Westinghouse
Automatic Railway Substation
Switching Equipment

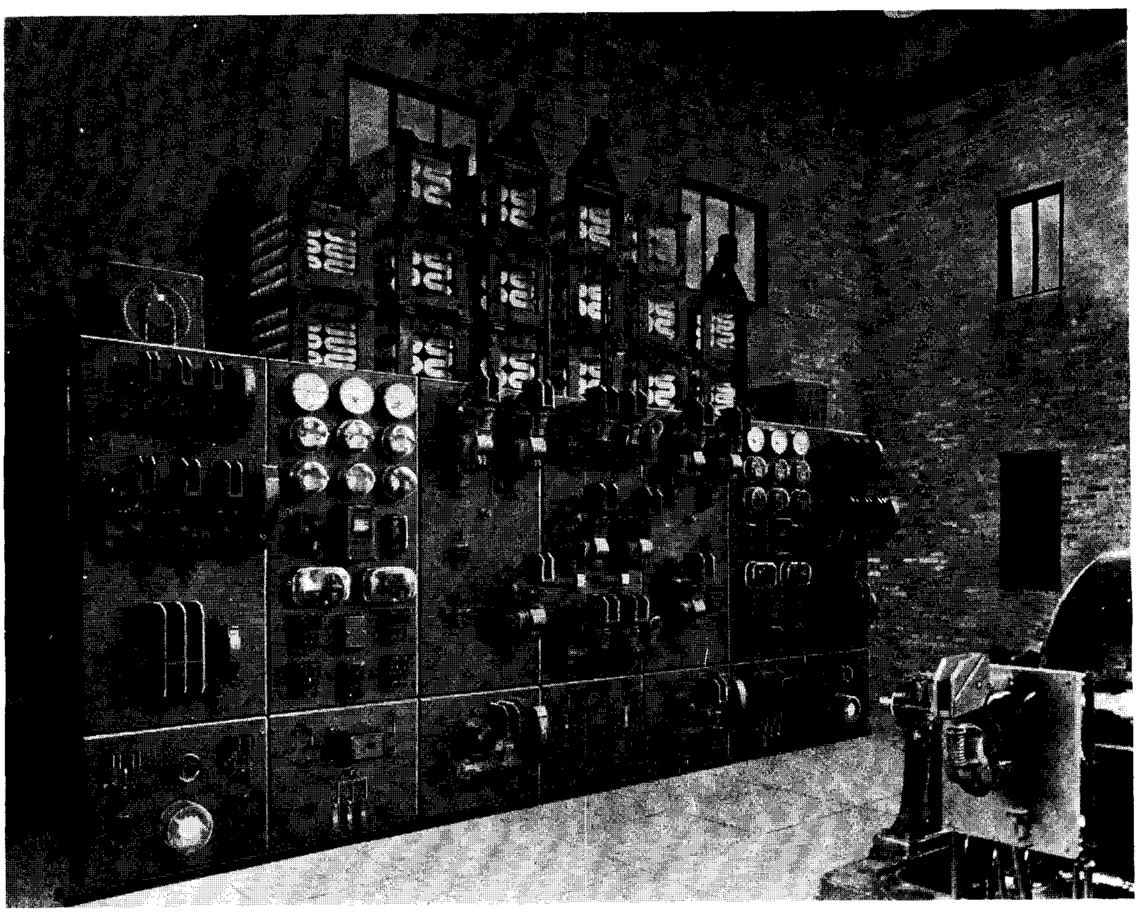


Fig. 1—Automatic Railway Substation with Two 500-Kw. Synchronous Converters.
The Milwaukee Electric Railway & Light Co., Waukesha Gravel Pit Substation.
(Center Panel Controls Two D-C. Feeders.)

INDEX

Westinghouse Automatic Railway Substation Switching Equipment

GENERAL INFORMATION

Application—

Automatic Substations are designed for:
A-C. Self-Starting Synchronous Converters
Motor Started Synchronous Converters
Synchronous Motor, D-C. Generator Sets
Induction Motor, D-C. Generator Sets
Synchronous Condensers
Hydro-Electric Generating Stations

This instruction book deals with the automatic equipment for synchronous converter railway substations. Both the control for the A-C. self started and for the motor started synchronous converters are described. The equipment is fully automatic, with the starting and stopping controlled entirely by the demand upon the system being fed by the substation. Semi-automatic equipment such as starting or stopping by the operation of a push button station at a remote point can be readily supplied, this being merely a simplification of the full automatic equipment.

Two or more machines in one station can be operated as successfully as a single unit. Each unit is supplied with practically a complete equipment as described herein. The first machine is started in the case of full automatic operation, by a low-voltage relay while the other machines are started by thermal relays which are set to operate when a given temperature is reached on the preceding machine, or by a timing device set in operation by a suddenly applied overload.

Capacities:

Practically any capacity and voltage desired can be taken care of by automatic equipment. Railway converter substations have been designed up to 1500 kw. 600 volts, D-C. This is usually the maximum capacity required but larger capacities can be readily taken care of by substituting larger oil circuit-breakers and contactors. Automatic equipment can also be readily supplied for machines of 1200 to 1500 Volt, D-C. for railway service.

Unpacking and Erection:

Panels are shipped separately with the contactors and most of the relays already mounted. The more sensitive relays and the meters are shipped in separate containers. These should be unpacked and mounted on panels after all other erecting work is completed.

Complete drawings and diagrams are shipped with equipment. If carefully followed no difficulty will be encountered in erection. If the erector has had little experience in switchboard erection he should study carefully Switchboard Instruction Book No. 5201, which is shipped with each switchboard, before proceeding with the work.

Reasonable care should be exercised in handling equipment as, although it is rugged and substantial, it can be thrown out of adjustment or broken by careless handling.

All instructions on tags and cards sent with individual apparatus should be carefully followed.

Wiring:

It will be noted that the cross connections between panels are very easily accomplished, as the terminals to be connected are adjacent to each other and are similarly lettered. The wires to the conduits are few and are so located that they can be easily run into the conduits. Figure 2 illustrates the simplicity of the external wiring that must be done in erection.

AUTOMATIC CONTROL FOR A-C. SELF STARTING SYNCHRONOUS CONVERTERS FOR RAILWAY SERVICE.

ARRANGEMENT:

Control Panels.

As a rule it will be found very advantageous to mount the switchboard control panels together. (Fig 7.) This permits connections between panels without going through conduit, making a simple compact arrangement, easy to erect and to maintain. For a single unit with a single outgoing D-C. feeder, only three panels are required, a relay panel, (Fig. 3), a D-C. contactor panel (Fig. 3) and an A-C. Starting and Running contactor panel (Fig. 4). Each machine requires practically duplicate equipment. All panels should be

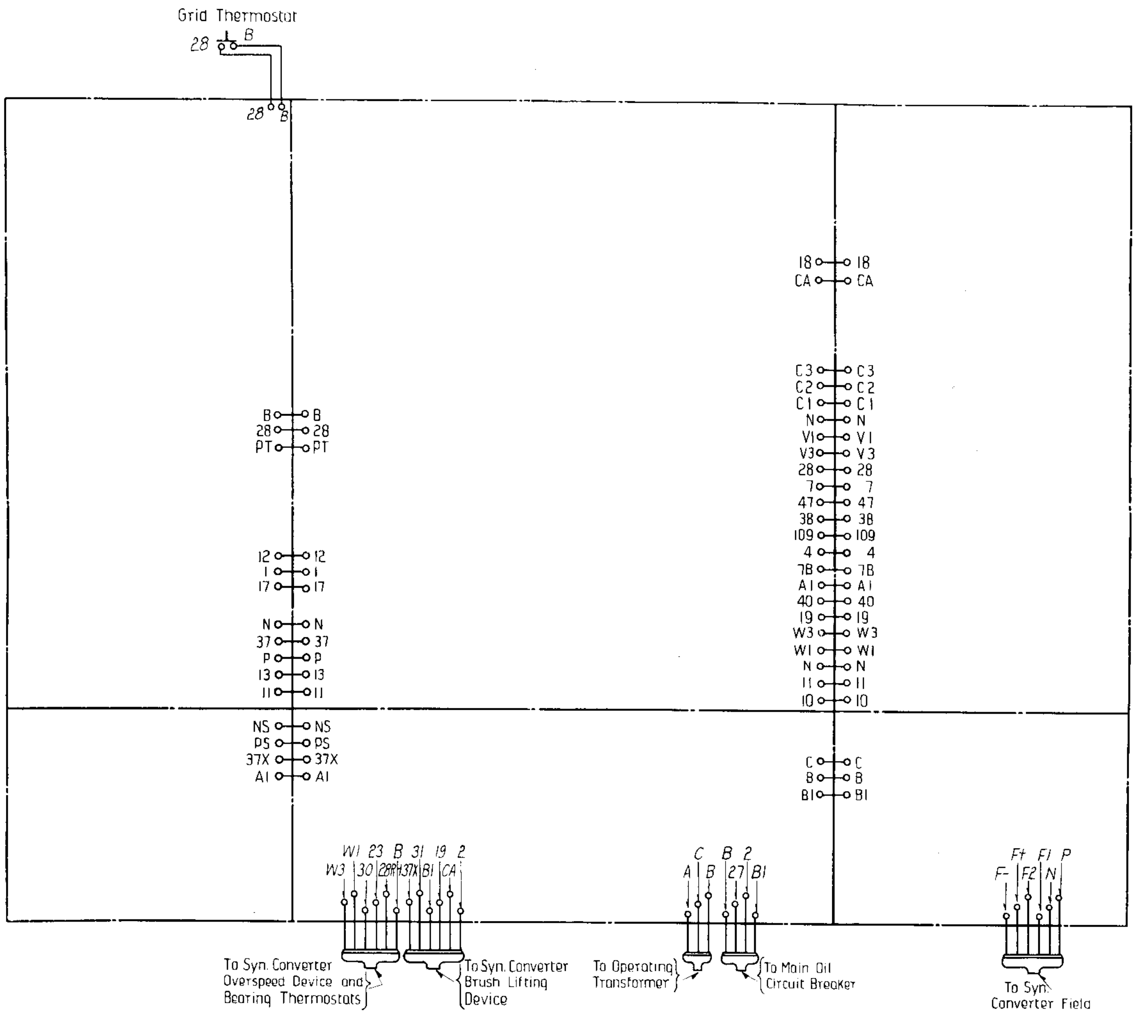


Fig. 2—External Wiring Diagram showing control wire connections between panels, and conduit wires required on a typical switchboard for the control of a 500 kilowatt railway synchronous converter.

erected according to the assembly drawings, shipped with the apparatus, as the connections have all been arranged in accordance with these.

Feeder Panels.

If more than one feeder is installed, a feeder panel for each feeder or pair for feeders is necessary. (Fig. 1).

Resistors.

Above or behind the D-C. panel should be located the grid resistors as illustrated in Fig. 5. These resistors are used for limiting the D-C. current to a safe value in case of overload and are inserted into the circuit by the opening of the Resistance Shunting Contactors located on the D-C. contactor panel. Resistance is also used in the feeder circuits, (which should be located near the feeder panels) and is inserted into the individual feeder circuits by means of the contactors on the feeder panels. In each of these resistor sections must be located a thermostat which protects them from over heating. Thermostats are shipped ready to attach to mounting plates, suitable for fastening to the top of the grids as illustrated in (Fig. 41.)

Main Circuit-Breaker.

The main oil circuit-breaker is electrically operated and is either mounted on a panel of its own (Fig. 32) or else in a pipe or cell structure. When mounted on a panel the breaker mechanism is shipped as a unit with the panel ,the breaker unit itself being shipped

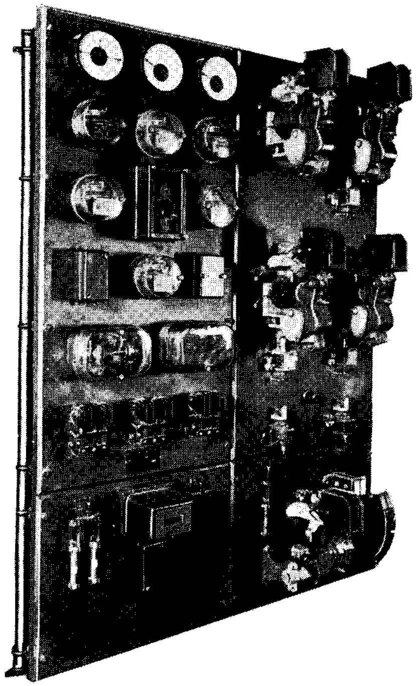


Fig. 3—Relay and D-C. Contactor Panels

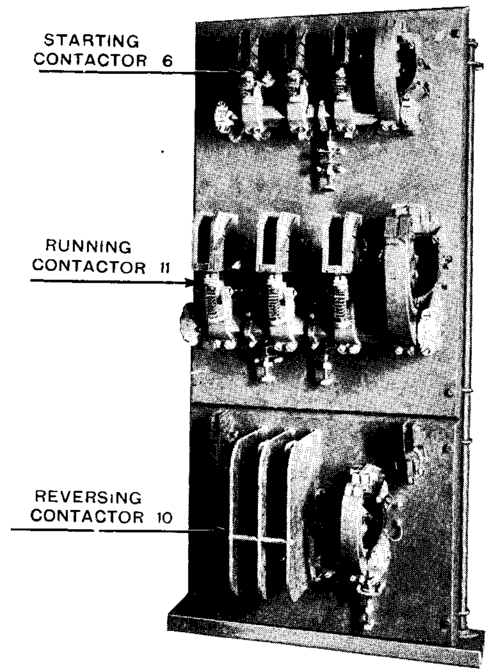


Fig. 4—A-C. Starting and Running Contactor Panel

separately. If it is cell or pipe mounted, assembly drawings will be usually supplied and the breakers will be shipped with the necessary fittings.

Machine Overspeed & Bearing Protection.

The converter is equipped with an overspeed device mounted on the end of the shaft. Each bearing is also supplied with a thermostat to provide against overheating.

Brush Lifting Device (Fig. 6.)

With the modern interpole converter of 300 kw. capacity and above, it is necessary to raise the brushes off the commutator when starting in order to prevent sparking. To accomplish this a brush lifting device is required. This consists of a motor, connected through gear reduction and levers, to the brush arm ring which upon revolving causes the brushes to lift off or lower on to the commutator. The motor, reduction gearing and drum, carrying interlocks, are mounted in a suitable housing on the bed plate of the converter (Fig. 6.) The brush lifting device is shipped mounted on the converter while the bearing thermostats are shipped separately to avoid possible breakage in shipment.

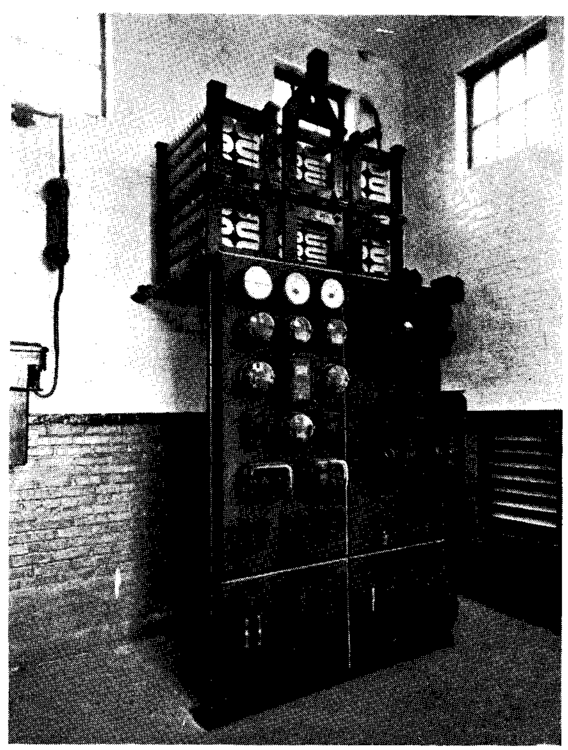


Fig. 5—D-C. Grid Resistor Arrangement

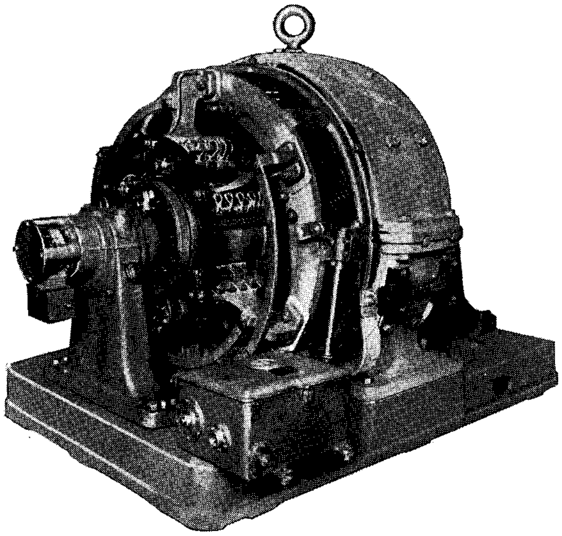


Fig. 6—Brush Lifting Device mounted on Converter Bedplate

Rheostat.

The field rheostat can be located in any convenient place as it can be set in the proper position and thereafter will not require adjustment. When the station is first put into operation the rheostat should be adjusted until the best power factor is obtained. This place should then be marked and thereafter the rheostat can be left in this position.

Main Connection:

Connections between contactors are made on the panels by means of copper strap. If bus bar is required it will usually be furnished by the manufacturer with the necessary clamps, and supports and should be erected strictly in accordance with the assembly drawing. Terminals are supplied for connecting the cable to the copper. Cable supports are not generally supplied but it is **very important that in erection all cable be substantially supported so that its weight is not carried by the copper strap or panels.** All connections should be carefully cleaned before making and clamp connections should be tight.

NOMENCLATURE—DIAGRAMS—SEQUENCE CHARTS.

Each relay, contactor and operating device which has a function to perform is identified by a number. This number is used thruout this book and corresponds to the numbers shown on the diagrams shipped with the apparatus. The diagrams and the explanation of the principle of operations in this book are typical for the application covered.

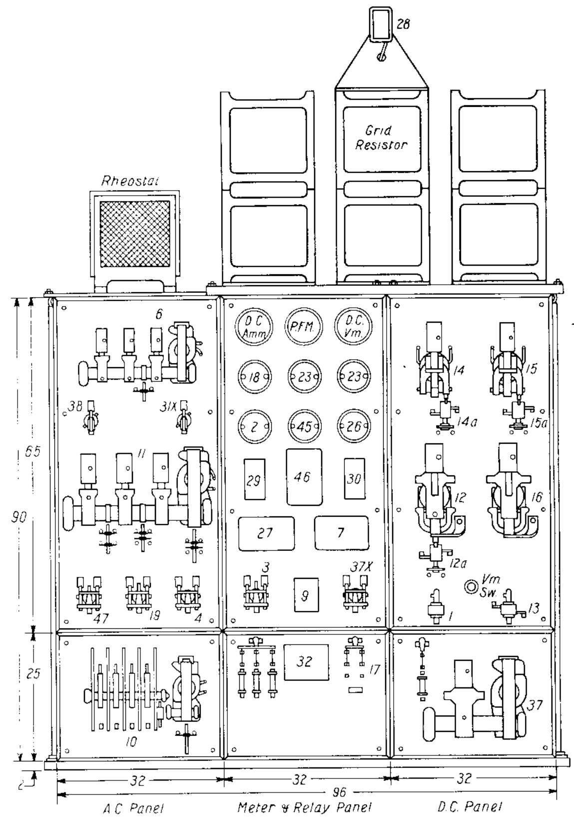


Fig. 7—Three Panel Switchboard for the control of a Railway Synchronous Converter with a Single D-C. Feeder

Switchboard for A-C. Self-Starting Synchronous Converter

1 Undervoltage D-C. Relay
2 Low Voltage Delay A-C. Relay
3 Master Relay
4 Starting Contactor Relay
6 A-C. Starting Contactor
7 D-C. Polarized Motor Relay
9 Field Contactor Relay
10 Field Reversing Contactor
11 A-C. Running Contactor
12 D-C. Line Contactor
12-a, 14-a, 15-a D-C. Overload Relay
13 D-C. Underload Relay
14, 15, 16 D-C. Resistance Shunting Contactors
17 S. P. D. T. Knife Switch
18 Reverse Phase and Low Voltage A-C. Relay
19 A-C. Shunt Relay
23 A-C. Overload Relays
27 Underload Delay Relay
28 Grid Thermostat
29 Thermal Overload Relay
30 Lockout Relay
32 D-C. Reverse Current Relay
37 D-C. Line Contactor
37-x D-C. Line Contactor Relay
38 Field Current Relay (Low Tension Protection)
45 Phase Balance Relay
46 Phase Balance Relay (High Tension Protection)
47 A-C. Shunt Relay (Corresponds to 5 in Fig. 8)

Particular installations may differ in details but once the scheme is understood, the operation of a particular substation may be quickly grasped by the study of the schematic diagrams and sequence chart sent out with the equipment.

In the explanation of the method of operation the wiring diagram Fig. 8 should be carefully followed. The schematic diagram Fig. 9, is intended only to enable a person to readily see the interlocks between the devices and should be studied in connection with the sequence chart. It is of great value in checking thru the various sequences but need not be followed in connection with the explanation.

A-C. SELF STARTING SYNCHRONOUS CONVERTERS.

Principle of Operation:

Interconnections of the control devices for a self starting commutating pole converter are shown in the diagram, Fig. 8. In it is shown only the apparatus required in the sequence of operation, the various protective devices being omitted. These are described later under "PROTECTIVE FEATURES." The numbers in parentheses indicate the device referred to and correspond to those used on the diagram and the sequence chart shown in Figs. 9 and 10. The operation numbers refer to those on the sequence chart.

Starting:

A car or train enters the zone of any station which at that instant is idle. As the train approaches the station, the trolley voltage at the station is reduced. The single pole, double throw knife switch (17) is closed in the "automatic" position, thereby permitting the station to start up automatically.

Operation 1.

When the trolley voltage falls to a predetermined value, for example, to 75% of normal or below, the contact of undervoltage D-C. relay (1) in the trolley circuit closes. As a result A-C. low voltage delay relay (2) is energized from the operating transformer as follows: From Bus-A through the auxiliary switch on breaker (20), (closed when the breaker is open) through the low voltage relay (2), through the contact of relay (1) to Bus-B.

Operation 2.

At the end of a definite time interval, which may be adjusted from instantaneous to 5 seconds or longer in special cases, the contacts of relay (2) close. This time interval prevents the station starting in case of momentary lowering of the trolley voltage.

Operation 3.

The closing of relay (2) energizes master relay (3-a) as follows: From Bus-B through the contacts (A) of relay (7) through relay (2), through the operating coil of relay (3-a), through a resistance to Bus-A.

Operation 4.

Master relay (3-a) closing, energizes A-C. shunt relay (3), which on closing, completes the holding circuit of master relay (3-a) so that it will remain closed regardless of whether relay (2) opens or not. This makes further functioning of the control apparatus independent of the trolley voltage. The closing of relay (3) energizes auxiliary bus (A-1). Master relay (3-a) also energizes the relay (31-a) of the brush lifting device as follows: From Bus-A through the contacts of relay (3-a), through an interlock on running contactor (11) (closed when the contactor is open) through a limit switch (31-L) on the brush lifting device (closed except when the brushes are in the full up position) through the control relay coil (31-a) to Bus-B.

Operation 5.

The control relay (31-a) in turn energizes the motor of the brush lifting motor device (31) causing this to operate until the brushes are fully lifted from the commutator of the converter. The limit switch opens at this point, de-energizing the control relay (31-a), thereby stopping the motor. An interlock (31-U) on the brush lifting device closes when the brushes are fully lifted. This causes starting contactor relay (4) to be energized as follows: From Bus-B through the interlock (31-U), through the operating coil of relay (4), through the interlocks of relay (19) and running contactor (11) (closed when these contactors are open) to Bus-A-1.

Operation 6.

The closing of starting contactor relay (4) energizes the operating coil of starting contactor (6) as follows: From bus-B, through the interlock (31-U) on the brush lifting device, through relay (4), through the coil of contactor (6) to Bus-A-1. Another contact of relay (4) causes the control relay (21) of the main oil circuit-breaker to close.

Operation 7.

This in turn energizes the main oil circuit-breaker contactor (22) which energizes the solenoid (20) of the breaker and causes the breaker to close.

Operation 8.

The breaker latches in on closing, at the same time energizing the low voltage relay

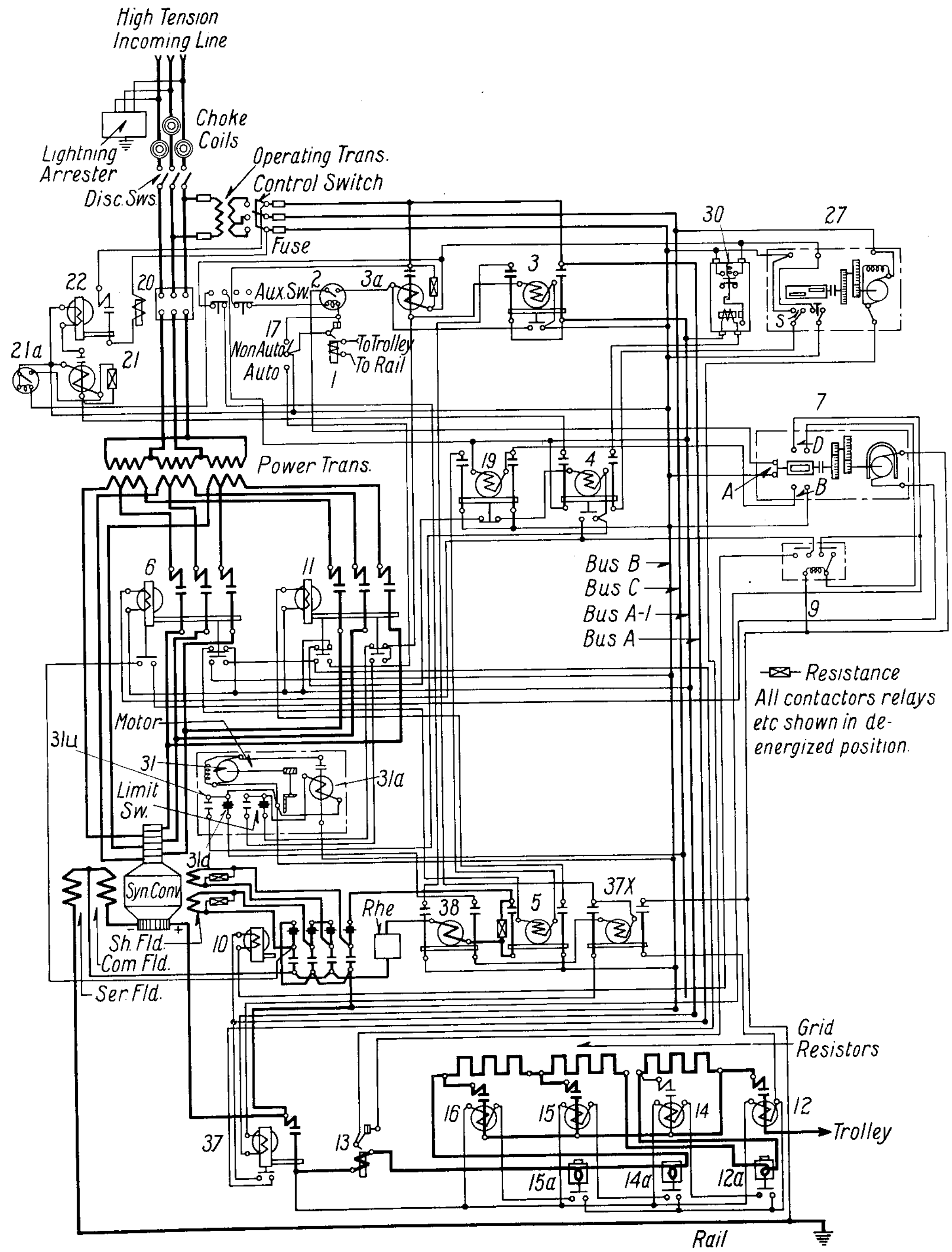


Fig. 8—Diagram of Connections for A-C. Self-Starting Synchronous Converter

1	Undervoltage D-C. Relay
2	Low Voltage Delay A-C. Relay
3-a	Master Relay
3	Auxiliary Master Relay
4	Starting Contactor Relay
5	A-C. Shunt Relay
6	A-C. Starting Contactor
7	D-C. Polarized Motor Relay
9	Field Contactor Relay
10	Field Reversing Contactor
11	A-C. Running Contactor
12	D-C. Line Contactor
12-a,14-a,15-a	D-C. Overload Relay
13	D-C. Underload Relay
14,15,16	D-C. Resistance Shunting Contactor
17	S. P. D. T. Knife Switch
19	A-C. Shunt Relay
20	Oil Circuit Breaker—(solenoid operated)
21	Circuit Breaker Control Relay
21-a	Low Voltage A-C. Relay
22	Circuit Breaker Contactor
27	Underload Delay Relay
27-S	Contacts closed in 2 minutes
27-T	Contact closed in from 3 to 30 minutes
30	Lockout Relay
31	Brush Lifting Device Motor
31-d	Interlock closed with brushes down
31-u	Interlock closed with brushes up
31-a	Brush Lifting Device Relay
37	D-C. Line Contactor
37-X	D-C. Line Contactor Relay
38	Field Current Relay

(21-a). After a short interval this closes, short circuiting the coil of relay (21) which drops open and de-energizes the closing coil circuit of the breaker. The breaker is now held closed only by means of the latch.

Operation 9.

The starting contactor (6) and the main oil circuit-breaker (20) now being closed causes the converter to start on reduced voltage. The field contactor (10) is normally closed in the position shown. If the polarity of the converter builds up in the wrong direction, it is necessary to reverse the field to cause the converter to slip a pole. To accomplish this, polarized motor relay (7) is used.

This relay is driven by a D-C. motor having a permanent magnet field. In starting, so long as the starting contactor (6) is closed, it will be noted that the motor is connected to the D-C. side of the converter (through the field contactor (10), and the interlock on contactor (6)). Until the converter pulls into step, alternating current is delivered to the motor armature of this relay, causing it to oscillate. When the converter is in step, direct current is delivered to the armature, causing it to rotate in a direction dependent upon the polarity of the converter. The motor drives, through gears and a magnetic clutch, a drum which when rotating counter clock-wise, causes a set of contacts (7-B) to close; if rotated clockwise, it causes another set of contacts (7-D) to close. A third set of contacts (7-A) is open when the motor starts to revolve. As soon as the motor stops the clutch disengages and contact (7-B) or (7-D) is opened and contact (7-A) is closed by means of a spring return.

Assuming that the polarity is incorrect, the polarized motor relay (7) rotates counter clock-wise until contact (7-D) is closed.

Operation 10.

This energizes the field contactor relay (9) which on closing completes its own holding circuit.

Operation 11.

Field contactor relay (9) closed, energizes the operating coil of the field contactor (10) as follows: From Bus-A-1 through the coil of field contactor (10), through relay (9), through the interlock of relay (4) (closed when relay (4) is closed) through the interlock (31-U) of brush lifting device to Bus-B). This causes the field contactor (10) to throw to the other side and reverse the field connections. Under these conditions, the converter voltage drops to zero. It will be noted that the field winding is broken up into two parts which are paralleled on reversing. This insures rapid operation.

Operation 12.

Zero voltage de-energizes relay (9) (as its closing coil is energized from D-C. terminals of the converter) which thereupon allows field contactor (10) to return to its normal position. This operation corrects the polarity.

Operation 13.

The polarized motor relay (7) now rotates in a clock-wise direction until contact (7-B) is closed. This causes the A-C. shunt relay (19) to close, which on closing completes its holding circuit.

Operation 14.

Relay (19) closing, opens an interlock which in turn de-energizes the coil of relay (4). This causes starting contactor (6) to open. The polarized motor relay (7) is similarly cut out of the circuit by contactor (6) opening.

Operation 15.

Running contactor relay (5) is now energized as follows: From Bus-B through the contact of relay (19) through the coil of relay (5), through the interlock of contactor (6) (closed when the contactor opens) to Bus-A-1.

Operation 16.

Relay (S) closing energizes the coil of A-C. running contactor (11) which connects the converter to the running taps of the power transformer. The converter is now running light with correct polarity and is ready to take load as soon as the brushes are lowered.

Operation 17.

When running contactor (11) is closed the brush lifting control relay (31-a) is again energized as follows:—From Bus-A through the contact on relay (3-a) through an interlock on contactor (11) (closed when the contactor is closed), through the limit switch on the brush lifting device (closed except when the brushes are in the full down position), through the coil of relay (31-a) to Bus-B. This energizes the motor (31) causing it to operate until the brushes are in the full down position, at which time the limit switch opens, thereby stopping the motor.

Operation 18.

Line contactor relay (37-X) is now energized as follows: From Bus-A-1 through the contact of relay (3), through the coil of relay (37-X), through the contact of field current relay (38) and through the interlock on the brush lifting device (31-D) to Bus-B. Field current relay (38) insures that the converter field is excited before an attempt is made to close the D-C. line contactors.

Operation 19.

The closing of relay (37-X) energizes line contactor (37). This contactor on closing shunts the contacts of relay (3) connecting the auxiliary, Bus-A-1 to A. This prevents any possibility of relay (3) by opening, cutting off the A-C. side of the converter until the D-C. side is opened.

Operation 20.

As soon as the line contactor (37) is closed, the coil of the second line contactor (12) is energized, through the contacts of relay (37-X) and contactor (37), thereby connecting the converter to the trolley through the resistance grids.

Operations 21, 22 and 23.

Resistances shunting contactors (14), (15) and (16) are closed in turn by direct current overload relays, (12-A), (14-A) and (15-A), if normal load is not exceeded. The converter now takes its load and continues in operation until light load indicates that its capacity is not required.

STOPPING

Operation 1.

When the load demand has decreased below a pre-determined minimum, D-C. underload relay (13) closes its contacts, thereby energizing the motor of underload delay relay (27), as follows: From Bus-C through the motor of relay (27), through the contact of relay (13) through an interlock on running contactor (11) (closed when contactor (11) is closed), through the knife switch (17) (thrown unto the auto position) to Bus-B.

Underload delay relay (27) consists of an A-C. motor driving, (through a train of gears and a magnetic clutch), a disc which at the end of its travel closes a pair of contacts (T). An intermediate set of contacts (S) close momentarily after motor operates for approximately two minutes. In case load is demanded from the station before underload delay relay (27) closes its contacts (T), this relay will be de-energized by the opening of underload relay (13) and the contacts will be returned to the original position by means of a spring. For this reason the underload must be continuous for a certain period to take the station out of service.

Operation 2.

If the underload continues for a certain predetermined period (3 to 30 minutes), the contact (T) of underload delay relay (27) will close. This short circuits the closing coil of master relay (3-a) causing this relay to open.

Operation 3.

The opening of relay (3-a) in turn causes all the alternating and direct current contactors and relays to open, shutting down the station. This also de-energizes time delay relay (27) allowing this to reset. The station will now remain out of service until the D-C. voltage drops sufficiently to allow relay (1) to close its contacts.

PROTECTIVE FEATURES

By referring to the schematic diagram, Fig. 9, the relation of the protective devices to the rest of the apparatus as explained below may be readily understood.

Lockout Features:

In case of trouble which cannot automatically be cleared,—such as a short circuit inside the converter—it is necessary to lockout the station until the trouble can be remedied. This is accomplished by lockout relay (30) the contacts of which are normally open. When the relay is energized its contacts close, and these in turn short circuit the closing coil of Master Relay (3-a). The opening of Master Relay (3-a) then shuts down the station. The contacts of Lockout Relay (30) on closing, are held in this position by a spring and this prevents the station from starting up again, until the relay is relatched by hand. The Lockout Relay is energized by various protective devices, operating in case of trouble which cannot be automatically cleared.

Starting Protection:

In case the converter fails to rotate and therefore remains on the starting taps of the transformer for a period exceeding from one and one-half to two minutes, it is desirable to lock out the station until the trouble is corrected. This is accomplished through

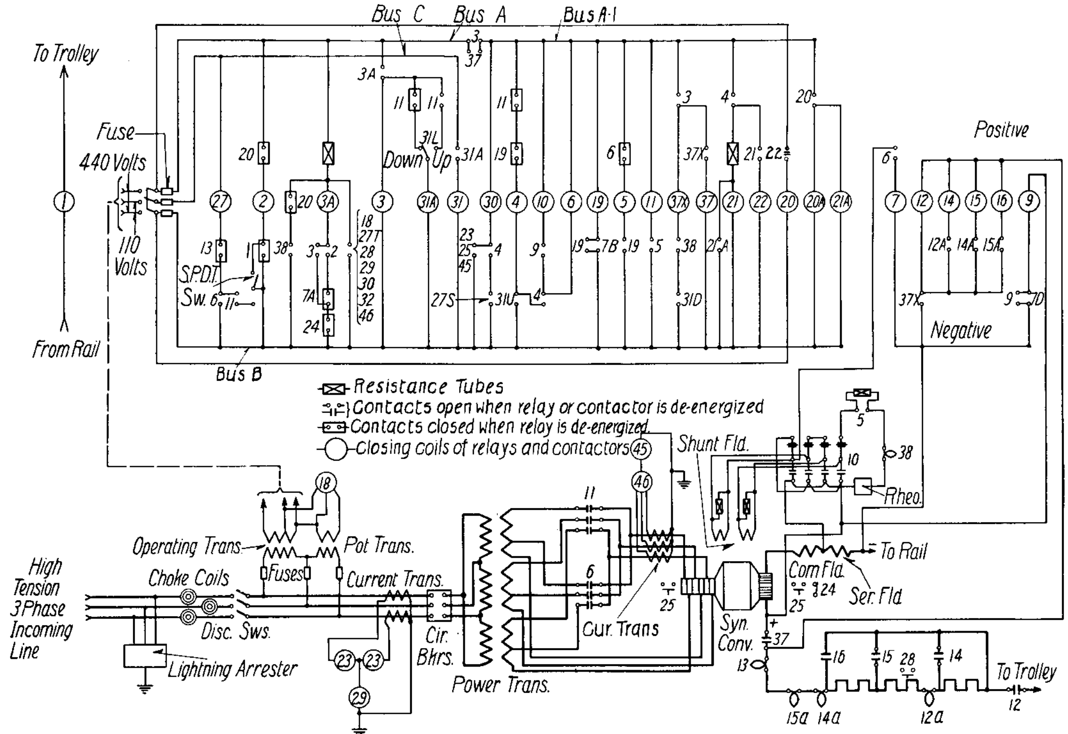


Fig. 9—Simplified Schematic Diagram for A-C. Self-Starting Synchronous Converter

1 Undervoltage D-C. Relay
2 Low Voltage Delay A-C. Relay
3-a Master Relay—(1 pole)
3 Auxiliary Relay—(2 pole)
4 Starting Contactor Relay—(3 pole)
5 A-C. Shunt Relay—(2 pole)
6 A-C. Starting Contactor—(3 pole)
7 D-C. Polarized Motor Relay
9 Field Contactor Relay—(2 pole)
10 Field Reversing Contactor (4 P.D.T.)
11 A-C. Running Contactor—(3 pole)
12 D-C. Line Contactor—(1 pole)
12-a, 14-a, 15-a D-C. Overload Relays
13 D-C. Overload Relay
14, 15, 16 D-C. Resistance Shunting Contactors
17 S. P. D. T. Knife Switch
18 Reverse Phase and Low Voltage A-C. Relay
19 A-C. Shunt Relay—(2 pole)
20 Oil Circuit Breaker—(Solenoid Operated)
20-a No Voltage Release
21 Circuit Breaker Control Relay
21-a Low Voltage A-C. Relay
22 Circuit Breaker Contactor
23 A-C. Overload Relay
24 Overspeed Device
25 Bearing Thermostat
27 Underload Delay Relay
27-S Contact closed in 2 minutes
27-T Contact closed in from 3 to 30 minutes
28 Grid Thermostat
29 Thermal Overload Relay
30 Lockout Relay
31 Brush Lifting Device Motor
31-a Brush Lifting Device Relay
31-d Interlock closed with brushes down
31-u Interlock closed with brushes up
32 D-C. Reverse Current Relay
37 Line Contactor
37-x D-C. Line Contactor Relay
38 Field Current Relay
45 Phase Balance Relay—(low tension protection)
46 Phase Balance Relay—(high tension protection)

	Sequence Chart — Device Number	1	2	3	3a	4	5	6	7	9	10	11	12	13	14	15	16	19	20	21	21a	22	27T	31a	31D	31u	37x	37	38	Remarks
Start	Operation Number 1	O							A					O											O					Station Idle Trolley Voltage reduced
	2	O	O						A					O											O					Relay 2 closes after a few seconds
	3	O	O		O				A					O											O					Master Relay 3a energized
	4	O	O	O	O				A					O										O	O					Auxiliary Relay 3 energizes Aux Control Bus A-1
	5	O	O	O	O	O			A					O												O				Brushes lifted off commutator
	6	O	O	O	O	O		O	A					O						O						O				Starting Contactor closed
	7	O	O	O	O	O		O	A					O					O	O		O				O				Oil Circuit Breaker 20 closed converter starts
	8	O		O	O	O		O	A					O					O		O					O				Bkr Latch 21a energized Bkr coil 20 de energized
	9	O		O	O	O		O	D					O					O		O					O			O	Polarity of Converter incorrect - Contact 10 closed
	10	O		O	O	O		O	D	O				O					O		O					O			O	Field Contactor Relay 9 closed
	11	O		O	O	O		O	D	O	O			O					O		O					O				Field Contactor 10 reverses field
	12	O		O	O	O		O	A					O					O		O					O			O	Polarity of Converter correct
	13	O		O	O	O		O	B					O				O	O		O					O			O	Interlock Relay 19 energized by contact 7B
	14	O		O	O				A					O				O	O		O					O			O	Converter disconnected from starting taps
	15	O		O	O		O		A					O				O	O		O					O			O	Running Contactor Relay 5 closed
	16	O		O	O		O		A			O		O				O	O		O					O			O	Converter connected to running taps
	17	O		O	O		O		A			O		O				O	O		O			O		O			O	Brushes lowered onto commutator
	18	O		O	O		O		A			O		O				O	O		O				O		O		O	Line Contactor Relay 37X closes
	19	O		O	O		O		A			O		O				O	O		O				O		O	O	O	Line Contactor 37 closes
	20	O		O	O		O		A			O	O	O				O	O		O				O		O	O	O	Converter connected to Trolley thru res
	21			O	O		O		A			O	O	O	O			O	O		O				O		O	O	O	" " " " part res
	22			O	O		O		A			O	O	O	O	O		O	O		O				O		O	O	O	" " " " "
	23			O	O		O		A			O	O		O	O	O	O	O		O				O		O	O	O	" " directly to Trolley
Stop	1			O	O		O		A			O	O	O	O	O	O	O	O		O				O		O	O	O	Load light - Time Delay Relay 27 operating
	2			O	O		O		A			O	O	O	O	O	O	O	O		O		O		O		O	O	O	Contact "T" of Relay 27 closes
	3								A					O											O					Station Idle - Voltage Normal

Fig. 10—Sequence Chart for A-C. Self-Starting Synchronous Converter

Underload Relay (27). This is a motor operated relay the contacts of which are closed after the motor has operated a certain length of time. The motor starts to rotate as soon as the sequence of operation is started and one set of its contacts (27S) closes in approximately two minutes. If for any reason the Starting Contactor Relay (4) remains closed approximately two minutes after the sequence of operation is started, these contacts will close, which energizes Lockout Relay (30) thereby locking out the station.

Overload:

Alternating Current—Induction Type Overload Relays (23) close their contacts on overload, energizing the lockout relay (30) thus locking out the station until relay (30) is reset by hand. These overload relays are given a high setting thus taking care of only very abnormal overloads, such as short circuits in the substation as the D-C Overload Relays protect against ordinary D-C. overloads.

Direct Current—Grid resistors are inserted in the D-C line circuit by means of D-C. overload relays (12a), (14-a), and (15-a) opening contactors (14), (15) and (16). This limits the D-C. current to one and a half times full load current. Resistances remain in only until the load decreases sufficiently to permit the overload relays to reclose the contactors.

Heating:

Converter—In order to take the maximum advantage of the overload capacity of the synchronous converter, the current limiting devices are usually set to correspond to the momentary overload rating, while an Overload Thermal Relay (29) protects against sustained or repeated overloads. This device is essentially a thermostat having a temperature characteristic similar to that of the machine which it protects. It is heated by a current proportional to that in the converter armature. As the armature conductors approach a dangerous temperature, the thermostat contacts close, shunting the coil of master relay (3-a), thereby shutting down the station until the apparatus has cooled. The station will automatically restart when the apparatus cools.

Bearings—Thermostats are placed in the machine bearings. Should a bearing reach a dangerous temperature, the thermostat will close the circuit of Lockout Relay (30), shutting down and locking out the station until restored to service by resetting Relay (30) by hand.

Resistors—A thermostat is mounted in each resistance section. Should a resistance overheat, the station will be shut down by the short circuiting of the coil of Master Relay (3-a). When the resistance temperature returns to normal, the station comes back on the line.

Phase Unbalancing:

If due to trouble on the incoming A-C. line, such as an open phase, etc., the phases are unbalanced on the high tension side of the transformer, Phase Balance Relay (46) closes its contacts which short circuits the coil of Master Relay (3) thereby shutting down the station. On the phases becoming balanced again, the station will restart.

If due to trouble in the station such as one of the low tension A-C. lines opening causing single-phase operation, phase Balance Relay (45) closes its contacts which in turn energizes Lockout Relay (30) and locks out the station until Relay (30) is reset by hand.

Reverse Phase Starting and Single Phase Starting:

These are prevented by the closing of the contacts of the Reverse Phase and Low Voltage Relay (18) which short circuits the coil of the Master Relay (3-a) thereby preventing station from starting.

Low Voltage:

If the alternating current line voltage is too low for satisfactory operation, relay (2) will not operate and the contacts of relay (18) will close, either of which prevents the station from starting. Should low voltage occur while the station is in operation, the contacts of relay (18) close, causing Master Relay (3a) to open and shut down the station. The station will automatically restart when the voltage again becomes normal.

No Field:

In case the field on the converter fails, the contacts of Field Current Relay (38), which is energized by the field current, opens and de-energizes D-C. Line Contactor Relay (37X). This opens the D-C. Line Contactor (37) and prevents the converter being tied to the trolley.

Overspeed:

Speed Limit Device (24) mounted on the

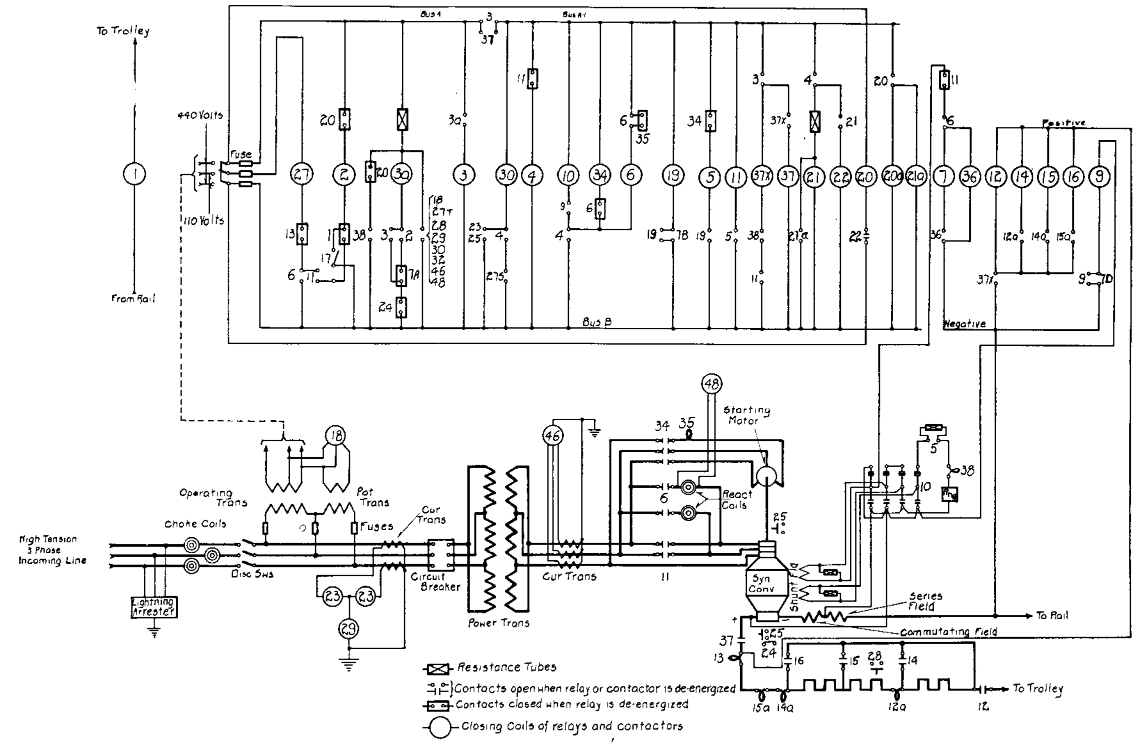


Fig. 11—Three Phase Motor Started Railway Converter

Simplified Schematic Diagram for 3-Phase Motor Started Synchronous Converters

1 Undervoltage D-C. Relay
2 Low Voltage Delay A-C. Relay
3-a Master Relay—(1 pole)
3 Auxiliary Relay—(2 pole)
4 Starting Contactor—(3 pole)
5 A-C. Shunt Relay—(2 pole)
6 A-C. Reactance Contactor—(2 pole)
7 D-C. Polarized Motor Relay
9 Field Contactor Relay—(2 pole)
10 Field Reversing Contactor—(4 P.D.T.)
11 A-C. Running Contactor—(2 pole)
12 D-C. Line Contactor—(1 pole)
12-a,14-a,15-a D-C. Overload Relays
13 D-C. Underload Relay
14,15,16 D-C. Resistance Shunting Contactors
17 S. P. D. T. Knife Switch
18 Reverse Phase and Low Voltage A-C. Relay
19 A-C. Shunt Relay—(2 pole)
20 Oil Circuit Breaker—(Solenoid Operated)
20-a No Voltage Release
21 Circuit Breaker Control Relay
21-a Low Voltage A-C. Relay
22 Circuit Breaker Contactor
23 A-C. Overload Relay
24 Overspeed Device
25 Bearing Thermostat
27 Underload Delay Relay
27-S Contact closed in 2 minutes
27-T Contact closed in from 3 to 30 minutes
28 Grid thermostat
29 Thermal Overload Relay
30 Lockout Relay
32 D-C. Reverse Current Relay
34 Starting Motor Contactor—(3 pole)
35 A-C. Accelerating Relay
36 D-C. Shunt Relay
37 D-C. Line Contactor
37-x D-C. Line Contactor Relay
38 Field Current Relay
46 Phase Balance Relay—(high tension protection)
48 A-C. Voltage Relay

SEQUENCE CHART

	Operation Number	1	2	3	3a	4	5	6	7	9	10	11	12	13	14	15	16	19	20	21	21a	22	27T	34	35	36	37X	37	38	Remarks
START	1	O							A					O																Station Idle - Trolley Voltage Reduced
	2	O	O						A					O																Relay 2 closes after a few seconds
	3	O	O		O				A					O																Master Relay 3a energized
	4	O	O	O	O				A					O																Auxiliary Relay 3 energizes Bus A-1
	5	O	O	O	O	O			A					O																Starting Motor Relay 4 closed
	6	O	O	O	O	O			A					O						O				O						Starting Motor Contactor 34 closed
	7	O	O	O	O	O			A					O					O	O		O		O						Oil Circuit Breaker 20 closed - Motor starts
	8	O		O	O	O			A					O					O	O	O	O		O	O					Starting Current Decreases - Contacts of Relay 35 close
	9	O		O	O	O		O	A					O					O		O			O	O					Converter energized thru reactance contactor 6
	10	O		O	O	O		O	A					O					O		O					O			O	Starting Motor de-energized - Converter in step
	11	O		O	O	O		O	D					O					O		O					O			O	Polarity Incorrect - Contact 7D closed
	12	O		O	O	O		O	D	O				O					O		O					O			O	Field Contactor Relay 9 closed
	13	O		O	O	O		O	D	O	O			O					O		O									Field Contactor 10 reverses field
	14	O		O	O	O		O	A					O					O		O					O			O	Polarity of Converter correct
	15	O		O	O	O		O	B					O				O	O		O					O			O	Interlock Relay 19 energized by contact 7B
	16	O		O	O	O	O	O	A					O				O	O		O					O			O	Running Contactor Relay 5 closed
	17	O		O	O	O	O	O	A			O		O				O	O		O					O			O	Converter connected directly to line thru contactor 11
	18	O		O	O		O		A			O		O				O	O		O						O		O	Reactance Contactor 6 opened
	19	O		O	O		O		A			O		O				O	O		O						O	O	O	D.C. Line Contactor 37 closed
	20	O		O	O		O		A			O	O	O				O	O		O						O	O	O	Converter connected to Trolley thru resistance
	21	O		O	O		O		A			O	O	O	O			O	O		O						O	O	O	Converter connected to Trolley thru part resistance
	22	O		O	O		O		A			O	O	O	O	O		O	O		O						O	O	O	Converter connected to Trolley thru part resistance.
	23			O	O		O		A			O	O		O	O	O	O	O		O						O	O	O	Converter connected directly to Trolley
STOP	1			O	O		O		A			O	O	O	O	O	O	O	O		O						O	O	O	Load light - Time Delay Relay 27 operating
	2			O	O		O		A			O	O	O	O	O	O	O	O		O		O				O	O	O	Contact "T" of Relay 27 closes
	3													O																Station Idle - Voltage Normal

Fig. 12—Sequence Chart for 3-phase Motor Started Railway Converter

stamped on the nameplate in the rear of the board. It is extremely important to give reference numbers as otherwise it will be impossible to identify the desired article at the Factory. Always order parts through the nearest district office of the Westinghouse Electric & Manufacturing Company.

All coils for contactors, relays, etc., have a number and sometimes the voltage rating stamped or printed upon the side. In ordering a new coil, this information should always be given as well as the device number and name of the relay or contactor for which the coil is to be used.

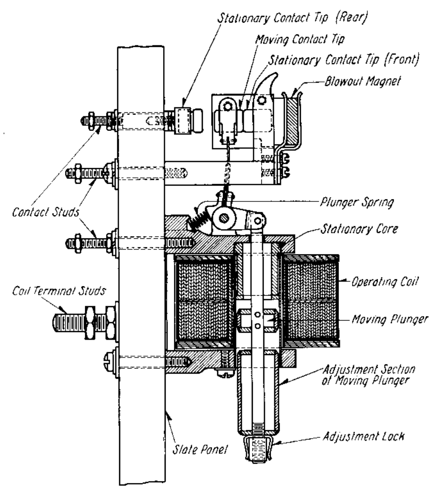


Fig. 15—Under Voltage D-C. Relay (1)

No. 1. Undervoltage D-C. Relay Fig. 15.

This is a D-C. shunt relay which closes a contact when the voltage drops to a predetermined value.

Adjustment:

To adjust this relay, turn the adjustment section of the moving plunger; turning it into the relay lowers the setting or, in other words, makes the substation cut in at a lower voltage; turning it out of the relay raises the setting allowing the station to start on a higher trolley voltage.

The sensibility of the relay depends on the plunger spring which should never be changed. However, if it is necessary to replace this spring, a duplicate should be ordered in accordance with instructions for ordering repair parts given on this page. The adjustment should be such as to allow the contact to open when the relay is subjected to normal D-C. voltage.

Care:

The surfaces of the contact tips should be adjusted to give a good surface contact, any pitting or signs of burning being carefully removed with emery cloth or a fine file.

The blowout magnet shown in the illustration is not used with this particular relay.

No. 1. Undervoltage D-C. Relay Fig. 16.

For installations where a very accurate setting of the D-C. relay is desired, the one shown in figure 16 is supplied. An external resistance is shipped with the relay and should be installed in series with the operating coil. Only the main coil is for this service, the small compounding coils being left unconnected. The instruction card pasted inside the cover states the voltage which should be impressed upon the coil (with the resistance in series). The external wiring to this relay should be made in accordance with the diagram of connections furnished with the switchboard, and it will be noted that only the contacts, which are closed when the voltage is low, are used.

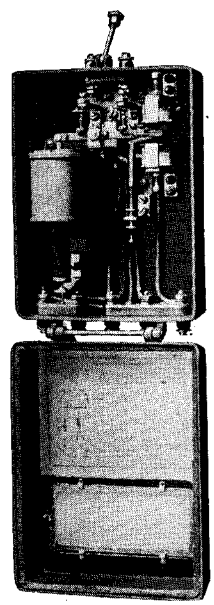


Fig. 16—Under Voltage D-C. Relay (Highly Sensitive Type)

Adjustment:

Adjustment is made by changing the tension of the adjusting spring, the voltage at which the relay operates being read on a voltmeter.

Care:

Once adjusted, little care will be required. The contacts should be examined occasionally to see that they are in good condition. Follow instructions given on the instruction card.

No. 2. Voltage Delay A-C. Relay Fig. 17.

This relay is a standard Type CV induction relay. It is designed to close its contacts when the voltage on the windings exceeds a certain minimum. External resistance is usually used with this relay.

Adjustments:

Adjustment of the voltage at which relay contacts will close is made by changing the

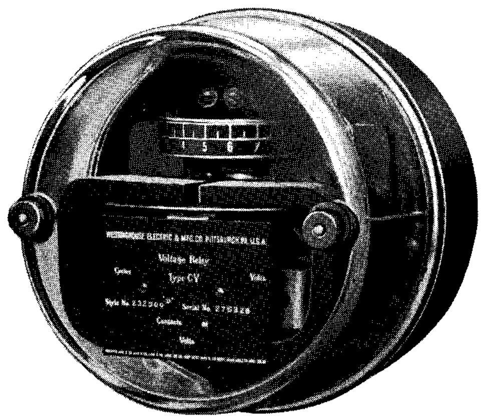


Fig. 17—Low Voltage Delay A-C. Relay (2)

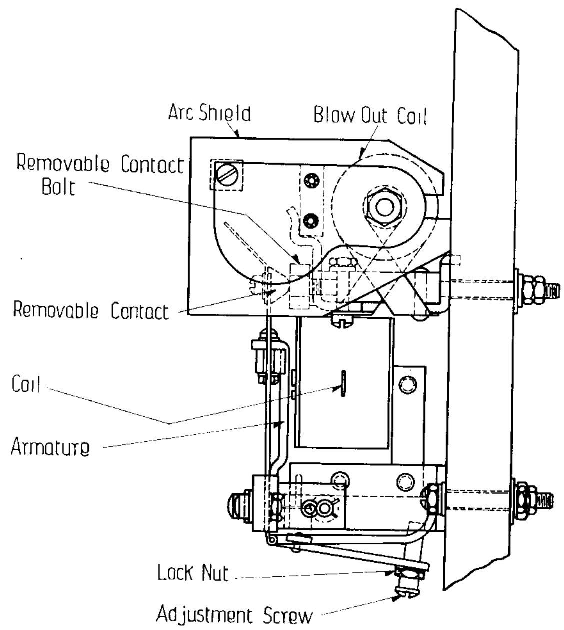


Fig. 18—Master Relay (3A)

external resistance. Once installed there will, however, be no necessity for making any changes. An index lever located in front of the scale can be shifted to vary the time setting of the relay.

Care:

This relay is strong and very sensitive. It will not require periodic attention, but occasionally the contacts should be inspected to see that they are not pitted and that they make contact properly. New contacts can be obtained through the nearest District Office.

No. 3A Master Relay (Fig. 18.)

This is a small contactor type of relay the closing coil of which is of the A-C. shunt type. An external resistor will always be in series with the coil.

Adjustment:

No adjustments are usually required on this relay other than to see that contacts are clean and make proper contact when the relay coil is energized. The travel of the armature can be adjusted by the set screw on the tail piece. After adjustment the lock nut should be tightened.

Care:

The relay should be inspected periodically. Make sure that there is no binding which impedes movement of the armature. Examine the contacts to see that they all make firm even contacts when the relay is energized. The stationary contact consists of a copper bolt while the moving contact is held in place by one machine screw. When worn or badly pitted they can readily be replaced by a new set of contacts. Contacts should not be filed or otherwise dressed because the life is materially shortened by filing and the best shape for the surfaces results from natural wear.

Failure of the relay to close may be due to the following causes:

No voltage.
Low voltage.
Loose, broken or wrong connections.
Defective coil.
Mechanical Binding.

In case of the coil burning out, the supply voltage should be carefully checked to make sure that it is that for which the coil is designed. Check also to see that the resistance is in series with the coil as shown on the diagram. All the coils for contactor type of relays are rated conservatively for continuous service and should not burn out unless subjected to abnormally high voltage or large frequency variations.

No. 3. Auxiliary Master Relay: (Fig. 19.)

This is a contactor type of relay operated by an A-C. shunt coil and is somewhat similar to relay No. 3a. It is considerably stronger mechanically and is designed to carry more current. The same instructions regarding care should be followed as for relay 3a. No adjustments should be necessary. Both the stationary and moving contacts are held by means of a single machine screw so that they can be readily removed and replaced when necessary.

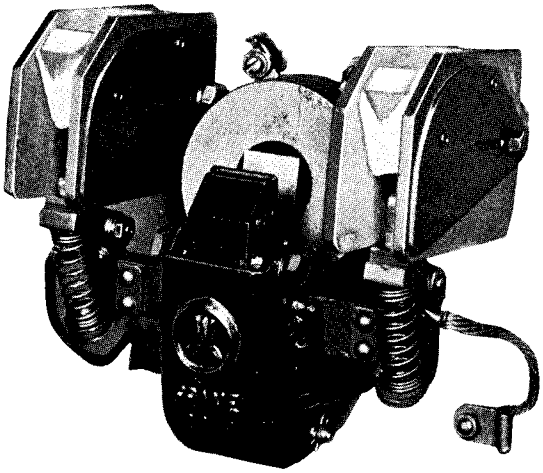


Fig. 19—Auxiliary Master Relay (3)

No. 4. Starting Contactor Relay (Fig. 19.)

This is an A-C. contactor type of relay with a shunt closing coil of the same type as Relay No. (3). The same remarks apply.

No. 5. A-C. Shunt Relay (Fig. 19.)

This relay is similar to Relay (3) and the same instructions apply.

No. 6. A-C. Starting Contactor (Fig. 20.)

This is a type "F" A-C. contactor similar to that shown in Fig. 20 except that it is 3 pole instead of 2 pole. The coil is an A-C. shunt coil which is usually connected across the line without any resistance in series.

Repair parts should be ordered from Part Catalogue No. 6083 or in accordance with instructions given on page 15.

The moving contact (Fig. 20) and the magnet armature are mounted on a common shaft and so arranged that the contactor opens by gravity, assisted by the action of strong non adjustable springs.

In all the contactors of 250 amperes capacity and larger, the circuit is made and broken between copper and graphite, Fig. 22 and in all cases the final contact is between heavy copper pieces. In closing, the contacts roll against each other with a very slight wiping motion, and are finally pressed firmly together.

Adjustments:

No adjustments are required on this contactor other than to see that good contact is made when coil is energized. This will be assured if proper attention is given to the contactor as explained under care.

Care:

Best results will be obtained when no lubrication is used.

Fig. 22 illustrates a set of contacts as they appear when new. When they have worn away, as shown in Fig. 23, they should be replaced. Since the surface of a new contact will not fit that of one which is worn, they should always be replaced in sets—never singly. Contact bolts or screws should not be used more than once but should be replaced whenever a new set of contacts is installed.

Contacts must never be filed or otherwise dressed, because their life will be materially shortened by filing, the best shape for the surfaces resulting from natural wear.

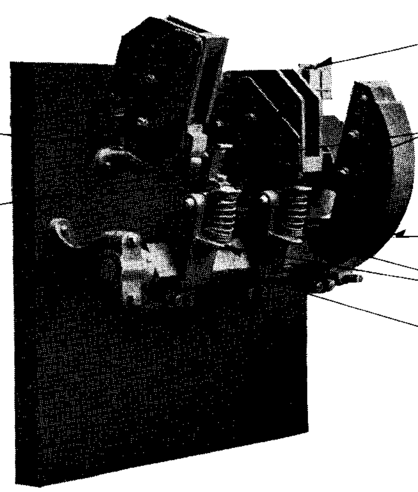


Fig. 20—Type "F" Two Pole A-C. Contactor

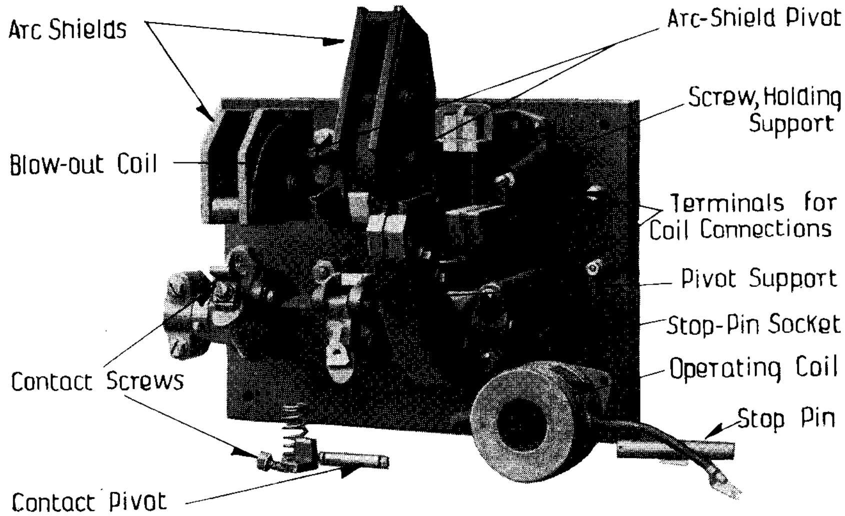


Fig. 21—Type "F" 125 Ampere Contactor

To remove the contact, it is only necessary to take out the contact screws (Fig. 24). Those of small size are held in place by one screw, larger ones have two screws. The contact screws should be replaced by new ones whenever a new set of contacts is installed.

Contacts can be obtained in complete sets from any District Office or from the East Pittsburgh Works by ordering one of the style number shown in Fig. 25.

The pivot on which the moving contact turns, can be removed easily and without the use of tools. Fig. 21 shows one style of pivot. This is held in its support by snap pins at each end. It can be removed by taking out the snap pins and pushing it out of the support. Another style of pivot is used on large sizes of contactors. This kind is held in place by a small pin which in turn is held by a flat spring. The pivot, however, can be removed by simply pushing it out by hand.

The arc shields shown in Fig. 24 are hinged so that they can be lifted to expose the contacts. Should an arc shield need removing, it can be easily replaced by removing the arc shield pivot, taking off the old shield and slipping on the new one in its stead.

Blow-out coils shown in Fig. 24 are used on all line contactors. They are riveted and soldered to the stationary contact support and in case of damage are replaced with the support with which the coil is always furnished.

Operating coils are wound for continuous service at the rated voltage and frequency, marked on the coil. The coils are designed so that they will close the contacts with proper pressure at 80 per cent. of normal voltage. Failure of the contactors to close may be due to the following causes:

No Voltage
Low Voltage
Wrong Connection
Broken Connections
Mechanical Obstacles

If an operating coil should burn out, the characteristics of the power supply should be checked up very carefully before making any

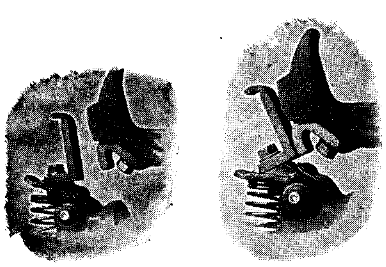


Fig. 22—New Contacts

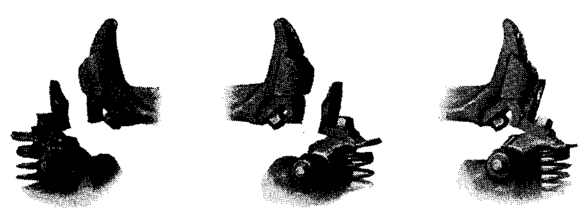


Fig. 23—Worn Contacts Requiring Replacement

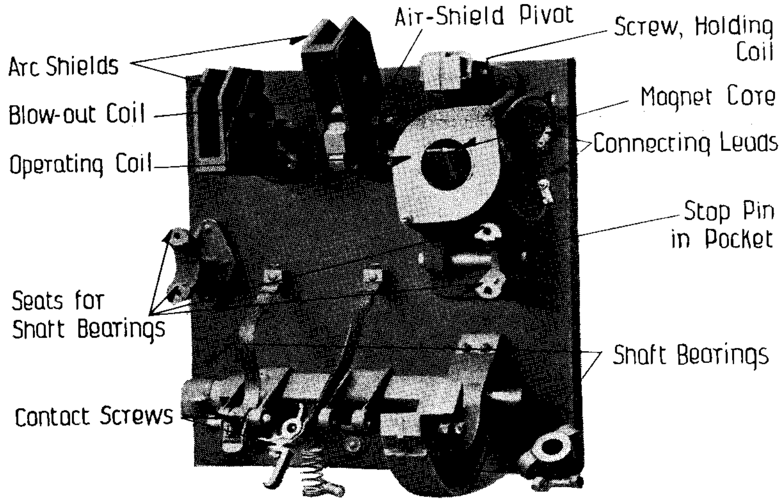


Fig. 24—250-Ampere Contactor Partly Dismantled

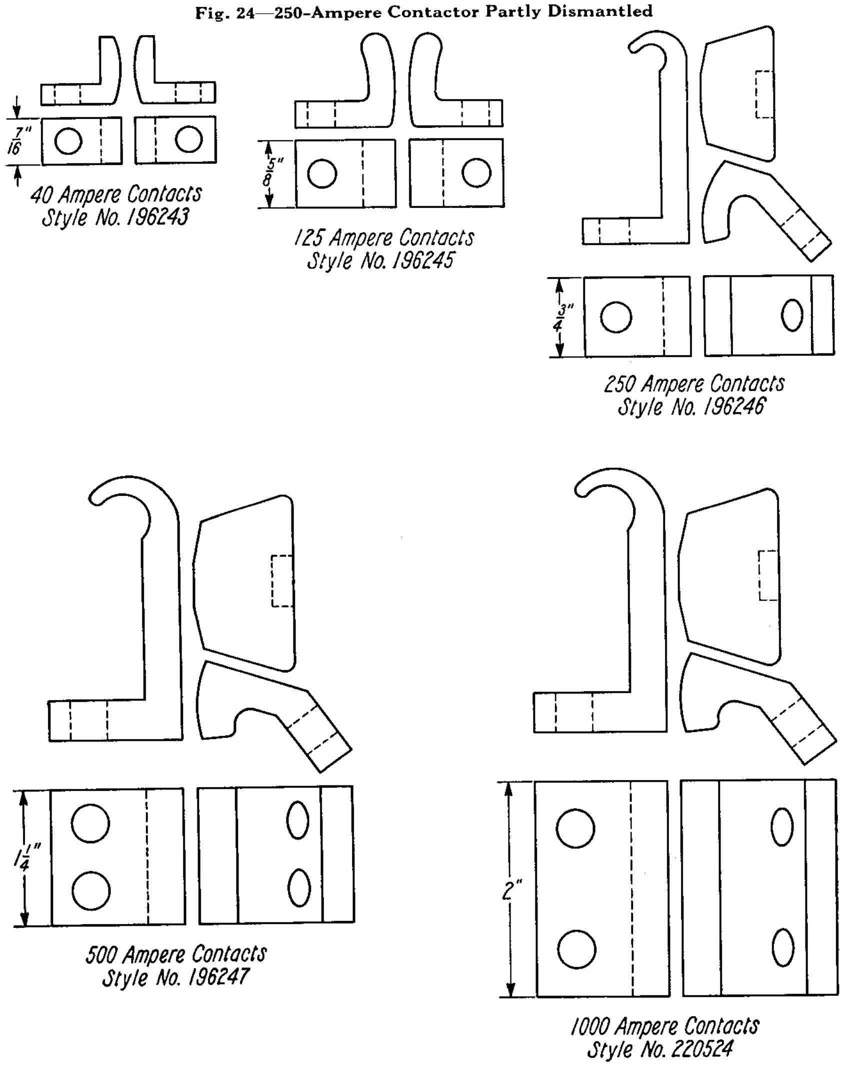


Fig. 25—Type F Contacts—Style Numbers Include Complete Set of Contacts with Screws

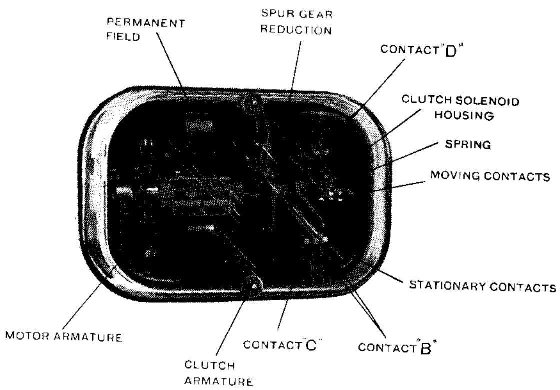


Fig. 26—D-C. Polarized Motor Relay (7)

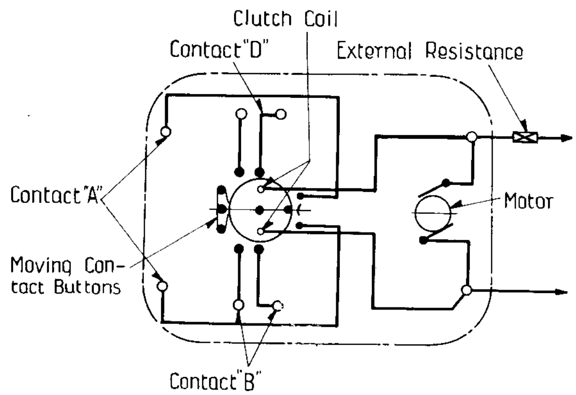


Fig. 27—Internal Diagram of Connections for Polarized Motor Relay—Rear View (7)

replacement. The coils are conservatively rated so that there should be no burn-outs, unless the coils are subject to high over-voltage or abnormal frequency variations.

The removal of an operating coil is simple. The stop pin is first pushed out after removing a cotter pin from either end. This allows the armature to fall back as shown in Fig. 21, so that the two screws holding the coil can be removed and the two connecting leads unfastened. The coil can then be slipped off the magnet core.

The shaft is supported in bearings which are interchangeable, reversible and self-adjusting, so that the shaft can be easily removed and placed in perfect alignment. Removing four screws allows the shaft with the moving contacts and operating arm to drop down, as shown in Fig. 24.

No. 7. D-C. Polarized Motor Relay (Figs. 26 and 27.)

This is a motor driven relay having a D-C. motor, the field of which is produced by permanent magnets. The motor drives, through a double spur gear reduction, the armature of a magnetic clutch. When the clutch coil is energized, the clutch solenoid housing which is mounted loose on the shaft is drawn along the shaft until it engages with the clutch armature. Attached to the outside of the clutch housing is an arm carrying three contact buttons, (Moving Contacts). A helical spring mounted on the shaft ordinarily keeps the clutch housing in such a position that these contacts are held half way between the stationary contacts B and D as in (Fig. 26). When the clutch is engaged and the motor revolves, the clutch housing turns until the contacts B or D make contact, the direction of rotation being dependent upon the polarity of the motor armature circuit. Fig. 27, shows the internal diagram of connections as viewed from the rear. The clutch coil should be connected in parallel with the motor armature, so that the clutch will engage and disengage simultaneously with the starting and the stopping of motor. Immediately upon becoming disengaged the moving contacts on the clutch housing will be returned to the open position by means of the helical spring. Contact A shown on the internal wiring diagram cannot be seen on Fig. 26 as it is underneath the clutch housing. This contact is closed when the relay is de-energized.

Adjustment:

The speed of the motor is varied by inserting external resistance in series with the armature. This resistance is originally furnished with the relay and will probably never need to be changed, and in any case should not be changed except upon advice from the East Pittsburgh Works. No other adjustment will ever be necessary.

Care:

This relay should be inspected periodically.

Contacts:

All contacts should be kept clean, unpitted and so adjusted that they make firm even contact when closed. They may be cleaned by lightly rubbing with fine sand paper. If new contacts are required they should be ordered in accordance with instructions on page 15. In ordering specify which contacts, (moving or stationary) A, B or D are desired.

In case the moving contacts do not return to the open position, examine the spring on the shaft. If it is necessary to replace the spring, it is quite easily accomplished by removing the end bearing pillow block. If the

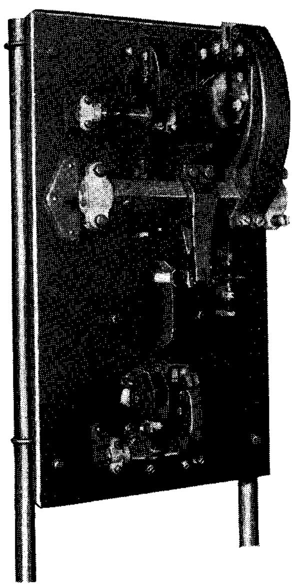


Fig. 32—"Clapper" Type Operating Mechanism for Oil Circuit Breaker (20)

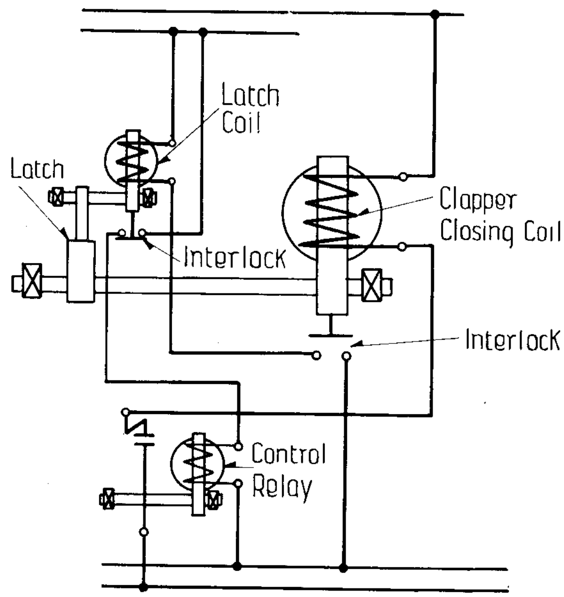


Fig. 33—Diagram of Connetions for a Clapper Operated Oil Circuit-Breaker (20)

throw the switch cuts out the Underload Delay Relay (27) and the D-C. Low Voltage Relay (1) causing the station to start and run continuously but with all protective features. On the other side relays (27) and (1) are connected in and the station will start and stop automatically.

No. 18. Reverse Phase and Low Voltage A-C. Relay:

This relay is very similar to relay (2) except that it is a polyphase instrument. Adjustments are made in a manner similar to those for relay (2). Each relay is adjusted before leaving the factory and should require little or no attention other than an occasional inspection of the relay contact.

No. 19. A-C. Shunt Relay. (Fig. 19.)

This is a relay similar to relay (3) and the same remarks apply.

No. 20. Main Oil Circuit-Breakers:

In railway automatic substations, the main oil circuit-breaker will nearly always be electrically operated. The circuit-breaker may be of the clapper operated type Fig. 32 or it may in the case of the cell or pipe frame mounted breakers be of the solenoid or motor operated type. Instruction cards will generally be supplied with each breaker and they should be carefully followed.

Clapper Operated Breakers: (Fig. 32.)

This is an oil circuit-breaker electrically operated by means of a clapper type mechanism such as is used with the large type of contactors. The closing coil is of the A-C. shunt type. The breaker is horizontal pull and its operating rod projecting through the front of panel is connected to the operating mechanism by means of a tongue and clevis which are pinned together.

This breaker is latched when closed. The diagram of connections showing the interlocking between the closing coil and the latching coil is shown on Fig. 33.

The sequence of operations is as follows: The control relay coil is energized from an A-C. source by the closing of an interlock on another relay (not shown on diagram). This in turn energizes the clapper closing coil, thus closing the breaker.

On closing, an interlock contact is made which causes the closing coil of the latch to be energized. The latch drawn into place by its closing coil, holds the operating mechanism of the breaker in the closed position. The operating arm of the latch mechanism on closing, opens an interlock which in turn de-energizes the closing coil circuit of the control relay. The breaker is thus kept closed by the latch as long as the latch coil is energized, the closing coil being entirely de-energized.

Adjustment:

The breaker as shipped from the factory has been adjusted to permit no play between

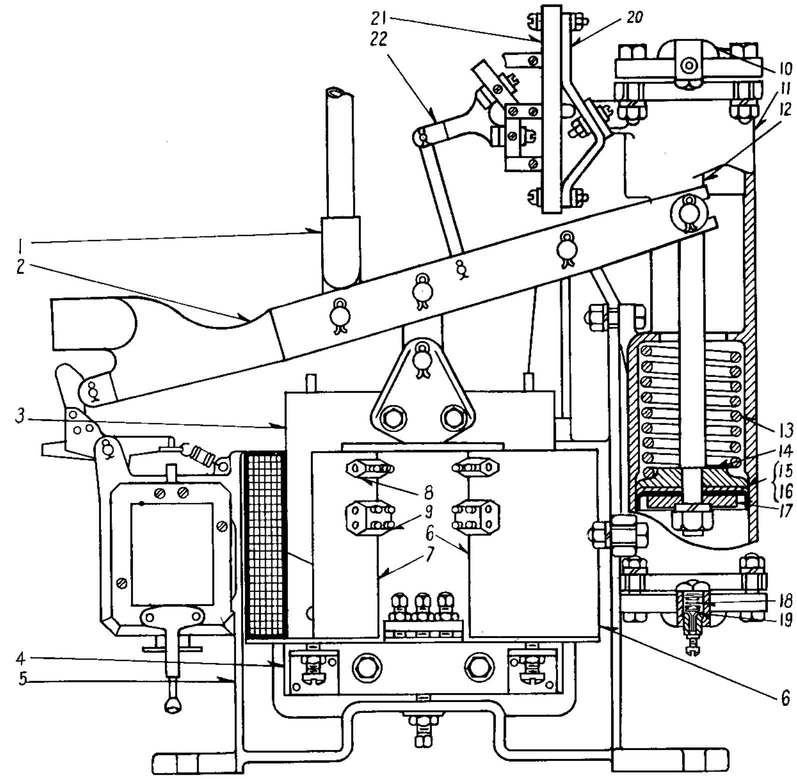


Fig. 34—Main Oil Switch Operating Mechanism (20)

1 Rod end for operating rod
2 Magnet lever
3 Moving core for closing coil
4 Stationary core for closing coil
5 Frame for magnet
6 Closing coil, right hand
7 Closing coil, left hand
8 Small terminal for closing coil
9 Large terminal for closing coil
10 Head with valve for dash pot cylinder
11 Dash pot cylinder
12 Piston rod for dash pot
13 Spring for dash pot piston
14 Shouldered collar for piston
15 Leather packing
16 Packing expander
17 Follower washer
18 Valve spring
19 Valve with stem
20 Bracket to support signal switch
21 Signal switch
22 Operating rod for signal switch

operating mechanism and breaker when closed. There will therefore be little need for adjustment. If at some time it is necessary to disassemble the parts, the breaker on reassembly should be carefully adjusted, to make sure, first, that the contacts of breaker are fully closed when the contactor arm is pulled closed and second, that the contactor arm comes fully up against the stationary core (without banging) when the breaker contacts are well seated. To make this adjustment, knock out the pin of tongue and clevis joint and screw tongue in or out on operating rod.

Care:

The breaker should be inspected periodically. Lower the tank and inspect the contacts. If they show uneven pitting or burning, the arms carrying the moving contacts should be adjusted until the breaker will close with a good and equal contact pressure on all poles. If the contacts are pitted or burned so badly that a good contact is not maintained, a set of new ones (both the stationary and moving contacts) should be installed. Always close the breaker several times to be sure that good contact is obtained, on all poles before replacing tank.

No set rule can be given for changing oil at certain intervals. In general it should be changed when it becomes badly clouded and sludge collects. If an oil filter is available the oil may be filtered and used again. If replaced by new oil the proper grade of Westinghouse oil should be used. Wemco "B" oil is correct for all breakers when the temperature does not go below 0° centrigrade. Where lower temperatures may be encountered Wemco "C" oil should be used.

The clapper mechanism should be examined to see that it operates freely and that there is no binding in the bearings, etc. No lubrication is necessary and best results are obtained without it.

Solenoid Operated Breakers (Fig. 34.)

This mechanism is of the single phase solenoid type in which a "U" shaped laminated core is pulled down by two coils wound over a similar core. The closing of the breaker mechanism is cushioned by an air dash pot, which is in the upper end of the cylindrical housing on the end of the breaker mechanism. The speed of closing may be regulated by adjusting the small brass valve on the side of the cylindrical housing. The breaker should close rapidly and steadily, but should slow down at the extreme end of the stroke so as not to unnecessarily strain the parts by a sledge hammer blow. The coils on this mechanism are for intermittent duty only and will not stand application of the control voltage for more than a few seconds at any one time. The faces of the moving core and of the stationary core are ground off smooth so that in the closed position, these faces will touch as nearly as possible over the entire surface. It is very important that this condition be maintained, and if for any reason the mechanism is dis-assembled, care should be taken in re-assembling that the cores are put together with the same faces opposite each other. If any dirt is allowed to get on top of the lower core, or if the cores should not properly seat, the vibration will be so extreme that the latch may not hold the lever in the closed position. This mechanism requires a very heavy flow of current when the moving core is at the top of the stroke. As the core moves down toward the stationary core, when the cores are energized, the reactance rises rapidly until the cores are together when the current input will be at the minimum. Owing to this heavy rush of current, the mechanism should never be wired with anything less than No. 4-B. and S. gauge. It should be located as closely as possible to the operating transformer in order to avoid voltage drop in the leads between the transformer and breaker mechanism. This mechanism should always be installed on a very solid foundation, preferably one of concrete, which should be massive enough to withstand the sudden shock to which the mechanism is subjected at the time of closing. As a usual rule, foundation bolts leaded into an ordinary cement floor will not be adequate for holding the mechanism, as it will pull such bolts loose in a very short time. After erecting and leveling the mechanism, the connecting rods between the mechanism and the breaker should be installed and roughly adjusted for length. The breaker should then be closed by hand, using the hand closing lever. Never, under any circumstances, close the breaker electrically before it has first been adjusted by closing it by hand.

The tank should be off the oil breaker so that the contacts may be inspected to see that they are properly seated and are making good electrical connections. The connecting rod should be just long enough to seat these contacts properly, and pull the breaker operating lever against its stop. If the rod is too short, the laminated cores will not seat, and the resultant vibration will probably prevent the breaker latching. On the other hand, if the rod is too long, poor electrical contact will be made, and much trouble experienced.

After once adjusting the mechanism and getting it in proper working condition, no further adjustment should be necessary. The only attention required will be to see that all nuts and bolts are tight, and to blow the dust and dirt out of the mechanism occasionally with an air hose or bellows.

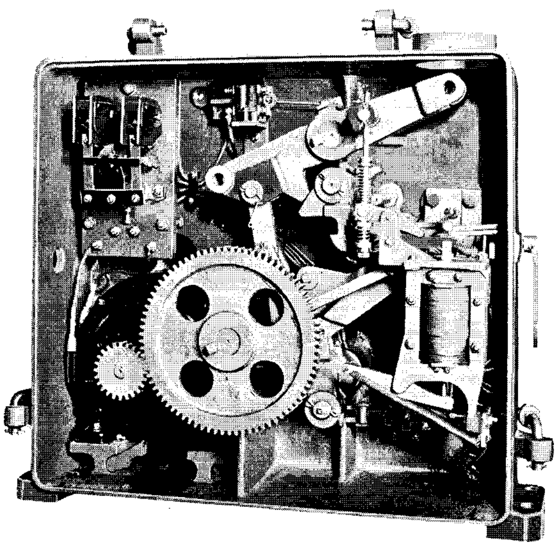


Fig. 35—Motor Operating Mechanism for an Oil Circuit-Breaker (20)

Motor Operated Breakers.

Figure 35 shows the A-C. motor operating mechanism for an oil circuit-breaker. It is connected to the breaker by means of a crank and levers, the mechanism itself being usually mounted on the floor. In the upper left hand corner is shown the small control relay, while at the right is shown the low voltage coil. The system of levers is so arranged that the mechanism is trip free, i.e. cannot be kept closed on overload even though the motor is operating.

The operation is as follows:
(Refer to diagram figure 36.)

The control relay is energized by the closing of the control circuit. This, closing, energizes the motor which starts to rotate.

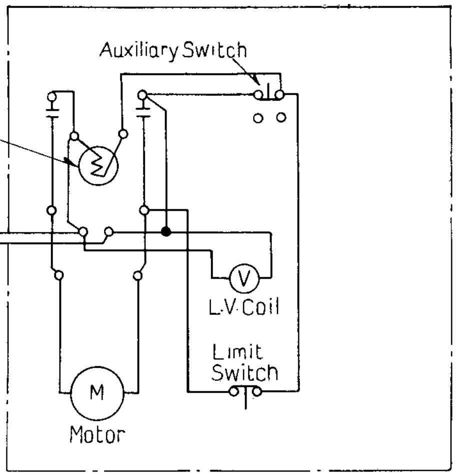


Fig. 36—Diagram of Connections—Motor Operated Mechanism for Oil Circuit-Breakers

It will be noted that the circuit of the control relay coil is first completed through the auxiliary switch (shown for the open position of the breaker). As soon as the relay closes, it completes its own holding circuit (through the limit switch) so that when the breaker, on closing, opens the auxiliary switch, the relay circuit is not opened. Therefore, the motor continues to operate until the breaker is fully closed at which time the "limit" switch opens, causing the relay to be de-energized and the motor to stop. The breaker is tripped by either the trip coil or the low voltage release mechanism striking the toggle and allowing the spring to reopen the breaker.

Adjustment:

Care should be taken to see that the limit switch opens at the proper moment and also that the auxiliary switch makes contact when the breaker is open.

Care:

Examine the contacts of the relay occasionally to see that they are in good condition. The motor brushes should also be inspected to see that there is good contact and no sparking at the commutator. The motor bearings should be lubricated about once in three months. Use a small amount of heavy grease on the gears and keep the fulcrum pins lubricated but do not allow grease or oil to get on the coils or contacts. Inspect mechanism occasionally and make sure that there is no excessive binding or friction.

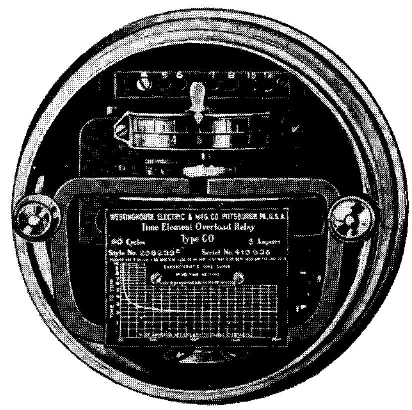


Fig. 37—Type "CO" A-C. Overload Relay (23)

No. 23. A-C. Overload Relay (Fig. 37.)

This is a standard Type CO relay and should be adjusted to operate with the shortest possible time element at overloads in the neighborhood of the guaranteed swing capacity of the machine.

The small machine screw in the coil terminal plate just above the scale makes connections so as to include various numbers of turns in the main winding and by placing this screw in the different holes the relay will close its contacts at the corresponding current, 4, 5, 6, 7, or 8 amperes, or as marked on the terminal plate. The setting will generally be such as to give from 150 per cent to 300 per cent of full load as the minimum operating value.

Caution:

This relay must be short-circuited by connecting the current binding posts (the two lower posts) together while the internal current setting screw is being changed. Be sure that the screw is turned up tight since the operating current passes through this screw, and a good connection must be made. To determine the line current at which the relay operates, multiply the setting by the ratio of the current transformer.

The index lever limits the motion of the disc and thus varies the time element. The characteristic time curve is given on the name plate, and this shows the time values with index lever at 10 for currents up to 2000 per cent of operating point. The time element setting is proportional to the line lever position.

Example:

Assuming the current connection screw is at No. 4 and assuming a short circuit current such as to give 40 amperes on the relay, this should mean 10 times the tripping point, or 1000 per cent on the curve. At this point the curve shows two seconds as a maximum. It is desired to obtain one second time element under these conditions; the index lever should be set at No. 5 on the scale. If 0.2 seconds is desired, the lever should be set at No. 1, etc.

Formula for Determining Relay Current from KVA in Circuit.

$$A = \frac{\text{Kva. x } 1000}{\text{v x r x } 1.7}$$

A=Amperes in Relay
v=Line Voltage
r=Ratio of Series Transformer
Kva.=Kilovolt Amperes on Line

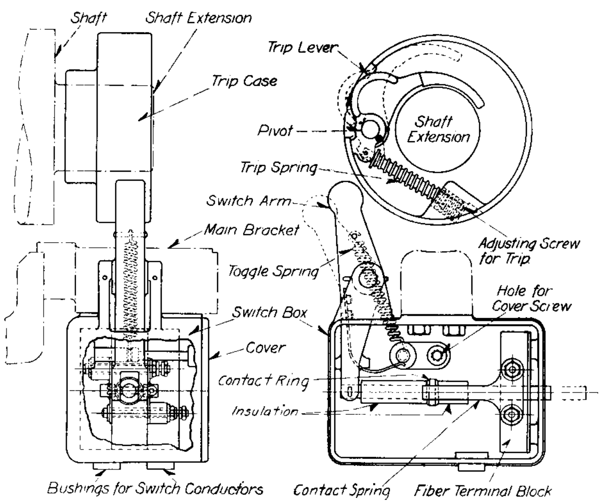


Fig. 38—Speed Limit Device (24) Details

No. 24. Speed Limit Device (Figs. 38 and 39.)

As a safeguard against overspeed, a speed limit device consisting of a spring closed switch, is attached to the commutator end of the converter shaft. When the converter reaches a certain speed above normal, a centrifugal governor mechanism operates the switch and opens the circuit breakers, thus cutting the converter from its source of supply.

In order to re-set the switch it is merely necessary to move the switch arm back to the normal position by hand. This can readily be done at any time whether the machine is running or not, and without opening the switch box.

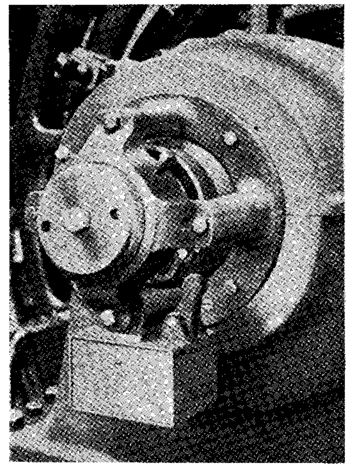


Fig. 39—Speed Limit Device Installed on a Synchronous Converter

All speed limit devices are set and tested at the Works. The switch box complete is shipped attached to the oscillator bracket. Bolt the parts in place, fasten the trip case to the shaft, and then push in the switch arm. There should be at least 1/8 inch between the switch arm and the trip case. (See Fig. 38).

All standard converters are provided with a test pulley extension on the collector end. When testing for overspeed, the synchronous converter can be run as a motor from the direct current side, or can be belted to a motor on the pulley end. It is important to have complete control of the speed during test. Use a tachometer or any reliable direct reading speed indicator, but do not use the ordinary revolving dial indicator.

In testing for overspeed, the switch should trip at about 15 per cent above synchronous speed. Bring the speed up slowly and watch for the tripping speed of governor trip lever. Should it be found necessary to re-set the governor, proceed as follows:

First, determine the tripping speed, and assemble the governor as shown in Fig. 38. Screw in the adjusting screw even with the governor case, and give the screw about one-half turn inward at each run until it trips at the overspeed. Then tighten the small locking screw on the side of the trip case. Before starting each test, see that the switch arm is in, and pull the trip lever several times by hand to see that it works freely.

Speed limit devices should be operated at regular intervals as a part of the routine inspection to insure that all parts are operative and all circuits complete. Failure to properly

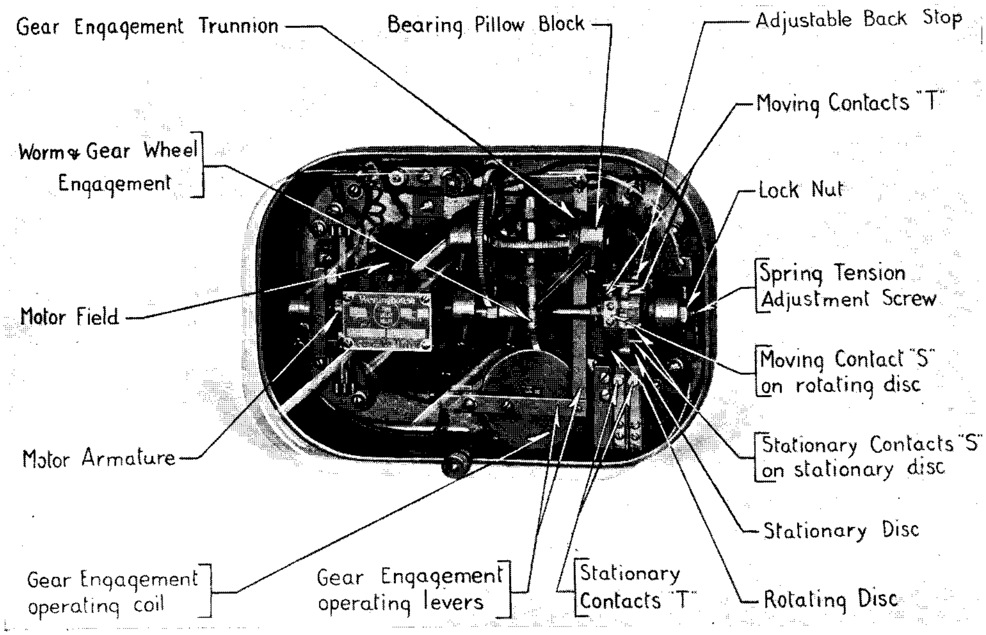


Fig. 40—Time Delay Relay (27)

maintain the overspeed device and wiring may result in the loss of a machine.

No. 25. Bearing, Thermostat Similar to (Figs. 41 and 42.)

These thermostats consist of a copper bellows connected thru a tube to a bulb which is embedded in the bearing. The bulb and bellows are partially filled with a liquid which evaporates as the bearing heats up. This elongates the bellows which operates the contactor mechanism (Fig. 41).

The contacts are operated through a toggle mechanism. Very little attention will be required, tho occasionally inspect the contacts, to see that they "make" properly.

The contacts must be re-opened by hand once the thermostat has operated. This gives a positive indication of the operation of the device.

Adjustment:

The thermostat element is built to produce a certain elongation of the bellows at a specified temperature and is not subject to calibration in service.

A set screw located just above the bellows (Fig. 41) can be screwed up or down, so that the device can be adjusted to operate properly. This should be set so that the contact arm operates when the bellows elongates approximately one eighth of an inch.

Care:

The thermostats should be carefully handled as the tubes are easily broken. Avoid excessive bending or kinking. The stuffing box should be examined occasionally to see that the oil from the bearing does not leak out.

No. 27. A-C. Underload Delay Relay (Fig. 40.)

This is a motor operated relay having an A-C. motor driving through a spur and worm gear reduction and a gear engaging mechanism, a disc which carries a moving contact. The function of the relay is to provide a long definite time interval between the starting of the motor and the closing of the contacts. For this reason the gear reductions are large so that time intervals of from 3 to 30 minutes may be obtained.

In addition to the slow closing contacts "T" there is a second set of contacts "S" provided which close momentarily at approximately a minute and a half or two minutes after the motor starts to revolve.

These consist of two contact arms mounted on the periphery of the moving disc. These are carried into momentary *wiping* contact with contact bars mounted on a stationary disc, after the moving disc has revolved a certain distance.

The gear engaging mechanism consists of a small electro magnet, the armature of which is attached to the worm gear which is so pivoted on trunnions that when the electro magnet is energized, the worm is drawn into engagement with the worm gear. When the electro-magnet is de-energized the worm flies out of engagement with the worm gear and the revolving disc is returned to its original position by means of a spring. The electro-magnet is operated by an A-C. shunt coil, which is energized at the same time that the motor is. Be sure to see that resistances are in series with both the motor and the electro magnet, if the wiring diagram indicates this. However, the resistances may not in all cases be required, the wiring diagram indicating when these are necessary.

Adjustment:

The motor speed should never be changed by inserting different external resistance.

The time setting is obtained by adjusting the distance between the moving and stationary contacts so that the time of travel of the moving contacts will be longer or shorter as desired. There are two means of making this adjustment. They are:

(1) There is a back stop on the stationary disc. When the clutch is released, the moving disc is rotated back by a spring until it strikes this stop . There is a slot cut in the switch stop so that this stop can be moved forward or backward thereby decreasing or increasing the travel required to close the contacts "T" and "S". It should be noted that this adjustment affects the time setting of both sets of contacts. Make this adjustment before adjustment (2).

(2) If it is desired to change the setting of the long time contacts "T", without disturbing the time setting of the contacts "S", the whole stationary disc must be moved with the stop. This is accomplished by loosening the lock nut on the end, of the shaft and turning the stationary disc until the required opening between contacts is obtained. In as much as the moving and stationary disc are both turned in this adjustment the relative distance between contacts "S" is not changed though the moving contact "T" is brought nearer the stationary contact "T".

By a combination of both settings the short time setting can be changed without affecting the setting of contacts "T".

Any time interval from a few seconds to approximately three minutes can be obtained with the short time contacts "S" and from three to thirty minutes with the long time contacts "T".

Spring Adjustment: To adjust the tension of the return spring of the moving disc, loosen the lock nut on the end of the shaft and turn the set screw by means of a screw driver. The tension of the spring should be sufficient to cause the disc to return to the original position with a quick "snappy" action.

Care:

This relay should be inspected periodically.

Contacts—Keep the contacts clean and see that when closed, there is a firm even contact. If contacts become badly pitted new ones may be obtained from the factory and readily put in place of worn ones.

Motor—The motor is an induction motor with a squirrel cage rotor. It should require little attention but if replacement parts are required they should be ordered from the factory in accordance with instructions given on page 15.

Lubrication—Grease cups on bearings should be cleaned and refilled occasionally with Fan Motor Grease Style 247597 and the gears should frequently be oiled with a few drops of light machine oil.

Gear Engagement: The gear engagement should be kept clean and free from sticking. When the motor is de-energized it should be noted that gear engagement springs open and that the moving disc quickly rotates back until stopped by back stop. If there is any sticking look for binding on the shaft and if necessary remove the shaft from the bearing and clean and lubricate with light oil. Also examine the return spring of the disc to see that it forces the moving disc against the backstop when the clutch is released.

No. 28. Grid Thermostats. (Figs. 41 and 42)

These thermostats are mounted over the

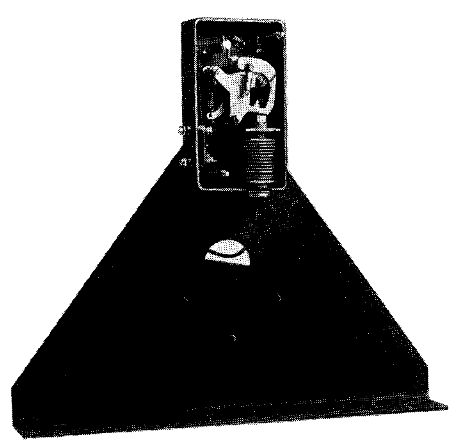


Fig. 41—Grid Thermostat Mechanism

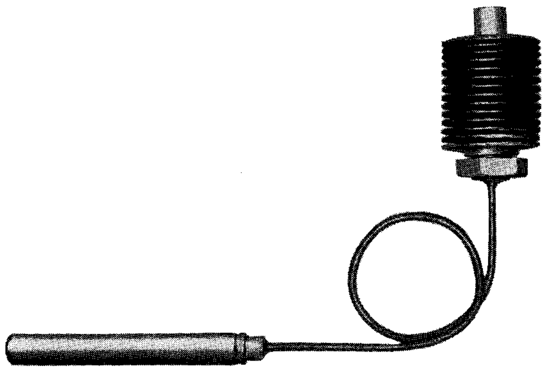


Fig. 42—Thermostat Element

current limiting resistance and serve as a protection against direct current overload. They are identical with the bearing thermostats except that they are designed to operate at a higher temperature. They are supported from a bracket with the bulb so arranged as to get the maximum heating from the grids.

No. 29. Thermal Overload Relay. (Figs. 43 and 44.)

This relay consists of a number of bimetallic springs attached in such a way to the shaft, that when heated, the expansion of the springs rotate the shaft. This causes the contacts

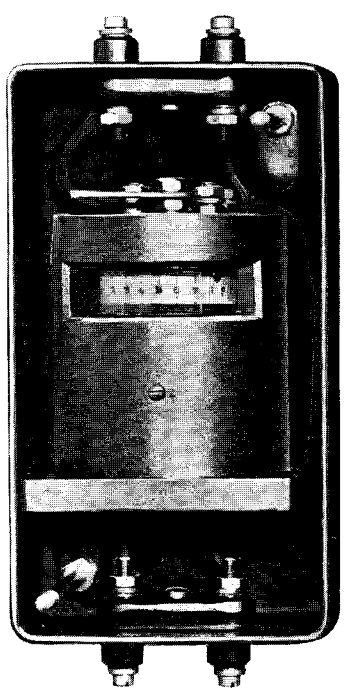


Fig. 43—Thermal Overload Relay (29) (Ratio Coil Not Shown)

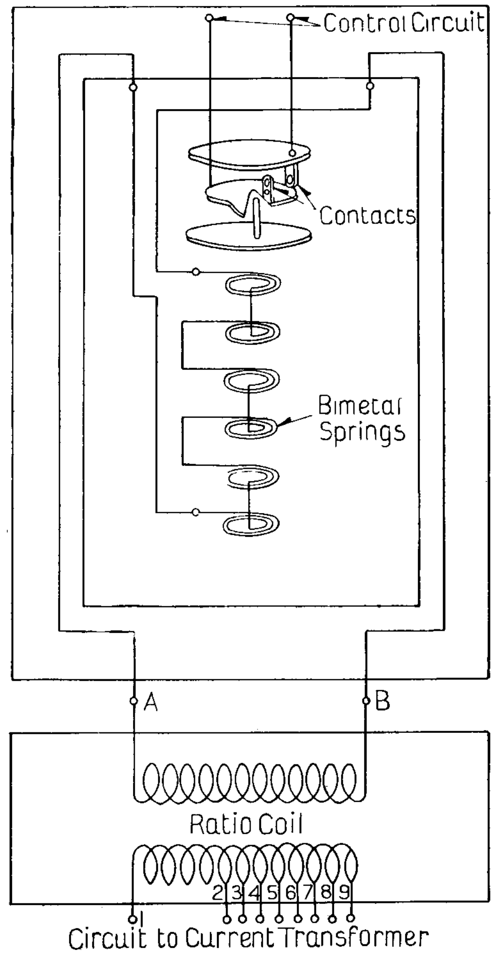


Fig. 44—Internal Diagram of Connections of Thermal Overload Relay (29)

to close. The whole element is immersed in oil and covered by a heat insulating case. The springs are heated by the current passed through them, this current being usually the secondary current of a current transformer.

Adjustment:

On the top of the case is a lever by which the amount of rotation of the shaft, necessary to close contacts, can be changed. A pointer shown through glass window indicates the setting. A calibration curve is shipped with the relay and adjustment should be made in accordance with this.

Instructions For Connecting Thermal Relays.

A-C. Thermal overload relays of the oil immersed type such as are supplied with automatic switchboards, are equipped with ratio coils. The ratio coil is either mounted in the same case with the relay or may be mounted separately. Diagram Fig. 44 shows the internal connections and the connections to be made between the thermal relay and the ratio coils. The coil with the taps is the one to be used with the current transformer, while the other coil is connected to the relay (A-B). The current transformer should be connected to the two main terminal posts located at the top of the end bracket above the terminal board. It will be noted that one of these main terminals is connected to the terminal bus and that this terminal bus has a number of tap holes which permit varying the ratio. This ratio is determined by the position of the set screw. If it is in the hole at the extreme right (9) the ratio between the current flowing in the thermal relay and the transformer secondary current will be the largest, i.e., the current in the thermal relay will be the largest for a given value of current in the secondary of the current transformer. By changing this set screw to other holes, this ratio can be decreased until in the hole at the extreme left (2) the ratio will be approximately 1/1.

The ratio values obtained are approximately as follows: The numbering refers to the tap hole, No. 2 tap hole being at the left and No. 9 at the right end of the terminal board.

Tap Hole Number	Ratio—Thermal Relay Current to Transformer Secondary Current
2	1.0
3	1.15
4	1.3
5	1.4
6	1.55
7	1.7
8	1.8
9	1.9

Caution.

Never remove set screw and change ratio adjustment unless current transformer is de-energized, as the removal of the set screw opens the secondary circuit of the transformer. Be sure the set screw is screwed in tight so that good contact is made.

If the ratio of the current transformers (i.e. the line transformer) does not give the desired current in the thermal relay, it is possible to step down the current by reversing the connections of the ratio coils; i.e. connecting the coil with the taps to the thermal relay while the other coil is connected to the current transformers. Doing this will simply reverse the ratios given above so that the current in the thermal relay will be less than that in the secondary of the current transformer.

Care:

The relay cannot be repaired in the field as the element is sealed in oil. If any failure occurs this should therefore be returned to the factory for repairs.

No. 30. Lockout Relay. (Fig. 45.)

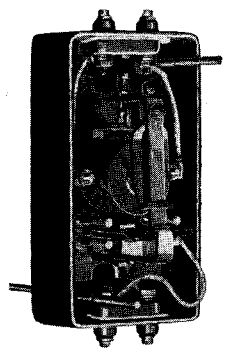


Fig. 45—Lock-Out Relay

This relay is normally in the latched position with the lower contacts closed. When the coil is energized the latch is pulled open and a spring forces the moving contact arm up, opening the lower contacts and closing the upper contacts. To reset, the button on top of the case must be depressed.

Adjustment:

The armature travel can be adjusted by means of the back stop screw. No other adjustment is necessary.

Care:

This relay will require little attention other than to see that contacts are clean and make proper contact. On inspection the relay should be operated once or twice by hand to make sure that there is no sticking.

No. 31. Brush Lifting Device. (Fig. 46.)

This device consists of a motor connected through a gear reduction and lever arms to a brush lifting ring on the converter. A jack

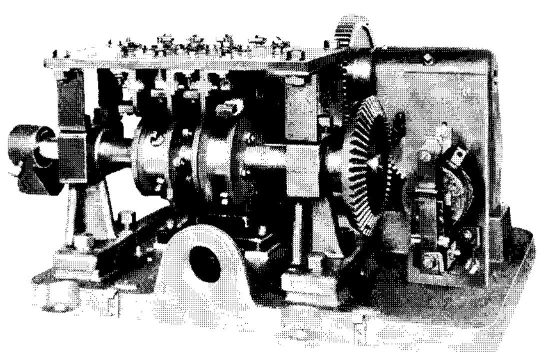


Fig. 46—Brush Lifting Device—Motor Operated (Cover Removed)

shaft carries four cams, two of which operate interlock contacts and two which operate the limit contact to prevent overtravel. The complete device is mounted in a suitable case attached to the bed plate of the converter.

Adjustment:

The device is mounted on the converter bed plate and is adjusted for proper operation before being shipped from the factory. Only minor mechanical adjustments will therefor be required in the field.

Care:

Keep the gear case filled sufficiently with heavy oil so that the worm and high speed gears run continuously in oil. The slow speed exposed gears should likewise be kept well greased with a heavy grease. Clean and fill the grease cups of the motor with vaseline about once in 3 months. Inspect the cam operating mechanism and see that contacts are clean and make proper contact. On inspection, watch the operation of the device, making sure that all the brushes seat properly on the commutator when down and all the brushes, (except the two pilot brushes) are raised at least three-sixteenths of an inch off the commutator when in the up or off position. (Two pilot brushes are left permanently in contact with the commutator, so that energy for operating the field and the polarized motor relay (7) may be obtained.) Two sets of contacts operated by the cams act as limit switches for disconnecting the motor at the time when the brushes are in the full down or up position. These contacts should not break until the brushes fully seat on, or are fully off, the commutator.

No. 32. Reverse Current Relay. (Fig. 47.)

This device is a standard type "D" reverse current overload relay. The leads should be connected across a shunt of not more than one hundred millivolts at full load. The relay operates on the moving coil principle and is so connected across a shunt that the contacts are not closed except when a current flows in a reverse direction. The contacts close with a speed inversely proportional to the current in the coils. The controlling magnet is excited by a coil connected across the main trolley circuit.

Numbers on the adjusting scale indicate in millivolts the minimum reverse voltage at the terminals of the moving element that will cause the relay to operate. When used on a

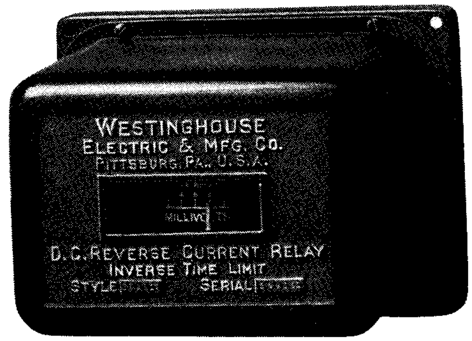


Fig. 47—D-C. Reverse Current Relay (32)

50 millivolt ammeter shunt, a two millivolt tripping adjustment gives a 4 per cent. sensitiveness. It is often advisable to shunt sufficient of the bus to retain a MV. drop of as high as 120 MV. at full load. This assures high sensitivity at light load.

The time element varies from eight seconds at the lowest current that will close the contacts to practically instantaneous action on high current values.

No. 34. A-C. Contactor For Starting Motor:

This is a type F contactor and the instructions given for the starting contactor (6) apply to this device.

Note: As the name implies, this contactor is used only with automatic switching equipment for control of a motor started converter.

No. 35. A-C. Accelerating Relay For Starting Motors (Fig. 48.)

This relay is used only on automatic switching for control of a motor started converter. This relay is mechanically connected to contactor in such a way that it is inoperative as long as the contactor is open. When the contactor closes, it presses down the cap of the relay which is mounted below it, and thereby leaves the armature of the relay held only by the current in the series operating coil. As the motor speeds up, the current in this coil is reduced until it reaches the value for which the relay is set at which point the armature falls, the relay then operating to close its contacts.

The relay is adjusted before shipment to operate at a current value considered proper to accelerate the motor. Means are provided, however, for introducing and varying an air gap in the magnetic circuit of the relay so that the settings can be changed, should adjust-

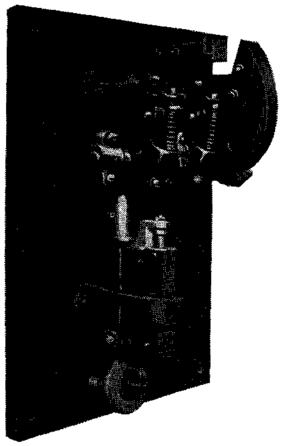


Fig. 48—A-C. Accelerating Relay (35) Mounted with Type F Contactor (34)

ments be necessary to meet special conditions. The relay, however, should not be set at a point where the disc fails to drop after the motor has come up to speed. The value of the current at which the moving magnet armature falls, is fixed by the adjustment of the air gap. Lowering the moving magnet coil by means of the screw and lock nuts above it, decreases the air gap, and lowers the value of the current at which the current operates. Increasing the air gap, raises the current value at which the relay operates and causes the relay disc to drop out at a higher current.

The contacts of the contactor with which the relay is mounted should touch before the tail piece or operating arm hits the relay cap. Contacts should therefore be renewed often enough to maintain this condition.

No. 36. D-C. Voltage Relay:

(This relay is used only with automatic switching equipment for control of a motor started converter.) This is a simple type of D-C. single contact shunt relay built up of punched metal parts. The relay is calibrated to operate on approximately two-thirds of normal D-C. voltage of the converter. The contacts of this relay will seldom, if ever need replacing. They however should be kept clean in order to insure proper operation.

No. 37. D-C. Line Contactor (A-C. Operated).

This is a type F contactor operated by an A-C. shunt coil. It is similar to the A-C. starting contactor (6) except that it is single pole instead of three pole. The same remarks under (6) apply.

No. 37x. Line Contactor Relay (A-C. Shunt Relay).

This is the same type of relay as No. 3 and the same remarks apply.

No. 38. Field Current Relay.

This is a D-C. contactor type of relay energized by a series coil. It is designed to close its contacts when the field current is approximately 80 per cent. of the normal value.

No adjustment is required other than to see that contacts close properly.

Care:

Keep the contacts clean and see that they make proper contact. Otherwise the relay will need little attention.

No. 40. Main Contactors for Feeders (Fig. 28.)

In case individual D-C. feeder contactors are used, No. (40) will be the contactors disconnecting the feeders from the bus. They are the same as the type C contactor used for No. (12) and the same instructions apply.

No. 40A D-C. Overload Relay. (Fig. 29.)

These are the same as (12a) but are used in connection with the feeder contactors.

No. 41. D.-C. Feeder Resistance Shunting Contactors.

These are type C contactors and the same instructions covering D-C. Contactor (12) apply.

No. 45. Phase Balanced Relay Low Tension Protection. (Fig. 49.)

This is a type "CO" induction relay, the

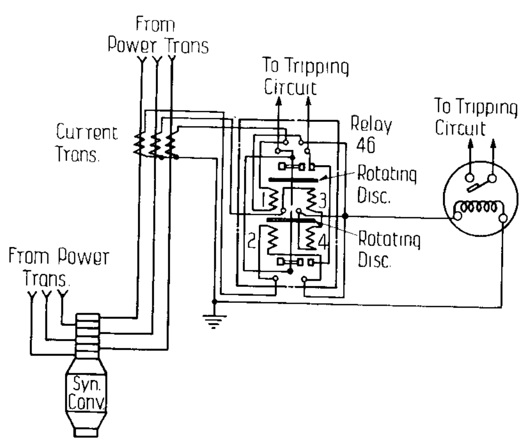


Fig. 49—Diagram of Connections for Balanced Phase Relays—(45 and 46)

coil of which is designed to operate the relay at a very low current. It is connected in the common return wire of three current transformers, (Fig. 49) so that if there is an unbalance of currents in the transformers thus causing current to flow through the common return wire it will cause the relay to close its contacts, and shut down the station as explained, under protective devices. The relay is identical with the overload relays (23) except that the coil is designed to operate the relay on approximately one-half ampere. The same instructions therefore apply.

No. 46. Phase Balanced Relay (High Tension Protection) (Fig. 50.)

In some cases of unbalance such as single phase operation, no current will pass through

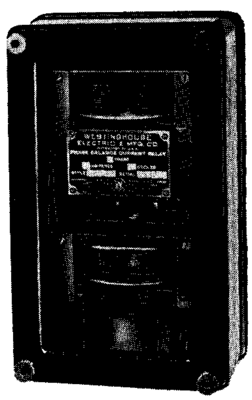


Fig. 50—Phase Balance Current Relay (46)

the common return wire (and relay 45) (Fig. 49) as the current of the transformers will exactly balance and neutralize each other. The Phase Balance Relay (46) will protect against this condition. This is a special polyphase induction type of relay having four windings. The connections are shown in Fig. 49. The two rotating discs are mounted on shafts independent of each other, each of which carries a contacter. (these contacters being in parallel). The current of one transformer passes through coil 1, of another through coils 3 and 4 in series and of the third through coil 2. Ordinarily when the current transformers carry equal currents the relay will be balanced as the ampere turns of coils 1 and 2 exactly equal the ampere turns of 3 and 4, and the torque produced by coil 1 opposes that of coil 3, while that of coil 2 opposes the torque of coil 4. However, if an unbalanced load occurs, say by a phase failure on the high tension side of the transformers this will unbalance the relay and the contacts of the upper or lower elements or both will close and shunt the coil of Master Relay (3-a), shutting down the station.

Adjustment:

The relay is very sensitive and is adjusted before leaving the factory. The same current adjustment can be made as on the type CO overload relay (23) and the same instructions apply. Be sure that all four coils are adjusted alike. It sometimes happens that unbalance is encountered in starting and in this case the relay may be made less sensitive by making the connections to tap 6 on the relay.

Care:

Contacts should be inspected occasionally to see that they are clean and make proper contact.

No. 48. Type CV Relay.

This is a Type "CV" Undervoltage Relay whose contacts close when the relay is energized. It is used only with motor started converters, as explained on page 14. The same remarks covering relay (2) apply here.

No. 51. Reset Relay used with Service Restoring Contactor. (Fig. 51.)

This relay is provided with a direct current operating coil and when used with

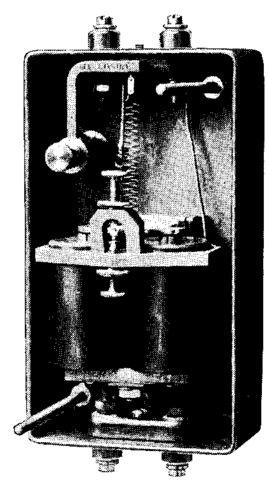


Fig. 51—Reset Relay used with Service Restoring Contactor

the service restoring contactor, must always have a resistance in series with it. It is very sensitive to changes in current and is capable of being accurately adjusted to operate at a definite current.

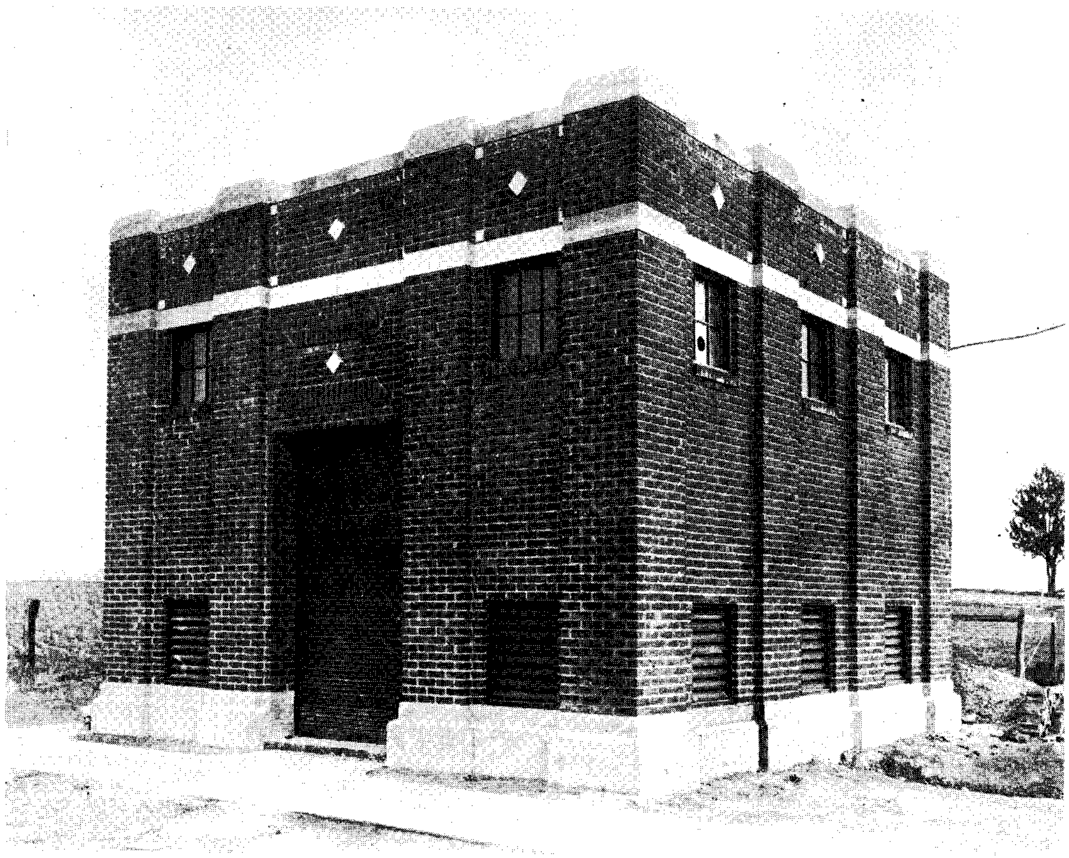


Fig. 52—Typical Automatic Substation Building for One 500 Kilowatt 600 Volt D-C. Railway Converter

Adjustment:

The pull of the relay coils is opposed by a helical spring. When the pull exceeds the tension of the spring, the contacts close. The adjustable arm is used to adjust the tension of the spring which regulates the voltage drop required across the coils to cause the contacts to close. The calibration figures given on the arm should be disregarded as giving the actual millivolt drop across the relay, as these are only correct when the relay is used (with a shunt) as an overload relay.

Care:

Little attention is required but occasionally the relay should be cleaned and inspected to see that there is no binding or poor contact. The relay contacts are not designed to open a circuit, so that an auxiliary contact must be used in parallel with it as shown in Fig. 14.

INSPECTION

As a general rule an automatic substation should be given a periodic inspection at intervals of not longer than one week. However, the thoroughness and care of the inspector may make frequent inspections unnecessary, while on the other hand, hasty and haphazard inspections will result eventually in trouble even if made once a week. Inspectors should, therefore, be thoroughly instructed and experienced in both the functions and the adjustments of the various devices and should have a uniform method of making the inspections.

It is suggested that in each substation a framed blue print, both of the diagram of connections and the schematic diagram be located where it can be easily referred to, by the inspector. In case of trouble, he can, therefore, quickly refresh his memory as to the connections and the interlocks.

WEAR:

Practically the only parts which will wear enough in ordinary operation to require replacement are the contacts of the relays, breakers and contactors. These will need only occasional replacement, but should be inspected thoroughly as it is here that trouble may be expected through slipshod care.

CONNECTIONS:

All connections should be examined to make sure that none are broken or loosened. Particular care should be taken that lock nuts holding adjustment screws on the various devices are tight.

TROUBLE:

In case of a station locking out automatically, the trouble man will first examine the lockout relay (30) to see if this has operated.

If so, he should inspect (1) the bearings of the converter, and (2) the overspeed device of the converter. If these are all right, he should then inspect the main circuits of the converter and the transformers and also look for blown fuses on the voltage transformers, the small operating transformer and the control switches. Reverse phase relay (18) should be examined to make sure that there is not phase failure on the incoming A-C. line. If everything is apparently in operating condition and lockout relay (30) is reset, he may then attempt to start up the station by closing the control switch. If it does not start up properly and the trouble is difficult to locate, it may be advisable to block out each relay in turn by which method of elimination the location of the trouble should be easily found.

If the station goes into operation without any apparent trouble, he should repeat the starting operation several times and then allow the station to operate, remaining long enough for trouble to show up if such still exists.

LIGHTNING ARRESTER:

If an electrolytic lightning arrester is installed, it is necessary to charge this either once a day or once a week depending upon which type of arrester is used. This does not require any special knowledge or skill, so that one of the crewmen of the first car out in the morning can be detailed for this duty.

ROUTINE INSPECTION:

Some standard form of inspection report will greatly aid in methodical and thorough inspection. A sample form for such a purpose is submitted on page 38.

PERIODICAL INSPECTION REPORT ON RAILWAY AUTOMATIC SUBSTATIONS

For A-C. Self Started Synchronous Converters

NOTE to Inspector: If possible, make inspection when machine is lightly loaded. Shut down station by opening switch (17) and control switch to operating transformer. Open A-C. line disconnecting switches. Check the items, if O.K., if not, make note under remarks of any adjustments made or necessary to make and whether any replacements are necessary.

Check Off Each Item if O. K.

	DEVICE NUMBER																			
	1	3	3a	4-5-6	9	10	11	12	12a	13	14	14a	15	15a	16	19	30	31	37	37x
Contacts—Clean—Good Condition Good Contact																				
Connections Tight Lock Nuts Tight																				
Mechanical Operation—(No Binding)																				
*Electrical Operation																				

*Watch Electrical Operation when starting up.

ADDITIONAL INSPECTION:

Operating Transformer:
- Fuses unblown?
- Oil—Clean—Level Correct?

Current Transformers:
- Connections Tight?

Voltage Transformers:
- Connections Tight?
- Fuses unblown?

Main Connections:
- A-C. Connections Tight?
- D-C. Connections Tight?
- Grid Resistor Connections Tight?

Relays 2, 18, 23, 32, 45, 46:
(These relays require only occasional inspection.)

Contacts:
- Clean—Good condition—good contact?
- Connections Tight?

Polarized Motor Relay No. 7:

Contacts A-B-D:
- Clean—good condition—good contact?

Mechanical Operation:
- No Binding (Spin Motor—Turn Disc)?
- Clutch releases (allows contacts to open)?
- Lubrication:—Gears—Bearings?
- Connections Tight?

Motor:
- Brushes in good contact?
- Commutator clean?

Main Oil Circuit Breaker No. 20:

- Foundation bolts solid and tight?

Mechanical Operation:
- No abnormal Friction?
- No excessive play in parts?
- Fulcrum pins tight and oiled?
- Lock nuts tight?

Oil:
- Proper height, clean?

Auxiliary Switches:
- Contacts clean—make proper contact?

Low voltage: Trip Latch Mechanism free from friction.

Underload Delay Relay No. 27:

Contacts—S-T:
- Clean, good condition, good contact?

Mechanical Operation:
- No binding (Spin Motor—turn disc)?
- Clutch releases (allows disc to return to open position)?
- Lubrication—Gears—Bearings?

Connections Tight?

Bearing Thermostats No. 25:
- Stuffing Box oil tight?
- Tube from bearing to bellows unbroken?

Rheostats:
- Connections Tight?
- Setting correct?

Brush Lifting Device No. 31:

Lubrication:
- Grease cups filled?
- Oil in pan to proper level?
- All brushes (except Pilot brushes) clear commutator by at last $\frac{3}{16}$" when in up position.
- All brushes seat on commutator in down position?

Converter:

Bearings?
- Oil sufficient—clean?
- Oil Rings free to revolve?

Cable Connections:
- Tight?

Slip Rings:
- Clean—unpitted?
- Brushes seat properly?
- Brush connections tight?
- Brush holders tight?
- Brush rigging rigid?
- Brush spring tension proper?

Commutator:
- Clean, unpitted, no high mica?
- Segments tight?
- Brushes seat properly?
- Brush spring tension proper ?
- Pilot brushes seat properly?
- Brush connections tight?
- Brush holders tight?
- Brush rigging rigid?

RUNNING INSPECTION:

Close A-C. Line Disconnects.

Close knife switch connecting operating transformer to control circuits.

Close switch (17) on the non auto. side.

Station should now start up. Watch operation of all devices. Answer the fourth question in table marked *.

Does station start up smoothly? (It not, rectify trouble before leaving or make a detailed report under remarks).

Polarized Motor Relay No. 7:
- Does clutch engage when motor runs?
- Does clutch slip?
- Do gears engage without slipping?
- Does moving disc return promptly to original position on disengagement of gears?
- (Throw switch No. 17 on non auto side).
- (Close contact T of relay No. 27 by hand).
- Does station shut down?
- Do Contacts "T & S" make proper contact?

Brush Lifting Device No. 31:

Do brushes raise off commutator properly as soon as relay (3-a) closes?

Do brushes lower properly after running contactor (11) closes?

Main Oil Circuit Breaker No. 20:
- Open knife switch (17).
- Does low voltage mechanism trip breaker?
- Close knife switch (17).

Underload Delay Relay No. 27:
- (Throw switch No. 17 onto "auto" side).
- (Open D-C. feeder circuits).
- Does relay motor operate?
- Does moving disc. return promptly to original position on disengagement of clutch?

Bearing Thermostat No. 25:
- (Close contacts by hand).
- Does station shut down?
- Open thermostat contacts.
- (Reset lockout relay 30).

Grid Thermostat No. 28:
- (Close contacts by hand).
- Does station shut down?

Overspeed Device No. 31:
- (Trip device by hand).
- Does station shut down?
- (Reset trip device—station should restart).

Converter:
- Commutation O. K.?

A-C. Lightning Arrester:
- (Charge arrester).
- Is charge O. K.?
- (Should be blue and snappy).

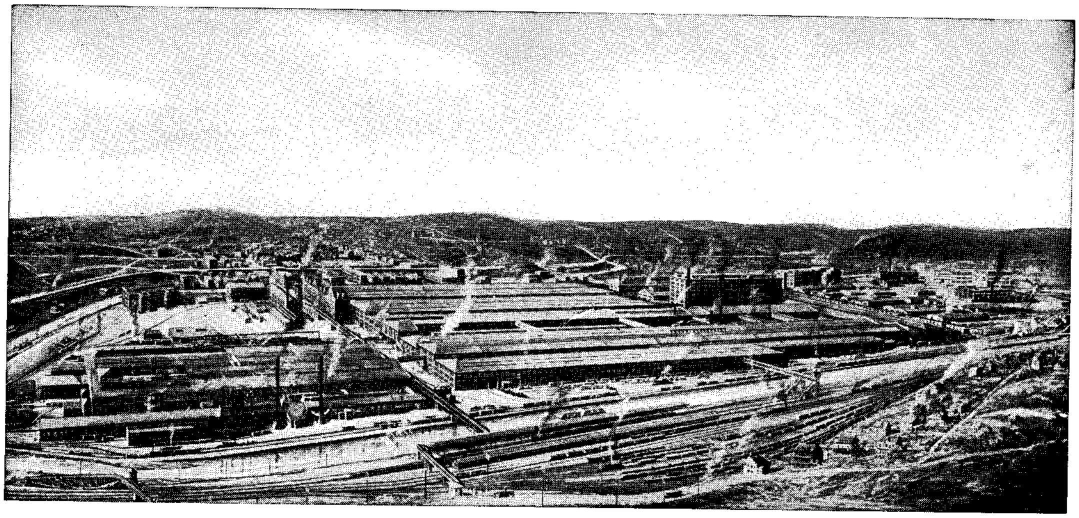
After the inspection switch (17) should be opened and then closed on the auto side. All necessary control switches should also be closed. Note that station comes onto line properly (unless relay (1) is energized).

REMARKS:

Time of completion of inspection..............................

....

(Signed)..



The Company's Works at East Pittsburgh, Pa.

Westinghouse Products

A few of the Westinghouse Products are listed below and will furnish some idea of the great variety of electrical apparatus manufactured by the Company and the many extensive fields for their use.

For Industrial Use

Instruments

Motors and controllers for every application, the more important of which are: Machine shops, woodworking plants, textile mills, steel mills, flour mills, cement mills, brick and clay plants, printing plants, bakeries, laundries, irrigation, elevators and pumps.

Welding outfits

Gears

Industrial heating devices, such as: Glue pots, immersion heaters, solder pots, hat-making machinery and electric ovens.

Lighting Systems

Safety switches

For Power Plants and Transmission Lines

Circuit-breakers and switches
Condensers
Controllers
Control switches
Frequency changers
Fuses and fuse blocks
Generators
Insulating material
Instruments
Lamps, incandescent and arc
Lightning arresters
Line material
Locomotives
Meters
Motors
Motor-generators
Portable Power Stands, 110 volts
Rectifiers
Regulators
Relays
Solder and soldering fluids
Stokers
Substations, portable and automatic
Switchboards
Synchronous converters
Transformers
Turbine-generators

For Transportation

Locomotives
Railway equipment
Marine equipment

For Mines

Lamps
Locomotives
Motors for hoists and pumps
Motor-generators
Portable substations
Switchboards
Line material
Ventilating outfits

For Farms

Fans

Household appliances

Motors for driving churns, cream separators, corn shellers, feed grinders, pumps, air compressors, grindstones, fruit cleaning machines and sorting machines.

Generators for light, power and heating apparatus

Portable Power Stands, 32 Volts

Radio Apparatus

Transformers

For Office and Store

Electric radiators

Fans

Arc lamps

Incandescent lamps

Small motors for driving addressing machines, dictaphones, adding machines, cash carriers, moving window displays, signs, flashers, envelope sealers, duplicators, etc.

Ventilating outfits

For Electric and Gasoline Automobiles and the Garage

Battery charging outfits

Charging plugs and receptacles

Lamps

Instruments

Motors and controllers

Small motors for driving lathes, tire pumps, machine tools, polishing and grinding lathes.

Solder and soldering fluids

Starting, lighting and ignition systems, embracing: Starting motor generators, ignition units, lamps, headlights, switches, etc.

Tire vulcanizers

For the Home

Electric ware, including: Table stoves, toasters, irons, warming pads, curling irons, coffee percolators, chafing dishes, disc stoves, radiators and sterilizers.

Automatic electric ranges

Fans

Incandescent lamps

Radio Apparatus

Small motors for driving coffee grinders, ice cream freezers, ironing machines, washing machines, vacuum cleaners, sewing machines, small lathes, polishing and grinding wheels, pumps and piano players

Sew-motors

Westinghouse Press
Printed in U. S. A.