INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE LC-2 LINEAR COUPLER RELAY

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, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The type LC-2 linear coupler relay is intended for use with linear couplers to provide reliable, high-speed differential protection of station buses.

Two type relays, the LC-1 and the LC-2, are available. The type LC-1 relay is described in I.L. 41-342. The type LC-2 is more sensitive than the type LC-1, and is intended primarily to be a ground relay. However three type LC-2 relays may be used for both phase and ground fault protection where the type LC-1 is not sufficiently sensitive to operate at the minimum tripping current desired. When the type LC-2 relay is used as a fourth relay for ground fault protection, it will usually be in conjunction with the type HVS single phase to ground fault detecting relay.

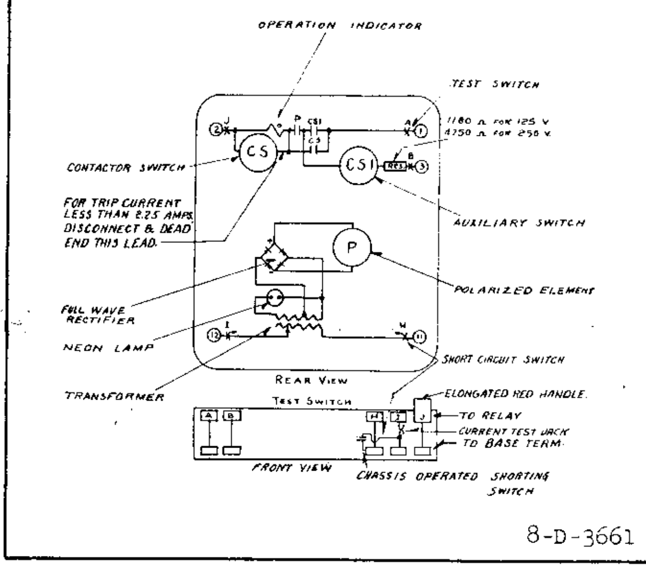

Fig. 1 Internal Schematic of the Type LC-2 Relay in the Type FT Case. Omit Test Switches for the Relay in the Standard Case.

CONSTRUCTION

The type LC-2 relay consists of an impedance matching transformer, a Rectox rectifying unit, a sensitive permanent magnet type polar element, a neon lamp, an auxiliary switch, a contactor switch, and an operation indicator. These elements are connected as shown in Fig. 1.

The impedance matching transformer has a tapped primary winding with taps marked 30, 40, 60 and 80 ohms. These are for the purpose of approximately matching the impedance of the relay to the impedance of the linear couplers with which it is used. A portion of the secondary voltage developed by this transformer is rectified by means of the full wave Rectox rectifier and applied to the coil of the sensitive polar element. A neon lamp is connected across the full secondary winding of the impedance matching transformer. This is done to protect the Rectox unit from overvoltage in the case of heavy operating currents. The impedance matching transformer is a saturated device and tends to produce a peaked wave form at heavy currents. The neon lamp flashes on these peaks of voltage and effectively reduces the voltage applied to the Rectox.

The auxiliary and contactor switches in the relay are small solenoid type d-c switches. 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 contactor switch coil is in series with the main contacts of the relay.

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring-restrained armature releases a 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.

OPERATION

The linear coupler bus differential scheme operates on the differential principle where voltages are used in a series connection instead of currents in a parallel connection. For external faults, the voltages induced in the linear couplers by currents entering the bus are balanced out by the voltage induced in the linear coupler in the faulted circuit, where the fault

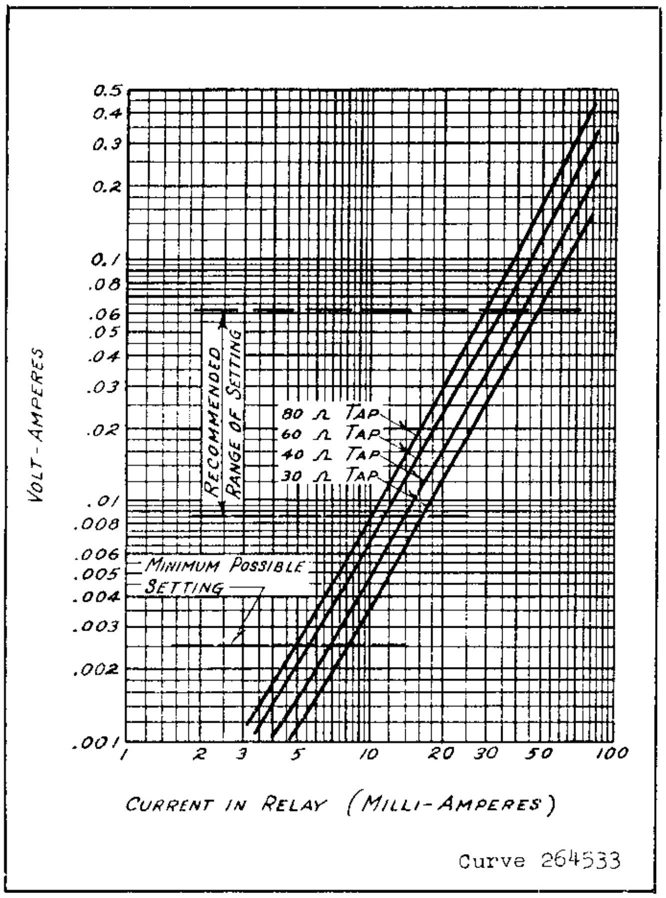

Fig. 2 Typical Voltampere Curve of the Type LC-2 Relay.

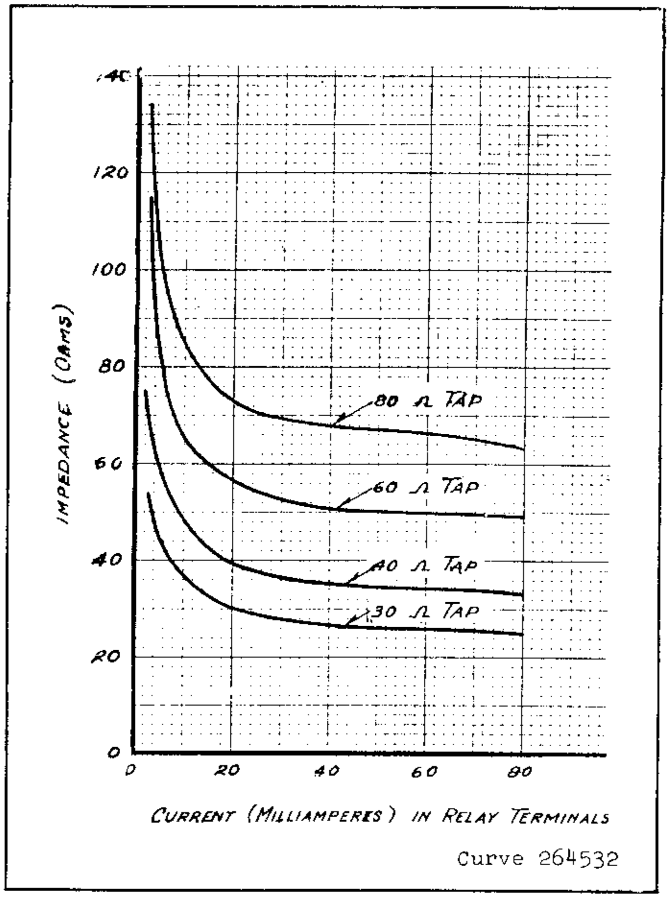

Fig. 3 Typical Impedance Curve of the Type LC-2 Relay.

current leaves the bus. For the internal fault condition, current entering the bus induces a voltage in the linear coupler circuit. This voltage is not balanced out, since the fault current leaves the faulted phase through a path containing no linear couplers. Thus, a net voltage is induced in the secondary circuit to cause relay operation.

The net secondary voltage closes the polar element contacts, P, which are connected in series with the coil of the auxiliary switch, CS-1, and its contacts. When the polar element contacts, P, close, the coil of the CS-1 switch is energized through terminals 2 and 3 of the relay. After approximately 3/4 cycle, the CS-1 switch closes and completes the trip through terminals 1 and 2 of the relay.

The auxiliary switch CS-1 is incorporated in the relay design to give an overall shock-proof quality not obtainable with an extremely sensitive high-speed master element. If the polar element contacts, P, are jarred closed momentarily due to an accidental heavy jar to the switchboard panel, they will not remain closed sufficiently long to pick up the CS-1 contacts and complete the trip circuit.

CHARACTERISTICS

Present linear couplers are designed to within an accuracy of ±1%. Hence, the maximum range of application of linear couplers is restricted to systems where the ratio of maximum external to minimum internal fault current is 50 to 1. However, a 25 to 1 range is recommended for all systems except those with a high resistance ground. This allows a safety factor of 2 to 1 in selecting the range of application of the relay. For systems with a high resistance ground, the range of application may be extended by using a type HVS relay in conjunction with the type LC-2 relays.

The type LC-2 relay may be set to operate at an energy level ranging from .062 to .0085 volt-amperes. It may also be used to an energy level as low as .0025 with limitations which will be discussed. This range of application is shown on the typical voltampere curves of Fig. 2. Typical impedance curves are shown in Fig. 3. The phase angle of the relay is substantially constant (within 3^{o}) at 22^{o}.

The operating time of the type LC-2 relay is 1-1/4 to 1-3/4 cycles. This includes the operating time of the auxiliary switch, which is approximately 3/4 cycle.

The schematic one line connections are shown in Fig. 4, and complete three phase connections in Fig. 5.

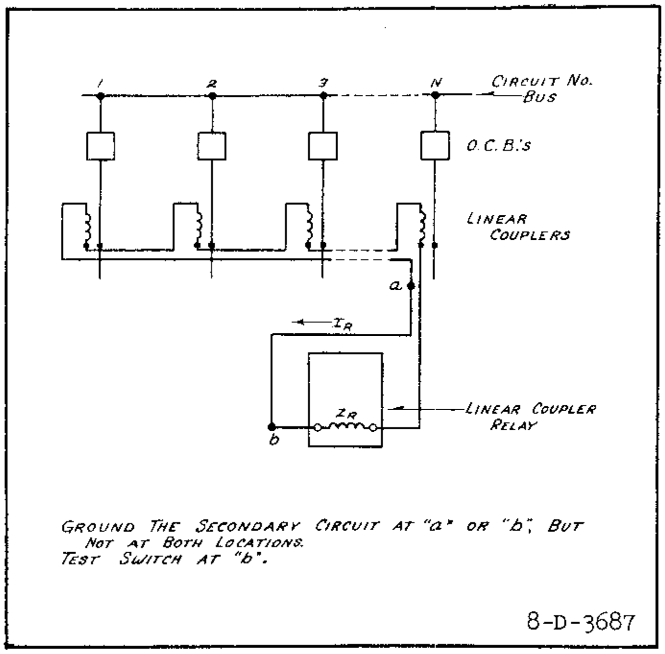

Fig. 4 Schematic One-Line External Connections of the Type LC-2 Relay.

As indicated in Fig. 5, the four conductor cables used to connect the linear couplers and the relay in series should be transposed with respect to all other circuits. This may be accomplished by using a control cable with a spiral lay to the conductors. The cable may then be placed in the same duct run with other circuits, but there should not be other circuits in the same cable. For example, do not use four conductors of a six conductor cable, even though it has spiral lay, when the two remaining conductors are to be used for some other service, unless such other service cannot possible induce tripping voltage in the linear coupler circuit.

Trip Circuit

The main contacts will safely close on 30 amperes at 250 volts d-c, and the switch contacts will safely carry this current long enough to trip a breaker.

The relay is shipped with the operation indicator and the contacter switch connected in parallel. This circuit is suitable for all trip currents above 2.25 amperes d-c. If the trip current is less than 2.25 amperes, there is no need for the contactor switch and it should be disconnected. To disconnect the coil, remove the short lead to the coil on the front stationary contact of the contactor switch. This lead should be fastened (deadended) under the small fillister head screw located in the Micarta base of the contactor switch.

Contact Circuit Constants

Resistance of 0.2 ampere target . . . . . . 2.8 ohms
Resistance of 2.0 ampere contactor switch . . . . 0.25 ohms
Resistance of target and switch in parallel . . . . 0.23 ohms

SETTING CALCULATIONS

The following fundamental equations apply referring to Fig. 5:

$$E = I_{pM} \qquad (1)$$

$$I_r = \frac{E}{Z_s} \qquad (2)$$

$$I_r = \frac{I_pM}{Z_s} = \frac{I_pM}{NZ_c + Z_r} \qquad (3)$$

$$I_p = \frac{I_rZ_s}{M} = \frac{I_r(NZ_c + Z_r)}{M} \qquad (4)$$

where:

E = Voltage induced in linear coupler secondary

I_p = Primary current in linear coupler

M = Mutual impedance of linear coupler = .005 ohm for 60 cycles.

I_r = Relay current

Z_s = Impedance of Secondary Circuit

N = Number of secondary circuit = Number of linear coupler secondaries in series per phase.

Z_c = Self-impedance of linear coupler secondary.

Z_r = Relay impedance.

Equation (3) is used to determine the current at which the relay trips for an internal fault on the bus of magnitude, I_p. Equation (4) is used to determine the primary current necessary to trip the relay when it has been adjusted to trip at a known value of relay current. It should be noted, however, that the relay impedance is not constant, but varies with relay current as indicated in Fig. 3. Therefore, in using equation (3), it is desirable to assume a value of relay impedance equal to the impedance tap, and make a first calculation of the relay current. When this is obtained, a new value of relay impedance should be selected from Fig. 3, and a second value of relay current calculated. Usually, it will not be necessary to continue the calculation any further, as the values resulting from the second calculation will be sufficiently accurate.

Example

Assume a six circuit bus has linear couplers with a self-impedance of $Z_c = 3.7 + j8.9 = 9.64 \angle 67.4^{\circ}$. Three type LC-2 relays are used, one per phase, to

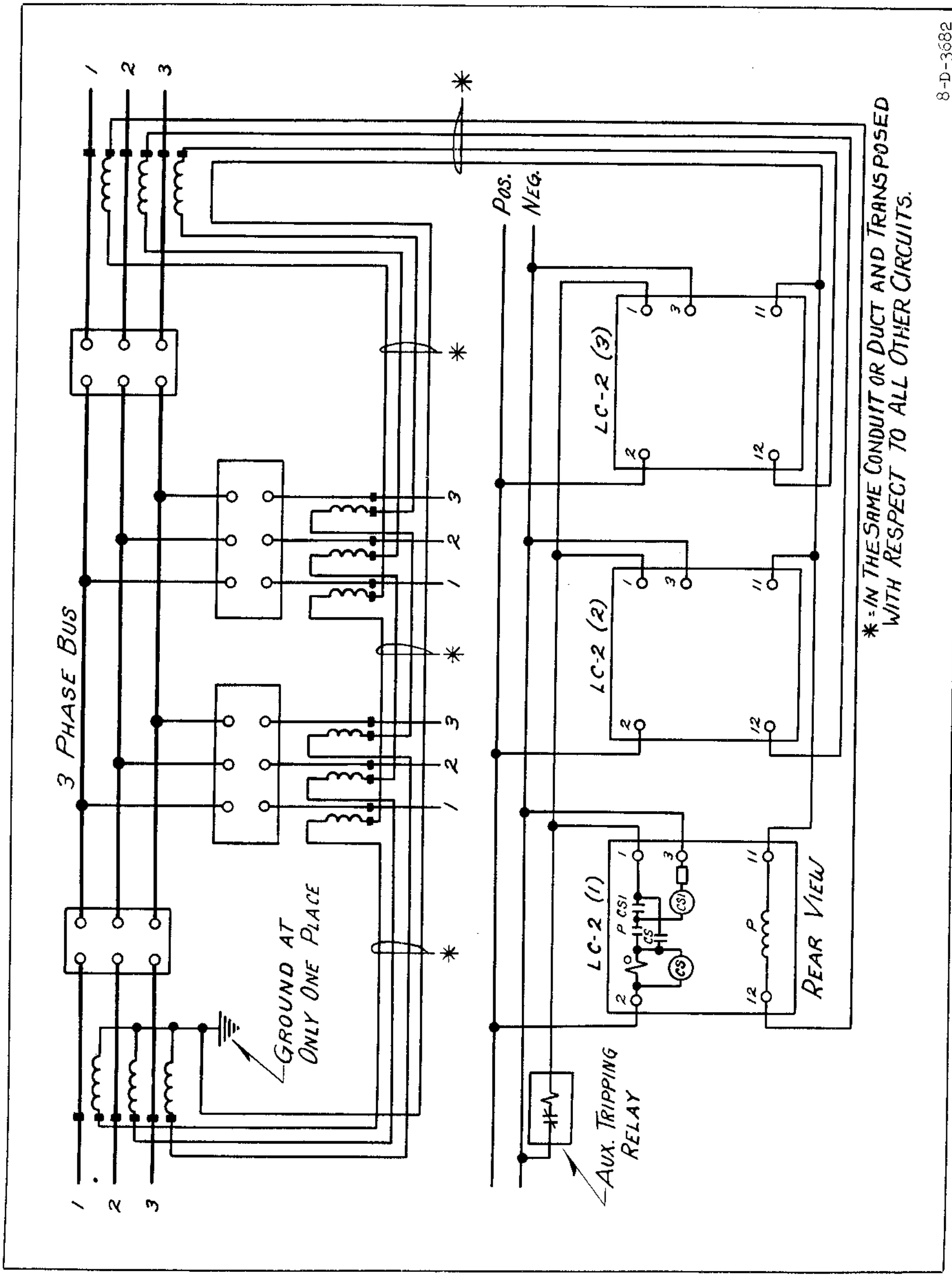

Fig. 5 External Connections of the Type LC-2 Relay for Phase and Ground Fault Protection.

obtain phase and ground fault protection. The maximum external fault current is 12,000 amperes rms symmetrical. Since the linear couplers and relays will operate over a 25/1 range with an adequate factor of safety, the realys may be set for 480 amperes, which is 1/25 of 12,000.

The relay operates with maximum energy when its impedance equals the impedance of the linear coupler circuit, $NZ_c = 6\ (3.7 + j8.9) = 22.2 + j53.4 = 57.8\angle 67.4^{\circ}$. Therefore, choose a tap setting, $Z_r = 60$, for the relay, which is an approximate match. Since the phase angle of Z_r is substantially constant (within 3°) at 22°, $Z_r = 60\angle 22^{\circ} = 55.6 + j22.5$.

$$NZ_c = 22.2 + j53.4$$

$$Z_r = 55.5 + j22.5$$

$$Z_s = 77.8 + j75.9 = 108.8 \text{ ohms}$$

$$I_pM = 480 \times .005 = 2.4 \text{ volts}$$

From equation (3)

$$I_r = \frac{I_pM}{Z_s} = \frac{2.4}{108.8} = .0221 \text{ amperes}$$

This is within the recommended setting range of the relay as indicated in Fig. 2.

From Fig. 3, on the 60 ohm tap, at $I_r = .0221$, $Z_r = 55.5\angle 22^{\circ} = 51.5 + j20.8$.

This new value of Z_r should be used in equation (3).

$$NZ_c = 22.2 + j53.4$$

$$Z_r = 51.5 + j20.8$$

$$Z_s = 73.7 + j74.2 = 104.6 \text{ ohms}$$

$$I_r = \frac{I_pM}{Z_s} = \frac{2.4}{104.6} = .023 \text{ amperes}$$

At $I_r = .023$ on the 60 ohm tap, Fig. 4 indicates that $Z_r = 55$ ohms. Since a value of $Z_r = 55.5$ was used in the above calculation, it is not necessary to carry the calculation any further.

The relay should be adjusted to trip at I = .023 amperes on the 60 ohm tap using the magnetic shunts at the rear of the polar element assembly.

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 studs on the flange for the semi-flush type FT case. Either of the stud 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.

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. S#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.

SETTING THE RELAY

The connector screw on the tap plate makes connections to various turns on the impedance matching transformer. By placing the screw in the various holes, the impedance of the relay can be adjusted to match the impedance of different linear coupler circuits. Adjustments to trip the relay at different values of current are explained in the ADJUSTMENTS AND MAINTENANCE of the polar element.

As shown in the external connections of Fig. 6, the linear coupler differential circuit can be provided with a test scheme to check the bus differential circuit for major defects while the bus is carrying load current. Defects such as short circuited linear coupler transformers, ground faults and open circuits in the secondary loop, wrong polarity or phasing connections to the linear couplers, and severe steady state stray voltage effects from foreign sources can be revealed by the scheme. The equipment used in the test scheme includes three high resistance Rectox type voltmeters, a one-half ohm resistor, a test transformer, and a test switch with three positions, NORMAL DIFFERENTIAL-OFF-SERIES.

When the test switch is in the NORMAL DIFFERENTIAL position, a voltmeter is connected across each phase relay. On an unfaulted secondary circuit the voltmeters measure the differential voltage induced in the linear coupler secondary by load current in the bus. Due to the tolerance of the linear couplers, the induced voltage may be some low value other than zero. Hence, for each installation, a maximum normal differential load voltage should be determined and marked on either the voltmeters or the normal differential position of the test switch.

In the SERIES position, the test switch not only connects the volt-meters across the phase relays, but also applies a low voltage across a one-half ohm resistor in the neutral of the differential secondary circuit. On an unfaulted secondary circuit, the voltmeters read more than the normal differential reading or approximately half of the applied test voltage. While the applied test voltage is not large enough to operate the relays during load current flow, it may reduce the safety factor for relay tripping on external faults. Hence, a contact of the test switch should open the relay's trip circuit. If the trip circuit is not opened by this contact, the series test should not be used if the normal differential voltage is higher than marked.

The periodic test procedure is to turn the test switch first to NORMAL DIFFERENTIAL. This connects the voltmeters across the relays to measure the differential voltages due to load currents. If a voltmeter reads higher than the marked maximum normal differential voltage, it indicates a major defect such as a short circuited linear coupler or a wrong connection in the differential circuit. Since these defects can cause relay tripping on external faults, the relay, or relays, associated with the high voltage should be removed from service until the defect is corrected. If a voltmeter reads zero, it may be an indication of an open circuit in the secondary differential circuit. This should be checked by using the series test.

The next step is to turn the test switch to SERIES. If any voltmeter reads zero, it indicates an open circuit in the coupler portion of the circuit. If the voltmeter reads full scale, it indicates an open circuit in the relay winding.

Test

Referring to the schematic diagram of connections, Fig. 4, the secondary circuit may be opened at the test switch and a variable voltage inserted in series with the circuit to check the relay operation. The relay should operate at a voltage calculated as described under "Settings". This checks the continuity of the circuit as well as the calibration of the relay.

Polar Element

The sensitivity of the polar element is adjusted by means of two screw type magnetic shunts at the rear of the assembly. Looking at the relay front view, drawing out the left-hand shunt increases the amount of current required to close the relay contacts. Conversely, drawing out the right-hand shunt decreases the amount of current required to trip the relay. It will usually be possible to set the relay to the desired tripping value by leaving the right-hand shunt at the extreme "in" position and make all the adjustments with the left-hand shunt. The shunts are held securely in position by means of a spring type clamp.

There is a small residual magnetism effect in this relay element amounting to approximately .001 ampere on the 80 ohm tap. For this reason it is desirable to calibrate the relay after first applying a polarizing current to it. For example, the relay would be adjusted to trip at .010 ampere on the 80 ohm tap, and would then be momentarily subjected to a current of .250 ampere, which is 25 times minimum pickup. The minimum trip current would then be checked and the relay readjusted to trip at .010 ampere. After another momentarily applied polarization of .250 ampere the minimum trip would be rechecked. This process would be repeated back and forth until there were no change in the minimum trip current of .010 ampere after polarization. This manner of calibration is especially important at the low values of minimum trip currents, since the same residual magnetism effect of approximately .001 ampere would amount to a 20 percent change in the minimum trip setting if the relay were set for 5 milliamperes on the 80 ohm tap. It is for this reason that the lower limit of the recommended range of settings has been shown at .010 ampere for tap 80. The limit for the other taps is at the same value of voltamperes. It is possible, however, to set the relay down to an energy level of .0025 voltamperes as indicated on curve of Fig. 3. On the other taps, the residual magnetism effect is equal to

$$.001\sqrt{\frac{80}{T}}, \text{ where } T = \text{ohms tap value.}$$

When the relay is operated electrically, the contacts should have a deflection equivelent to one-half to one turn of the stationary contact screw. This is obtained by allowing the armature rivet to strike the right-hand pole face, then bringing up the stationary contact screw until the contact circuit just makes, then giving the stationary contact screw an additional one-half to one turn before locking it in place with the lock nut provided. After setting one-half to one turn contact deflection, set the contact travel for one turn of the backstop screw. With the contacts in the closed position, bring up the backstop screw until it just touches the moving contact. Then back off one turn and lock in place.

Auxiliary Switch

The auxiliary switch CS-1 mounted in the rear should have a free contact travel of 3/32" and a magnetic air gap equivalent to one turn of the stationary core screw. This magnetic air gap may be determined in one of two ways. If the relay is free of the panel, it may be turned up-side-down and the core screw turned in the right-hand direction until it becomes obvious that it is in contact with the movable core or plunger. Then turn the core screw in the left hand direction until the silver disc rests on the stationary contacts and stops turning. The plunger itself will next stop turning as the play is taken up. The core screw may then be given an additional one turn before being locked in place. If the relay is mounted on a panel, the adjustment may be made in the same manner except that, since the relay will be in the normal position, it will be necessary to pick up the plunger by applying voltage to the coil of the unit.

Contactor Switch and Operation Indicator

With the contactor switch and operation indicator connected in parallel, both should operate at 2.25 amperes d-c. The contactor switch is adjusted as described above for the auxiliary switch. The switch itself should pick up at 2 amperes d-c. Test for sticking after 30 amperes d-c have been passed through the coil.

Adjust the operation indicator separately to operate at 0.2 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 0.2 ampere calibration.

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.

Test Equipment Common for all Bus Sections:

1 – S#1534529 type SD 406 transformer 60 cy 20 VA, 120/240 volt primary to 0.6/1.2 volt secondary.

Use 0.6 volt for loads up to 2500 A through a bus.

Use 1.2 volt for loads up to 5000 A through a bus.

3 – Voltmeters Rectox type 5000 ohms per volt.

Use 0.5 V voltmeters with 0.6 V test transformer connection.

Use 1.0 V voltmeters with 1.2 V test transformer connection.

For miniature RC-35 Vm: S#1159978 is 0.5 V, and S#1159979 is 1.0 V.

1 – Key handle to operate type W transfer switches.

Test Equipment for Each Bus Section:

1 – Type W transfer switch similar to S#1534632, except without handle, for key operation.

1 – S#874922 Ribflex 10" tube 0.5 ohm resistor. Add suitable mounting.

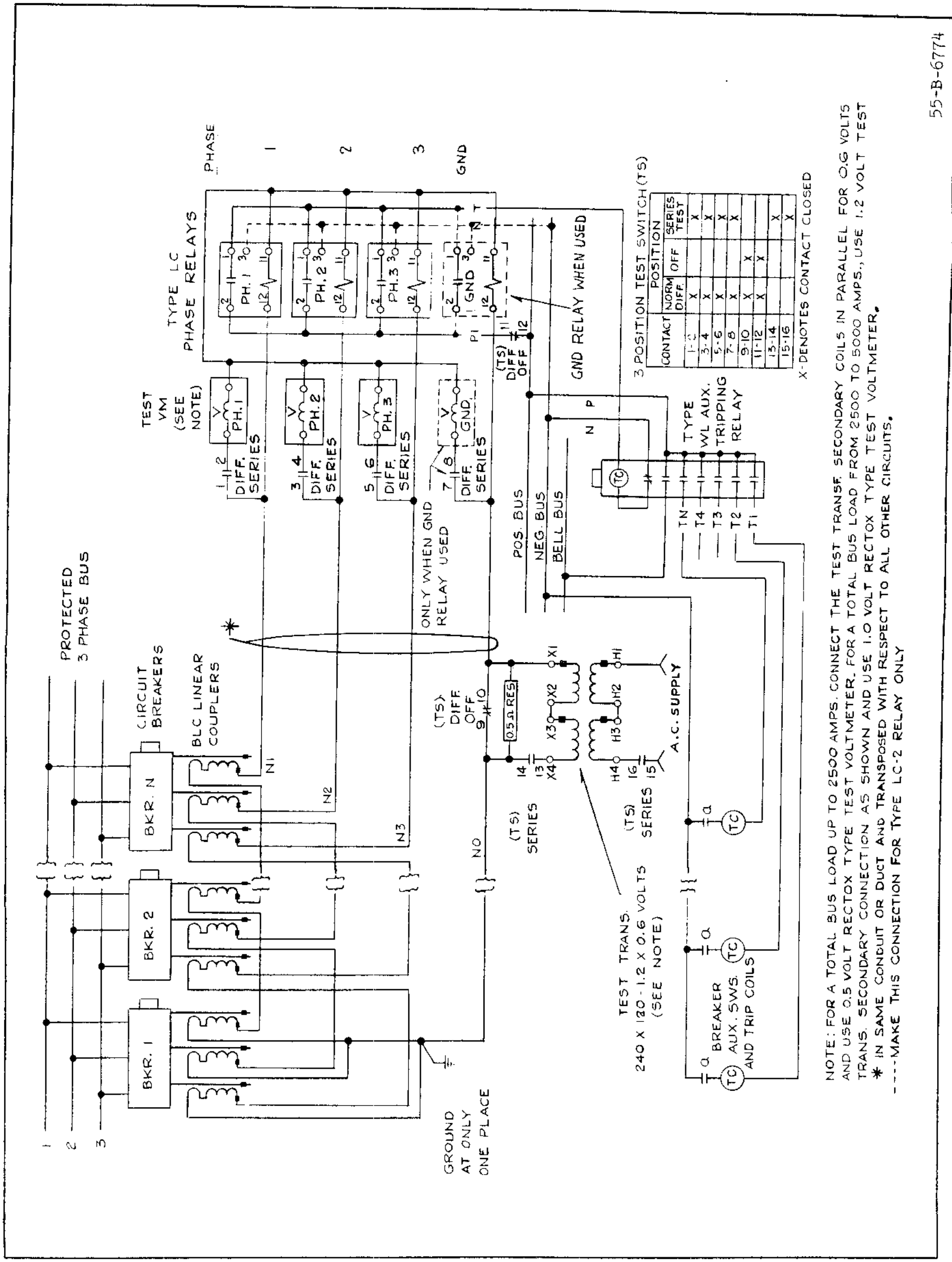

Fig. 6 External Connections for Test Diagram of the Type LC-2 Relay.

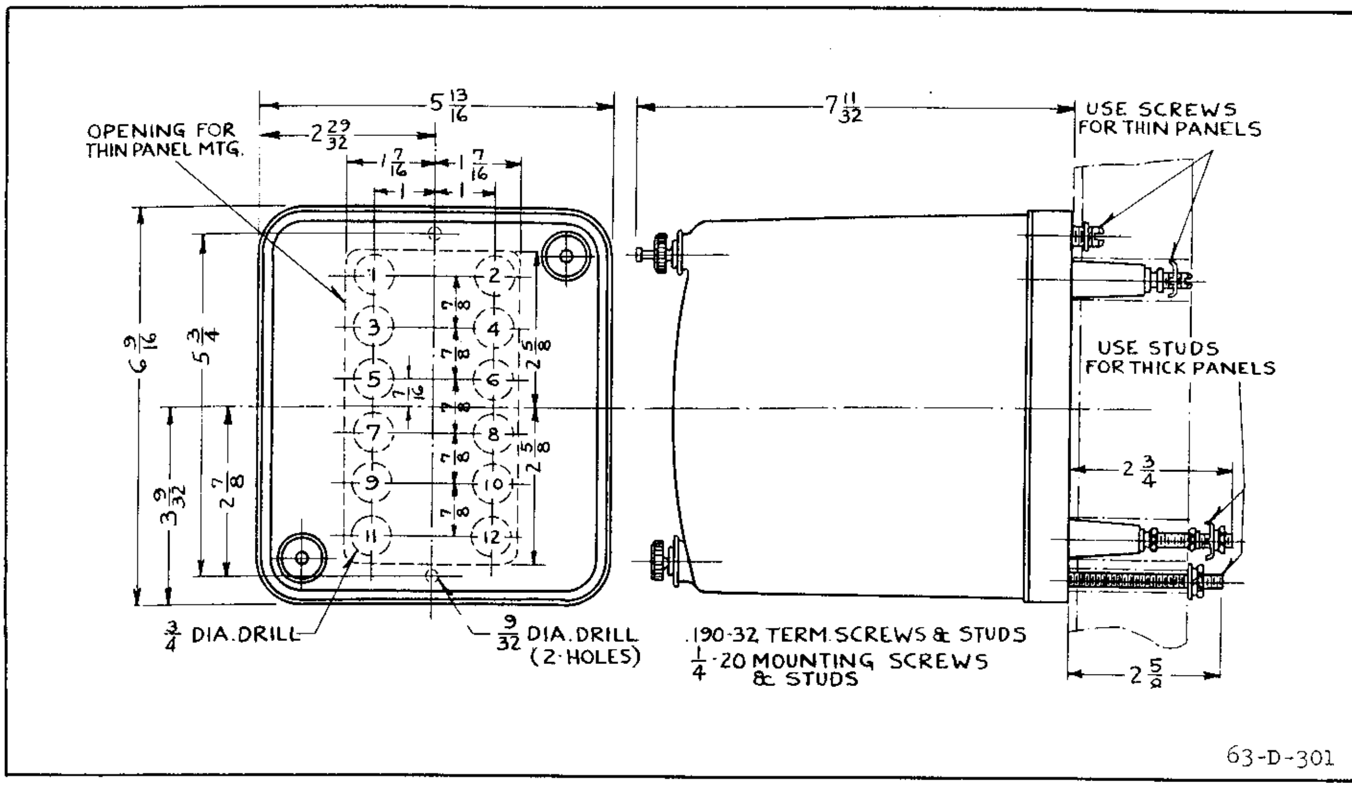

Fig. 7 Outline and Drilling Plan for the Standard Projection Type Case. See the Internal Schematic for Terminals Supplied. For Reference Only.

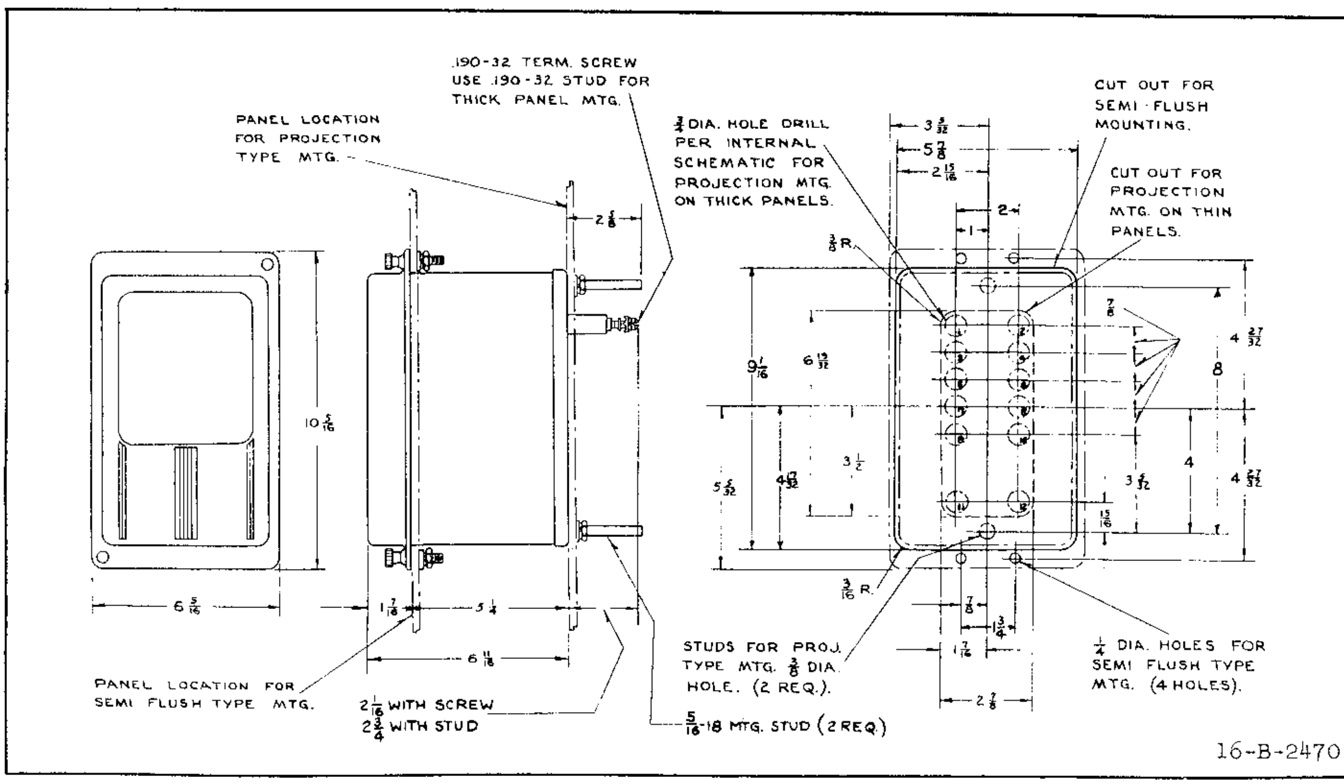

Fig. 8 Outline and Drilling Plan for the S10 Semi-Flush or Projection Type FT Case. See the Internal Schematic for Terminals Supplied. For Reference Only.