INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES H-3 AND HV-3 THREE PHASE DIRECTIONAL RELAYS

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CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment. Make sure that all moving parts operate freely and inspect the contacts to see that they are clean and close properly. Operate the relay to check the settings and electrical connections.

APPLICATION

The types H-3 and HV-3 relays are polyphase direction relays which are used to obtain high speed directional discrimination during faults on power systems. The type HV-3 relay has a voltage restraint element which introduces a restraining torque on the relay proportional to the area of the voltage triangle. Thus, at normal voltage, sufficient torque is produced to prevent operation of the relay on normal load current flow. Any fault on the system reduces the area of the voltage triangle, and consequently the amount of restraint. At the same time the current in the relay increases and the relay operates if the fault is in the contact closing direction. Since the voltage triangle does not collapse as much on ground faults as it does on phase faults, it is desirable to remove voltage restraint on ground faults. This may easily be done by an instantaneous overcurrent ground relay (type SC) with its back contacts connected to open any one of the leads to the voltage restraint element.

The direction of power flow for both phase and ground faults can be detected with these relays. To obtain correct operation during ground faults, it is necessary that the minimum current in the faulted conductor be at least twice the maximum load current flow (with no voltage restraint on the relay) so that if the fault current and load currents are in opposition, the former will always predominate and give a net torque on the relay in the correct direction. Stated another way, the minimum line-to-ground current must be at least three times the maximum load current for correct ground fault protection. Low ground current occurs most frequently on impedance grounded systems. Where positive directional indication cannot be obtained under all system conditions, it is recommended that a separate ground directional relay be used.

Both the type H-3 and the type HV-3 relays can be furnished with either a watt characteristic or a 45° characteristic.

CONSTRUCTION AND OPERATION

The type H-3 relay consists of a polyphase directional unit, two contactor switches, and two operation indicators. The type HV-3 relay consists of a polyphase directional unit, a voltage restraint unit, and two indicating contactor switches.

Polyphase Directional Unit

This unit consists of three electromagnets, and a vertical shaft with three movable loops, arranged as shown in figure 1. Each loop has its outer side located in an air gap within the electromagnet. Each electromagnet has a three-legged magnetic circuit wound with three coils. The coils on the two outer legs are the voltage windings. Voltage applied to these coils induces a large current in the loop by transformer action. Current flowing thru the current coil on the center leg of the electromagnet produces an air gap flux which interacts with the loop current flux in the outer side of the loop and causes rotation of the shaft in the direction corresponding to the direction of flow of the alternating current power.

One loop and its associated electromagnet make up one phase of the three-phase relay. With the 45° characteristic relay a delta voltage and a star current are applied to each electromagnet, and proper phase angle characteristics are obtained as follows. The loop, which is considered as the secondary load of a transformer, has a much higher resistance than reactance, and the loop current lags the voltage applied to the electromagnet by an angle of 10 to 15 degrees. The air gap flux lags the applied current by about 55 to 60 degrees because of the lag loops around the centerpole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by 45 degrees.

SUPERSEDES I.L. 41-226.2B
*Denotes change from superseded issue.

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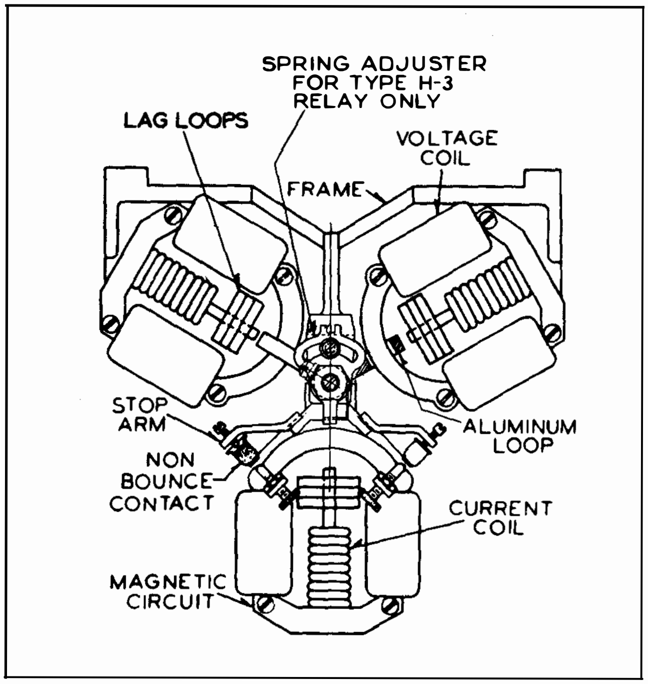

Fig. 1 — Schematic — Top View of Polyphase Directional Unit.

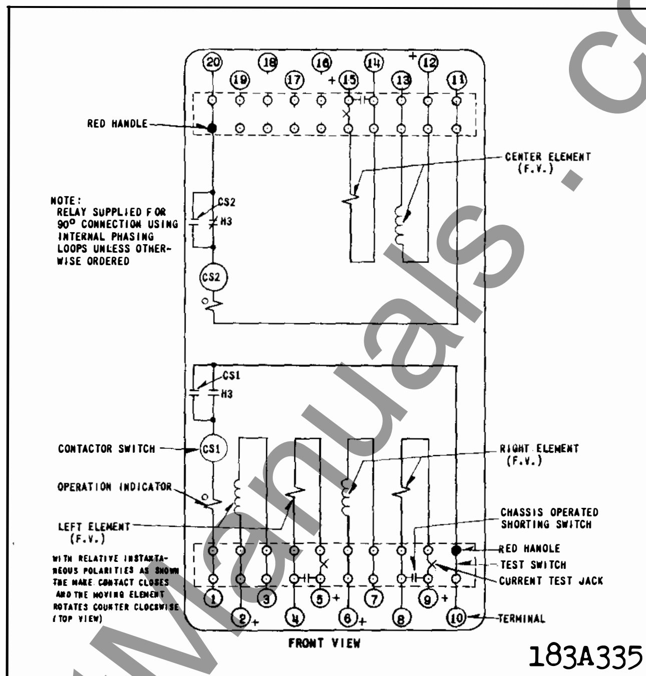

Fig. 2 — Internal Schematic of the Type H-3 Relay in the FT22 Case.

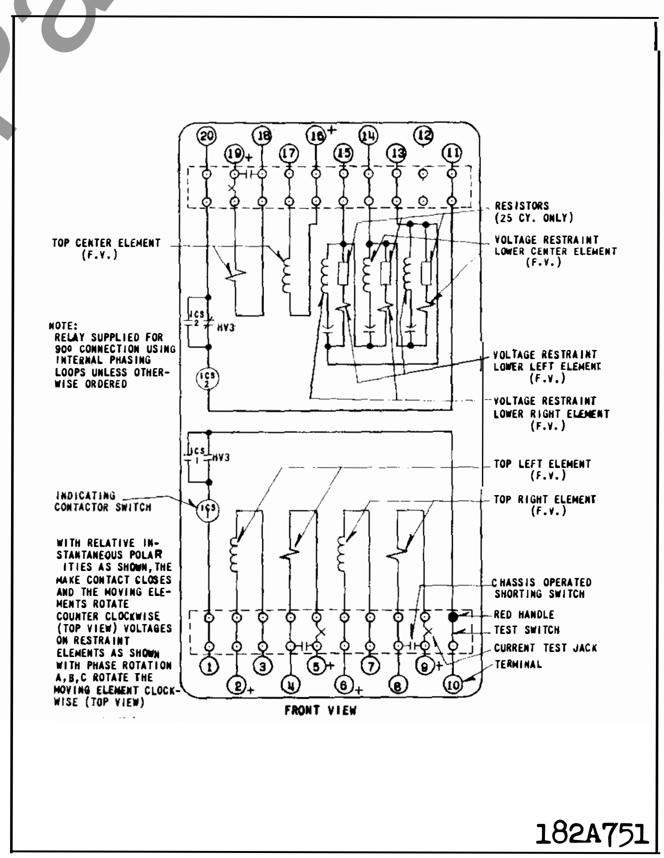

Fig. 3 — Internal Schematic of the Type HV-3 Relay in the FT32 Case.

The 90° Connection is used on the relay to give the required delta voltage and star current. With this connection one of the electromagnets will have "A phase" (star) current and "BC" (delta) voltage which for a system power factor of unity, lags the current by 90°. Hence, with this connection and the above (45°) relay characteristics, maximum torque is obtained when the system fault current is lagging its unity power factor position by 45°.

With the watt characteristic relay a star current and a star voltage are applied to each electromagnet. The air gap flux lags the applied current by about 10 to 15 degrees because of the lag loops around the center pole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by about 0 degrees.

The instantaneous torque in each element of the relay is produced by the instantaneous products of voltage (loop current) and current (air gap flux) in the electromagnet, which is a double frequency pulsating torque. The torques in the other two electromagnets are also pulsating, but they are displaced 120 degrees in time phase and when all three instantaneous values are added, the result is a uniform non-pulsating torque.

Two moving contacts are mounted at right angles to each other on the outer end of a leaf spring which in turn is mounted on Isolantite arm on the moving shaft. A stop bracket with a small cylinder partially

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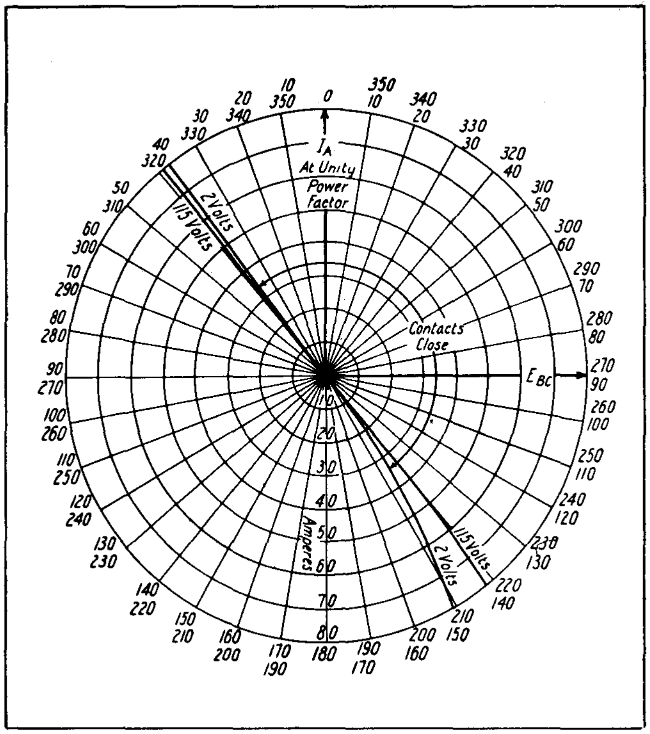

Fig. 4 – Typical Phase Angle Curve for 45° Characteristic; 50 and 60 Cycle, H-3 and HV-3 Relays – Balanced Three Phase Power Applied and No Spring Restraint.

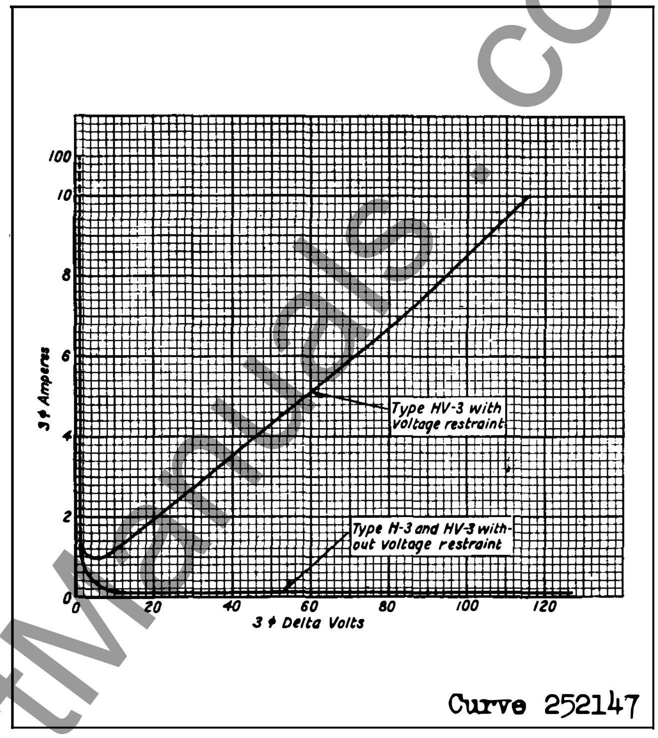

Fig. 5 – Typical Sensitivity Curve for 50 and 60 Cycle, H-3 and HV-3 Relays – at Maximum Torque Angle.

filled with tungsten powder is mounted behind each moving contact. When the moving contact strikes against the rigid fixed contact screw, the spring is deflected for the necessary contact follow, after which the stop strikes the moving contact. Thus, the full torque of the relay is transmitted thru the contacts to maintain full contact pressure. The particles of tungsten powder in the small cylinder slide over each other at the instant of impact and absorb the energy in the moving element. A flexible metal ribbon conducts current to the moving contacts.

The type H-3 relay is supplied with spring restraint which is adjusted to hold the contacts in the normal non-trip position when the relay is deenergized. This prevents an incorrect directional indication by the element under the condition of loss of load. However, the spring restraint may be adjusted to give a bias torque in either direction.

Voltage Restraint Unit

This element is supplied only in the type HV-3 relays and consists of three electromagnets and loops similar to those used on the directional element. The restraining unit is mounted below the directional unit and the loops of the two units are fastened to a common vertical shaft which operates the two contacts as described above. The outer coils of each electromagnet have one delta voltage (E_1) applied and the center coil has another delta voltage (E_2) applied. By means of the capacitor units in series with the outer two coils, the phase angle characteristics of the electromagnets are such that the torque of the element is proportional to:

$$V_1 \cdot V_2 \cdot \sin \theta$$

where θ is the angle between the two delta voltages and is normally 60°.

If any one of the three delta voltages completely collapses during a fault, there is no torque on the electromagnet, since the collapse of the third voltage makes the sine of the angle between the voltages zero. If all three voltages decrease uniformly, the torque varies as the square of their magnitude. Each electromagnet is connected to a different combination of delta voltages so that a uniform restraint torque and balanced burdens are obtained.

Restraint can be removed by opening any one supply lead to the restraint element. This applies single phase to all three electromagnets and the sine of the

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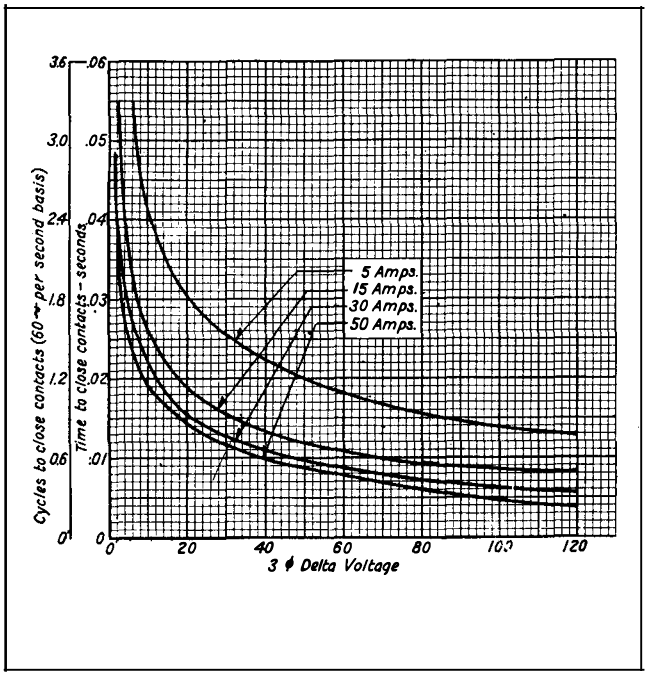

Fig. 6 — Typical Time — Current Curves of 50 and 60 Cycle H-3 Relay for Three Phase Faults at Maximum Torque Angle.

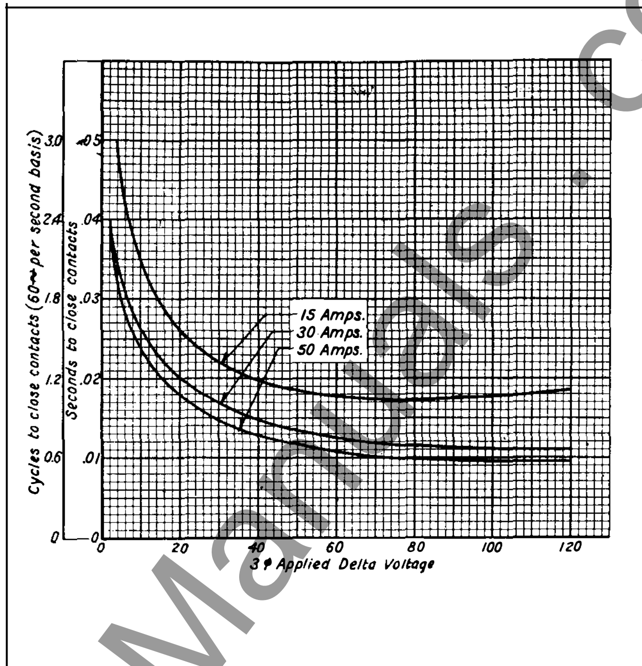

Fig. 7 — Typical Time — Current Curves of 50 and 60 Cycle HV-3 Relay for Three Phase Faults at Maximum Torque Angle.

angle becomes zero. At normal voltages 10.5 amperes is required in each element at maximum torque to overcome the restraint torque.

Contactor Switches

The d-c contactor switch in the relay is a small solenoid type switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward, the disc bridges three silver stationary contacts. The coil is in series with the main contacts of the relay and with the trip coil of the breaker. When the relay contacts close, the coil becomes energized and closes the switch contacts. This shunts the main relay contacts, thereby relieving them of the duty of carrying tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring-restrained armature releases the white target which falls by gravity to indicate completion of the trip circuit. The indicator is reset from outside of the case by a push rod in the cover or cover stud.

Indicating Contactor Switch Unit (ICS) — (HV-3 only)

The d-c indicating contactor switch is a small clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pickup value of the switch.

CHARACTERISTICS

The types H-3 relays are provided with independent make and break contacts. Two auxiliary contactor switches — one in each contact circuit — provide seal-in circuits for the main relay contact. The main contacts will close 30 amperes at 250 volts d-c and the auxiliary contactors will safely carry this current until the breaker is tripped and the auxiliary "a" switch opens. The contactor switch has a minimum

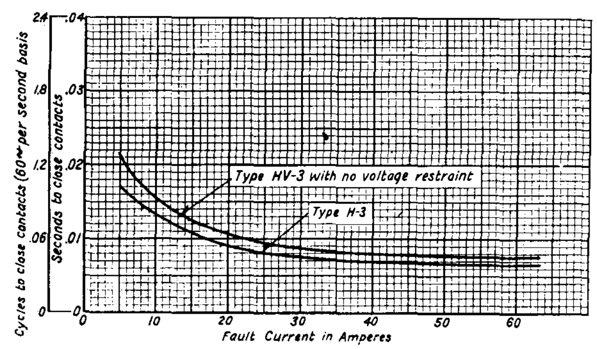

Fig. 8 – Typical Time – Current Curves for 50 and 60 Cycle H-3 and HV-3 Relays, Without Voltage Restraint for Phase to Phase Faults at Maximum Torque Angle – Full Voltage Collapse on Faulted Phase, 86% Voltage on Unfaulted Phase.

pick-up of one ampere d-c and a coil resistance of one ohm.

Typical 50 and 60 cycle phase angle characteristics of the 45° characteristic relay are shown in figure 4. Maximum torque, in the contact closing direction, occurs when the line current lags the line-to-neutral voltage by approximately 45 degrees, when using the 90° connection.

Typical 50 and 60 cycle sensitivity curves maximum torque are shown in figure 5. The sensitivity of the type HV-3 relay without voltage restraint is the same as the type H-3 relay. The 60-cycle three phase minimum pick-up without spring restraint of the type H-3 relay is 0.08 amperes at 115 volts, 0.15 ampere at 10 volts, and 5.0 amperes at 1 volt. The single phase minimum pick-up currents are approximately three times those for three phase. In the absence of sufficient operating current, the contacts may be held either open or closed by a toggle acting voltage – only torque. The affect of this torque is described in the section under "Watt Characteristic Relay Adjustments." It will be noted from the curves that the sensitivity of the type HV-3 relay with voltage restraint is decreased only at voltages above 2 volts. The curves also show that 10 amperes 60 cycles are required at 115 volts to overcome voltage restraint.

Typical time curves are shown in figures 6 to 9. All curves are for a contact spacing of .035 inch and at maximum torque for 60 and 50 cycle relays and .070 inch for 25 cycle relays.

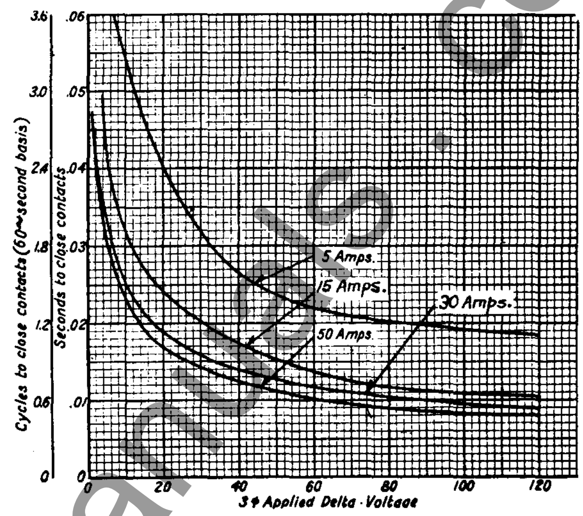

Fig. 9 – Typical Time – Current Curves for 50 and 60 Cycle Type HV-3 Relay Without Voltage Restraint for Three Phase Faults at Maximum Torque.

Trip Circuit (HV-3 only)

The main contacts will safely close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pickup setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

Trip Circuit Constant (HV-3 only)

Indicating Contactor Switch (ICS)

0.2 ampere tap 6.5 ohms d-c resistance
2.0 ampere tap 0.15 ohms d-c resistance

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by

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means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT case information refer to I.L. 41-076.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Adjust the lower bearing so that both the top and bottom of the loops are equi-distant from their respective magnetic circuits. Energize the potential circuits of the relay until the loops reach operating temperature. About ten minutes at normal voltage is necessary to reach this condition. When the operating temperature is reached, adjust the upper bearing for 1/64 inch clearance.

The loops of each element must be in line with the center of the middle leg of the magnetic circuit. If necessary, this adjustment can be obtained by loosening the electromagnet mounting screws and moving the whole electromagnet in the desired direction. All three elements must have the same relative position of loop and magnetic circuit.

Type H-3 Relay

The polarity of the relay is checked as follows: Refer to figure 2 and apply 115 bolts and 5 amperes (in phase) to the corresponding voltage and current coils in turn, with the terminals marked with polarity marks connected together. Looking at the top of the relay, the moving element should rotate in a counter-clockwise direction.

Adjust the back-up strip located in front of each moving contact by bending so that it just touches the contact spring when the contacts are open. Adjust the small cylinder behind the moving contact to obtain .009 inch contact follow. This is done by advancing the cylinder until it just touches the rear of the moving contact spring, and then backing off 1/2 turn.

45° Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase current of 50 amperes with polarities as shown on internal schematic diagram to the current coils which should be connected in series. Each potential coil should be short-circuited. When energized the relay moving element will center itself due to the combined torques produced by the 50 amperes of current and the spring restraint. Readjust the spring adjuster until the centering position of the moving element is exactly the same for the condition of zero current or with 50 amperes in the current coils. Under this condition the torque produced by the spring at the centering position is zero and does not tend to "offset" or shift the centering position due to the current. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

There are two adjustable stop screws located on the frame casting. These stops are used when the relay is supplied with two circuit closing contacts and perform the same function as the stops on the moving contact assembly.

Watt Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase potential of 67 volts with polarities as shown on internal schematic diagram to the potential coils which should be connected in parallel. Each current coil should be open-circuited. When the potential circuits are deenergized the moving element will tend to be centered by the spring. When the potential circuits are energized the moving element may move either to the right or to the left. If under this condition the moving element moves the contacts to the right, the spring should be readjusted to move the deenergized spring centering position of the moving element to the left. If under this condition the moving element moves the contacts to the left, the spring should be readjusted to move the deenergized spring centering position of the moving element to the right. Continue to shift the centering position of the spring until a small movement of the spring adjuster will cause the moving element to move in one direction when the potential is applied and a small movement in the other direction will cause the

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moving element to move in the opposite direction. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

Type HV-3 Relay

The tests outlined for the type H-3 45° characteristic relay also apply to the HV-3 relay when the voltage restraint circuit is not connected. To make a complete check on the type HV-3 relay with all circuits connected, involves three-phase test source, phase shifter, potentiometers, and non-inductive resistors for controlling the voltage and current to the relay respectively. This test will permit checking of all the characteristics of the relay at the proper phase angle. This test procedure however is usually too complicated for routine field testing. The complete test may be simplified for field testing by the following modifications. Apply three phase restraining voltage to the restraining element and single phase to all three phases of the directional element. For the latter element the potential coils are all connected in parallel and the current coils are connected in series. With a non-inductive load, the relay will be operating about 45° away from its maximum torque position and consequently current values to trip a given voltage will be increased by about 30%. Since the combination of three-phase restraining torque and single-phase operating torques on all three elements produces some unbalanced torque in the moving element, it is recommended that tests be made at a reduced voltage (65 volts or less). With 65 volts applied to voltage restraint elements, about 8 amperes is required at unity power factor to make the relay operate.

To check the circuits thru the voltage restraint element, the relay should be energized at normal voltage for about 10 minutes. The potential circuit of the directional element should then be opened. Then open the phase A potential to the voltage restraint unit and observe the torque produced on the moving element, if any. Replace A lead and remove the B lead and again observe the torque. Repeat for the C lead and in all cases there should be no torque or a very slight torque present. Any defects in the coils or capacitors of the voltage restraint circuits will be made apparent by the presence of excessive torque during this test.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core when the switch is picked up. This can be most conveniently done by turning the relay up-side-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 1.0 ohm.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced by new springs, they should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 0.16 ohm.

Indicating Contactor Switch (ICS) – (HV-3 only)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMENTS

The burdens and constants of the relays are as follows per phase:

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TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.050	2070	0.050	2070	*1480
Reactance (ohms)	0.052	1530	0.052	1530	1840
Impedance (ohms)	0.072	2580	0.072	2580	2360
Watts	1.25	4.59	1.25	4.59	3.84
Vars	1.29	3.40	1.29	3.40	4.75
Voltamperes	1.82	5.71	1.82	5.71	6.1
Power Factor	46° lag	36.5° lag	46° lag	36° lag	51° lag
Continuous Rating (Amperes or Volts)	5	120	5	120	120
One Second Current (Amps.)	230	. . .	230	. . .	. . .

VALUES AT 120 VOLTS, 5 AMPERES, 50 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.0488	2560	0.0488	2560	2720
Reactance (ohms)	0.0349	975	0.0349	975	1570
Impedance (ohms)	0.060	2740	0.060	2740	3140
Watts	1.22	4.89	1.22	4.89	3.44
Vars	.87	1.86	.87	1.86	2.00
Voltamperes	1.5	5.23	1.5	5.23	3.98
Power Factor	33.5° lag	20.8° lag	33.5° lag	20.8° lag	30.1° lag
Continuous Rating (Amperes or Volts)	5	120	5	120	120
One Second Current (Amps.)	230	. . .	230	. . .	. . .

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TYPE H-3, WATT CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3	
	Current Circuit	Voltage Circuit
Resistance (ohms)	.028	2740
Reactance (ohms)	.0192	1440
Impedance (ohms	.034	3100
Watts	.70	4:09
Vars	.48	2.14
Voltamperes	.85	4.62
Power Factor	34.5° lag	27.8° lag
Continuous Rating (Amperes or Volts)	5	120
One Second Current (Amps.)	230	...

TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 25 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint
Resistance (ohms)	.0380	3830	.0380	3830	3980
Reactance (ohms)	.0192	3200	.0192	3200	990
Impedance (ohms)	.0420	5000	.0420	5000	4100
Watts	.94	2.20	.94	2.20	3.39
Voltamperes	1.05	2.88	1.05	2.88	3.50
Power Factor	26° lag	40° lag	26° lag	40° lag	14° lag
Continuous Rating	5	120	5	120	120
One Second Rating	230	...	230	...	...

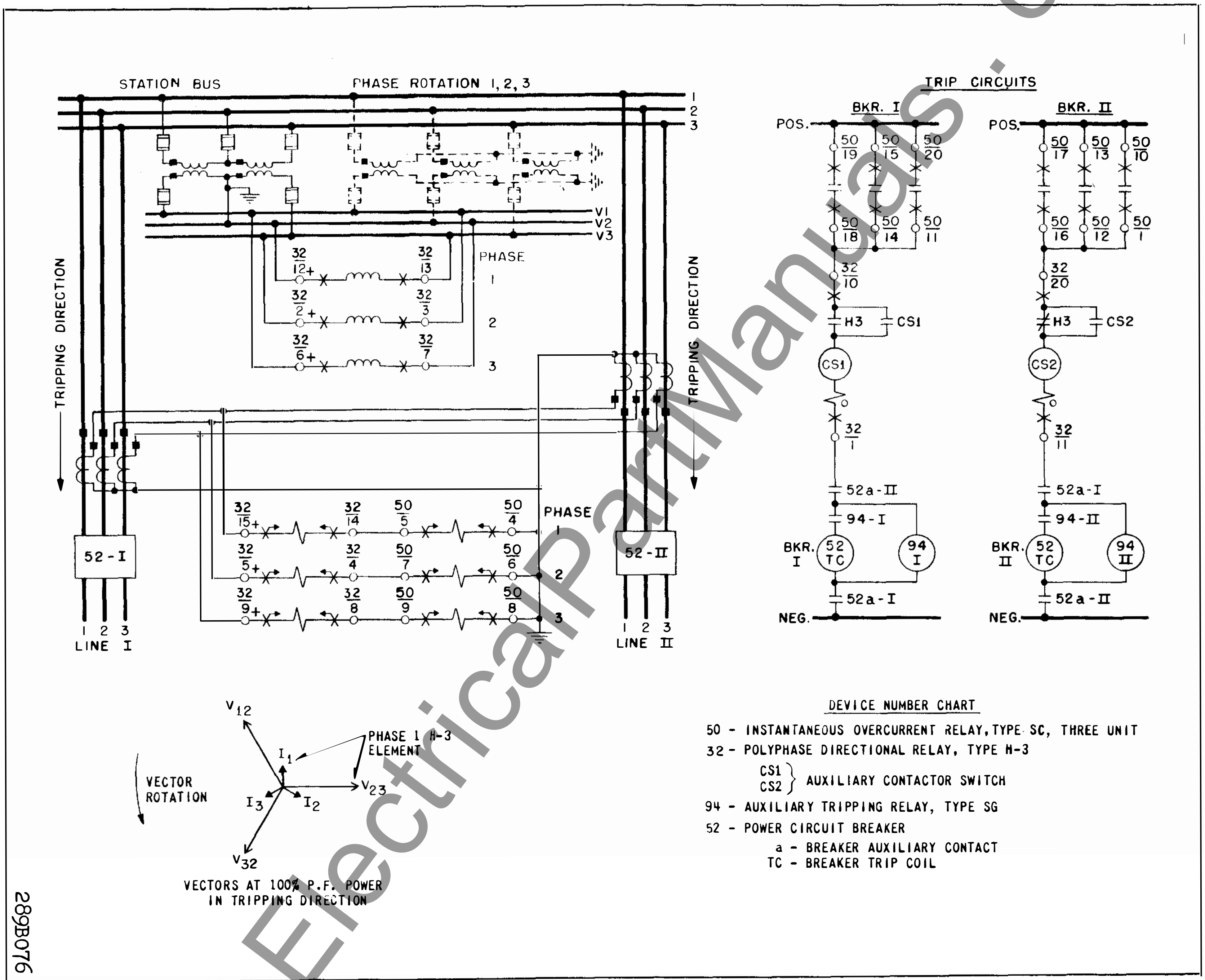

Fig. 10 – External Schematic for Phase Fault Parallel Line Protection – H-3 and Three Unit SC in FT32 Case (90° Connection).

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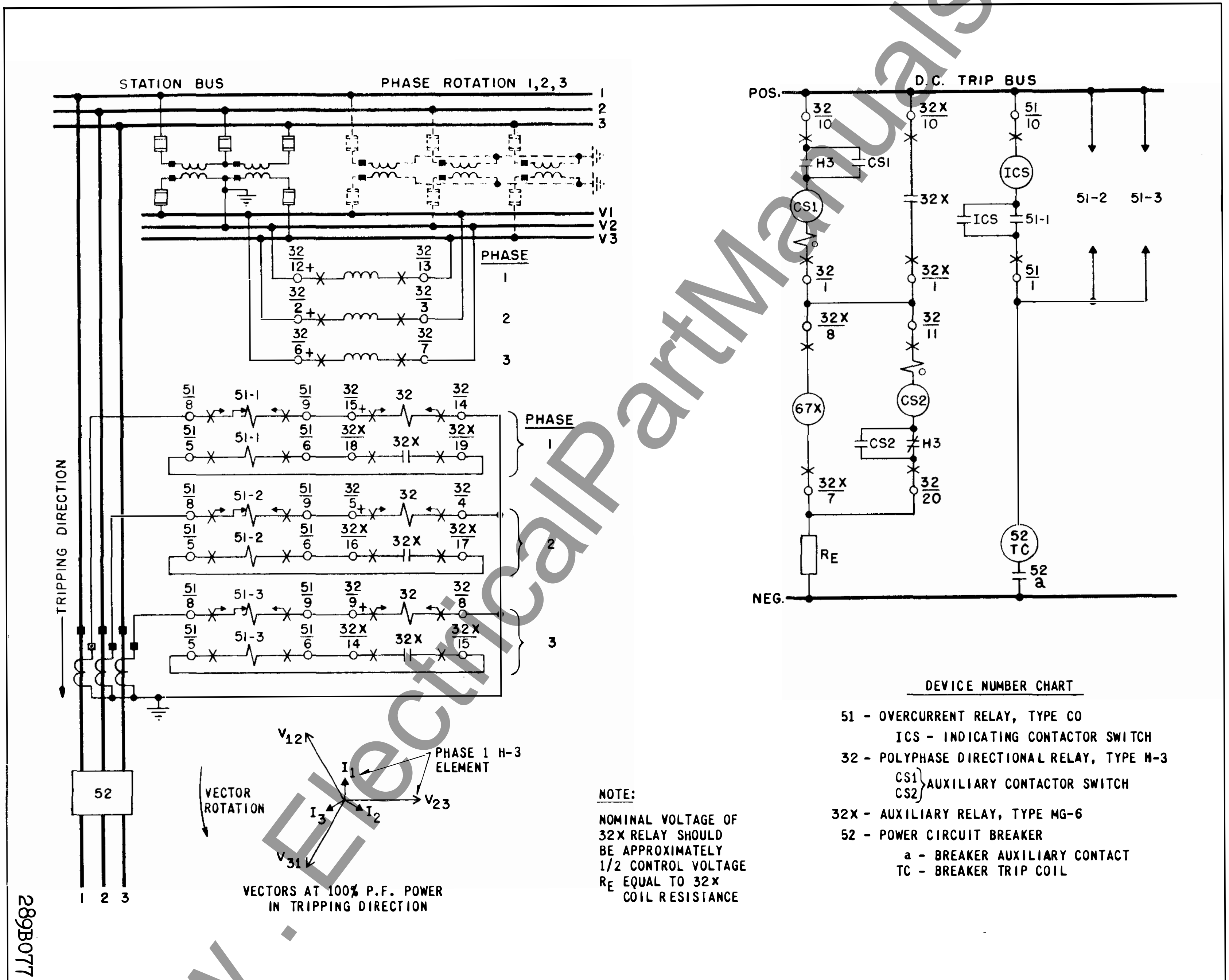

Fig. 11 – External Schematic for H-3, Torque Controlling Three CO Relays in FT11 Cases, with MG-6 in FT22 Case (90° Connection).

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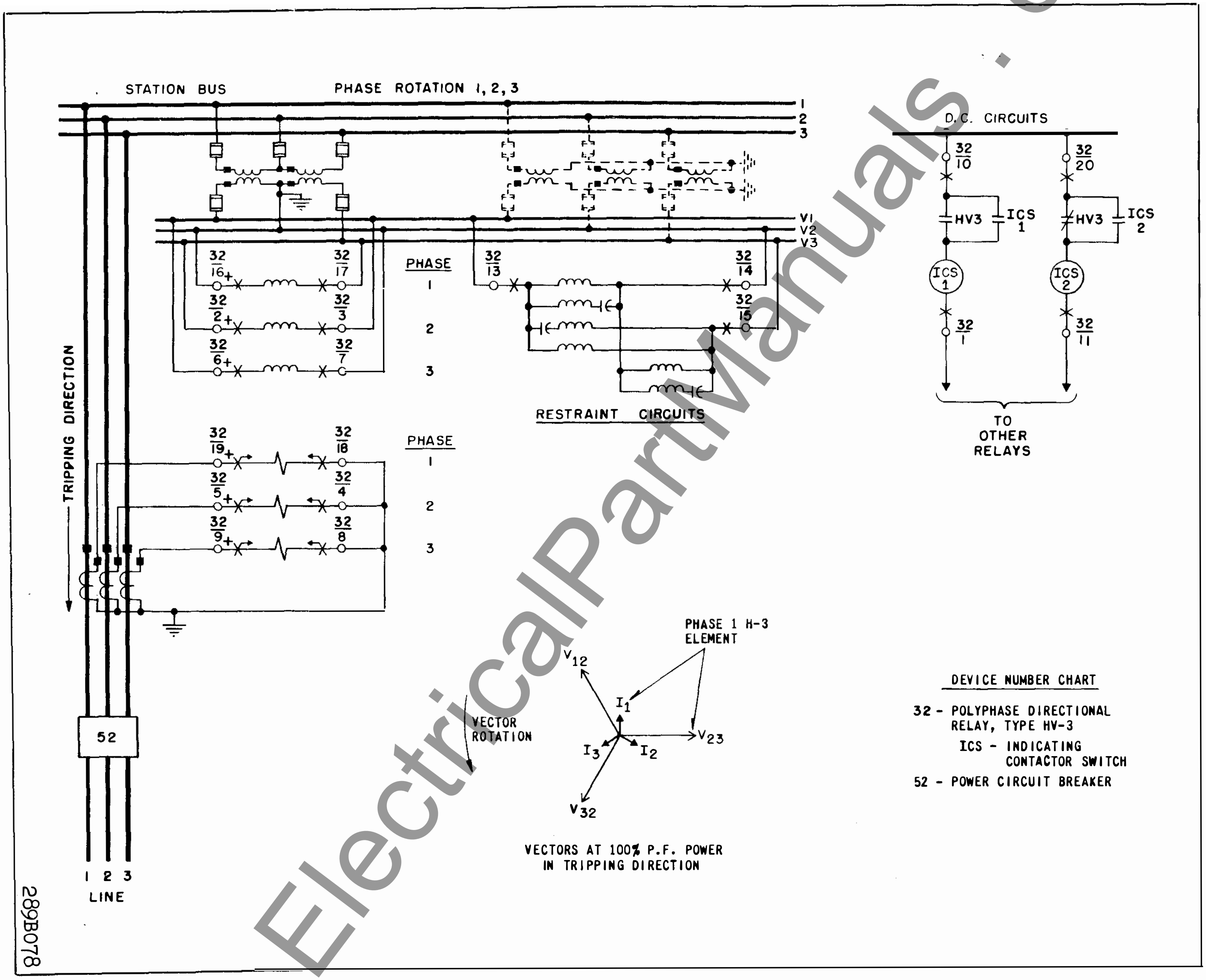

Fig. 12 — External Schematic for HV-3 Relay (90° Connection).

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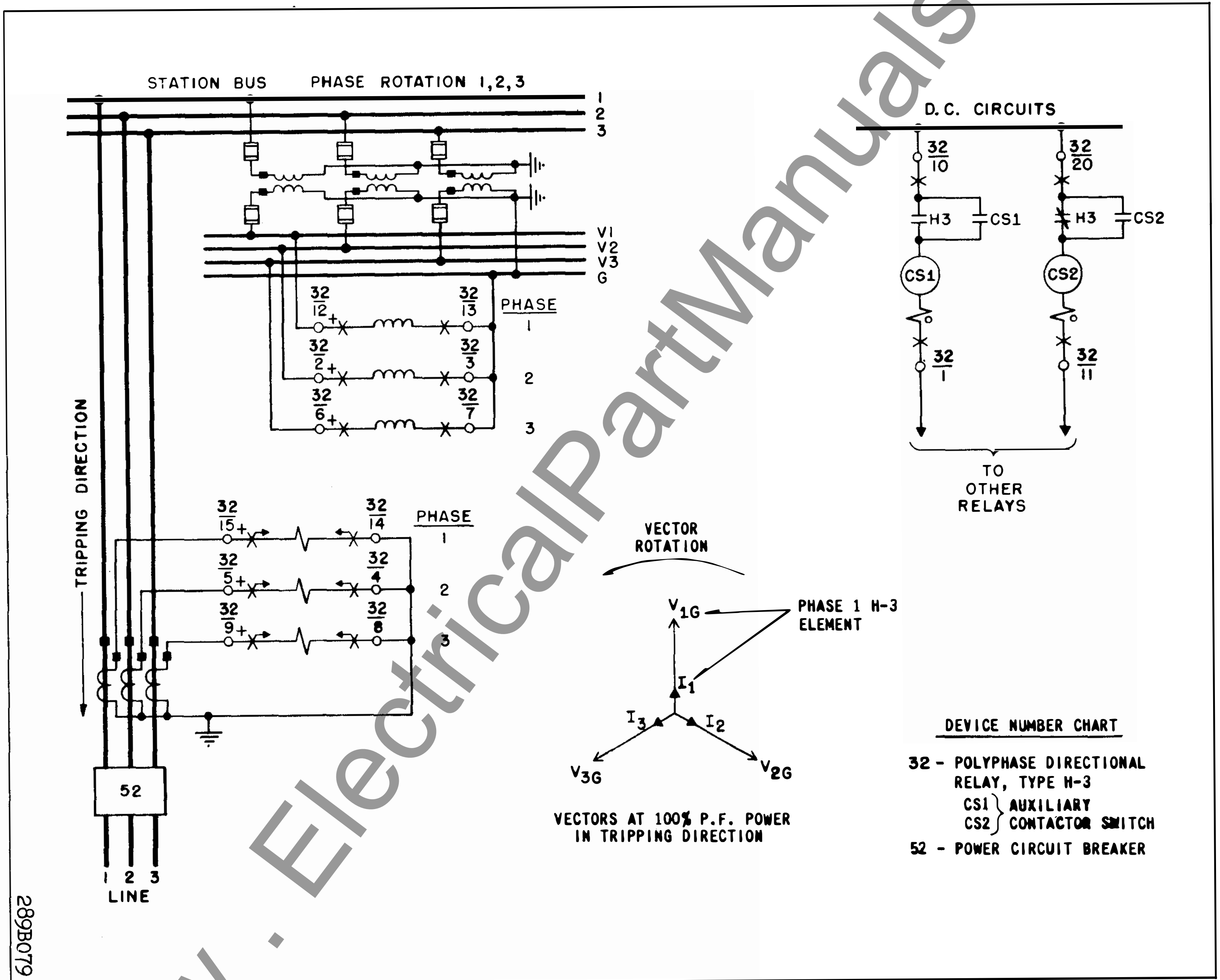

* Fig. 13 – External Schematic for H-3 Relay (Watt Connection).

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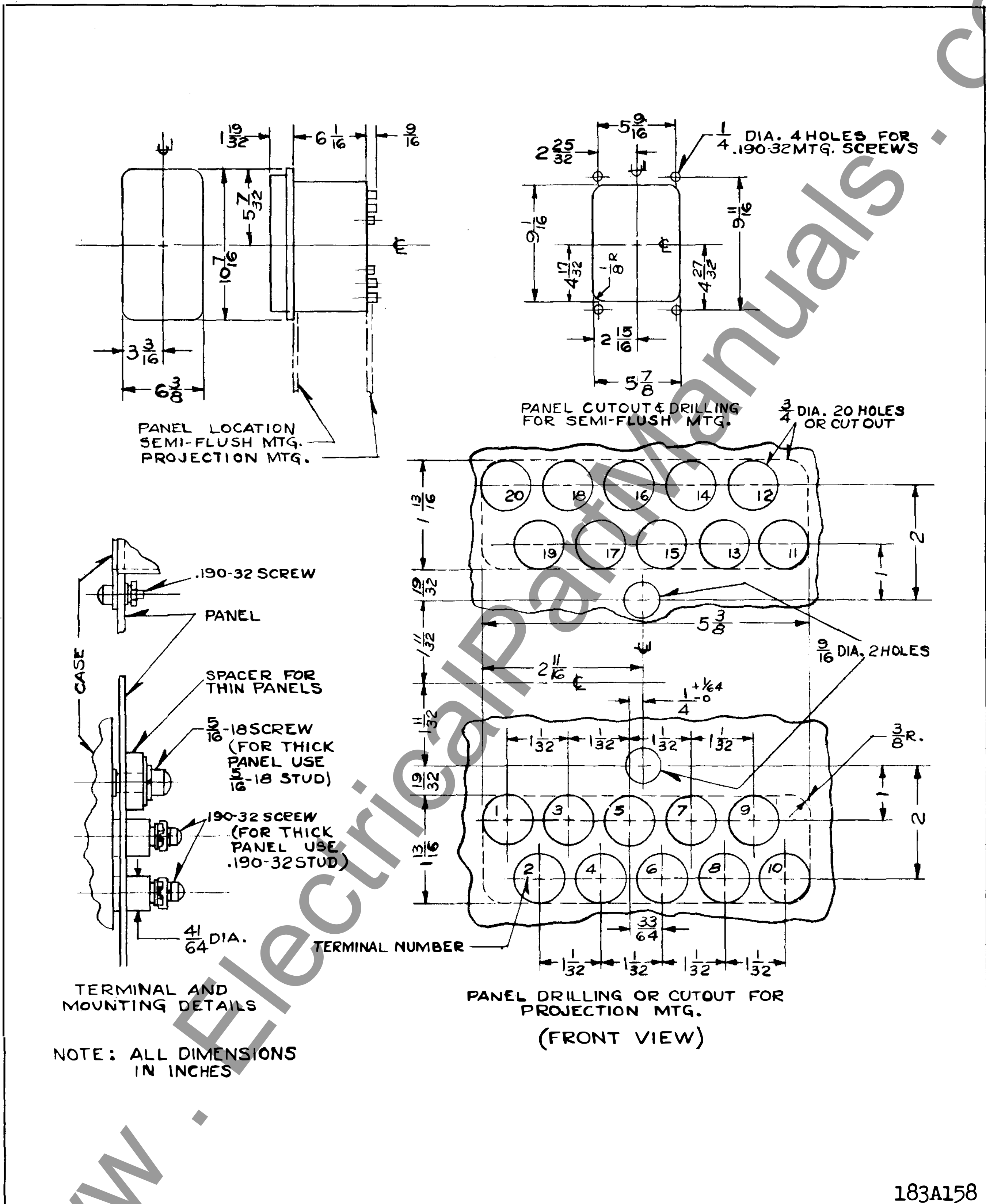

Fig. 14 – Outline and Drilling Plan for the H-3 Relay in the FT22 Case.

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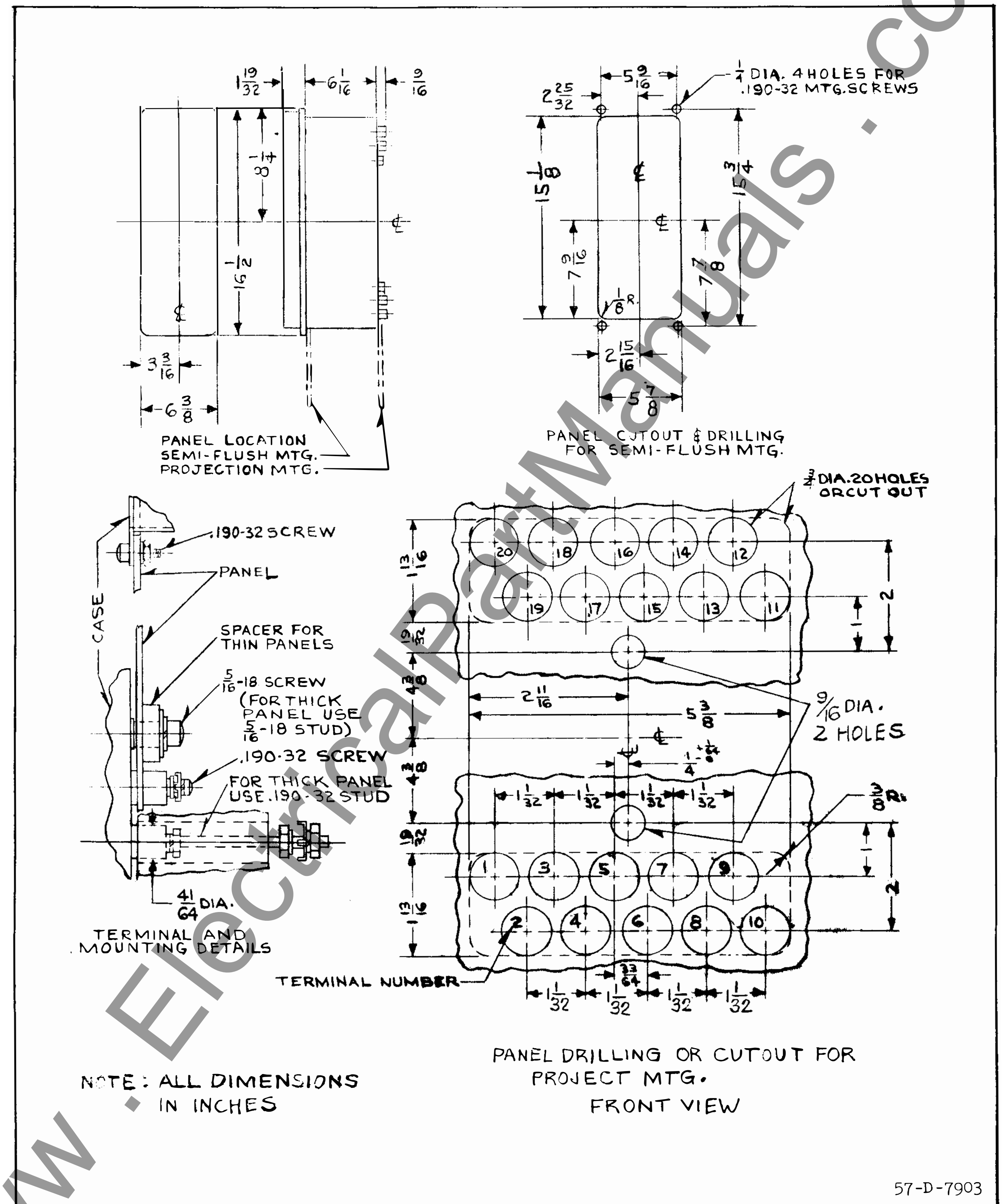

Fig. 15 — Outline and Drilling Plan for the HV-3 Relay in the FT32 Case.

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CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment. Make sure that all moving parts operate freely and inspect the contacts to see that they are clean and close properly. Operate the relay to check the settings and electrical connections.

APPLICATION

The types H-3 and HV-3 relays are polyphase direction relays which are used to obtain high speed directional discrimination during faults on power systems. The type HV-3 relay has a voltage restraint element which introduces a restraining torque on the relay proportional to the area of the voltage triangle. Thus, at normal voltage, sufficient torque is produced to prevent operation of the relay on normal load current flow. Any fault on the system reduces the area of the voltage triangle, and consequently the amount of restraint. At the same time the current in the relay increases and the relay operates if the fault is in the contact closing direction. Since the voltage triangle does not collapse as much on ground faults as it does on phase faults, it is desirable to remove voltage restraint on ground faults. This may easily be done by an instantaneous overcurrent ground relay (type SC) with its back contacts connected to open any one of the leads to the voltage restraint element.

The direction of power flow for both phase and ground faults can be detected with these relays. To obtain correct operation during ground faults, it is necessary that the minimum current in the faulted conductor be at least twice the maximum load current flow (with no voltage restraint on the relay) so that if the fault current and load currents are in opposition, the former will always predominate and give a net torque on the relay in the correct direction. Stated another way, the minimum line-to-ground current must be at least three times the maximum load current for correct ground fault protection. Low ground current occurs most frequently on impedance grounded systems. Where positive directional indication cannot be obtained under all system conditions, it is recommended that a separate ground directional relay be used.

Both the type H-3 and the type HV-3 relays can be furnished with either a watt characteristic or a 45° characteristic.

CONSTRUCTION AND OPERATION

The type H-3 relay consists of a polyphase directional unit, two contactor switches, and two operation indicators. The type HV-3 relay consists of a polyphase directional unit, a voltage restraint unit, and two indicating contactor switches.

Polyphase Directional Unit

This unit consists of three electromagnets, and a vertical shaft with three movable loops, arranged as shown in figure 1. Each loop has its outer side located in an air gap within the electromagnet. Each electromagnet has a three-legged magnetic circuit wound with three coils. The coils on the two outer legs are the voltage windings. Voltage applied to these coils induces a large current in the loop by transformer action. Current flowing thru the current coil on the center leg of the electromagnet produces an air gap flux which interacts with the loop current flux in the outer side of the loop and causes rotation of the shaft in the direction corresponding to the direction of flow of the alternating current power.

One loop and its associated electromagnet make up one phase of the three-phase relay. With the 45° characteristic relay a delta voltage and a star current are applied to each electromagnet, and proper phase angle characteristics are obtained as follows. The loop, which is considered as the secondary load of a transformer, has a much higher resistance than reactance, and the loop current lags the voltage applied to the electromagnet by an angle of 10 to 15 degrees. The air gap flux lags the applied current by about 55 to 60 degrees because of the lag loops around the centerpole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by 45 degrees.

SUPERSEDES I.L. 41-226.2B
*Denotes change from superseded issue.

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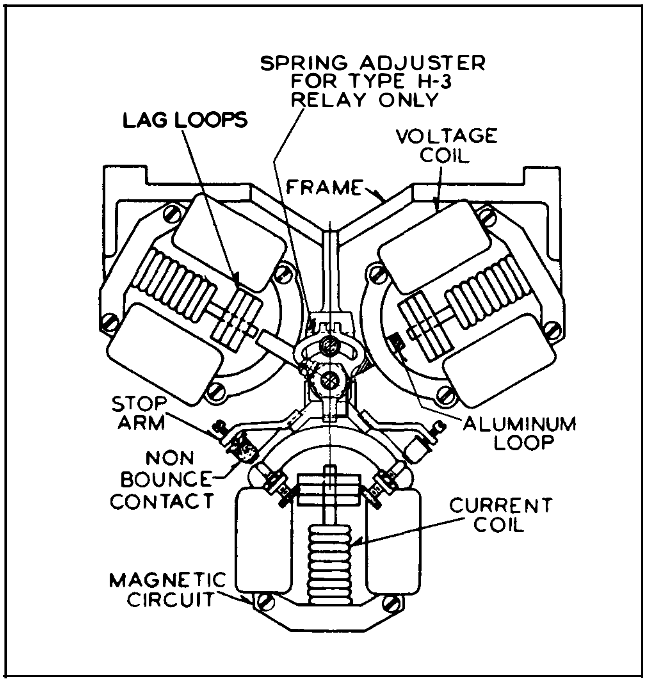

Fig. 1 — Schematic — Top View of Polyphase Directional Unit.

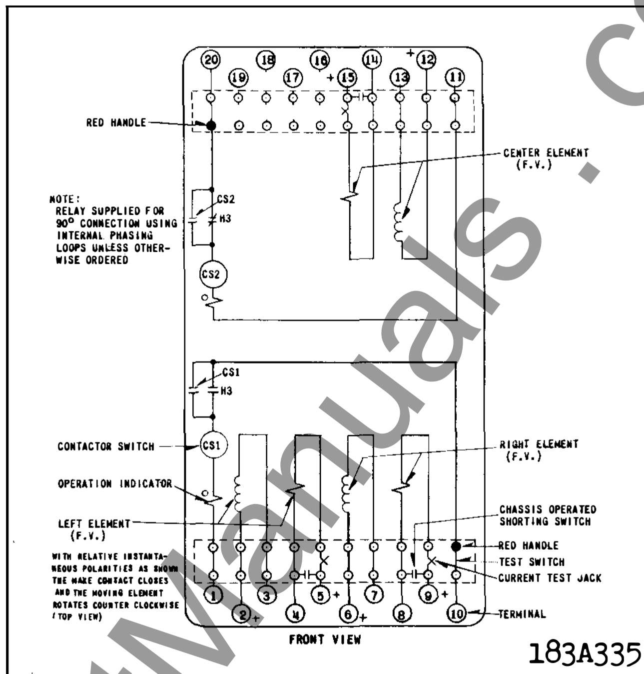

Fig. 2 — Internal Schematic of the Type H-3 Relay in the FT22 Case.

The 90° Connection is used on the relay to give the required delta voltage and star current. With this connection one of the electromagnets will have "A phase" (star) current and "BC" (delta) voltage which for a system power factor of unity, lags the current by 90°. Hence, with this connection and the above (45°) relay characteristics, maximum torque is obtained when the system fault current is lagging its unity power factor position by 45°.

With the watt characteristic relay a star current and a star voltage are applied to each electromagnet. The air gap flux lags the applied current by about 10 to 15 degrees because of the lag loops around the center pole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by about 0 degrees.

The instantaneous torque in each element of the relay is produced by the instantaneous products of voltage (loop current) and current (air gap flux) in the electromagnet, which is a double frequency pulsating torque. The torques in the other two electromagnets are also pulsating, but they are displaced 120 degrees in time phase and when all three instantaneous values are added, the result is a uniform non-pulsating torque.

Two moving contacts are mounted at right angles to each other on the outer end of a leaf spring which in turn is mounted on Isolantite arm on the moving shaft. A stop bracket with a small cylinder partially

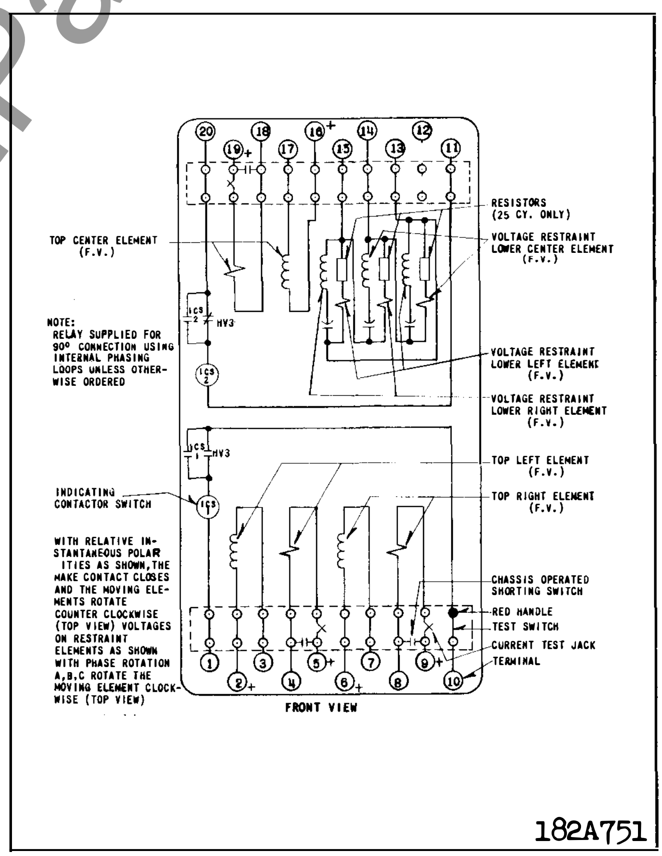

Fig. 3 — Internal Schematic of the Type HV-3 Relay in the FT32 Case.

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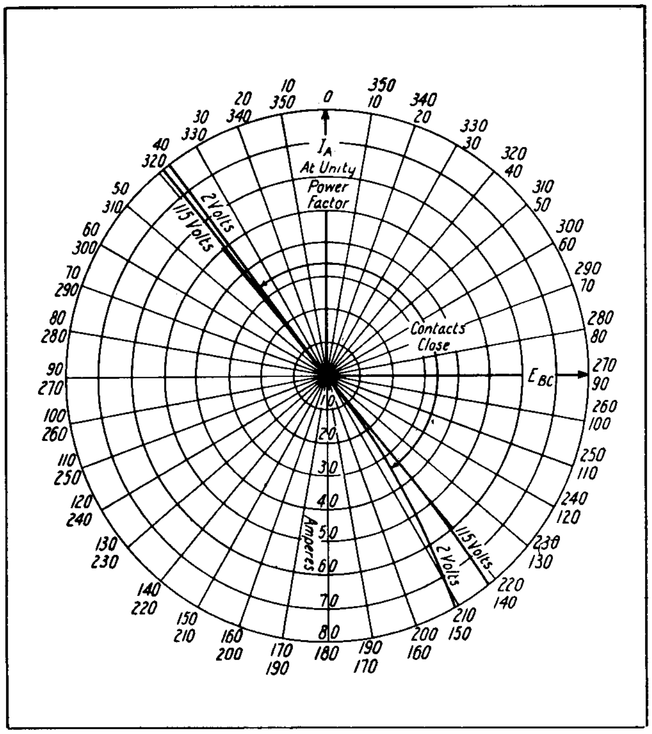

Fig. 4 – Typical Phase Angle Curve for 45° Characteristic; 50 and 60 Cycle, H-3 and HV-3 Relays – Balanced Three Phase Power Applied and No Spring Restraint.

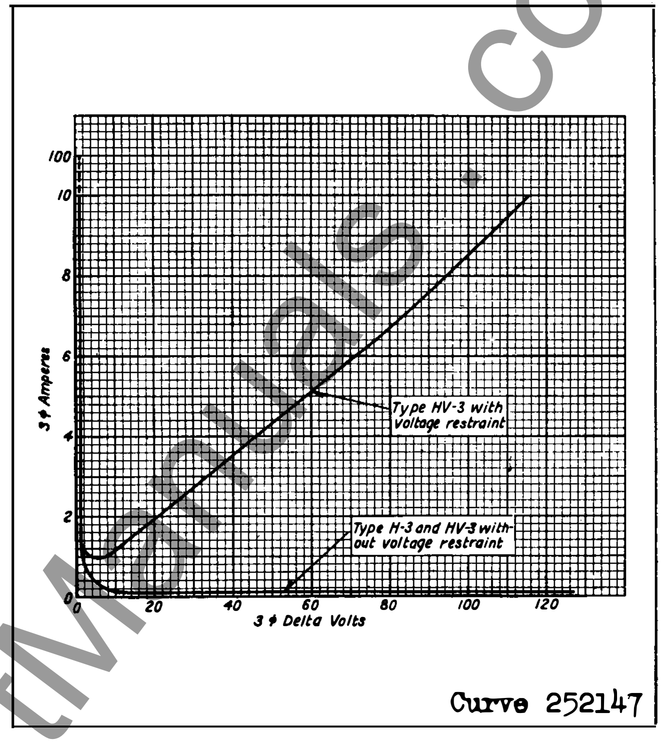

Fig. 5 – Typical Sensitivity Curve for 50 and 60 Cycle, H-3 and HV-3 Relays – at Maximum Torque Angle.

filled with tungsten powder is mounted behind each moving contact. When the moving contact strikes against the rigid fixed contact screw, the spring is deflected for the necessary contact follow, after which the stop strikes the moving contact. Thus, the full torque of the relay is transmitted thru the contacts to maintain full contact pressure. The particles of tungsten powder in the small cylinder slide over each other at the instant of impact and absorb the energy in the moving element. A flexible metal ribbon conducts current to the moving contacts.

The type H-3 relay is supplied with spring restraint which is adjusted to hold the contacts in the normal non-trip position when the relay is deenergized. This prevents an incorrect directional indication by the element under the condition of loss of load. However, the spring restraint may be adjusted to give a bias torque in either direction.

Voltage Restraint Unit

This element is supplied only in the type HV-3 relays and consists of three electromagnets and loops similar to those used on the directional element. The restraining unit is mounted below the directional unit and the loops of the two units are fastened to a common vertical shaft which operates the two contacts as described above. The outer coils of each electromagnet have one delta voltage (E_1) applied and the center coil has another delta voltage (E_2) applied. By means of the capacitor units in series with the outer two coils, the phase angle characteristics of the electromagnets are such that the torque of the element is proportional to:

$$V_1 \cdot V_2 \cdot \sin\theta$$

where θ is the angle between the two delta voltages and is normally 60°.

If any one of the three delta voltages completely collapses during a fault, there is no torque on the electromagnet, since the collapse of the third voltage makes the sine of the angle between the voltages zero. If all three voltages decrease uniformly, the torque varies as the square of their magnitude. Each electromagnet is connected to a different combination of delta voltages so that a uniform restraint torque and balanced burdens are obtained.

Restraint can be removed by opening any one supply lead to the restraint element. This applies single phase to all three electromagnets and the sine of the

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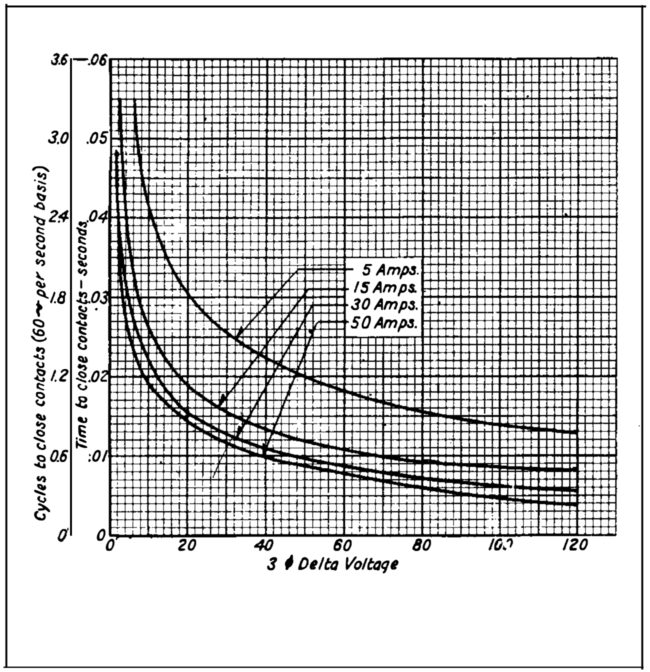

Fig. 6 – Typical Time – Current Curves of 50 and 60 Cycle H-3 Relay for Three Phase Faults at Maximum Torque Angle.

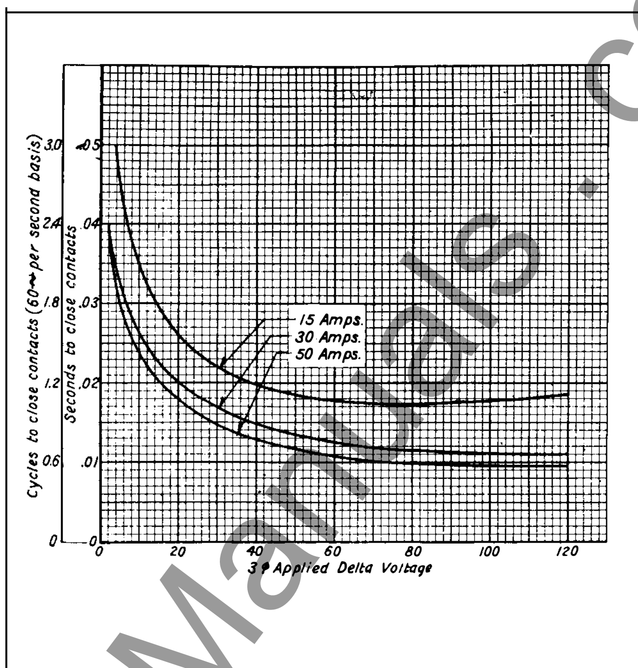

Fig. 7 – Typical Time – Current Curves of 50 and 60 Cycle HV-3 Relay for Three Phase Faults at Maximum Torque Angle.

angle becomes zero. At normal voltages 10.5 amperes is required in each element at maximum torque to overcome the restraint torque.

Contactor Switches

The d-c contactor switch in the relay is a small solenoid type switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward, the disc bridges three silver stationary contacts. The coil is in series with the main contacts of the relay and with the trip coil of the breaker. When the relay contacts close, the coil becomes energized and closes the switch contacts. This shunts the main relay contacts, thereby relieving them of the duty of carrying tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring-restrained armature releases the white target which falls by gravity to indicate completion of the trip circuit. The indicator is reset from outside of the case by a push rod in the cover or cover stud.

Indicating Contactor Switch Unit (ICS) – (HV-3 only)

The d-c indicating contactor switch is a small clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pickup value of the switch.

CHARACTERISTICS

The types H-3 relays are provided with independent make and break contacts. Two auxiliary contactor switches – one in each contact circuit – provide seal-in circuits for the main relay contact. The main contacts will close 30 amperes at 250 volts d-c and the auxiliary contactors will safely carry this current until the breaker is tripped and the auxiliary "a" switch opens. The contactor switch has a minimum

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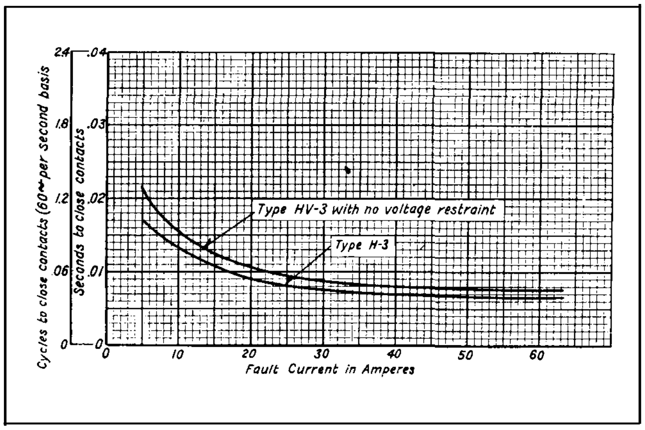

Fig. 8 — Typical Time — Current Curves for 50 and 60 Cycle H-3 and HV-3 Relays, Without Voltage Restraint for Phase to Phase Faults at Maximum Torque Angle — Full Voltage Collapse on Faulted Phase, 86% Voltage on Unfaulted Phase.

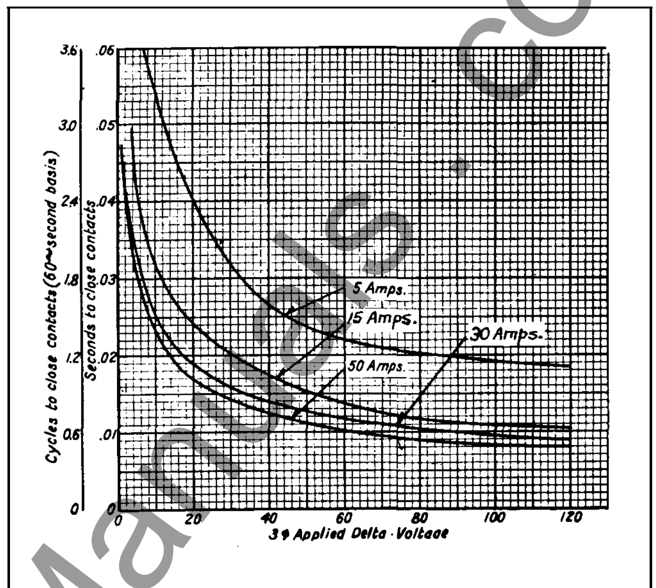

Fig. 9 — Typical Time — Current Curves for 50 and 60 Cycle Type HV-3 Relay Without Voltage Restraint for Three Phase Faults at Maximum Torque.

pick-up of one ampere d-c and a coil resistance of one ohm.

Typical 50 and 60 cycle phase angle characteristics of the 45° characteristic relay are shown in figure 4. Maximum torque, in the contact closing direction, occurs when the line current lags the line-to-neutral voltage by approximately 45 degrees, when using the 90° connection.

Typical 50 and 60 cycle sensitivity curves maximum torque are shown in figure 5. The sensitivity of the type HV-3 relay without voltage restraint is the same as the type H-3 relay. The 60-cycle three phase minimum pick-up without spring restraint of the type H-3 relay is 0.08 amperes at 115 volts, 0.15 ampere at 10 volts, and 5.0 amperes at 1 volt. The single phase minimum pick-up currents are approximately three times those for three phase. In the absence of sufficient operating current, the contacts may be held either open or closed by a toggle acting voltage — only torque. The affect of this torque is described in the section under "Watt Characteristic Relay Adjustments." It will be noted from the curves that the sensitivity of the type HV-3 relay with voltage restraint is decreased only at voltages above 2 volts. The curves also show that 10 amperes 60 cycles are required at 115 volts to overcome voltage restraint.

Typical time curves are shown in figures 6 to 9. All curves are for a contact spacing of .035 inch and at maximum torque for 60 and 50 cycle relays and .070 inch for 25 cycle relays.

Trip Circuit (HV-3 only)

The main contacts will safely close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pickup setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

Trip Circuit Constant (HV-3 only)

Indicating Contactor Switch (ICS)

0.2 ampere tap 6.5 ohms d-c resistance
2.0 ampere tap 0.15 ohms d-c resistance

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by

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means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT case information refer to I.L. 41-076.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Adjust the lower bearing so that both the top and bottom of the loops are equi-distant from their respective magnetic circuits. Energize the potential circuits of the relay until the loops reach operating temperature. About ten minutes at normal voltage is necessary to reach this condition. When the operating temperature is reached, adjust the upper bearing for 1/64 inch clearance.

The loops of each element must be in line with the center of the middle leg of the magnetic circuit. If necessary, this adjustment can be obtained by loosening the electromagnet mounting screws and moving the whole electromagnet in the desired direction. All three elements must have the same relative position of loop and magnetic circuit.

Type H-3 Relay

The polarity of the relay is checked as follows: Refer to figure 2 and apply 115 bolts and 5 amperes (in phase) to the corresponding voltage and current coils in turn, with the terminals marked with polarity marks connected together. Looking at the top of the relay, the moving element should rotate in a counter-clockwise direction.

Adjust the back-up strip located in front of each moving contact by bending so that it just touches the contact spring when the contacts are open. Adjust the small cylinder behind the moving contact to obtain .009 inch contact follow. This is done by advancing the cylinder until it just touches the rear of the moving contact spring, and then backing off 1/2 turn.

45° Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase current of 50 amperes with polarities as shown on internal schematic diagram to the current coils which should be connected in series. Each potential coil should be short-circuited. When energized the relay moving element will center itself due to the combined torques produced by the 50 amperes of current and the spring restraint. Readjust the spring adjuster until the centering position of the moving element is exactly the same for the condition of zero current or with 50 amperes in the current coils. Under this condition the torque produced by the spring at the centering position is zero and does not tend to "offset" or shift the centering position due to the current. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

There are two adjustable stop screws located on the frame casting. These stops are used when the relay is supplied with two circuit closing contacts and perform the same function as the stops on the moving contact assembly.

Watt Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase potential of 67 volts with polarities as shown on internal schematic diagram to the potential coils which should be connected in parallel. Each current coil should be open-circuited. When the potential circuits are deenergized the moving element will tend to be centered by the spring. When the potential circuits are energized the moving element may move either to the right or to the left. If under this condition the moving element moves the contacts to the right, the spring should be readjusted to move the deenergized spring centering position of the moving element to the left. If under this condition the moving element moves the contacts to the left, the spring should be readjusted to move the deenergized spring centering position of the moving element to the right. Continue to shift the centering position of the spring until a small movement of the spring adjuster will cause the moving element to move in one direction when the potential is applied and a small movement in the other direction will cause the

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moving element to move in the opposite direction. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

Type HV-3 Relay

The tests outlined for the type H-3 45° characteristic relay also apply to the HV-3 relay when the voltage restraint circuit is not connected. To make a complete check on the type HV-3 relay with all circuits connected, involves three-phase test source, phase shifter, potentiometers, and non-inductive resistors for controlling the voltage and current to the relay respectively. This test will permit checking of all the characteristics of the relay at the proper phase angle. This test procedure however is usually too complicated for routine field testing. The complete test may be simplified for field testing by the following modifications. Apply three phase restraining voltage to the restraining element and single phase to all three phases of the directional element. For the latter element the potential coils are all connected in parallel and the current coils are connected in series. With a non-inductive load, the relay will be operating about 45° away from its maximum torque position and consequently current values to trip a given voltage will be increased by about 30%. Since the combination of three-phase restraining torque and single-phase operating torques on all three elements produces some unbalanced torque in the moving element, it is recommended that tests be made at a reduced voltage (65 volts or less). With 65 volts applied to voltage restraint elements, about 8 amperes is required at unity power factor to make the relay operate.

To check the circuits thru the voltage restraint element, the relay should be energized at normal voltage for about 10 minutes. The potential circuit of the directional element should then be opened. Then open the phase A potential to the voltage restraint unit and observe the torque produced on the moving element, if any. Replace A lead and remove the B lead and again observe the torque. Repeat for the C lead and in all cases there should be no torque or a very slight torque present. Any defects in the coils or capacitors of the voltage restraint circuits will be made apparent by the presence of excessive torque during this test.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core when the switch is picked up. This can be most conveniently done by turning the relay up-side-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 1.0 ohm.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced by new springs, they should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 0.16 ohm.

Indicating Contactor Switch (ICS) – (HV-3 only)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMENTS

The burdens and constants of the relays are as follows per phase:

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TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY
VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.050	2070	0.050	2070	* 1480
Reactance (ohms)	0.052	1530	0.052	1530	1840
Impedance (ohms)	0.072	2580	0.072	2580	2360
Watts	1.25	4.59	1.25	4.59	3.84
Vars	1.29	3.40	1.29	3.40	4.75
Voltamperes	1.82	5.71	1.82	5.71	6.1
Power Factor	46° lag	36.5° lag	46° lag	36° lag	51° lag
Continuous Rating (Amperes or Volts)	5	120	5	120	120
One Second Current (Amps.)	230	. . .	230	. . .	. . .

VALUES AT 120 VOLTS, 5 AMPERES, 50 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.0488	2560	0.0488	2560	2720
Reactance (ohms)	0.0349	975	0.0349	975	1570
Impedance (ohms)	0.060	2740	0.060	2740	3140
Watts	1.22	4.89	1.22	4.89	3.44
Vars	.87	1.86	.87	1.86	2.00
Voltamperes	1.5	5.23	1.5	5.23	3.98
Power Factor	33.5° lag	20.8° lag	33.5° lag	20.8° lag	30.1° lag
Continuous Rating (Amperes or Volts)	5	120	5	120	120
One Second Current (Amps.)	230	. . .	230	. . .	. . .

TYPE H-3, WATT CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3	
	Current Circuit	Voltage Circuit
Resistance (ohms)	.028	2740
Reactance (ohms)	.0192	1440
Impedance (ohms	.034	3100
Watts	.70	4.09
Vars	.48	2.14
Voltamperes	.85	4.62
Power Factor	34.5° lag	27.8° lag
Continuous Rating (Amperes or Volts)	5	120
One Second Current (Amps.)	230	...

TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 25 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint
Resistance (ohms)	.0380	3830	.0380	3830	3980
Reactance (ohms)	.0192	3200	.0192	3200	990
Impedance (ohms)	.0420	5000	.0420	5000	4100
Watts	.94	2.20	.94	2.20	3.39
Voltamperes	1.05	2.88	1.05	2.88	3.50
Power Factor	26° lag	40° lag	26° lag	40° lag	14° lag
Continuous Rating	5	120	5	120	120
One Second Rating	230	...	230	...	...

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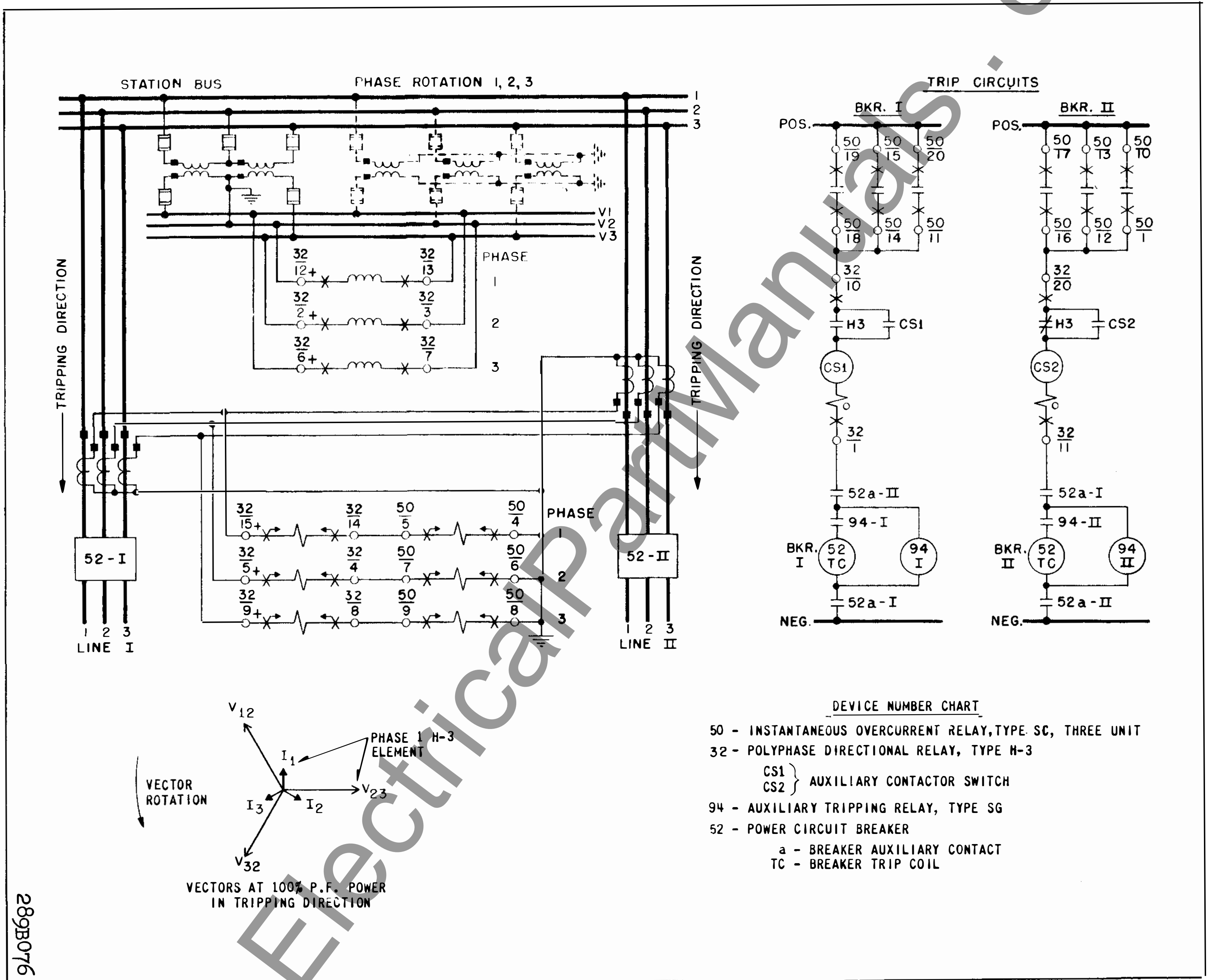

Fig. 10 — External Schematic for Phase Fault Parallel Line Protection — H-3 and Three Unit SC in FT32 Case (90° Connection).

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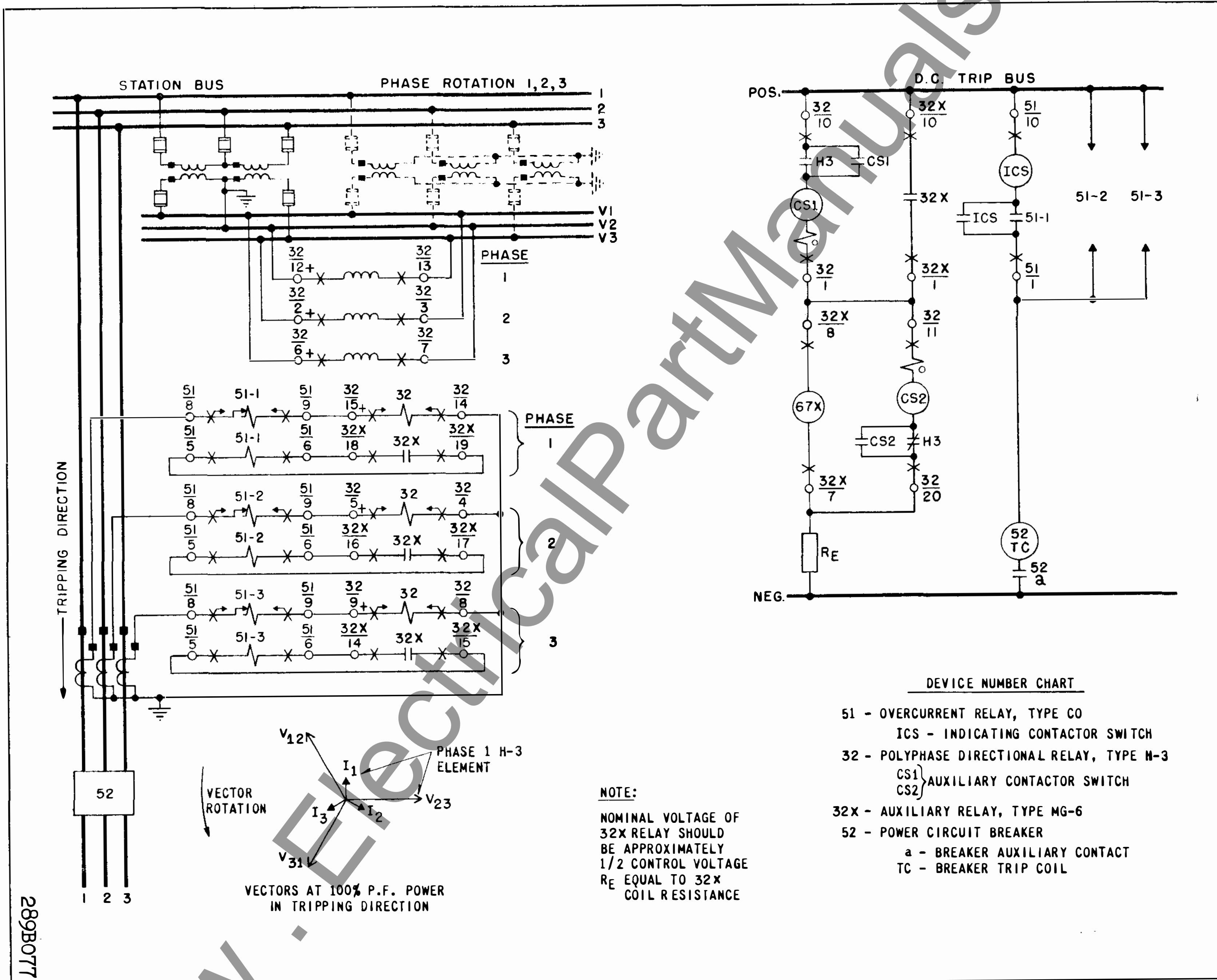


Fig. 11 — External Schematic for H-3, Torque Controlling Three CO Relays in FT11 Cases, with MG-6 in FT22 Case (90° Connection).

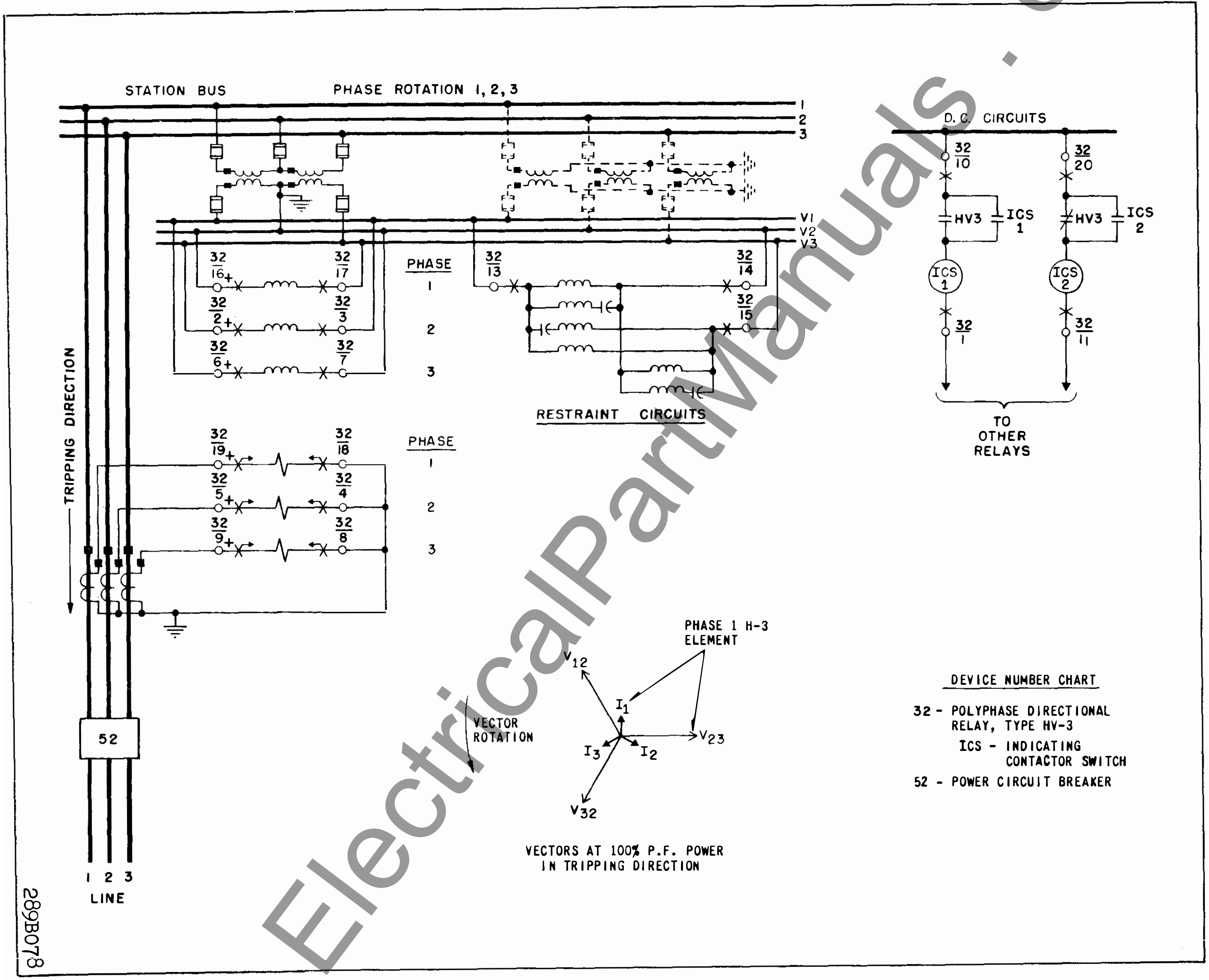
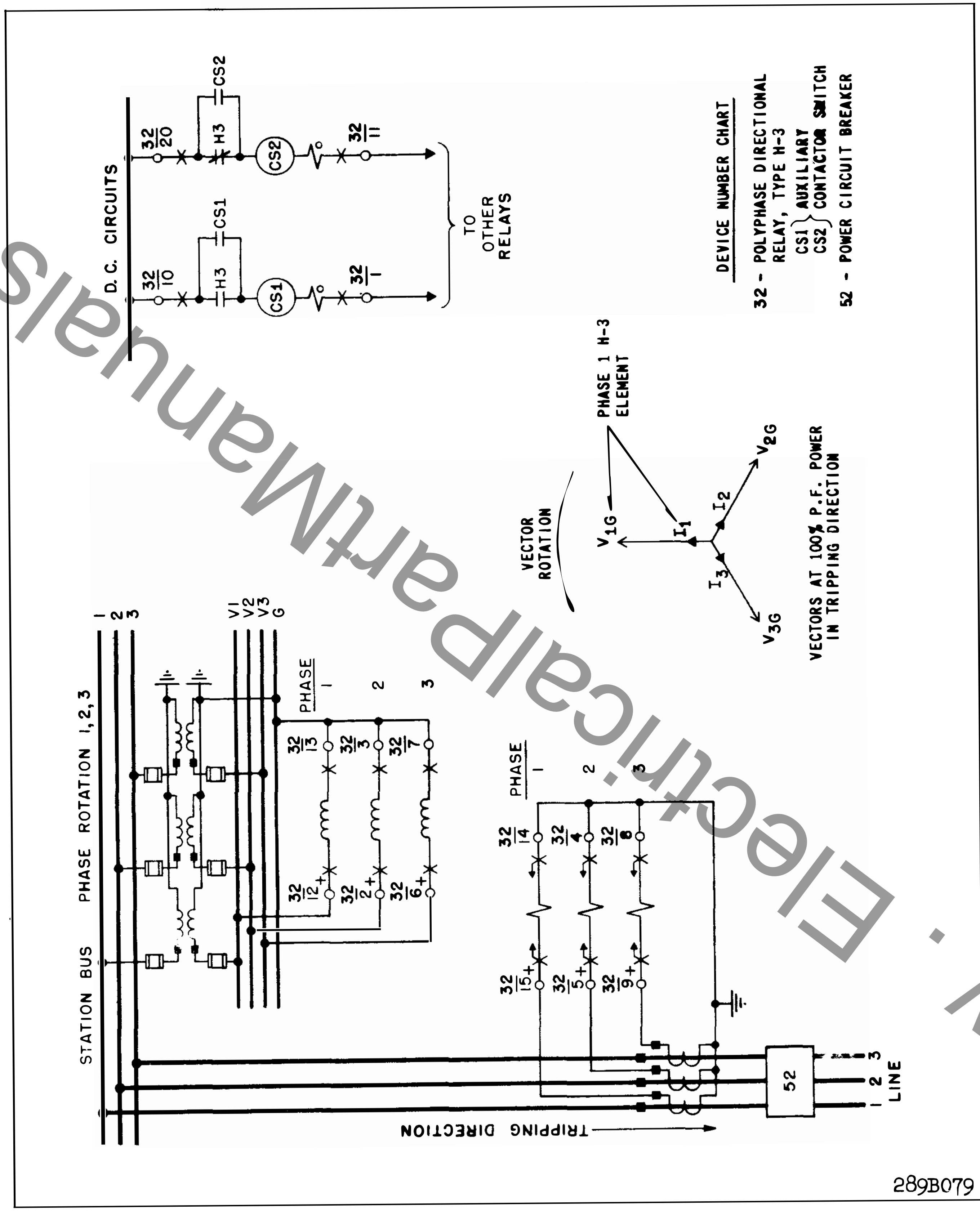


Fig. 12 – External Schematic for HV-3 Relay (90° Connection).



* *Fig. 13 – External Schematic for H-3 Relay (Watt Connection).*

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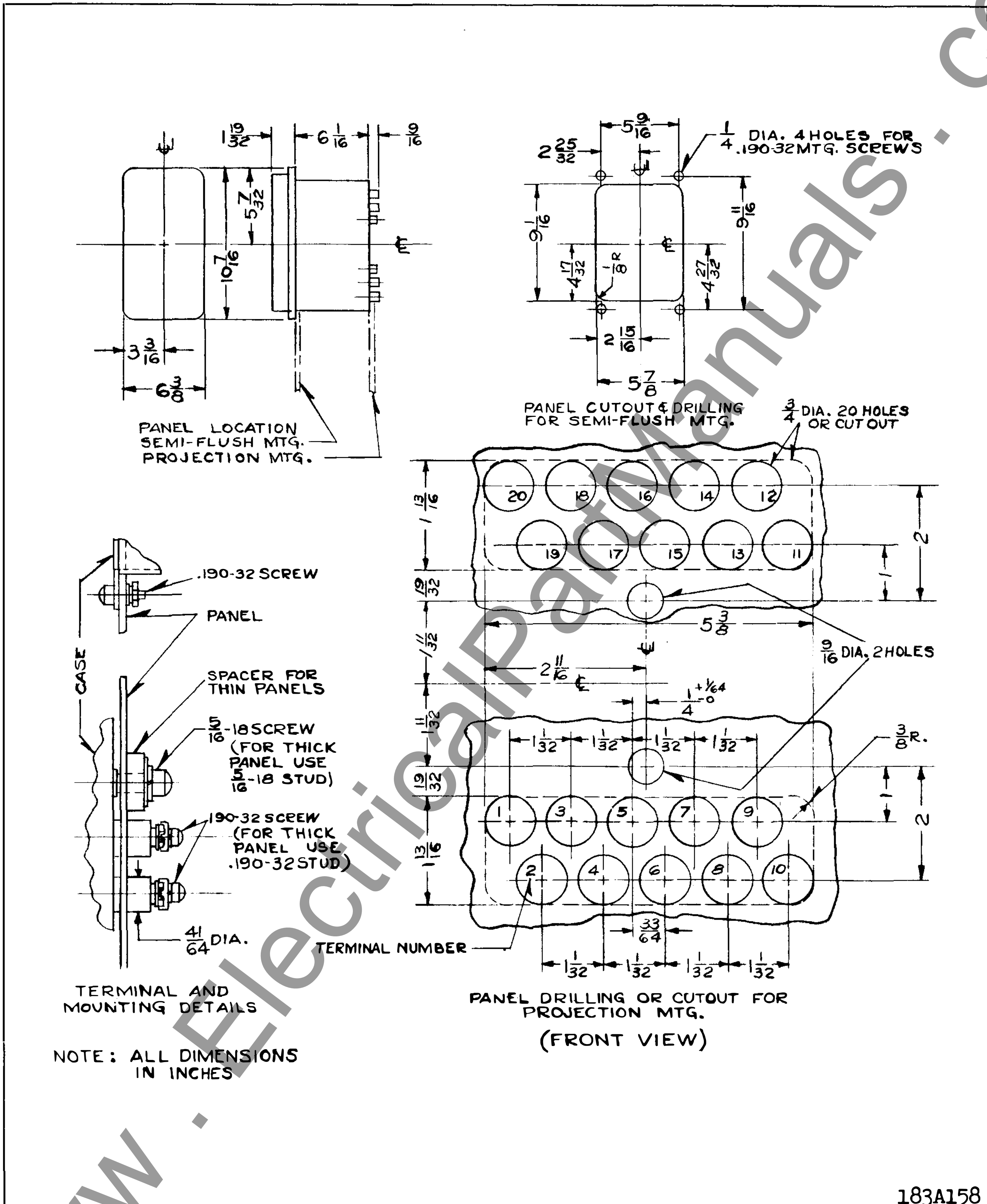

Fig. 14 – Outline and Drilling Plan for the H-3 Relay in the FT22 Case.

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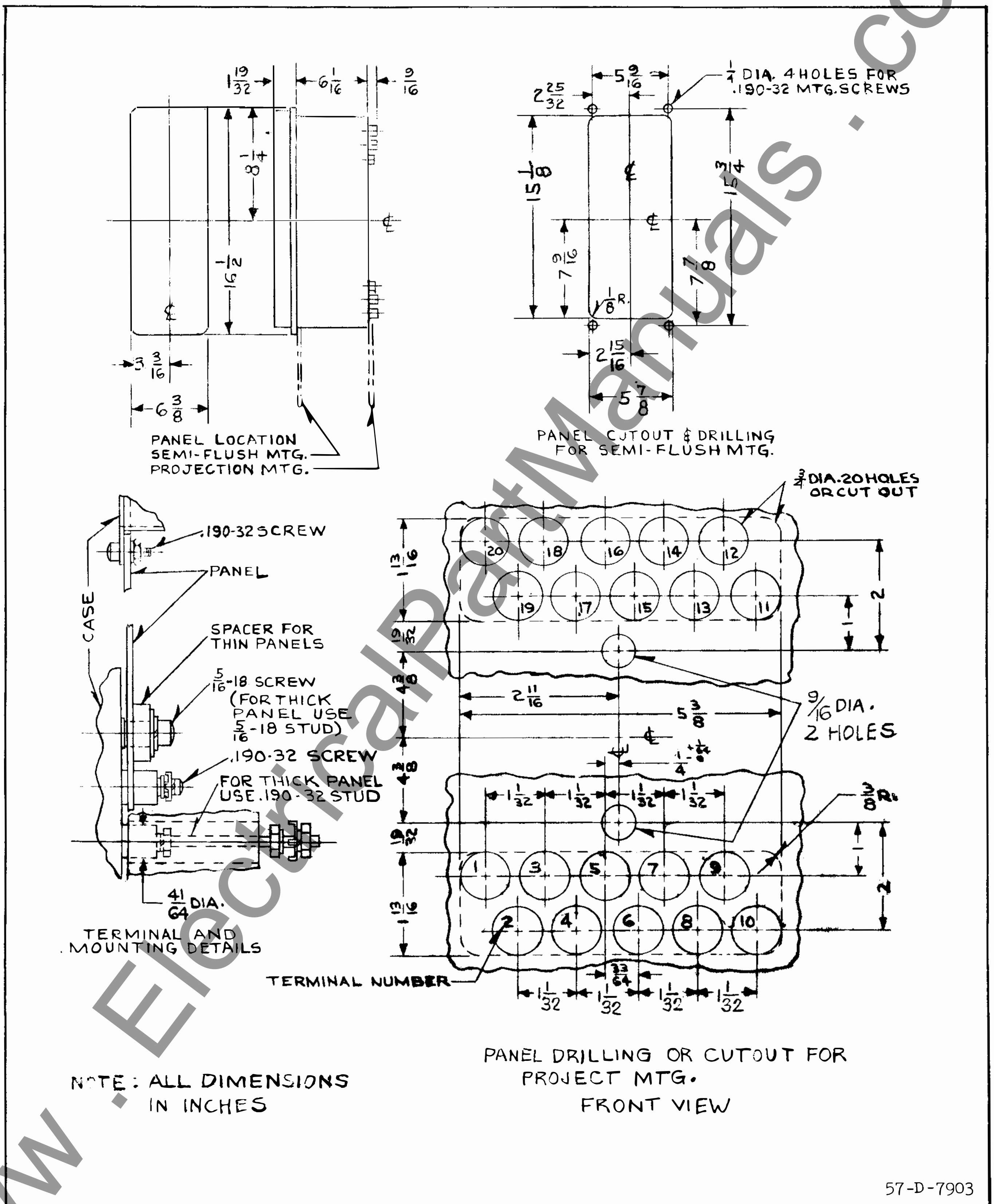

Fig. 15 – Outline and Drilling Plan for the HV-3 Relay in the FT32 Case.

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INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES H-3 AND HV-3 THREE PHASE DIRECTIONAL RELAYS

CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment. Make sure that all moving parts operate freely and inspect the contacts to see that they are clean and close properly. Operate the relay to check the settings and electrical connections.

APPLICATION

The types H-3 and HV-3 relays are polyphase directional relays which are used to obtain high speed directional discrimination during faults on power systems. The type HV-3 relay has a voltage restraint element which introduces a restraining torque on the relay proportional to the area of the voltage triangle. Thus, at normal voltage, sufficient torque is produced to prevent operation of the relay on normal load current flow. Any fault on the system reduces the area of the voltage triangle, and consequently the amount of restraint. At the same time the current in the relay increases and the relay operates if the fault is in the contact closing direction. Since the voltage triangle does not collapse as much on ground faults as it does on phase faults, it is desirable to remove voltage restraint on ground faults. This may easily be done by an instantaneous overcurrent ground relay (type SC) with its back contacts connected to open any one of the leads to the voltage restraint element.

The direction of power flow for both phase and ground faults can be detected with these relays. To obtain correct operation during ground faults, it is necessary that the minimum current in the faulted conductor be at least twice the maximum load current flow (with no voltage restraint on the relay) so that if the fault current and load currents are in opposition, the former will always predominate and give a net torque on the relay in the correct direction. Stated another way, the minimum line-to-ground current must be at least three times the maximum load current for correct ground fault protection. Low ground current occurs most frequently on impedance grounded systems. Where positive directional indication cannot be obtained under all system conditions, it is recommended that a separate ground directional relay be used.

Both the type H-3 and the type HV-3 relays can be furnished with either a watt characteristic or a 45° characteristic.

CONSTRUCTION AND OPERATION

The type H-3 relay consists of a polyphase directional element, two contactor switches, and two operation indicators. The type HV-3 relay consists of a polyphase directional element, a voltage restraint element, two contactor switches, and two operation indicators. These elements are as follows:

Polyphase Directional Element

This element consists of three electromagnets, and a vertical shaft with three movable loops, arranged as shown in figure 1. Each loop has its outer side located in an air gap within the electromagnet. Each electromagnet has a three-legged magnetic circuit wound with three coils. The coils on the two outer legs are the voltage windings. Voltage applied to these coils induces a large current in the loop by transformer action. Current flowing thru the current coil on the center leg of the electromagnet produces an air gap flux which interacts with the loop current flux in the outer side of the loop and causes

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tacts. Two auxiliary contactor switches--one in each contact circuit--provide seal-in circuits for the main relay contact. The main contacts will close 30 amperes at 250 volts d-c and the auxiliary contactors will safely carry this current until the breaker is tripped and the auxiliary "a" switch opens. The contactor switch has a minimum pick-up of one ampere d-c and a coil resistance of one ohm.

Typical 50 and 60 cycle phase angle characteristics of the 45° characteristic relay are shown in figure 6. Maximum torque, in the contact closing direction, occurs when the line current lags the line-to-neutral voltage by approximately 45 degrees, when using the 90° connection.

Typical 50 and 60 cycle sensitivity curves at maximum torque are shown in figure 7. The sensitivity of the type HV-3 relay without voltage restraint is the same as the type H-3 relay. The 60 cycle three phase minimum pick-up without spring restraint of the type H-3 relay is 0.08 amperes at 115 volts, 0.15 ampere at 10 volts, and 5.0 amperes at 1 volt. The single phase minimum pick-up currents are approximately three times those for three phase. It will be noted from the curves that the sensitivity of the type HV-3 relay with voltage restraint is decreased only at voltages above 2 volts. The curves also show that 10 amperes 60 cycles are required at 115 volts to overcome voltage restraint.

Typical time curves are shown in figures 8 to 11. All curves are for a contact spacing of .035 inch and at maximum torque for 60 and 50 cycle relays and .070 inch for 25 cycle relays.

* INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the two mounting studs for the standard cases and the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

The external connections for typical applications of the type H-3 and HV-3 relays are shown in figures 12 thru 19.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

* All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Adjust the lower bearing so that both the top and bottom of the loops are equi-distant from their respective magnetic circuits. Energize the potential circuits of the relay until the loops reach operating temperature. About ten minutes at normal voltage is necessary to reach this condition. When the operating temperature is reached, adjust the upper bearing for 1/64 inch clearance.

The loops of each element must be in line with the center of the middle leg of the magnetic circuit. If necessary, this adjustment can be obtained by loosening the electromagnet mounting screws and moving the whole electromagnet in the desired direction. All three elements must have the same relative position of loop and magnetic circuit.

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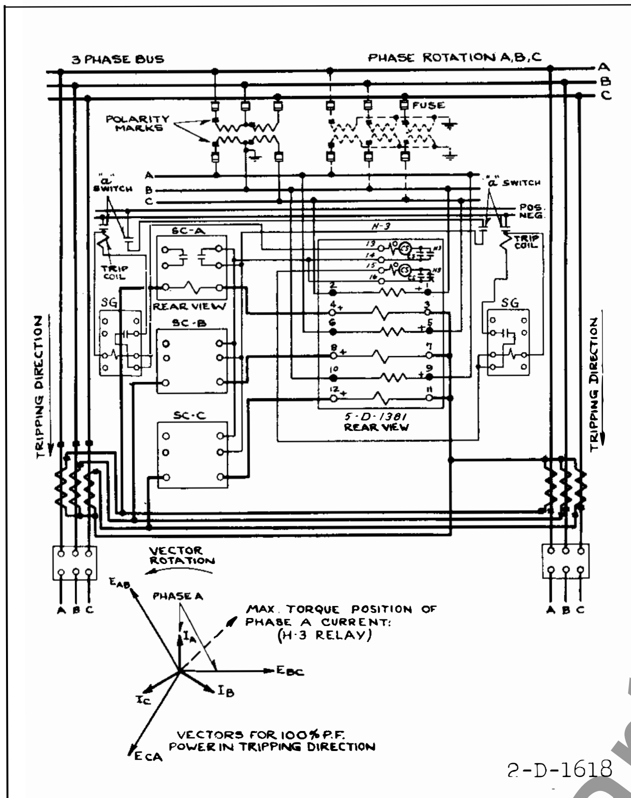

Fig. 12—External Connections for Directional Balanced Overcurrent Phase Protection of Two Parallel Lines Using One Type H-3 (90° Connection) and Three Type SC Relays All in the Standard Cases.

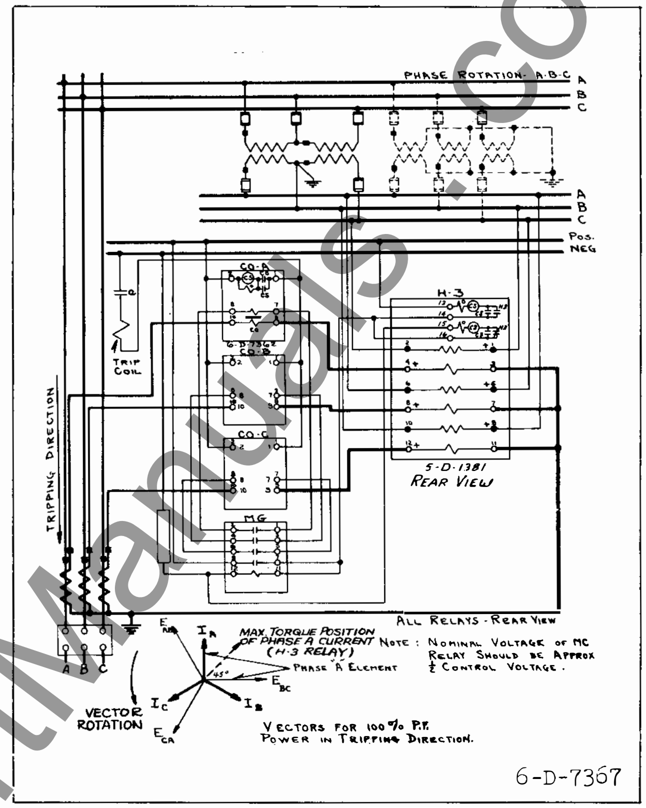

Fig. 13—External Connections for Directional Overcurrent Phase Protection of a Three Phase Line Using Three Type CO Torque Controlled Relays Directionally Controlled By One Type H-3 (90° Connection) and One Type MG Relay All in the Standard Cases.

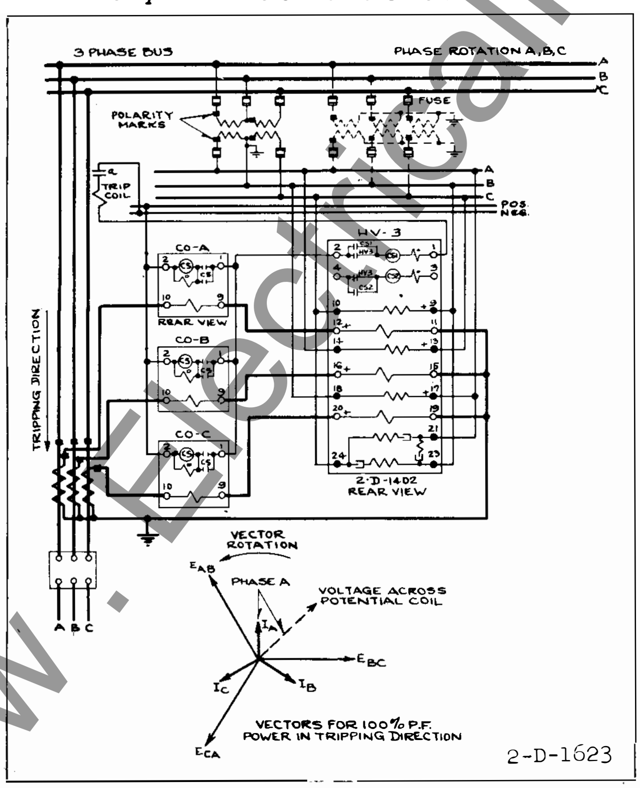

Fig. 14—External Connections for Directional Phase Protection of a Three Phase Line Using the Type **HV-3** (90° Connection) Relay and Three Type CO Relays All in the Standard Cases.

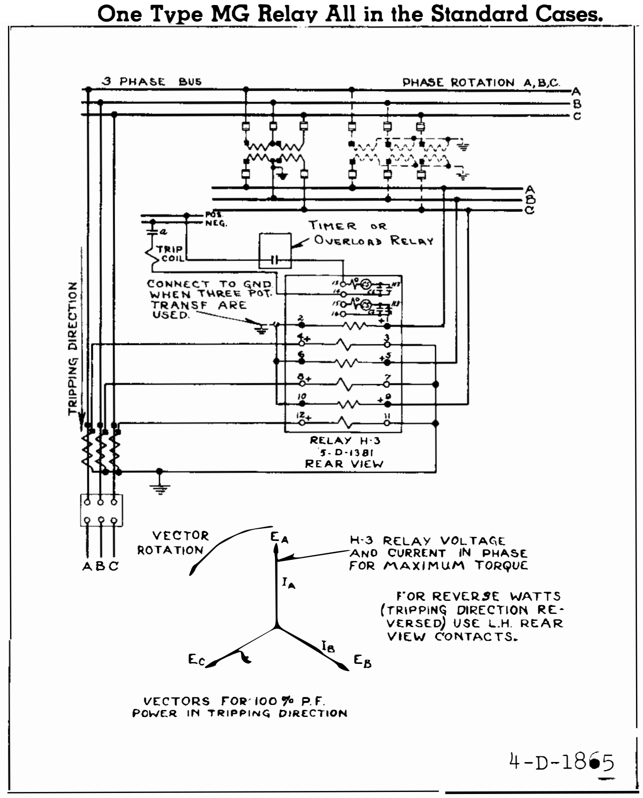

Fig. 15—External Connections for Reverse Power, or Directional Phase Protection Using the Type **H-3** (Watt Connection) Relay in the Standard Case.

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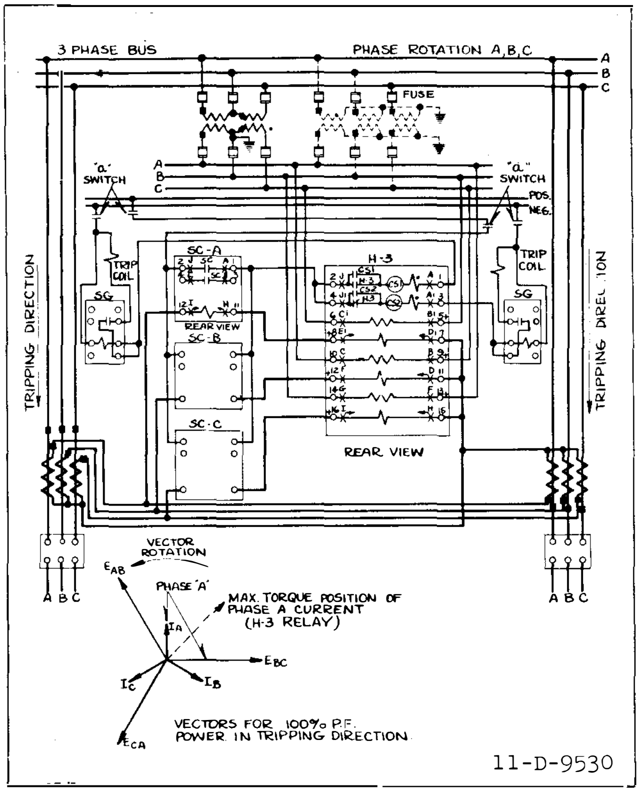

Fig. 16—External Connections for Directional Balanced Overcurrent Phase Protection of Two Parallel Lines Using One Type H-3 (90° Connection) and Three Type SC Relays All in the Type FT Cases.

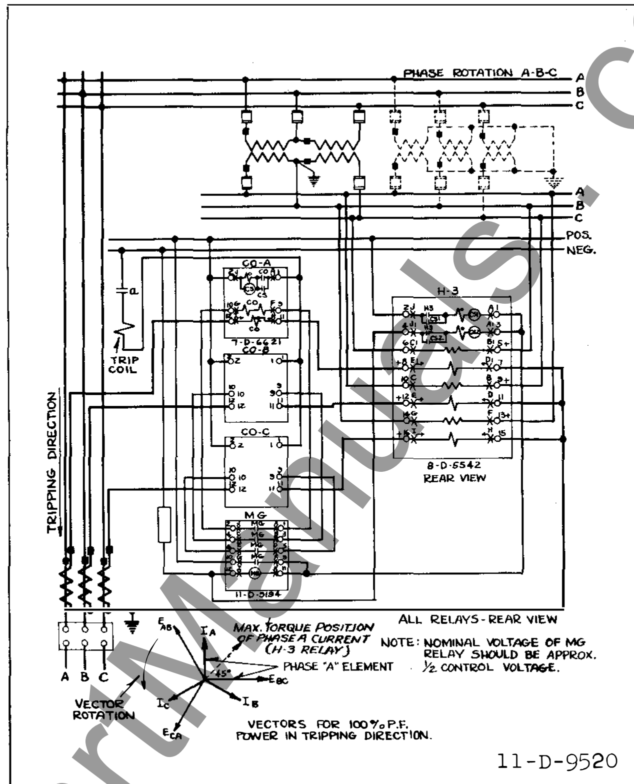

Fig. 17—External Connections for Directional Overcurrent Phase Protection of a Three Phase Line Using Three Type CO Torque Controlled Relays Directionally Controlled By One Type H-3 (90° Connection) and One Type MG Relay All in the Type FT Cases.

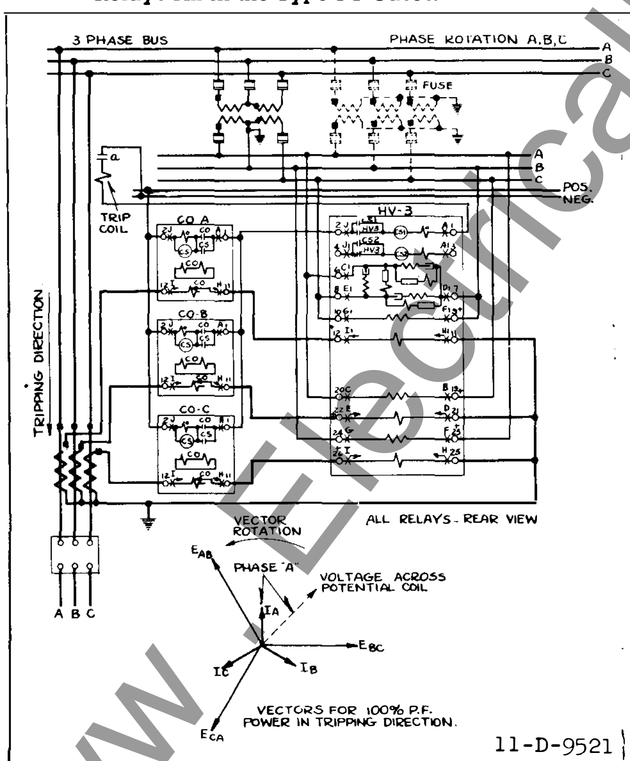

Fig. 18—External Connections for Directional Phase Protection of a Three Phase Line Using the Type HV-3 (90° Connection) Relay and Three Type CO Relays All in the Type FT Case.

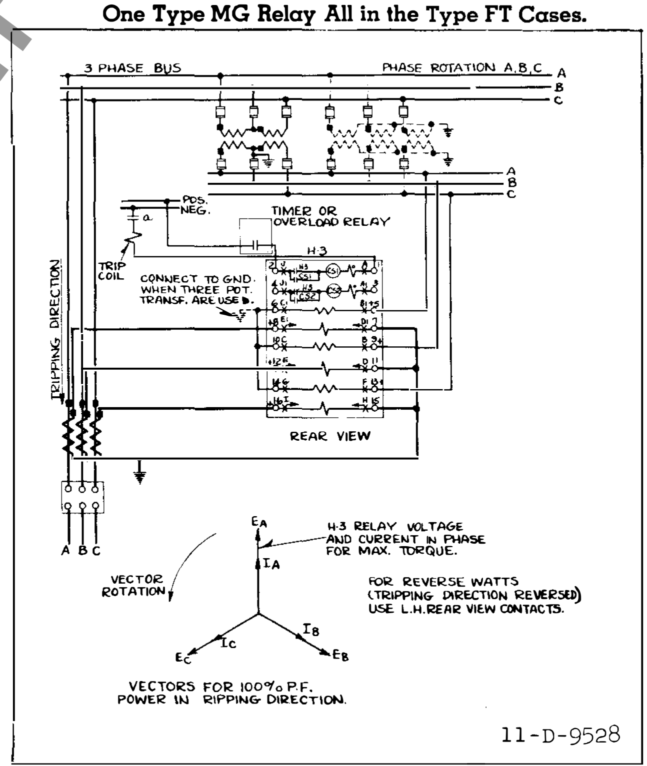

Fig. 19—External Connections for Reverse Power or Directional Phase Protection Using the Type H-3 (Watt Connection) Relay in the Type FT Case.

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Type H-3 Relay

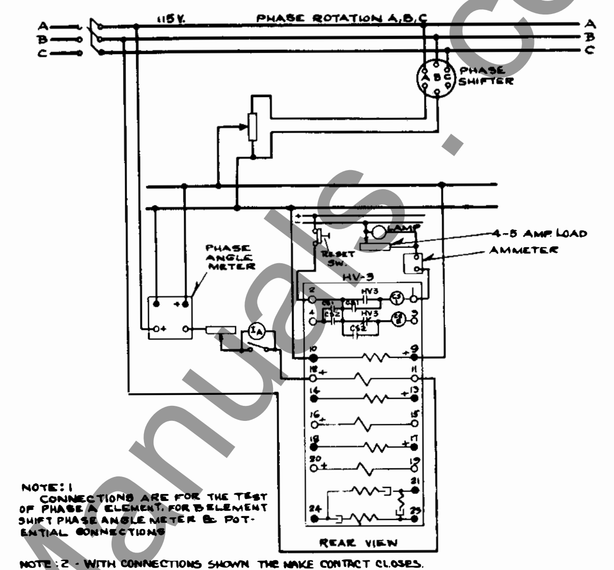
The polarity of the relay is checked as follows: Refer to figure 2 or 3 and apply 115 volts and 5 amperes (in phase) to the corresponding voltage and current coils in turn, with the terminals marked with polarity marks connected together. Looking at the top of the relay, the moving element should rotate in a counter-clockwise direction.

Adjust the back-up strip located in front of each moving contact by bending so that it just touches the contact spring when the contacts are open. Adjust the small cylinder behind the moving contact to obtain .009 inch contact follow. This is done by advancing the cylinder until it just touches the rear of the moving contact spring, and then backing off 1/2 turn.

45° Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase current of 50 amperes with polarities as shown on internal schematic diagram to the current coils which should be connected in series. Each potential coil should be short-circuited. When energized the relay moving element will center itself due to the combined torques produced by the 50 amperes of current and the spring restraint. Readjust the spring adjuster until the centering position of the moving element is exactly the same for the condition of zero current or with 50 amperes in the current coils. Under this condition the torque produced by the spring at the centering position is zero and does not tend to "offset" or shift the centering position due to the current. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

There are two adjustable stop screws located on the frame casting. These stops are used when the relay is supplied with two circuit closing contacts and perform the same function



TERMINAL ARRANGEMENTS FOR DIFFEREN TYPE H-3 & HV-3 RELAYS

CIRCUIT	HV-3 IN DIE-CAST BASE DWG. 4-D-1145	H-3 IN DIE-CAST BASE DWG. 4-D-1100	H-3 IN DIE-CAST BASE DWG. 5-D-1381	HV-3 IN FLEXI-TEST BASE 9-D-8079	H-3 IN FLEXI-TEST BASE 8-D-5542	
TRIP (MAKE)	*1 - *2	*13 - *14	*13 - *14	*1 - *2	*1 - *2	
PHASE A POTENTIAL CURRENT	9 - 10 11 - 12	1 - 2 3 - 4	1 - 2 3 - 4	9 - 10 11 - 12	5 - 6 7 - 8	
PHASE B POTENTIAL CURRENT	13 - 14 15 - 16	5 - 6 7 - 8	5 - 6 7 - 8	23 - 24 25 - 26	13 - 14 15 - 16	
PHASE C POTENTIAL CURRENT	17 - 18 19 - 20	9 - 10 11 - 12	9 - 10 11 - 12	19 - 20 21 - 22	9 - 10 11 - 12	
RESTRAINT PHASE A PHASE B PHASE C	21 23 24	——	——	6 7 8	——	

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Fig. 20—Diagram of Test Connections for the Types H-3 and HV-3 Relays.

as the stops on the moving contact assembly.

Watt Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase potential of 67 volts with polarities as shown on internal schematic diagram to the potential coils which should be connected in parallel. Each current coil should be open-circuited. When the potential circuits are deenergized the moving element will tend to be centered by the spring. When the potential circuits are energized the moving element may move either to the right or to the left. If under this condition the moving element moves the contacts to the right, the spring should be readjusted to move the deenergized spring centering position of the moving element to the left. If under this condition the moving element moves the contacts to the left, the spring should be readjusted to move the de-

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energized spring centering position of the moving element to the right. Continue to shift the centering position of the spring until a small movement of the spring adjuster will cause the moving element to move in one direction when the potential is applied and a small movement in the other direction will cause the moving element to move in the opposite direction. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

Type HV-3 Relay

The tests outlined for the type H-3 45° characteristic relay also apply to the HV-3 relay when the voltage restraint circuit is not connected. To make a complete check on the type HV-3 relay with all circuits connected, involves three-phase test source, phase shifter, potentiometers, and non-inductive resistors for controlling the voltage and current to the relay respectively. This test will permit checking of all the characteristics of the relay at the proper phase angle. This test procedure however is usually too
* complicated for routine field testing. The complete test may be simplified for field testing by the following modifications. Apply three phase restraining voltage to the restraining element and single phase to all three phases of the directional element. For the latter element the potential coils are all connected in parallel and the current coils are connected in series. With a non-inductive load, the relay will be operating about 45° away from its maximum torque position and consequently current values to trip a given voltage will be increased by about 30%. Since the combination of three-phase restraining torque and single-phase operating torques on all three elements produces some unbalanced torque in the moving element, it is recommended that tests be made at a reduced voltage (65 volts or less). With 65 volts applied to voltage restraint elements, about 8 amperes is required at unity power factor to make the relay operate.

To check the circuits thru the voltage restraint element, the relay should be energized at normal voltage for about 10 minutes. The potential circuit of the directional element should then be opened. Then open the phase A potential to the voltage restraint element and observe the torque produced on the moving element, if any. Replace A lead and remove the B lead and again observe the torque. Repeat for the C lead and in all cases there should be no torque or a very slight torque present. Any defects in the coils or capacitors of the voltage restraint circuits will be made apparent by the presence of excessive torque during this test.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core when the switch is picked up. This can be most conveniently done by turning the relay up-side-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 1.0 ohm.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced by new springs, they

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should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 0.16 ohm.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMENTS

The burdens and constants of the relays are as follows per phase:

TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 115 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.045	3040	0.045	3040	1760
Reactance (ohms)	0.045	1320	0.045	1320	2040
Impedance (ohms)	0.064	3310	0.064	3310	2700
Watts	1.13	3.67	1.13	3.67	3.2
Vars	1.13	1.59	1.13	1.59	3.7
Voltamperes	1.6	4.0	1.6	4.0	4.9
Power Factor	45° lag	23.5° lag	45° lag	23.5° lag	49° lag
Continuous Rating (Amperes or Volts)	5	115	5	115	115
One Second Current (Amps.)	230	...	230	...	...

VALUES AT 115 VOLTS, 5 AMPERES, 50 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.0488	2560	0.0488	2560	2720
Reactance (ohms)	0.0349	975	0.0349	975	1570
Impedance (ohms)	0.060	2740	0.060	2740	3140
Watts	1.22	4.5	1.22	4.5	3.17
Vars	.87	1.71	.87	1.71	1.84
Voltamperes	1.5	4.82	1.5	4.82	3.66
Power Factor	33.5° lag	20.8° lag	33.5° lag	20.8° lag	30.1° lag
Continuous Rating (Amperes or Volts)	5	115	5	115	115
One Second Current (Amps.)	230	...	230	...	...

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TYPE H-3, WATT CHARACTERISTIC RELAY

VALUES AT 115 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3	
	Current Circuit	Voltage Circuit
Resistance (ohms)	.028	2740
Reactance (ohms)	.0192	1440
Impedance (ohms)	.034	3100
Watts	.70	3.76
Vars	.48	1.97
Voltamperes	.85	4.25
Power Factor	34.5° lag	27.8° lag
Continuous Rating (Amperes or Volts)	5	115
One Second Current (Amps.)	230	...

TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 115 VOLTS, 5 AMPERES, 25 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	.0380	3830	.0380	3830	3980
Reactance (ohms)	.0192	3200	.0192	3200	990
Impedance (ohms)	.0420	5000	.0420	5000	4100
Watts	.94	2.03	.94	2.03	3.12
Voltamperes	1.05	2.65	1.05	2.65	3.22
Power Factor	26° lag	40° lag	26° lag	40° lag	14° lag
Continuous Rating	5	115	5	115	115
One Second Rating	230	...	230	...	...

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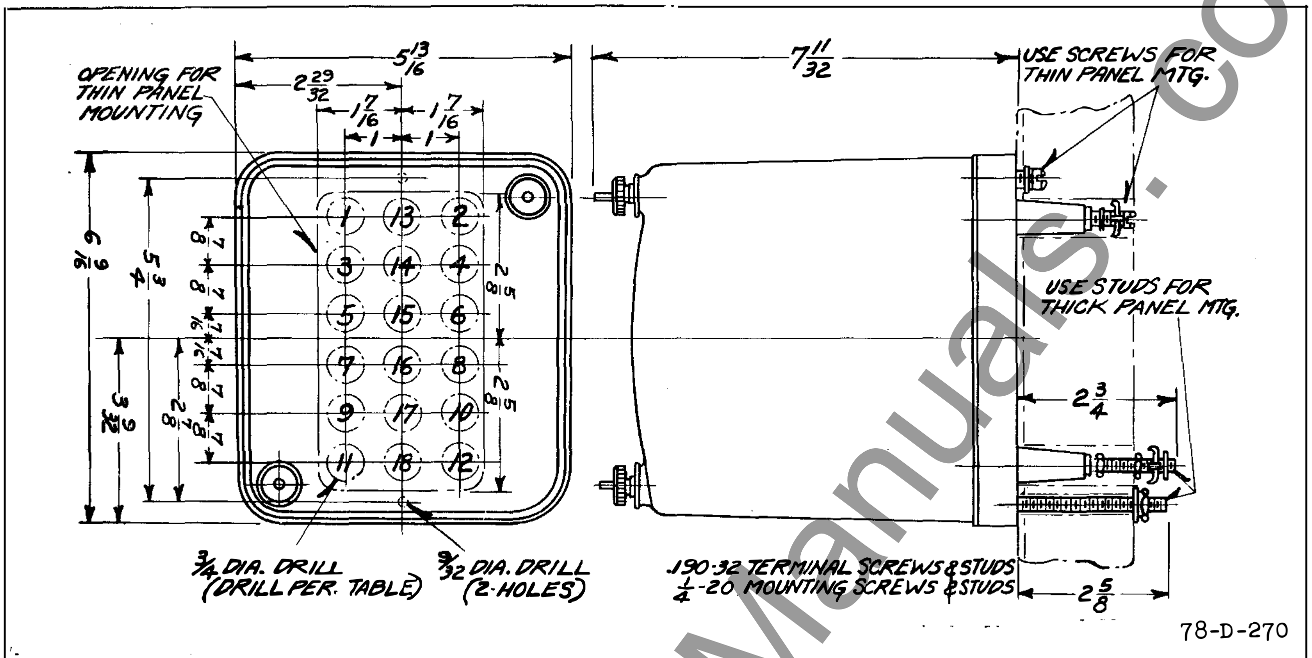

Fig. 21—Outline and Drilling Plan for the Projection Type Standard Case for the Type H-3 Relay. See the Internal Schematics For The Terminals Supplied. For Reference Only.

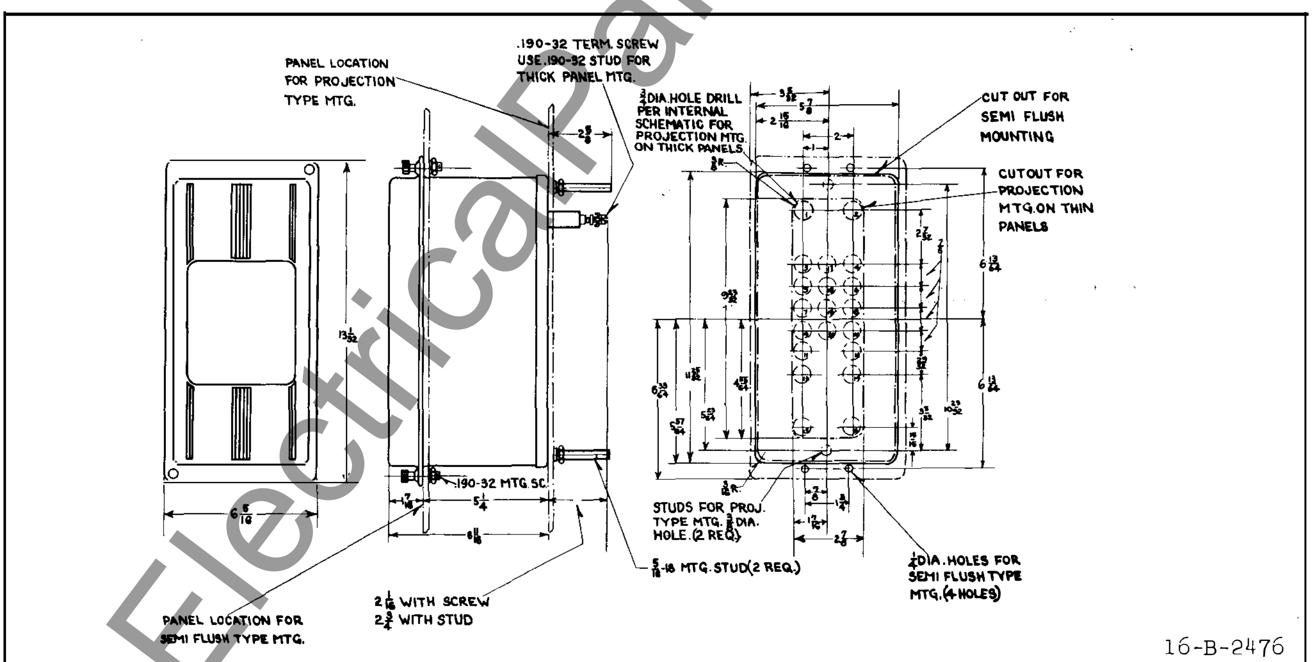

Fig. 22—Outline and Drilling Plan for the S20 Semi-Flush or Projection Type FT Flexitest Case For The Type H-3 Relay. See the Internal Schematics For The Terminals Supplied. For Reference Only.

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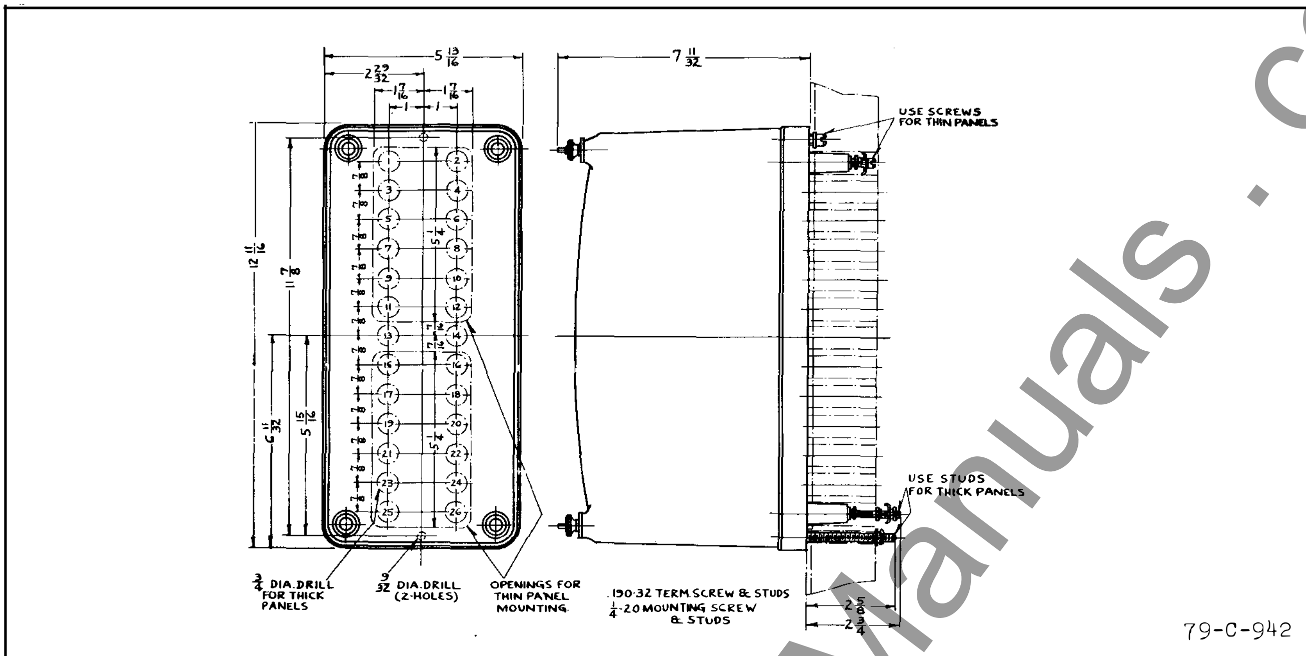

Fig. 23—Outline and Drilling Plan For the Projection Type Standard Case For the Type HV-3 Relay. See The Internal Schematics for the Terminals Supplied. For Reference Only.

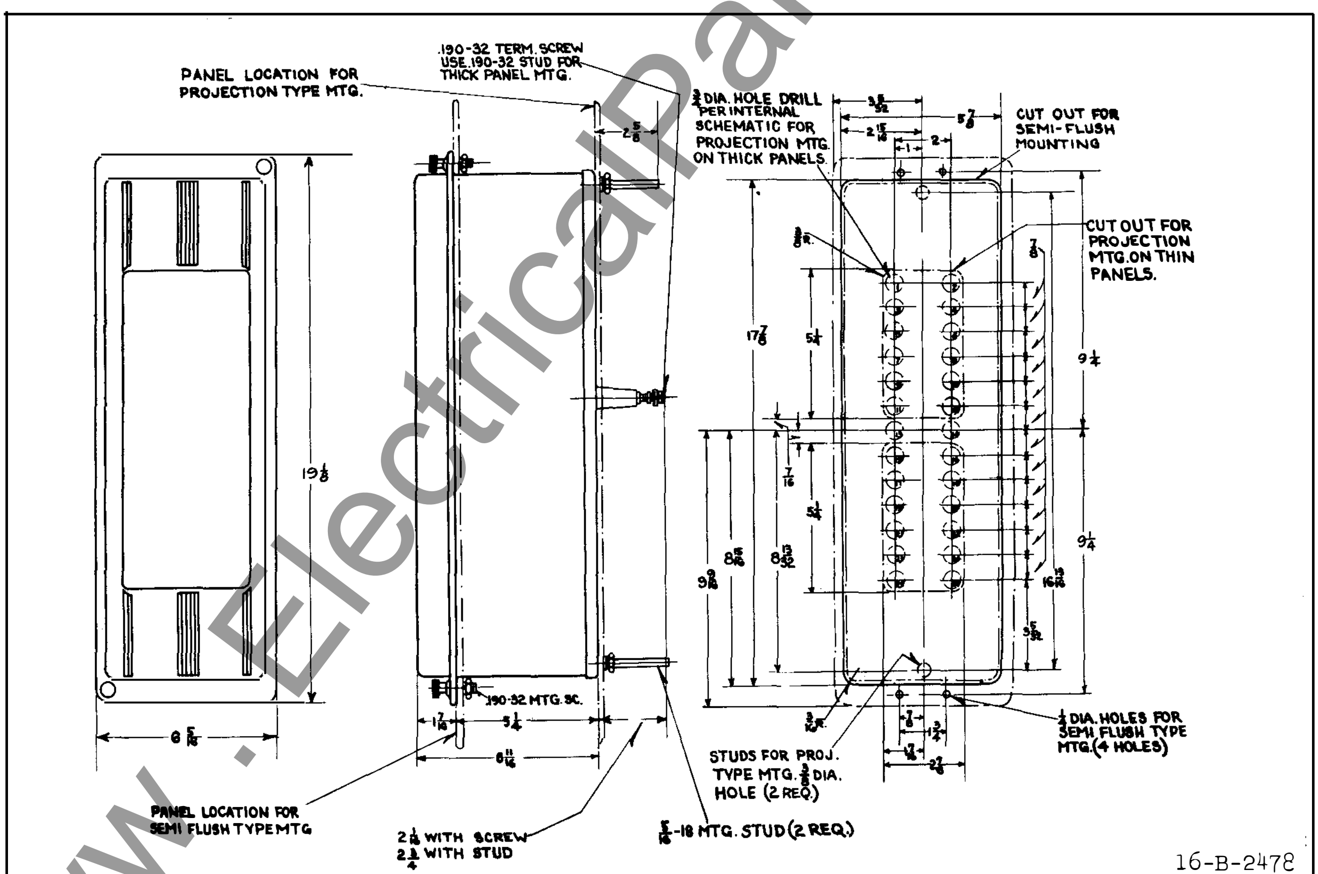

Fig. 24—Outline and Drilling Plan for the M20 Semi-flush or Projection Type FT Flexitest Case for the Type HV-3 Relay. See the Internal Schematics For Terminals Supplied. For Reference Only.

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INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES H-3 AND HV-3 THREE PHASE DIRECTIONAL RELAYS

CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment. Make sure that all moving parts operate freely and inspect the contacts to see that they are clean and close properly. Operate the relay to check the settings and electrical connections.

APPLICATION

The types H-3 and HV-3 relays are polyphase direction relays which are used to obtain high speed directional discrimination during faults on power systems. The type HV-3 relay has a voltage restraint element which introduces a restraining torque on the relay proportional to the area of the voltage triangle. Thus, at normal voltage, sufficient torque is produced to prevent operation of the relay on normal load current flow. Any fault on the system reduces the area of the voltage triangle, and consequently the amount of restraint. At the same time the current in the relay increases and the relay operates if the fault is in the contact closing direction. Since the voltage triangle does not collapse as much on ground faults as it does on phase faults, it is desirable to remove voltage restraint on ground faults. This may easily be done by an instantaneous overcurrent ground relay (type SC) with its back contacts connected to open any one of the leads to the voltage restraint element.

The direction of power flow for both phase and ground faults can be detected with these relays. To obtain correct operation during ground faults, it is necessary that the minimum current in the faulted conductor be at least twice the maximum load current flow (with no voltage restraint on the relay) so that if the fault current and load currents are in opposition, the former will always predominate and give a net torque on the relay in the correct direction. Stated another way, the minimum line-to-ground current must be at least three times the maximum load current for correct ground fault protection. Low ground current occurs most frequently on impedance grounded systems. Where positive directional indication cannot be obtained under all system conditions, it is recommended that a separate ground directional relay be used.

Both the type H-3 and the type HV-3 relays can be furnished with either a watt characteristic or a 45° characteristic.

CONSTRUCTION AND OPERATION

The type H-3 relay consists of a polyphase directional unit, two contactor switches, and two operation indicators. The type HV-3 relay consists of a polyphase directional unit, a voltage restraint unit, and two indicating contactor switches.

Polyphase Directional Unit

This unit consists of three electromagnets, and a vertical shaft with three movable loops, arranged as shown in figure 1. Each loop has its outer side located in an air gap within the electromagnet. Each electromagnet has a three-legged magnetic circuit wound with three coils. The coils on the two outer legs are the voltage windings. Voltage applied to these coils induces a large current in the loop by transformer action. Current flowing thru the current coil on the center leg of the electromagnet produces an air gap flux which interacts with the loop current flux in the outer side of the loop and causes rotation of the shaft in the direction corresponding to the direction of flow of the alternating current power.

One loop and its associated electromagnet make up one phase of the three-phase relay. With the 45° characteristic relay a delta voltage and a star current are applied to each electromagnet, and proper phase angle characteristics are obtained as follows. The loop, which is considered as the secondary load of a transformer, has a much higher resistance than reactance, and the loop current lags the voltage applied to the electromagnet by an angle of 10 to 15 degrees. The air gap flux lags the applied current by about 55 to 60 degrees because of the lag loops around the centerpole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by 45 degrees.

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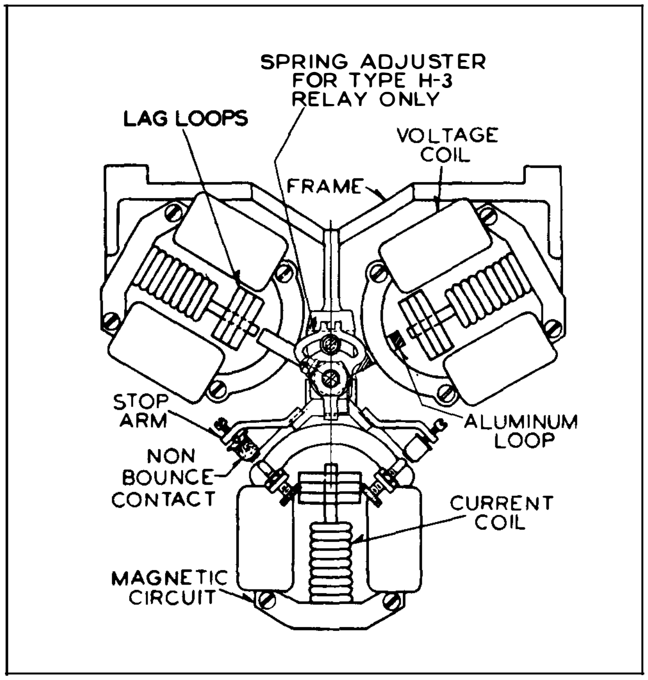

Fig. 1 – Schematic – Top View of Polyphase Directional Unit.

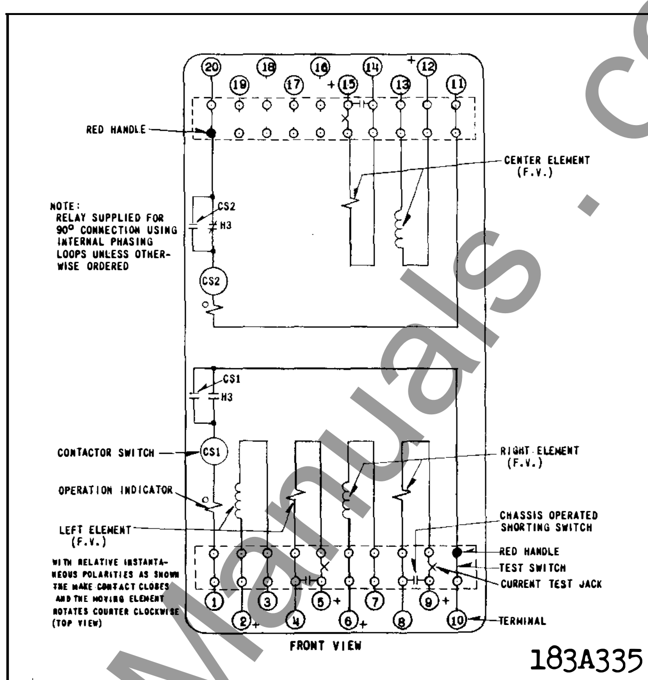

Fig. 2 – Internal Schematic of the Type H-3 Relay in the FT22 Case.

The 90° Connection is used on the relay to give the required delta voltage and star current. With this connection one of the electromagnets will have "A phase" (star) current and "BC" (delta) voltage which for a system power factor of unity, lags the current by 90°. Hence, with this connection and the above (45°) relay characteristics, maximum torque is obtained when the system fault current is lagging its unity power factor position by 45°.

With the watt characteristic relay a star current and a star voltage are applied to each electromagnet. The air gap flux lags the applied current by about 10 to 15 degrees because of the lag loops around the center pole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by about 0 degrees.

The instantaneous torque in each element of the relay is produced by the instantaneous products of voltage (loop current) and current (air gap flux) in the electromagnet, which is a double frequency pulsating torque. The torques in the other two electromagnets are also pulsating, but they are displaced 120 degrees in time phase and when all three instantaneous values are added, the result is a uniform non-pulsating torque.

Two moving contacts are mounted at right angles to each other on the outer end of a leaf spring which in turn is mounted on Isolantite arm on the moving shaft. A stop bracket with a small cylinder partially

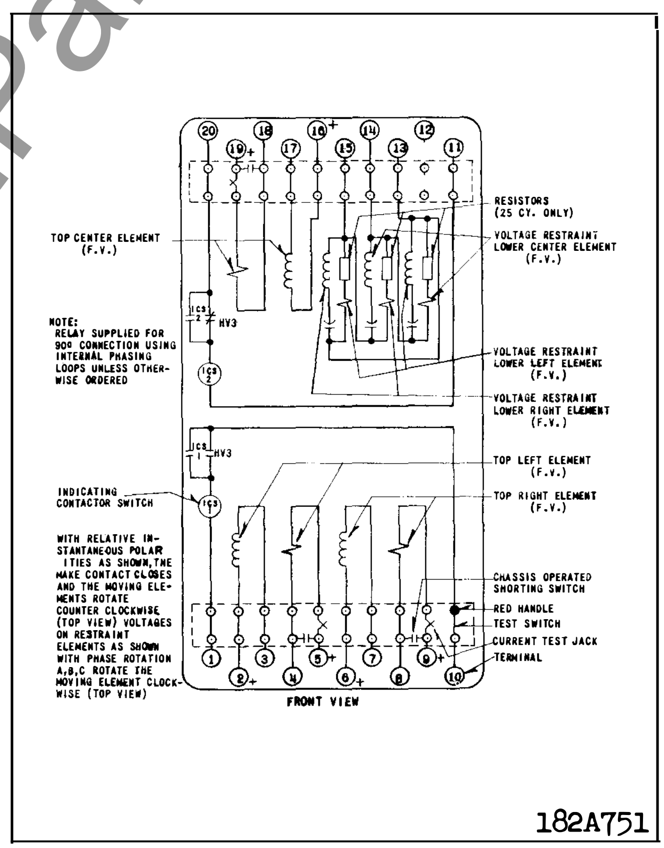

Fig. 3 – Internal Schematic of the Type HV-3 Relay in the FT32 Case.

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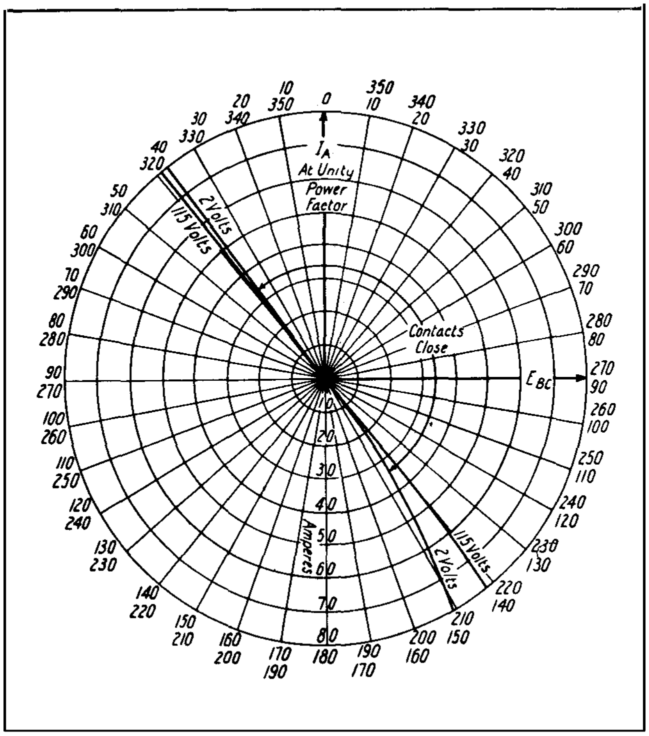

Fig. 4 – Typical Phase Angle Curve for 45° Characteristic; 50 and 60 Cycle, H-3 and HV-3 Relays – Balanced Three Phase Power Applied and No Spring Restraint.

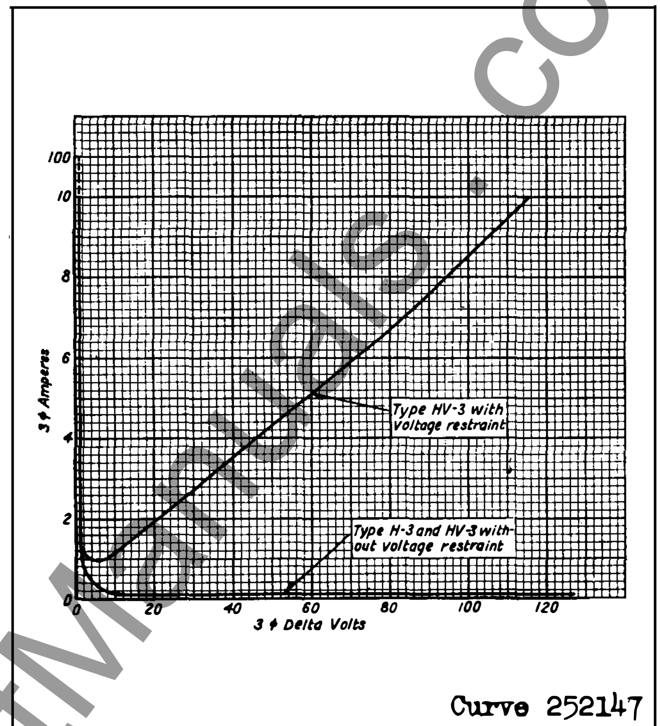

Fig. 5 – Typical Sensitivity Curve for 50 and 60 Cycle, H-3 and HV-3 Relays – at Maximum Torque Angle.

filled with tungsten powder is mounted behind each moving contact. When the moving contact strikes against the rigid fixed contact screw, the spring is deflected for the necessary contact follow, after which the stop strikes the moving contact. Thus, the full torque of the relay is transmitted thru the contacts to maintain full contact pressure. The particles of tungsten powder in the small cylinder slide over each other at the instant of impact and absorb the energy in the moving element. A flexible metal ribbon conducts current to the moving contacts.

The type H-3 relay is supplied with spring restraint which is adjusted to hold the contacts in the normal non-trip position when the relay is deenergized. This prevents an incorrect directional indication by the element under the condition of loss of load. However, the spring restraint may be adjusted to give a bias torque in either direction.

Voltage Restraint Unit

This element is supplied only in the type HV-3 relays and consists of three electromagnets and loops similar to those used on the directional element. The restraining unit is mounted below the directional unit and the loops of the two units are fastened to a common vertical shaft which operates the two contacts as described above. The outer coils of each electromagnet have one delta voltage (E_1) applied and the center coil has another delta voltage (E_2) applied. By means of the capacitor units in series with the outer two coils, the phase angle characteristics of the electromagnets are such that the torque of the element is proportional to:

$$V_1 \bullet V_2 \bullet \sin \theta$$

where θ is the angle between the two delta voltages and is normally 60°.

If any one of the three delta voltages completely collapses during a fault, there is no torque on the electromagnet, since the collapse of the third voltage makes the sine of the angle between the voltages zero. If all three voltages decrease uniformly, the torque varies as the square of their magnitude. Each electromagnet is connected to a different combination of delta voltages so that a uniform restraint torque and balanced burdens are obtained.

Restraint can be removed by opening any one supply lead to the restraint element. This applies single phase to all three electromagnets and the sine of the

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For detailed FT case information refer to I.L. 41-076.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Adjust the lower bearing so that both the top and bottom of the loops are equi-distant from their respective magnetic circuits. Energize the potential circuits of the relay until the loops reach operating temperature. About ten minutes at normal voltage is necessary to reach this condition. When the operating temperature is reached, adjust the upper bearing for 1/64 inch clearance.

The loops of each element must be in line with the center of the middle leg of the magnetic circuit. If necessary, this adjustment can be obtained by loosening the electromagnet mounting screws and moving the whole electromagnet in the desired direction. All three elements must have the same relative position of loop and magnetic circuit.

Type H-3 Relay

The polarity of the relay is checked as follows: Refer to figure 2 and apply 115 bolts and 5 amperes (in phase) to the corresponding voltage and current coils in turn, with the terminals marked with polarity marks connected together. Looking at the top of the relay, the moving element should rotate in a counterclockwise direction.

Adjust the back-up strip located in front of each moving contact by bending so that it just touches the contact spring when the contacts are open. Adjust the small cylinder behind the moving contact to obtain .009 inch contact follow. This is done by advancing the cylinder until it just touches the rear of the moving contact spring, and then backing off 1/2 turn.

45° Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase current of 50 amperes with polarities as shown on internal schematic diagram to the current coils which should be connected in series. Each potential coil should be short-circuited. When energized the relay moving element will center itself due to the combined torques produced by the 50 amperes of current and the spring restraint. Readjust the spring adjuster until the centering position of the moving element is exactly the same for the condition of zero current or with 50 amperes in the current coils. Under this condition the torque produced by the spring at the centering position is zero and does not tend to "offset" or shift the centering position due to the current. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

There are two adjustable stop screws located on the frame casting. These stops are used when the relay is supplied with two circuit closing contacts and perform the same function as the stops on the moving contact assembly.

Watt Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase potential of 67 volts with polarities as shown on internal schematic diagram to the potential coils which should be connected in parallel. Each current coil should be open-circuited. When the potential circuits are deenergized the moving element will tend to be centered by the spring. When the potential circuits are energized the moving element may move either to the right or to the left. If under this condition the moving element moves the contacts to the right, the spring should be readjusted to move the deenergized spring centering position of the moving element to the left. If under this condition the moving element moves the contacts to the left, the spring should be readjusted to move the deenergized spring centering position of the moving element to the right. Continue to shift the centering position of the spring until a small movement of the spring adjuster will cause the moving element to move in one direction when the potential is applied and a small movement in the other direction will cause the moving element to move in the opposite direction. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

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Type HV-3 Relay

The tests outlined for the type H-3 45° characteristic relay also apply to the HV-3 relay when the voltage restraint circuit is not connected. To make a complete check on the type HV-3 relay with all circuits connected, involves three-phase test source, phase shifter, potentiometers, and non-inductive resistors for controlling the voltage and current to the relay respectively. This test will permit checking of all the characteristics of the relay at the proper phase angle. This test procedure however is usually too complicated for routine field testing. The complete test may be simplified for field testing by the following modifications. Apply three phase restraining voltage to the restraining element and single phase to all three phases of the directional element. For the latter element the potential coils are all connected in parallel and the current coils are connected in series. With a non-inductive load, the relay will be operating about 45° away from its maximum torque position and consequently current values to trip a given voltage will be increased by about 30%. Since the combination of three-phase restraining torque and single-phase operating torques on all three elements produces some unbalanced torque in the moving element, it is recommended that tests be made at a reduced voltage (65 volts or less). With 65 volts applied to voltage restraint elements, about 8 amperes is required at unity power factor to make the relay operate.

To check the circuits thru the voltage restraint element, the relay should be energized at normal voltage for about 10 minutes. The potential circuit of the directional element should then be opened. Then open the phase A potential to the voltage restraint unit and observe the torque produced on the moving element, if any. Replace A lead and remove the B lead and again observe the torque. Repeat for the C lead and in all cases there should be no torque or a very slight torque present. Any defects in the coils or capacitors of the voltage restraint circuits will be made apparent by the presence of excessive torque during this test.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core when the switch is picked up. This can be most conveniently done by turning the relay up-side-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 1.0 ohm.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced by new springs, they should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 0.16 ohm.

Indicating Contactor Switch (ICS) – (HV-3 only)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMEMENTS

The burdens and constants of the relays are as follows per phase:

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TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY
VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.045	3040	0.045	3040	1760
Reactance (ohms)	0.045	1320	0.045	1320	2040
Impedance (ohms)	0.064	3310	0.064	3310	2700
Watts	1.13	4.0	1.13	4.0	3.48
Vars	1.13	1.73	1.13	1.73	4.02
Voltamperes	1.6	4.35	1.6	4.35	5.31
Power Factor	45° lag	23.5° lag	45° lag	23.5° lag	49° lag
Continuous Rating (Amperes or Volts)	5	115	5	115	115
One Second Current (Amps.)	230	...	230	...	...

VALUES AT 120 VOLTS, 5 AMPERES, 50 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.0488	2560	0.0488	2560	2720
Reactance (ohms)	0.0349	975	0.0349	975	1570
Impedance (ohms)	0.060	2740	0.060	2740	3140
Watts	1.22	4.89	1.22	4.89	3.44
Vars	.87	1.86	.87	1.86	2.00
Voltamperes	1.5	5.23	1.5	5.23	3.98
Power Factor	33.5° lag	20.8° lag	33.5° lag	20.8° lag	30.1° lag
Continuous Rating (Amperes or Volts)	5	115	5	115	115
One Second Current (Amps.)	230	...	230	...	...

TYPE H-3, WATT CHARACTERISTIC RELAY
VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3	
	Current Circuit	Voltage Circuit
Resistance (ohms)	.028	2740
Reactance (ohms)	.0192	1440
Impedance (ohms	.034	3100
Watts	.70	4.09
Vars	.48	2.14
Voltamperes	.85	4.62
Power Factor	34.5° lag	27.8° lag
Continuous Rating (Amperes or Volts)	5	115
One Second Current (Amps.)	230	...

TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY
VALUES AT 120 VOLTS, 5 AMPERES, 25 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint
Resistance (ohms)	.0380	3830	.0380	3830	3980
Reactance (ohms)	.0192	3200	.0192	3200	990
Impedance (ohms)	.0420	5000	.0420	5000	4100
Watts	.94	2.20	.94	2.20	3.39
Voltamperes	1.05	2.88	1.05	2.88	3.50
Power Factor	26° lag	40° lag	26° lag	40° lag	14° lag
Continuous Rating	5	115	5	115	115
One Second Rating	230	...	230	...	...

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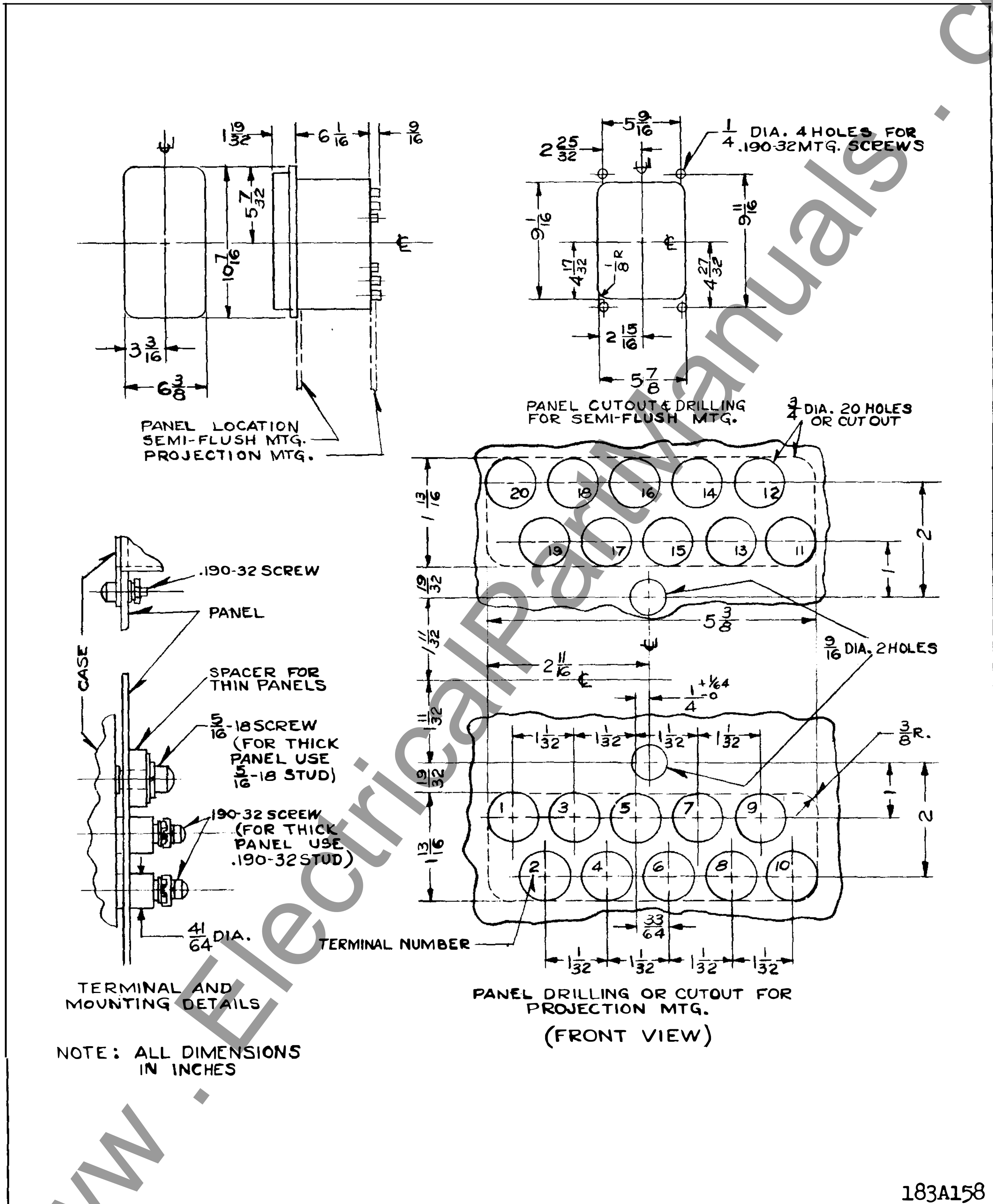

Fig. 14 – Outline and Drilling Plan for the H-3 Relay in the FT22 Case.

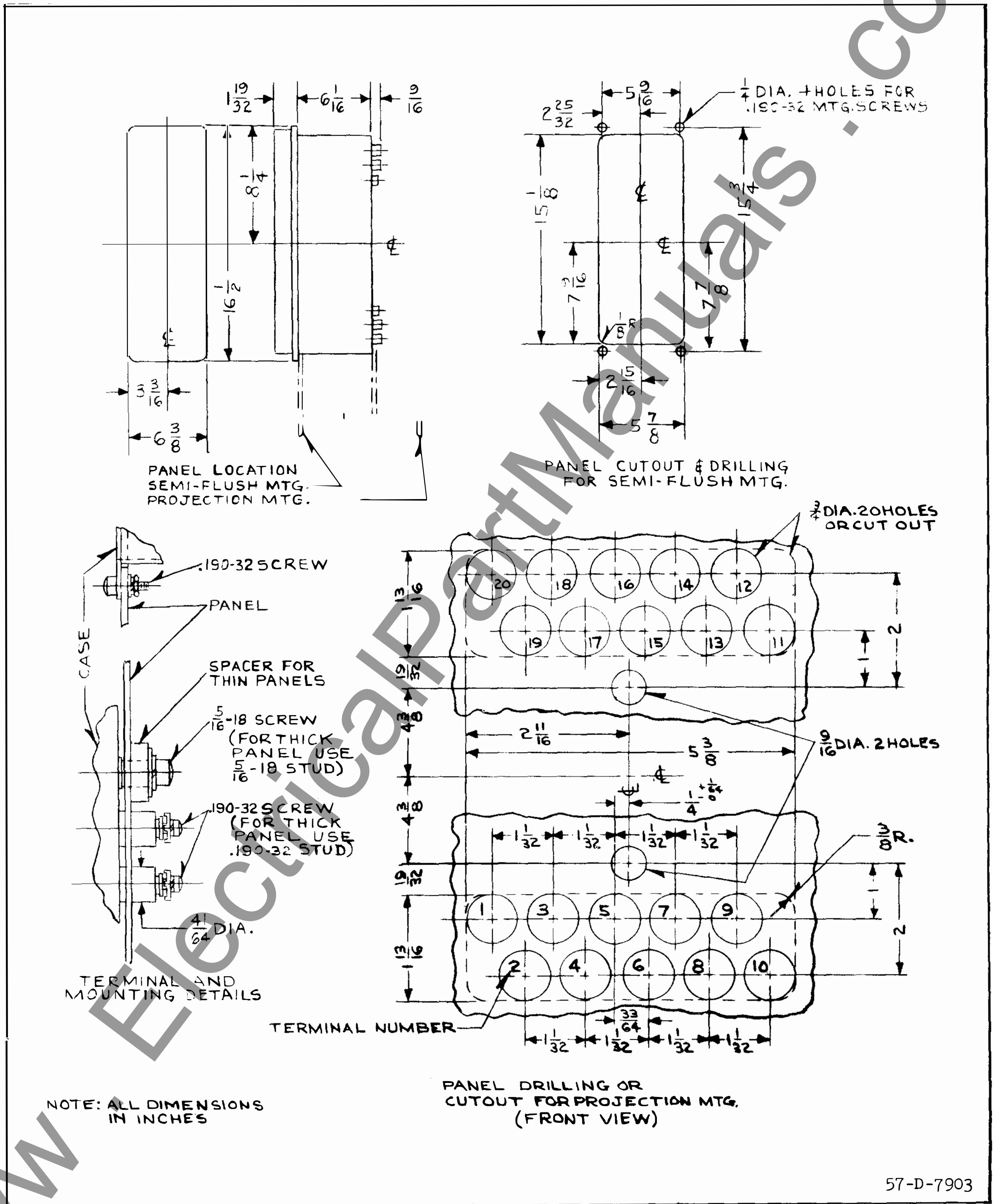

Fig. 15 – Outline and Drilling Plan for the HV-3 Relay in the FT32 Case.

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METER DIVISION • NEWARK, N.J.

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INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES H-3 AND HV-3 THREE PHASE DIRECTIONAL RELAYS

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CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment. Make sure that all moving parts operate freely and inspect the contacts to see that they are clean and close properly. Operate the relay to check the settings and electrical connections.

APPLICATION

The types H-3 and HV-3 relays are polyphase direction relays which are used to obtain high speed directional discrimination during faults on power systems. The type HV-3 relay has a voltage restraint element which introduces a restraining torque on the relay proportional to the area of the voltage triangle. Thus, at normal voltage, sufficient torque is produced to prevent operation of the relay on normal load current flow. Any fault on the system reduces the area of the voltage triangle, and consequently the amount of restraint. At the same time the current in the relay increases and the relay operates if the fault is in the contact closing direction. Since the voltage triangle does not collapse as much on ground faults as it does on phase faults, it is desirable to remove voltage restraint on ground faults. This may easily be done by an instantaneous overcurrent ground relay (type SC) with its back contacts connected to open any one of the leads to the voltage restraint element.

The direction of power flow for both phase and ground faults can be detected with these relays. To obtain correct operation during ground faults, it is necessary that the minimum current in the faulted conductor be at least twice the maximum load current flow (with no voltage restraint on the relay) so that if the fault current and load currents are in opposition, the former will always predominate and give a net torque on the relay in the correct direction. Stated another way, the minimum line-to-ground current must be at least three times the maximum load current for correct ground fault protection. Low ground current occurs most frequently on impedance grounded systems. Where positive directional indication cannot be obtained under all system conditions, it is recommended that a separate ground directional relay be used.

Both the type H-3 and the type HV-3 relays can be furnished with either a watt characteristic or a 45° characteristic.

CONSTRUCTION AND OPERATION

The type H-3 relay consists of a polyphase directional unit, two contactor switches, and two operation indicators. The type HV-3 relay consists of a polyphase directional unit, a voltage restraint unit, and two indicating contactor switches.

Polyphase Directional Unit

This unit consists of three electromagnets, and a vertical shaft with three movable loops, arranged as shown in figure 1. Each loop has its outer side located in an air gap within the electromagnet. Each electromagnet has a three-legged magnetic circuit wound with three coils. The coils on the two outer legs are the voltage windings. Voltage applied to these coils induces a large current in the loop by transformer action. Current flowing thru the current coil on the center leg of the electromagnet produces an air gap flux which interacts with the loop current flux in the outer side of the loop and causes rotation of the shaft in the direction corresponding to the direction of flow of the alternating current power.

One loop and its associated electromagnet make up one phase of the three-phase relay. With the 45° characteristic relay a delta voltage and a star current are applied to each electromagnet, and proper phase angle characteristics are obtained as follows. The loop, which is considered as the secondary load of a transformer, has a much higher resistance than reactance, and the loop current lags the voltage applied to the electromagnet by an angle of 10 to 15 degrees. The air gap flux lags the applied current by about 55 to 60 degrees because of the lag loops around the centerpole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by 45 degrees.

SUPERSEDES I. L. 41-226.2

*Denotes change from superseded issue.

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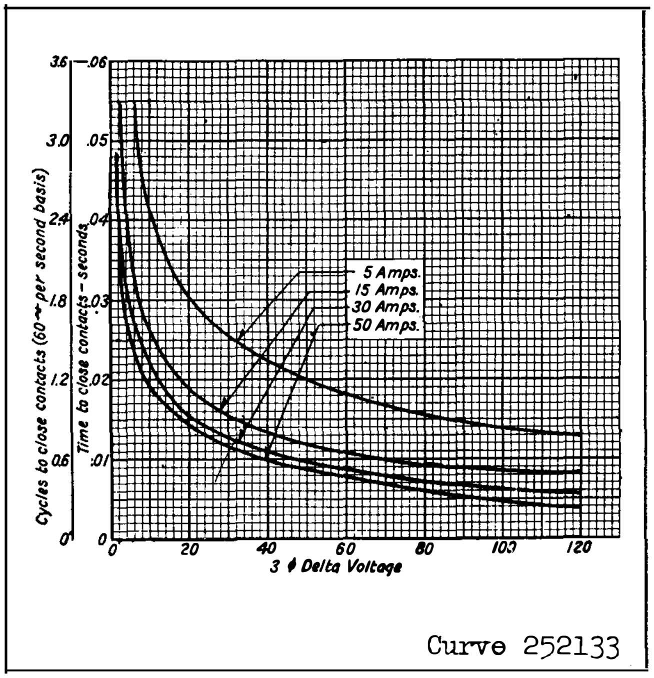

Fig. 6 – Typical Time – Current Curves of 50 and 60 Cycle H-3 Relay for Three Phase Faults at Maximum Torque Angle.

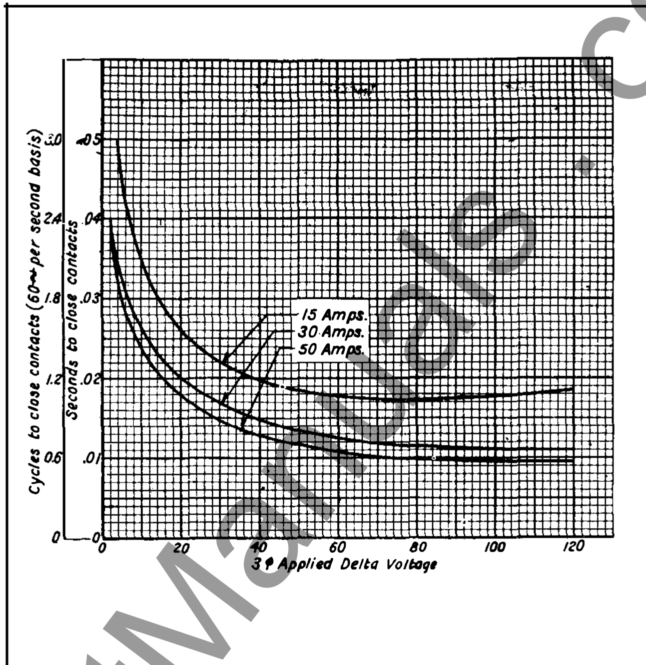

Fig. 7 – Typical Time – Current Curves of 50 and 60 Cycle HV-3 Relay for Three Phase Faults at Maximum Torque Angle.

angle becomes zero. At normal voltages 10 amperes is required in each element at maximum torque to overcome the restraint torque.

Contactor Switches

The d-c contactor switch in the relay is a small solenoid type switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward, the disc bridges three silver stationary contacts. The coil is in series with the main contacts of the relay and with the trip coil of the breaker. When the relay contacts close, the coil becomes energized and closes the switch contacts. This shunts the main relay contacts, thereby relieving them of the duty of carrying tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring-restrained armature releases the white target which falls by gravity to indicate completion of the trip circuit. The indicator is reset from outside of the case by a push rod in the cover or cover stud.

Indicating Contactor Switch Unit (ICS) – (HV-3 only)

The d-c indicating contactor switch is a small clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pickup value of the switch.

CHARACTERISTICS

The types H-3 relays are provided with independent make and break contacts. Two auxiliary contactor switches – one in each contact circuit – provide seal-in circuits for the main relay contact. The main contacts will close 30 amperes at 250 volts d-c and the auxiliary contactors will safely carry this current until the breaker is tripped and the auxiliary "a" switch opens. The contactor switch has a minimum

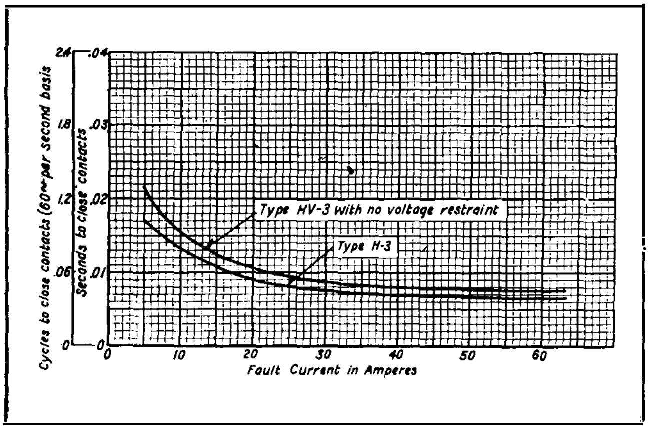

Fig. 8 – Typical Time – Current Curves for 50 and 60 Cycle H-3 and HV-3 Relays, Without Voltage Restraint for Phase to Phase Faults at Maximum Torque Angle – Full Voltage Collapse on Faulted Phase, 86% Voltage on Unfaulted Phase.

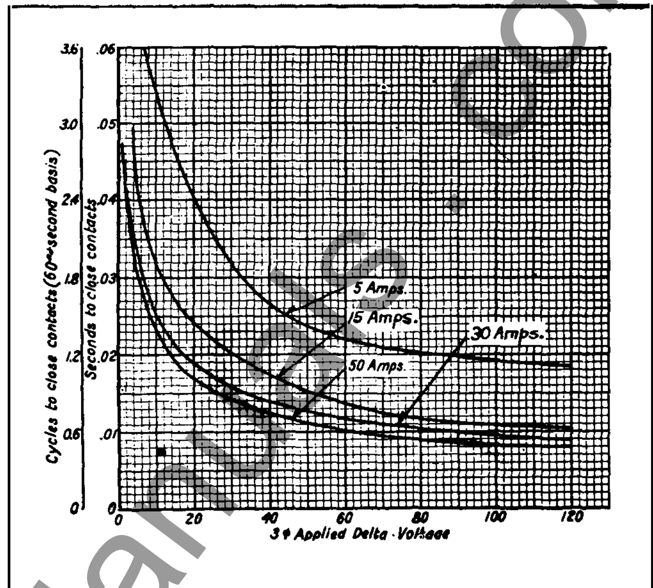

Fig. 9 – Typical Time – Current Curves for 50 and 60 Cycle Type HV-3 Relay Without Voltage Restraint for Three Phase Faults at Maximum Torque.

pick-up of one ampere d-c and a coil resistance of one ohm.

Typical 50 and 60 cycle phase angle characteristics of the 45° characteristic relay are shown in figure 4. Maximum torque, in the contact closing direction, occurs when the line current lags the line-to-neutral voltage by approximately 45 degrees, when using the 90° connection.

Typical 50 and 60 cycle sensitivity curves at maximum torque are shown in figure 5. The sensitivity of the type HV-3 relay without voltage restraint is the same as the type H-3 relay. The 60 cycle three phase minimum pick-up without spring restraint of the type H-3 relay is 0.08 amperes at 115 volts, 0.15 ampere at 10 volts, and 5.0 amperes at 1 volt. The single phase minimum pick-up currents are approximately three times those for three phase. It will be noted from the curves that the sensitivity of the type HV-3 relay with voltage restraint is decreased only at voltages above 2 volts. The curves also show that 10 amperes 60 cycles are required at 115 volts to overcome voltage restraint.

Typical time curves are shown in figures 6 to 9. All curves are for a contact spacing of .035 inch and at maximum torque for 60 and 50 cycle relays and .070 inch for 25 cycle relays.

Trip Circuit (HV-3 only)

The main contacts will safely close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pickup setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

Trip Circuit Constant (HV-3 only)

Indicating Contactor Switch (ICS)

0.2 ampere tap 6.5 ohms d-c resistance
2.0 ampere tap 0.15 ohms d-c resistance

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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For detailed FT case information refer to I.L. 41-076.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Adjust the lower bearing so that both the top and bottom of the loops are equi-distant from their respective magnetic circuits. Energize the potential circuits of the relay until the loops reach operating temperature. About ten minutes at normal voltage is necessary to reach this condition. When the operating temperature is reached, adjust the upper bearing for 1/64 inch clearance.

The loops of each element must be in line with the center of the middle leg of the magnetic circuit. If necessary, this adjustment can be obtained by loosening the electromagnet mounting screws and moving the whole electromagnet in the desired direction. All three elements must have the same relative position of loop and magnetic circuit.

Type H-3 Relay

The polarity of the relay is checked as follows: Refer to figure 2 and apply 115 bolts and 5 amperes (in phase) to the corresponding voltage and current coils in turn, with the terminals marked with polarity marks connected together. Looking at the top of the relay, the moving element should rotate in a counterclockwise direction.

Adjust the back-up strip located in front of each moving contact by bending so that it just touches the contact spring when the contacts are open. Adjust the small cylinder behind the moving contact to obtain .009 inch contact follow. This is done by advancing the cylinder until it just touches the rear of the moving contact spring, and then backing off 1/2 turn.

45° Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase current of 50 amperes with polarities as shown on internal schematic diagram to the current coils which should be connected in series. Each potential coil should be short-circuited. When energized the relay moving element will center itself due to the combined torques produced by the 50 amperes of current and the spring restraint. Readjust the spring adjuster until the centering position of the moving element is exactly the same for the condition of zero current or with 50 amperes in the current coils. Under this condition the torque produced by the spring at the centering position is zero and does not tend to "offset" or shift the centering position due to the current. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

There are two adjustable stop screws located on the frame casting. These stops are used when the relay is supplied with two circuit closing contacts and perform the same function as the stops on the moving contact assembly.

Watt Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase potential of 67 volts with polarities as shown on internal schematic diagram to the potential coils which should be connected in parallel. Each current coil should be open-circuited. When the potential circuits are deenergized the moving element will tend to be centered by the spring. When the potential circuits are energized the moving element may move either to the right or to the left. If under this condition the moving element moves the contacts to the right, the spring should be readjusted to move the deenergized spring centering position of the moving element to the left. If under this condition the moving element moves the contacts to the left, the spring should be readjusted to move the deenergized spring centering position of the moving element to the right. Continue to shift the centering position of the spring until a small movement of the spring adjuster will cause the moving element to move in one direction when the potential is applied and a small movement in the other direction will cause the moving element to move in the opposite direction. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

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Type HV-3 Relay

The tests outlined for the type H-3 45° characteristic relay also apply to the HV-3 relay when the voltage restraint circuit is not connected. To make a complete check on the type HV-3 relay with all circuits connected, involves three-phase test source, phase shifter, potentiometers, and non-inductive resistors for controlling the voltage and current to the relay respectively. This test will permit checking of all the characteristics of the relay at the proper phase angle. This test procedure however is usually too complicated for routine field testing. The complete test may be simplified for field testing by the following modifications. Apply three phase restraining voltage to the restraining element and single phase to all three phases of the directional element. For the latter element the potential coils are all connected in parallel and the current coils are connected in series. With a non-inductive load, the relay will be operating about 45° away from its maximum torque position and consequently current values to trip a given voltage will be increased by about 30%. Since the combination of three-phase restraining torque and single-phase operating torques on all three elements produces some unbalanced torque in the moving element, it is recommended that tests be made at a reduced voltage (65 volts or less). With 65 volts applied to voltage restraint elements, about 8 amperes is required at unity power factor to make the relay operate.

To check the circuits thru the voltage restraint element, the relay should be energized at normal voltage for about 10 minutes. The potential circuit of the directional element should then be opened. Then open the phase A potential to the voltage restraint unit and observe the torque produced on the moving element, if any. Replace A lead and remove the B lead and again observe the torque. Repeat for the C lead and in all cases there should be no torque or a very slight torque present. Any defects in the coils or capacitors of the voltage restraint circuits will be made apparent by the presence of excessive torque during this test.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core when the switch is picked up. This can be most conveniently done by turning the relay up-side-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 1.0 ohm.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced by new springs, they should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 0.16 ohm.

Indicating Contactor Switch (ICS) – (HV-3 only)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMEMENTS

The burdens and constants of the relays are as follows per phase:

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TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

*** VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES**

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.050	2070	0.050	2070	500
Reactance (ohms)	0.052	1530	0.052	1530	610
Impedance (ohms)	0.072	2580	0.072	2580	790
Watts	1.25	4.59	1.25	4.59	3.84
Vars	1.29	3.40	1.29	3.40	4.75
Voltamperes	1.82	5.71	1.82	5.71	6.1
Power Factor	46° lag	36.5° lag	46° lag	36.5° lag	51° lag
Continuous Rating (Amperes or Volts)	5	120	5	120	120
One Second Current (Amps.)	230	. . .	230	. . .	. . .

*** VALUES AT 120 VOLTS, 5 AMPERES, 50 CYCLES**

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.0488	2560	0.0488	2560	2720
Reactance (ohms)	0.0349	975	0.0349	975	1570
Impedance (ohms)	0.060	2740	0.060	2740	3140
Watts	1.22	4.89	1.22	4.89	3.44
Vars	.87	1.86	.87	1.86	2.00
Voltamperes	1.5	5.23	1.5	5.23	3.98
Power Factor	33.5° lag	20.8° lag	33.5° lag	20.8° lag	30.1° lag
Continuous Rating (Amperes or Volts)	5	120	5	120	120
One Second Current (Amps.)	230	. . .	230	. . .	. . .

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*

TYPE H-3, WATT CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3	
	Current Circuit	Voltage Circuit
Resistance (ohms)	.028	2740
Reactance (ohms)	.0192	1440
Impedance (ohms	.034	3100
Watts	.70	4.09
Vars	.48	2.14
Voltamperes	.85	4.62
Power Factor	34.5° lag	27.8° lag
Continuous Rating (Amperes or Volts)	5	120
One Second Current (Amps.)	230	. . .

*

TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 25 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint
Resistance (ohms)	.0380	3830	.0380	3830	3980
Reactance (ohms)	.0192	3200	.0192	3200	990
Impedance (ohms)	.0420	5000	.0420	5000	4100
Watts	.94	2.20	.94	2.20	3.39
Voltamperes	1.05	2.88	1.05	2.88	3.50
Power Factor	26° lag	40° lag	26° lag	40° lag	14° lag
Continuous Rating	5	120	5	120	120
One Second Rating	230	. . .	230	. . .	. . .

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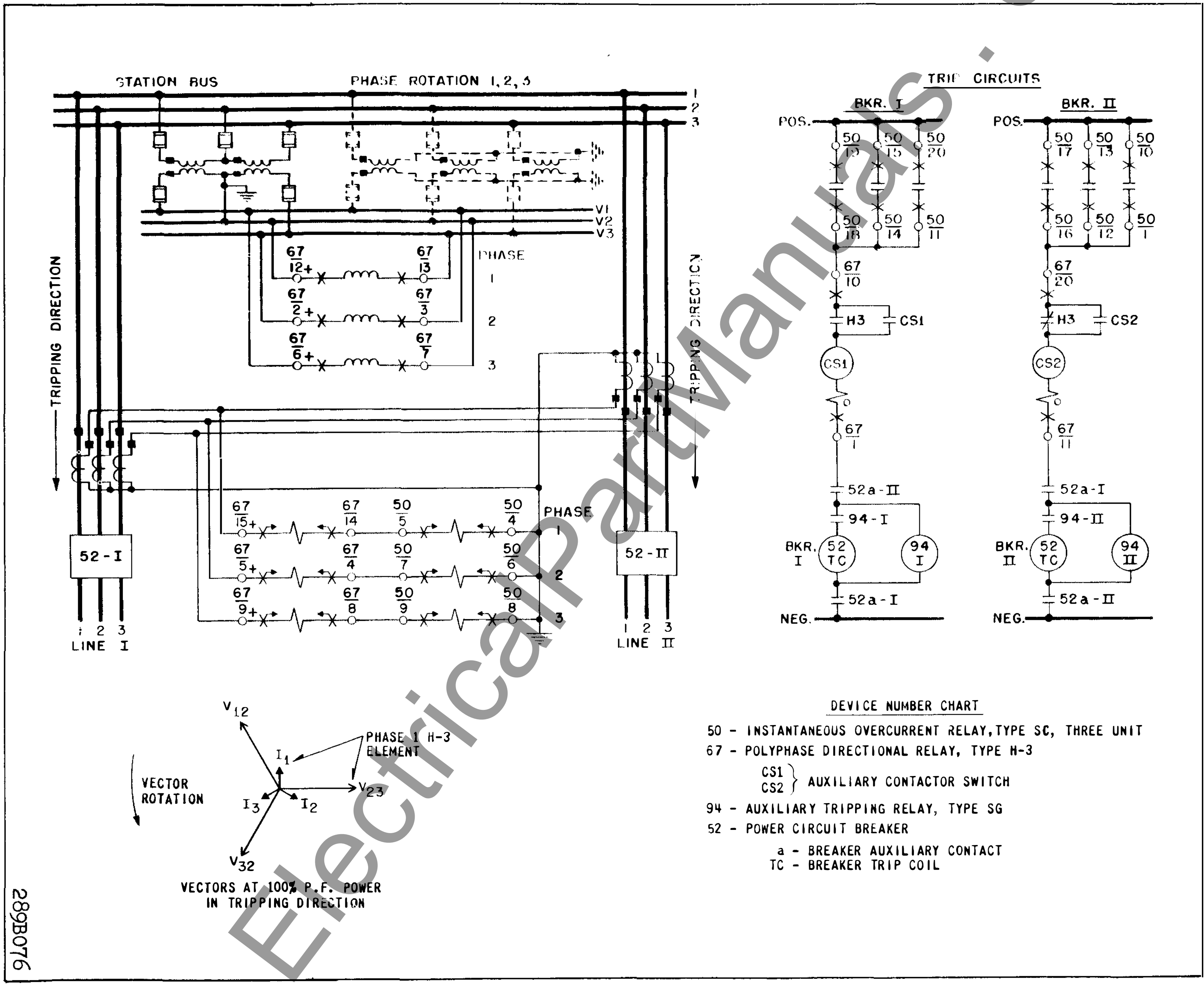
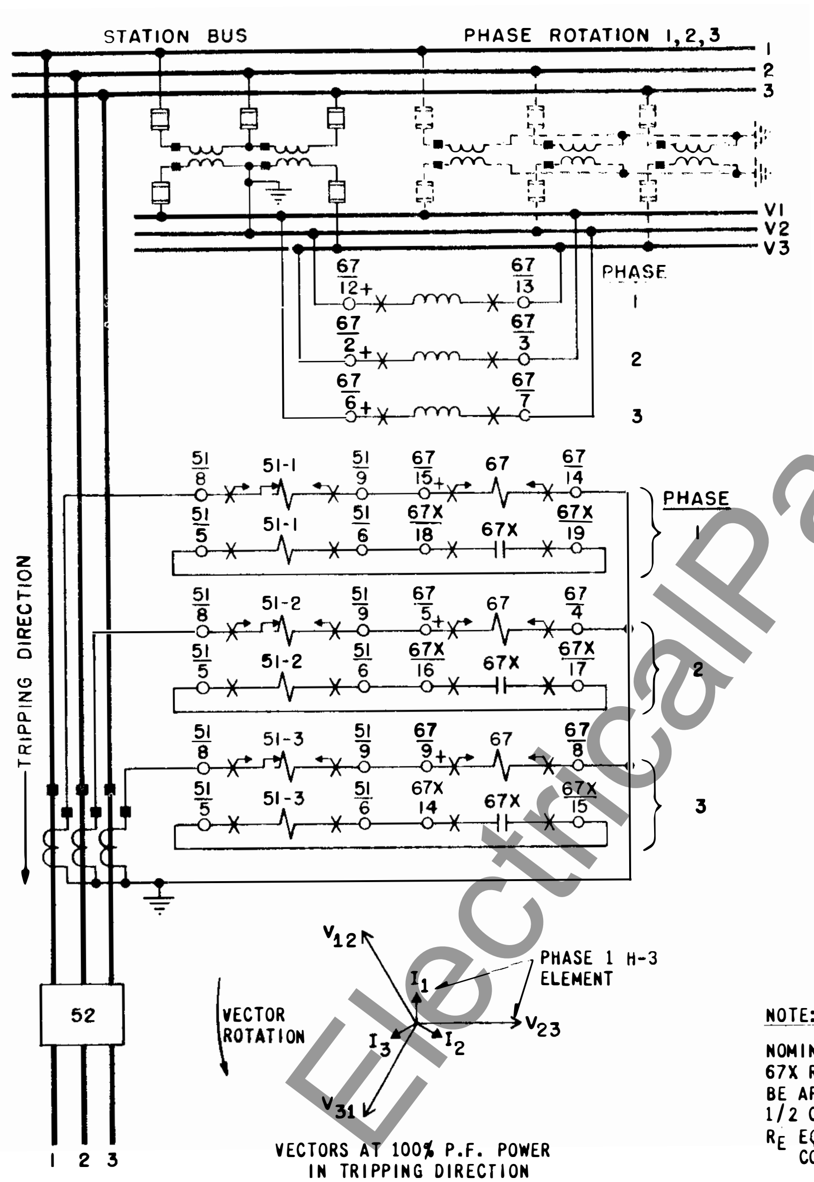
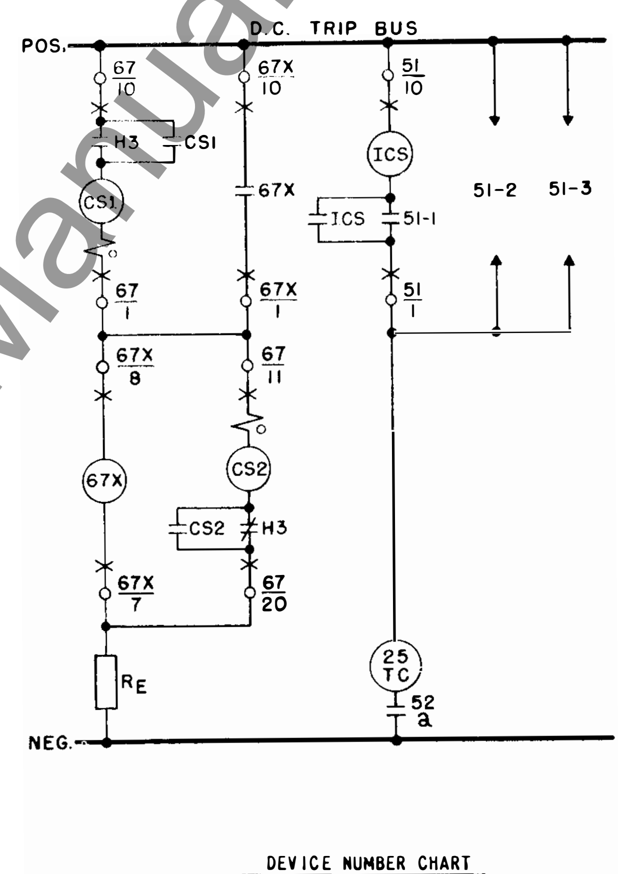


Fig. 10 – External Schematic for Phase Fault Parallel Line Protection – H-3 and Three Unit SC in FT32 Case (90° Connection).





NOTE:

NOMINAL VOLTAGE OF 67X RELAY SHOULD BE APPROXIMATELY 1/2 CONTROL VOLTAGE

R_E EQUAL TO 67X COIL RESISTANCE

DEVICE NUMBER CHART

51 - OVERCURRENT RELAY, TYPE CO
- ICS - INDICATING CONTACTOR SWITCH

67 - POLYPHASE DIRECTIONAL RELAY, TYPE H-3
- CS1, CS2 - AUXILIARY CONTACTOR SWITCH

67X - AUXILIARY RELAY, TYPE MG-6

52 - POWER CIRCUIT BREAKER
- a - BREAKER AUXILIARY CONTACT
- TC - BREAKER TRIP COIL

Fig. 11 – External Schematic for H-3, Torque Controlling Three CO Relays in FT11 Cases, with MG-6 in FT22 Case (90° Connection).

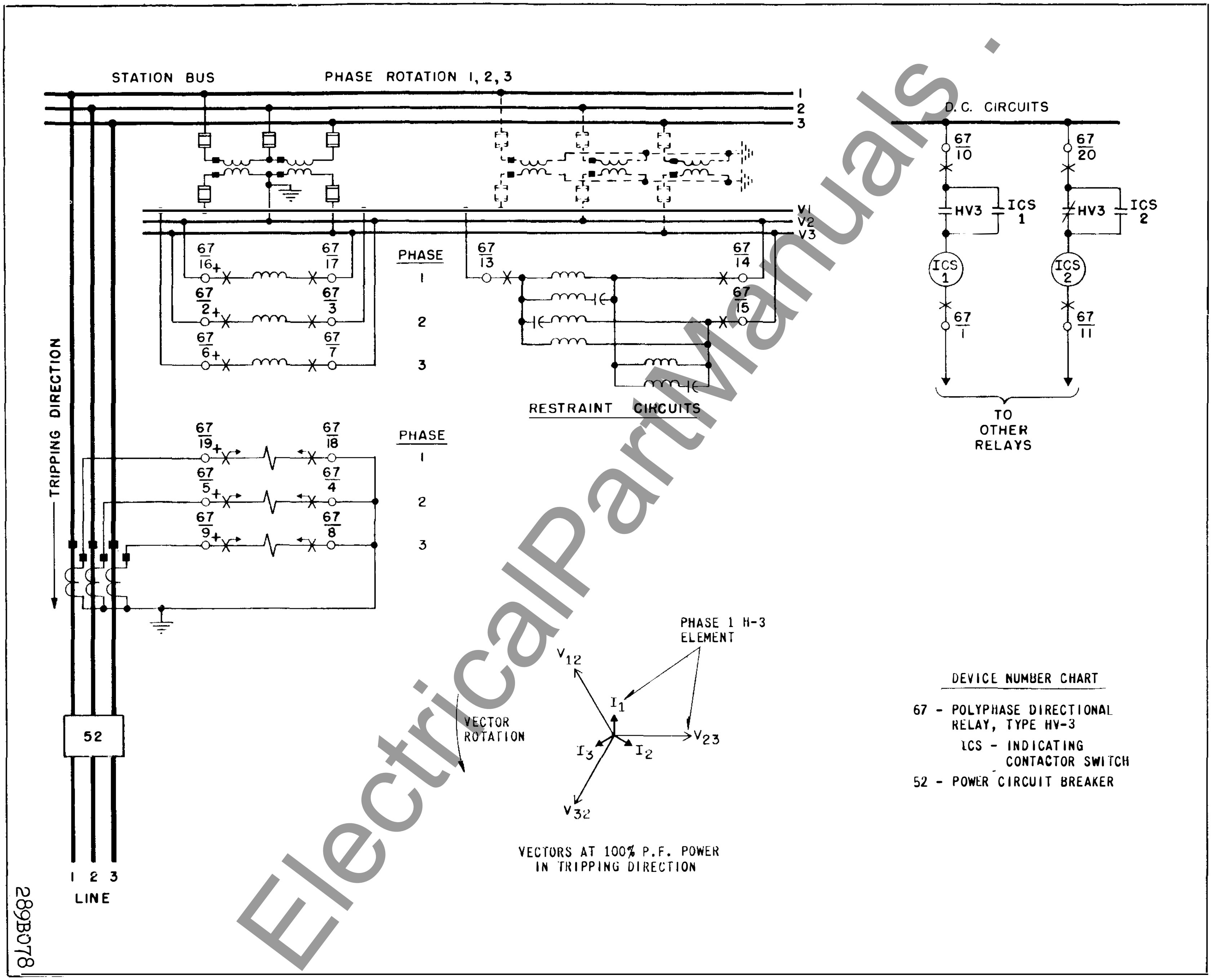


Fig. 12 – External Schematic for HV-3 Relay (90° Connection).

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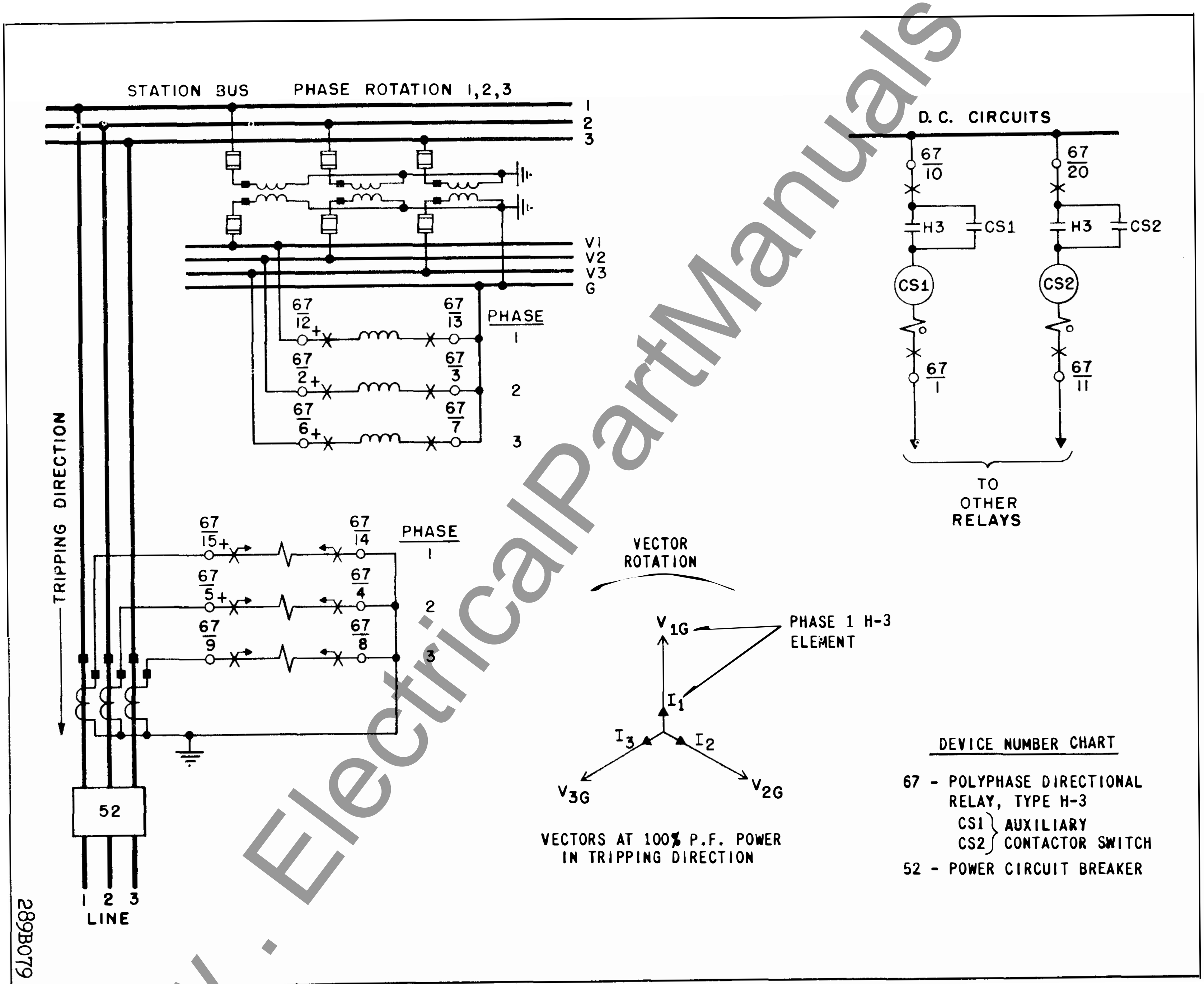

Fig. 13 – External Schematic for H-3 Relay (Watt Connection).

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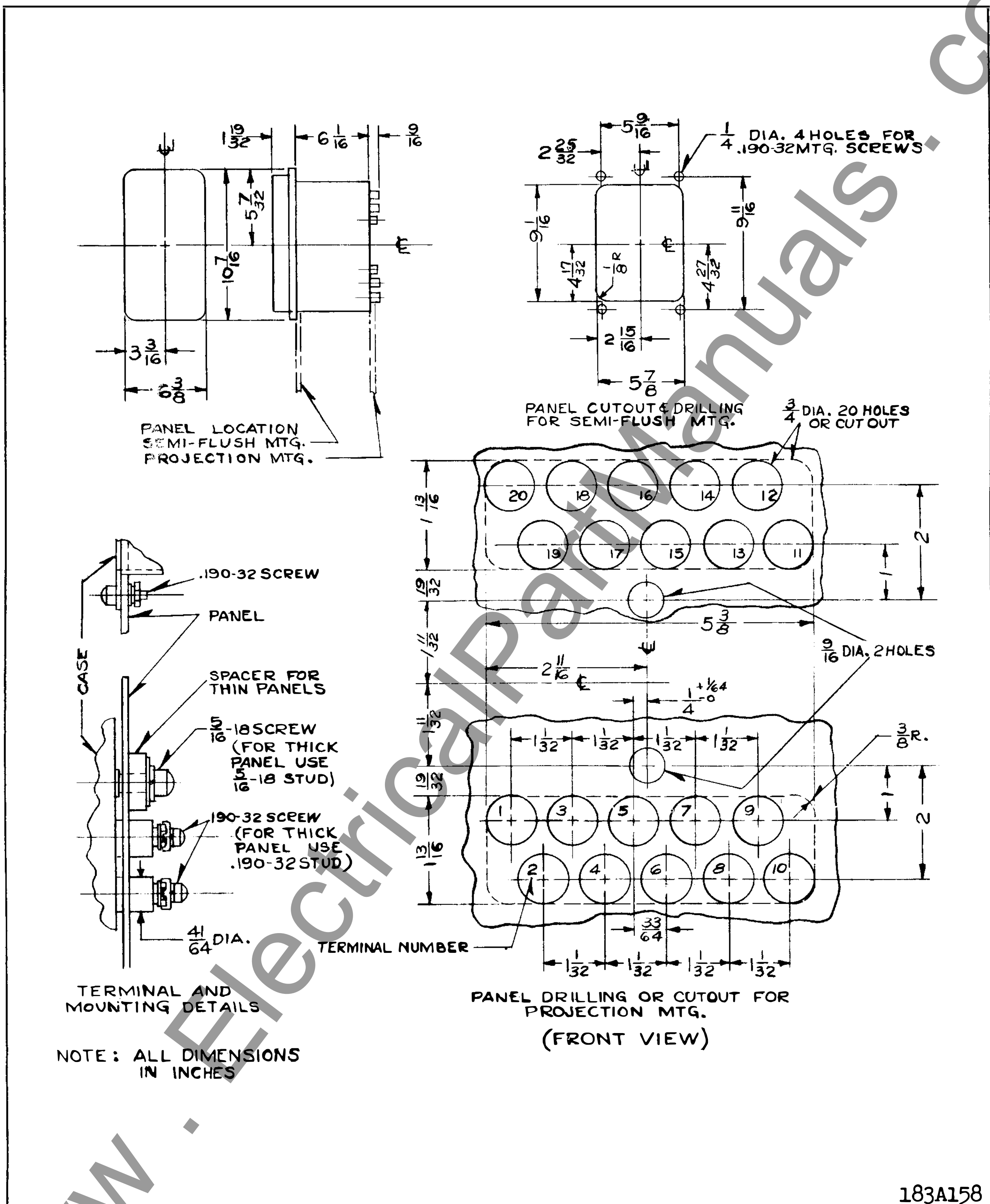

Fig. 14 – Outline and Drilling Plan for the H-3 Relay in the FT22 Case.

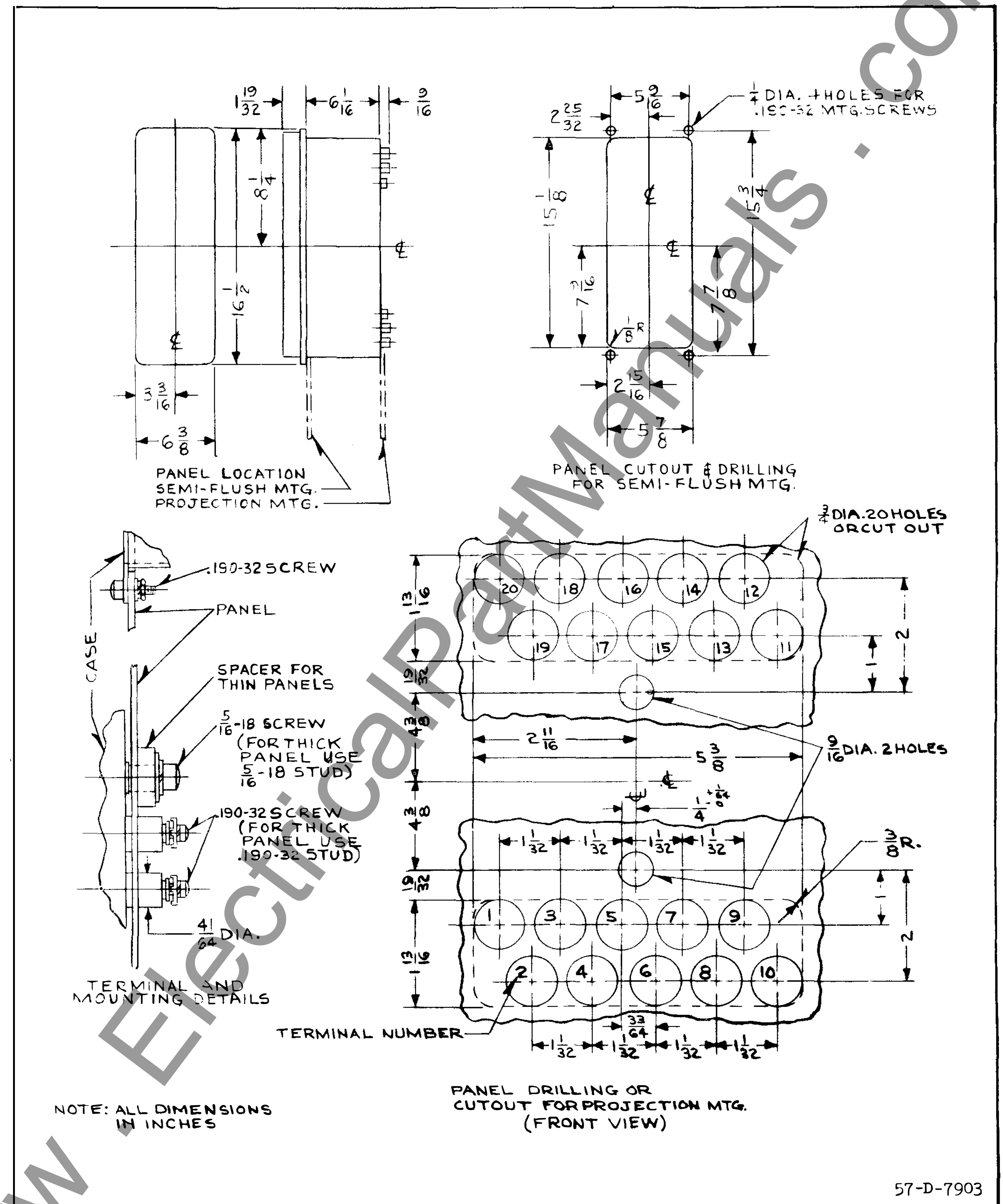

Fig. 15 — Outline and Drilling Plan for the HV-3 Relay in the FT32 Case.

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METER DIVISION • **NEWARK, N.J.**

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INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES H-3 AND HV-3 THREE PHASE DIRECTIONAL RELAYS

CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment. Make sure that all moving parts operate freely and inspect the contacts to see that they are clean and close properly. Operate the relay to check the settings and electrical connections.

APPLICATION

The types H-3 and HV-3 relays are polyphase directional relays which are used to obtain high speed directional discrimination during faults on power systems. The type HV-3 relay has a voltage restraint element which introduces a restraining torque on the relay proportional to the area of the voltage triangle. Thus, at normal voltage, sufficient torque is produced to prevent operation of the relay on normal load current flow. Any fault on the system reduces the area of the voltage triangle, and consequently the amount of restraint. At the same time the current in the relay increases and the relay operates if the fault is in the contact closing direction. Since the voltage triangle does not collapse as much on ground faults as it does on phase faults, it is desirable to remove voltage restraint on ground faults. This may easily be done by an instantaneous overcurrent ground relay (type SC) with its back contacts connected to open any one of the leads to the voltage restraint element.

The direction of power flow for both phase and ground faults can be detected with these relays. To obtain correct operation during ground faults, it is necessary that the minimum current in the faulted conductor be at least twice the maximum load current flow (with no voltage restraint on the relay) so that if the fault current and load currents are in opposition, the former will always predominate and give a net torque on the relay in the correct direction. Stated another way, the minimum line-to-ground current must be at least three times the maximum load current for correct ground fault protection. Low ground current occurs most frequently on impedance grounded systems. Where positive directional indication cannot be obtained under all system conditions, it is recommended that a separate ground directional relay be used.

Both the type H-3 and the type HV-3 relays can be furnished with either a watt characteristic or a 45° characteristic.

CONSTRUCTION AND OPERATION

The type H-3 relay consists of a polyphase directional element, two contactor switches, and two operation indicators. The type HV-3 relay consists of a polyphase directional element, a voltage restraint element, two contactor switches, and two operation indicators. These elements are as follows:

Polyphase Directional Element

This element consists of three electromagnets, and a vertical shaft with three movable loops, arranged as shown in figure 1. Each loop has its outer side located in an air gap within the electromagnet. Each electromagnet has a three-legged magnetic circuit wound with three coils. The coils on the two outer legs are the voltage windings. Voltage applied to these coils induces a large current in the loop by transformer action. Current flowing thru the current coil on the center leg of the electromagnet produces an air gap flux which interacts with the loop current flux in the outer side of the loop and causes

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*Denotes change from superseded issue.

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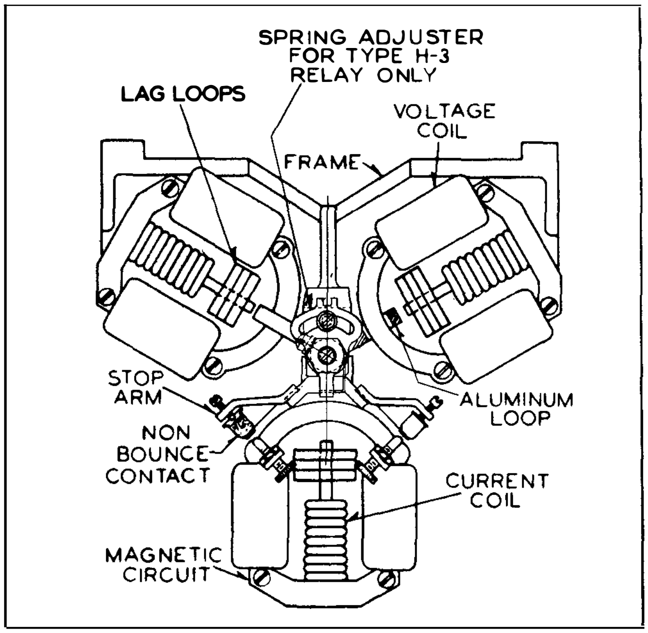

Fig. 1—Schematic Top View of the Three Phase Directional Element.

rotation of the shaft in the direction corresponding to the direction of flow of the alternating current power.

One loop and its associated electromagnet make up one phase of the three-phase relay. With the 45° characteristic relay a delta voltage and a star current are applied to each electromagnet, and proper phase angle characteristics are obtained as follows. The loop, which is considered as the secondary load of a transformer, has a much higher resistance than reactance, and the loop current lags the voltage applied to the electromagnet by an angle of 10 to 15 degrees. The air gap flux lags the applied current by about 55 to 60 degrees because of the lag loops around the centerpole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by 45 degrees.

The 90° Connection is used on the relay to give the required delta voltage and star current. With this connection one of the electromagnets will have "A phase" (star) current and "BC" (delta) voltage which for a system power factor of unity, lags the current by 90°. Hence, with this connection and the above (45°) relay characteristics, maximum torque is obtained when the system fault current is lagging its unity power factor position by 45°.

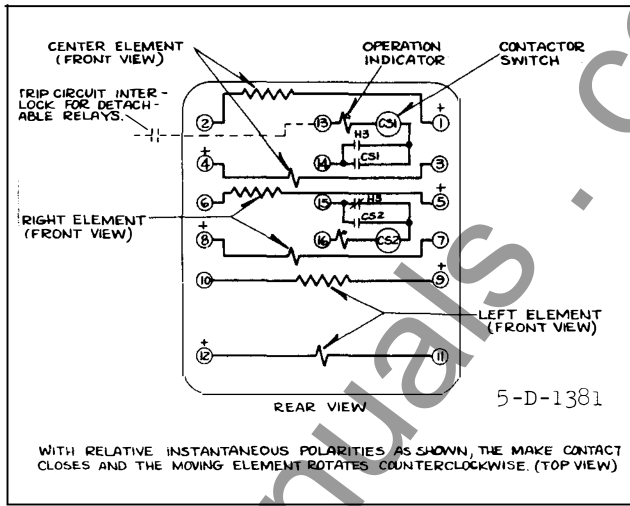

Fig. 2—Internal Schematic of the Type H-3 Relay in the Standard Case With Single Pole Double Throw Independent Contacts.

With the watt characteristic relay a star current and a star voltage are applied to each electromagnet. The air gap flux lags the applied current by about 10 to 15 degrees because of the lag loops around the center pole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by about 0 degrees.

The instantaneous torque in each element of the relay is produced by the instantaneous products of voltage (loop current) and current (air gap flux) in the electromagnet, which is a double frequency pulsating torque. The torques in the other two electromagnets are also pulsating, but they are displaced 120 degrees in time phase and when all three instantaneous values are added, the result is a uniform non-pulsating torque.

Two moving contacts are mounted at right angles to each other on the outer end of a leaf spring which in turn is mounted on Isolantite arm on the moving shaft. A stop bracket with a small cylinder partially filled with tungsten powder is mounted behind each moving contact. When the moving contact strikes against the rigid fixed contact screw, the spring is deflected for the necessary contact follow, after which the stop strikes the moving contact. Thus, the full torque of the relay is transmitted thru the contacts to maintain full contact pressure. The particles

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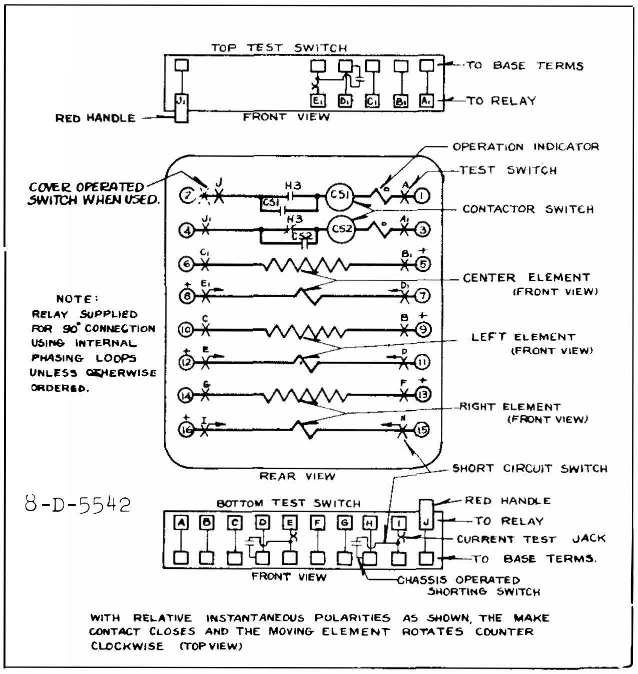

Fig. 3—Internal Schematic of the Type H-3 Relay in the Type FT Case With Single Pole Double Throw Independent Contacts.

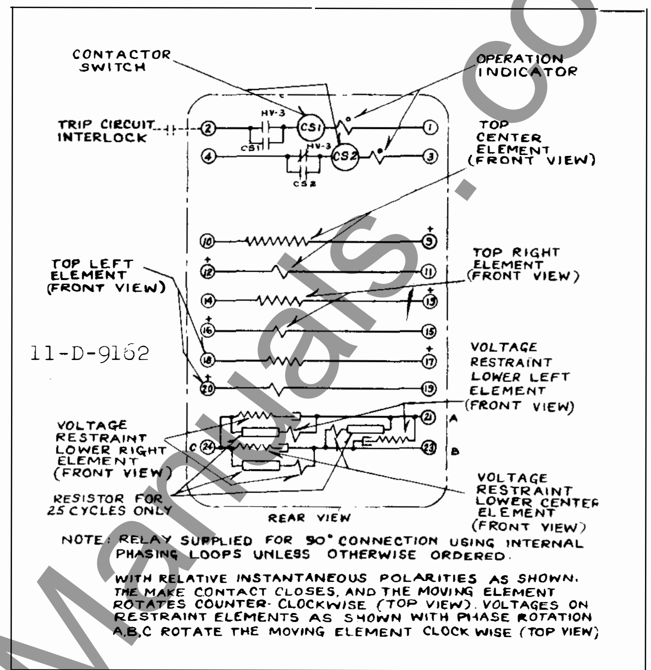

Fig. 4—Internal Schematic of the Type HV-3 Relay in the Standard Case With Single Pole Double Throw Independent Contacts.

of tungsten powder in the small cylinder slide over each other at the instant of impact and absorb the energy in the moving element. A flexible metal ribbon conducts current to the moving contacts.

The type H-3 relay is supplied with spring restraint which is adjusted to hold the contacts in the normal non-trip position when the relay is deenergized. This prevents an incorrect directional indication by the element under the condition of loss of load. However, the spring restraint may be adjusted to give a bias torque in either direction.

Voltage Restraint Element

This element is supplied only in the type HV-3 relays and consists of three electromagnets and loops similar to those used on the directional element. The restraining element is mounted below the directional element and the loops of the two elements are fastened to a common vertical shaft which operates the two contacts as described above. The outer coils of each electromagnet have one delta voltage (E_1) applied and the center coil has another delta voltage (E_2) applied. By means of the

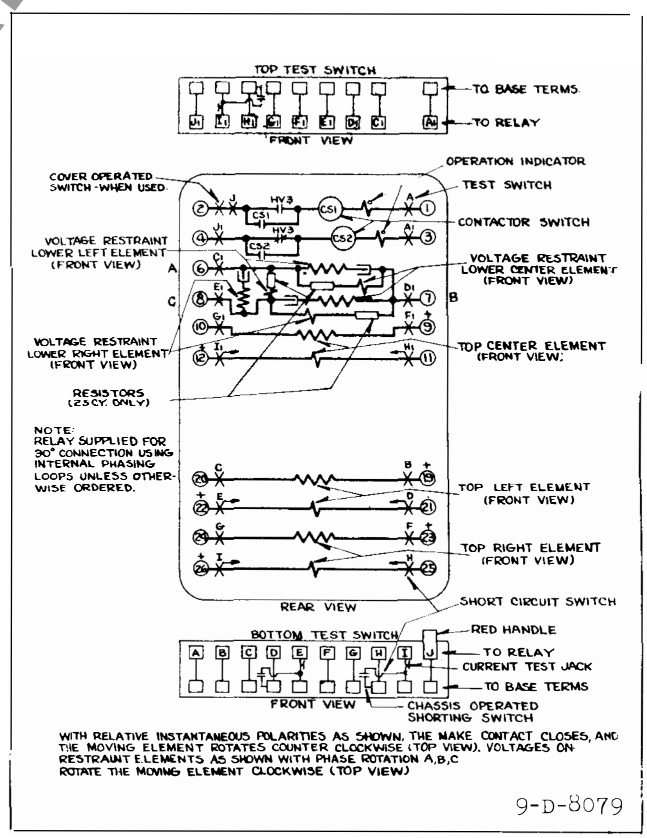

Fig. 5—Internal Schematic of the Type HV-3 Relay in the Type FT Case With Single Pole Double Throw Independent Contacts.

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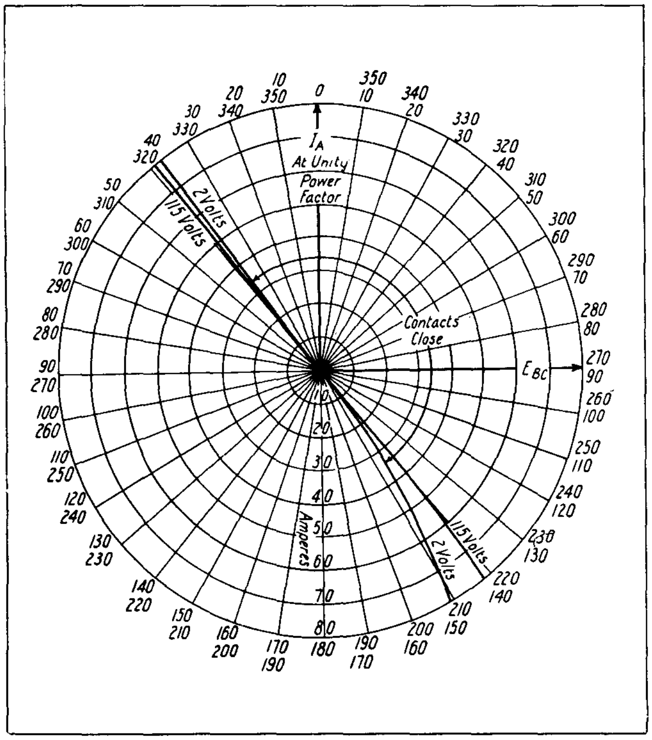

Fig. 6—Typical Phase Angle Curves for the 45° Characteristics 50 and 60 Cycle Types H-3 and HV-3 Relays With Balanced Three-Phase Power Applied and No Spring Restraint.

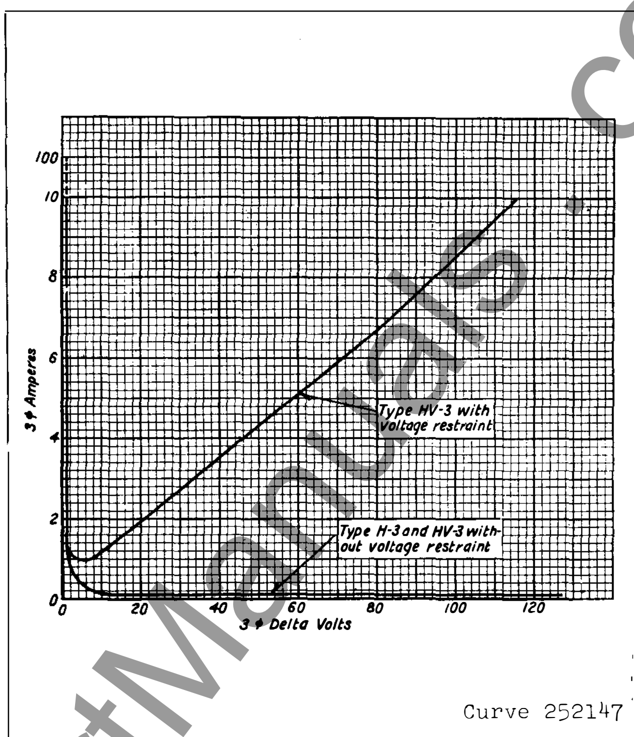

Fig. 7—Typical Sensitivity Curves for the 50 and 60 Cycle Types H-3 and HV-3 Relays at Maximum Torque.

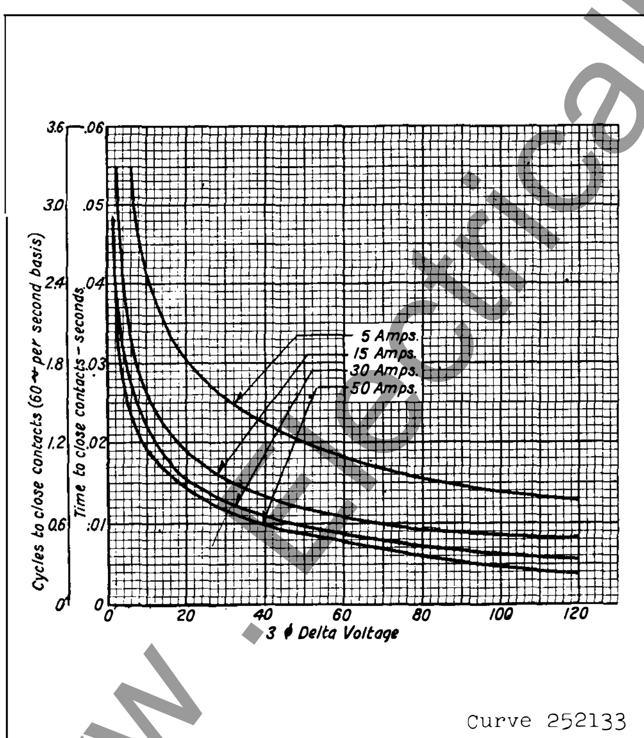

Fig. 8—Typical Time Curves for the 60 and 60 Cycle Type H-3 Relay for Three-Phase Faults at Maximum Torque.

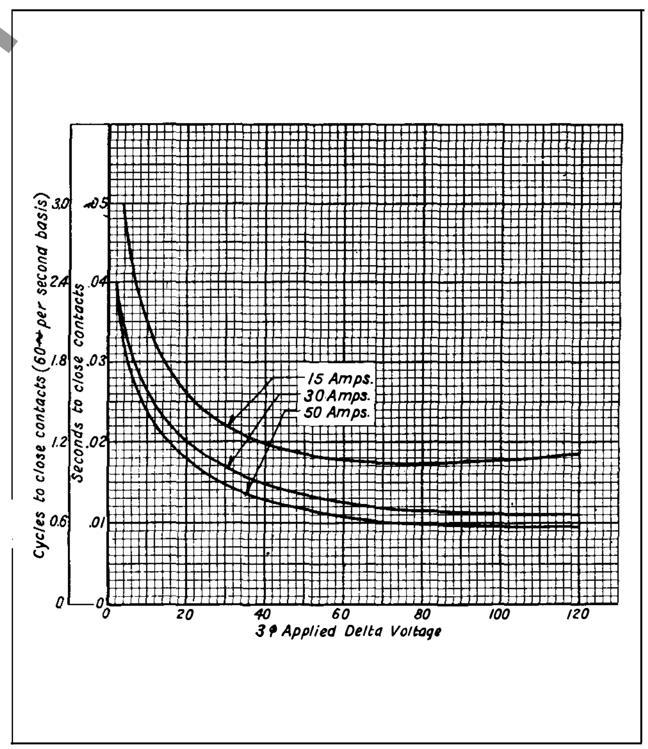

Fig. 9—Typical Time Curves for the 50 and 60 Cycle Type HV-3 Relay With Voltage Restraint For Three Phase Faults at Maximum Torque.

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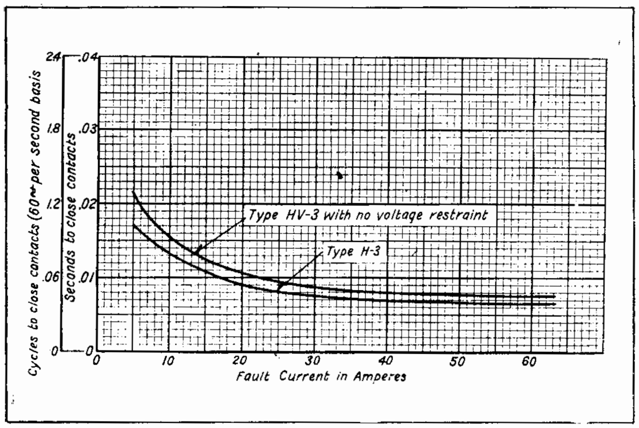

Fig. 10—Typical Time Curves for the 50 and 60 Cycle Types H-3 and HV-3 Relays Without Voltage Restraint for Phase to Phase Faults at Maximum Torque. Full Voltage Collapse on Faulted Phase. 86% Voltage on Unfaulted Phase.

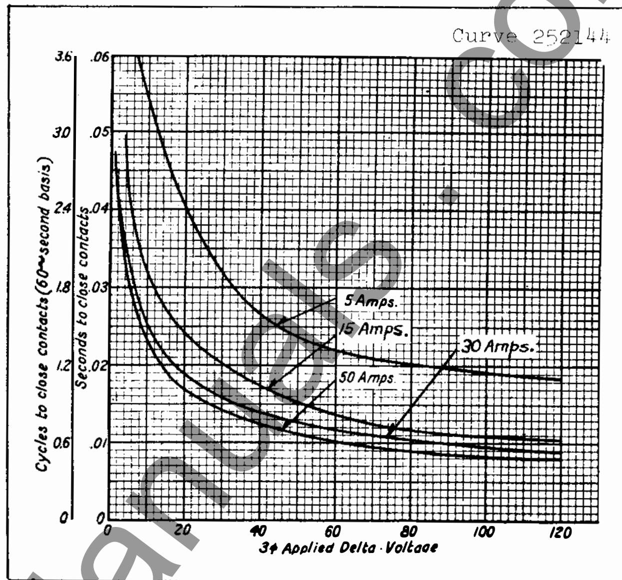

Fig. 11—Typical Time Curves for the 50 and 60 Cycle Type HV-3 Relay Without Voltage Restraint for Three Phase Faults at Maximum Torque.

capacitor untis in series with the outer two coils, the phase angle characteristics of the electromagnets are such that the torque of the element is proportional to:

$$E_1 E_2 \sin \theta$$

where θ is the angle between the two delta voltages and is normally 60°.

If any one of the three delta voltages completely collapses during a fault, there is no torque on the electromagnet, since the collapse of the third voltage makes the sine of the angle between the voltages zero. If all three voltages decrease uniformly, the torque varies as the square of their magnitude. Each electromagnet is connected to a different combination of delta voltages so that a uniform restraint torque and balanced burdens are obtained.

Restraint can be removed by opening any one supply lead to the restraint element. This applies single phase to all three electromagnets and the sine of the angle becomes zero. At normal voltages 10 amperes is required in each element at maximum torque to overcome the restraint torque.

Contactor Switches

The d-c contactor switch in the relay is a small solenoid type switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward, the disc bridges three silver stationary contacts. The coil is in series with the main contacts of the relay and with the trip coil of the breaker. When the relay contacts close, the coil becomes energized and closes the switch contacts. This shunts the main relay contacts, thereby relieving them of the duty of carrying tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring-restrained armature releases the white target which falls by gravity to indicate completion of the trip circuit. The indicator is reset from outside of the case by a push rod in the cover or cover stud.

CHARACTERISTICS

The types H-3 and HV-3 relays are normally provided with independent make and break con-

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tacts. Two auxiliary contactor switches--one in each contact circuit--provide seal-in circuits for the main relay contact. The main contacts will close 30 amperes at 250 volts d-c and the auxiliary contactors will safely carry this current until the breaker is tripped and the auxiliary "a" switch opens. The contactor switch has a minimum pick-up of one ampere d-c and a coil resistance of one ohm.

Typical 50 and 60 cycle phase angle characteristics of the 45° characteristic relay are shown in figure 6. Maximum torque, in the contact closing direction, occurs when the line current lags the line-to-neutral voltage by approximately 45 degrees, when using the 90° connection

Typical 50 and 60 cycle sensitivity curves at maximum torque are shown in figure 7. The sensitivity of the type HV-3 relay without voltage restraint is the same as the type H-3 relay. The 60 cycle three phase minimum pick-up without spring restraint of the type H-3 relay is 0.08 amperes at 115 volts, 0.15 ampere at 10 volts, and 5.0 amperes at 1 volt. The single phase minimum pick-up currents are approximately three times those for three phase. It will be noted from the curves that the sensitivity of the type HV-3 relay with voltage restraint is decreased only at voltages above 2 volts. The curves also show that 10 amperes 60 cycles are required at 115 volts to overcome voltage restraint.

Typical time curves are shown in figures 8 to 11. All curves are for a contact spacing of .035 inch and at maximum torque for 60 and 50 cycle relays and .070 inch for 25 cycle relays.

* INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the two mounting studs for the standard cases and the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

The external connections for typical applications of the type H-3 and HV-3 relays are shown in figures 12 thru 19.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be periodically cleaned with a fine file. Style 1002110 file is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Adjust the lower bearing so that both the top and bottom of the loops are equi-distant from their respective magnetic circuits. Energize the potential circuits of the relay until the loops reach operating temperature. About ten minutes at normal voltage is necessary to reach this condition. When the operating temperature is reached, adjust the upper bearing for 1/64 inch clearance.

The loops of each element must be in line with the center of the middle leg of the magnetic circuit. If necessary, this adjustment can be obtained by loosening the electromagnet mounting screws and moving the whole electromagnet in the desired direction. All three elements must have the same relative position of loop and magnetic circuit.

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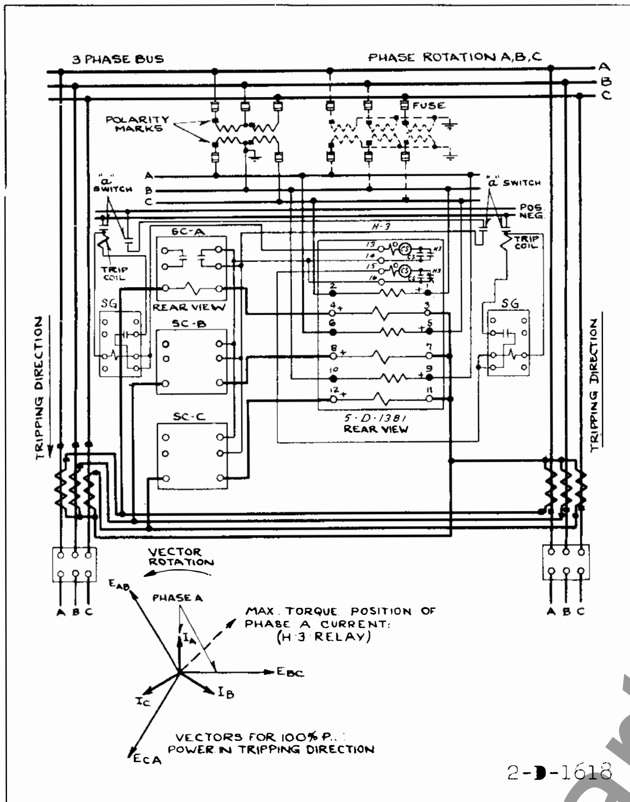

Fig. 12—External Connections for Directional Balanced Overcurrent Phase Protection of Two Parallel Lines Using One Type H-3 (90° Connection) and Three Type SC Relays All in the Standard Cases.

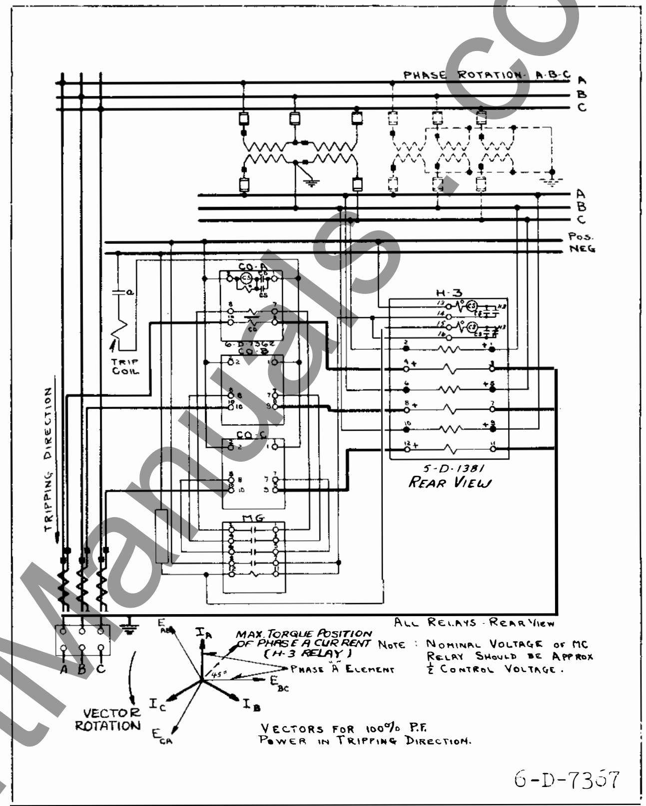

Fig. 13—External Connections for Directional Overcurrent Phase Protection of a Three Phase Line Using Three Type CO Torque Controlled Relays Directionally Controlled By One Type H-3 (90° Connection) and One Type MG Relay All in the Standard Cases.

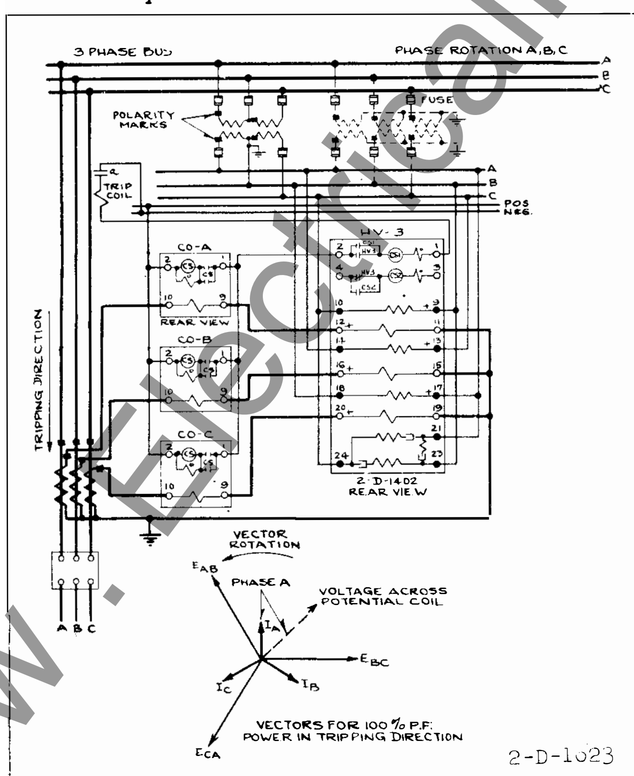

Fig. 14—External Connections for Directional Phase Protection of a Three Phase Line Using the Type HV-3 (90° Connection) Relay and Three Type CO Relays All in the Standard Cases.

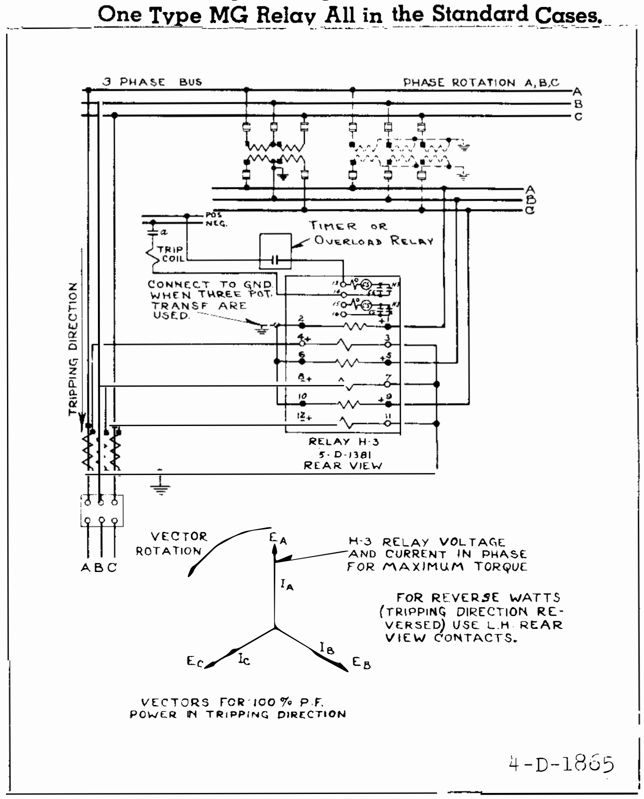

Fig. 15—External Connections for Reverse Power, or Directional Phase Protection Using the Type H-3 (Watt Connection) Relay in the Standard Case.

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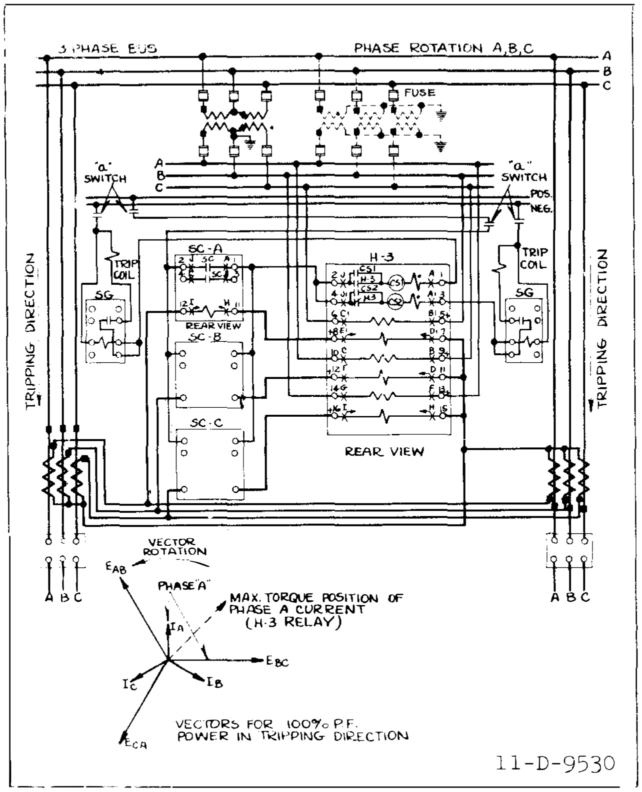

Fig. 16—External Connections for Directional Balanced Overcurrent Phase Protection of Two Parallel Lines Using One Type H-3 (90° Connection) and Three Type SC Relays All in the Type FT Cases.

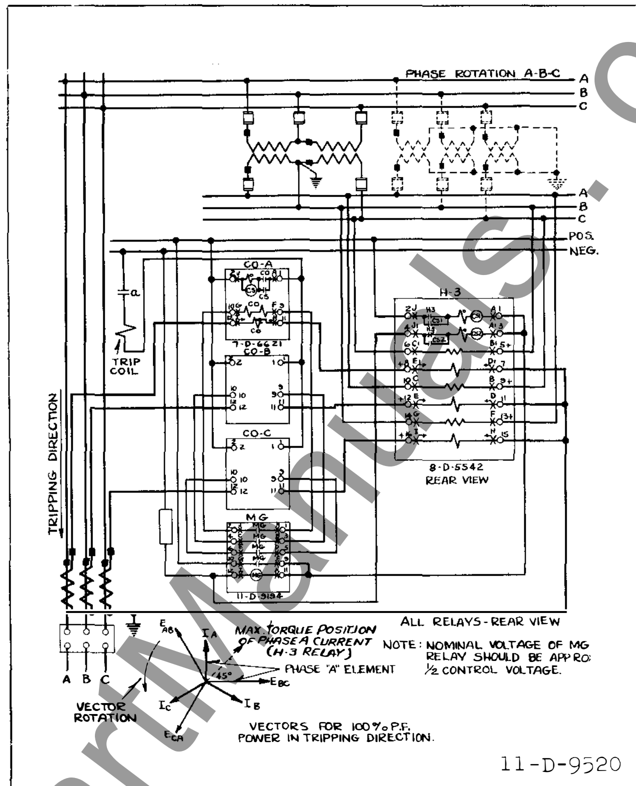

Fig. 17—External Connections for Directional Overcurrent Phase Protection of a Three Phase Line Using Three Type CO Torque Controlled Relays Directionally Controlled By One Type H-3 (90° Connection) and One Type MG Relay All in the Type FT Cases.

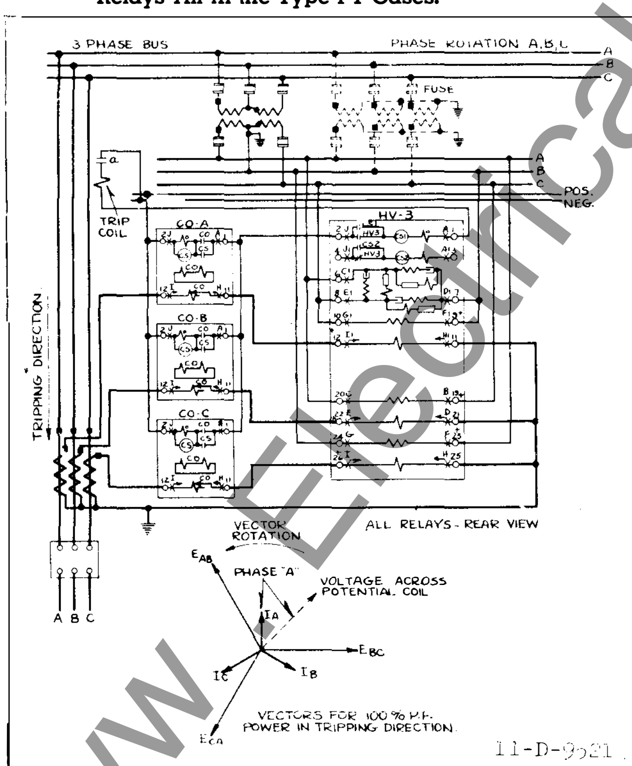

Fig. 18—External Connections for Directional Phase Protection of a Three Phase Line Using the Type HV-3 (90° Connection) Relay and Three Type CO Relays All in the Type FT Case.

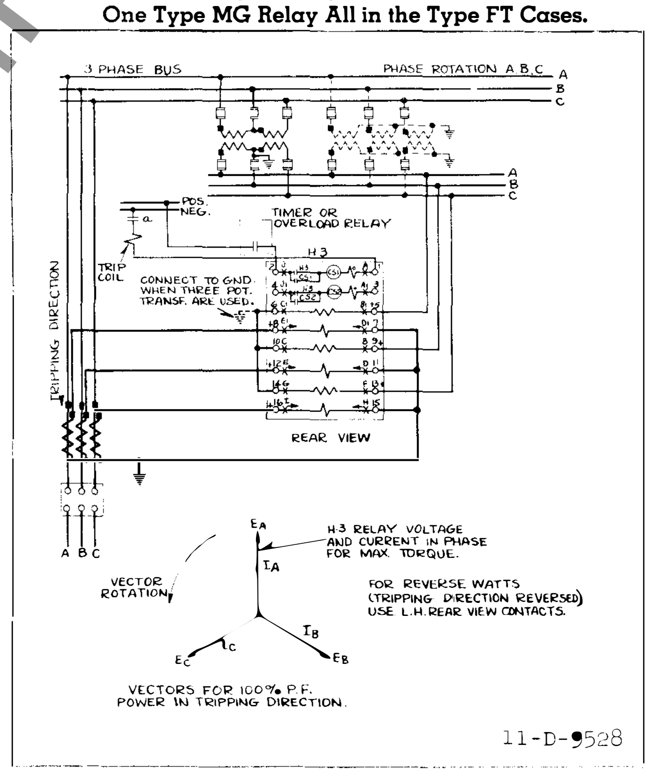

Fig. 19—External Connections for Reverse Power or Directional Phase Protection Using the Type H-3 (Watt Connection) Relay in the Type FT Case.

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Type H-3 Relay

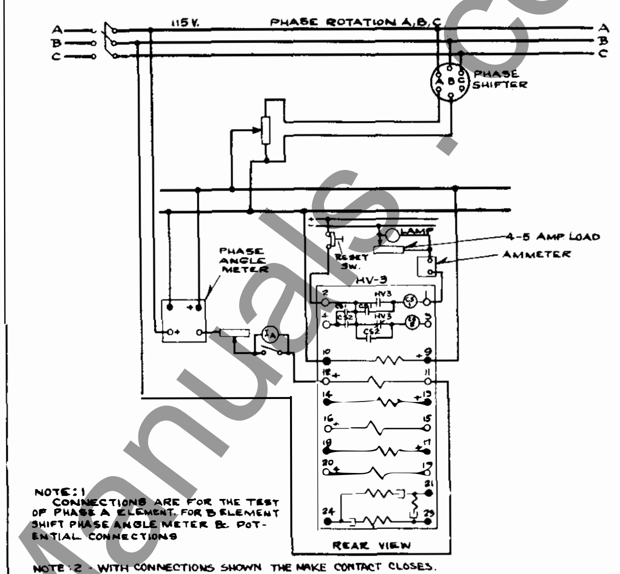
The polarity of the relay is checked as follows: Refer to figure 2 or 3 and apply 115 volts and 5 amperes (in phase) to the corresponding voltage and current coils in turn, with the terminals marked with polarity marks connected together. Looking at the top of the relay, the moving element should rotate in a counter-clockwise direction.

Adjust the back-up strip located in front of each moving contact by bending so that it just touches the contact spring when the contacts are open. Adjust the small cylinder behind the moving contact to obtain .009 inch contact follow. This is done by advancing the cylinder until it just touches the rear of the moving contact spring, and then backing off 1/2 turn.

45° Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase current of 50 amperes with polarities as shown on internal schematic diagram to the current coils which should be connected in series. Each potential coil should be short-circuited. When energized the relay moving element will center itself due to the combined torques produced by the 50 amperes of current and the spring restraint. Readjust the spring adjuster until the centering position of the moving element is exactly the same for the condition of zero current or with 50 amperes in the current coils. Under this condition the torque produced by the spring at the centering position is zero and does not tend to "offset" or shift the centering position due to the current. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

There are two adjustable stop screws located on the frame casting. These stops are used when the relay is supplied with two circuit closing contacts and perform the same function as the stops on the moving contact assembly.



TERMINAL ARRANGEMENTS FOR DIFFEREN TYPE H-3 & HV-3 RELAYS

CIRCUIT	HV-3 IN DIE-CAST BASE DWG. 4-D-1145	H-3 IN DIE-CAST BASE DWG. 4-D-1100	H-3 IN DIE-CAST BASE DWG. 5-D-1381	HV-3 IN FLEXI-TEST BASE 9-D-8079	H-3 IN FLEXI-TEST BASE 8-D-5542	
TRIP (MAKE)	*1 - *2	*13 - *14	*13 - *14	*1 - *2	*1 - *2	
PHASE A POTENTIAL CURRENT	9 - 10 11 - 12	1 - 2 3 - 4	1 - 2 3 - 4	9 - 10 11 - 12	5 - 6 7 - 8	
PHASE B POTENTIAL CURRENT	13 - 14 15 - 16	5 - 6 7 - 8	5 - 6 7 - 8	23 - 24 25 - 26	13 - 14 15 - 16	
PHASE C POTENTIAL CURRENT	17 - 18 19 - 20	9 - 10 11 - 12	9 - 10 11 - 12	19 - 20 21 - 22	9 - 10 11 - 12	
RESTRAINT PHASE A PHASE B PHASE C	21 23 24	——	——	6 7 8	——	

4-D-1294

Fig. 20—Diagram of Test Connections for the Types H-3 and HV-3 Relays.

Watt Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase potential of 67 volts with polarities as shown on internal schematic diagram to the potential coils which should be connected in parallel. Each current coil should be open-circuited. When the potential circuits are deenergized the moving element will tend to be centered by the spring. When the potential circuits are energized the moving element may move either to the right or to the left. If under this condition the moving element moves the contacts to the right, the spring should be readjusted to move the deenergized spring centering position of the moving element to the left. If under this condition the moving element moves the contacts to the left, the spring should be readjusted to move the de-

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energized spring centering position of the moving element to the right. Continue to shift the centering position of the spring until a small movement of the spring adjuster will cause the moving element to move in one direction when the potential is applied and a small movement in the other direction will cause the moving element to move in the opposite direction. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

Type HV-3 Relay

The tests outlined for the type H-3 45° characteristic relay also apply to the HV-3 relay when the voltage restraint circuit is not connected. To make a complete check on the type HV-3 relay with all circuits connected, involves three-phase test source, phase shifter, potentiometers, and non-inductive resistors for controlling the voltage and current to the relay respectively. This test will permit checking of all the characteristics of the relay at the proper phase angle. This test procedure however is usually too complicated for routine filed testing. The complete test may be simplified for field testing by the following modifications. Apply three phase restraining voltage to the restraining element and single phase to all three phases of the directional element. For the latter element the potential coils are all connected in parallel and the current coils are connected in series. With a non-inductive load, the relay will be operating about 45° away from its maximum torque position and consequently current values to trip a given voltage will be increased by about 30%. Since the combination of three-phase restraining torque and single-phase operating torques on all three elements, produces some unbalanced torque in the moving element, it is recommended that tests be made at a reduced voltage (65 volts or less). With 65 volts applied to voltage restraint elements, about 8 amperes is required at unity power factor to make the relay operate.

To check the circuits thru the voltage restraint element, the relay should be energized at normal voltage for about 10 minutes. The potential circuit of the directional element should then be opened. Then open the phase A potential to the voltage restraint element and observe the torque produced on the moving element, if any. Replace A lead and remove the B lead and again observe the torque. Repeat for the C lead and in all cases there should be no torque or a very slight torque present. Any defects in the coils or capacitors of the voltage restraint circuits will be made apparent by the presence of excessive torque during this test.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core when the switch is picked up. This can be most conveniently done by turning the relay up-side-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 1.0 ohm.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced by new springs, they

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should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 0.16 ohm.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMENTS

The burdens and constants of the relays are as follows per phase:

TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 115 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.045	3040	0.045	3040	1760
Reactance (ohms)	0.045	1320	0.045	1320	2040
Impedance (ohms)	0.064	3310	0.064	3310	2700
Watts	1.13	3.67	1.13	3.67	3.2
Vars	1.13	1.59	1.13	1.59	3.7
Voltamperes	1.6	4.0	1.6	4.0	4.9
Power Factor	45° lag	23.5° lag	45° lag	23.5° lag	49° lag
Continuous Rating (Amperes or Volts)	5	115	5	115	115
One Second Current (Amps.)	230	...	230	...	...

VALUES AT 115 VOLTS, 5 AMPERES, 50 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.0488	2560	0.0488	2560	2720
Reactance (ohms)	0.0349	975	0.0349	975	1570
Impedance (ohms)	0.060	2740	0.060	2740	3140
Watts	1.22	4.5	1.22	4.5	3.17
Vars	.87	1.71	.87	1.71	1.84
Voltamperes	1.5	4.82	1.5	4.82	3.66
Power Factor	33.5° lag	20.8° lag	33.5° lag	20.8° lag	30.1° lag
Continuous Rating (Amperes or Volts)	5	115	5	115	115
One Second Current (Amps.)	230	...	230	...	...

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TYPE H-3, WATT CHARACTERISTIC RELAY

VALUES AT 115 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3	
	Current Circuit	Voltage Circuit
Resistance (ohms)	.028	2740
Reactance (ohms)	.0192	1440
Impedance (ohms)	.034	3100
Watts	.70	3.76
Vars	.48	1.97
Voltamperes	.85	4.25
Power Factor	34.5° lag	27.8° lag
Continuous Rating (Amperes or Volts)	5	115
One Second Current (Amps.)	230	...

TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 115 VOLTS, 5 AMPERES, 25 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	.0380	3830	.0380	3830	3980
Reactance (ohms)	.0192	3200	.0192	3200	990
Impedance (ohms)	.0420	5000	.0420	5000	4100
Watts	.94	2.03	.94	2.03	3.12
Voltamperes	1.05	2.65	1.05	2.65	3.22
Power Factor	26° lag	40° lag	26° lag	40° lag	14° lag
Continuous Rating	5	115	5	115	115
One Second Rating	230	...	230	...	...

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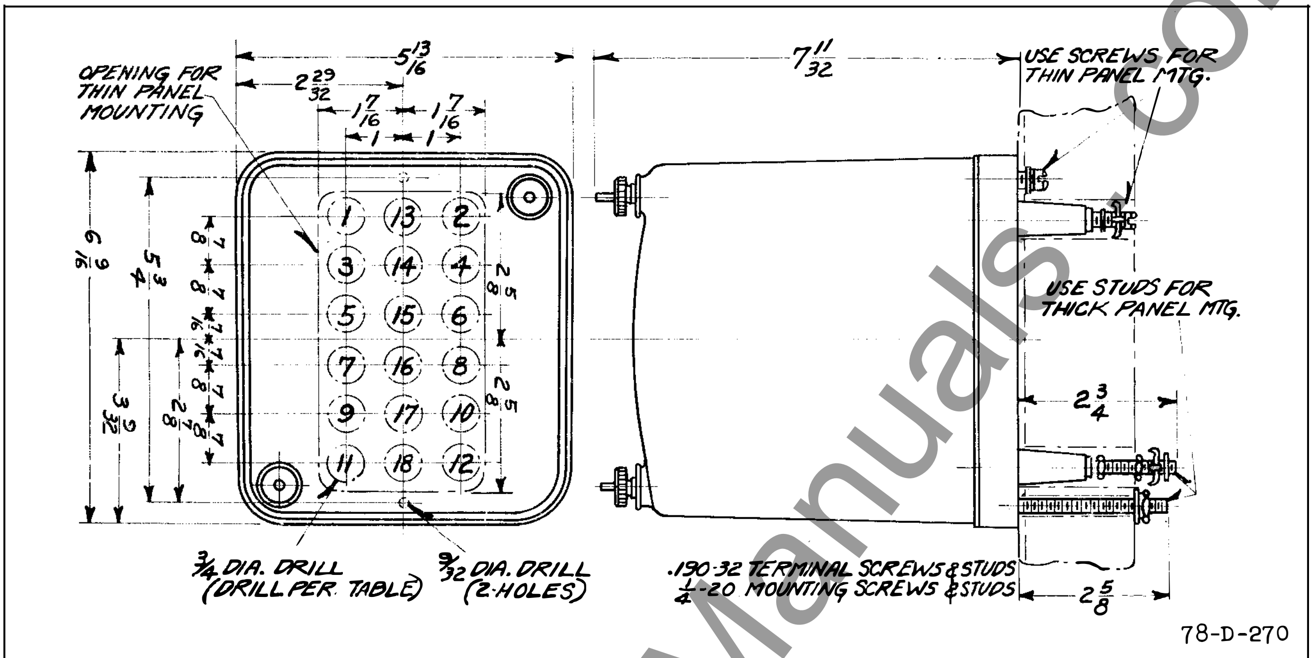

Fig. 21—Outline and Drilling Plan for the Projection Type Standard Case for the Type H-3 Relay. See the Internal Schematics For The Terminals Supplied. For Reference Only.

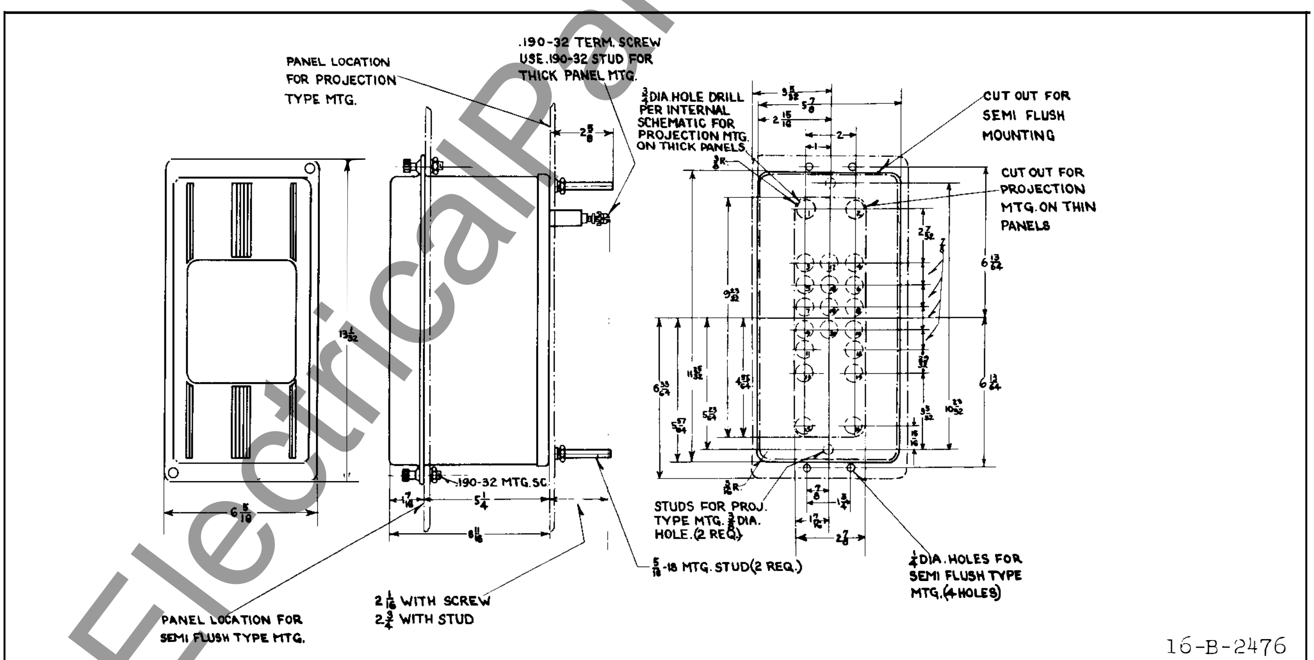

Fig. 22—Outline and Drilling Plan for the S20 Semi-Flush or Projection Type FT Flexitest Case For The Type H-3 Relay. See the Internal Schematics For The Terminals Supplied. For Reference Only.

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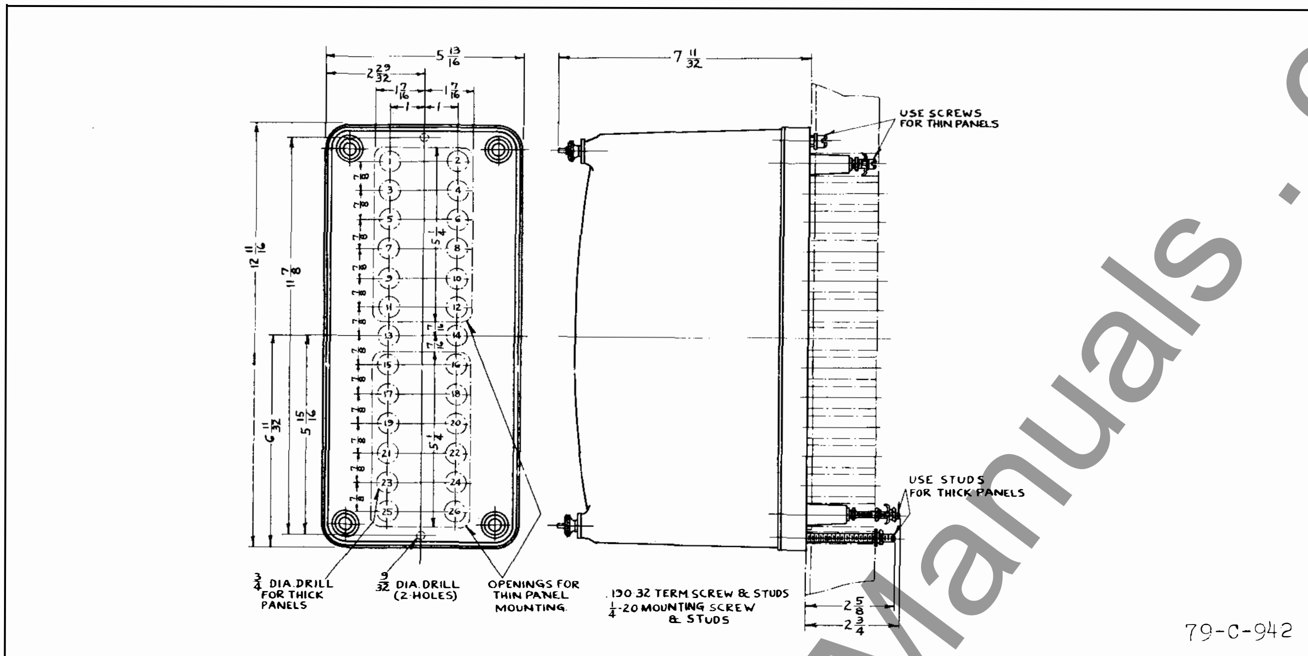

Fig. 23—Outline and Drilling Plan For the Projection Type Standard Case For the Type HV-3 Relay. See The Internal Schematics for the Terminals Supplied. For Reference Only.

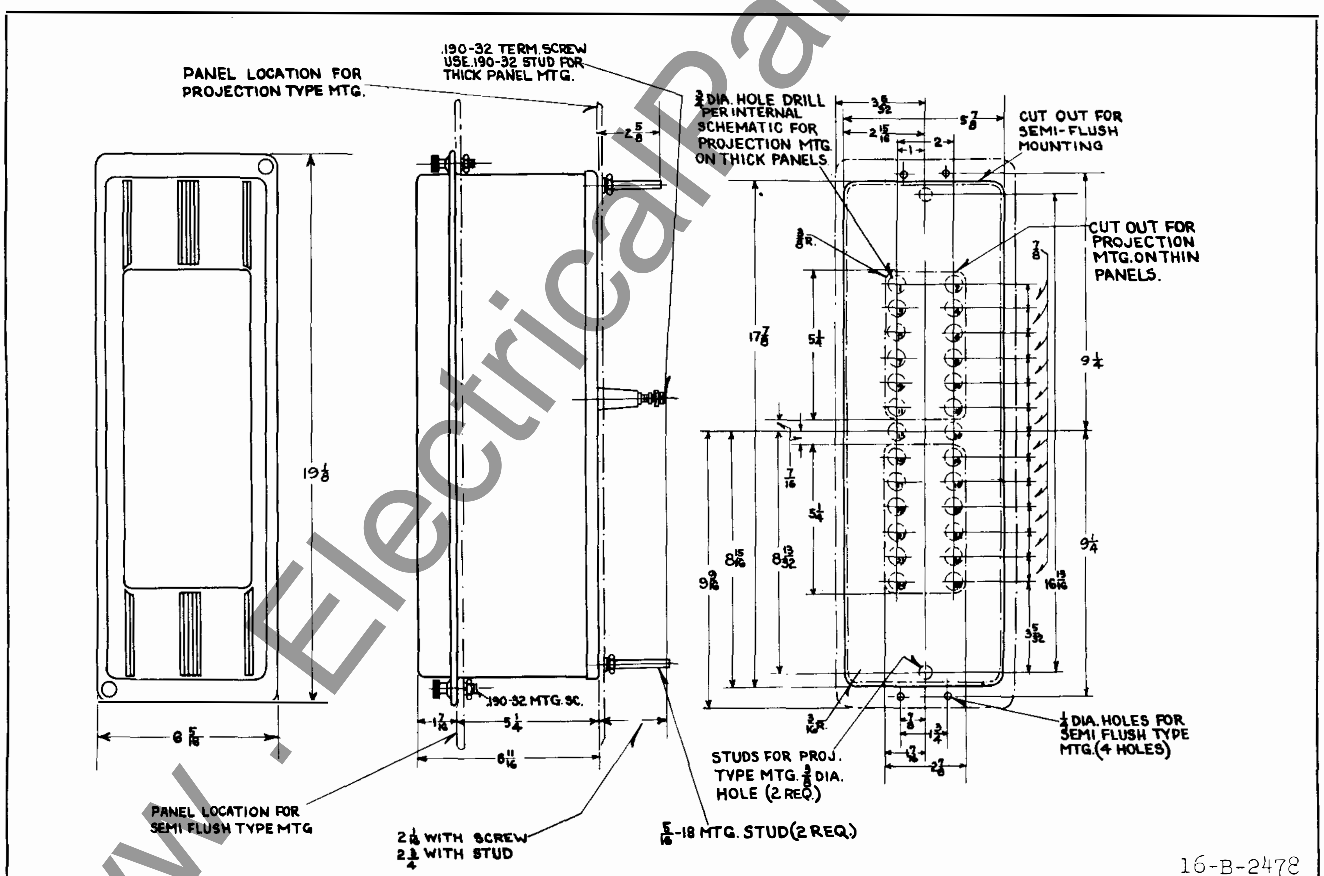

Fig. 24—Outline and Drilling Plan for the M20 Semi-flush or Projection Type FT Flexitest Case for the Type HV-3 Relay. See the Internal Schematics For Terminals Supplied. For Reference Only.

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INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES H-3 AND HV-3 THREE PHASE DIRECTIONAL RELAYS

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CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment. Make sure that all moving parts operate freely and inspect the contacts to see that they are clean and close properly. Operate the relay to check the settings and electrical connections.

APPLICATION

The types H-3 and HV-3 relays are polyphase direction relays which are used to obtain high speed directional discrimination during faults on power systems. The type HV-3 relay has a voltage restraint element which introduces a restraining torque on the relay proportional to the area of the voltage triangle. Thus, at normal voltage, sufficient torque is produced to prevent operation of the relay on normal load current flow. Any fault on the system reduces the area of the voltage triangle, and consequently the amount of restraint. At the same time the current in the relay increases and the relay operates if the fault is in the contact closing direction. Since the voltage triangle does not collapse as much on ground faults as it does on phase faults, it is desirable to remove voltage restraint on ground faults. This may easily be done by an instantaneous overcurrent ground relay (type SC) with its back contacts connected to open any one of the leads to the voltage restraint element.

The direction of power flow for both phase and ground faults can be detected with these relays. To obtain correct operation during ground faults, it is necessary that the minimum current in the faulted conductor be at least twice the maximum load current flow (with no voltage restraint on the relay) so that if the fault current and load currents are in opposition, the former will always predominate and give a net torque on the relay in the correct direction. Stated another way, the minimum line-to-ground current must be at least three times the maximum load current for correct ground fault protection. Low ground current occurs most frequently on impedance grounded systems. Where positive directional indication cannot be obtained under all system conditions, it is recommended that a separate ground directional relay be used.

Both the type H-3 and the type HV-3 relays can be furnished with either a watt characteristic or a 45° characteristic.

CONSTRUCTION AND OPERATION

The type H-3 relay consists of a polyphase directional unit, two contactor switches, and two operation indicators. The type HV-3 relay consists of a polyphase directional unit, a voltage restraint unit, and two indicating contactor switches.

Polyphase Directional Unit

This unit consists of three electromagnets, and a vertical shaft with three movable loops, arranged as shown in figure 1. Each loop has its outer side located in an air gap within the electromagnet. Each electromagnet has a three-legged magnetic circuit wound with three coils. The coils on the two outer legs are the voltage windings. Voltage applied to these coils induces a large current in the loop by transformer action. Current flowing thru the current coil on the center leg of the electromagnet produces an air gap flux which interacts with the loop current flux in the outer side of the loop and causes rotation of the shaft in the direction corresponding to the direction of flow of the alternating current power.

One loop and its associated electromagnet make up one phase of the three-phase relay. With the 45° characteristic relay a delta voltage and a star current are applied to each electromagnet, and proper phase angle characteristics are obtained as follows. The loop, which is considered as the secondary load of a transformer, has a much higher resistance than reactance, and the loop current lags the voltage applied to the electromagnet by an angle of 10 to 15 degrees. The air gap flux lags the applied current by about 55 to 60 degrees because of the lag loops around the centerpole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by 45 degrees.

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*Denotes change from superseded issue.

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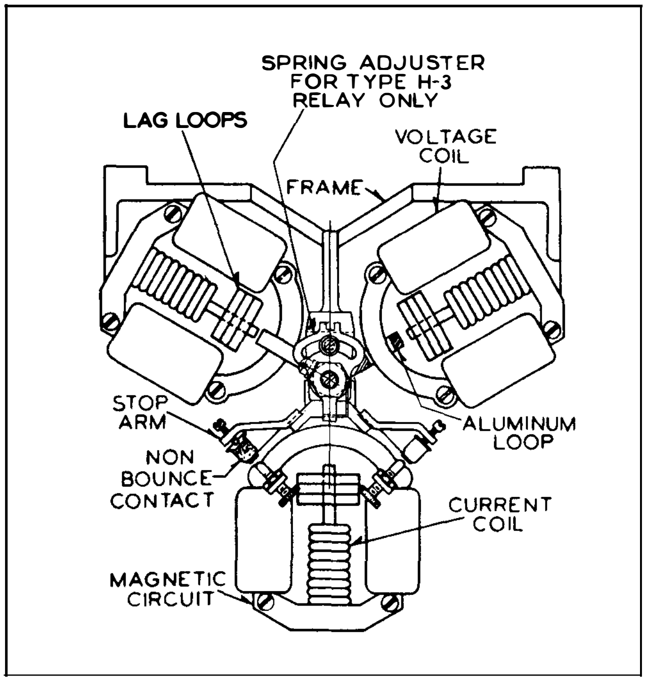

Fig. 1 — Schematic — Top View of Polyphase Directional Unit.

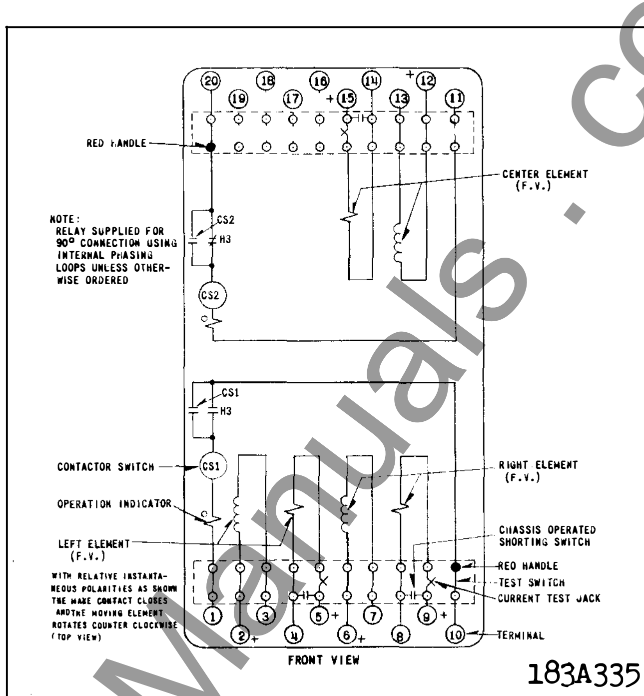

Fig. 2 — Internal Schematic of the Type H-3 Relay in the FT22 Case.

The 90° Connection is used on the relay to give the required delta voltage and star current. With this connection one of the electromagnets will have "A phase" (star) current and "BC" (delta) voltage which for a system power factor of unity, lags the current by 90°. Hence, with this connection and the above (45°) relay characteristics, maximum torque is obtained when the system fault current is lagging its unity power factor position by 45°.

With the watt characteristic relay a star current and a star voltage are applied to each electromagnet. The air gap flux lags the applied current by about 10 to 15 degrees because of the lag loops around the center pole of the electromagnet. Thus maximum torque occurs when the relay current leads the relay voltage by about 0 degrees.

The instantaneous torque in each element of the relay is produced by the instantaneous products of voltage (loop current) and current (air gap flux) in the electromagnet, which is a double frequency pulsating torque. The torques in the other two electromagnets are also pulsating, but they are displaced 120 degrees in time phase and when all three instantaneous values are added, the result is a uniform non-pulsating torque.

Two moving contacts are mounted at right angles to each other on the outer end of a leaf spring which in turn is mounted on Isolantite arm on the moving shaft. A stop bracket with a small cylinder partially

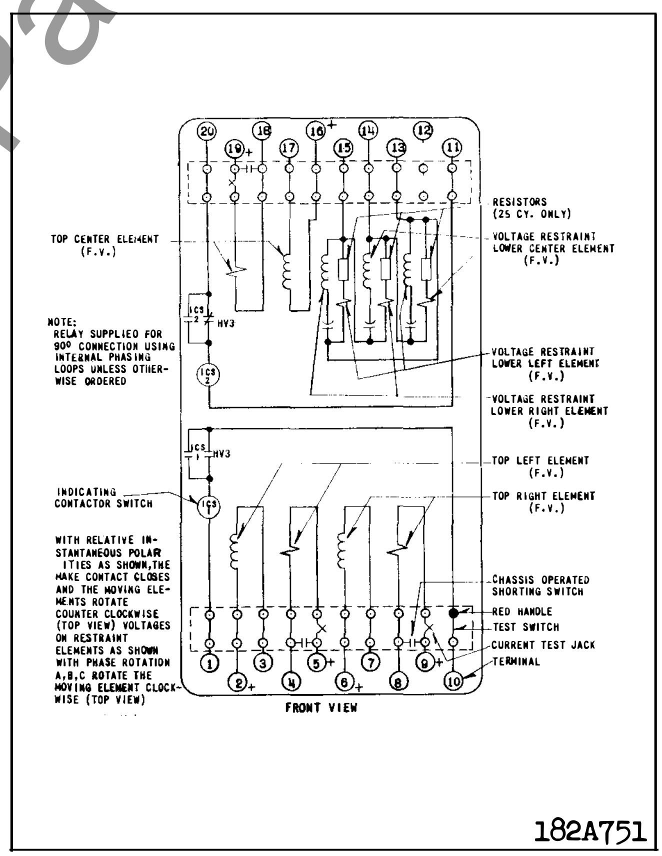

Fig. 3 — Internal Schematic of the Type HV-3 Relay in the FT32 Case.

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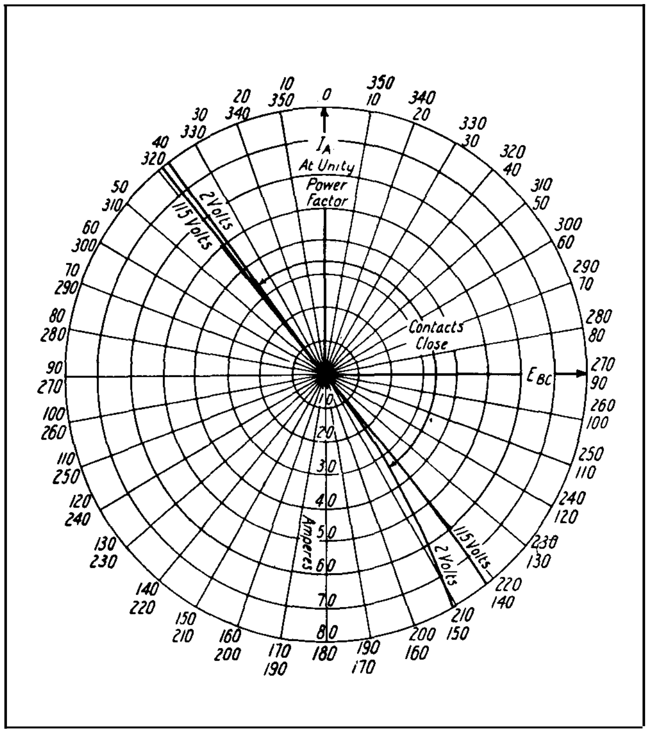

Fig. 4 — Typical Phase Angle Curve for 45° Characteristic; 50 and 60 Cycle, H-3 and HV-3 Relays — Balanced Three Phase Power Applied and No Spring Restraint.

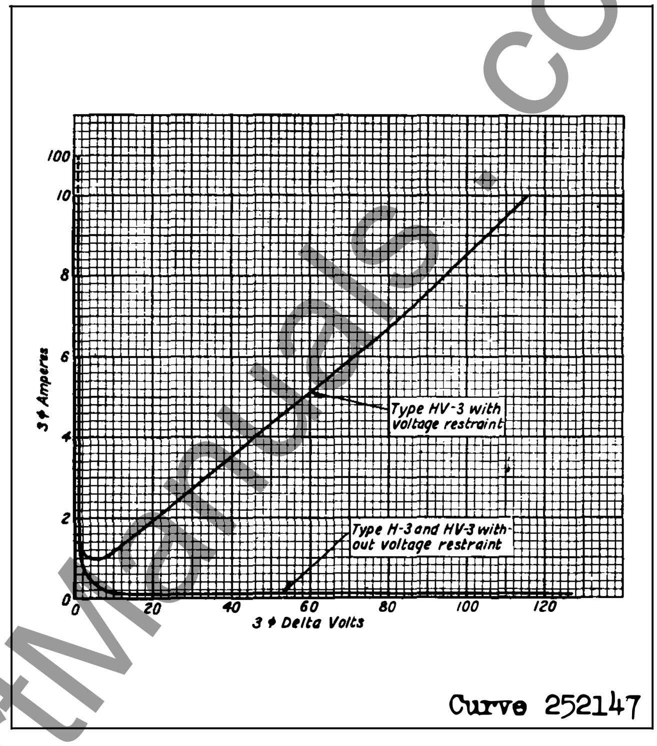

Fig. 5 — Typical Sensitivity Curve for 50 and 60 Cycle, H-3 and HV-3 Relays — at Maximum Torque Angle.

filled with tungsten powder is mounted behind each moving contact. When the moving contact strikes against the rigid fixed contact screw, the spring is deflected for the necessary contact follow, after which the stop strikes the moving contact. Thus, the full torque of the relay is transmitted thru the contacts to maintain full contact pressure. The particles of tungsten powder in the small cylinder slide over each other at the instant of impact and absorb the energy in the moving element. A flexible metal ribbon conducts current to the moving contacts.

The type H-3 relay is supplied with spring restraint which is adjusted to hold the contacts in the normal non-trip position when the relay is deenergized. This prevents an incorrect directional indication by the element under the condition of loss of load. However, the spring restraint may be adjusted to give a bias torque in either direction.

Voltage Restraint Unit

This element is supplied only in the type HV-3 relays and consists of three electromagnets and loops similar to those used on the directional element. The restraining unit is mounted below the directional unit and the loops of the two units are fastened to a common vertical shaft which operates the two contacts as described above. The outer coils of each electromagnet have one delta voltage (E_1) applied and the center coil has another delta voltage (E_2) applied. By means of the capacitor units in series with the outer two coils, the phase angle characteristics of the electromagnets are such that the torque of the element is proportional to:

$$V_1 \cdot V_2 \cdot \sin \theta$$

where θ is the angle between the two delta voltages and is normally 60°.

If any one of the three delta voltages completely collapses during a fault, there is no torque on the electromagnet, since the collapse of the third voltage makes the sine of the angle between the voltages zero. If all three voltages decrease uniformly, the torque varies as the square of their magnitude. Each electromagnet is connected to a different combination of delta voltages so that a uniform restraint torque and balanced burdens are obtained.

Restraint can be removed by opening any one supply lead to the restraint element. This applies single phase to all three electromagnets and the sine of the

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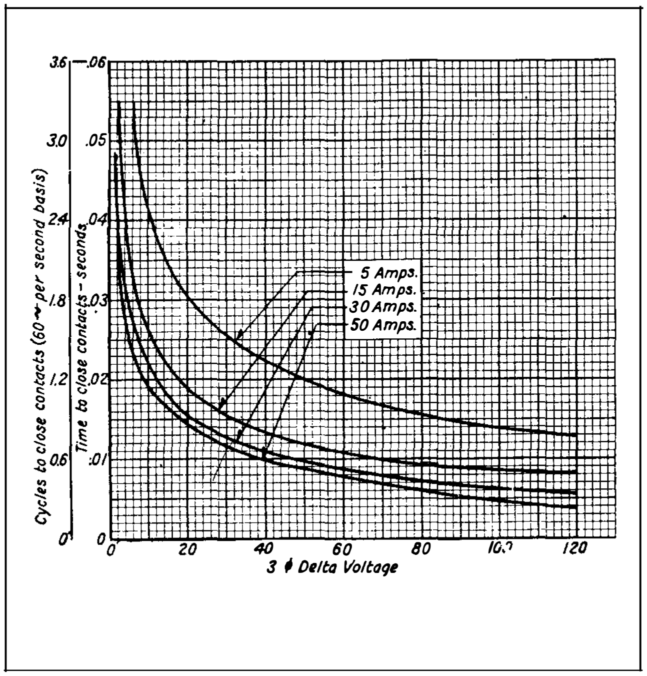

Fig. 6 – Typical Time – Current Curves of 50 and 60 Cycle H-3 Relay for Three Phase Faults at Maximum Torque Angle.

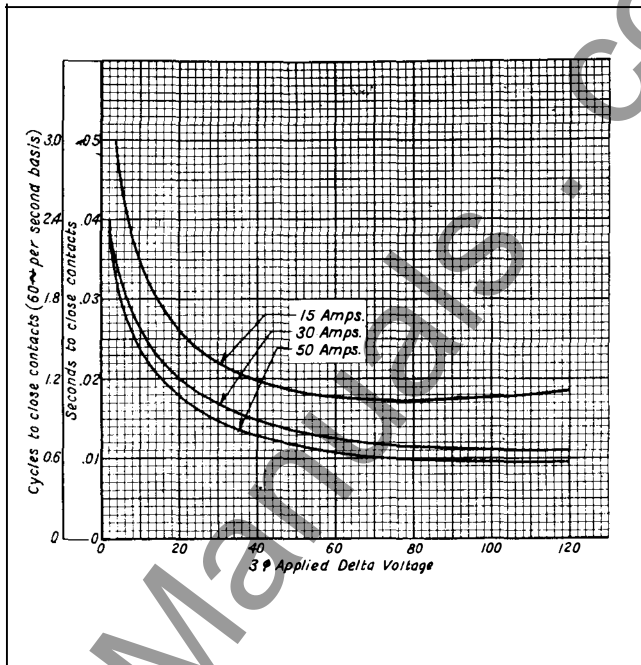

Fig. 7 – Typical Time – Current Curves of 50 and 60 Cycle HV-3 Relay for Three Phase Faults at Maximum Torque Angle.

* angle becomes zero. At normal voltages 10.5 amperes is required in each element at maximum torque to overcome the restraint torque.

Contactor Switches

The d-c contactor switch in the relay is a small solenoid type switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward, the disc bridges three silver stationary contacts. The coil is in series with the main contacts of the relay and with the trip coil of the breaker. When the relay contacts close, the coil becomes energized and closes the switch contacts. This shunts the main relay contacts, thereby relieving them of the duty of carrying tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring-restrained armature releases the white target which falls by gravity to indicate completion of the trip circuit. The indicator is reset from outside of the case by a push rod in the cover or cover stud.

Indicating Contactor Switch Unit (ICS) – (HV-3 only)

The d-c indicating contactor switch is a small clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pickup value of the switch.

CHARACTERISTICS

The types H-3 relays are provided with independent make and break contacts. Two auxiliary contactor switches – one in each contact circuit – provide seal-in circuits for the main relay contact. The main contacts will close 30 amperes at 250 volts d-c and the auxiliary contactors will safely carry this current until the breaker is tripped and the auxiliary "a" switch opens. The contactor switch has a minimum

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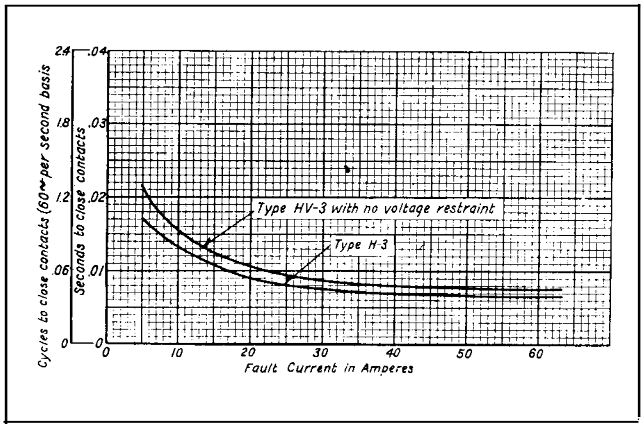

Fig. 8 — Typical Time — Current Curves for 50 and 60 Cycle H-3 and HV-3 Relays, Without Voltage Restraint for Phase to Phase Faults at Maximum Torque Angle — Full Voltage Collapse on Faulted Phase, 86% Voltage on Unfaulted Phase.

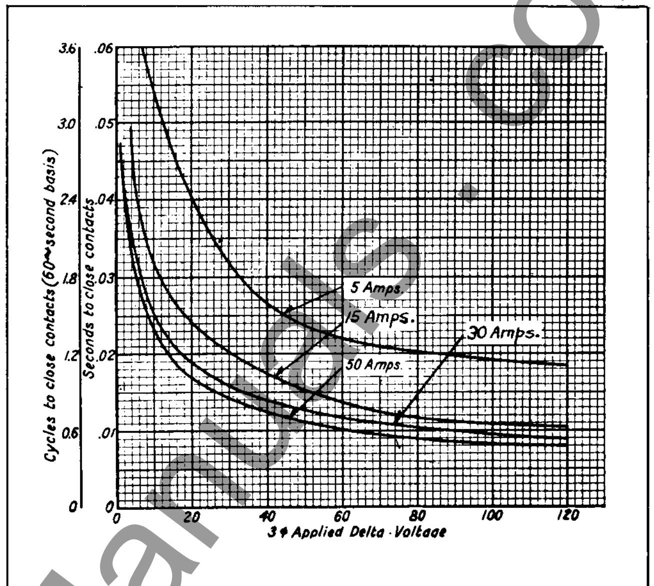

Fig. 9 — Typical Time — Current Curves for 50 and 60 Cycle Type HV-3 Relay Without Voltage Restraint for Three Phase Faults at Maximum Torque.

pick-up of one ampere d-c and a coil resistance of one ohm.

Typical 50 and 60 cycle phase angle characteristics of the 45° characteristic relay are shown in figure 4. Maximum torque, in the contact closing direction, occurs when the line current lags the line-to-neutral voltage by approximately 45 degrees, when using the 90° connection.

Typical 50 and 60 cycle sensitivity curves maximum torque are shown in figure 5. The sensitivity of the type HV-3 relay without voltage restraint is the same as the type H-3 relay. The 60-cycle three phase minimum pick-up without spring restraint of the type H-3 relay is 0.08 amperes at 115 volts, 0.15 ampere at 10 volts, and 5.0 amperes at 1 volt. The single phase minimum pick-up currents are approximately three
* times those for three phase. In the absence of sufficient operating current, the contacts may be held either open or closed by a toggle acting voltage — only torque. The affect of this torque is described in the section under "Watt Characteristic Relay Adjustments." It will be noted from the curves that the sensitivity of the type HV-3 relay with voltage restraint is decreased only at voltages above 2 volts. The curves also show that 10 amperes 60 cycles are required at 115 volts to overcome voltage restraint.

Typical time curves are shown in figures 6 to 9. All curves are for a contact spacing of .035 inch and at maximum torque for 60 and 50 cycle relays and .070 inch for 25 cycle relays.

Trip Circuit (HV-3 only)

The main contacts will safely close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pickup setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

Trip Circuit Constant (HV-3 only)

Indicating Contactor Switch (ICS)

0.2 ampere tap 6.5 ohms d-c resistance
2.0 ampere tap 0.15 ohms d-c resistance

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by

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means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT case information refer to I.L. 41-076.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Adjust the lower bearing so that both the top and bottom of the loops are equi-distant from their respective magnetic circuits. Energize the potential circuits of the relay until the loops reach operating temperature. About ten minutes at normal voltage is necessary to reach this condition. When the operating temperature is reached, adjust the upper bearing for 1/64 inch clearance.

The loops of each element must be in line with the center of the middle leg of the magnetic circuit. If necessary, this adjustment can be obtained by loosening the electromagnet mounting screws and moving the whole electromagnet in the desired direction. All three elements must have the same relative position of loop and magnetic circuit.

Type H-3 Relay

The polarity of the relay is checked as follows: Refer to figure 2 and apply 115 bolts and 5 amperes (in phase) to the corresponding voltage and current coils in turn, with the terminals marked with polarity marks connected together. Looking at the top of the relay, the moving element should rotate in a counterclockwise direction.

Adjust the back-up strip located in front of each moving contact by bending so that it just touches the contact spring when the contacts are open. Adjust the small cylinder behind the moving contact to obtain .009 inch contact follow. This is done by advancing the cylinder until it just touches the rear of the moving contact spring, and then backing off 1/2 turn.

45° Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase current of 50 amperes with polarities as shown on internal schematic diagram to the current coils which should be connected in series. Each potential coil should be short-circuited. When energized the relay moving element will center itself due to the combined torques produced by the 50 amperes of current and the spring restraint. Readjust the spring adjuster until the centering position of the moving element is exactly the same for the condition of zero current or with 50 amperes in the current coils. Under this condition the torque produced by the spring at the centering position is zero and does not tend to "offset" or shift the centering position due to the current. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

There are two adjustable stop screws located on the frame casting. These stops are used when the relay is supplied with two circuit closing contacts and perform the same function as the stops on the moving contact assembly.

Watt Characteristic Relay Adjustments

Remove spring restraint by adjusting the spring adjuster. Apply single-phase potential of 67 volts with polarities as shown on internal schematic diagram to the potential coils which should be connected in parallel. Each current coil should be open-circuited. When the potential circuits are deenergized the moving element will tend to be centered by the spring. When the potential circuits are energized the moving element may move either to the right or to the left. If under this condition the moving element moves the contacts to the right, the spring should be readjusted to move the deenergized spring centering position of the moving element to the left. If under this condition the moving element moves the contacts to the left, the spring should be readjusted to move the deenergized spring centering position of the moving element to the right. Continue to shift the centering position of the spring until a small movement of the spring adjuster will cause the moving element to move in one direction when the potential is applied and a small movement in the other direction will cause the

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moving element to move in the opposite direction. This final centering position will be called the neutral position. With the moving element in the neutral position adjust each stationary contact for .015 inch contact spacing and lock in this position for 60 and 50 cycle relays and .035 inch for 25 cycle relays.

Type HV-3 Relay

The tests outlined for the type H-3 45° characteristic relay also apply to the HV-3 relay when the voltage restraint circuit is not connected. To make a complete check on the type HV-3 relay with all circuits connected, involves three-phase test source, phase shifter, potentiometers, and non-inductive resistors for controlling the voltage and current to the relay respectively. This test will permit checking of all the characteristics of the relay at the proper phase angle. This test procedure however is usually too complicated for routine field testing. The complete test may be simplified for field testing by the following modifications. Apply three phase restraining voltage to the restraining element and single phase to all three phases of the directional element. For the latter element the potential coils are all connected in parallel and the current coils are connected in series. With a non-inductive load, the relay will be operating about 45° away from its maximum torque position and consequently current values to trip a given voltage will be increased by about 30%. Since the combination of three-phase restraining torque and single-phase operating torques on all three elements produces some unbalanced torque in the moving element, it is recommended that tests be made at a reduced voltage (65 volts or less). With 65 volts applied to voltage restraint elements, about 8 amperes is required at unity power factor to make the relay operate.

To check the circuits thru the voltage restraint element, the relay should be energized at normal voltage for about 10 minutes. The potential circuit of the directional element should then be opened. Then open the phase A potential to the voltage restraint unit and observe the torque produced on the moving element, if any. Replace A lead and remove the B lead and again observe the torque. Repeat for the C lead and in all cases there should be no torque or a very slight torque present. Any defects in the coils or capacitors of the voltage restraint circuits will be made apparent by the presence of excessive torque during this test.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core when the switch is picked up. This can be most conveniently done by turning the relay up-side-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 1.0 ohm.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced by new springs, they should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 0.16 ohm.

Indicating Contactor Switch (ICS) – (HV-3 only)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMEMENTS

The burdens and constants of the relays are as follows per phase:

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TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.050	2070	0.050	2070	*1480
Reactance (ohms)	0.052	1530	0.052	1530	1840
Impedance (ohms)	0.072	2580	0.072	2580	2360
Watts	1.25	4.59	1.25	4.59	3.84
Vars	1.29	3.40	1.29	3.40	4.75
Voltamperes	1.82	5.71	1.82	5.71	6.1
Power Factor	46° lag	36.5° lag	46° lag	36° lag	51° lag
Continuous Rating (Amperes or Volts)	5	120	5	120	120
One Second Current (Amps.)	230	. . .	230	. . .	. . .

VALUES AT 120 VOLTS, 5 AMPERES, 50 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint Circuit
Resistance (ohms)	0.0488	2560	0.0488	2560	2720
Reactance (ohms)	0.0349	975	0.0349	975	1570
Impedance (ohms)	0.060	2740	0.060	2740	3140
Watts	1.22	4.89	1.22	4.89	3.44
Vars	.87	1.86	.87	1.86	2.00
Voltamperes	1.5	5.23	1.5	5.23	3.98
Power Factor	33.5° lag	20.8° lag	33.5° lag	20.8° lag	30.1° lag
Continuous Rating (Amperes or Volts)	5	120	5	120	120
One Second Current (Amps.)	230	. . .	230	. . .	. . .

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TYPE H-3, WATT CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 60 CYCLES

	Type H-3	
	Current Circuit	Voltage Circuit
Resistance (ohms)	.028	2740
Reactance (ohms)	.0192	1440
Impedance (ohms	.034	3100
Watts	.70	4.09
Vars	.48	2.14
Voltamperes	.85	4.62
Power Factor	34.5° lag	27.8° lag
Continuous Rating (Amperes or Volts)	5	120
One Second Current (Amps.)	230	...

TYPES H-3, HV-3, 45° CHARACTERISTIC RELAY

VALUES AT 120 VOLTS, 5 AMPERES, 25 CYCLES

	Type H-3		Type HV-3		
	Current Circuit	Voltage Circuit	Current Circuit	Voltage Circuit (Directional)	Restraint
Resistance (ohms)	.0380	3830	.0380	3830	3980
Reactance (ohms)	.0192	3200	.0192	3200	990
Impedance (ohms)	.0420	5000	.0420	5000	4100
Watts	.94	2.20	.94	2.20	3.39
Voltamperes	1.05	2.88	1.05	2.88	3.50
Power Factor	26° lag	40° lag	26° lag	40° lag	14° lag
Continuous Rating	5	120	5	120	120
One Second Rating	230	...	230	...	...

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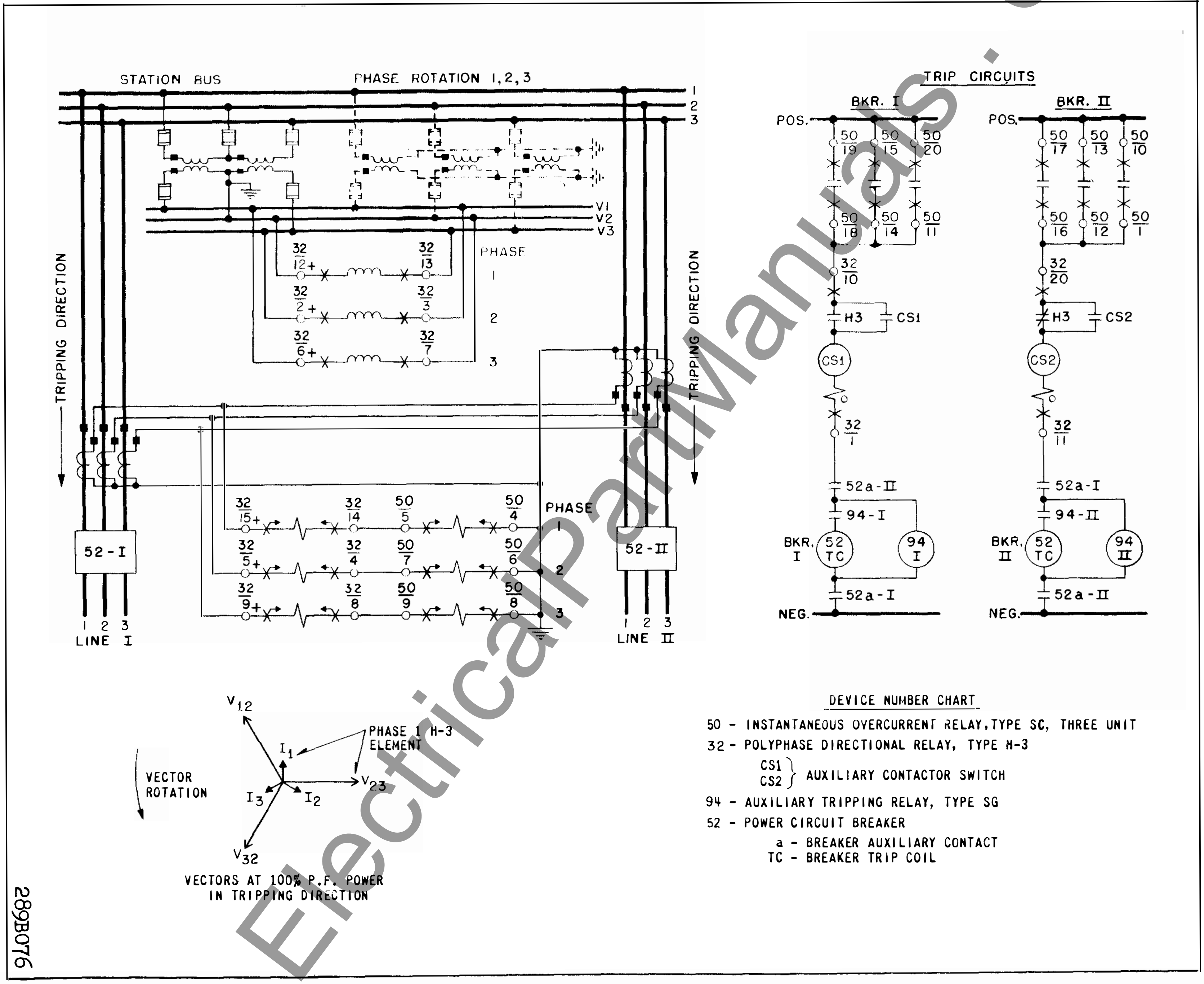
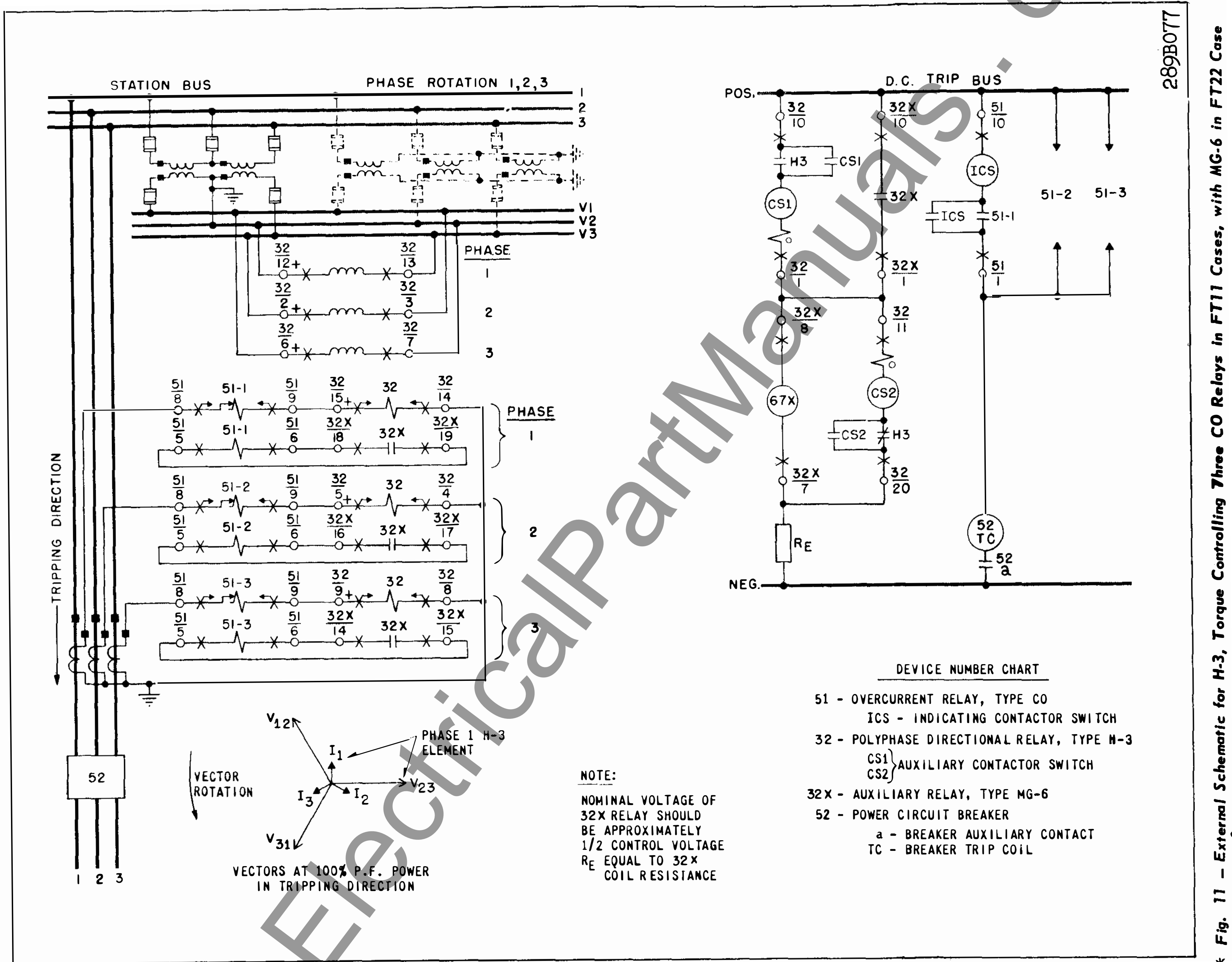


* *Fig. 10 — External Schematic for Phase Fault Parallel Line Protection — H-3 and Three Unit SC in FT32 Case (90° Connection).*



* *Fig. 11 — External Schematic for H-3, Torque Controlling Three CO Relays in FT11 Cases, with MG-6 in FT22 Case (90° Connection).*

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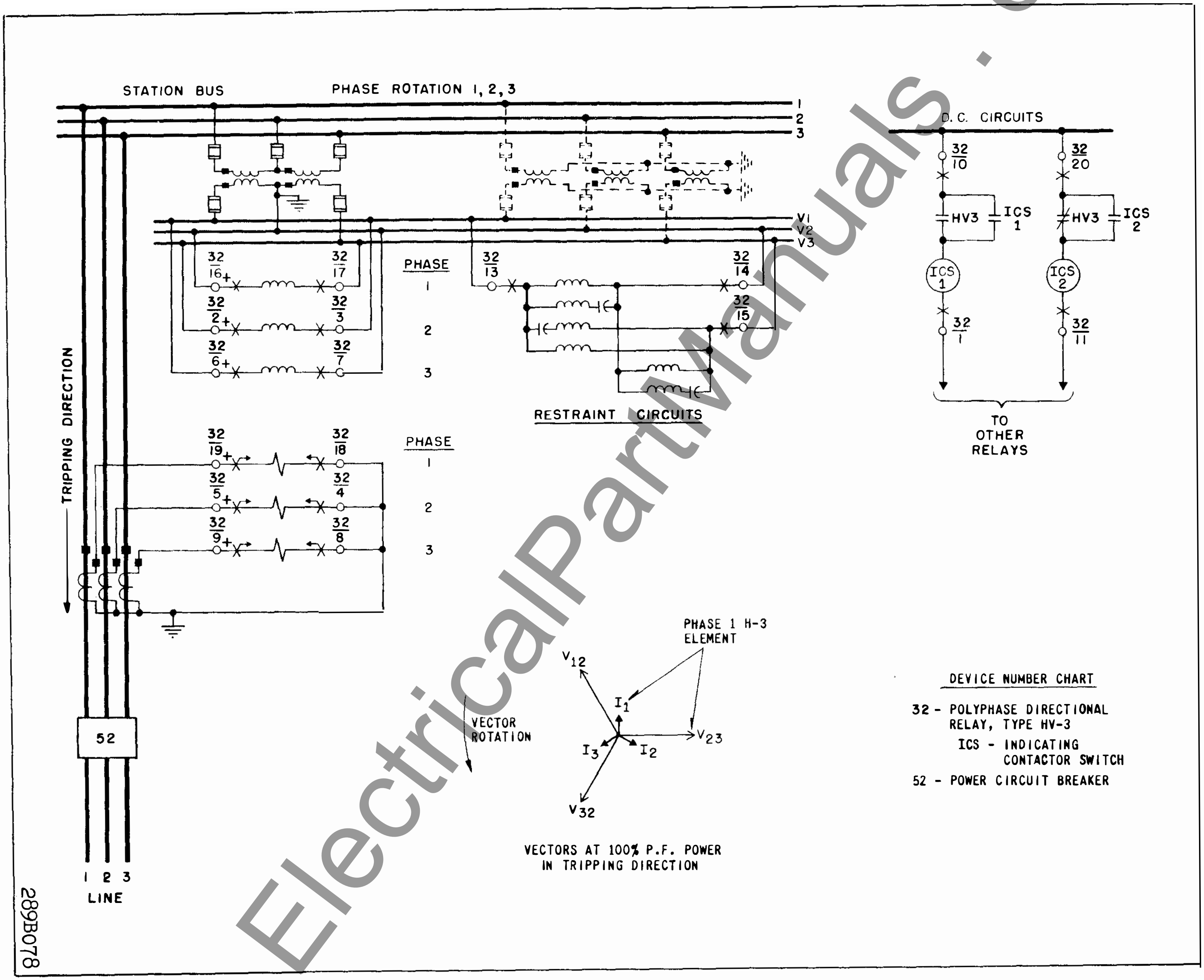
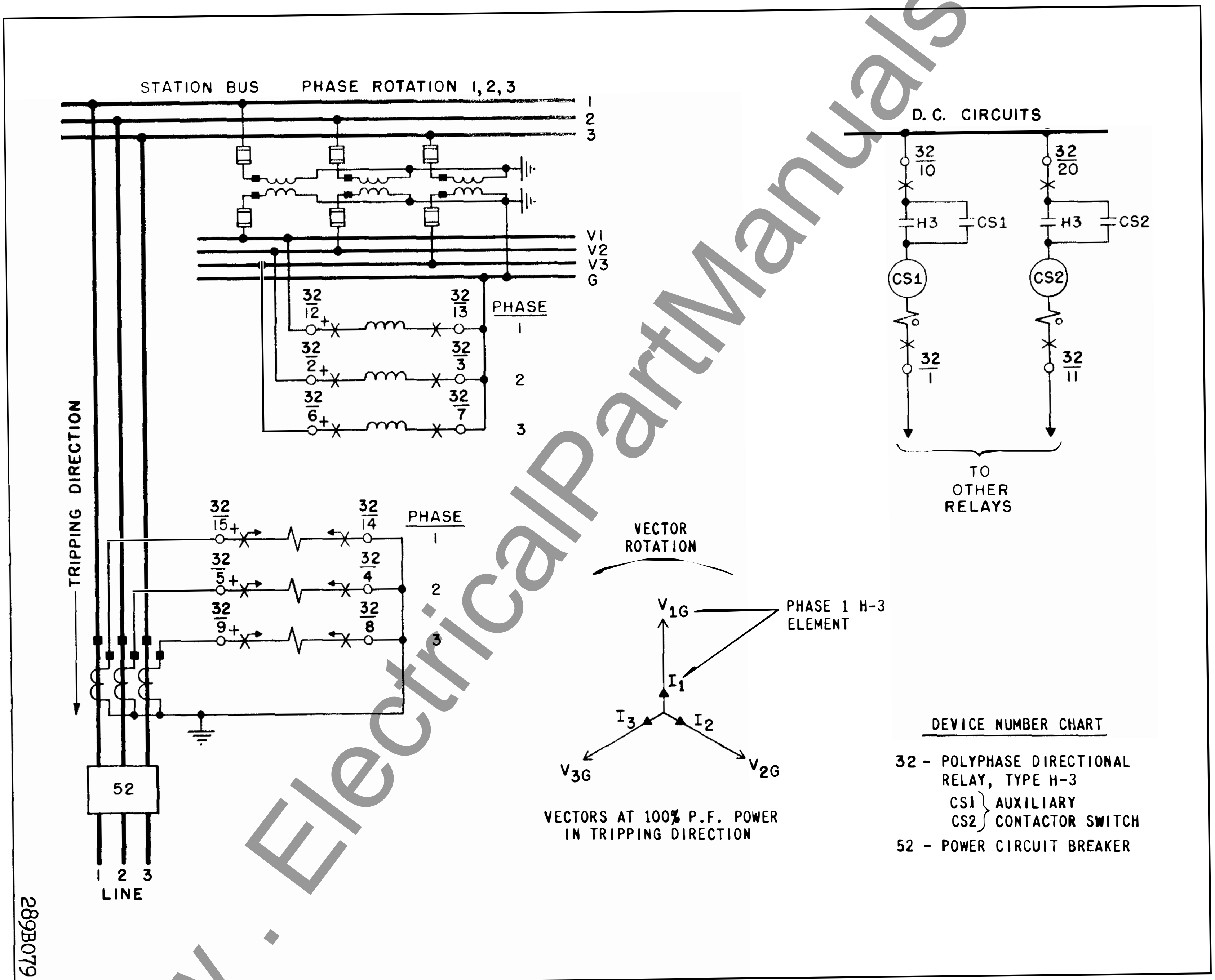


* *Fig. 12 – External Schematic for HV-3 Relay (90° Connection).*



*** Fig. 13 – External Schematic for H-3 Relay (Watt Connection).**

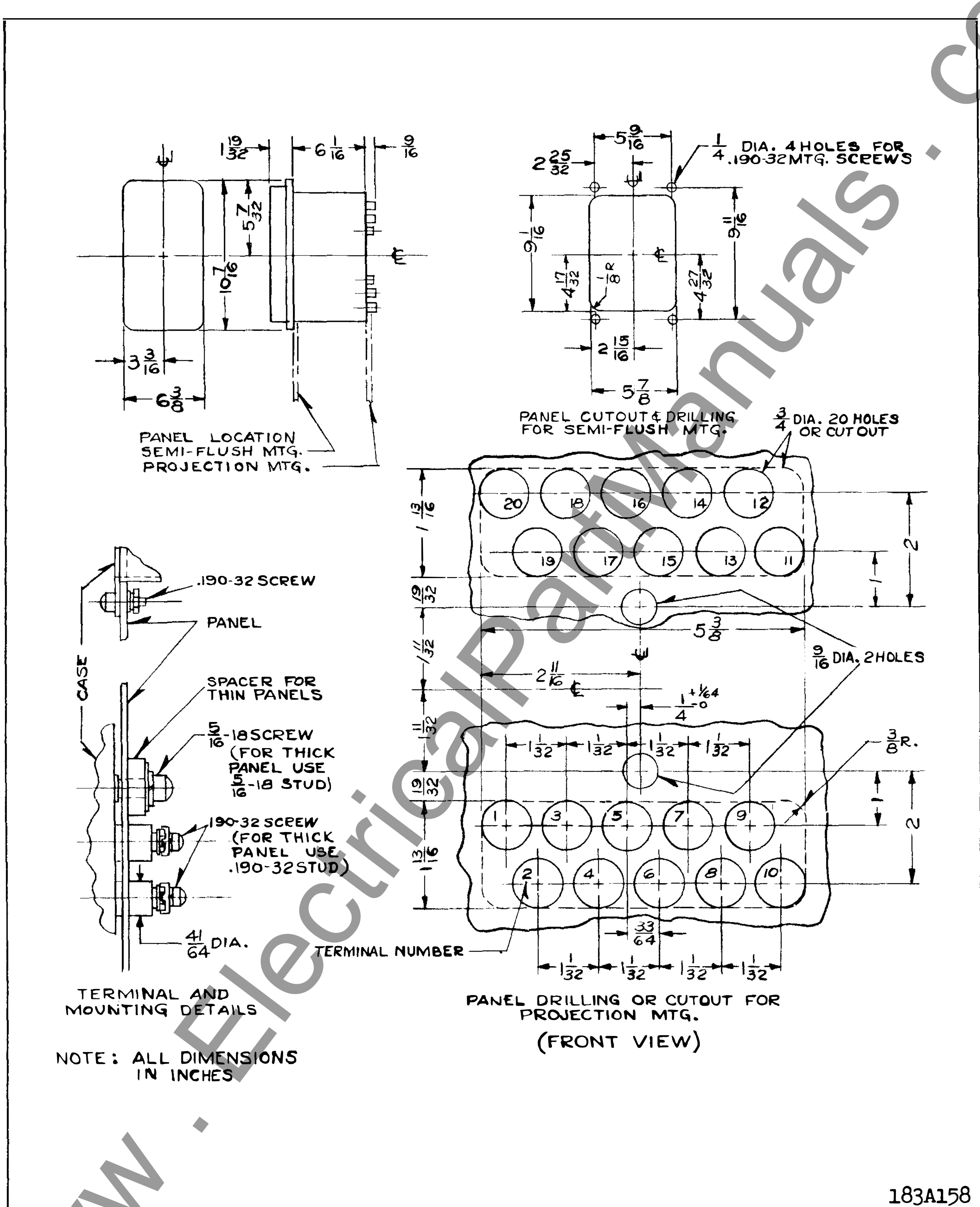


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Fig. 14 – Outline and Drilling Plan for the H-3 Relay in the FT22 Case.

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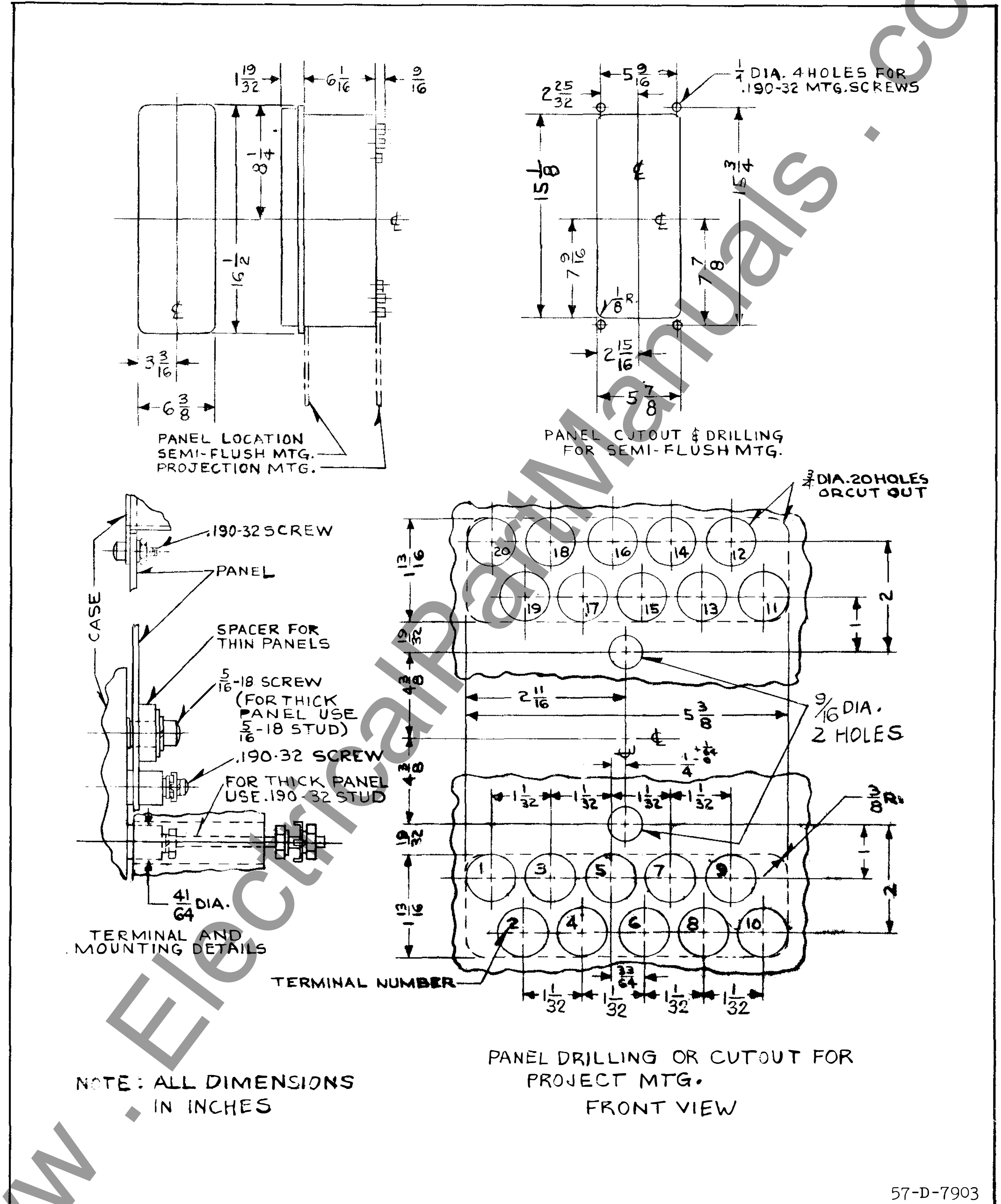

* *Fig. 15 — Outline and Drilling Plan for the HV-3 Relay in the FT32 Case.*

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