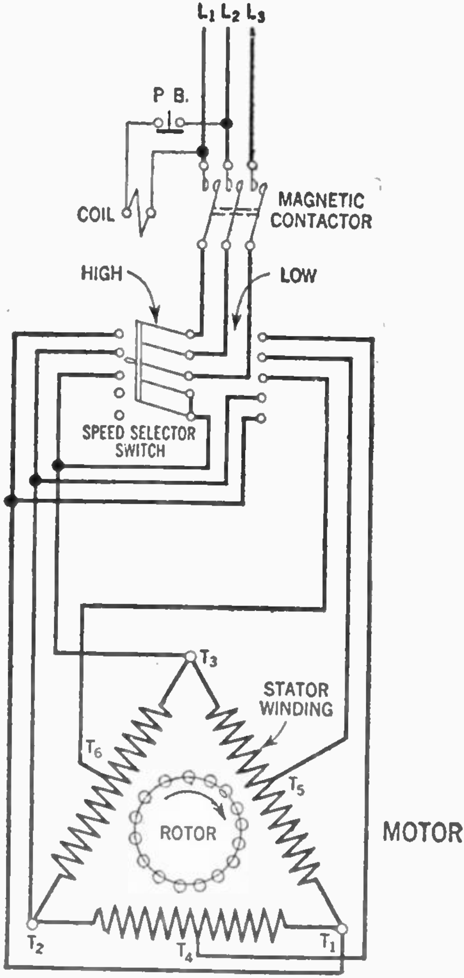
Fundamental Wiring Diagram of Typical Reduced Voltage, Two-Speed
Reversible, Manually Operated Squirrel-Cage Induction Motor.



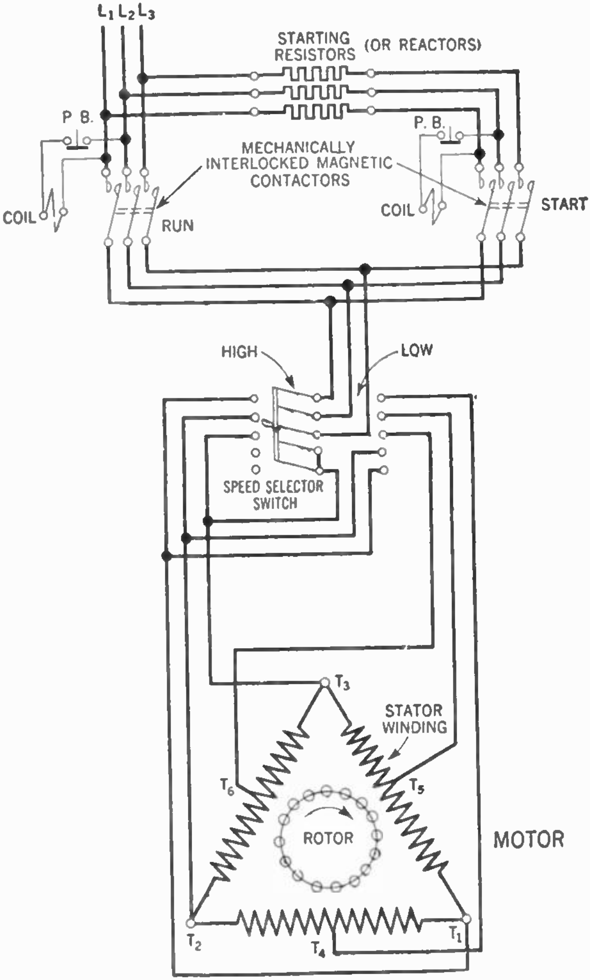
damental Wiring Diagram of Typical Across the Line, Two Speed, Non-ersible, Manually Operated Squirrel-Cage Induction Motor.



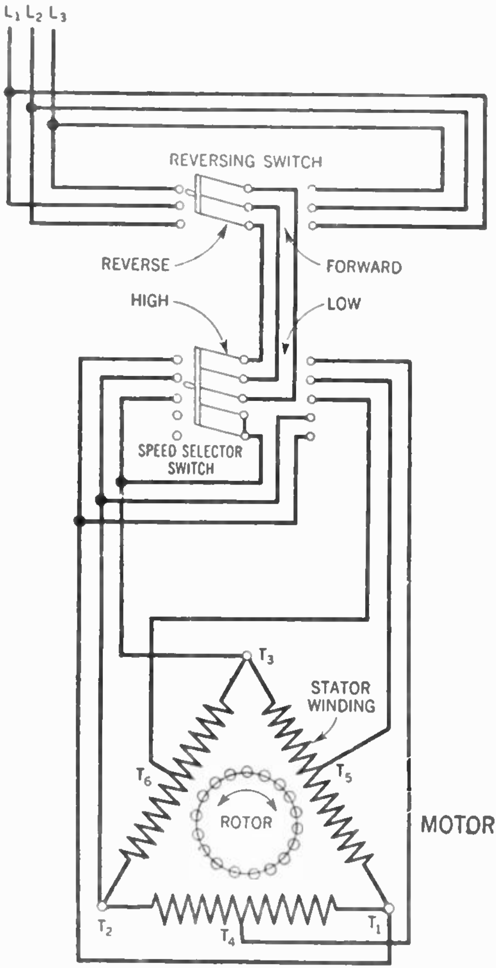
Fundamental Wiring Diagram of Typical Reduced Voltage, Two-Speed, N Reversible, Manually Operated Squirrel-Cage Induction Motor.



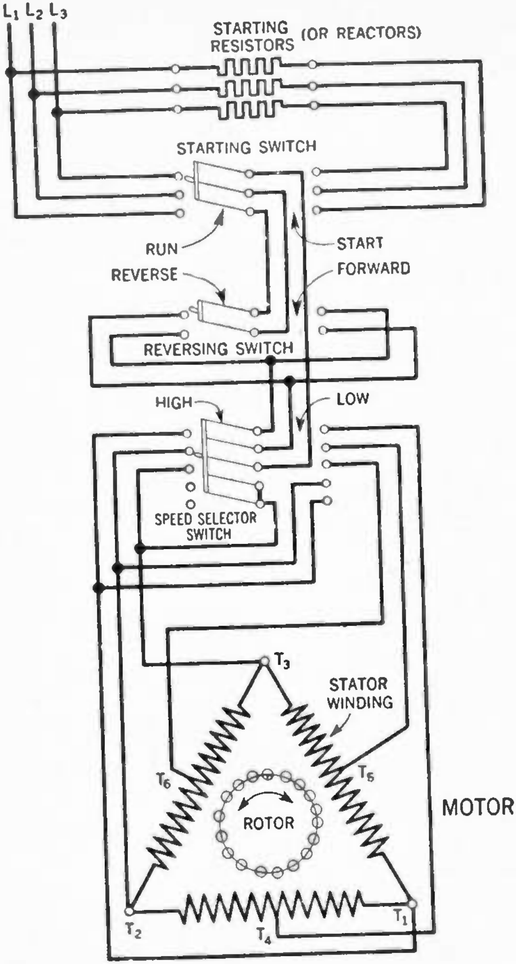
Fundamental Wiring Diagram of Typical Across the Line, Two-Speed, Non-Reversible, Magnetically Operated Squirrel-Cage Induction Motor.



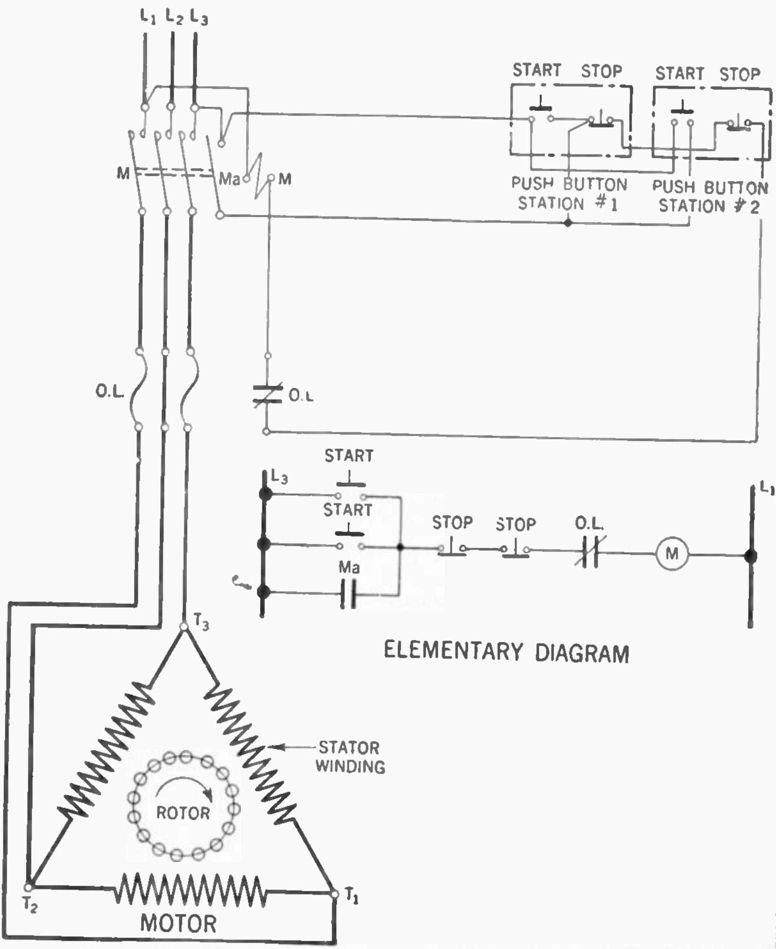
Fundamental Wiring Diagram of Typical Reduced Voltage, Two-Speed, Non Reversible, Magnetically Operated Squirrel-Cage Induction Motor.



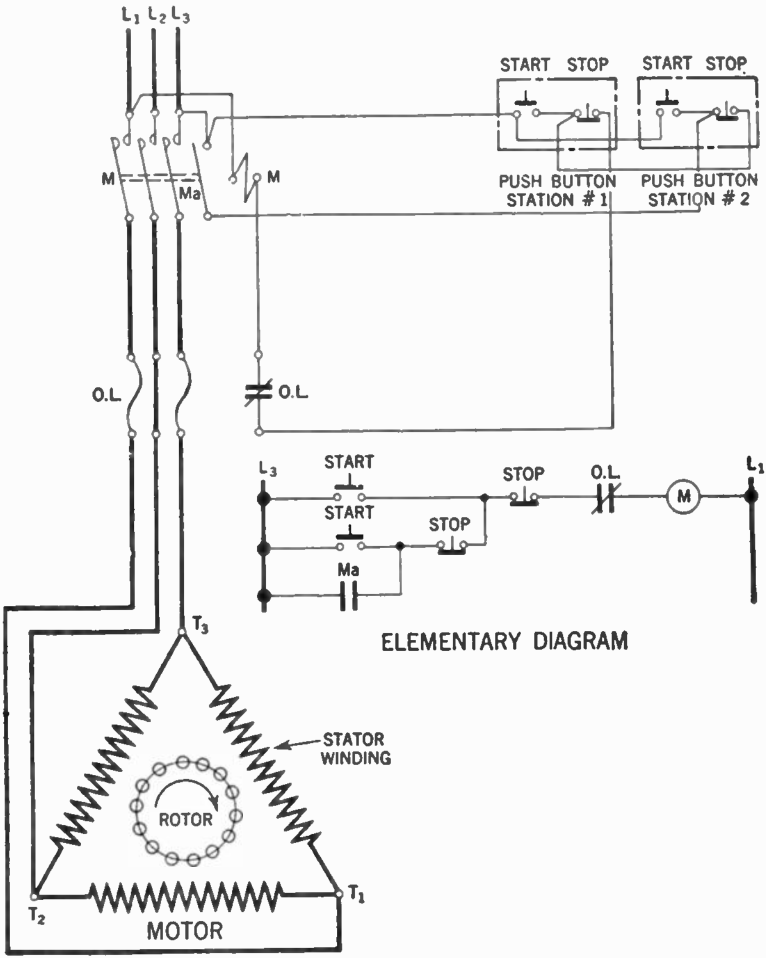
Fundamental Wiring Diagram of Typical Across the Line, Two-Speed, Reversible, Manually Operated Squirrel-Cage Induction Motor.



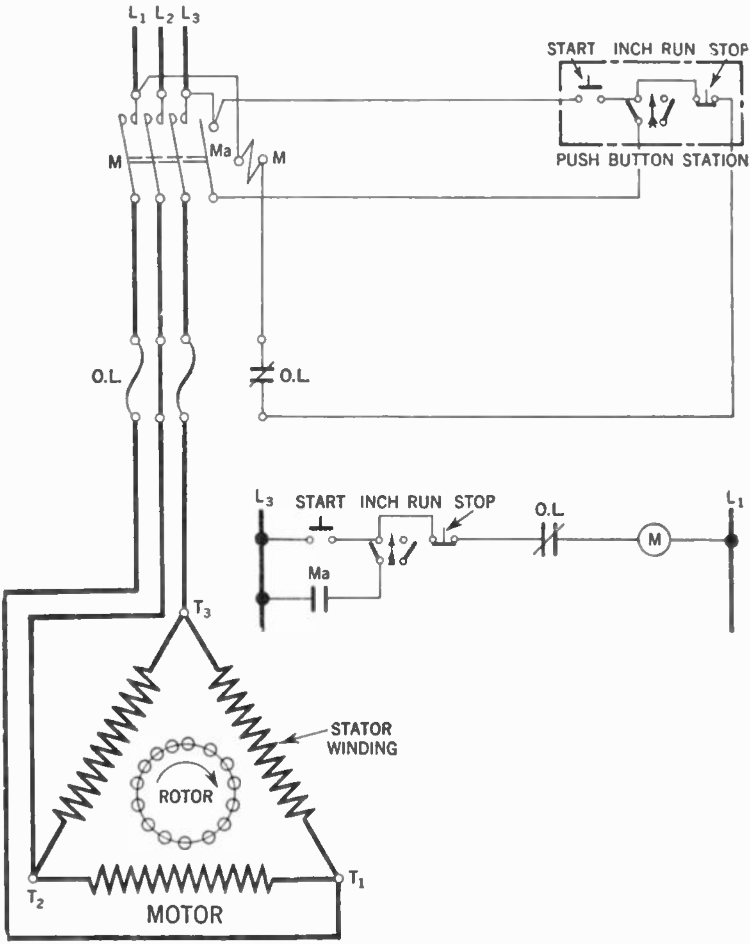
Fundamental Wiring Diagram of Typical Reduced Voltage, Two-Speed, Reversible, Manually Operated Squirrel-Cage Induction Motor.



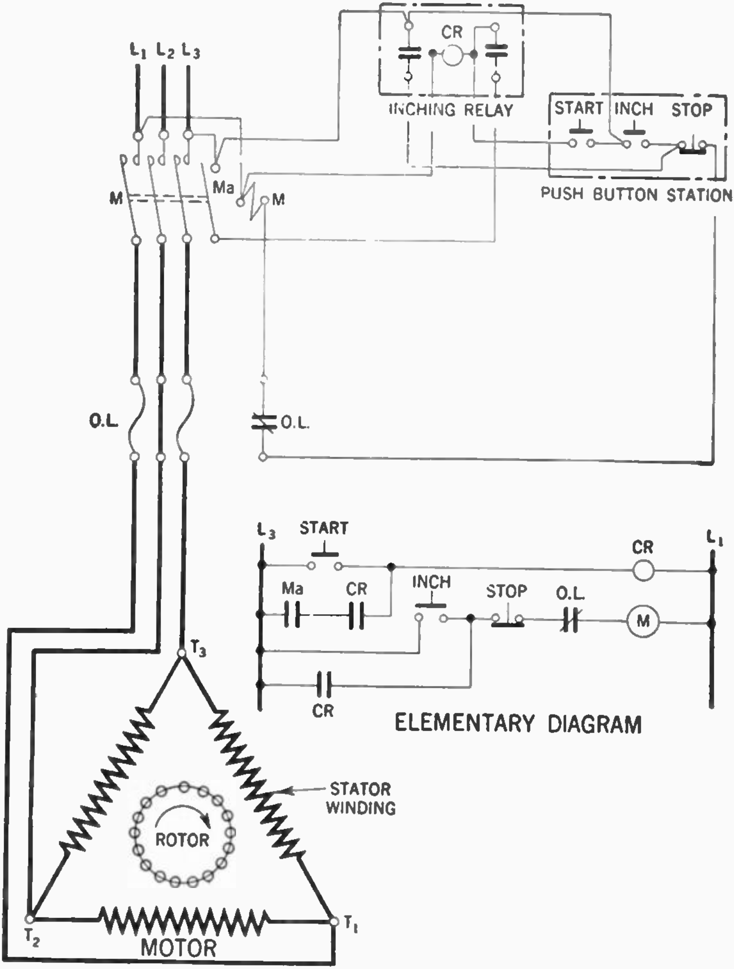
Wiring Diagram of Typical Remotely Controlled Magnetically Operated Squirrel-Cage Induction Motor. The push button circuit consists of two control stations, each with two momentary contacts, one closed and one open. The circuit provides under-voltage protection. The operating duty is: **Start-stop, start-stop.**



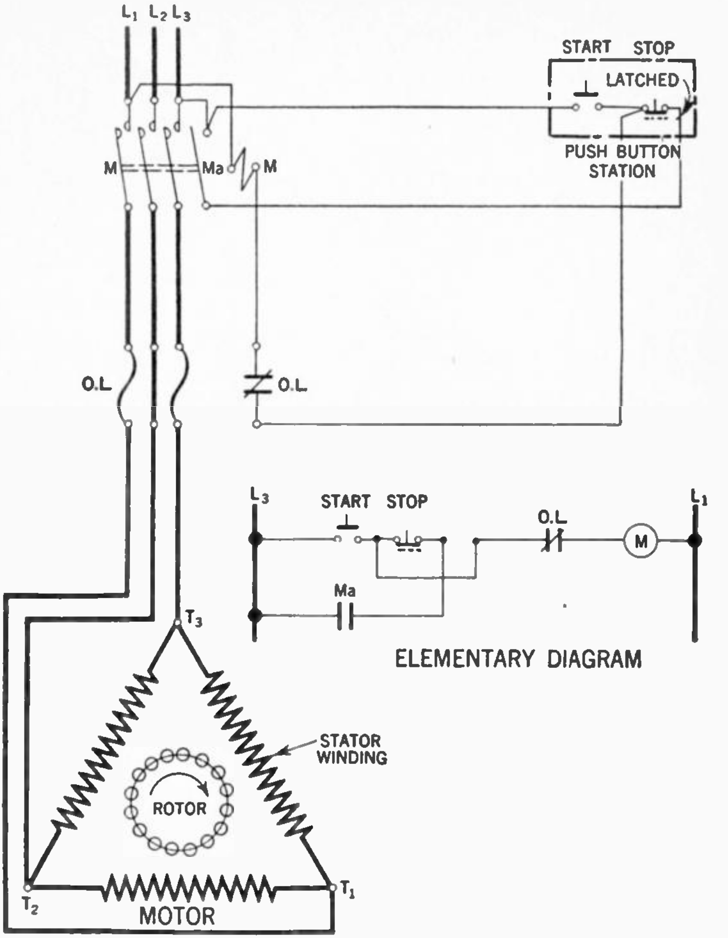
Wiring Diagram of Typical Remotely Controlled Magnetically Operated Squirrel-Cage Induction Motor. The push button circuit consists of two control stations with only three wires between the stations. The circuit provides under-voltage protection. The operating duty is: **Start-stop, start-stop.**



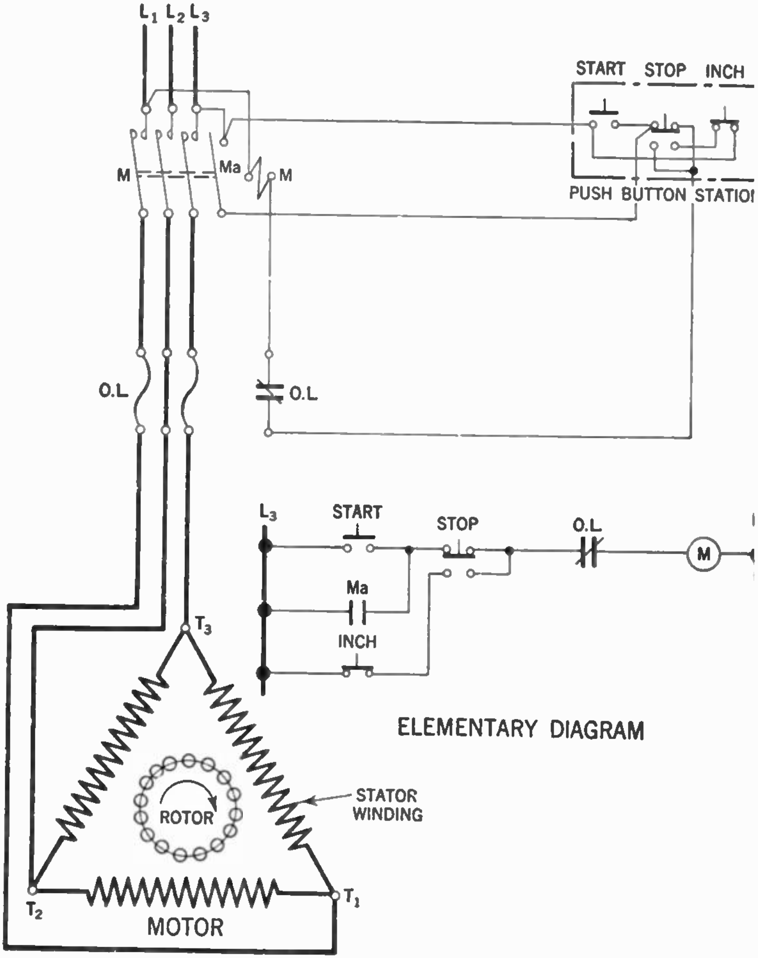
Wiring Diagram of Typical Remotely Controlled Magnetically Operated Squirrel-Cage Induction Motor. The push button circuit consists of one control station, with two momentary-contact buttons and one selector switch. The circuit provides under-voltage protection plus inching. The operation duty is: **Start-run, inch-stop.**



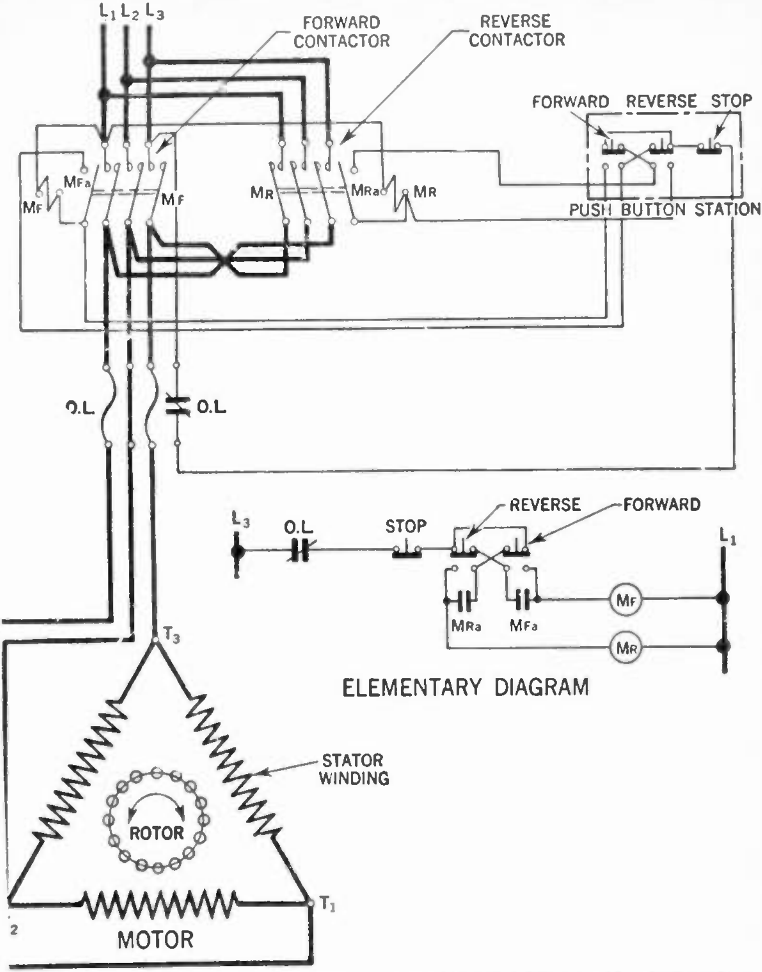
Wiring Diagram of Typical Remotely Controlled Magnetically Operated Squirrel-Cage Induction Motor. The push button circuit consists of one push button station, with three momentary contacts and an inching relay. The circuit provides under-voltage protection plus fool-proof inching. The operating duty is: **Start-inch-stop.**



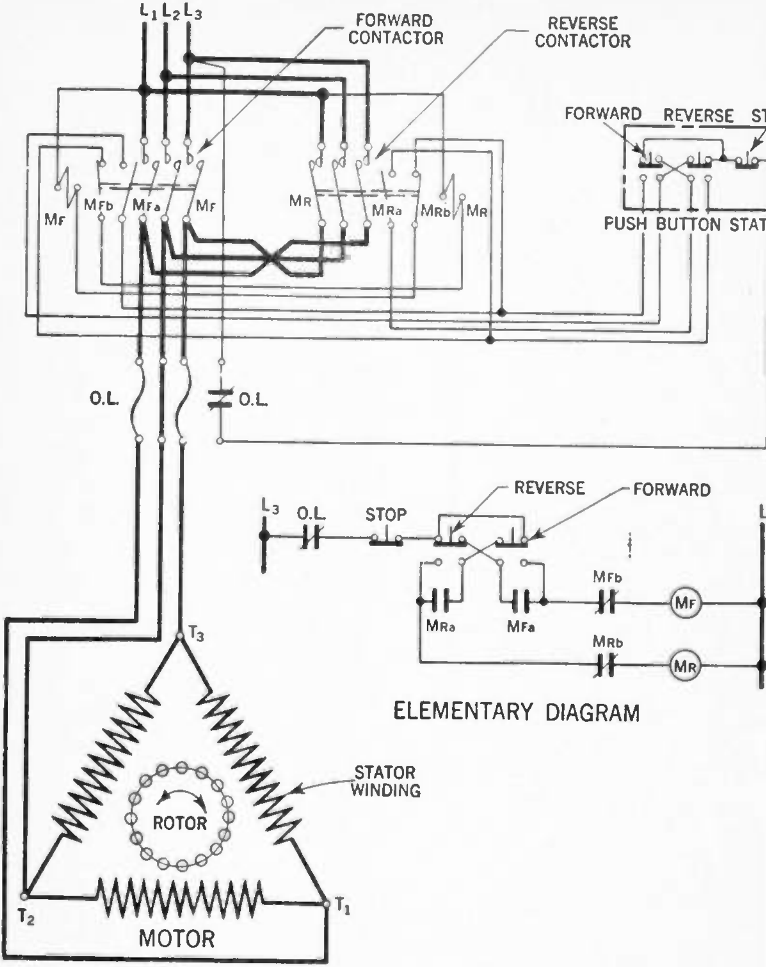
Viring Diagram of Typical Remotely Controlled Magnetically Operated Squirrel-'age Induction Motor. The push button circuit consists of one control station vith two momentary-control buttons, one open and one closed with safety latch. he circuit provides under-voltage protection. The operating duty is: **Start-stop on inch for latch).**



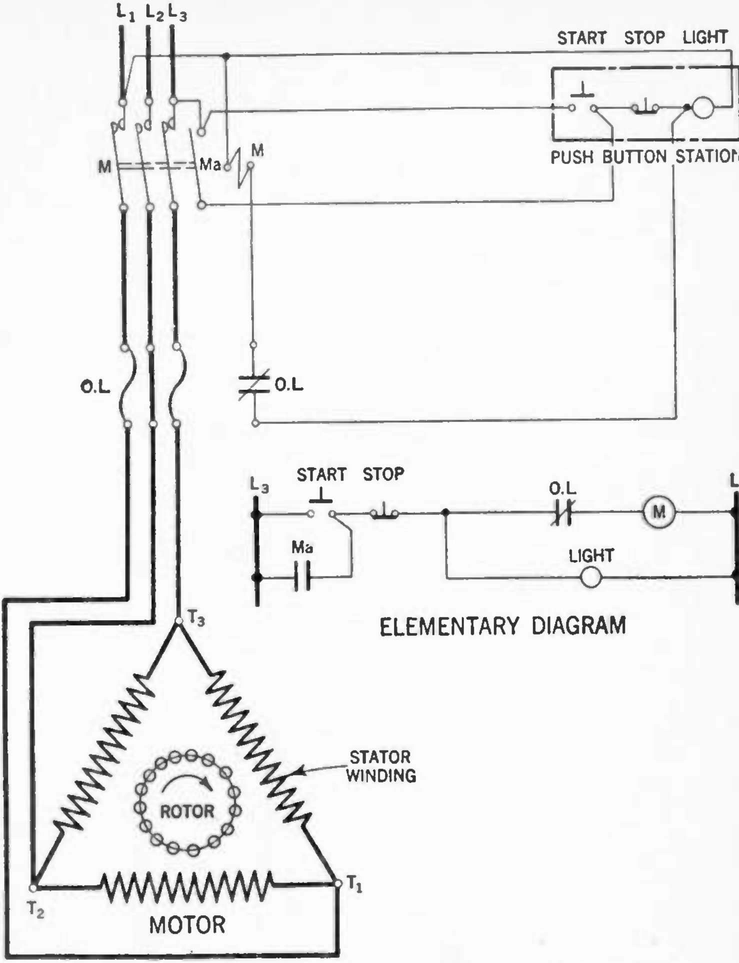
Wiring Diagram of Typical Remotely Controlled Magnetically Operated Squirrel Cage Induction Motor. The push button circuit consists of one-control station with three momentary contact buttons of which two are open and one closed The circuit provides under-voltage protection plus inching by holding down stop button. The operating duty is: **Start-inch-stop.**



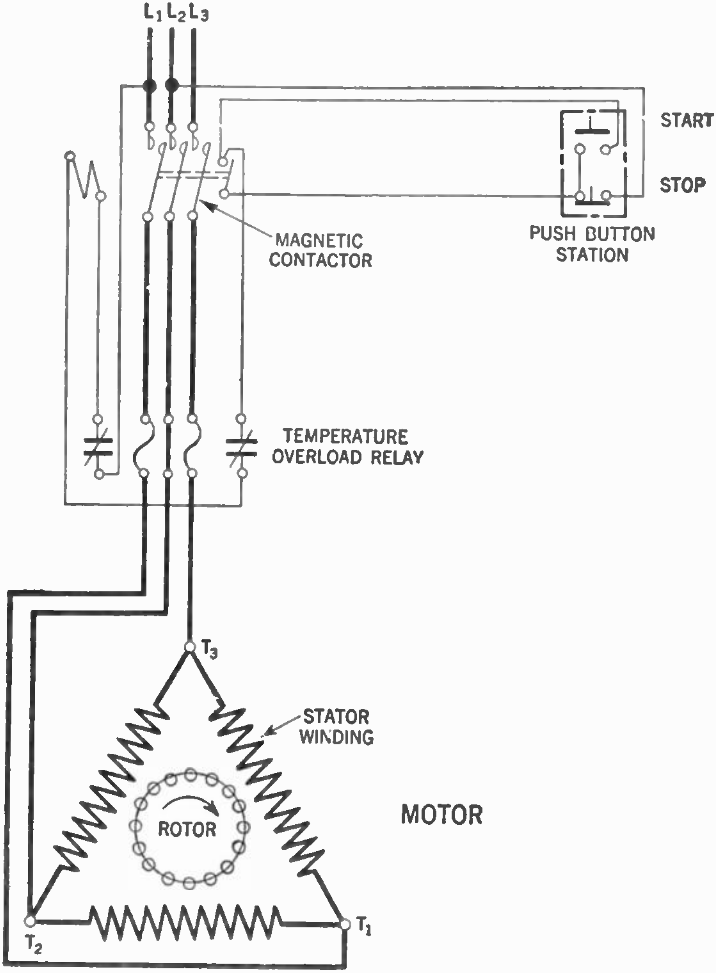
/iring Diagram of Typical Remotely Controlled Magnetically Operated Re- :rsible Squirrel-Cage Induction Motor. The push button circuit consists of one ›ntrol station, with three momentary contact buttons, two open and one closed. ıe circuit provides under-voltage protection, interlocked through push buttons. ıe operating duty is: **Forward-reverse-stop.**



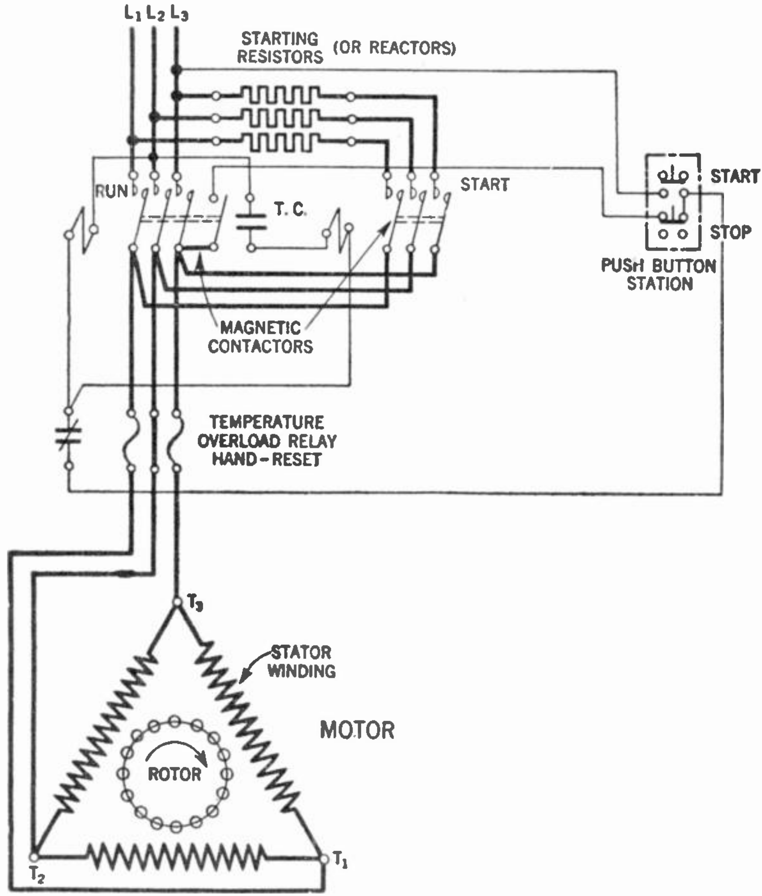
Wiring Diagram of Typical Remotely Controlled Magnetically Operated Reversible Squirrel-Cage Induction Motor. The push button circuit consists of or control station, with three momentary contact buttons, two open and one close The circuit provides under-voltage protection with electrical interlocks. Th operating duty is: **Forward-reverse-stop.**



Wiring Diagram of Typical Remotely Controlled Magnetically Operated Squirrel-Cage Induction Motor. The push button circuit consists of one control station with two momentary control buttons, one open and one closed, plus an indicating light showing operating position of contactor. The circuit provides under-voltage protection. The operation duty is: **Start-stop.**

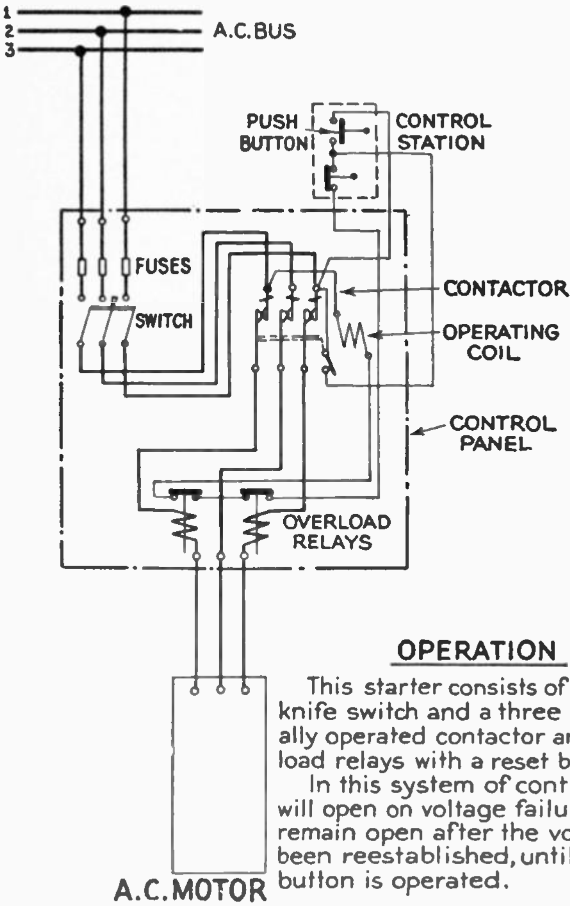


Wiring Diagram of Typical Across the Line, Single Speed, Non-Reversible, Magnetically Operated Squirrel-Cage Induction Motor.



Wiring Diagram of Typical Reduced Voltage, Single Speed, Non-Reversible, Magnetically Operated Squirrel-Cage Induction Motor. In the Diagram T.C. is a Time Closing Contact.

ACROSS THE LINE A.C. MOTOR STARTING ARRANGEMENT

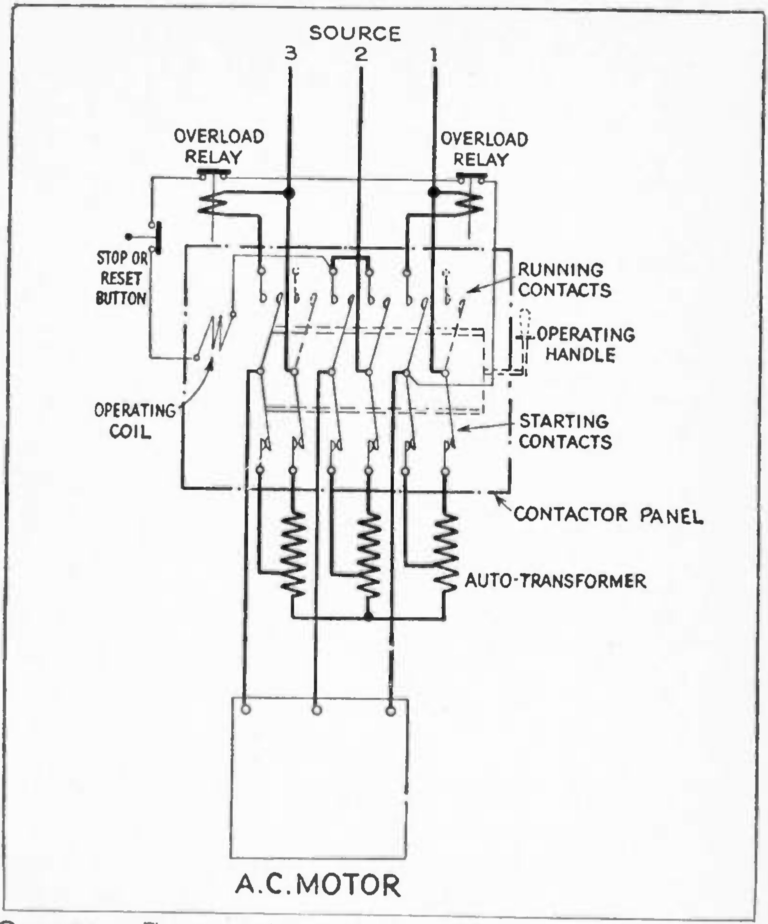


OPERATION

This starter consists of a three pole knife switch and a three pole magnetic ally operated contactor and two over-load relays with a reset button.

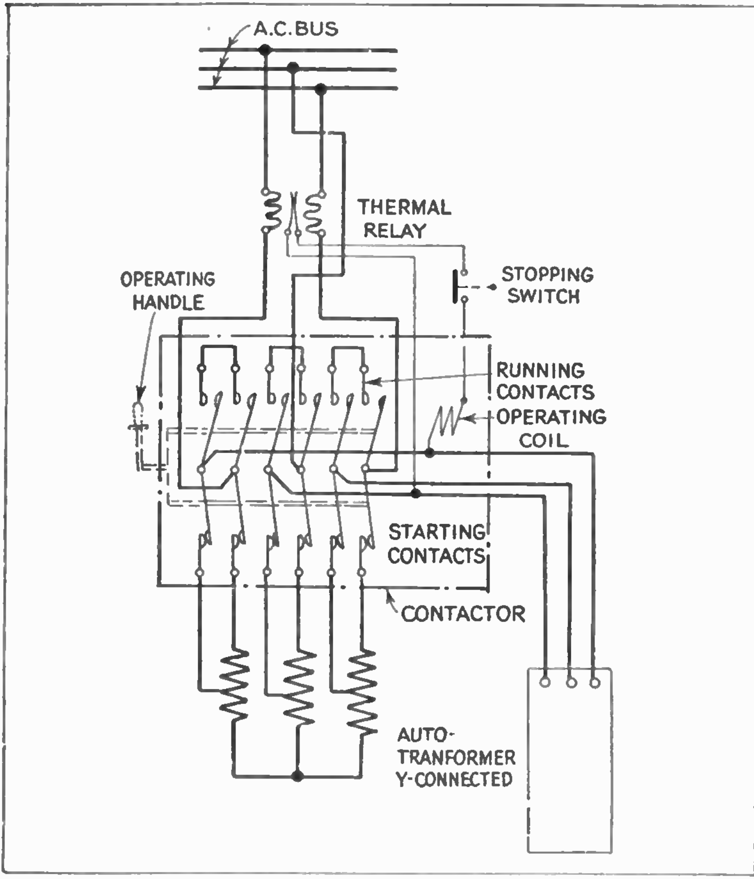
In this system of control, the contact will open on voltage failure and will remain open after the voltage has been reestablished, until the start button is operated.

MANUAL COMPENSATOR WITH MAGNETIC OVERLOAD RELAYS



Operation. The motor is disconnected from the line when the contactor operating handle is in the **off position.** In starting, the handle is thrown to the **start position** which closes the starting contacts forming connections through the Y-connected auto-transformers which reduces the impressed voltage of the motor during the **starting period.** After normal speed is reached, the operating handle is thrown to the **run position,** which opens the starting, and closes the running contacts, connecting the motor directly across the line.

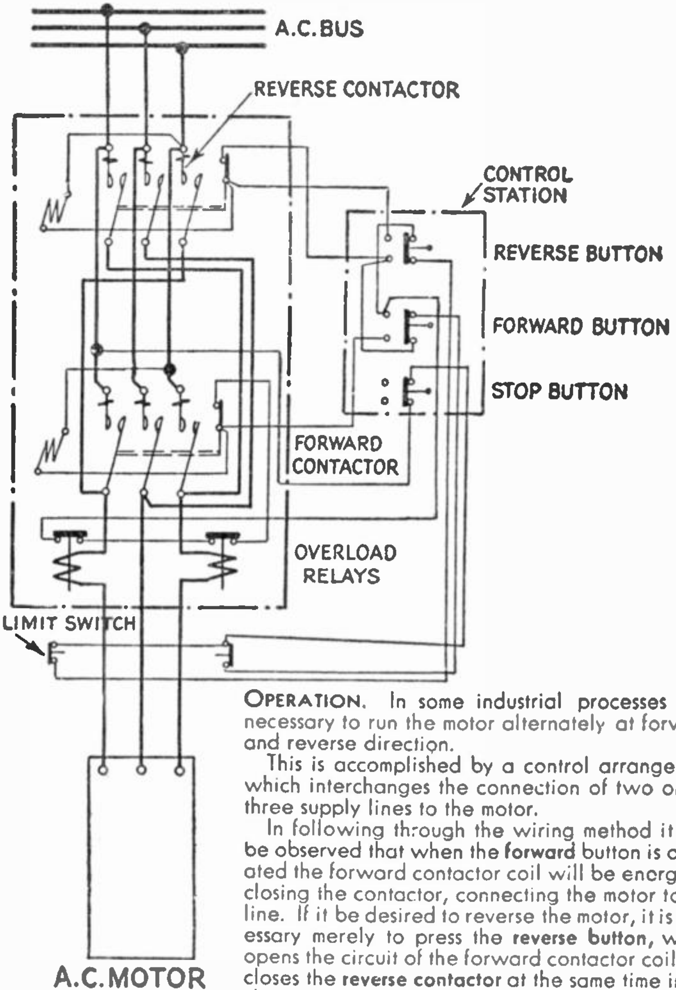
MANUAL COMPENSATOR WITH THERMAL OVERLOAD RELAY



OPERATION. The starting of the motor is accomplished as follows: With the motor disconnected from the line the operating handle is in **off position. First step.** Throw the operating handle to the start position. The motor is now connected to the line at reduced voltage through the taps of the auto-transformer.

Second step. After the motor has reached normal speed operate the handle to **run position;** at this time the starting contacts are automatically disengaged, and the motor is connected across the line at full voltage.

STARTING AND REVERSING CONTROL ARRANGEMENT FOR A THREE PHASE INDUCTION MOTOR

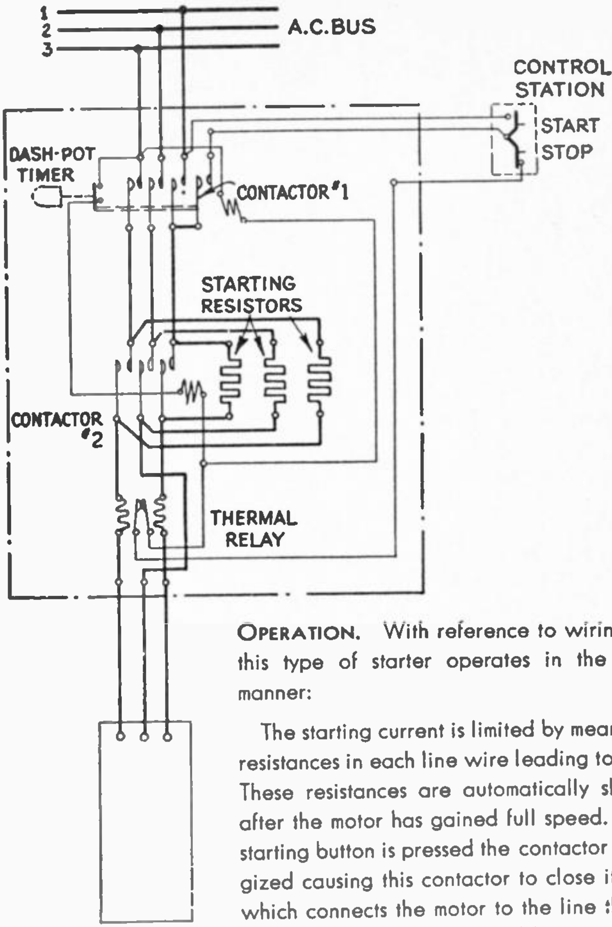


OPERATION. In some industrial processes it is necessary to run the motor alternately at forward and reverse direction.

This is accomplished by a control arrangement which interchanges the connection of two of the three supply lines to the motor.

In following through the wiring method it will be observed that when the **forward** button is operated the forward contactor coil will be energized closing the contactor, connecting the motor to the line. If it be desired to reverse the motor, it is necessary merely to press the **reverse button,** which opens the circuit of the forward contactor coil and closes the **reverse contactor** at the same time interchanging two of the line wires. The motor is now running in the reverse direction. This operating method is not common where large motors are employed due to the fact that a heavy starting current will cause undesirable voltage fluctuation in the power line system.

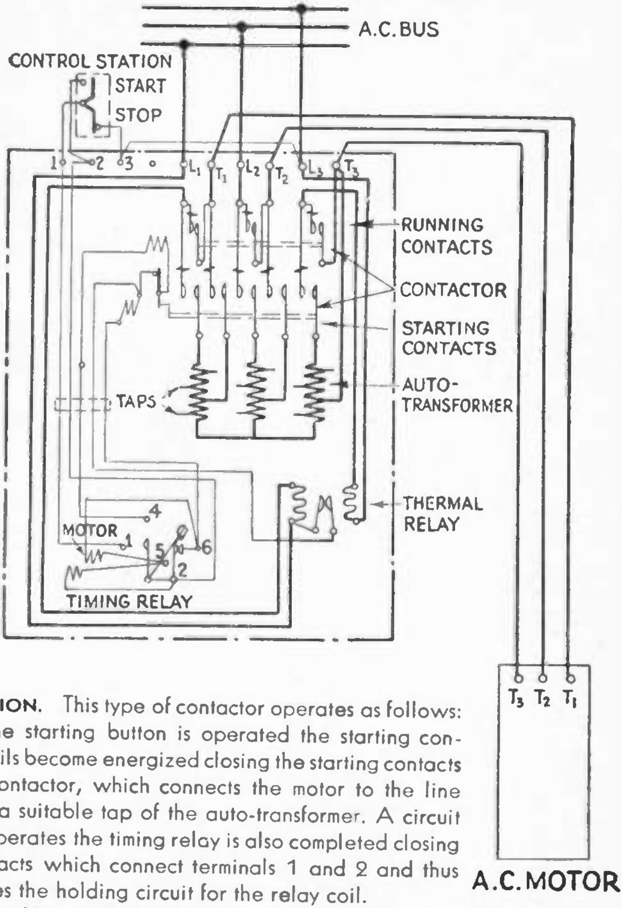
RESISTANCE STARTING FOR A.C. MOTOR



OPERATION. With reference to wiring diagram this type of starter operates in the following manner:

The starting current is limited by means of equal resistances in each line wire leading to the motor. These resistances are automatically shunted out after the motor has gained full speed. When the starting button is pressed the contactor #1 is energized causing this contactor to close its contacts which connects the motor to the line through the starting resistors. The circuit of the #1 contactor coil is maintained through the time interlock on the dash-pot timer, whose contacts close after a definite time has elapsed. This in turn completes the circuit through the coil of contactor #2, which closes its contacts, shunting out the starting resistance and connects the motor at full voltage directly across the line.

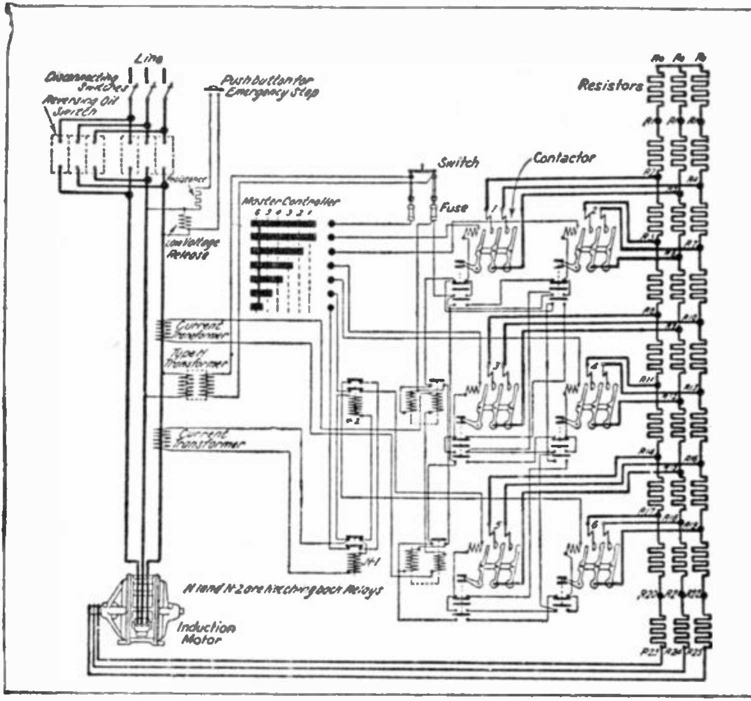
AUTOMATIC STARTING CONTACTOR FOR REMOTE CONTROL OPERATION



Operation. This type of contactor operates as follows: when the starting button is operated the starting contactor coils become energized closing the starting contacts of the contactor, which connects the motor to the line through a suitable tap of the auto-transformer. A circuit which operates the timing relay is also completed closing the contacts which connect terminals 1 and 2 and thus completes the holding circuit for the relay coil.

Finally after a definite time depending upon the relay setting the escapement releases and allows the contact arm to break the contact at 6 and make contact at 4 causing the starting contact to open and the running contacts to close connecting the motor directly across the line.

DIAGRAM OF INDUCTION MOTOR CONTROL FOR STEEL MILL, MAIN ROLL DRIVE

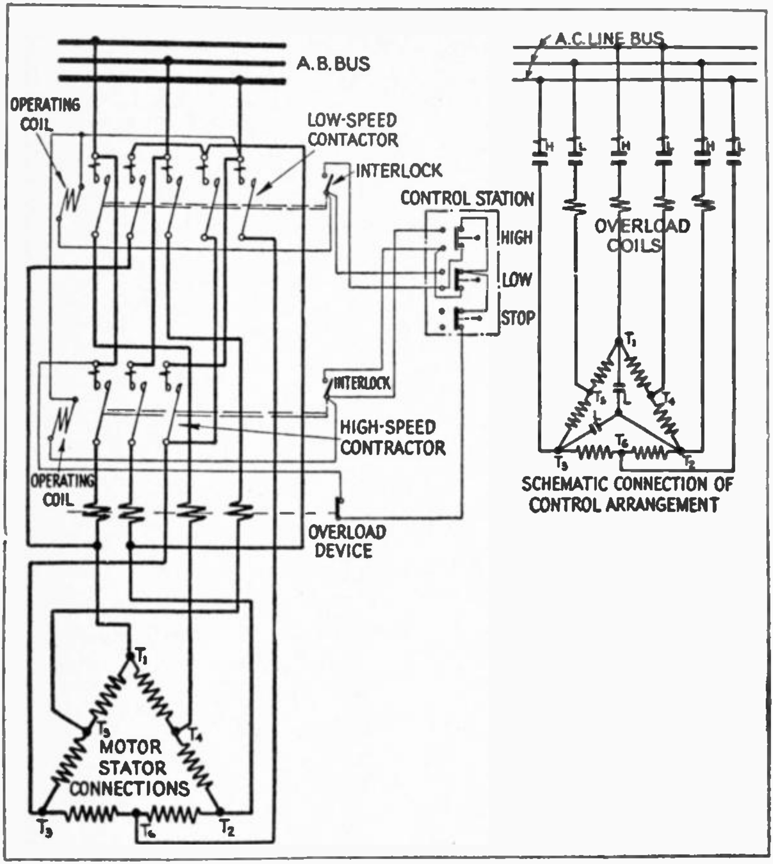


OPERATION. The essential parts of the control for a large induction motor are relatively few and simple, though sometimes the interlocking devices when carried to an unnecessary extent become exceedingly complex. This diagram shows a typical arrangement of control for such a motor where only occasional partial speed operations or reversal is required. The incoming line passes through disconnecting switches by means of which the motor and control can be completely isolated from the line during adjustments or repairs. For high voltage motors a double-throw hand-operated reversing oil switch with inverse time limit overload and no-voltage release is employed in addition. A push button located conveniently in the mill short circuits the no-voltage release, thus tripping out the oil switch and stopping the motor in emergency. *(Text continued)*

INDUCTION MOTOR CONTROL FOR STEEL MILL, MAIN ROLL DRIVE

The motor panel should be provided with a voltmeter, ammeter and indicating wattmeter. Integrating and curve drawing wattmeters are often desirable. The secondary circuit consists of a three-phase resistance permanently connected to the slip rings. Shunt contactors of the double-pole type (where sizes permit) are used to short circuit successive portions of the resistance as the motor accelerates. The energizing current is obtained from a potential transformer in the primary circuit between the oil switch and the motor. Current limit relays govern the rate of acceleration. In case the primary oil switch is opened intentionally, or by means of the no-voltage release, the secondary contactors open up, automatically inserting the entire resistance in the secondary circuit so that, even with the master controller still in the running position, the motor will receive no harm when the voltage is again thrown on the line. This automatic action of the secondary contactors also affords protection against reversing with the resistance all cut out, since the contactors drop out as the oil switch is opened and notch again as it is thrown to the reverse position.

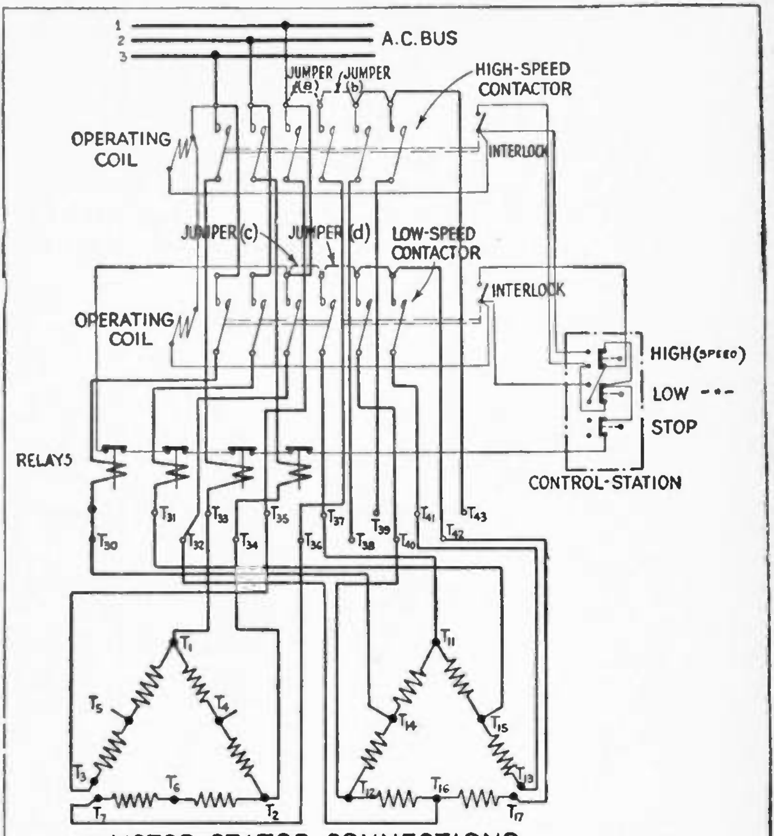
CONTROLLERS FOR A.C. MOTOR OPERATING AT TWO SPEEDS



Operation. Generally the purpose of controllers for motors having more than one speed is to interconnect the stator terminals in a desirable manner and also to connect them to the line as required for each speed. In the system of control under consideration, the schematic diagram shows the basic principles. Here for the sake of clarity the **high** speed and **low** speed contacts are labeled "H" and "L" respectively.

With reference to the complete diagram, one button is utilized for each speed. If it be desired to change the speed from low to high for example, the operation of the high speed button will automatically cause the motor to change over to that speed.

CONTROLLERS FOR A.C. MULTI-SPEED MOTOR



MOTOR STATOR CONNECTIONS

Note. For operating data see following page.

CONNECTION DATA FOR MULTI-SPEED A.C. MOTOR

SPEEDS	OMIT JUMPERS	CONNECT TERMINALS AS FOLLOWS
600/900	a and c	T1-T37, T2-T40, T3-T41, T4-T30, T5-T31, T6-T32, T7-T42, T11-T36, T12-T38, T14-T33, T15-T34, T16-T35, T17-T43
600/1200	b and c	T1-T33-T37, T2-T34-T40, T3-T35-T41, T4-T30, T5-T31, T6-T32, T7-T36-T42
600/1800	b and c	T1-T37, T2-T40, T3-T41, T4-T30, T5-T31, T6-T32, T7-T42, T11-T32, T12-T34, T13-T35, T17-T36
900/1200	b and c	T1-T33, T2-T34, T3-T35, T12-T40, T13-T41, T14-T30, T15-T31, T16-T32, T17-T42
900/1800	b and c	T11-T33-T37, T12-T34-T40, T13-T35-T40, T14-T30 T15-T31, T16-T32, T17-T36-T42
1200/1800	b and d	T1-T30, T2-T31, T3-T32, T7-T37, T11-T33, T12-T34, T13-T35, T17-T37

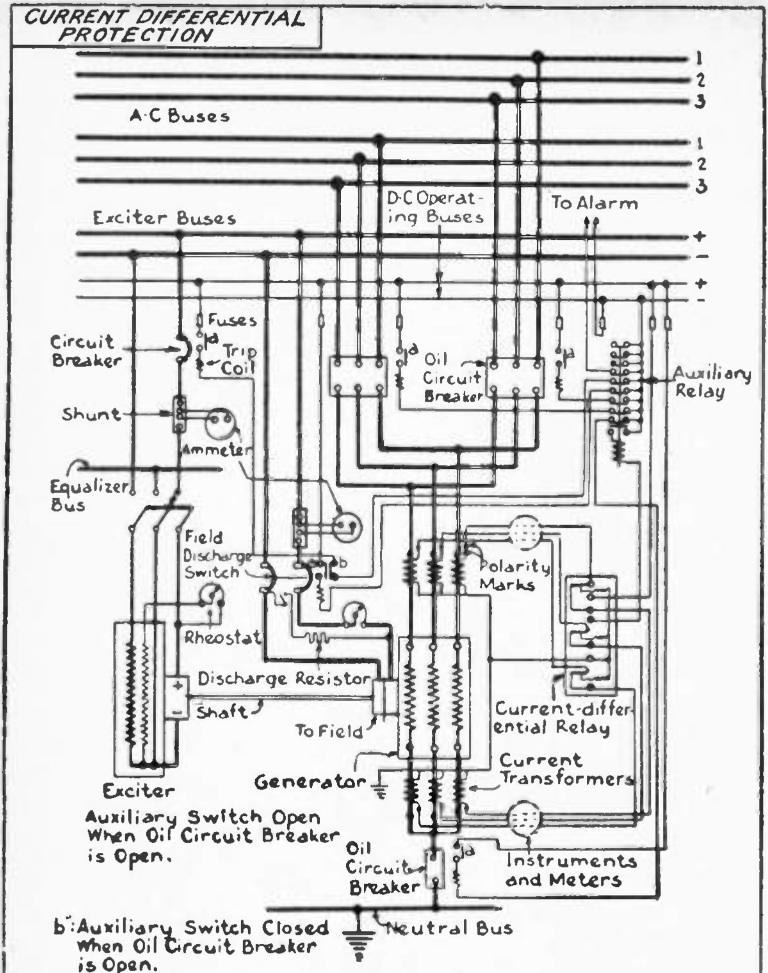
OPERATION. In the connection diagram shown on the previous page, the 4-speed motor is connected for two speeds, that is when the low speed button is operated three of the contacts connect the winding parallel-star and the three connect the winding to the line.

This gives eight poles or a synchronous speed of $\frac{120 \times 60}{8}$ or 900 r.p.m.

Again when the high speed button is operated the low speed contacts opens and the delta connection is completed connecting the winding to the line through six poles which gives a synchronous speed of $\frac{120 \times 60}{6}$ or 1200 r.p.m.

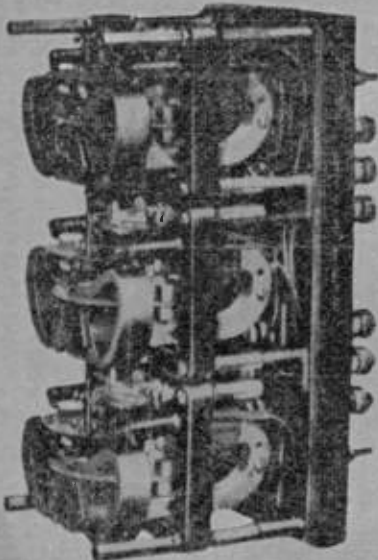
Method of connection to obtain 4 speeds is shown in the accompanying table.

MISCELLANEOUS WIRING DIAGRAMS



Complete diagram of connections for current differential protection of three phase "Star"-connected alternating current generator with grounded neutral and direct current exciter.

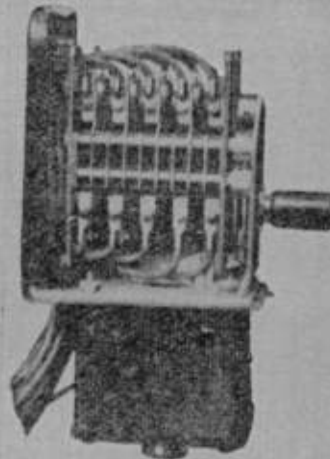
Photografic illustration of auxiliary relay and current differential relay shown on the following page.



FRONT VIEW
(Cover removed)

FRONT VIEW

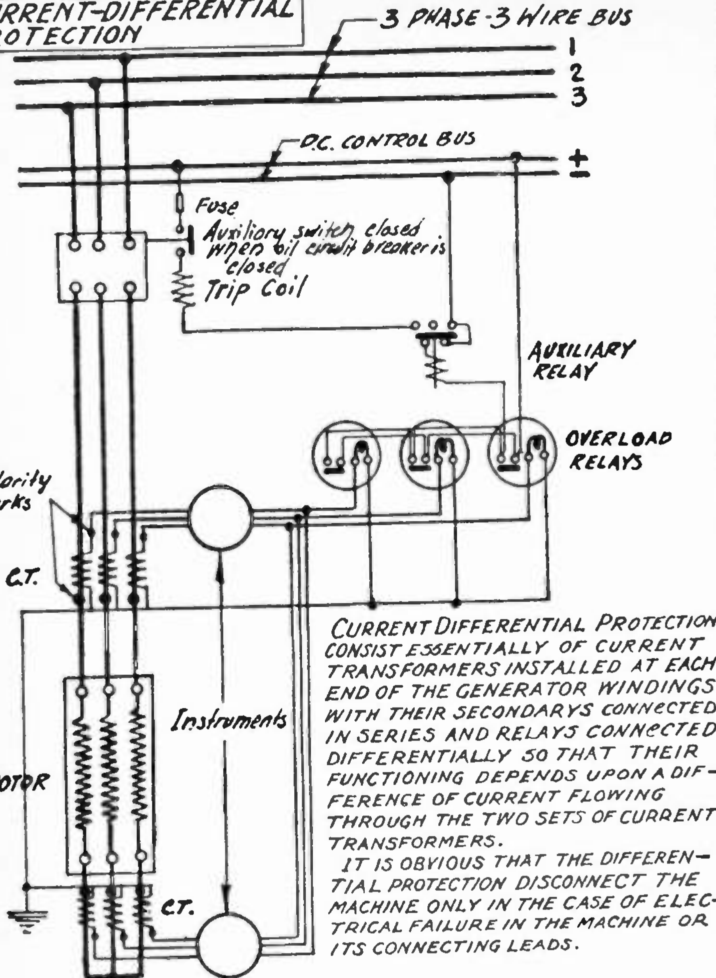
Typical current differential Relay.
(For connection: See opposite page.)



FRONT VIEW
(Cover removed)

Ten circuit auxiliary relay. (For connection, See opposite page.)

CURRENT-DIFFERENTIAL PROTECTION



CURRENT DIFFERENTIAL PROTECTION CONSIST ESSENTIALLY OF CURRENT TRANSFORMERS INSTALLED AT EACH END OF THE GENERATOR WINDINGS WITH THEIR SECONDARYS CONNECTED IN SERIES AND RELAYS CONNECTED DIFFERENTIALLY SO THAT THEIR FUNCTIONING DEPENDS UPON A DIFFERENCE OF CURRENT FLOWING THROUGH THE TWO SETS OF CURRENT TRANSFORMERS.

IT IS OBVIOUS THAT THE DIFFERENTIAL PROTECTION DISCONNECT THE MACHINE ONLY IN THE CASE OF ELECTRICAL FAILURE IN THE MACHINE OR ITS CONNECTING LEADS.

CURRENT-DIFFERENTIAL PROTECTION OF STATION AUXILIARY FEEDER USING INDUCTION TYPE OVERLOAD RELAYS.

DIFFERENTIAL PROTECTION

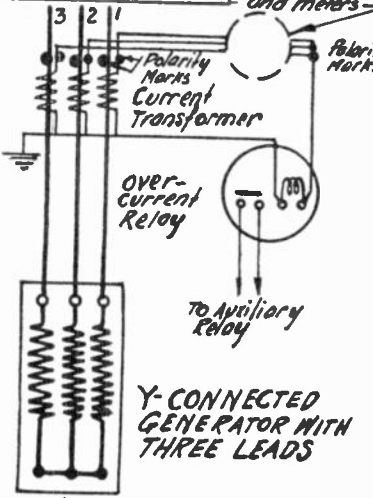


Fig. 1

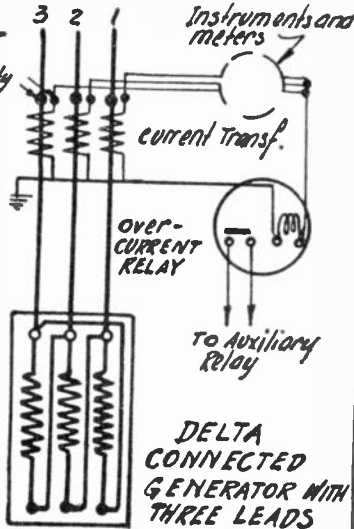


Fig. 2

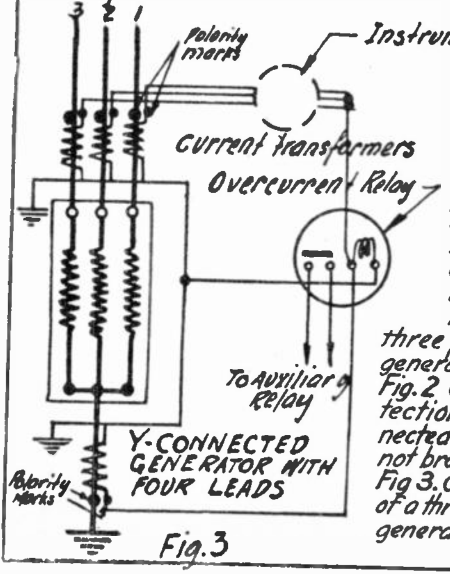


Fig. 3

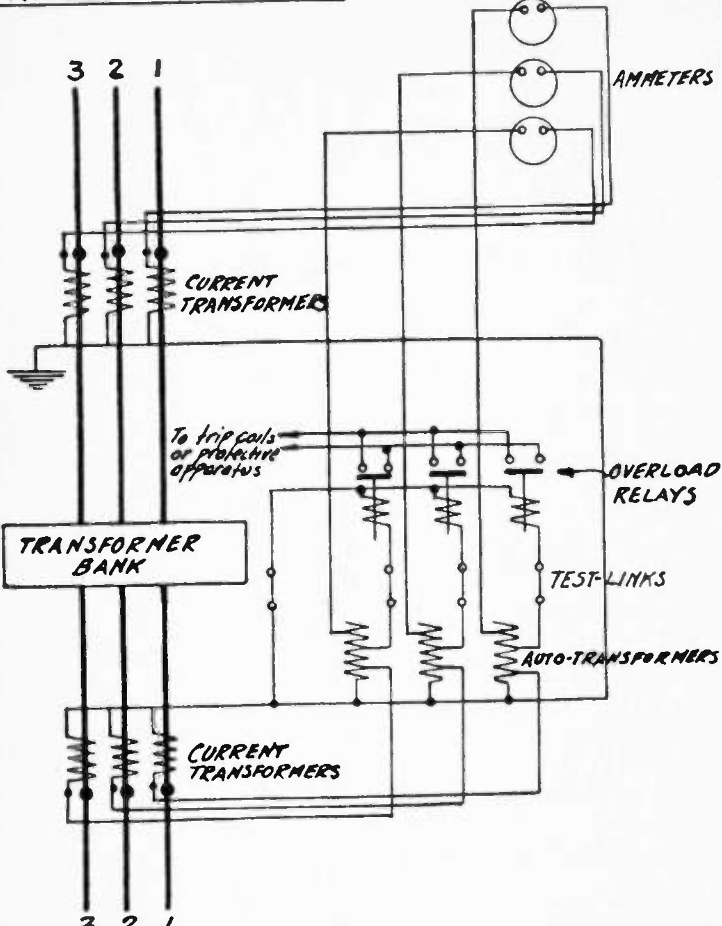
Method to obtain differential protection when such provision was not made in the Manufacture of the machine (where the phase leads were not brought out). Figs. 1, 2 and 3, show the connection used as expedients in such cases.

Fig. 1 shows current Differential protection of a three phase Y-connection A.C. generator, Neutral not brought out.

Fig. 2 Current differential protection of a three phase Δ-connected A.C. generator, phase leads not brought out.

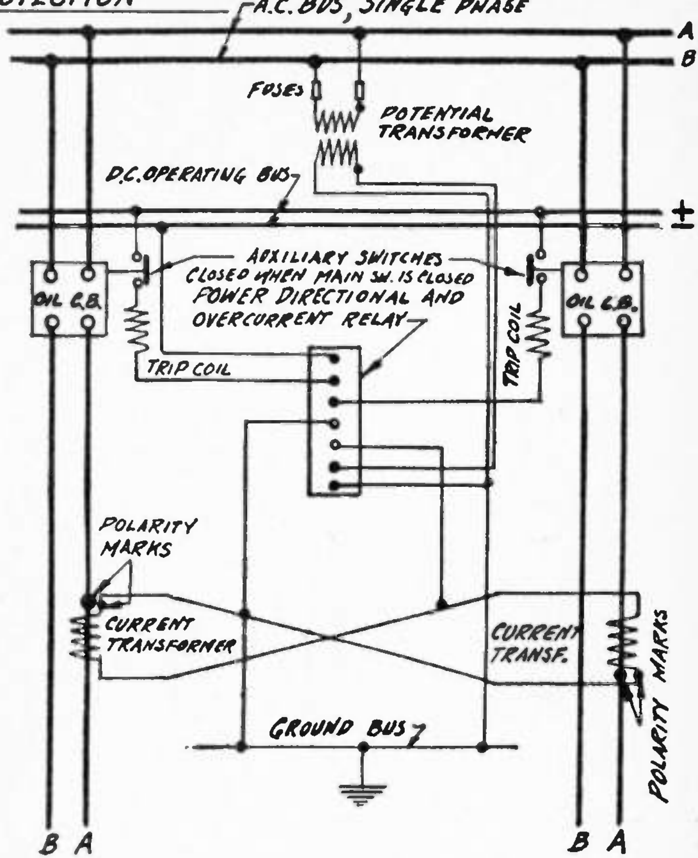
Fig 3. Current differential protection of a three phase Y-connected A.C. generator, Neutral only, brought out.

CURRENT-DIFFERENTIAL PROTECTION



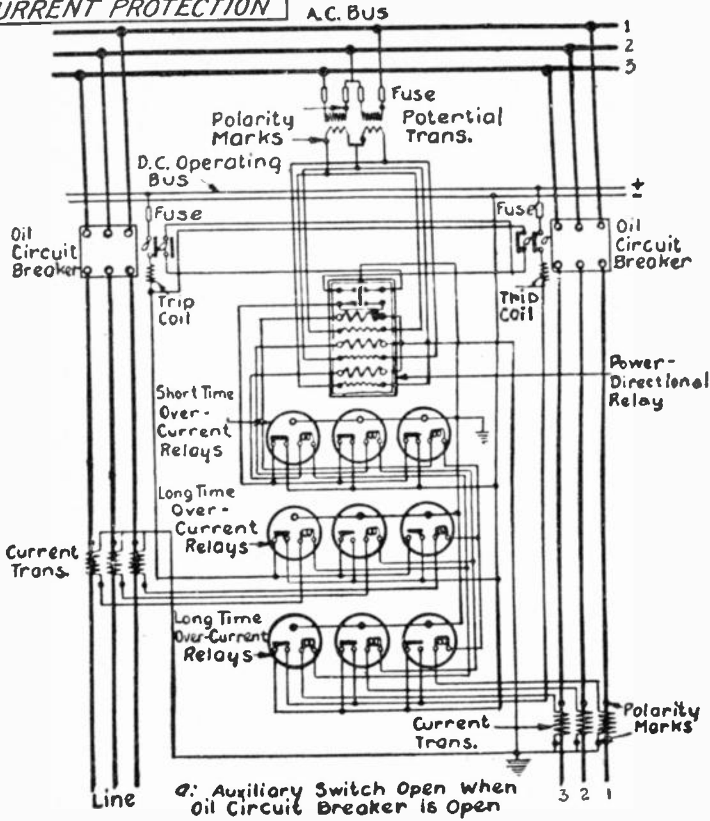
CURRENT DIFFERENTIAL PROTECTION OVER A TRANSFORMER BANK SHOWING APPLICATION OF TEST-LINKS, FACILITATING TESTING OF RELAY COILS.

BALANCED POWER PROTECTION



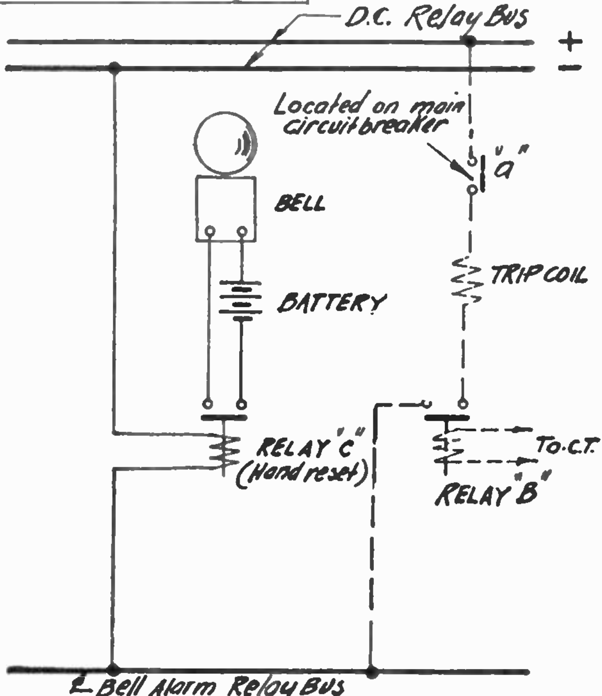
BALANCED POWER CONNECTION FOR TWO PARALLEL INCOMING, OUTGOING OR TIE LINES, SINGLE PHASE D.C. CURRENT USED FOR TRIPPING OIL CIRCUIT BREAKERS.

BALANCED AND OVER-CURRENT PROTECTION



Separate balanced and overcurrent pro-tection for two parallel Three phase incoming, outgoing or tie lines with grounded neutral.

BELL ALARM CONNECTIONS



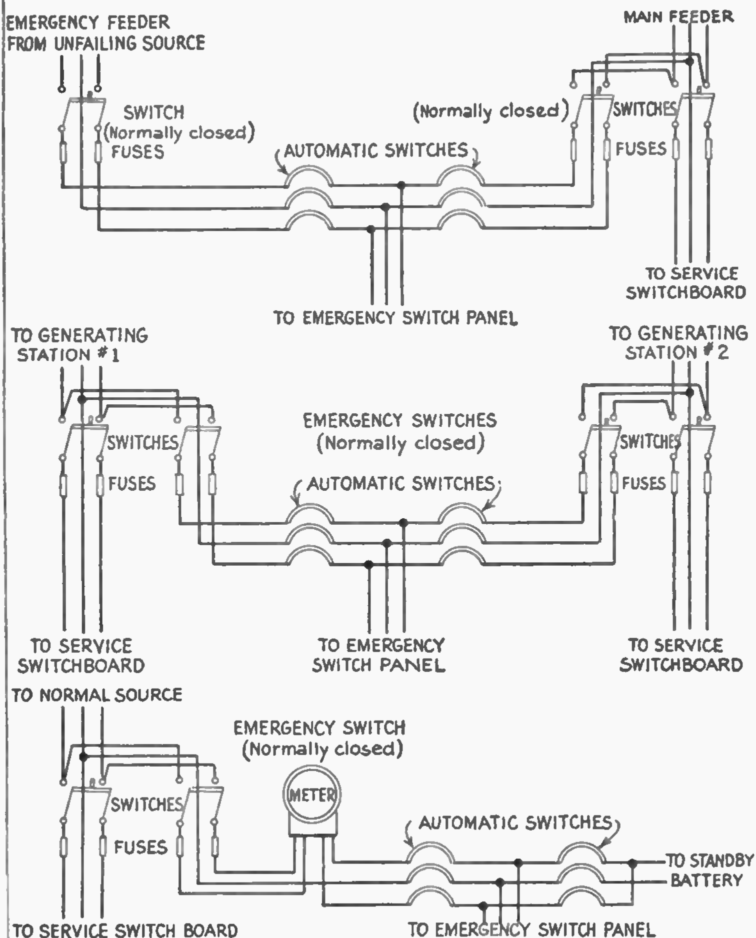
OPERATION

"a" = Auxiliary switch closed when main breaker is closed.

When current from transformer exceeds current setting of relay "B," the relay closes its contact energizing the trip coil, also energizing relay "C" which in turn closes the Battery circuit sending a current thru the bell giving an alarm to the operator, notifying him that the oil circuit breaker is out of service.

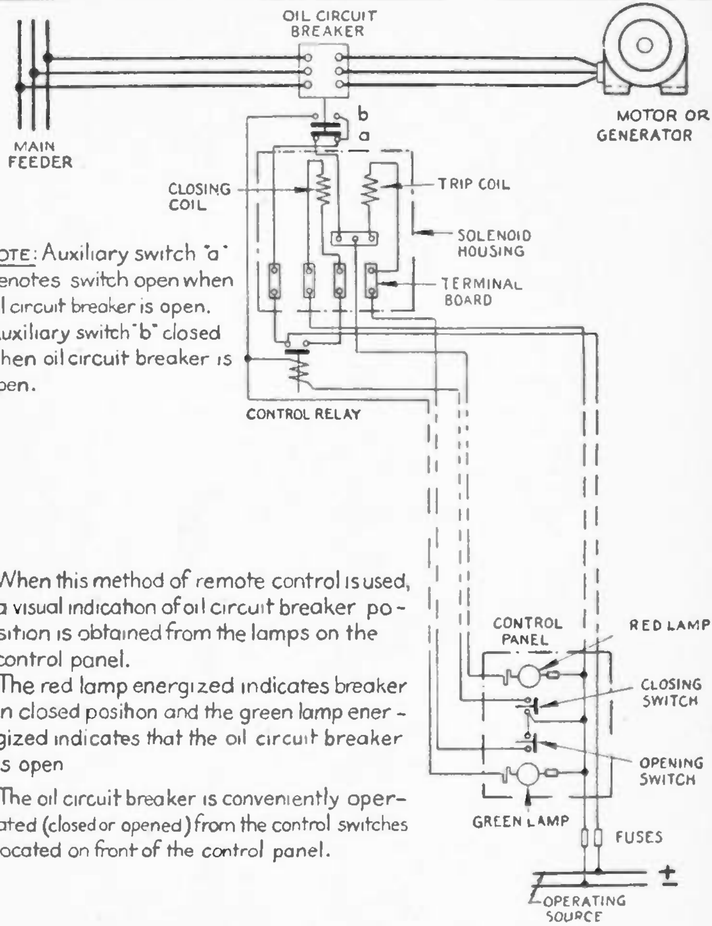
Note, that relay "C" is usually hand reset; and is reset for service by the attendant.

EMERGENCY SWITCHING METHODS



OPERATION: The above diagrams represent emergency switching methods generally utilized in public institutions such as HOSPITALS, SCHOOLS etc. where it is imperative that an unfailing lighting source be available. The automatic switches shown will automatically close themselves when the normal supply fails causing the service to remain uninterrupted.

REMOTE CONTROL WIRING FOR OIL CIRCUIT BREAKER (SOLENOID OPERATED TYPE)



NOTE: Auxiliary switch "a" denotes switch open when oil circuit breaker is open. Auxiliary switch "b" closed when oil circuit breaker is open.

When this method of remote control is used, a visual indication of oil circuit breaker position is obtained from the lamps on the control panel.

The red lamp energized indicates breaker in closed position and the green lamp energized indicates that the oil circuit breaker is open

The oil circuit breaker is conveniently operated (closed or opened) from the control switches located on front of the control panel.

VARIOUS SWITCHING METHODS

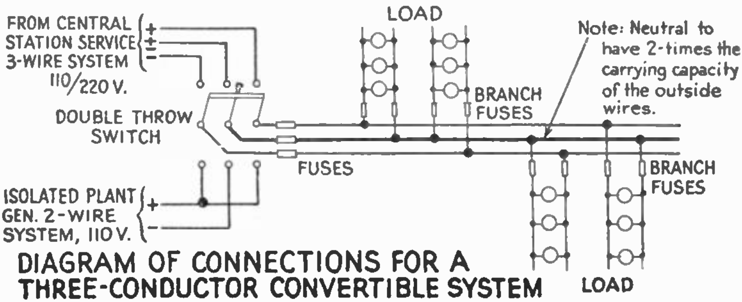
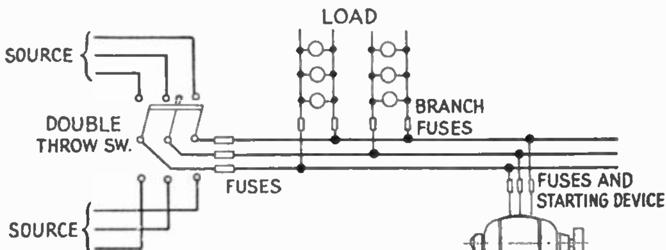
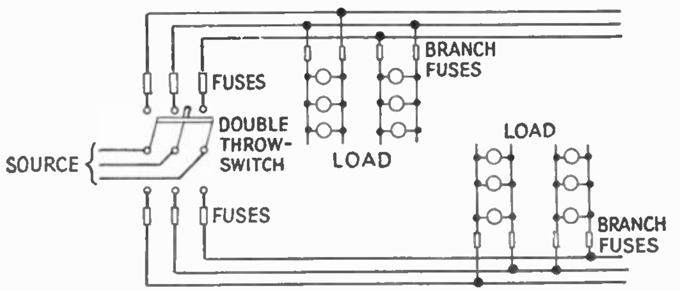


DIAGRAM OF CONNECTIONS FOR A THREE-CONDUCTOR CONVERTIBLE SYSTEM

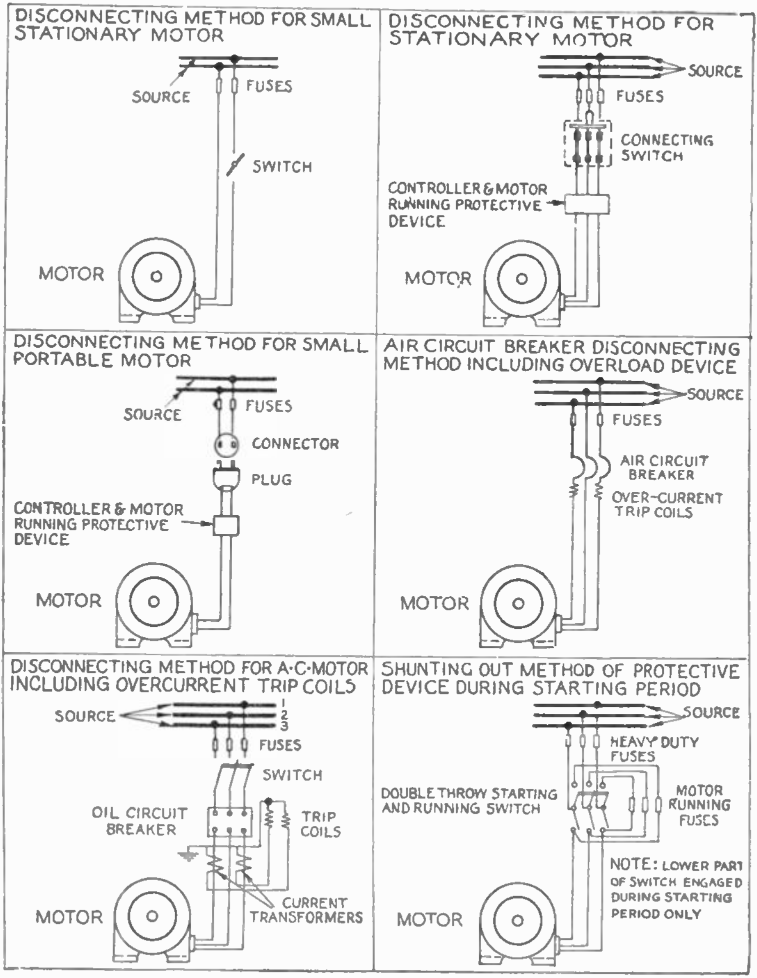


CONNECTIONS FOR UTILIZING EITHER OF TWO FEEDERS ALTERNATELY

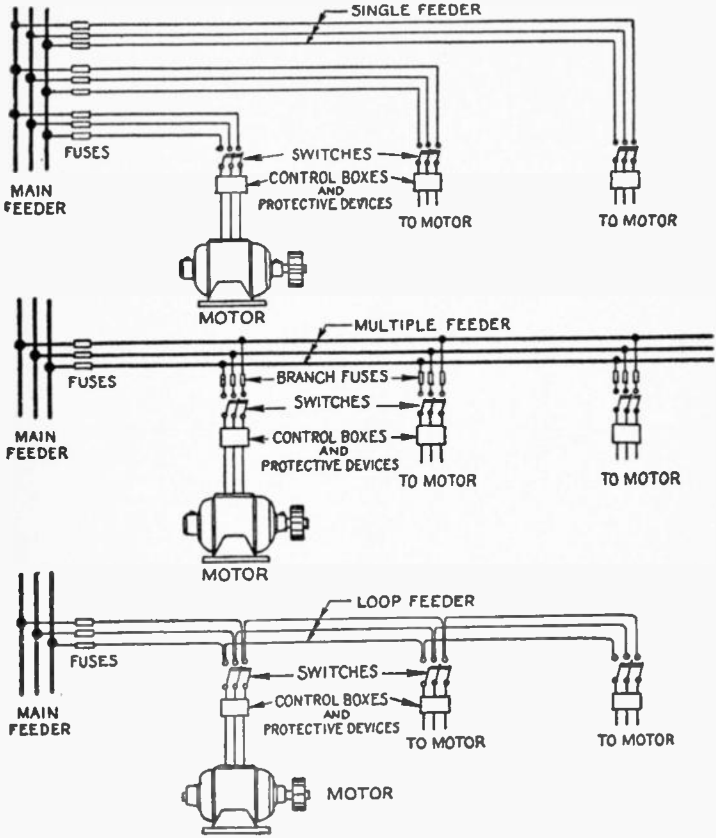


CONNECTIONS FOR FEEDING ALTERNATE LOADS FROM ONE SOURCE

MOTOR DISCONNECTING AND CONTROL METHODS

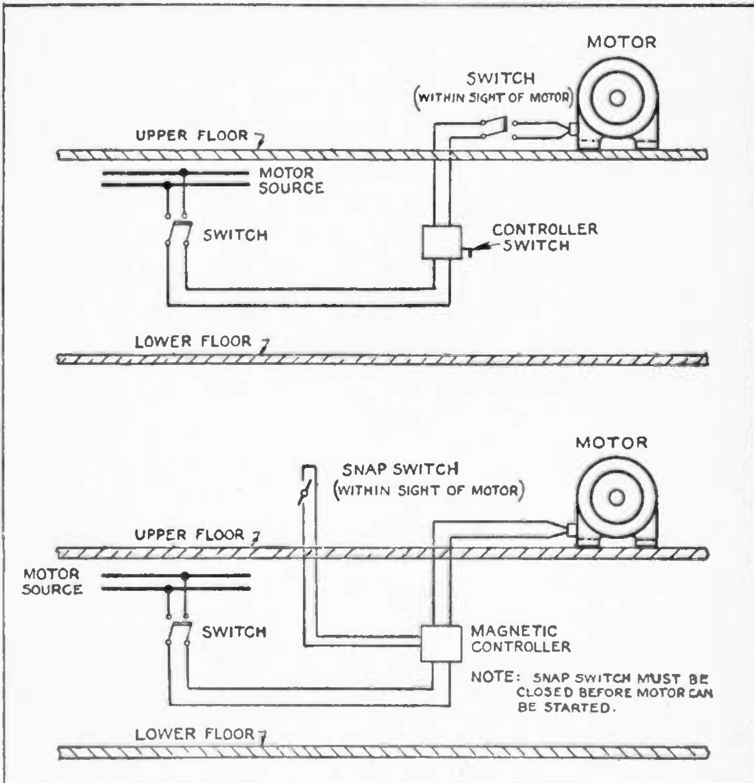


POWER DISTRIBUTION AND WIRING METHODS



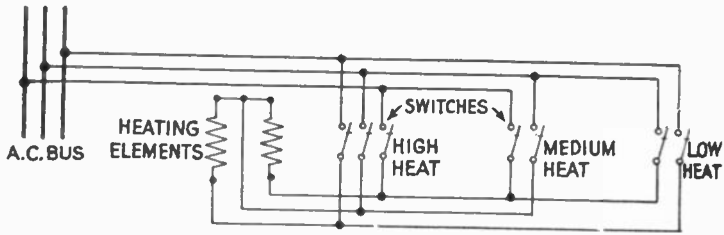
The above diagrams suggest three methods of motor wiring. However, due to individual operating conditions the type of wiring adopted should be carefully analyzed for the particular case involved. Certain applications for example by their very nature will prove themselves better suited for one scheme than the other. The **"National Electric Code"** as well as any local requirements should be strictly adhered to and the wire should be of ample capacity to prevent excessive voltage drops.

REMOTE CONTROL WIRING FOR SMALL MOTORS



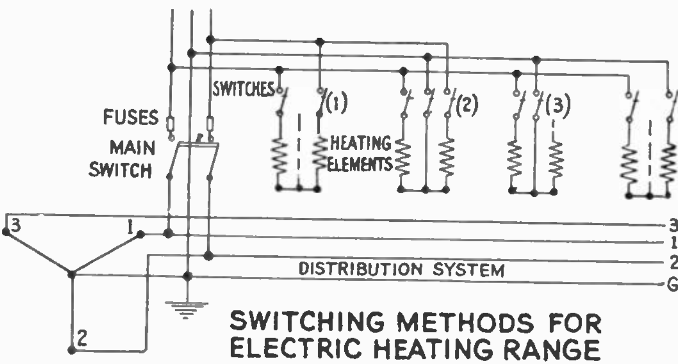
Note. All motors and control wiring should be carefully installed in accordance with the "**National Electric Code**" and any local requirement. The wire should be of ample capacity based on a maximum drop of 2 per cent of line voltage at full load current.

HEATING ELEMENTS ON THREE-PHASE SYSTEMS



METHOD OF CONNECTING HEATING ELEMENTS FOR VARIOUS DEGREES OF HEAT

To prevent exessive voltage drop in load systems containing heating elements several LOAD BALANCING switches may be utilized as shown. Maximum heating is provided when switches marked HIGH HEAT are closed. This is due to the fact that in this position of the switches both heating elements receive the maximum voltage.

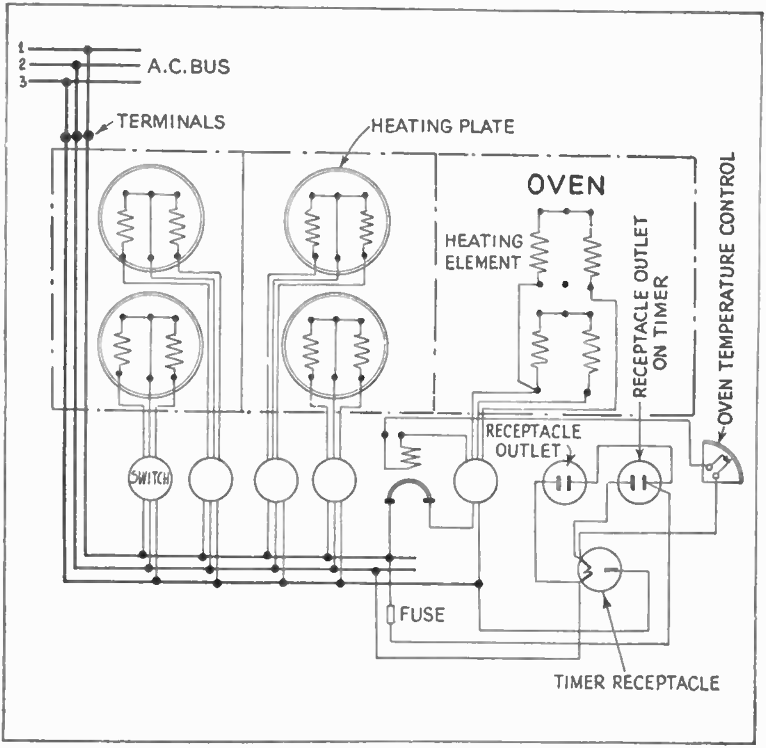


SWITCHING METHODS FOR ELECTRIC HEATING RANGE

When an electric heating range be connected as shown, the heat is regulated by connecting the heating element in various ways depending upon the amount of heat required.

Most heating ranges are connected as shown in (1) or (2) for HIGH HEAT and as in (3) and (4) for medium and low heat respectively.

DIAGRAM OF CONNECTION FOR ELECTRIC RANGE

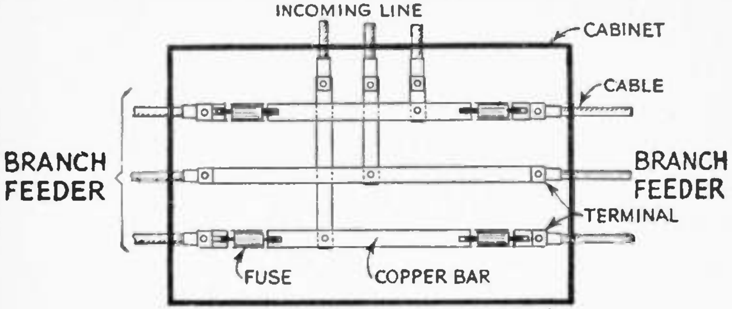


In a standard type of electric range such as that shown, the various heating elements are connected in such a manner that a nearly balanced load is established under all conditions of usage.

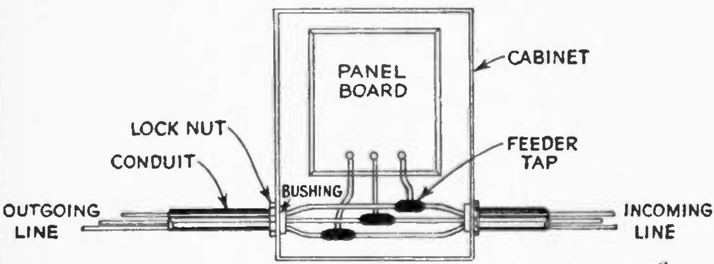
As each heating element is rated at less than 30 amp. each no fuses are required to protect the elements and their connecting wires except in the receptacle circuit, where an exterior appliance may be connected.

The wiring should be of an approved and sufficient size to supply the range at its rated wattage without overheating. Generally for a range rated at 7500 watts #8 wire is required.

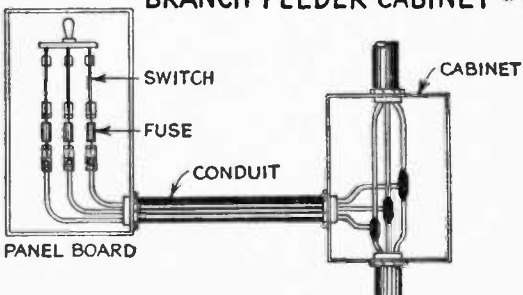
SWITCHING PANELS AND FEEDER DISTRIBUTION METHODS



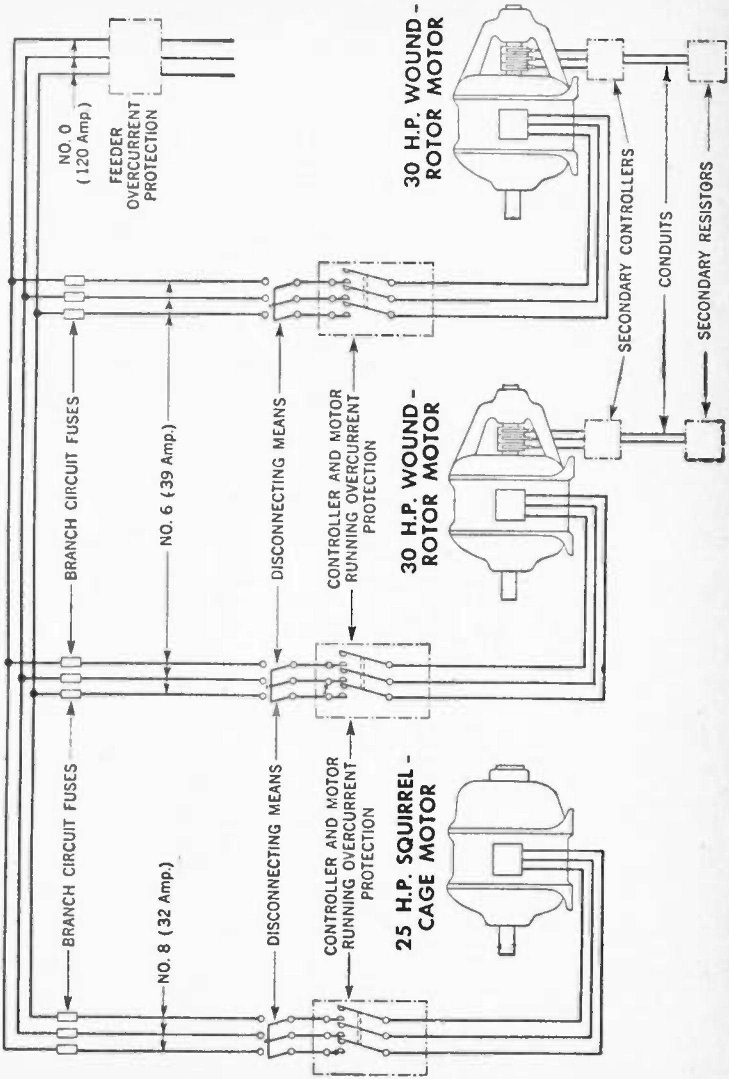
BRANCH FEEDER CABINET #1



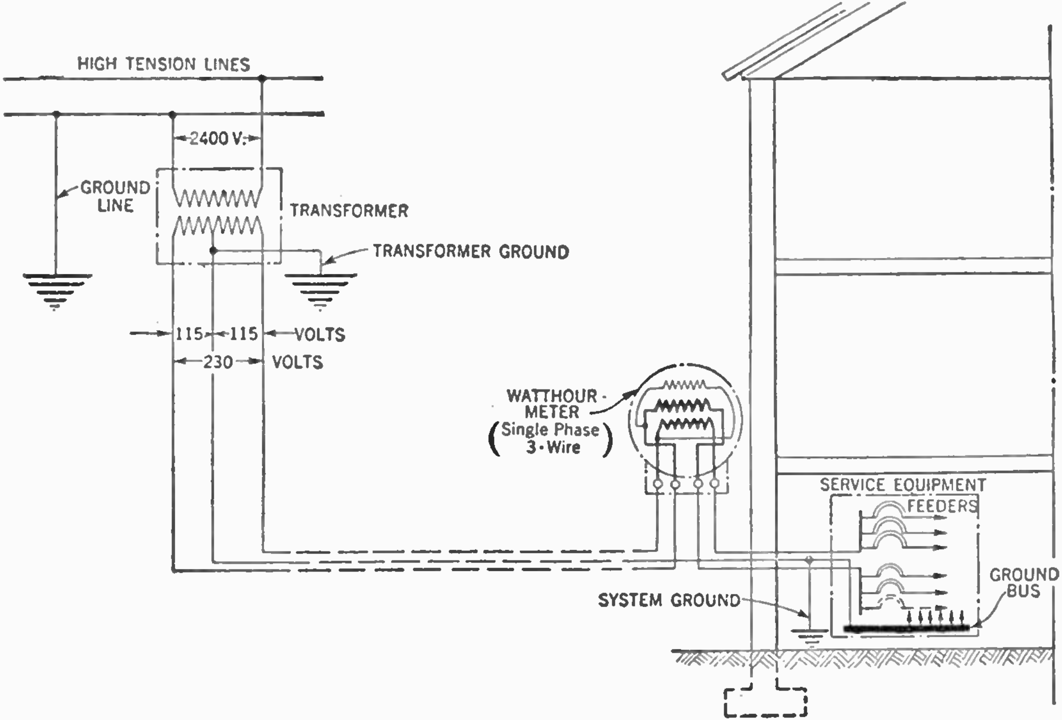
BRANCH FEEDER CABINET #2



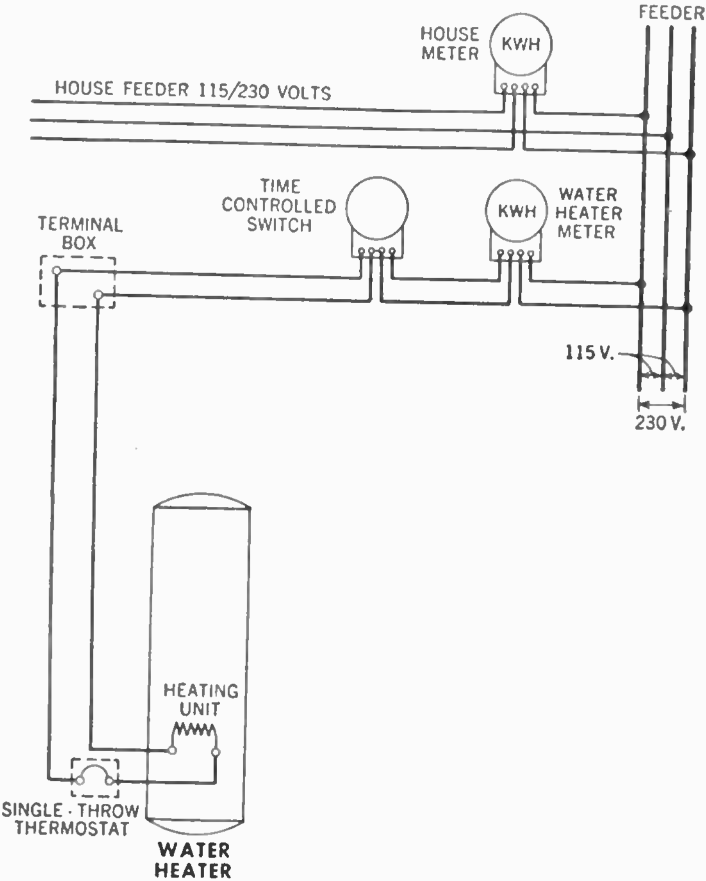
BRANCH FEEDER CABINET #3



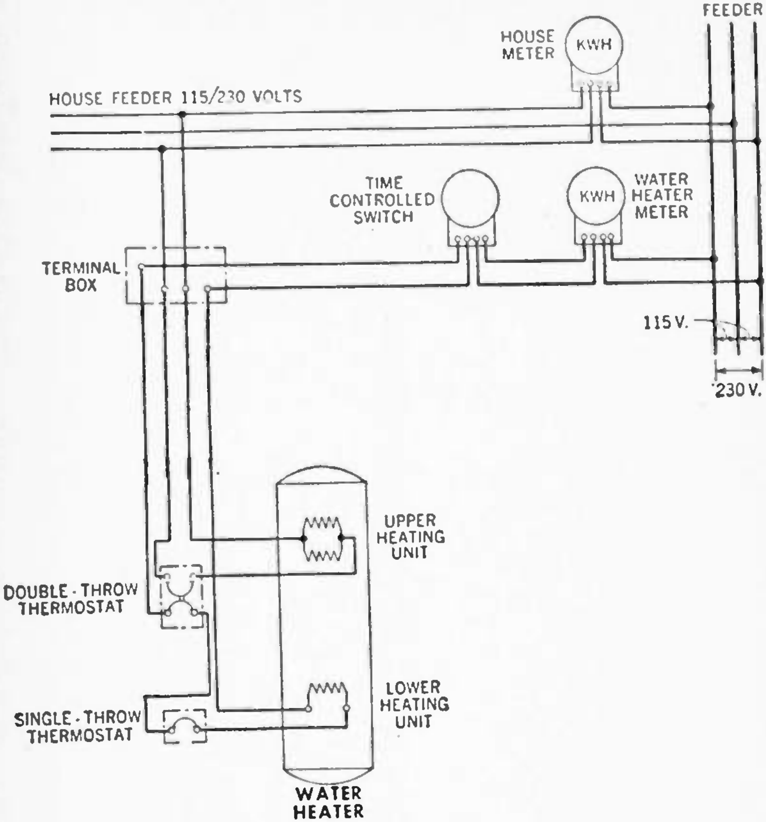
Wiring diagram showing individual branch circuits, feeder circuit and protective devices in a typical motor layout.



Schematic wiring diagram showing typical feeder layout and watthour meter connections for a single phase three wire 115/230 volt a.c. system.

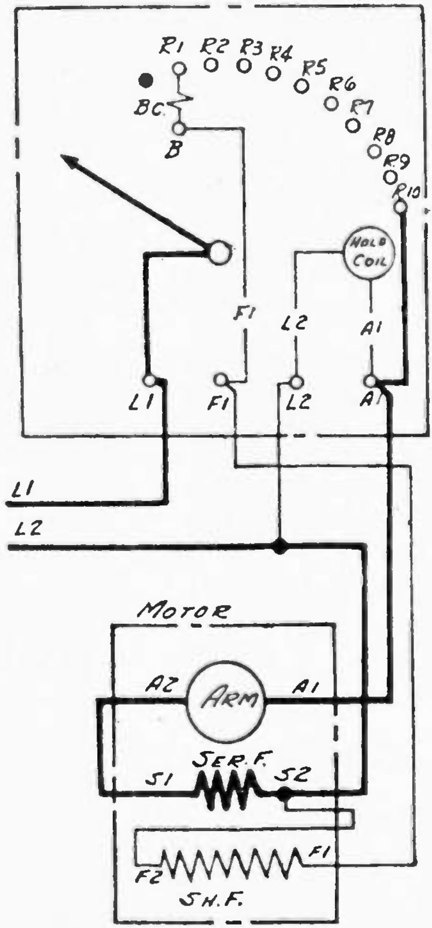


Wiring diagram for limited demand service on a single unit water heater. In a circuit of this type, the single throw, single pole thermostat functions to close and open the circuit to the heating unit, at specified temperatures according to its setting. The time controlled switch will determine the hours of the day when the circuit will be opened or closed, thus preventing unlimited use of hot water during the hours of greatest power load.



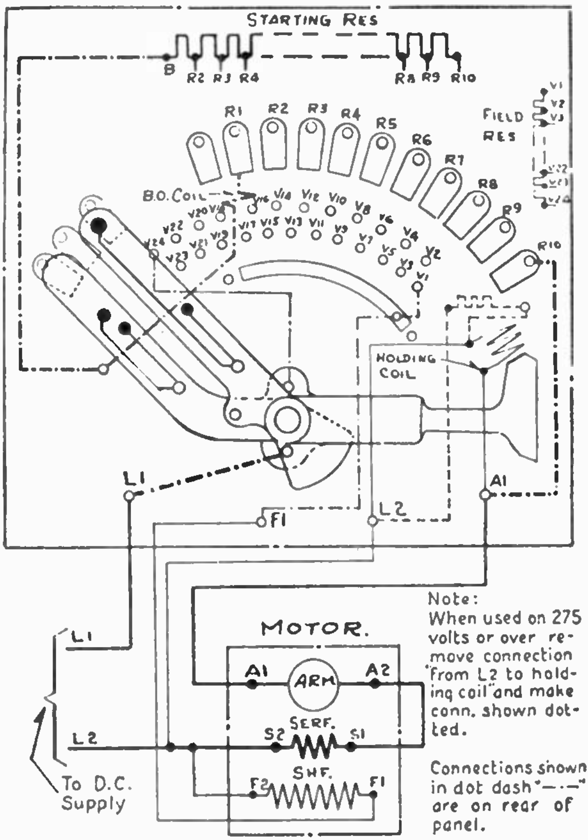
Wiring diagram for limited demand service on double-unit water heater. In a wiring method of this type the upper heating unit is controlled by a double throw single pole thermostatic switch. This switch has two sets of contacts, one of which controls the flow of current to the upper heating unit and the other controls the flow of current to the lower thermostat. The lower heating unit is controlled by a single throw, single pole thermostatic switch. This switch has only one set of contacts and opens and closes in response to the temperature of the water in the lower tank. The function of the time switch is to prevent unlimited use of hot water during a predetermined time (or times) usually during that period of the day when the general demand for power is the greatest.

CONNECTION DIAGRAMS FOR D.C. COMPOUND-WOUND MOTORS



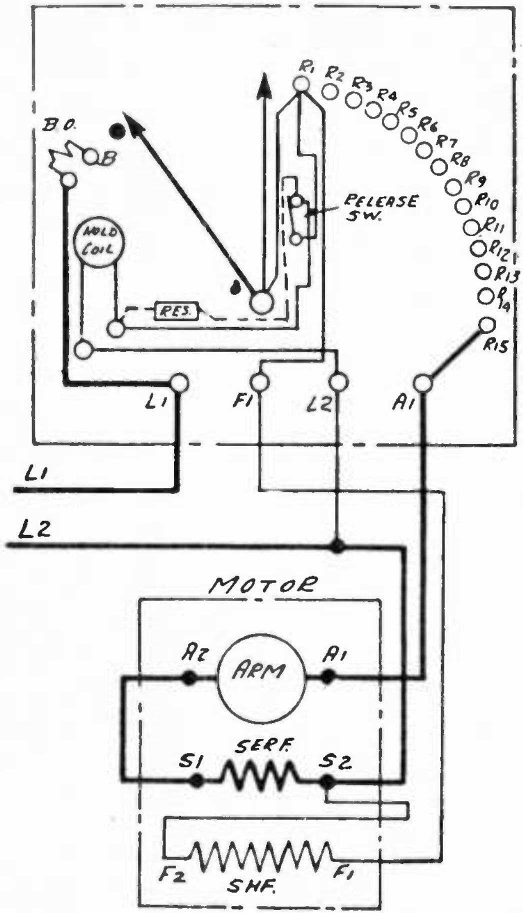
Typical wiring diagram showing connection of a compound-wound motor to its face plate starter. For shunt-wound motors the series field coil is omitted. This starter is used for *starting duty only.*

CONNECTION DIAGRAMS FOR D.C. COMPOUND-WOUND MOTORS



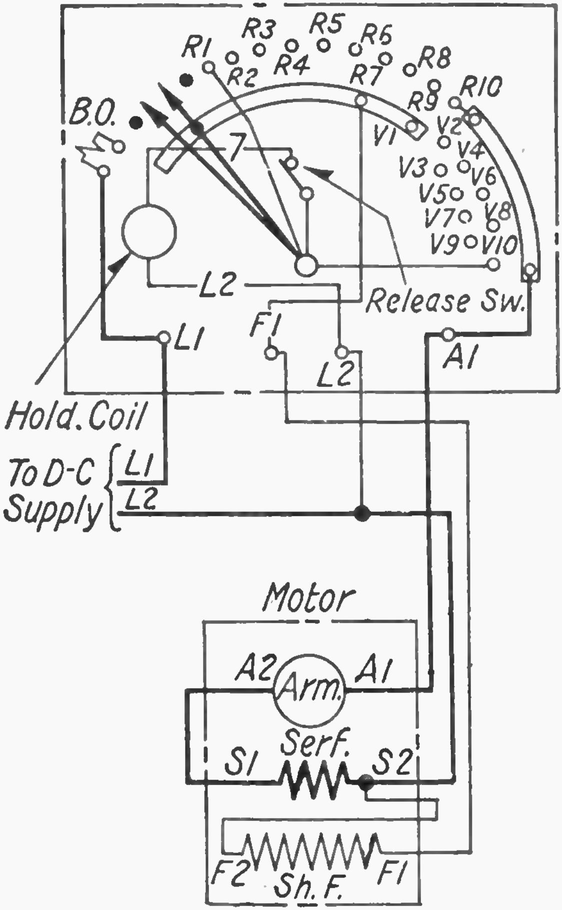
Typical wiring diagram showing connection of a compound-wound motor to its face plate starter. For shunt-wound motors the series field coil is omitted. This starter is used for *starting and speed regulating duty by field control only.*

CONNECTION DIAGRAMS FOR D.C. COMPOUND-WOUND MOTORS



Typical wiring diagram showing connection of a compound-wound motor to its face plate starter. For shunt-wound motors the series field coil is omitted. This starter is for speed regulating duty—*50% speed reduction by armature control.*

CONNECTION DIAGRAMS FOR D.C. COMPOUND-WOUND MOTORS



Typical wiring diagram showing connection of a compound-wound motor to its face plate starter. For shunt-wound motors the series field coil is omitted. This starter is used for speed regulating duty—*50% speed reduction by armature control and 25% increase by field control.*

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